Study of Market Value of Partially Upgraded Bitumen®

Prepared for

Alberta Innovates

AI 2492

by

Turner, Mason & Company
CONSULTING ENGINEERS

Suite 2920
2100 Ross Avenue
Dallas, TX 75201
214/754-0898
www.turnermason.com

January 23, 2019

John R. Auers, P.E.
Robert Auers
John M. Mayes
Brian Mason

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I. INTRODUCTION, BACKGROUND AND SCOPE

Turner, Mason & Company (TM&C) was retained by Alberta Innovates (AI) to analyze and provide independent assessments of the refinery and market values of four specific Partially Upgraded Bitumen (PUB) streams. This work will be used by AI to support investment decisions on the commercialization of bitumen partial upgrading (BPU) technologies being considered as part of the Alberta Partial Upgrading Program. AI, and its predecessor organizations, have been working on the evaluation of BPU processes since 2007 and are planning for the initiation of significant investment beginning in 2019 partnering with a variety of other government-funding sources to assist the technology developers with commercialization efforts.

The stream properties for four subject PUBs were sourced from the technology developers, labeled in this report as PUB 1, PUB 2, PUB 3, and PUB 4. The values were determined for the three regions where the PUBs are likely to be primarily marketed; which, for this study, were U.S. Petroleum Administration for Defense District (PADD) II (Midwest), PADD III (Gulf Coast) and China. The primary deliverable of this work was a set of Refining Value Correlation Equations (RVCEs) and a Market Value Correlation Methodology (MVCM) which can be used to reasonably correlate the refining and market value of the PUB streams to competitive/reference crudes in each of the regions for a range of WTI (Cushing) crude price values between US$50 and US$80 per barrel (Note: all prices quoted in this report and the associated Tables and Figures are in US$ per barrel, unless noted). A variety of supporting analyses are also included in this study report, including a supply and demand outlook for medium and heavy competitive crudes, a discussion of commercial considerations and influences, and other factors impacting the market value of the PUB streams.

To calculate the refinery values (defined as the value of the streams at the refinery gate based on refinery yields and variable operating costs), TM&C used our proprietary refining modeling system and representative “price-setting” refinery configurations for each of the three regions. The assays used to represent the four streams were provided by the individual companies. Where relevant properties were not included, TM&C estimated those based on our expertise and judgment and obtained agreement from the PUB producers. The price sets used were based on our most recent price forecasts from our biannual ***CRUDE AND REFINED PRODUCTS OUTLOOK*** (C&RPO) which was issued in August and adjusted to create four separate price decks reflecting flat WTI (Cushing) price levels of $50, $60, $70 and $80 per barrel. Transportation costs to move the PUBs and competitive marker crudes to the three specified refining markets were also developed for each of the four price scenarios and these, together with commercial adjustments, were used to convert refinery values to market values.

The Tables in the Appendix, together with the discussion in the following report sections, detail the RVCEs and MVCM, the assumptions which were used to develop the equations, and the supporting market analysis data. The methodology used to develop the equations, along with other commercial and market considerations which we expect to impact the value of the PUBs, are also discussed in the report sections.

TM&C has prepared this analysis utilizing reasonable care in applying methodologies consistent with industry practice but makes no representations or warranties about the accuracy or completeness of any of these observations. It likewise assumes no liability for damages including, but not limited to, consequential damages in connection with the recipients' use or inability to use the information provided herein.

II. EXECUTIVE SUMMARY

The results of our study and key observations are summarized below:

- The key qualities of the PUB streams studied are summarized below in Table II-1 with more detail, including complete stream properties provided in Appendix Table III-1.

Table II-1 PUB Qualities				
	PUB 1	**PUB 2**	**PUB 3**	**PUB 4**
Whole Stream Properties				
API Gravity	20.9	19.3	19.3	23.3
Sulfur (wt. %)	3.69	3.49	3.74	0.39
K Factor	11.24	11.26	11.46	11.69
TAN	1.65	0.30	0.90	<0.1
Yields, LV%				
Light Ends	0.8%	0.3%	0.1%	0.5%
Naphtha	8.5%	8.4%	9.5%	16.5%
Distillate	32.5%	28.4%	24.5%	18.3%
Gas Oil	44.7%	44.5%	40.5%	37.7%
Vac. Tower Btms (VTB)	13.6%	18.5%	25.4%	27.0%

- All of the PUB streams will be attractive feedstocks for deep conversion refineries in the three markets studied – PADDs II and III in the U.S. and China. We believe this will be the primary price-setting mechanism for each of them, with the possible exception of PUB 4.
  - In PADD II, the PUBs will compete with and displace/replace other Canadian medium/heavy grades, which currently make up the entirety of the medium/heavy crude supply to regional refiners. While very limited capacity expansion is expected, there could be room to expand the total volume of medium/heavy crudes processed, especially for PUBs with lower VTB content.
  - In PADD III, the PUBs will primarily compete against heavy Latin American crudes, Gulf of Mexico (GOM) medium sour grades and both heavy and medium Middle East crudes. Some limited, deep-conversion, capacity expansion is expected and as in PADD II, lower VTB content PUBs can “stretch” the existing capacity.

  - In China (and the rest of Asia), Middle East medium and heavy crudes will be the main competition. With capacity expected to grow in tandem with product demand, new markets will supplement displacement opportunities.

- The lower resid content of PUB 1 and PUB 2 will provide expanded market opportunities for Canadian bitumen derived crudes in deep conversion limited markets and refineries, especially in combination with light sweet crude oils.

- Because of its low sulfur, PUB 4 has even more opportunities beyond just as a deep conversion refinery feedstock. These include use as an anode coking refinery feedstock, cracking refinery feedstock, and International Maritime Organization (IMO) compliant bunker fuel blendstock. We have incorporated the anode coke price benefits in our analysis, but it is very possible that higher values could be achieved in the other possible markets. This is especially likely in the 2020 to 2025 time period when the premium for low sulfur resid as a result of the IMO regulations will be the highest.

- While other configurations and operating modes, including resid hydrocracking, could also provide attractive homes for the PUB streams, we do not believe these refineries would be the price-setters. The potential of higher values from these other options would justify characterizing our price assessments for the PUB streams in this study as "conservative."

  - There are no resid hydrocrackers in the USMC and only very limited resid hydrocracking capacity in the USGC.

  - While resid hydrocracking is more widespread in China (and Asia in general), each unit is unique, utilizing different catalysts and employing a variety of technologies and process design characteristics. Yield patterns and operating costs, along with how these are impacted by feed qualities vary to a much greater degree than with delayed cokers.

  - Any "uplift" in value that would exist in a resid hydrocracking refinery would primarily reside with the refiner and not impact open market prices to any great degree.

  - The above comment also applies to other operating modes or capabilities which specific refiners could use to realize higher refining values for the PUB streams.

- PUB producers could participate in the higher values which a specific refinery or configuration provides, and although this might provide some upside to the values we have estimated, this added value could best be captured through one-on-one negotiations and longer term supply arrangements. The potential "uplift" would certainly be situationally and facility specific and while it is difficult to precisely quantify without a targeted analysis, it could approach or exceed $1 per barrel at the right facility.

- Each of the four PUB streams is unique and has both positive and negative relative qualities. As a result, our analysis shows they have estimated refining values which cover a wide range and vary by region.

  - PUB 1 has the lowest Vacuum Tower Bottoms (VTB) yield, but has the most challenging gas oil (low K factor/high nitrogen, concarbon and sulfur) and distillate (low cetane/high sulfur) properties and the highest TAN content (1.65). Overall, it has a refining value greater than WCS by about $6.50 to $9.00+ per barrel in both the USGC and USMC (higher values in the higher price sets). In China, PUB 1 has a refining value of between $3.50 and $5.00 per barrel vs. Arab Heavy.

    - Certain refiners (particularly with hard coker limits) could realize higher values for PUB 1 by taking advantage of the lower VTB content through optimized crude selection (co-processing with higher resid content/lower market value crudes) and downstream unit utilization.

    - The lower VTB content of PUB 1 also provides the opportunity to expand the market for this stream to less complex refineries without deep conversion capabilities, especially in combination with sweet light crudes such as U.S. produced Light Tight Oils (LTOs).

  - PUB 2 is higher in VTB content than PUB 1, has comparable gas oil and slightly better distillate properties, and has a much lower TAN content (0.30). Overall, it has a refining value which is a bit lower, varying from about WCS plus $5.00 per barrel to plus $7.00 per barrel in the two U.S. regions. In China, PUB 2 has an approximate refining value of between $2.00 and $3+ per barrel over Arab Heavy.

    - As with PUB 1, PUB 2 also has the potential of capturing a higher value in certain coker constrained refineries or combining with light sweet crudes as a feedstock to refineries with limited or no deep conversion capacity.

- PUB 3 has the highest resid content and overall is similar in most respects to WCS, both in distillation cuts and properties. The TAN content is also very similar to WCS at 0.90. As a result the refining value also tracks WCS very closely in both the USMC and USGC refining regions. Our modeling shows it to have a refining value premium vs. WCS in those two markets of between about $0.10 per barrel and $0.70 per barrel. In China, PUB 3 has a refining value which is below Arab Heavy by about $2.50 per barrel to $3+ per barrel.

- PUB 4 is very unique being a heavy stream, but one that is very low sulfur (and also very low TAN). For the purposes of this study, we evaluated a PUB 4 stream that was blended with 20% diluent to meet pipeline viscosity specifications. This 24 API gravity stream still has 27% resid (1050+), but the whole stream sulfur is only 0.39 wt.%; and more importantly, the resid is only 0.74 wt.%. As a result, it was able to produce higher valued anode coke and had the highest refining values of the four PUBs. In the USMC and USGC, PUB 4 had a refining value which varies between $7.50 and $10.00 per barrel over WCS. In China, PUB 4 has a refining value that is between $4.50 and $6.00 per barrel above Arab Heavy. Due to the impacts of IMO, which is expected to provide a significant bump to anode coker capable feedstock in the early years of implementation, these premiums will be several dollars per barrel higher in 2020.

    - As noted earlier, PUB 4, due to its low sulfur resid properties, has opportunities in other markets beyond just as an anode coker feedstock. The 2020 IMO low sulfur bunker regulations make these opportunities more attractive, especially during the early period after implementation when compliant bunker fuel will be in short supply. These opportunities can be realized through multiple including:

        - As a feedstock to a cracking refinery with the bottoms selling into the compliant bunker market. A potential upside in this operation is the ability to dilute with Synthetic Crude Oil (SCO) instead of condensate, with none of the downgrade concerns that SynBits have when going to coking refineries; and

        - As a direct blendstock into the compliant bunker market.

- We developed RVCEs for each of the PUB streams based on our refinery modeling analysis (shown in Table III-5 in Section III). This involved identifying those quality parameters which are most relevant in determining the refining value of the streams.
  - The variables identified from rigorous empirical testing were: distillation (as measured by using the volume yield for VTB, VGO and middle distillates), VTB sulfur and VTB Concarbon.

  - A “WTI price” factor is included in each equation to adjust for absolute price level, allowing the equation to be valid across the entire price range tested (WTI at $50 to $80 per barrel).

  - Separate equations were developed for each of the three regions and each of three volume/penetration levels, for a total of nine different equations in all.

  - The RVCEs are to be used in conjunction with competitive reference crudes in each specific market. The RVCE will predict a refining value for both the subject PUB stream and the reference crude and the delta can be used to relate the value of the PUB to the reference crude.

    - In the USMC, we expect WCS to be the proper reference crude. In the USGC, we believe Arab Heavy, Mars and WCS could be potential reference crudes, while in China, Arab Heavy is the proper reference crude.

  - These RVCEs are meant to predict “refinery gate” refining values for the PUBs (and competitive crudes). In the price range tested in this study, they are generally accurate to within $0.50 per barrel in this prediction, with maximum deviations limited to about $2.00 per barrel.

- The PUBs will incur additional market-related discounts/price adjustments beyond those that are due to quantifiable yields and qualities that can be calculated from refining value modeling. These will be based both on qualities (specifically TAN for two of the PUBs and beneficially low sulfur resid in the PUB 4) and “other commercial/market factors” primarily related to market entry issues.

  - Both the TAN and other commercial/market adjustments are transitory and will decline as the new PUB streams become accepted into the regional markets.

- These discounts will vary by region, with the lowest in the USMC (due to familiarity with similar crudes) and the highest in China (for the opposite reason). PUB 1, due to its high TAN and difficult gas oil properties will see the biggest discounts, while PUB 3 and PUB 4 will see the smallest.

  - Estimated total market discounts for PUB 1 vary from as high as $2.70 per barrel in the first year of introduction in China ($1.30 per barrel in the USMC) and declining to between $0.25 and $0.50 per barrel within five to seven years.

  - PUB 2, which has similarly difficult gas oil properties, but does not have the same TAN issues, has total estimated market discounts which start at $1.50 per barrel in China ($0.70 per barrel in the USMC) in the first year of introduction and decline to zero within five to seven years.

  - For PUB 3, which has a medium/high TAN content, we have estimated total market discounts which start at $1.60 per barrel in China ($0.50 per barrel in the USMC), declining to a long-term TAN discount of $0.25 per barrel after five to seven years.

  - For PUB 4, we estimate that there would be a market premium for its low sulfur resid properties in coastal markets (USGC and China), starting at $0.50 per barrel and declining to $0.10 per barrel long-term. Combined with some market entry discount, this results in total market adjustments which vary from a discount of $0.50 per barrel at the beginning to no discount or a premium of $0.10 per barrel long term after five to seven years.

- Our estimates for these commercial/market discounts are very subjective and will certainly vary, depending on the specific market environment. This will be particularly true during the early phase of PUB introduction, where the discounts could be particularly wide for higher volumes.

- The RVCEs can be converted to market values by adjusting for the TAN and other commercial/market factors and transportation costs from Alberta to each of the specified refining markets through a specified Market Value Correlation Methodology (MVCM) detailed on pages 39 through 41.

  - Transportation costs were estimated separately for each of the price sets and are based on the assumption that pipelines are completed to both Vancouver and the USGC to remove pipeline constraints.

- We did include estimated rail costs from Edmonton to Vancouver to represent a pipeline constrained scenario. This presumes rail capabilities, which do not currently exist for this route, are added by 2025.

- The MVCM provides a way to calculate the relative market values of PUBs vs. specified reference crudes in each of the three regions. It can further be used to predict "netback" market values for the PUBs by applying the calculated market value differentials to the actual/forecasted price of the select reference crude and adjusting to the appropriate refinery gate price).

  - Table II-2 below shows the summarized results of an analysis we did using the MVCM methodology to estimate the market prices for the PUBs in each of the regions and price sets we studied.

Table II-2 Forecast PUB Netback Market Values 2025 to 2045 Averages Across All Penetration Levels FOB Edmonton/Hardisty – US $per Barrel				
	$50 WTI	$60 WTI	$70 WTI	$80 WTI
PUB 1				
USGC				
vs. WCS	39.82	48.95	58.09	67.22
vs. Mars/Arab Heavy	40.27	49.79	59.30	68.81
USMC vs. WCS	39.99	49.14	58.28	67.42
China vs. Arab Heavy				
Pipeline to Vancouver	43.52	52.96	62.44	71.73
Rail to Vancouver	36.92	46.16	55.24	64.43
PUB 2				
USGC				
vs. WCS	38.60	47.55	56.49	65.44
vs. Mars/Arab Heavy	39.05	48.38	57.71	67.03
USMC vs. WCS	38.61	47.56	56.50	65.45
China vs. Arab Heavy				
Pipeline to Vancouver	42.79	52.08	61.43	70.57
Rail to Vancouver	36.19	45.28	54.23	63.27
PUB 3				
USGC				
vs. WCS	33.87	42.28	50.69	59.10
vs. Mars/Arab Heavy	34.33	43.11	51.90	60.69
USMC vs. WCS	33.98	42.39	50.80	59.21
China vs. Arab Heavy				
Pipeline to Vancouver	38.00	55.06	55.59	64.21
Rail to Vancouver	31.40	48.26	48.39	56.91
PUB 4				
USGC				
vs. WCS	42.17	51.16	60.16	69.15

vs. Mars/Arab Heavy	42.48	51.84	61.20	70.55
USMC vs. WCS	41.07	50.11	59.16	68.20
China vs. Arab Heavy				
Pipeline to Vancouver	45.68	55.06	64.48	73.70
Rail to Vancouver	39.08	48.26	57.28	66.40

- Some key observations from the MVCM netback analysis (the results of which are further detailed in Appendix Tables III-10A through 10D) are:
    - Depending on whether P/L or rail transportation was assumed, China showed both the highest (by about $2 to $4 per barrel) and lowest (for rail) netback values for the PUBs.
    - The calculated netback values for the PUBs in the U.S. were highest when medium grade (Mars/Arab Heavy) crudes were used as the reference marker.
    - The netback values for all of the PUBs, when using WCS as the reference crude, are very close between the USMC and USGC (with the exception of PUB 4). PUB 4 is valued higher on the coast due to its advantaged resid sulfur properties.

- Overall, we feel that it is still very likely that the USGC could end up as the price setting region for the PUB streams due to its size, feedstock flexibility and appetite for crudes which are similar to the PUBs.
    - The China market shows very good potential, based both on a potentially higher value (given no pipeline constraints to Vancouver) and the growing market size.
    - The USMC market could also be an attractive market despite no expectations of capacity growth, due to its favorable location and familiarity with similar Canadian feedstocks.

- The RVCEs/MVCM we developed in this study is based on how we feel the PUBs would be valued in an "open market" environment. Because of the unconventional (both good and bad) properties of each of PUBs, we believe significant opportunities exist to improve on these values through targeted negotiations with specific refiners.
    - The development of longer term supply agreements with these specific refiners could allow for the minimization or even elimination of the TAN and other commercial/market discounts we estimated.

- Premiums could be realized for some of the PUBs due to specifically attractive properties (low sulfur resid in the PUB 4, yield patterns in some of the other PUBs which are synergistic with existing feedslates, etc.).

- While we do feel delayed coking will set the open market price for most of these PUBs, other configurations could result in higher refining values.

- With various processing options still being evaluated in the production of the PUBs, identifying specific refiner's needs regarding yields and cut properties would be a valuable input in maximizing the value of the PUBs.

III. REFINING VALUE CORRELATION EQUATIONS and MARKET VALUE CORRELATION METHODOLOGY (RVCEs and MVCM)

Key Model Inputs

Perhaps the most important factor in providing reasonable and model outputs is the quality of the input data. The key data input sets for the model runs in this study are: (1) the assays for the PUB streams and the competitive crudes with which they are to be compared, (2) the refinery models used in the analysis, and (3) the price sets selected for the analysis. While assumptions on transportation costs and logistical constraints do not play a direct role in the modeling exercise and calculation of refining values, they are important in converting the regional refining values back to market values in Alberta. In the same vein, other market and commercial factors not captured by refinery modeling will also play a role in the market value calculations. The sections below describe the key model inputs and transportation assumptions, while the market and commercial factors are discussed in more detail in Section V.

PUB and Competitive Crude Assays

The assays which define the composition and quality of the four PUB streams (PUB 1 through 4) were provided to us by the producing companies. Most of the key qualities were included in these assays, but in certain cases we had to estimate properties, which we did using our professional expertise and judgment. In each case where we made estimates, they were reviewed and approved by the relevant company.

Since the main focus of this study was to develop correlations between the PUBs and key competitive crudes, it was also important to use representative and current assay information for those streams as well. The competitive crudes were selected based on their importance within the refining centers chosen for this study and their likely competitive positioning vs. the PUBs. The competitive crudes used in this study were: Access Western Blend (AWB), Western Canadian Select (WCS), Mexican Maya, Mars and Arabian Heavy. AWB and WCS are relevant crudes for U.S. PADD II; AWB, WCS, Maya and Mars are relevant for PADD III and Arab Heavy was applicable as a competitor in China. TM&C maintains an updated assay database for all of these crudes and the assays used in this study were drawn from this source, after review and agreement from the Steering Committee.

The detailed assays for both the PUBs and the competitive crudes, including the estimated properties which are noted, are summarized in Appendix Table III-1.

Refining Regions and Models

TM&C maintains a robust proprietary refining modeling system (Turner Mason Modeling System - TMMS) which we utilize in the crude valuation work we do for a variety of clients on both an ongoing and engagement specific basis. We also use TMMS to support the price forecasts we develop for the ***C&RPO*** and special studies which we do on a regular basis***.*** Within TMMS, we maintain unique regional models which represent major refining regions/hubs around the world. The regional models are based on actual refinery configurations, capabilities, product specifications and other key characteristics specific to the individual regions.

For this study, three regions, U.S. PADD II, U.S. PADD III, and China were selected to analyze the PUB refining and market values for this study and develop the RVCEs and MVCM. While other regions could and likely will be candidates for processing the PUB streams, the selected regions are probably the most economic and highest demand options. As such, they should provide a very representative estimate for the market value range of the PUB streams.

The refining models we used to represent the three study regions are based on our existing regional models and were modified to reflect refining configurations which we believe would represent "price-setting" facilities. We believe a delayed coking refinery configuration targeted toward medium and heavy high sulfur crudes will be the marginal and price-setting consumer for the PUBs (with the possible exception of PUB 4). While in some cases, other types of refineries, notably those with resid hydrocracking capability, might provide "uplift" in value, we believe those refiners will generally capture that uplift, and not impact the overall market price. It is certainly possible that PUB producers could participate in the uplift through negotiating term supply contracts, but again would not expect those sorts of arrangements to influence the open market price for the streams. Other reasons we believe resid hydrocrackers will not be "price setters" include their limited presence in the U.S. and their individual uniqueness which makes consistent comparisons between different refineries impractical.

Price Sets

As per the decision of the Steering Committee, four price sets, representing flat WTI (Cushing) price levels of $50, $60, $70 and $80 per barrel were selected for this study to test the PUB values at various price levels. In arriving at crude differentials, product margins and other price relationships consistent with the chosen absolute WTI prices and our views on market factors, TM&C used our proprietary pricing model and our most recent market forecasts. These market forecasts came from our most recent ***C&RPO.*** This product is a detailed, worldwide assessment and forecast of petroleum supply, demand and pricing which we market on a biannual basis to international subscribers. The most recent issue of this report is the ***2018 MID-YEAR UPDATE,*** which was published in August 2018. We used the forecast from this report as the basis for the price sets which were used in this study, adjusting the key relationships as necessary to be consistent within the individual absolute crude price sets.

In generating our ***C&RPO*** price forecast, TM&C is not intending to "call the market" at any particular point in time (which is essentially a guessing game), but rather to provide an independent view of mid- to long-term relationships, which can be used to compare competing crude oils and evaluate long-term strategies, capital investments and financial decisions. It is consistent with a specified view of regional and worldwide economic growth, government regulation, technical innovation and overall petroleum supply and demand fundamentals. As such, it is particularly appropriate to this project (as a starting point) to develop the four price sets reflecting the different price levels used to draw "boundaries" for the applicability of the RVCEs and MVCM, which are being used to assist AI and the technology developers to help determine investment decision on "shaping: the quality of the PUB streams.

Another factor supporting the use of our ***C&RPO*** price forecast as a basis for this study is the consistency of the absolute crude price forecast with the range of the four selected study price sets. In our August ***C&RPO*** forecast, WTI (Cushing) ranges from $65 to $75 per barrel over the 20-year time frame of the analysis, falling within the low and high limits of the study decks.

The price sets for both crude and products are shown in the Appendix (Appendix Tables III-2A through 2D for crude and Appendix Tables III-3A through 3D, 4A through 4D, and 5A through 5D for products). Our overall market outlook, along with some of the key assumptions used to support the price relationships in the ***C&RPO*** and the adjusted individual price sets are summarized below.

- Continued strong growth in North American crude production (primarily from U.S. tight oil), together with technology improvements which keep crude exploration and production costs low will result in a generally moderate crude price environment over the next two decades.
    - As noted above, our ***C&RPO*** forecast for absolute crude prices falls within the range of the four price sets used for this study.
- Heavy/Medium high sulfur crude discounts will widen significantly in 2020 as a result of the IMO LS bunker regulations, but most of this effect will be gone by 2025 with further tightening in subsequent years. Over the longer term, the spread will

equilibrate at levels keeping existing deep conversion units (delayed cokers/resid hydrocrackers) profitable but below new build economics.

- This results in the following long-term LLS-Maya spreads: $50 WTI - $8 to $8.50,: $60 WTI – $9 to $9.50; $70 WTI - $10.50 to $11; and $80 WTI - $11.50 to $12 per barrel. In each case the % discount for Maya vs. LLS averages between 15 and 16%.
  - To put these relationships in historical perspective, the LLS-Maya spread (on an annual average basis since 1995) has ranged from a low of about $5 per barrel (when crude prices were in the teens) to a high of $18+ (in a $100+ crude price environment), averaging $9.60 per barrel for the entire 1995 to 2018 period (LLS average of $56.25 per barrel). The percent discount averaged about 17% for the same period. This data is shown in Appendix Table II-1.

- New deep conversion capacity will be added, but only through integrated heavy crude production deals (JVs, LT supply contracts, etc.), as part of larger refinery projects or through cost advantaged brownfield expansions. This will keep the heavy/light spread below new build levels (which generally would have to be above 20 to 25%) while still providing homes for growing production.

- There is significant uncertainty in the heavy crude supply forecast due to the impact of “above ground” limitations (politics, logistics, etc.) on production in key countries such as Venezuela, Mexico and Canada.

- The Middle East will become a more important new player in the deep conversion refinery supply/demand equation as production grows and IMO shifts more of the high sulfur medium grades away from bunker fuel markets.

- Section IV provides a detailed look at both the historical and current global medium and heavy crude supply/demand balances, our forecast for how it will change and the factors which will be critical to this forecast. Also included at the end of Section IV is comparison of historical heavy/light spreads with the forecasts used in this study and a more detailed explanation supporting those forecasts.

- Overall, global petroleum product demand growth will continue but slow as both efficiency gains and alternatives eat into petroleum’s proportion of total demand.

- After growing recently at levels above 1.5% per year, global petroleum demand growth will slow to average 1.2% annually from 2020 to 2025. It will fall below 1.0% per year after 2025 and decline farther to below 0.5% after 2030.

- As has been the case for most of the past decade, this growth will almost exclusively come from developing economies, primarily in Asia.

- U.S./North American petroleum demand will peak by 2025 and decline by about 1 million BPD over the next ten years.

- Despite the slowing demand growth, we expect refining capacity to remain relatively tight for most of the period of our forecast.

  - There will be some excess of capacity additions over the next four years (about 1 million BPD on a global basis), but the effects of this overbuild is mitigated by the current tight capacity and our expectations of the shutdown of inefficient capacity due to IMO impacts.

  - Over the longer term, the fear of “peak demand” itself will keep refiners cautious and limit capacity additions and expansions.

- All of the above factors taken together will contribute to relatively attractive refining margins (on a sustainable basis) during the period of our forecast.

- Complex U.S. refiners will remain very competitive, continuing to expand product exports to developing countries as domestic demand flattens and then declines.

  - Superior hardware and manpower capabilities, along with advantaged natural gas and crude costs will allow U.S. refiners to maintain their competitive stature.

  - Troubles experienced in operating and expanding capacity in developing countries will also help support the export model.

  - Overall refining capacity in the U.S. will show some growth in both total and deep conversion capacity; most likely on the USGC. Growth will be limited by export opportunities.

- Chinese refining capacity will continue to grow in tandem with domestic product demand growth and will be more complex and capable of processing medium and high sulfur crudes such as the PUBs.

Transportation Assumptions

- The most important logistical assumption is that pipeline capacity will be in place to transport Western Canadian crude to the USMC, USGC, and the West Coast of Canada by 2025.

- Prior to the completion of the necessary pipelines, we expect unit rail to be the marginal, price setting form of transportation from Canada to the USGC, with costs about $4 to $5 per barrel above post-2025 pipeline levels.

- We have assumed that the capacity to the USMC and USGC will not be limiting throughout the time period of our forecast (2025 through 2045). For transport to the West Coast (Vancouver, BC), we have included two transportation scenarios, pipeline and rail (assuming pipeline is limited).

- For the purposes of this study we have assumed that transport from the field to Edmonton or Hardisty is equal, so that the netback price for the PUBs is at Hardisty if going to the USMC or USGC and Edmonton if going to China.

- Pipeline tariff forecasts to the USMC, USGC and Vancouver are estimates based on our best knowledge of proposed or anticipated rates for Keystone XL and the Transmountain Expansion and adjusted to be consistent with the four individual price sets.

- The tariff forecasts are held constant throughout the 2025 to 2045 period consistent with the flat absolute crude price assumptions in each case. It is possible that if and when new capacity is necessary, the marginal cost to transport could increase.

- The tariff forecast for Hardisty to USMC varies from $4.80 per barrel ($50 WTI) to $5.20 per barrel ($80 WTI) among the four price sets, while the tariff forecast to the USGC varies from $12.80 per barrel ($50 WTI) to $14.00 per barrel ($80 WTI).

- Transportation to China is based on transport from Edmonton to Vancouver plus marine transport to Asia. An additional cost is added to reflect movement from the port to the refinery in China.

- As noted earlier, we have included a scenario where pipeline space is limited and incremental movements are by rail. Our estimates for "all in" rail costs" from Edmonton to Vancouver vary from $13 per barrel (for the $50 WTI case) to $14.50 per barrel ($80 WTI).

- The transportation assumptions, along with the forecast transportation costs for the four study price sets are detailed in Appendix Tables III-6A through 6E.

Modeling Methodology

A variety of different approaches could be used to calculate refinery value differences between specific crudes. These can include different strategies with regards to what if any other crudes and feedstocks are "co-processed" with the subject crude, variations in how downstream processing constraints are considered, different "seasonality" considerations, how product grade limitations are treated, and a variety of other factors. For this study, we leveraged our experience in past studies and in ongoing crude valuation assessments to use methodologies and strategies which we feel most effectively capture the anticipated refining values of the PUB streams in the three target markets. This methodology is consistent with that which we currently use in both our daily Platt's crude price assessments and the weekly analyses we conduct for a major U.S. refiner, along with recurring engagements for other participants who are responsible for making crude supply and purchasing decisions. The specific markets (USMC, USGC and Asia) targeted in this study are heavily represented in all of these engagements.

This methodology involves running the specific PUBs and competitive crudes in the selected regional price setting models we described earlier in "pure quill" mode, but adjusting key downstream capacities as necessary to represent different processing levels. We have found that this leads to more consistent and representative results in a regional analysis such as this, rather than introducing other "co-processed" crudes into the cases, a methodology that works better when assessing specific individual refinery economics. Intermediate feedstock (naphtha, gas oil) and blendstock (natural gasoline) purchase options are also allowed, consistent with regional availability and other limitations. As noted earlier, the refining models include product specifications, unit capabilities and other important parameters specific to the individual regions. Since product specifications (particularly for gasoline), vary seasonally, we also employed the resulting seasonal variations in operating modes and yields in making the model runs.

Table III-1 shows the base unit capacities used for each region as a percentage of crude capacity. All refining units not shown in the Table are assumed to have sufficient spare capacity or not functionally limiting, an assumption which is consistent with

Table III-1: Regional Unit Capacities

experience in "price-setting" analysis. The refineries are allowed to buy or sell intermediates to ensure that all upgrading (coking / cracking) units are full.

(As a Percentage of Crude Capacity)			
	USGC	**USMC**	**China**
Coker	29%	20%	22%
FCC	30%	34%	22%
Mild HCU	15%	6.8%	10%
Conv HCU	7.5%	4.5%	15%
C4 Isom	0%	0%	0%
C5/C6 Isom	2.3%	5.7%	0.5%
MTBE	0%	0%	3%

In this study, we developed and analyzed three different cases – 1) a low "penetration" case that represents a low PUB volume scenario, nominally 10 MBPD, 2) a medium penetration case that represents 40 MBPD of PUB volume, and 3) a high penetration case, representing 100 MBPD of PUB. The low penetration case was assumed to be nonconstraining, with the key upgrading units (including the FCCU and delayed coker) essentially "open." In making this assumption, we are saying that refineries in each of the regions can fit 10,000 BPD or less of the PUB streams into their facilities (region-wide) without hitting major unit or blending constraints which would impact the refining value.

In order to assess the higher penetration cases (40 MBPD and 100 MBPD cases); we considered how the unconventional VGO, diesel, and resid properties (high aromatics, low K factor, high concarbon) of many of the PUBs would affect various unit operations when these PUBs are processed in higher volumes. The higher penetration cases had the largest effect on PUB 1 and PUB 2 due to their high yields of VGO, coupled with high aromatics and concarbon content in that cut, negatively impacting FCCU operations.

Modeling Results

The refining values we calculated for each of the PUBs (and the competitive crudes) are the major components determining the relative market value for the streams, but should not be taken as market values. These refining values are in fact the value of all refined products produced by processing the crude/PUB less variable operating costs (electricity, purchased fuel, and catalyst/chemical costs), while these yields are shown in Appendix Tables 7A through 7L. Refining margins, fixed costs and SG&A are not included in the refining value calculation, nor are they included in the market value (see the Key Definitions section on page 80 for a detailed explanation of the difference between refining values and market values). However, other elements do go into determining market value beyond just the refining values. These include adjustments (generally discounts) for other crude properties that cannot be effectively modeled and other commercial/market factors not related directly to refining values. They are discussed in more detail and quantified in Section V of this report. Transportation costs are also not included in the refining values, which are calculated at the refinery gate and were discussed and quantified in a previous section.

Refining Values

A summary of the results from each case is present here. Values were generated for each year and averaged across the entire time period in this summary. The more detailed results for each model case, paired with each price set can be found in Appendix Tables III-8A through 8L.

Low Penetration/No Constraint Case – 10,000 BPD Production

As noted earlier, the low penetration case assumed effectively open downstream capacities and therefore did not account for how specific stream properties would impact the effective capacity of key units. It also did not account for the likely shorter catalyst life in the DHT, hydrocracker, and other units that would be associated with some of the PUB

Table III-2: Relative Refining Values – 10 MBPD Case
Approximate Average Refining Value
over 2025 - 2045 Time Period

	$50 WTI	$60 WTI	$70 WTI	$80 WTI
USGC				
PUB 1	$64.51	$75.66	$86.82	$97.98
PUB 2	$62.68	$73.66	$84.64	$95.61
PUB 3	$58.06	$68.49	$78.91	$89.34
PUB 4	$65.51	$76.55	$87.58	$98.62
Access Western Blend (AWB)	$55.52	$65.82	$76.12	$86.42
Western Canadian Select (WCS)	$57.51	$67.97	$78.42	$88.87
Maya	$57.56	$68.01	$78.46	$88.92
Arabian Heavy	$59.83	$70.48	$81.13	$91.77
Mars	$62.69	$73.65	$84.60	$95.56
WTI	$65.84	$76.91	$87.97	$99.04
Marlim	$64.60	$75.68	$86.76	$97.83
USMC				
PUB 1	$62.54	$73.51	$84.47	$95.43
PUB 2	$60.61	$71.38	$82.14	$92.90
PUB 3	$56.07	$66.28	$76.50	$86.72
PUB 4	$62.88	$73.72	$84.56	$95.39
Access Western Blend (AWB)	$53.36	$63.45	$73.53	$83.61
Western Canadian Select (WCS)	$55.39	$65.63	$75.87	$86.11
WTI	$64.23	$75.16	$86.10	$97.04
China				
PUB 1	$62.12	$73.29	$84.47	$95.65
PUB 2	$60.73	$71.77	$82.81	$93.85
PUB 3	$56.11	$66.61	$77.11	$87.62
PUB 4	$63.20	$74.30	$85.40	$96.50
Access Western Blend (AWB)	$53.76	$64.12	$74.49	$84.85
Western Canadian Select (WCS)	$55.60	$66.12	$76.63	$87.15
Arabian Heavy	$58.45	$69.15	$79.85	$90.56
WTI	$64.35	$75.40	$86.45	$97.50
Marlim	$63.08	$74.29	$85.51	$96.72

properties. This is because, at low volumes, these effects will be negligible and the PUBs would likely find their way to refineries having constraints that are not limited by some of the more troublesome stream properties of the PUBs (particularly PUB 1 and PUB 2); for example, low K factor/highly aromatic VGO typically produces more coke and would further limit the capacity of an FCC that is already air-limited. In this low penetration case, we expect that these PUBs could be absorbed into refineries without impacting unit constraints in any significant way because of the ability to “blend away” the relatively small volumes involved.

It should be emphasized that in this case (as with the others) we still fully account for the direct change in yields and product qualities that are associated with the individual stream properties.

Medium Penetration/Limited Constraint Case – 40,000 BPD Production

Table III-3 Relative Refining Values – 40 MBPD Case
Approximate Average Refining Value over 2025 - 2045 Time Period

	$50 WTI	$60 WTI	$70 WTI	$80 WTI
USGC				
PUB 1	$64.38	$75.52	$86.67	$97.81
PUB 2	$62.54	$73.49	$84.44	$95.40
PUB 3	$57.98	$68.39	$78.80	$89.22
PUB 4	$65.44	$76.47	$87.50	$98.53
Access Western Blend (AWB)	$55.52	$65.82	$76.12	$86.42
Western Canadian Select (WCS)	$57.51	$67.97	$78.42	$88.87
Maya	$57.56	$68.01	$78.46	$88.92
Arabian Heavy	$59.83	$70.48	$81.13	$91.77
Mars	$62.69	$73.65	$84.60	$95.56
WTI	$65.84	$76.91	$87.97	$99.04
Marlim	$65.36	$75.68	$86.76	$97.83
USMC				
PUB 1	$62.38	$73.32	$84.26	$95.20
PUB 2	$60.47	$71.21	$81.96	$92.70
PUB 3	$55.97	$66.18	$76.38	$86.59
PUB 4	$62.86	$73.70	$84.53	$95.37
Access Western Blend (AWB)	$53.36	$63.45	$73.53	$83.61
Western Canadian Select (WCS)	$55.39	$65.63	$75.87	$86.11
WTI	$55.66	$65.92	$76.17	$86.43
China				
PUB 1	$61.98	$73.14	$84.30	$95.46
PUB 2	$60.56	$71.58	$82.60	$93.61
PUB 3	$56.01	$66.50	$77.00	$87.49
PUB 4	$63.10	$74.20	$85.29	$96.38
Access Western Blend (AWB)	$53.76	$64.12	$74.49	$84.85
Western Canadian Select (WCS)	$55.60	$66.12	$76.63	$87.15
Arabian Heavy	$58.45	$69.15	$79.85	$90.56
WTI	$64.35	$75.40	$86.45	$97.50
Marlim	$63.08	$74.29	$85.51	$96.72

This case was a modification of the low penetration case, making adjustments to key downstream units, especially to the FCC, hydrocracker, and hydrotreaters to account for how the unconventional nature of some of the PUBs would affect the operation of these units at higher feed rates. Particularly, we adjusted for how specific stream properties might affect the effective unit capacity and the frequency of catalyst a change outs.

The impacts of the more constraining processing environment resulted in somewhat lower refining values for all of the PUBs, most notably for the PUB 1 and PUB 2, although the impacts weren't especially high even for those streams. PUB 1 and PUB 2 both saw similar effects, declining by between $0.14 and $0.23 per barrel compared to the Low Penetration cases, while, PUB 3 and PUB 4 also were affected similarly, declining by between $0.02 and $0.13 per barrel. The impacts varied by region and price set for each of the streams.

High Penetration/Harder Constraint Case – 100,000 BPD Production

This case was executed in a similar way as the medium penetration (40 MBPD) case, except that additional adjustments were made to key units, especially the FCC, hydrocracker, and hydrotreaters to account for how the unconventional nature of some of the PUBs would further affect the operation of these units at still higher feed rates. As with the Medium Penetration Case, the most important adjustments involved how specific stream properties impact the effective unit capacity and the frequency of catalyst change outs.

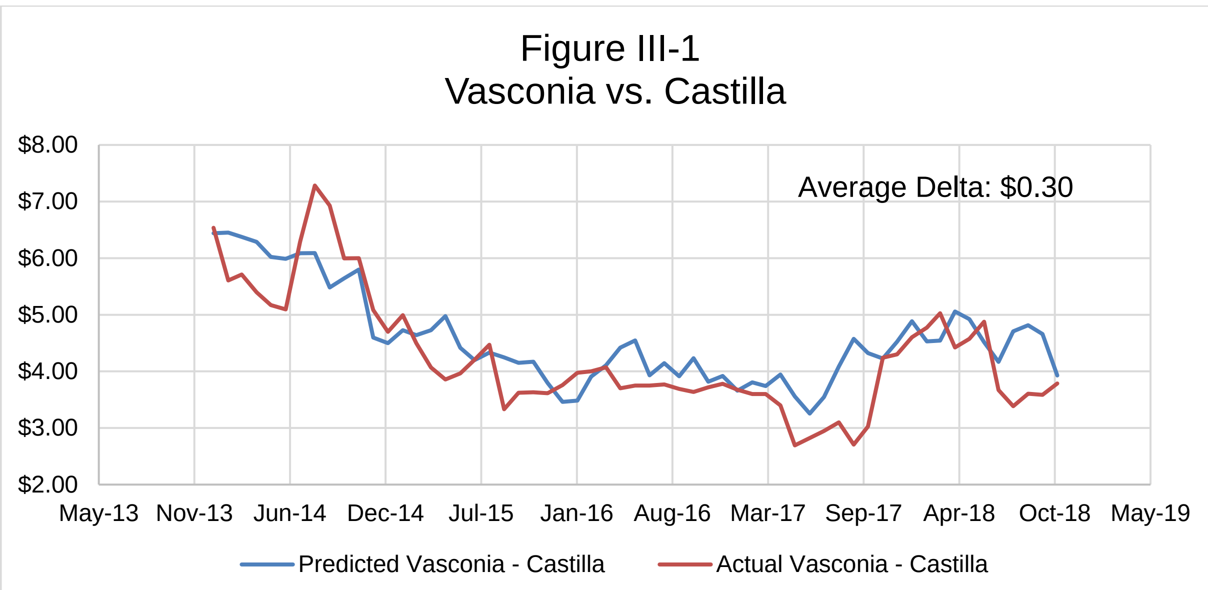
The impacts of this, even more constraining case, resulted in additional decreases in refining values for all of the PUBs. Again, the biggest impacts were on PUB 1 and PUB 2. PUB 1 and PUB 2 declined by between $0.22 and $0.38 per barrel compared to the Medium Penetration Cases ($0.35 and $0.61 vs. the Low Penetration Cases). The PUB 3 stream was impacted to a greater extent than PUB 4, with values declining by between $0.16 and $0.23 per barrel vs. the Medium Penetration Cases (between $0.25 and $0.36 per barrel versus the Low Penetration Cases). PUB 4 continued to see very limited impacts, with values declining by between $0.04 and $0.09 per barrel versus the Medium Penetration Cases (between $0.06 and $0.18 per barrel vs. the Low Penetration Cases). Just as with the Medium Penetration Cases, the impacts varied by region and price set for each of the streams.

Table III-4: Relative Refining Values - 100 MBPD Case Approximate Average Refining Value over 2025 - 2045 Time Period	$50 WTI	$60 WTI	$70 WTI	$80 WTI
USGC				
PUB 1	$64.15	$75.26	$86.37	$97.48
PUB 2	$62.29	$73.21	$84.13	$95.05
PUB 3	$57.81	$68.21	$78.60	$88.99
PUB 4	$65.38	$76.40	$87.42	$98.44
Access Western Blend (AWB)	$55.52	$65.82	$76.12	$86.42
Western Canadian Select (WCS)	$57.51	$67.97	$78.42	$88.87
Maya	$57.56	$68.01	$78.46	$88.92
Arabian Heavy	$59.83	$70.48	$81.13	$91.77
Mars	$62.69	$73.65	$84.60	$95.56
WTI	$65.84	$76.91	$87.97	$99.04
Marlim	$64.60	$75.68	$86.76	$97.83
USMC				
PUB 1	$62.11	$73.01	$83.92	$94.82
PUB 2	$60.21	$70.92	$81.63	$92.34
PUB 3	$55.81	$65.99	$76.17	$86.36
PUB 4	$62.82	$73.65	$84.48	$95.31
Access Western Blend (AWB)	$53.36	$63.45	$73.53	$83.61
Western Canadian Select (WCS)	$55.39	$65.63	$75.87	$86.11
WTI	$64.23	$75.16	$86.10	$97.04
China				
PUB 1	$61.76	$72.89	$84.01	$95.14
PUB 2	$60.32	$71.31	$82.29	$93.28
PUB 3	$55.85	$66.33	$76.80	$87.27
PUB 4	$63.07	$74.15	$85.24	$96.33
Access Western Blend (AWB)	$53.76	$64.12	$74.49	$84.85
Western Canadian Select (WCS)	$55.60	$66.12	$76.63	$87.15
Arabian Heavy	$58.45	$69.15	$79.85	$90.56
WTI	$64.35	$75.40	$86.45	$97.50
Marlim	$63.08	$74.29	$85.51	$96.72

Historical Validation

Historical validation of the model can be difficult because there are many factors not directly related to the actual value of crudes that can impact the short-term market differentials. Furthermore, some prices (such as the Saudi and Mexican crude OSPs) are set retroactively, and as a result there can often be a delay between the market price and the true efficient market pricing for these crudes. Lastly, transportation costs for many inland crudes, like WCS, WTI, and Bakken, are heavily dependent on the availability of pipeline and/or rail transport at any given point in time. As a result, prices of these crudes can drift far from their relative refining values when transportation constraints are encountered. Because of this, we chose to use crudes that are subject only to consistent and easily quantifiable transportation costs for our comparisons (generally those transported by marine movements).

The following figures show the monthly differentials for several medium and heavy crudes predicted using the Turner Mason model and the actual spot price differential between those crudes in the open market. In each case, the refining value differentials were adjusted for estimated transportation to be consistent with the spot location basis. The figures cover the time period from January 2014 through November 2018. While actual monthly variations in crude differentials vary due to market inefficiencies and short-term commercial and other factors, these variances cancel out and the predicted refining value differentials match the market differentials very closely over longer periods of time for each of the seven pairs of crudes we tested. In cases where there were significant variations for short periods of times, they could be explained by timing issues during rapid increases or decreases in prices, especially for the crudes such as Maya or Arab Heavy which are set through OSP mechanisms which lag market events.



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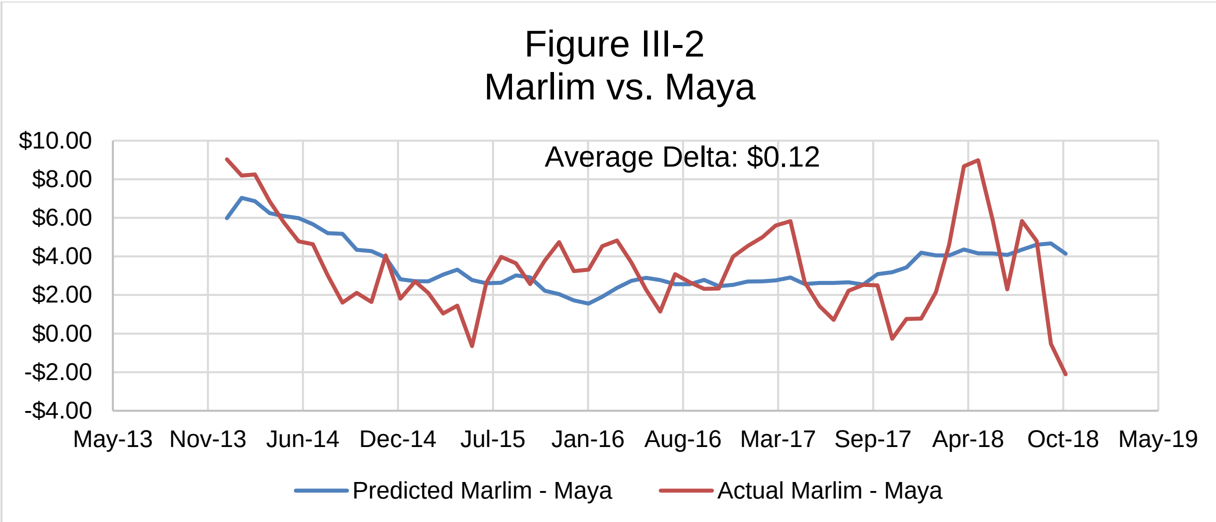


Figure III-2
Marlim vs. Maya
Average Delta: $0.12
$10.00
$8.00
$6.00
$4.00
$2.00
$0.00
-$2.00
-$4.00
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Jan-16
Aug-16
Mar-17
Sep-17
Apr-18
Oct-18
May-19
Predicted Marlim - Maya
Actual Marlim - Maya

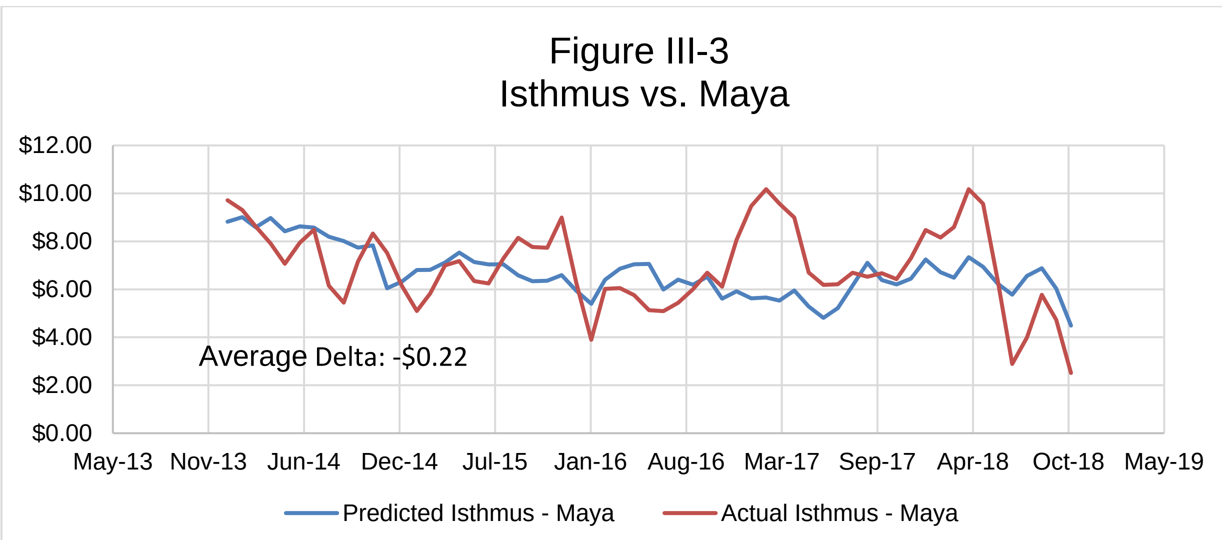


Figure III-3
Isthmus vs. Maya
Average Delta: -$0.22
$12.00
$10.00
$8.00
$6.00
$4.00
$2.00
$0.00
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Jan-16
Aug-16
Mar-17
Sep-17
Apr-18
Oct-18
May-19
Predicted Isthmus - Maya
Actual Isthmus - Maya

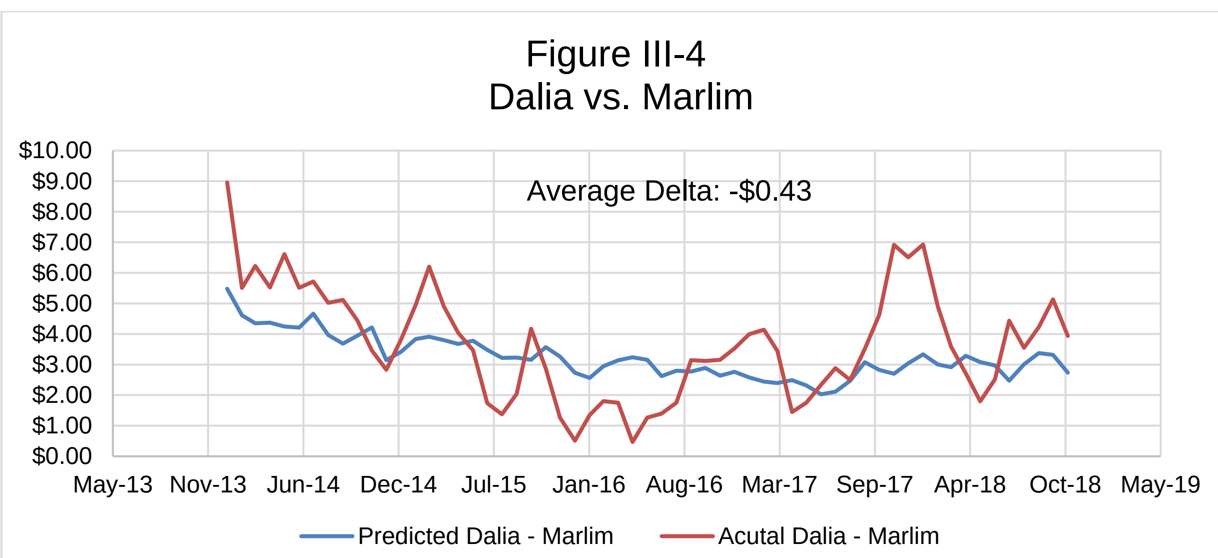


Figure III-4
Dalia vs. Marlim
Average Delta: -$0.43
$10.00
$9.00
$8.00
$7.00
$6.00
$5.00
$4.00
$3.00
$2.00
$1.00
$0.00
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Jan-16
Aug-16
Mar-17
Sep-17
Apr-18
Oct-18
May-19
Predicted Dalia - Marlim
Acutal Dalia - Marlim

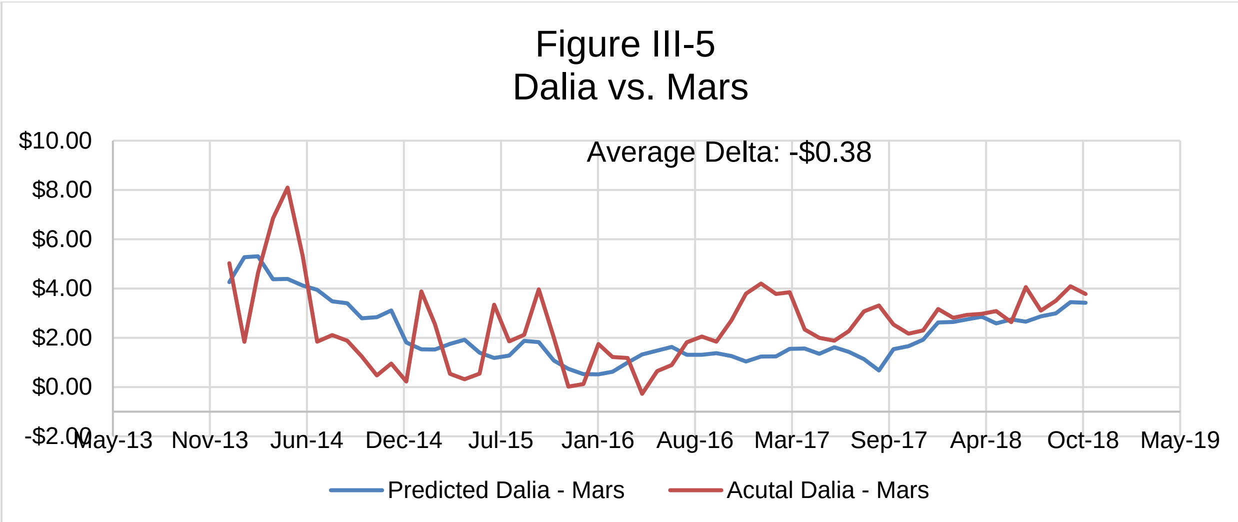


Figure III-5
Dalia vs. Mars
Average Delta: -$0.38
$10.00
$8.00
$6.00
$4.00
$2.00
$0.00
-$2.00
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Jan-16
Aug-16
Mar-17
Sep-17
Apr-18
Oct-18
May-19
Predicted Dalia - Mars
Acutal Dalia - Mars

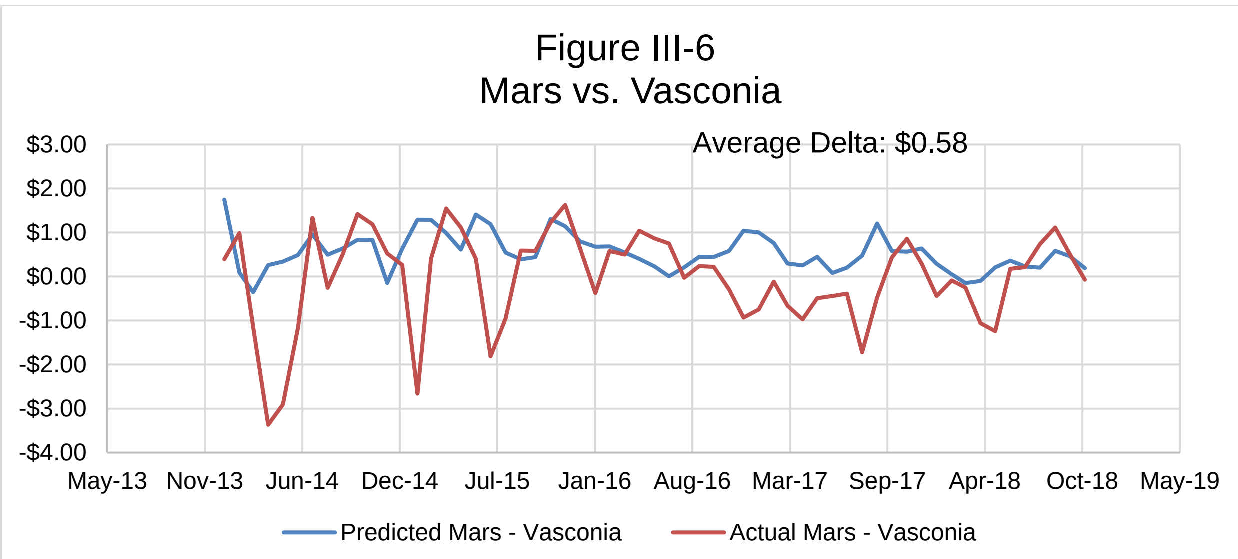


Figure III-6
Mars vs. Vasconia
Average Delta: $0.58
$3.00
$2.00
$1.00
$0.00
-$1.00
-$2.00
-$3.00
-$4.00
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Jan-16
Aug-16
Mar-17
Sep-17
Apr-18
Oct-18
May-19
Predicted Mars - Vasconia
Actual Mars - Vasconia

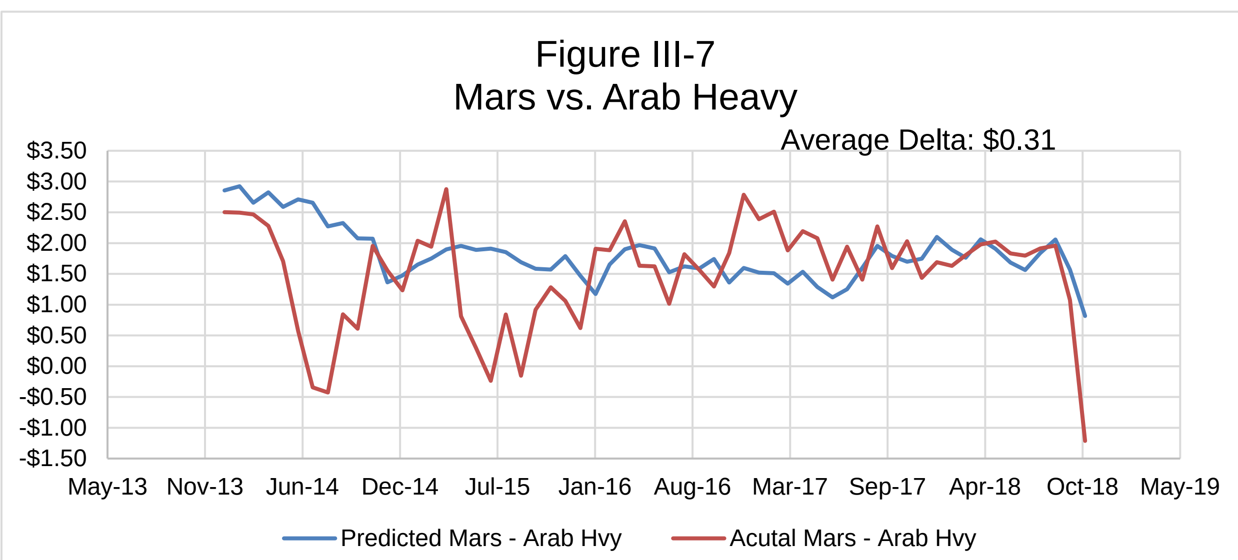


Figure III-7
Mars vs. Arab Heavy
Average Delta: $0.31
$3.50
$3.00
$2.50
$2.00
$1.50
$1.00
$0.50
$0.00
-$0.50
-$1.00
-$1.50
May-13
Nov-13
Jun-14
Dec-14
Jul-15
Jan-16
Aug-16
Mar-17
Sep-17
Apr-18
Oct-18
May-19
Predicted Mars - Arab Hvy
Acutal Mars - Arab Hvy

We have performed our comparison only for the U.S.G.C, because of the superior price transparency in this region for the heavy and medium crudes which are prevalent in the region and for which we believe the USGC is the price-setting region. Included among these crudes were three from this study, Maya, Mars and Arab Heavy, which were tested against other crudes and each other in five of the seven comparisons we performed. WCS (Hardisty) market prices could not be tested due to the issues with pipeline constraints, which resulted in unpredictable values unrelated to the refining value of WCS.

In Section V, we did some additional backcast analysis comparing our model results with market prices for Maya vs. WCS on the USGC. In this analysis, which is shown graphically in Appendix Table V-1, we used the Platt's prices for WCS at Nederland, which have only been available since February 2016. A similar analysis was done correlating AWB and other Canadian dilbits with WCS. As discussed in Section V, the market values in all cases correlated reasonably well with the model estimated refining value differentials after adjusting for reasonable TAN and commercial/market value adjustments.

Overall, we believe this exercise provides a very good validation vs. actual market prices for the refining values predicted by the Turner Mason model across a fairly wide range of medium and heavy crude oils.

Refining Value Correlation Equations (RVCEs)

Refining Value Correlation Equations (RVCEs) were developed from the validated refining values we calculated for each of the three regions and each of the three volume/penetration levels, for a total of nine separate equations in all. These equations can be used to estimate the "refinery gate" refining value of a crude or PUB based off of the crude/PUB properties. We developed these equations so that they are typically able to estimate the refining value of a given crude/PUB within $0.50 of the model output, with a maximum deviation of $2 vs. model-calculated refining values. They were tuned to be most accurate in a longer term, sustainable price environment with the deviations from "price disturbances" expected to cancel out over time. This is consistent with their stated purpose of providing indications of longer term values for capital planning purposes rather than as predictors of short term price movements. The equations are generally a bit less accurate and possibly conservative for PUB 4, due largely to its unconventional properties as a heavy sweet crude.

In order to develop the RVCEs, we considered and tested all of the crude/PUB properties that could impact refining yields and operating costs and therefore refining value. We then empirically tested these factors in multiple combinations and statistically evaluated how they correlated against the model-calculated refining values. Ultimately, we determined the most important crude/PUB properties in determining refining value were distillation (as measured by using the volume yield VTB, gasoil, and middle distillates), VTB sulfur, and VTB Concarbon. We also added a “WTI price” variable as a “scaling element” to provide applicability of the RVCEs across a broad range of absolute crude price environments. Key assumptions and aspects of the RVCEs we developed are shown below.

- The output of the RVCEs is the expected “refinery gate” refining value (as defined earlier) of the crude/PUB.
- The equations do not apply any market discount for TAN or other commercial/market factors and do not include transportation costs to the refinery. These are applied separately and included in the MVCM, which we discuss in the following section. (See also Section V for the details on how we estimated these adjustments).
- Resid yield defined as 1050+ F volume fraction as decimal (Ex. 10% Vol Yield = 0.1 Vol Fraction). Applicable for the range of 0.0 to 0.5 (0 to 50 LV%)
- Resid CCR defined as resid (1050+) concarbon in wt. % (Ex. 25.0 wt. % entered as 25.0). Applicable for the range of 0.0 to 50 wt.%.
- Resid sulfur defined as resid (1050+) sulfur in wt. % (Ex. 3.5 wt. % entered as 3.5). Applicable for the range of 0.0 to 10.0 wt.%.
- VGO yield defined as 635-1050 F volume fraction as decimal (Ex. 10% Vol Yield = 0.1 Vol Fraction). Applicable for the range of 0.0 to 0.5 (0 to 50 LV%)
- Diesel + Jet yield defined as 330-635 F volume fraction as decimal (Ex. 10% Vol Yield = 0.1 Vol Fraction). Applicable for the range of 0.0 to 0.5 (0 to 50 LV%)
- WTI price in USD/BBL at Cushing. Applicable for the range of $50 to $80 per barrel.

It should be noted that the applicability ranges specified are consistent with the data sets used in this study. They could potentially be wider,

Table III-5 below displays the equations for each region under each of the three cases and these are also shown in Appendix Tables III-9A through 9 F:

Table III-5: Refining Value Correlation Equations (RVCEs)
10 MBPD Equations
USGC
[Resid Yield * (-1.2 + Resid CCR * -0.028) * ((MIN (Resid Sulfur , 3.693) ^ 1.88 + MAX (Resid Sulfur - 3.693 , 0)) * 43.01 + 386.5) + VGO Yield * 363.7 + (Diesel + Jet Yield) * (221)] * [(WTI Price) * 0.0001362696 + 0.00933858] + [(WTI Price) * 1.106 + 9.27]
USMC
[Resid Yield * (-351.1 + Resid CCR * -2.513) * ((Resid Sulfur ^ 0.96) * 18.95 + 66.9) + VGO Yield * -8438.6 + (Diesel + Jet Yield) * (16168)] * [(WTI Price) * 0.0000036886 + 0.0002645] + [(WTI Price) * 1.105 + 10.22]
China
[Resid Yield * (-515.4 + Resid CCR * -15.651) * ((MIN (Resid Sulfur , 4.491) ^ 2.38 + MAX (Resid Sulfur - 4.491 , 0)) * 0.17 + 4.6) + VGO Yield * 1000 + (Diesel + Jet Yield) * (3312)] * [(WTI Price) * 0.0000221206 + 0.00194191] + [(WTI Price) * 1.103 + 7.25]
40 MBPD Equations
USGC
[Resid Yield * (-1.9 + Resid CCR * -0.043) * ((MIN (Resid Sulfur , 3.693) ^ 1.82 + MAX (Resid Sulfur - 3.693 , 0)) * 64.81 + 623.6) + VGO Yield * 868.6 + (Diesel + Jet Yield) * (115)] * [(WTI Price) * 0.0000597501 + 0.00412279] + [(WTI Price) * 1.112 + 9.75]
USMC
[Resid Yield * (-58.2 + Resid CCR * -0.412) * ((Resid Sulfur ^ 0.96) * 13.58 + 47.8) + VGO Yield * -1000 + (Diesel + Jet Yield) * (1889)] * [(WTI Price) * 0.0000313288 + 0.00224403] + [(WTI Price) * 1.105 + 10.24]
China
[Resid Yield * (53.6 + Resid CCR * 1.491) * ((MIN (Resid Sulfur , 4.564) ^ 2 + MAX (Resid Sulfur - 4.564 , 0)) * 9.41 + 135.1) + VGO Yield * -2911.5 + (Diesel + Jet Yield) * (-10927)] * [(WTI Price) * -0.0000071244 + -0.00062325] + [(WTI Price) * 1.102 + 7.18]
100 MBPD Equations
USGC
[Resid Yield * (-2 + Resid CCR * -0.045) * ((MIN (Resid Sulfur , 3.693) ^ 1.82 + MAX (Resid Sulfur - 3.693 , 0)) * 66.48 + 639.6) + VGO Yield * 890.8 + (Diesel + Jet Yield) * (118)] * [(WTI Price) * 0.0000569088 + 0.00393587] + [(WTI Price) * 1.11 + 9.74]
USMC
[Resid Yield * (-78.5 + Resid CCR * -0.548) * ((Resid Sulfur ^ 0.96) * 10.09 + 35.3) + VGO Yield * -1000 + (Diesel + Jet Yield) * (1883)] * [(WTI Price) * 0.0000314799 + 0.00224755] + [(WTI Price) * 1.103 + 10.17]
China
[Resid Yield * (25.2 + Resid CCR * 0.752) * ((MIN (Resid Sulfur , 4.492) ^ 2.37 + MAX (Resid Sulfur - 4.492 , 0)) * 3.62 + 94) + VGO Yield * -999.9 + (Diesel + Jet Yield) * (-3451)] * [(WTI Price) * -0.000022032 + -0.00193302] + [(WTI Price) * 1.1 + 7.15]

Justification of RVCE Variables

In developing the RVCE Equations, we needed to determine which variables were necessary to include in the equations. Based on our refining experience, we determined that distillation yields and key cut properties would be the most important factors in determining crude and PUB refining values. We chose this method (as opposed to using whole crude properties) due to the fact that whole crude properties can often be a poor predictor of actual crude value; for example, PUB 1, PUB 2, and PUB 3 all appear very similar (aside from TAN) to each other and to WCS, AWB, and Maya, despite the fact that the refining values for these crudes/PUBs vary substantially. Table III-6 shows this comparison.

Table III-6: Whole Crude Properties vs. Refining Values

	PUB 1	PUB 2	PUB 3	AWB	WCS	Maya
API Gravity	20.9	19.3	19.3	20.7	20.3	22.3
Sulfur (wt. %)	3.69	3.49	3.74	3.98	3.44	3.38
UOP K Factor	11.24	11.26	11.46	11.51	11.32	11.54
TAN	1.65	0.30	0.90	1.85	0.98	0.28
Estimated Refining Value[(1)]	$62.56	$60.91	$56.21	$53.73	$55.86	$56.30

[(1)]Represents 2025 Refining Value for 100 MBPD case at $50 WTI

Additionally, we chose to use the same set of variables for each region due to the fact that crude oil and petroleum products trade in a global market and all prices are largely linked throughout the globe. As a result, the same factors tend to affect crude values in all regions. Due to different refinery configurations and different (but related) regional prices, the weight of each factor may vary across regions, but we do not believe this variation is significant enough to necessitate a change in the variables used across different regions. Lastly, this method allows a better comparison of how different crude/PUB properties affect refining value in each region.

First, we elected to use resid yield (in volume %) as one of our dependent variables due to its large effect on expected crude values. The coker is the limiting unit at many refineries (we expect coking capacity to represent an even more significant constraint post 2020) and coking margins tend to be strong. In our model, higher resid yields reduce the amount of resid that can be purchased to fill the coker. We expect IMO 2020 will strengthen coking margins significantly, with the effect decaying over time, but still maintaining coking margins above 2018 levels through the entire forecast period. Furthermore, we decided to include two resid stream properties: sulfur and Concarbon (CCR). Resid sulfur will be particularly important post 2020, as the value of low sulfur fuel oil and resid will increase particularly relative high sulfur fuel oil and resid. In a coking refinery, this will manifest itself in terms of higher prices for anode grade coke. This effect will be most pronounced immediately post 2020 and will degrade over time, eventually stabilizing by 2030; however, even at this point, the value of low sulfur resid, relative to high sulfur resid, will be higher than it is presently. We included Concarbon because it is the major determinant of coker yields between different crudes. Therefore, a crude with lower resid Concarbon will have much better coker yields (more gasoline, distillate and gasoil; less coke) than similar crude with higher Concarbon.

The next variable used in the RVCEs is VGO yield (in volume %). VGO upgrading (both fluid catalytic cracking and hydrocracking) can also be limiting at a refinery, and the capacity of these units can often play and important role in determining the crude slate. Additionally, many refiners that do have spare capacity in these units purchase intermediates to fill these units due to economic incentives to do so. In our model, we bought and/or sold VGO to ensure all cracking units remained full. However, VGO yield also correlates negatively with naphtha yield, which is typically less valuable than VGO due to our forecast for relatively weak gasoline yields and strong distillate yields going forward. As a result, the effect of VGO yield on crude value, taking into account its correlation with other variables, can be positive or negative. VGO properties, particularly UOP K or aniline point and Concarbon, are also important in determining crude value due to these properties' ability to influence FCC and hydrocracker yields and effective capacity. We considered including these variables in our RVCEs, but found that they added little additional value due to their correlation with other dependent variables.

The last variable we chose to include was middle distillate yield, measured in volume percent. Due to our forecast for strong middle distillate refining margins going forward, middle distillate yield is clearly a large positive for any crude/PUB. However, as middle distillate yields have a relatively strong negative correlation with resid yield, the direct effect of middle distillate yield on crude value does not fully present itself in the RVCEs. Still, due to the true importance that middle distillate yield has on crude value; we felt it necessary to include it as a variable.

Finally, as both absolute and relative crude values strongly correlate to global marker crude prices, we included the price of WTI (Cushing) as a "scaler" in the RVCEs to adjust for changes in the absolute level of global crude prices. This allows the RVCEs to be applicable across a wide range of prices, which would not be possible without this "scaling" element. We chose WTI (Cushing) for this role both because it is used as the pricing basis for the four price sets designated in this study and more importantly because it represents a highly transparent and widely traded commodity which strongly correlates to the price of other major marker crudes (Brent, LLS, and Dubai) in normal circumstances. This does assume that distortionary pipeline constraints are not present in the post-2025 environment. It should be noted that the reference crudes - WCS, Maya, Mars, or Arab Heavy are not as appropriate to be used as "scaling elements" because of transparency, market depth and the fact that they are not true measures of long term absolute global oil price levels.

A full ANOVA analysis was not performed on the individual variables due to the fact that it is not a true linear equation, with the resid quality variables affecting the weighting of the resid yield variable. Rather, an analysis was conducted to measure the significance of each variable in each of the RVCEs, while holding all of the other variables constant. The results of this analysis are shown below in Table III-7. Note that these sensitivities have not been adjusted to account for the multicollinearity or any other correlation between dependent variables.

Table III-7: RVCE Factor Significance

Each value represents the expected change in crude value for a 1% absolute increase in the stated dependent variable[(1)]

		Resid Yield Sensitivity	Resid Sulfur Sensitivity	Resid CCR Sensitivity	VGO Yield Sensitivity	Diesel + Jet Yield Sensitivity	Overall R-Squared
USGC	10 MBPD	($0.247)	($0.627)	($0.088)	$0.059	$0.035	0.966
USGC	40 MBPD	($0.258)	($0.622)	($0.091)	$0.062	$0.008	0.968
USGC	100 MBPD	($0.245)	($0.618)	($0.091)	$0.065	$0.022	0.968
USMC	10 MBPD	($0.252)	($0.802)	($0.037)	($0.038)	$0.073	0.934
USMC	40 MBPD	($0.253)	($0.802)	($0.037)	($0.038)	$0.072	0.934
USMC	100 MBPD	($0.252)	($0.801)	($0.037)	($0.038)	$0.072	0.934
China	10 MBPD	($0.236)	($0.677)	($0.098)	$0.031	$0.101	0.959
China	40 MBPD	($0.235)	($0.692)	($0.093)	$0.029	$0.107	0.959
China	100 MBPD	($0.235)	($0.678)	($0.097)	$0.030	$0.102	0.959

[(1)]For example, an absolute 1% increase in resid yield would be an increase from 13% to 14%

As a final word regarding our selection of the final RVCEs we developed, we believe they are the best compromise between simplicity, prediction precision and applicability across a wide range of price environments and PUB qualities. It is certainly possible to develop a simpler, linear equation with fewer terms, but such a “stripped down” version would be more limited in its applicability and result in greater deviation from expected market values.

Market Value Correlation Methodology (MVCM)

The RVCEs can be converted to market values using a Market Value Correlation Methodology (MVCM) by including transportation costs and other commercial/market value adjustments and comparing to market relevant competitive crude oil. The relevant transportation costs were discussed earlier in this section and are summarized in Appendix Tables III-6A through III-6E. As noted in that section, we have assumed that transportation from the field to either Edmonton or Hardisty is equivalent. Based on this assumption, the MVCM for USMC and USGC values will be based on transportation from Hardisty and the MVCM for China values will be based on transportation from Edmonton and the values can be considered comparable.

While refining values, as calculated by our refining models, are the primary determinant of the relative values of different crude oils, other factors also go into determining the final market price of a crude oil. These include properties that cannot be readily modeled but impact refiners costs or purchasing decisions and also other commercial/market factors which are not directly related to the value of the crude oil, but do impact their price. For two of the PUBs (PUB 1 and Pub 3), high acid levels (as measured by TAN) will be important (negative) factors in the market price, while the low resid sulfur level of PUB 4 will have a smaller (and positive) impact due to the IMO LS bunker rules. Because all of the PUBs are somewhat unique, we expect that they will also incur some "market entry" discounts when they are first introduced. In Section V, we discuss both the TAN and other commercial/market adjustments and quantify our estimates for these factors in Appendix Tables V-5, 6 and 7.

When the appropriate transportation and commercial/market value adjustment factors are applied to the RVCE for a particular PUB stream, the result is a relative market value from which has to be subtracted the market price (adjusted to the appropriate refinery gate price) of the relevant crude with which the PUB will be competing in a specific market. Because the PUBs will be competing in multiple markets and against multiple different crude oils, there are several possible market values for each PUB, depending on the regional market, the volume/penetration level and the selected competitive/reference crude, and each will provide a different forecasted "netback market" value. In the end, the market will settle on a price that takes into account the different values, with the ultimate "price setting" region and marker crude changing depending on a variety of market conditions.

Table III-8 illustrates how the MVCM works for a specific PUB in a specific circumstance. This example shows the calculation of the netback for PUB 2 in Hardisty in 2035 based on the USGC refining values in the high penetration case at $50 WTI.

Table III-8: Market Value Correlation Example
PUB 2 Netback (Hardisty) = PUB 2 Refining value -PUB 2 Transportation) - (Mars Refining Value - Mars Transportation) + Forecast Mars Spot Price

PUB 2 Properties (From Appendix Table III-1)				
Resid Yield	Resid Sulfur	Resid Concarbon	VGO Yield	Diesel + Jet Yield
18.5%	5.9%	25.8%	44.5%	28.4%

WTI Price	Predicted PUB 2 Refining Value (Using RVCE)	Mars Refining Value (From Appendix Table III-7I)
$50	$62.20	$62.39

USGC Transportation (From Appendix Table III-6A)		Forecast Mars Spot Price
PUB 2	Mars	(From Appendix Table III-2A)
$12.80	$0.60	$51.58

PUB 2 Netback at Hardisty	
Predicted Using MVCM	Actual (From Appendix Table III-9A)
$39.19	**$39.05**

PUB Market Value Forecast

To further illustrate how the MVCM methodology we outlined above would work in forecasting PUB values, we took the actual refining value differentials (RVCE calculated values could be used as well) vs. selected reference crudes we calculated for each of the PUBs in each of the prices sets (which could also be estimated accurately across the $50 to $80 price range using the RVCEs). We then adjusted these to market values using the appropriate transportation and commercial/market factors and comparing to the forecasted price of the selected reference crude. For the USMC, we selected WCS; for the USGC, we used both Mars, Arab Heavy and WCS; and for China, we used Arab Heavy. In the case of China, we also tested two transportation cost scenarios: pipeline to Vancouver and rail to Vancouver (pipeline limited).

This analysis is summarized in Appendix Tables III-10A through 10D, and we make the following observations.

- China, assuming the PUB can be delivered to Vancouver by pipeline shows the highest netback value for each of the PUBs. In most cases, this premium is in the range of $2 to $4 per barrel.
- We would not conclude from this analysis that the China “premiums” would necessarily materialize at the indicated levels or even that China will be the price-setting market.

- In an Edmonton to Vancouver pipeline constrained environment, netbacks to China are lower than for the U.S. markets.

- The China (and Asia as a whole) market is likely to become more competitive as North American crudes arrive in larger volumes, and the Saudis could respond with lower prices to maintain market share.

- The calculated netback values for the PUBs are relatively similar between the USMC and USGC when using WCS as the marker/competitive crude. This is to be expected given the relatively similar relative refining values and other market adjustments between the two regions when processing WCS or the PUBs.

- The PUBs show a higher value on the USGC when Mars or Arab Heavy is selected as the marker/competitive crude. Whether this higher value can be captured in the market is not certain, but the ability to compete against medium grade crudes does provide potential market value upside vs. traditional dilbits.

Overall, we feel that it is still very likely that the USGC could end up as the price-setting region for the PUB streams due to its size, crude flexibility and appetite for crudes which are similar to the PUBs. However, the China market shows very good potential, based not only on the higher indicated market values we calculated (given no pipeline constraints to Vancouver), but also on the growing market size. Even the USMC market could be an attractive market, due to its location and familiarity with similar Canadian feedstocks.

IV. MEDIUM AND HEAVY CRUDE SUPPLY AND DEMAND OUTLOOK

All of the PUBs evaluated in this study will compete against other medium and heavy crude oils for space in refiners' feedslates. As such, they will be valued in competition with those crudes and will be impacted by changes in the medium and heavy crude oil supply and demand environment. In this section, we analyze that environment, both as it exists currently and how anticipated developments will change the balance in the future.

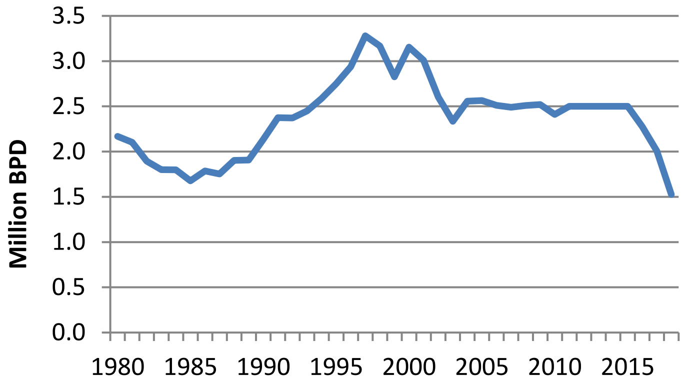
Crude oil producers have no ability to control the quality of the oil which comes out of the ground. As a result, the global refining industry must continually adapt to the ever-changing crude oil grade mix that producers deliver. This process may involve the construction of entirely new refineries or bitumen upgraders but also can be achieved by the reconfiguring or revamping of existing facilities. Generally, this refining adaption occurs in conjunction with production growth with minimal disruptions, as illustrated by the heavy crude growth in Canada and Venezuela (in recent decades) in parallel with coker capacity additions in the U.S. Sometimes, however, sudden shifts in production grades can catch the refining industry off guard, as with the recent spurt of shale output in North America. Political issues can also impact this process by penalizing some crude grades, as is expected with the 2020 IMO bunker fuel regulations. These anomalies can create significant pricing distortions to petroleum markets when the crude grades refiners prefer are out of balance with the grades being produced.

<u>The Changing Heavy Crude Market</u>

Driven by decades of massive investments in coking and hydrotreating expansions, the U.S.G.C. consumes a large percentage of the global heavy crude output. This investment was initially driven by the rapid growth in production of heavy crude in Mexico and Venezuela. The growth began in the 1980s and accelerated through the 1990s, with most of this crude heading to refineries on the USGC. Over the last 20 years, both production and imports from Mexico and Venezuela have in turn slowed, peaked and then fallen significantly. As a result, the proportion of heavy crude imports from those two countries has declined from 85% of the USGC total in 2007 to 56% in 2017. While Mexican imports have stabilized over the last three years, Venezuelan declines have accelerated as the political and economic situation in that country continues to deteriorate. While the appetite for heavy crude on the USGC remains strong and additional declines in Venezuela are expected, opportunities for other countries to increase their exports to the U.S. are growing. These dynamics, along with other external factors (such as the impending IMO bunker regulations in 2020), will create a continually evolving heavy crude supply picture for USGC refiners.

Background

Figure IV-1
Venezuelan Crude Production

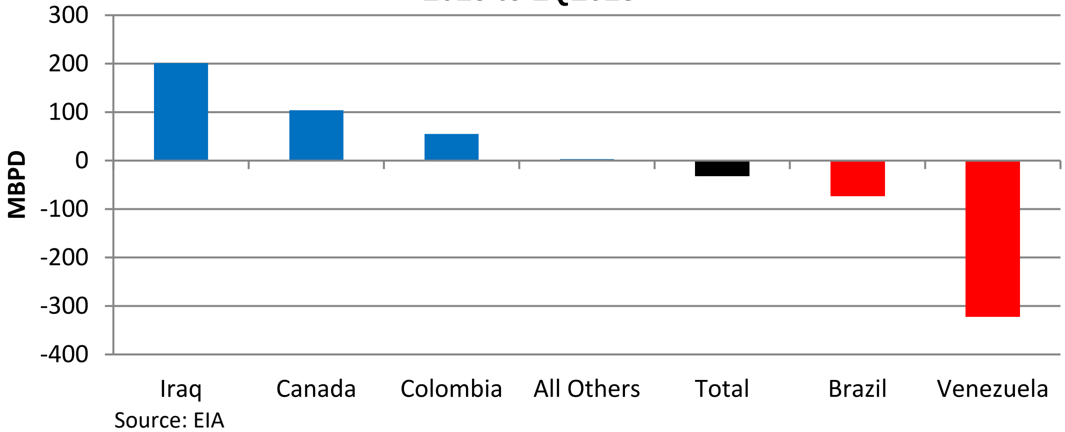


Source: EIA

Crude production in Venezuela (which is primarily heavy) peaked in 1997 at 3.3 million BPD (Figure IV-1), and while it fell below 3 million BPD in the early 2000s, it remained relatively stable (per reported numbers) at about 2.5 million BPD through 2015. By 2017, however, output fell to average only about 2 million BPD, while current estimates indicate a production level as low as one million BPD. As recently as 2015, Venezuela supplied 38% of the USGC heavy crude requirements. In the first quarter of the 2018, however, Venezuela only comprised 22% of the region's heavy imports and was eclipsed by the recently stabilized level of heavy imports from Mexico. Despite significant pipeline limitations from Alberta, Venezuelan imports to the USGC are only marginally above receipts from Canada. By 2017, heavy crude imports from Venezuela to the USGC had declined by 300 MBPD since the recent drop in production began in 2015 and by 700 MBPD from peak levels during the early 2000s.

When Venezuelan and Mexican heavy imports first began to decline in the middle of the last decade, growing production of heavy crude from Colombia and Brazil were ramping up to make up for the shortfalls. More recently, imports from those Latin American countries have also leveled off. Since 2015, rapidly rising volumes from the Middle East, especially Iraq, and Canada have been taking up the slack. Heavy crude imports into the USGC from Iraq have jumped from an average of only 14 MBPD in 2015 to over 200 MBPD in the first quarter of 2018 (Figure IV-2). The major driving force for this development has been the beginning of the segregation of heavy production into a new Basrah Heavy grade, which started in June 2015. Much of the future incremental output from Iraq is expected to fall into this category. Canadian volumes of heavy crude making it to the USGC have increased by about 100 MBPD, despite the periodic cross border pipeline limitations.

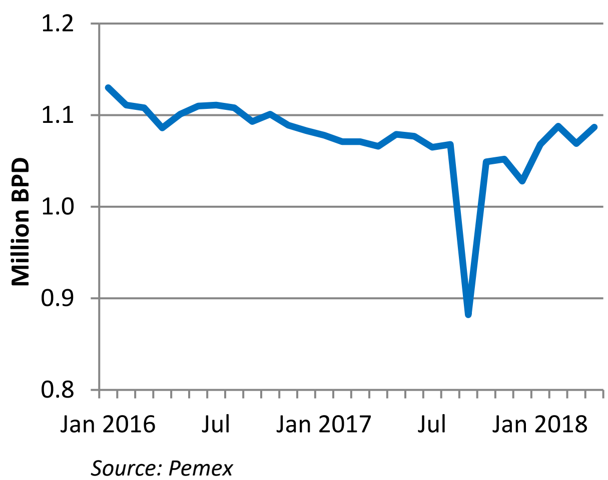
Figure IV-2
Change in Heavy Crude Imports to PADD III
2015 to 1Q2018



Near-Term Supply and Demand Changes

The short-term prognosis for heavy crude supply to the USGC appears very similar to recent history. Venezuelan crude production is expected to continue to decline even if regime change were to occur quickly. The longer the current turmoil continues, however, the greater the decline. The ultimate return of foreign capital and expertise will not occur quickly under any circumstance and the rebuilding of the Venezuelan oil industry and a return to production growth could take up to a decade or more.

Figure IV-3
Mexican Heavy Oil Production

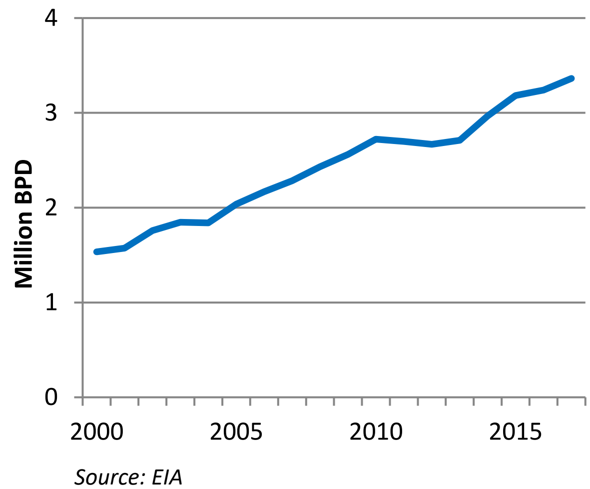


The other sources of heavy crude from Latin America also have supply issues for the near term. In the first quarter of 2018, Mexico temporarily re-emerged as the leading supplier of heavy crude to the USGC, but future production prospects do not look encouraging. Oil production, including Natural Gas Liquids (NGLs), peaked in 2004 at 3.8 million BPD but has since declined to only 2.1 million BPD. Heavy oil production has seen a modest rebound recently (Figure IV-3), which has allowed exports to the USGC to stabilize, but we expect this to be only temporary. The newly elected President of Mexico, Mr. Lopez Obrador, has made bold predictions of a rapid increase in production of as much as 600 MBPD; however, these statements appear to be mere wishful thinking, and we expect his moves to restrain or even stop the movement to reform Pemex and open Mexican petroleum markets to foreign investments which will further decrease production levels.

Oil production in Colombia has also peaked. Output exceeded 1 million BPD in 2015 but fell to 875 MBPD in 2017, even as imports to the USGC have remained relatively constant. Continued modest production declines are expected in the near future. Over 70% of Colombian crude is heavy.

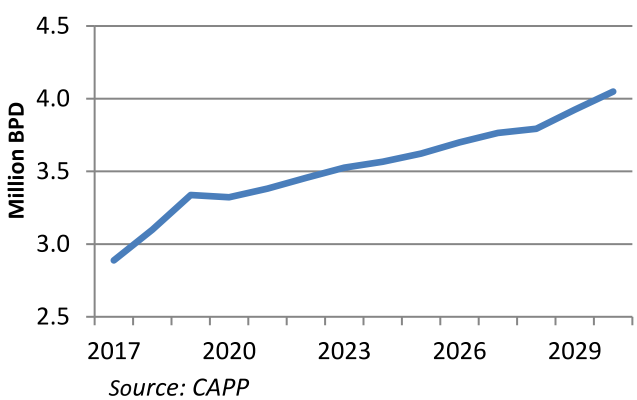
Unlike Venezuela, the decline in Brazilian heavy crude imports is not the result of declining production. Even with the backdrop of considerable political turmoil, oil output has been steadily increasing in recent years (Figure IV-4) and additional gains are expected in the near term. The shift away from heavy crude exports into the USGC is more economically driven than political as U.S. refiners transitioned to lower priced alternatives.

Figure IV-4
Brazilian Crude Production



Production growth is also not the issue with Canada, which is also expected to increase its heavy crude output. The Canadian Association of Petroleum Producers (CAPP) estimates that heavy crude production will grow from slightly under 2.9 million BPD in 2017 to 3.3 million BPD in 2020 and to 3.6 million BPD in 2025 (Figure IV-5). After the full ramp up of the Fort Hills development by the end of this year, the bulk of the future gains are through a series of smaller expansions. New projects are still being announced, however, with the latest being the Imperial Aspen development which will produce 75 MBPD beginning in 2022.

Figure IV-5
Projected Heavy Canadian Production

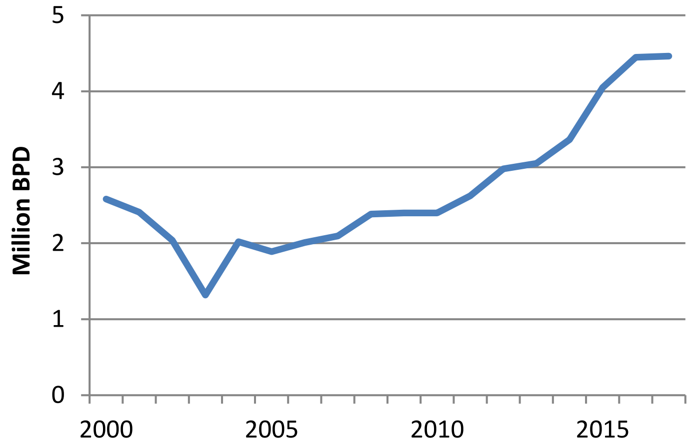


While pipeline exit capacity may become a limiting factor in raising production rates in Alberta, the government's recent action to purchase the Trans Mountain pipeline from Kinder Morgan indicates a substantive commitment to removing obstacles to future growth. Rising Canadian production represents a credible alternative to replacing declining output from Venezuela and Mexico, but an increase in pipeline capacity to the U.S. is critical. The potential to expand the Trans Mountain line also opens the opportunity for

Canada to export to Chinese and other Asian refineries and may ultimately reduce volumes flowing to the USGC.

As noted earlier, the country with the largest growth of heavy crude exports to the USGC since 2015 has been Iraq. Production growth has been impressive in recent years (Figure IV-6), rising from only 1.3 million BPD in 2003 to nearly 4.5 million BPD in 2017. While the country has not hit its recent growth targets, the increase has been dramatic nonetheless. Officially, the Iraqi government has plans to further increase output to 6.5 million by 2022. Many of the current limitations have less to do with production capabilities but are more related to export capacities resulting from pipeline limitations and bottlenecks at the Port of Basrah.

Figure IV-6
Iraqi Oil Production



Source: EIA

IMO Impacts

The IMO mandated reduction in bunker fuel sulfur levels, set to begin in January 2020, will have a variety of significant impacts on petroleum markets. Because of the expected diversions of 1-2 million BPD of distillates into the bunker pool, distillate prices are expected to spike higher, while the comparable volume of high sulfur fuel oil, which is backed out of the pool, will force the prices of High Sulfur Fuel Oil (HSFO) lower. The reduction in HSFO prices is expected to be so severe that some of the volume will become a refinery feedstock in the form of coker feed. This diversion of HSFO to coker feed, along with the decrease in value of high sulfur residual barrels will result in lower prices for heavy sour crudes.

While this dynamic is progressing, a similar trend is expected to cause light crude prices to rise. The natural instinct of fuel oil refiners, which are unable to produce a 0.5% sulfur compliant fuel, is to reduce their noncompliant fuel oil yields by lightening and sweetening their crude slates. Because there is a limit to the growth of light crude production, the higher demand will result in higher light crude prices.

The combination of these two trends is expected to widen the light/heavy crude differential in 2020. Not only will this incentivize heavy crude/resid processing on the USGC, it will also lead to the expansion of existing coker capacity or even new units (such as the recently announced by Valero to increase coker capacity at Port Arthur). It will also lead to a shift in crude trade patterns. We feel the most prominent shift will be the movement of Middle East high sulfur medium grades to USGC coking refineries as the economics of processing those barrels in less complex refineries in Europe and Asia that produce high sulfur residuals decline significantly.

Rebalancing Heavy Crude

While the oil markets are likely to continue to be plagued with political uncertainties, recent heavy crude production changes can present a reasonable picture of likely future trends. Heavy crude output in Venezuela is almost certain to decrease further in the near term, no matter the political events. The petroleum industry in Venezuela has been severely damaged and will take years to rebuild even after a regime change occurs. This will also continue to force reductions of heavy imports to the USGC. Additional output declines in both Mexico and Colombia are also expected, albeit at more modest rates, while continued production growth is forecast for Brazil, Canada, and Iraq.

In the first quarter of 2018, the USGC imported 439 MBPD of heavy oil from Venezuela. The loss of this supply is a credible possibility but not as calamitous as it might seem. By 2020, heavy oil output in Canada should rise by 350-400 MBPD, while Iraq is likely to increase heavy production by 300-400 MBPD. By 2025, Canadian heavy output should rise by 650-700 MBPD while Iraqi heavy could increase by up to 1.5 million BPD. Additional gains are also expected in Brazil.

Production increases by Canada, Iraq and Brazil cannot be taken for granted, however. The political situation in Iraq remains tenuous and is easily disrupted by surrounding political events. While Brazil has established a solid history of production growth, the political situation for the government and Petrobras has been chaotic in recent years. Even Canada has its share of uncertainties in its ability to supply the U.S. markets. An additional large diameter pipeline is needed to ensure the ability to flow increasing volumes southward, but the recent appellate decision in Montana continues to impede the development of the Keystone XL project. The government's acquisition of the Trans Mountain pipeline, however, creates a viable option for Canadian exports to Asia instead.

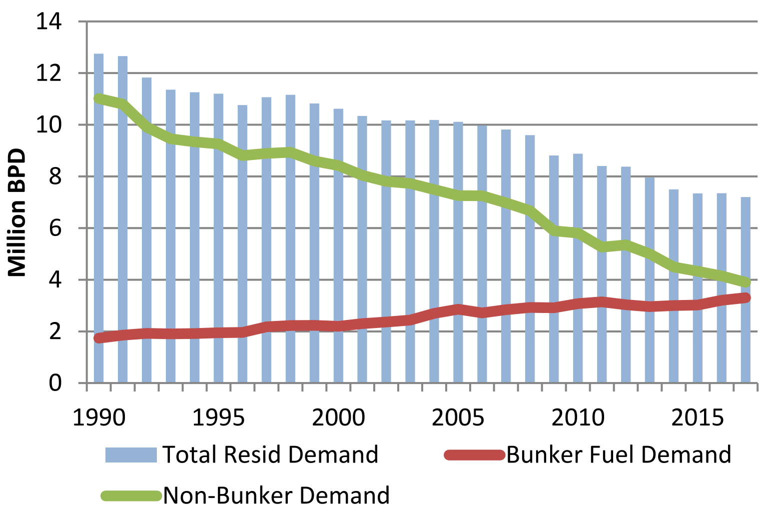
Complicating this ever-changing supply picture is the potential of the 2020 IMO regulations to cause a substantive diversion of fuel oil into the coker feed market and reduce demand for heavy crude grades. While this is likely to reduce heavy crude demand in the near term (through 2025), the resulting low fuel oil prices may well stimulate a new round of coker expansions on the USGC and drive up heavy oil demand after 2025. In other words, expect more volatility.

Current Refinery Medium and Heavy Crude Capabilities

When crude oil is processed in a refinery, the finished products serve a variety of markets. The light ends (propane and butane) are generally sold for home heating and cooking. Transportation fuels comprise the dominant share of the products with gasoline representing nearly half of product yields with jet fuel and diesel comprising an additional 20-30%. Vacuum gas oil (~650°F to ~1,050°F, 343°C – 566°C) is generally catalytically cracked to produce additional gasoline and distillates. The remaining fraction is residual fuel oil and is generally sold for electricity generation or bunker fuel for ships when it is not utilized as a feedstock for further processing within the refinery.

Global demand for residual fuel has been declining for decades (Figure IV-7). Driven largely by ever-tightening environmental regulations, fuel oil demand has fallen from 12.7 million BPD in 1990 to only 7.2 million BPD in 2017. Contrary to this overall trend, bunker fuel demand has nearly doubled over the same period, rising from 1.7 million BPD to 3.3 million BPD. This has resulted in a sharp decline in nonbunker demand, falling from 11.0 million BPD to only 3.9 million BPD in 2017.

Figure IV-7
Global Residual Fuel Demand



Source: EIA and TM&C

In reaction to this decrease in residual fuel oil demand and to rising heavy crude production levels in Canada, Venezuela, Mexico, and Colombia, refiners constructed numerous coking units, particularly on the USGC and in PADD II, as well as in India and China. The coking unit expansions enabled refiners to not only purchase lower priced heavy crudes but also to upgrade these heavier feedstocks into more valued transportation fuels. As a result, the presence of coking capacity is a primary indicator of a refinery's ability to process medium or heavy crude grades.

U.S. PADD II

There are 27 refineries in PADD II with a total crude-processing capacity of 4.1 million BPD. Thirteen of these refineries have coking units (Table IV-1) and represent 2.7 million BPD of crude-processing capacity, or about 67% of the total PADD II capacity.

The total coking capacity in the region is 521 MBPD. The coking capacities for each refinery ranged from a low of 11% of crude capacity at Phillips 66 Ponca City to 24% of crude capacity in the WRB Wood River, CHS McPherson, and Marathon Detroit refineries. Canada was the sole supplier of medium and heavy crude to the PADD II refineries in 2018.

Table IV-1
U.S. PADD II Medium/Heavy Crude Refineries

	Existing Refinery Capacities			2018 Imports*		Max
Company/Location	**Crude BPD**	**Coking BPD**	**% Coking**	**Medium BPD**	**Heavy BPD**	**Heavy** MBPD**
Illinois						
ExxonMobil - Joliet	247,000	53,460	22%	5,374	181,202	170
Marathon Pet. - Robinson	245,000	29,000	12%	0	55,840	50
Citgo Petroleum - Lemont	175,940	36,360	21%	161,774	1,193	113
WRB Ref. - Wood River	314,000	75,000	24%	0	174,708	253
Indiana						
BP - Whiting	408,500	91,800	22%	2,070	291,494	300
Kansas						
CHS Refining - McPherson	95,000	22,500	24%	0	32,593	66
CVR Refining - Coffeyville	118,750	22,500	19%	0	23,128	56
HollyFrontier - El Dorado	133,950	17,100	13%	0	61,267	61
Michigan						
Marathon Pet. - Detroit	139,000	33,300	24%	2,675	99,284	112
Minnesota						
Flint Hills - Rosemount	322,050	64,800	20%	0	282,918	283
Ohio						
BP-Husky -Toledo	152,000	31,500	21%	0	59,786	98
Husky Energy Inc.- Lima	161,500	20,700	13%	0	0	41
Oklahoma						
Phillips 66 Co.- Ponca City	203,000	23,100	11%	0	10,864	22
Other						
Other PADD II Refineries	-	-	-	26,506	69,485	89
PADD II Total	**2,715,690**	**521,120**	**18%**	**198,399**	**1,343,762**	**1,714**

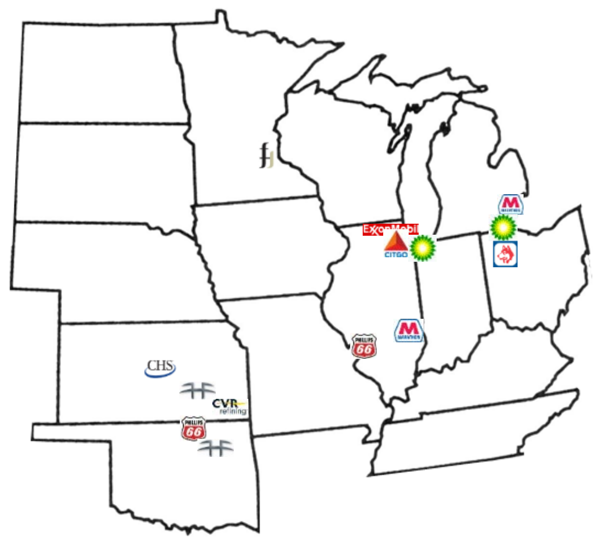
* January through August 2018, excludes deliveries to unknown facilities

** Maximum heavy volume is on a calendar day basis

Source: O&GJ, EIA and TM&C

The last column in Table IV-1 details the maximum heavy crude (WCS equivalent) which could be physically (not necessarily economically) processed at each refinery on a calendar day basis. The calendar day rate is the long-term rate which can realistically be achieved after adjusting for periodic down time for planned and unplanned outages and turnarounds. In 2018 through August for instance, the ExxonMobil Joliet refinery operated at a level slightly above its calendar day rate. This is typical during a period in which there have been no significant unit outages. The WRB Wood River Refinery however, had a major turnaround in 2018 and has operated well below its maximum heavy crude rate.

Figure IV-8
PADD II Heavy Crude Refineries



The total heavy crude processing capacity for PADD II is estimated at slightly over 1.7 million BPD. The respective refinery volumes are determined by calculating the vacuum tower bottoms (VTB) yield at 1,050°F (566°C) using three Canadian marker crudes: WCS for heavy crude (VTB of 27.8%), Bow River for medium crude (VTB of 23.0%) and Light Sour Blend for light crude (VTB of 7.7%). The maximum heavy crude rate represents the highest volume of heavy crude in a light/heavy mix which will fully load the crude and coking units on a calendar day basis.

Four of the coking refineries in PADD II also processed medium crude grades in 2018. Because medium crudes have a lower VTB content than do heavy grades, refiners can process higher volumes of medium crudes than heavy. Using the previously mentioned marker crudes as an example (WCS/heavy and Bow River/medium), a refiner could process up to 31% more medium crude than heavy. This would theoretically allow the 1.7 million BPD capacity of heavy crude to rise to nearly 2.2 million BPD of medium crude. The actual quantities of medium and heavy grades purchased, the yield proportions of different products and the economic results of running different proportions of heavy and medium crudes will depend on individual refinery processing configurations and crude-pricing differentials.

While coking capacity is the dominant variable in determining heavy crude processing rates, it is not the only one. Two of the coking refineries in PADD II (HollyFrontier El Dorado and Flint Hills Rosemount) also produced asphalt in 2018. This allowed these refineries to process heavy crude volumes in excess of coking unit capacities. As a result, the maximum heavy crude volumes shown for the two asphalt refineries in Table IV-1 reflect actual purchases in 2018.

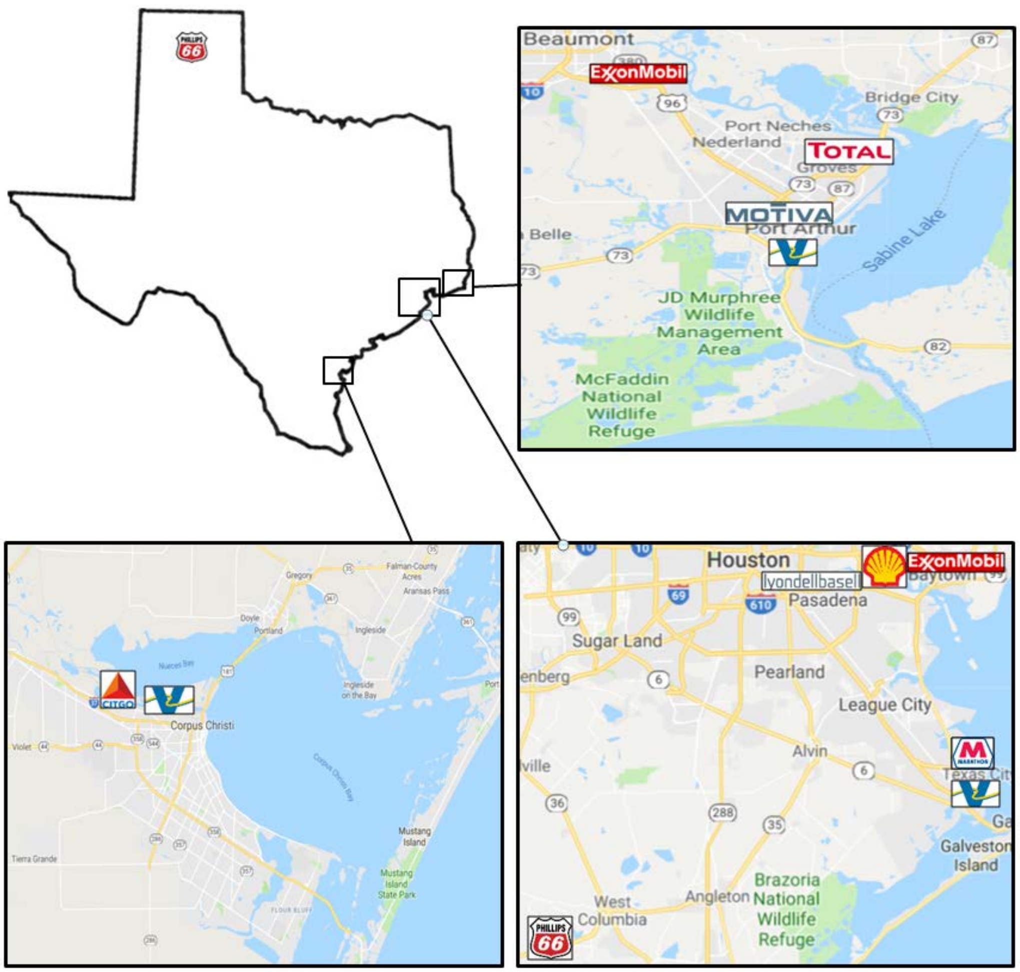
U.S. PADD III

Table IV-2 U.S. PADD III Medium/Heavy Crude Refineries						
	Existing Refinery Capacities			2018 Imports*		Max
Company/Location	**Crude BPD**	**Coking BPD**	**% Coking**	**Medium BPD**	**Heavy BPD**	**Heavy** MBPD**
Alabama						
Hunt - Tuscaloosa	38,000	28,800	76%	10,165	32,835	41
Louisiana						
Exxon Mobil - Baton Rouge	497,040	111,150	22%	28,391	52,136	363
Marathon - Garyville	556,000	89,800	16%	17,551	67,733	234
Shell - Norco	237,500	25,000	11%	0	1,296	33
PBF - Chalmette	187,150	25,200	13%	0	67,848	68
Citgo - Lake Charles	418,000	99,000	24%	4,140	137,473	332
Phillips 66 - Belle Chasse	247,000	23,400	9%	1,992	0	22
Phillips 66 - Lake Charles	249,000	61,000	24%	0	68,593	208
Valero - New Orleans	209,000	75,600	36%	0	69,786	209
Mississippi						
Chevron - Pascagoula	340,000	98,000	29%	19,683	189,021	340
Texas						
ExxonMobil - Baytown	554,800	86,400	16%	55,523	46,477	217
ExxonMobil - Beaumont	341,240	43,200	13%	2,049	40,926	84
LyondellBasell - Houston	287,185	89,550	31%	2,033	225,449	287
Marathon - Texas City	571,000	29,800	5%	22,568	46,737	64
Motiva - Port Arthur	603,000	150,000	25%	54,337	76,860	515
Citgo - Corpus Christi	155,325	40,410	26%	15,527	84,333	142
Phillips 66 Co - Sweeny	256,000	75,000	29%	0	146,835	256
Shell - Deer Park	323,000	81,000	25%	15,823	190,951	279
Total - Port Arthur	232,750	54,000	23%	0	17,206	179
Valero - Port Arthur	394,250	89,640	23%	4,025	220,630	295
Valero - Corpus Christi	285,000	15,300	5%	44,428	39,066	73
Valero - Texas City	219,450	48,150	22%	10,802	31,214	155
WRB Refining - Borger	143,000	27,000	19%	2,062	3,502	80
Other						
Other PADD III Refineries	-	-	-	56,012	174,140	217
Total	**7,344,690**	**1,466,400**	**20%**	**367,111**	**2,031,047**	**4,693**

* January through August 2018
** Maximum heavy volume is on a calendar day basis
Source: O&GJ, EIA and TM&C

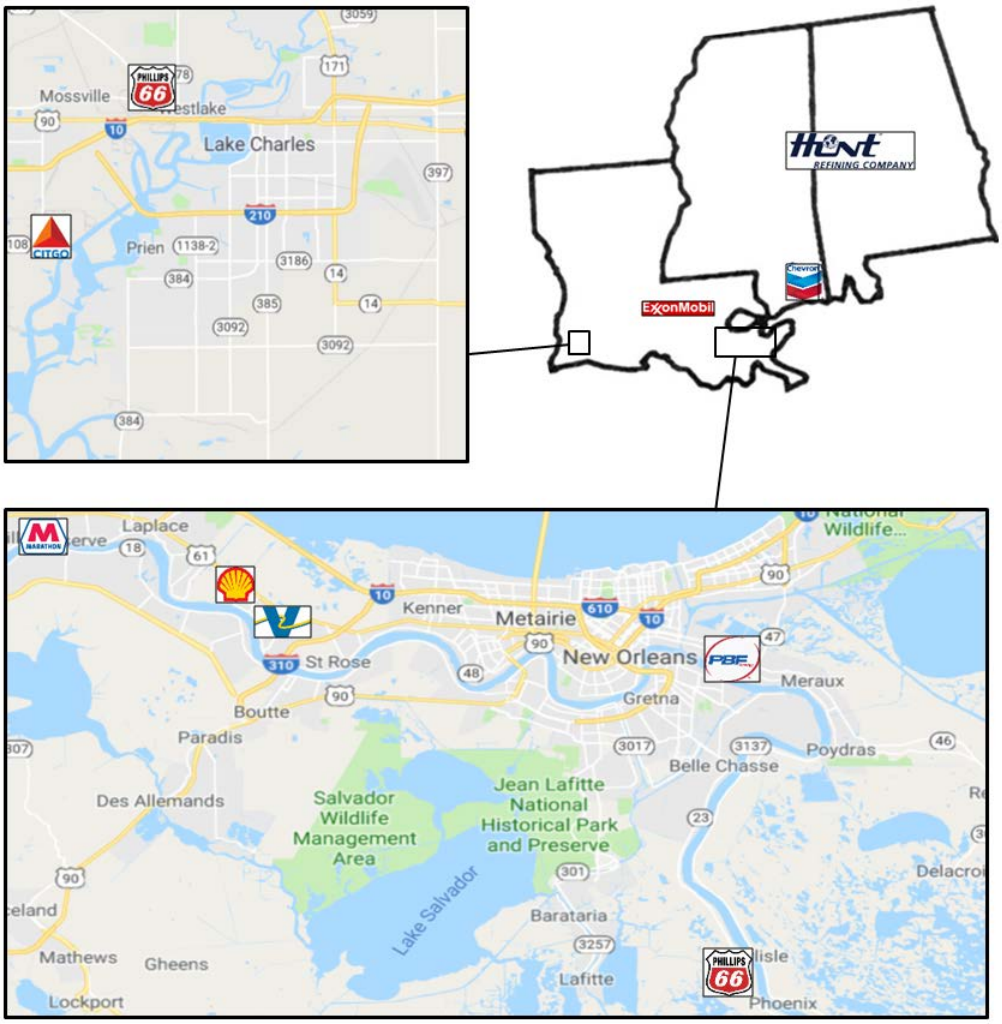
PADD III contains 56 refineries and represents over half of the total U.S. refining capacity. Twenty-three of these refineries process significant volumes of medium and heavy crudes with total crude-processing capacity of over 7.3 million BPD (Table IV-2). The coking capacity for these refineries is nearly 1.5 million BPD. The coking unit capacity as a percent of crude-processing capacity ranges from a low of 5% at Marathon Texas City to a high of 76% at Hunt Tuscaloosa, Alabama. The Hunt facility is primarily an asphalt refinery and processes an unusually heavy crude slate. The highest coking capacity ratio at a transportation fuels refinery is 36% at the Valero New Orleans facility. This complex is the combination of the former Valero New Orleans and Murphy Meraux refineries which resulted in the shutdown of crude-processing capacity and leaving an unusually high volume of coking capacity.

Figure IV-9
Heavy Crude Refineries in Texas



Unlike the PADD II facilities, refineries in PADD III process a significant volume of medium domestic crudes from the Gulf of Mexico such as Mars, Green Canyon and Poseidon. The heavy crude imports shown in Table IV-2 are generally from Venezuela, Mexico, Colombia, and Canada. For the first eight months of 2018, the heavy crude imports represented 23% of the PADD III crude inputs, while the medium imports comprised an additional 4%.

Figure IV-10
Heavy Crude Refineries in Louisiana

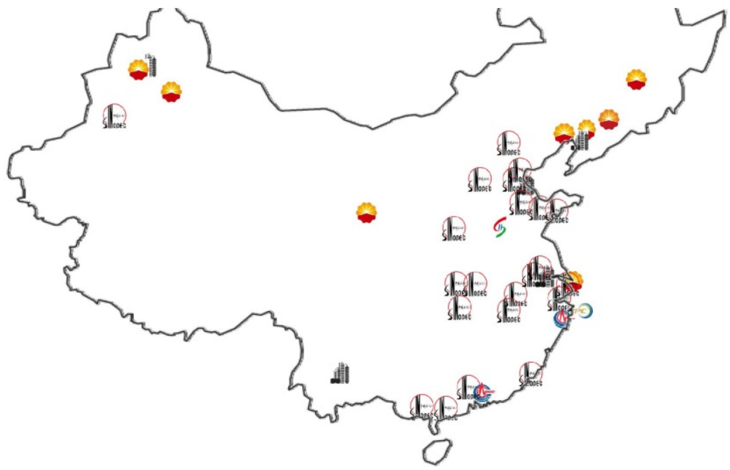


Maximum heavy crude-processing capacities were calculated for each refinery in a manner similar to the PADD II refineries. WCS was used as the marker heavy grade and Bow River as the market medium crude to determine the volume of VTB necessary to achieve a 100% utilization of the long-term calendar day coker rates. Five of the PADD III refineries also have the capacity to produce asphalt which resulted in adjustments to the maximum heavy crude volumes. The asphalt refineries are Hunt Tuscaloosa, Marathon Garyville, PBF Chalmette, Phillips 66 Lake Charles, and Valero Corpus Christi.

China

Current coking capacity in China exceeds that of U.S. PADD III, but only slightly. There are 38 coking refineries in China with a total coking capacity of 1.55 million BPD (Table IV-3 on next page). This equates to 20% of the Chinese crude-processing capacity, which is equal to that of PADD III and slightly above the 18% level for PADD II. Chinese coking refineries represent around three-fourths of total Chinese crude capacity. Most of the coking refineries are concentrated in coastal regions due to their reliance on medium and heavy crude imports.

Figure IV-11
Chinese Heavy Crude Refineries



China's ability to process heavy crude is also similar to that of U.S. PADD III. Chinese refineries are able to process up to 4.2 million BPD of heavy crude or up to 4.9 million BPD of medium grades. Five of the 38 refineries also produce asphalt and these additional capacities were included in the maximum heavy crude calculations. The marker crudes (WCS, Bow River, and LSB) used for the U.S. were also used in the Chinese calculations.

Table IV-3				
Chinese Medium/Heavy Crude Refineries				
	Existing Refinery Capacities			**Max**
Company/Location	**Crude Barrels/Day**	**Coking Barrels/Day**	**% Coking**	**Heavy* MBPD**
CNPC - Dushanzi	200,822	20,000	10%	23
CNPC - Fushun	200,822	48,000	24%	162
CNPC - Jilin	200,822	20,000	10%	23
CNPC - Jinxi	120,000	30,000	25%	103
CNPC - Jinzhou	100,000	30,000	30%	100
CNPC - Lanzhou	251,027	24,000	10%	23
CNPC - Liaoyang	200,822	24,000	12%	42
CNPC - Urumqi	120,493	24,099	20%	74
CNOOC Trading - Huzhou	240,000	84,000	35%	240
Hebei Xinhai Chem. Changzhou, Hebei	98,630	16,603	17%	99
Panjin North Asphalt Fuel Co. - Panjin	290,000	56,000	19%	217
Shandong Dongming Pet. - Heze City	298,315	92,411	31%	298
Sinopec Corp.—Anqing	160,658	30,123	19%	88
Sinopec Corp.—Beijing Yanshan	220,904	28,000	13%	55
Sinopec Corp.—Guangzhou	265,085	68,200	26%	238
Sinopec Corp.—Maoming	471,932	40,000	8%	18
Sinopec Corp.—Beihai, Guangxi	100,411	24,000	24%	100
Sinopec Corp.—Cangzhou, Hebei	70,288	24,099	34%	70
Sinopec Corp.—Shijiazhuang, Hebei	200,822	16,066	8%	3
Sinopec Corp.—Luoyang, Henan	160,658	28,115	17%	78
Sinopec Corp.—Jingmen City, Hebei	120,493	26,000	22%	83
Sinopec Corp.—Wuhan City, Hubei	160,658	50,000	31%	161
Sinopec Corp.—Yueyang, Hunan	230,945	24,000	10%	31
Sinopec Corp.—Nanjing, Jiangsu	281,151	48,000	17%	131
Sinopec Corp.—Nanjing, Jiangsu	421,726	68,000	16%	177
Sinopec Corp.—Jiujiang City, Jiangxi	160,658	20,000	12%	38
Sinopec Corp.—Jinan City, Shandong	100,411	24,000	24%	81
Sinopec Corp.—Qingdao, Shandong	240,986	82,000	34%	241
Sinopec Corp.—Zibo, Shandong	281,151	56,220	20%	172
Sinopec Corp.—Shanghai	261,068	52,200	20%	160
Sinopec Corp.—Tianjin	277,134	70,000	25%	242
Sinopec Corp.—Kuche County, Xinjiang	100,411	78,000	78%	100
Sinopec Corp.—Ningbo City, Zhejiang	461,890	70,000	15%	171
Sinopec Corp.—Quanzhou City, Fujian	281,151	32,000	11%	51
Wudi Xinyue Chemical - Shandong	161,000	20,000	12%	38
PetroChina - Karamay	70,000	36,000	51%	70
PetroChina - Anning, Kunming, YN	200,000	50,000	25%	172
CNOOC - Taizhou, JS	60,000	20,000	33%	60
Total	**7,843,344**	**1,554,136**	**20%**	**4,234**

***** Maximum heavy volume is on a calendar day basis

Source: O&GJ, and TM&C

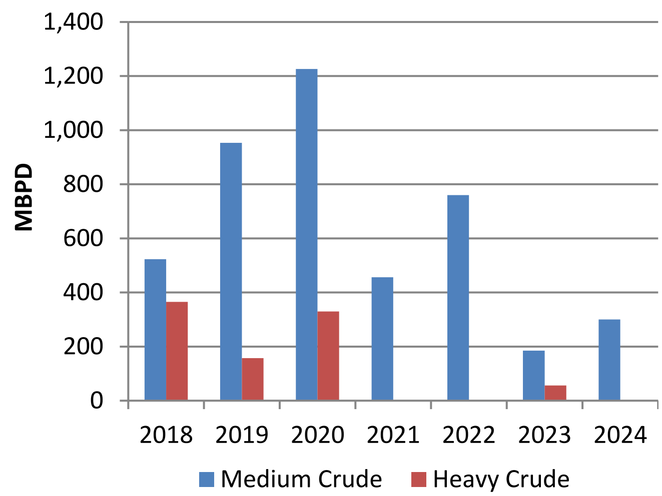
Medium and Heavy Crude Supply/Demand Forecast

As we have discussed earlier in this report, crude price differentials between light and heavier crudes will be substantially impacted by shifts in the medium and heavy crude supply/demand balance. Forecasting these shifts requires estimates for both the additions to refinery capabilities to process the heavier crudes (demand) and forecasts for the changes in medium and heavy crude production (supply). Our outlook for both these demand and supply elements is detailed below, along with an analysis of how they will affect the balance and what that means for prices.

Refinery Medium and Heavy Crude Capacity Growth

The construction of new refining capacity additions, especially those that are necessary to increase medium and heavy crude processing capabilities, is often a lengthy process. It can take up to five years to plan, approve, fund, design and construct new refineries or additions to existing facilities. TM&C has been monitoring global refining construction for nearly 15 years, and we have found that project announcements more than five years out are often vague and poorly defined. For this reason, we rarely assess projects as likely to be constructed outside of this five-year window. The latest global assessment of likely refinery capacity additions requiring medium and heavy grades is shown in Figure IV-12.

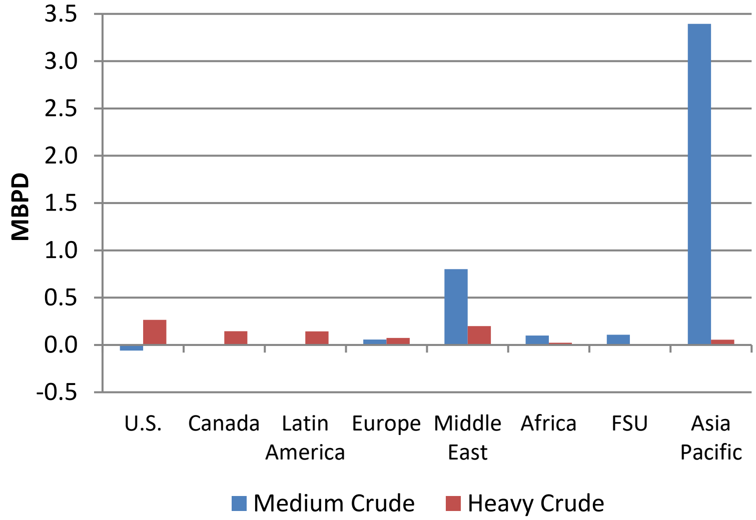
Figure IV-12
Global Refinery Capacity Growth



Through 2024, we see the construction of new refining capacity additions to increase demand for medium crude by 4.4 million BPD and for heavy crude by 900 MBPD. These additions are heavily weighted to the early years of the period, and it is highly likely that additional projects will be announced for completion in the 2021 through 2024 period.

As can be seen in Figure IV-13, the medium crude-capacity additions are heavily concentrated in Asia Pacific. This is a result of the region's heavy reliance on Middle East crudes such as Arab Medium, Arab Heavy and Iranian Heavy. Heavy crude additions are more evenly spread. The slight reduction in medium crude demand in the U.S. is a result of further asset consolidation with the Andeavor Wilmington and Carson refineries.

Figure IV-13
Global Refinery Capacity Growth by Region



The largest of the new refining projects are listed in Table IV-4.

Table IV-4
Largest Medium and Heavy Refining Projects

Country	Location	Company	Capacity Additions, MBPD Medium	Capacity Additions, MBPD Heavy	Expected Completion
Saudi Arabia	Jazan	Aramco	200	200	2018
Kuwait	Al-Zour	KNPC	215	0	2019+
China	Zoushan	Zhejiang Pet.	402	0	2020
India	Maharashtra	ADNOC/IOCL HPCL/Aramco	400	0	2022
Indonesia	Turban	Pertamina/ Rosneft	300	0	2024

Table IV-5 details the new projects for the target areas.

Table IV-5 Medium and Heavy Projects in PADD II, PADD III and China				
		Capacity Additions, MBPD		Expected
Location	Company	Medium	Heavy	Completion
PADD II				
Superior, WI	Husky	0	10	2018
Lima, OH	Husky	0	30	2019
PADD III				
Port Arthur, TX	Valero	0	100	2022
China				
Huabei	Petrochina	100	0	2018
Karamay	Petrochina	60	0	2018
Dalian, LN	Hengli Petrochemical	400	0	2019
Nanjing	Sinopec	200	0	2020
Quanzhou	Sinochem	60	0	2020
Zhanjing, GD	Sinopec/KNPC	200	0	2020
Zoushan	Zhejiang Petrochemical	402	0	2020
Zhenhai	Sinopec	200	0	2021

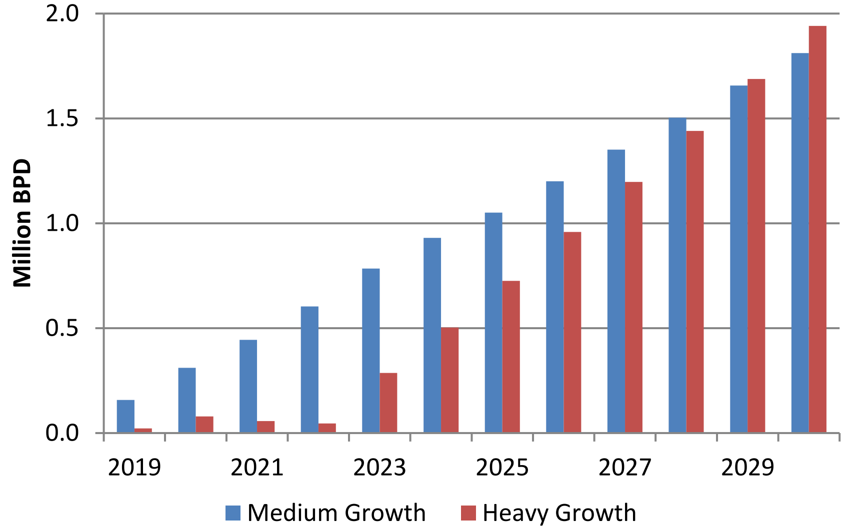
Medium and Heavy Crude Production Forecast

To keep pace with rising global production (which is forecast to increase by around 1.1 million BPD), world oil production is expected to rise by 800-1,000 MBPD per year in the coming decade. The balance of the demand growth will be met by NGLs, biofuels, and alternate fuels such compressed natural gas (CNG) and liquefied natural gas (LNG). Most of the incremental crude production will be light, however, led by increasing shale output in North America. As indicated previously, much of the heavy oil production is located in countries plagued by political disruptions which inhibit output growth.

Medium and heavy crude production levels are both expected to each grow by slightly under two million BPD between 2018 and 2030. Much of the incremental medium production will come from Iraq, Canada, and the Gulf of Mexico. The introduction of Basrah Heavy in 2015, shifted substantial output from medium to heavy, but the growth of total Iraqi output will increase production levels in both grades. The additional medium production in the Gulf of Mexico will be similar to the Mars, Poseidon and Green Canyon grades. These growth trends are seen in Figure IV-14.

The additional heavy production is largely from Iraq and Canada. Global heavy output is assumed to be stagnant for the near future due to declining production levels from Venezuela and Mexico. We have assumed continued declines in Venezuelan crude production through 2022 and a modest rebound thereafter. Even if the political environment were to change in the near future, it would take years to increase investment and rebuild the crumbling infrastructure. Output from Mexico is expected to decline in the near future with reforms to the petroleum industry not showing substantive impact until the middle of the next decade. Output gains in Canada will be slower than in previous years, but recently received a boost from the announcement by Imperial Oil to approve the Aspen development which is expected to yield 75 MBPD around 2022.

Figure IV-14
Global Medium and Heavy Crude Production Growth

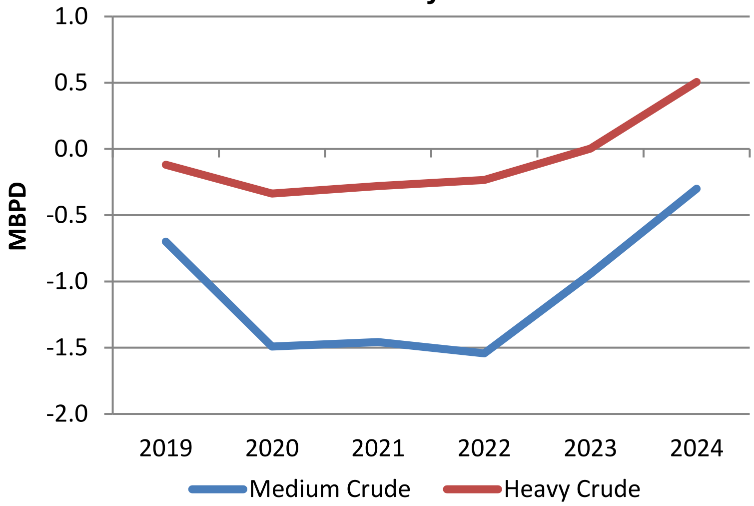


Forecast Medium and Heavy Crude Supply/Demand Balance

Refiners have long seen the need to match crude-processing capabilities to possible production trends. Because of the time lag to plan, design and construct refining projects, however, actual completion capabilities may not mesh well with changing crude production qualities. As a result, refiners often over-build for certain crude qualities, only to reverse directions in subsequent years. The crude supply/demand balance for the near term aptly illustrates this process.

The projected mismatch between near term (through 2024) refining projects and crude production is fairly typical. Figure IV-15 displays the cumulative difference between the supply and demand of medium and heavy crudes. Because of the completion of several large refining projects which focus on medium and heavy grades (Al-Zour in Kuwait,

Figure IV-15
Cumulative Surplus Crude Production by Grade



Zoushan in China for example), the demand for the heavier grades will exceed incremental production in 2019 and 2020. The imbalances remain relative constant through 2022 and then come back into balance around 2024. The imbalances seen in 2020 through 2022 could persist further, however, if additional projects for completion in this period are announced. The differences shown in Figure IV-15 should not be viewed as unusual. While refineries are designed for a principal crude slate, modest shifts in feedstock qualities can be accommodated.

PUB Placement in the Regional Medium/Heavy Crude Supply Balances

All of the PUB streams will be attractive feedstocks for deep conversion refineries in the three markets studied – PADDs II and III in the U.S. and China. They will both displace existing medium and heavy crudes which are currently processed in the regions and in cases where we expect capacity to be added, they will be competitors for filling that new capacity.

U.S. PADD II

Almost the entire existing demand for medium/heavy crude is currently sourced from Western Canada (in the form of dilbit, synbit and conventional), with over 1.5 million BPD processed last year (as shown previously in Table IV-2). In the future, as some of the Western Canadian bitumens are converted and brought to market as PUB streams, they will essentially replace the dilbit, synbit and conventional barrels on both the supply and demand side. The net change in that supply/demand balance will depend on both how PUB production impacts total Canadian medium/heavy production and the net change in VTB content of the overall supply of Canadian medium/heavy production coming to market. It is likely that these factors substantially cancel each other out. It should also be noted that although we expect only minimal increases in medium/heavy crude capacity in PADD II (30 MBPD of additional heavy capacity as shown in Table IV-5), there might be room for some additional medium/heavy barrels in PADD II refineries. This is based on the fact that the theoretical capacity to process these barrels is between 1.7 million BPD (100% heavy in the mix) to 2.2 million BPD (100% medium in the mix), as noted earlier on page 52, which exceeds the 1.6 million BPD actually processed in 2018.

PADD III

The existing demand for heavy crude In PADD III is primarily supplied by imports of heavy grades from Latin America (primarily Mexico, Venezuela, Brazil, and Colombia), Canada and Iraq, with the Latin American proportion equal to almost 2/3rd's of the total of the 2 million BPD shown in Table IV-2. Medium crude supplies primarily consist of GOM crudes such as Mars, Poseidon, SGC and similar crudes, which account for almost 1.5 million BPD, with most of the rest (about 0.4 million BPD) coming from Middle East imports. Total Canadian volumes reaching USGC refineries has recently been about 0.5 million BPD, with the vast majority being heavy. When the PUBs are brought to the market in the USGC, they will compete with all of these crudes, displacing some to other markets, potentially replacing others if production continues to decline in Mexico and Venezuela, and as in PADD II, replacing a portion of the Canadian dilbits and synbits as some bitumen is diverted to PUB production. Also, as in PADD II, PUBs that have lower VTB content, such as PUB 1 and PUB 2 could “stretch” the market as will the addition of some limited, deep-conversion capacity expansion which is expected, as shown in Table IV-5.

China

In China (and the rest of Asia), most of the medium and heavy sour crude is supplied by Middle East producers such as Saudi Arabia, Iraq, Kuwait and Iran, with most of these barrels falling in the medium gravity range. As shown in Table IV-5, significant new capacity, essentially all focused on medium sour crudes, is planned to come on line (1.6+ million) through 2021, and we can expect similar capacity to continue to grow in tandem with product demand as China maintains a policy of being largely self-sufficient in refined product supply. Canadian PUBs will compete for market share with the Middle East crudes in both the existing refineries and in the new plants, with the upgraded crudes fitting in well with the new refineries from a quality standpoint. The PUBs will likely see the best opportunities in those new refineries which are not JV projects with Middle East producers.

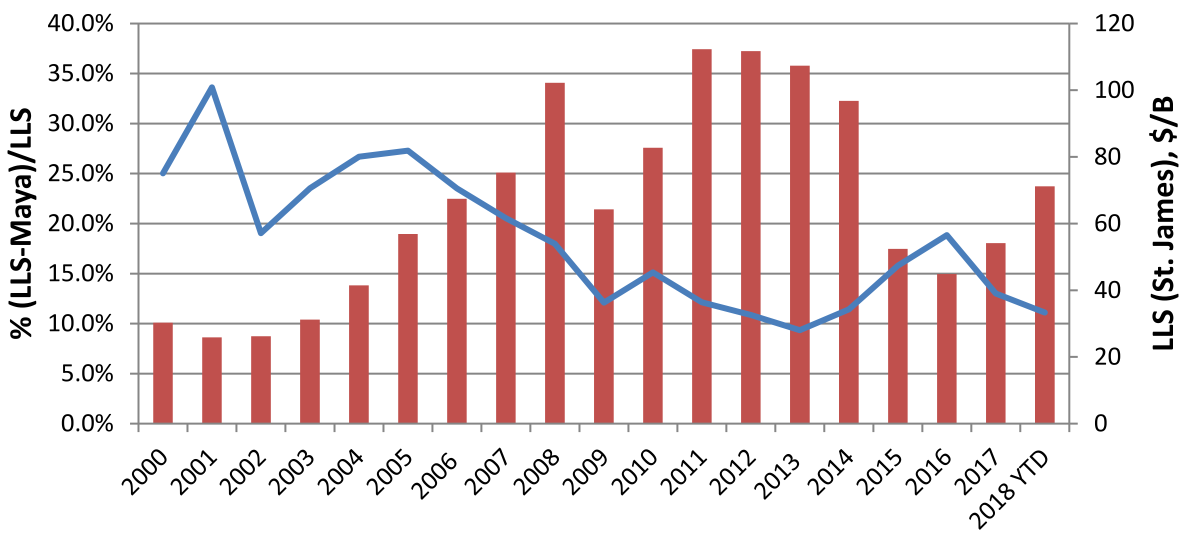
Price Impacts

Historical Perspective

As detailed in this section, the USGC is home to both the largest concentration of deep conversion capacity and is situated with ready access to significant volumes of medium and heavy crudes suited for that type of processing capability. These two factors are inter-related, with refiners investing to add deep conversion capacity as medium and especially heavy crude production is brought on line. The price differential between light and heavy crude is the key variable which both reacts to changes in the supply/demand balance between heavy and light crudes and incentivizes investment to restore that balance. The most representative measure of the heavy/light differential is the spread between LLS (St. James) and Maya (FOB Mexico). The use of these two crudes eliminates the distortions caused by transportation bottlenecks that have affected WTI, WCS and other crudes.

As was originally discussed in Section III – Price Sets, the heavy/light spread generally fluctuates between a sustainable ceiling set by new build deep conversion/coker economics and a floor set by the breakeven level of existing deep conversion/coker facilities. The floor and ceiling will in turn move up or down based both on relative product price relationships and absolute crude price, but generally falls in a range of a 20 to 25+% Maya discount to LLS for the ceiling and about 10% for the floor. An examination of the Maya discount to LLS since 2000 illustrates this dynamic and provides a good historical perspective of the forces that have and will continue to impact heavy/light crude prices in the future. Figure IV-16 below shows both the percentage discount of Maya vs. LLS (as a line graph) and the price of LLS (annual average in bar graph format). Please not that we included this data going back to 1995 (as far back as Maya price information is available) in the previously referenced Appendix Table II-1.

Figure IV-16
Heavy/Light Differential Since 2000



In the 1990's and early 2000's, growing production from Latin America and to some extent Canada led to a general surplus of heavy crude, which resulted in wide differentials, with the LLS/Maya differential exceeding 25% for much of the time. This incentivized the construction of new cokers, both in the USMC and USGC, which brought the discount below the "new build" ceiling. Over the last ten years it has moved within the floor to ceiling range (about 10% to 20% Maya discount to LLS) which incentivizes operations at existing cokers but is not enough to trigger significant new greenfield additions.

Crude supply trends, including the relative growth rates of light and heavy crude, have also played a role in the heavy/light differential movements. For example, as light crude production growth from US LTO grew rapidly in the first few years of this decade, while heavy production from Latin America stagnated, the differential went to floor levels (and below at times). With a slowdown in the growth of LTO after the crude price crash in 2014/2015, the differential widened, before falling again over the last couple of years as light crude growth has returned and heavy crude production, particularly from Venezuela, has fallen.

Forecast

Looking to the future, some of the same factors which have recently impacted the heavy/light crude differential,will continue to influence it in the coming years, with a new dynamic in the form of the IMO LS bunker regulations becoming an important player in 2020. The projected supply/demand imbalances resulting from falling and logistically constrained heavy crude supply and some new deep conversion additions which we quantified in Figure IV-15, modest as they are, will tend to tighten the differential, as is currenly happening.

A we approach 2020, the IMO bunker regulations will overwhelm these forces and lead to a fairly significant "bump" in the light/heavy spread by driving down the price of HSFO, decreasing the value of the resid portion of high sulfur crude oils and increasing the heavy crude pool through the use of surplus fuel oil as a feedstock for coking units. The sweet/sour spread will also widen, with resid sulfur content being the major value determinant impacted by the IMO regulations. Sulfur content of the other cuts and the whole stream sulfur content will not impact values and therefore prices in a significant way since most refineries processing high sulfur crudes already have the ability to remove sulfur from the cuts lighter than resid (having had to meet ULSD and gasoline sulfur specs due to previous fuel specification regulation enactments).

After 2020, we believe demand responses, along with investment by ship owners to install scrubbers will mitigate the IMO impact and the differential should decline. The wider light/heavy spread and depressed resid prices will also stimulate increased coker capacity additions, which will increase global medium and heavy demand and also serve to narrow the light/heavy crude spread. Over the next two decades, we forecast that the heavy/light differential will reach an "equilibrium" level between the floor and ceiling, with the Maya discount equal to about 14% to 16% of LLS. This equilibrium level will justify some addition of advantaged "brownfield" capacity to process growing heavy crude volumes and maintain a supply/demand balance. In some cases, production economics will play a role in the incentivization of new capacity addition. Figure IV-17 shows our forecast for each of the four price sets. It should be noted that the floor, ceiling and equilibrium shifts somewhat in relation to the absolute crude price (moving up in % terms as the absolute crude price declines) in tune with the economics of both existing coker operation and new build construction.

Figure IV-17

Forecast Heavy/Light Differential

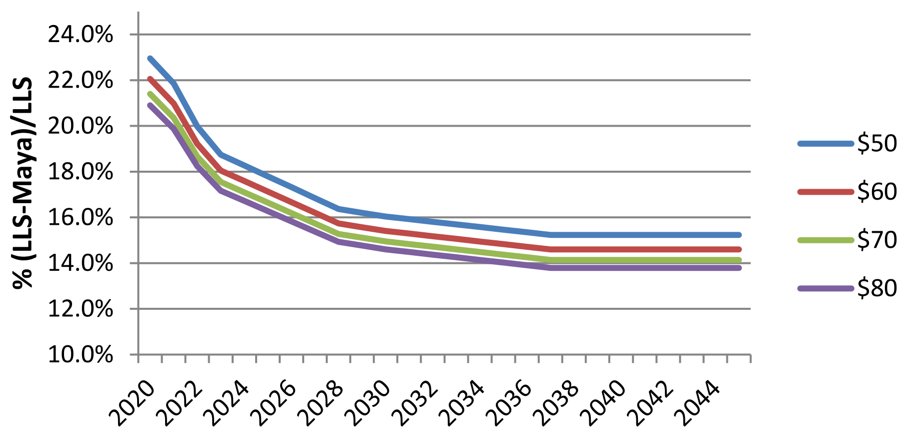
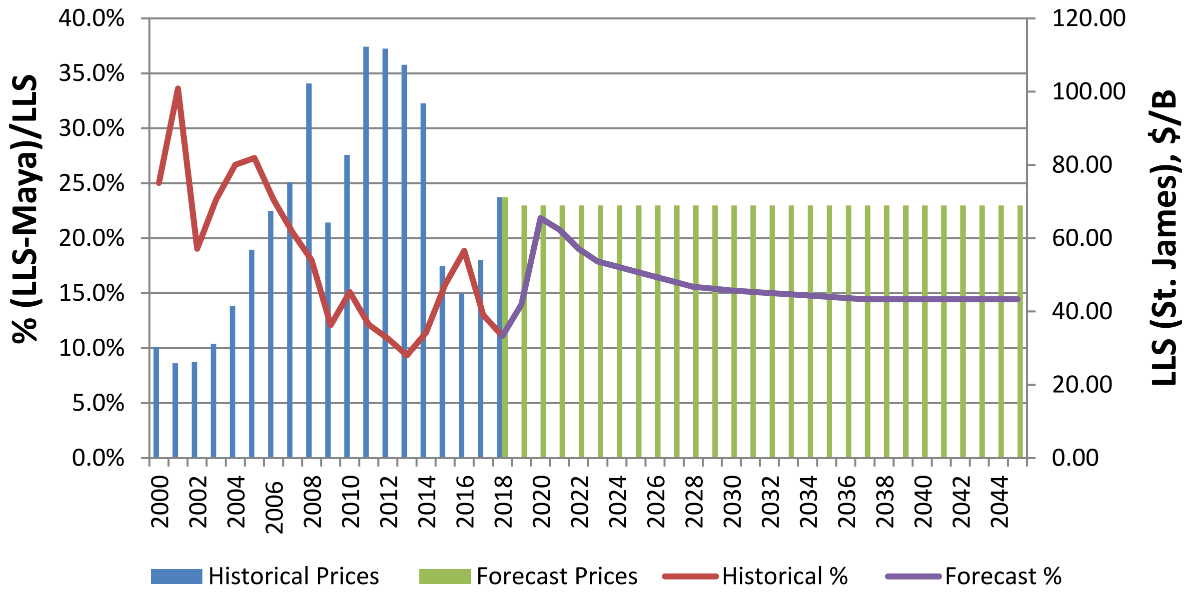


Figure IV-18 shows our forecast (average of the four price sets) together with the historical results and as shown it generally stays within historic boundaries. Of course, the future profile of the heavy/light differential will be much "bumpier" than our forecast and potentially similar to the "roller coaster" pattern exhibited historically, although we feel this would not necessarily impact the longer term average level.

Figure IV-18

Heavy/Light Differential - Forecast vs. History



On a global basis, the heavy/light spread will track the pattern of the USGC; with, of course, adjustments to reflect locational differences. Medium crude price relationships to light crude will follow a similar trend line to the heavy crude differential – widening in 2020 in reaction to IMO impacts and declining thereafter to an equilibrium level long term. Arab Heavy will see a longer term relative decline in value compared to Mars as a result of IMO impacts due to its particularly high level of sulfur in resid. Figures IV-19 and IV-20 show our forecast for the Mars vs. LLS discount and the Arab Heavy (China) vs. Brent discount.

Figure IV-19
Mars/Light Differential - Forecast vs. History

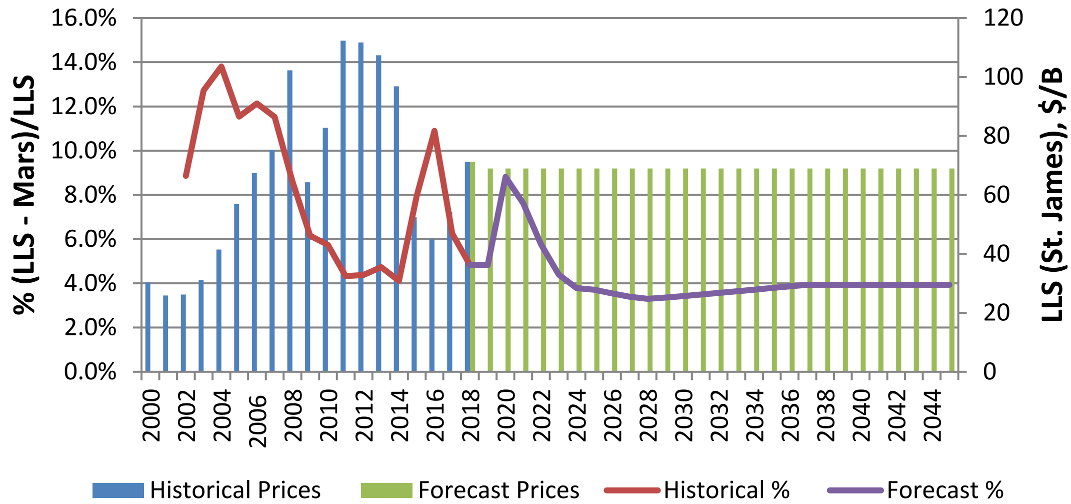
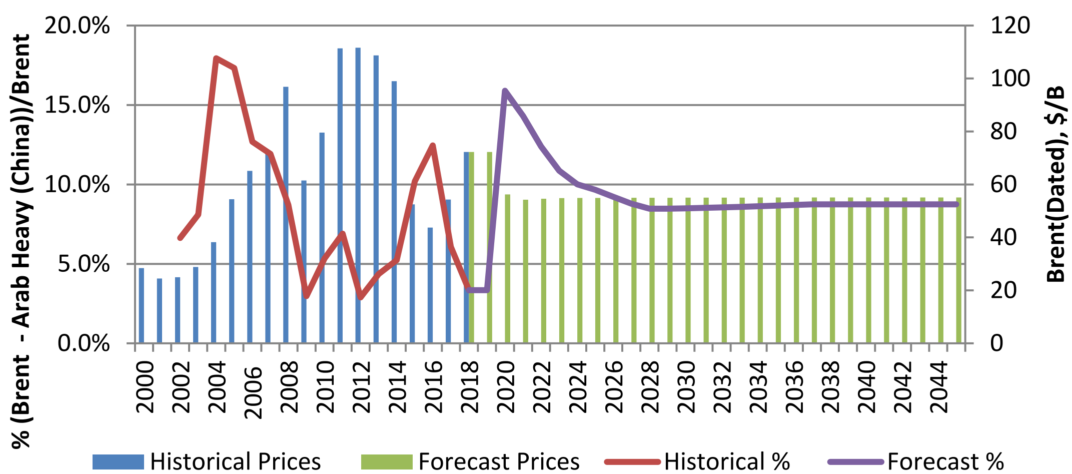


Figure IV-20
Brent/ Arab Heavy Differential - Forecast vs. History

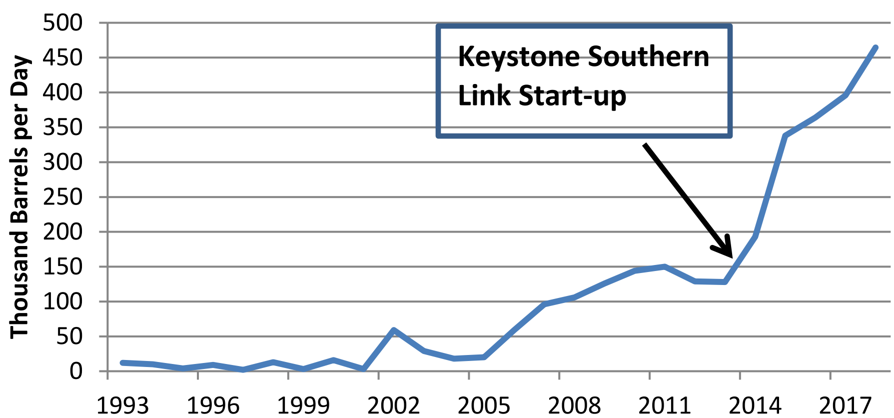


WCS vs. Maya

From a refining value standpoint, WCS and Maya are very comparable (within about $0.10 per barrel), as measured by using our USGC coking model and shown in Tables III-2,3 and 4 (pages 27 to 30). While yield and cut properties do vary somewhat between the two crudes, the differences are not very significant in most cases and the positive and negative value attributes of each cancel each other out very closely. For example (referencing the quality data shown in Appendix Table III-1): 1) Whole crude properties – WCS is higher in TAN and API gravity and very similar in sulfur – slightly favorable for Maya; 2) Light Ends/LSR – WCS yields slightly more of these relatively low value components - slightly favorable for Maya; 3) Heavy naphtha – WCS heavy naphtha is more aromatic – slightly favorable for WCS; 4) Distillate – Maya yields slightly more and properties are similar – slightly favorable for Maya; 5) Gas Oil – WCS yields more and has lower concarbon and nitrogen – favorable for WCS; 6) Resid – Maya yields more of this undesirable fraction but is lower in concarbon – neutral.

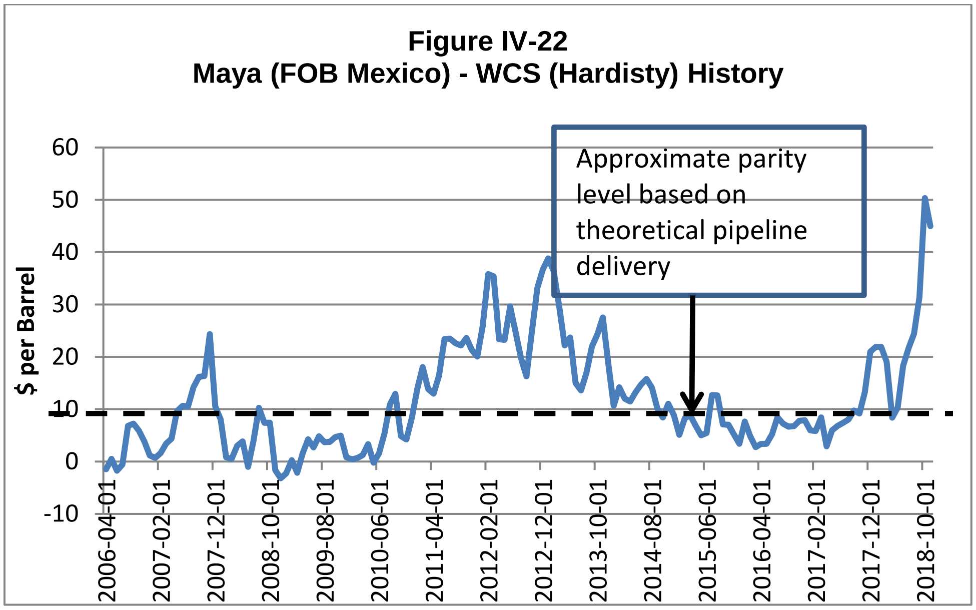
Due to logistical limitations, WCS (and other Canadian crudes) were historically not players in the USGC refining market. Only limited volumes actually made it to the USGC and the USMC was the real "price setting" market for WCS. This situation only changed earlier this decade with the development of several pipelines linking the Cushing Hub with the USGC (capped by the Keystone Southern Link start up in early 2014). These pipelines relieved a significant bottleneck, which existed not only for Canadian crudes, but also most other inland North American crudes. Canadian crude volumes flowing to the USGC have more than tripled since (from below 150 MBPD) and have recently exceeded 500 MBPD (as shown in Figure IV-21 below).

Figure IV-21
Canadian crude imports to PADD III

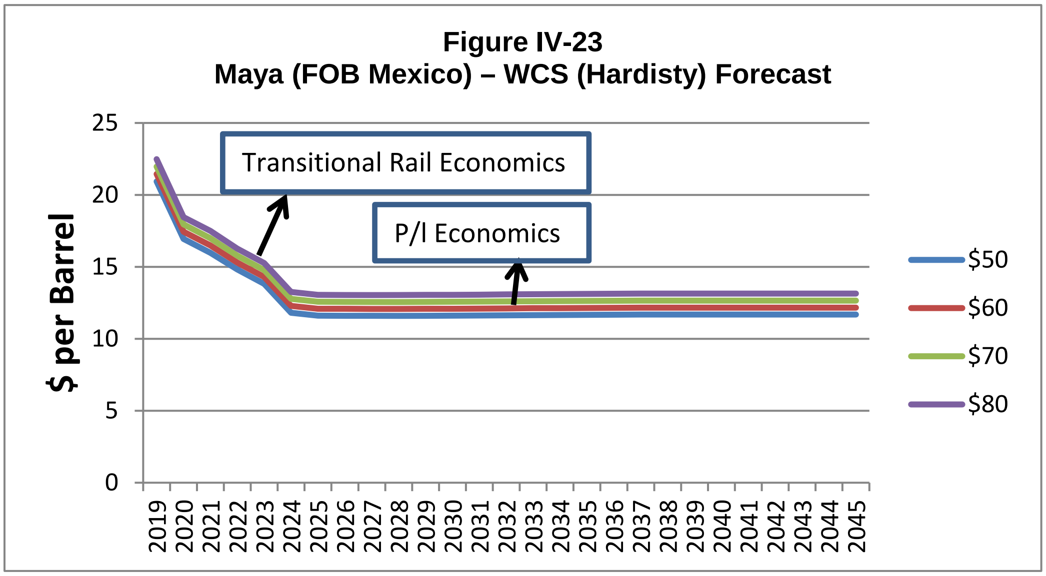


Source: EIA

Prior to 2014, the price of WCS, due to its limited presence on the USGC, was not linked to Maya in any meaningful way. Instead, its price was set in the USMC, a refining market where Maya had not had a meaningful presence since before 2000. This dynamic is shown in Figure IV-22, where there were times when WCS was priced both well above and below its calculated parity value to Maya on a (theoretical) pipeline delivered basis at the USGC. With a rateable "connection" established in 2014, WCS and Maya began to track relatively close to the USGC pipeline delivered parity level until 2017. At that point, US/Canada cross border pipelines began to hit capacity limits and with rail limitations also impacting logistics, the price relationship between WCS and Maya has again been broken. With a growing surplus of production vs. delivery options, the price of WCS has recently traded well below both pipeline and rail delivery to the USGC based levels vs. Maya.



Looking to the future, we expect that through a combination of production discipline (both government and market enforced) and the removal of rail capacity restrictions, which the price-setting mechanism for WCS will again transition to a predictable USGC parity basis with Maya based on unit rail movement to that market. Per our assumption that sufficient pipeline capacity (Keystone XL) is added in 2023/24 to allow the marginal barrel to move to the USGC by pipeline, our forecast for 2025 and beyond is based on the assumption that this remains the price setting mechanism. Given our estimate for quality differentials between WCS and Maya and pipeline transportation post-2025, this translates to a Maya (FOB Mexico) – WCS (Hardisty) differential of between about $12 and $13 per barrel, depending on the price set (see Figure IV-23). If Keystone XL does not get built, unit rail to the USGC will remain the price setting mechanism for WCS (and other Western Canadian heavy crudes), resulting in a Hardisty price (vs. Maya) which is $4 to $5 per barrel lower, or a differential of between $16 and $18 per barrel. Impacts on Canadian production levels and heavy/light spreads are difficult to quantify, but PUB production would be incentivized as it would allow more efficient utilization of the limited pipeline capacity.



V. COMMERCIAL AND MARKET FACTORS INFLUENCING VALUE

We believe that a substantial part of the relative price of different crudes can be estimated through the use of analytical tools, such as the refining models and methodologies we described in Section III. This does, of course, assume that the key inputs to those models, such as prices, yields, operating expenses and transportation costs are consistent and reasonable, that the models are representative of price-setting facilities and that the methodologies accurately capture the value of the crudes. However, even if these qualifications are met, as with any commodity, crude prices are also influenced and set by other factors which are not so clearly quantifiable. These other factors include: (1) quality factors which can't be effectively modeled, and (2) commercial/market factors not directly related to the calculable value of the crude stream. In addition to being difficult to precisely quantify, the timing and duration of the price impacts of these other factors is difficult to assess. In this section, we discuss these factors and provide our estimates of the relative magnitude they will have on the PUB streams, both when they are first brought to market and after they have become more established.

Quality Factors Which Cannot Be Effectively Modeled - TAN

The value impact of most of the key quality factors associated with crude oils (yields, product blending properties and intermediate feedstock qualities) can be effectively captured in the refinery modeling process through their effect on product yields, qualities or variable operating costs. Properties which do not affect those parameters, but can impact (usually negatively) refinery operations, fixed costs or other economics have to be adjusted for "outside the model."

In this study, the most important of these properties is the acid content of the feedstock. This quality is usually quantified by the Total Acid Number (TAN), which measures the amount of potassium hydroxide (KOH) necessary to neutralize the acids in the crude. Generally, crudes below a TAN level of 0.5 mg KOH/g are considered low acid, 0.5 to 1.0 TAN are medium acid, and TAN levels above 1.0 are classified as high acid crudes. The PUBs in this study differ significantly in TAN content ranging from negligible levels for PUB 4 to 1.65 for PUB 1. PUB 2 also has a low TAN at 0.30, while PUB 3 is borderline between medium and high at 0.90.

Acid is corrosive, especially at high temperatures, and while moderate TAN content can be mitigated to some extent by testing and inhibitor programs, higher TAN levels can only safely be addressed by equipping critical areas of refinery units with metallurgy which is resistant to acid corrosion. Blending is another strategy which can be employed by refiners – diluting higher TAN crudes with lower ones to bring the blended TAN content down to acceptable levels.

All of the options which a refinery has in dealing with moderate or high TAN levels in crudes require some cost, either upfront by "metaling up" or through blending or mitigation strategies. In the case of refineries which do have the proper metallurgy (generally chromium or molybdenum containing specialty steel grades), high TAN content generally incurs no additional processing costs (although replacement costs during turnarounds can be higher). Blending and mitigation strategies incur not only some additional direct costs, but also result in hard to quantify opportunity cost impacts and are limited in regards to the TAN levels and volumes of high TAN crude which can be safely handled. Many refiners make purchase decisions regarding high TAN crudes in a binary fashion – possible if the plant has appropriate metallurgy; not possible (at least in any volume) if it does not.

As a result of the difficulties in attaching directly quantifiable costs on the TAN content of crudes and the yes/no process involved in making purchase decisions, the primary price-setting mechanism determining the discount the market imposes on high TAN content is supply/demand driven and very volatile. In an environment where the volume of high TAN crudes exceeds or approaches the volume of high TAN capable and operable capacity (refiners with appropriate metallurgy), TAN discounts can get very large and conversely it declines when the demand side exceeds the supply side by a greater level. The supply/demand equation can be effected over the long term by growing (or declining) production of high TAN crudes and capital projects increasing high TAN capability at refineries. Over the short term, production shutdowns, refinery turnaround activity, and logistical issues can have major effects.

For all of the above reasons, It is very difficult to isolate and estimate the actual discount the market has attached to TAN in the past and even more difficult to forecast future impacts. Adding to the difficulties is the fact that high TAN crudes have poor market transparency. WCS, which is only borderline high TAN at about 1.0, is really the only widely marketed and price reported higher TAN crude. Prices for some of the other Canadian higher TAN dilbits can be obtained but the data is somewhat spotty and less reliable. After first discussing other nonquantifiable commercial and market factors which impact crude prices; in the following section, we will provide some relevant historical analysis on the competitive crudes and detail our estimates for both those and TAN discounts which can be expected for the PUB streams when they are marketed.

Other Commercial/Market Factors

Crude oil markets are perhaps the most complex and difficult to forecast commodity markets. This is due to a lot of reasons, including the following:

- Crude oils are highly unique and complicated, with each one composed of a large number of diverse molecules combined together in unlimited different combinations. This is unlike most other commodities such as natural gas, minerals, and agricultural products, all of which are relatively homogenous with limited quality differences.

    - These quality differences exist even among the same crude streams, the composition of which continually changes due to evolving production profiles and blending activities.

    - In addition, new crudes are constantly being introduced to the market, of varying qualities and in varying quantities. Their presence impacts the value of existing crudes in a variety of complex ways.

- Refineries are also all very different in their size, capability, limitations and other aspects which impact how they value different crudes and even if they can reasonably process certain crude oils.

- Logistics play a major and very dynamic role in crude-pricing. The location of crude production and petroleum refining markets can and are significantly disparate. Changes in production growth, refinery expansions or modifications, new pipelines, and changing marine freight rates have and will continue to change.
    - Situations where production growth exceeds takeaway capacity have played a major role in North American crude markets, with cross border constraints from Canada particularly impactful in recent months and years.
- Regulations, especially as they relate to product specifications also play a major, dynamic and hard to predict role in crude valuation. The IMO low sulfur bunker rules taking effect in 2020 will be particularly impactful, as we discussed earlier.
- The sheer size and importance of crude oil markets results in significant trading activity, with a wide range of participants, many of whom are not stakeholders (refiners, producers, or transporters), but merely financial actors. This results in high levels of unpredictable speculative activity which can significantly impact the price of crude oils, often in ways unrelated to fundamentals or quantifiable values.
- Petroleum markets are particularly susceptible to geopolitical factors and developments and these can also impact prices in directions which are difficult to predict and quantify.

The interaction of all of these factors result in crude oil markets which are very complex and unpredictable and put into play a variety of hard to quantify influences. While the relative value of individual crude oils is primarily driven by their relative refining values and the valuation methodology we used in modeling the different PUBs and competing crudes provides the "backbone" for the MVCM we presented earlier (see pages 39 through 41), these other influences will also impact market prices.

We have discussed the quality related factors (TAN) in the previous section and we can classify the remaining elements as "other commercial/market" factors. These are primarily related to supply/demand, relative market power between suppliers and refiners, and other similar factors. In the particular case of the PUBs in this study, we feel their uniqueness and sheer "newness" could result in the need to provide "incentives" to refiners to consider purchasing them versus the feedstocks they have more experience running in their plants. Over time, it is likely that the magnitude of these incentives would decline, but it is very difficult to provide precise estimates of either the magnitude itself or the timing of the increased market acceptance which would lead to the reduction in magnitude of these additional price discounts.

Estimates of TAN and Other Commercial/Market Factors for PUB Streams

By definition, it is impossible to analytically calculate a precise value for these types of discounts/price adjustments on historical prices, much less forecast them for future periods. While keeping this fact in mind, we have used our judgment and experience to estimate price discounts related both to the high TAN content of two of the PUB streams and the other commercial/market factor discounts or other adjustments which might be applied to each of the PUBs when they are brought to market.

Backcast Analysis

To support these judgments, we have performed a "backcast" market analysis of several similar high TAN crudes, focusing our attention on Western Canadian produced competitive streams which we feel will lead to the most relevant comparisons. In this exercise, we compared historical prices (since 2016) for WCS (1.0 TAN) and Maya (<0.3 TAN) and also AWB (1.85 TAN) vs. WCS, adjusting for estimated refining value and locational differences. We supplemented these two analyses with some less complete data (2018 only) for Western Canada Dilbit (WDB) and Christina/Cenovus Dilbit (CDB) vs. WCS.

We have always considered that WCS, which is a relatively new feedstock for deep conversion refineries on the USGC, has received a market discount (beyond quantifiable refining value differences) vs. the more established marker crude for the region, Mexican Maya. This market discount is based on its higher TAN content, its newness to the market and perhaps other commercial factors. In this analysis, we compared monthly market prices for WCS (Nederland) with Maya (adjusted for transport to the USGC). From this "market discount" for WCS, we subtracted our calculated refining value differential between the two using our USGC coking model) to arrive at an implied "TAN + other commercial/market value discount."

Unlike on the USGC, WCS has been the established benchmark deep conversion refinery feedstock in the Midcontinent region for quite some time. In this market, AWB, CDB and WDB are the more problematic streams, and therefore incur an additional market discount due both to their higher TAN content and less prominent market positions. We performed an exercise similar to the USGC WCS vs. Maya analysis, comparing WCS with AWB, CDB and WDB, using comparative refining values in a Midcontinent coking refinery.

Table V-1 in the Appendix details our monthly WCS vs. Maya analysis. We have started with February 2016 because that is the first month when WCS delivered to Nederland prices began to be reported. As shown in the Table, the calculated "TAN + other commercial/market discount" for WCS vs. Maya was very volatile on a monthly basis during 2016 and 2017 (varying from $4.29 to -$1.28), but on an annual average basis was very consistent, averaging $1.50 per barrel in 2016 and $1.44 per barrel in 2017. 2018 monthly values were even more volatile (varying from $6.21 to -$3.24) and have actually shown only a very small average discount ($0.04 per barrel) through October.

Table V-2 in the Appendix shows our monthly AWB vs. WCS analysis over the past three years. In this analysis, we estimated transportation and storage costs from Edmonton and compared market values at Hardisty. On an annual average basis, the calculated "TAN + other commercial/market" discount for AWB vs. WCS was $1.14 per barrel in 2016, $0.87 per barrel in 2017 and $1.87 per barrel in 2018. While monthly volatility is also high (with the TAN/commercial/market discount varying from $0.17 per barrel to $3.00 per barrel), they are lower than in the WCS/Maya analysis, but consistent with that analysis in that monthly volatility in 2018 has increased and the annual average is significantly different than in the previous two years. In both cases we believe this is likely due to the market uncertainty caused by the US/Canada cross border pipeline constraints which have developed in recent months.

While we only have data for 2018 for CDB and WDB, we have also analyzed that data to supplement the AWB vs. WCS comparison. We believe a similar dynamic exists for these lesser marketed and higher TAN streams (CDB TAN = 1.68; WDB TAN – 1.89). Tables V-3 and V-4 in the Appendix shows our monthly CDB and WDB vs. WCS analysis during 2018. As shown, the calculated "TAN + other commercial/market" discount averages $2.14 per barrel for the higher TAN content WDB and $1.91 per barrel for CDB. As in the other cases, especially for 2018, monthly volatility is significant in both analyses, ranging from the $1.30s per barrel to over $3.00 per barrel.

Key Assumptions and Final Forecast Estimates

Interpretation of the backcast data is difficult and imprecise, and they are only one input in our estimates for both the TAN and "other commercial/market" discounts we are using to convert refining values to market values (RVCE's to market values through the MVCM) in this study. As we noted earlier, these price adjustments are heavily influenced by our experience in past engagements and other analyses, along with a strong dose of judgment. Our forecast estimates are included in Appendix Tables V-5, V-6 and V-7 and the key assumptions we made to arrive at these values are shown below:

- Both the TAN and other commercial/market adjustments are transitory and will decline as the new PUB streams become accepted into the regional markets.
    - Most if not all of the other commercial/market adjustments are related to market entry discounts required for new streams, particularly those that are somewhat dissimilar to existing crudes and feedstocks.

- The TAN discount will also decline over time as refiners become more comfortable with mitigation strategies and invest in metallurgical upgrades.

- The TAN and other commercial/market assumptions will vary by region.
  - The PUBs will incur the lowest market discounts in the USMC because refiners in this region are both more acquainted with running similar crudes and “metaled up” to run higher TAN streams.
  - Market discounts will be highest in China for the opposite reasons they are lowest in the USMC (no familiarity with high TAN or Canadian bitumen based crudes in general).

- By 2025 (the assumed first year of commercial availability of the PUB streams), we expect that that the total “TAN + market/commercial” discount for WCS vs. Maya at the USGC will have declined from recent levels calculated in our backcast. This is due to our expectation that refiners in the region will become more familiar with WCS and other Western Canadian crudes and market demand will increase as Latin heavy crude production remains sluggish.
  - We have estimated that the total discount (TAN + other commercial/market adjustments) for WCS will be $0.75 per barrel, down from about the $1.50 we calculated in our backcast (based on 2016 and 2017 values).
  - $0.50 per barrel of this discount is allocated to TAN and the remaining $0.25 per barrel to “other commercial/market adjustments.” By 2030, we have the total discount declining to a long-term level of $0.25 per barrel based on the higher TAN level.

- The discounts we estimated for the PUBs at the USGC vary based on both TAN and our view on how the market might perceive the new streams and their idiosyncrasies/dissimilarities to existing crudes and feedstocks. These discounts will decline and reach long-term levels by 2030/31 which is based on TAN or another quality exclusively (where applicable).
  - PUB 1 has the highest total market discount due to its high TAN and challenging distillate/gas oil properties. We estimate the total discount is $2.00 per barrel in 2025 ($1.25 per barrel above WCS) allocated equally between TAN and “other commercial/market adjustments.” This declines

to a long-term level of $0.50 per barrel by 2031 based totally on its high TAN content.

- PUB 2, which is similar to PUB 1 in many ways except for TAN has an "other commercial/market" discount of $1.00 per barrel (equal to that we estimated for PUB 1) in 2025 and this goes away by 2031 (just as with PUB 1).

- As we noted earlier, PUB 3 is quite similar to WCS, and although we would expect some market entry discount simply because it is a new stream, we feel that it would be lower than for PUB 1 and PUB 2. Our estimate for the "other commercial/market discount" is $0.40 per barrel in 2025, declining to zero by 2029, while we have the TAN discount equivalent to that for WCS.

- For PUB 4, we feel that the market will allocate an extra premium for its low sulfur resid content, which we estimate at $0.50 per barrel in 2025, declining to $0.10 per barrel over the long term (2031+). Combined with our estimate for the market entry based "other commercial/market" discount of $0.70 per barrel in 2025, which declines to zero by 2031, we have a total market adjustment varying from a discount of $0.20 per barrel in 2025 and moving to a long-term premium of $0.10 per barrel by 2028.

  - If this stream is available prior to 2025, the low sulfur resid premium will be greater, perhaps by several dollars per barrel in the early part of the IMO rules implementation after January 2020.

- The lower USMC price adjustments are as follows:

  - PUB 1 has a total discount of $1.30 per barrel in 2025, which declines to its long-term TAN only discount of $0.50 per barrel (the same as in the USGC) by 2031;

  - As in the USGC, we have assumed that PUB 2 would carry the same market entry adjustment as PUB 1, which results in a $0.70 per barrel discount in 2025, declining to zero by 2031;

  - We estimate a market entry discount of $0.25 per barrel for the WCS-like PUB 3 in 2025, going away by 2028. Combined with the $0.25 per barrel TAN penalty (which is the same as WCS and equal to the long-term value beginning in 2025 as a result of market familiarity), the total discount is $0.50 per barrel in 2025, declining to $0.25 per barrel (TAN only) by 2028; and

- We do not include a premium for low sulfur resid for PUB 4 in the USMC due to the fact there is not a bunker fuel market. The total adjustment is equal to a market entry discount of $0.50 per barrel in 2025 which declines to zero by 2031.

- The higher China price adjustments are as follows:

  - PUB 1 has a total discount of $2.70 per barrel in 2025, which declines to its long-term TAN only discount of $0.50 per barrel (the same as in the other regions) by 2032;

  - As in the USGC and USMC, we have assumed that PUB 2 would carry the same market entry adjustment as PUB 1, which results in a $1.50 per barrel discount in 2025, declining to zero by 2032;

  - For PUB 3, we estimate a market entry discount of $1.00 per barrel in 2025, going away by 2032. Combined with the initial $0.60 per barrel TAN penalty in 2025, which declines to $0.25 per barrel by 2032, the total discount changes from $1.60 per barrel in 2025 to a long-term level of $0.25 per barrel in 2032; and

  - We estimate a premium for low sulfur resid for PUB 4 equivalent to what we used in the USGC, $0.50 per barrel in 2025, declining to a long-term level of $0.10 per barrel by 2031. Our estimated market entry discount of $1.00 in 2025 declines to zero by 2032. Combining the two results in a total adjustment of ($0.50) per barrel in 2025, declining and then becoming a long-term premium of $0.10 per barrel by 2032.

- Our estimates for all of these market adjustments are very "ballpark" in quality and subject to significant potential variation and month to month volatility. This was certainly demonstrated in the backcast analyses which were presented earlier and consistent with the nature of these types of market factors. Supply/demand developments, logistical bottlenecks, the relative level of pricing power between producers and refiners, investment in refining facilities, and a variety of other short- and long-term factors will all influence these price adjustments/discounts for the PUBs.

- The actual commercial/market discounts/adjustments will likely vary by price and penetration/volume level (generally trending higher as either price or volume increases). Because of the very subjective nature of our forecast and the difficulty in assessing the price/volume relationships, our estimates are meant to represent a mid-range (for both absolute price and penetration) forecast and, we have applied them across all the price and penetration refining value results. We believe most of any price/volume impacts would go away over the long term (after five to seven years).

A strategy to minimize TAN and “other commercial/market” price discounts and to maximize PUB value in general would be to develop contractual relationships with individual refiners. Of course these relationships should focus on the refineries which are particularly well-suited to processing the specific PUB streams. An important preliminary step in such a relationship would be the execution of test runs with the PUBs to determine how they perform in the refineries under well planned and executed conditions.

Glossary And Definitions

AI	Alberta Innovates
ANOVA	Analysis of Variance
AWB	Access Western Blend
CAPP	Canadian Association of Petroleum Producers
CDB	Christina/Cenovus Dilbit
CNG	Compressed Natural Gas
C&RPO	Crude and Refined Products Outlook
GOM	Gulf of Mexico
HSFO	High Sulfur Fuel Oil
IMO	International Maritime Organization
KOH	Potassium Hydroxide
LNG	Liquefied Natural Gas
LSB	Light Sour Blend
LTOs	Light Tight Oils
MVCM	Market Value Correlation Methodology
NGL	Natural Gas Liquids
PUB	Partially Upgraded Bitumen
RVCE	Refining Value Correlation Equations
TAN	Total Acid Number
TMMS	Turner Mason Modeling System
TM&C	Turner, Mason & Company
USGC	United States Gulf Coast
USMC	United States Midcontinent

VGO	Vacuum Gas Oil
VTB	Vacuum Tower Bottoms
WCS	Western Canadian Select
WDB	Western Canada Dilbit

KEY DEFINITIONS

Crude and PUB Valuation Terminology

Market Value	The actual price commanded by the crude/PUB in a marketplace composed of willing buyers and willing sellers. It is associated with a value at a given location, for instance WTI at Cushing or Houston, WCS at Hardisty or Nederland, etc. While related to the "refining value", it will also be impacted by commercial and market factors which can not readily be modeled or quantified. It will always be lower than the refining value, as the refiner requires a sufficient margin between market and refining value to cover fixed costs, S, G&A and allow for some level of profit.
Refining Value	The value of all refined products produced by processing a crude/PUB less variable operating costs (electricity, purchased fuel, and catalyst/chemical costs). The refining value can also be thought of as the "variable revenue" component for a refiner processing a given crude/PUB, with the market value (at the refinery gate) determining the "cost of goods sold." In this way, the refining value of a crude minus the market value paid for that crude would equal the "gross profit" that can be derived from that crude. Subtracting fixed and S, G&A costs from this would lead to the "net profit". In an efficient market, the difference in refining value between two crudes will determine the difference in market value between those same two crudes, allowing the refiner to maintain the same net profit from processing either crude.

APPENDIX – TABLES AND FIGURES

Appendix Table II-1
Historical Light/Heavy Crude Differentials

	LLS	Maya	WCS	Light/Heavy Differentials, $/B		% Discount
				LLS -	LLS -	
	St. James	FOB Mexico	Hardisty	Maya	WCS	Maya vs. LLS
1995	18.60	13.64		4.95		26.6%
1996	22.35	17.36		4.99		22.3%
1997	20.72	14.93		5.79		28.0%
1998	14.18	8.70		5.48		38.7%
1999	19.09	14.46		4.63		24.3%
2000	30.38	23.06		7.32		24.1%
2001	25.89	17.15		8.75		33.8%
2002	26.29	20.98		5.31		20.2%
2003	31.16	24.22		6.94		22.3%
2004	41.54	30.05		11.49		27.7%
2005	57.04	41.02		16.02		28.1%
2006	67.48	51.25	49.92	16.23	17.56	24.0%
2007	75.26	59.83	49.50	15.42	25.76	20.5%
2008	102.79	84.40	81.03	18.38	21.76	17.9%
2009	64.47	56.65	54.27	7.81	10.20	12.1%
2010	82.80	70.12	65.61	12.67	17.19	15.3%
2011	112.34	98.64	79.40	13.70	32.94	12.2%
2012	111.70	99.63	72.32	12.07	39.37	10.8%
2013	107.31	97.27	73.37	10.05	33.94	9.4%
2014	96.92	85.80	73.83	11.11	23.09	11.5%
2015	52.36	44.11	36.83	8.26	15.53	15.8%
2016	45.03	36.52	30.78	8.51	14.25	18.9%
2017	54.02	47.00	38.55	7.02	15.47	13.0%
2018	70.23	62.73	38.27	7.50	31.96	10.7%
1995 to 2018 Average	56.25	46.65	57.21	9.60	23.00	17.1%

Appendix Table III-1
PUB and Competitive Crudes
Summarized Assays

Values in red are estimated

Crude Name	PUB 1	PUB 2	PUB 3[1]	PUB 4	AWB	WCS	Maya	Arab Heavy	WTI	Mars
API Gravity (Calculated)[3]	20.9	19.3	19.3	23.3	20.7	20.3	22.3	26.6	43.3	29.8
API Gravity (Measured)[4]	20.9	19.1	17.8		20.7	20.3	22.3	26.6	43.3	29.8
Sulfur (wt %)	3.69	3.49	3.74	0.39	3.98	3.44	3.38	2.96	0.41	1.72
K Factor	11.24	11.26	11.46	11.69	11.51	11.32	11.54	11.66	12.31	11.49
TAN	1.65	0.30	0.90	<0.1	1.85	0.98	0.28	<0.1	<0.1	<0.1
Light Ends										
Fuel Gas	0.02%	0.01%	0.00%	0.01%	0.04%	0.10%	0.22%	0.06%	0.51%	0.14%
Propane	0.08%	0.06%	0.02%	0.09%	0.14%	0.41%	0.50%	0.28%	0.74%	0.58%
Isobutane	0.15%	0.06%	0.02%	0.08%	0.00%	0.00%	0.19%	0.22%	0.43%	0.58%
nButane	0.52%	0.19%	0.05%	0.27%	0.13%	0.61%	0.76%	0.55%	0.42%	1.59%
LSR (C5 - 180 F)	**2.4%[5]**	**2.8%[5]**	**5.0%**	**9.8%**	**12.2%**	**6.9%**	**4.4%**	**4.7%**	**7.7%**	**7.5%**
API Gravity	84.1	74.2	83.6	83.3	92.0	68.2	78.6	83.5	81.6	79.8
RON	74.4	73.8	73.5	69.1	78.4	68.6	65.4	63.6	61.3	69.9
MON	72.1	71.6	71.6	67.0	76.2	66.4	63.3	61.9	59.6	67.7
Sulfur (wt %)	1.29	0.67	0.16	0.00	0.00	0.05	0.05	0.00	0.02	0.01
K Factor	12.63	11.73	12.60	12.49	12.91	12.54	12.71	12.78	12.74	12.55
HSR (180-330 F)	**6.1%[5]**	**5.6%[5]**	**4.5%**	**6.7%**	**9.3%**	**6.3%**	**10.0%**	**11.3%**	**17.9%**	**11.8%**
API Gravity	60.7	53.2	57.3	62.7	60.2	54.9	56.4	58.4	59.1	55.8
RON	53.0	49.1	47.7	45.2	59.1	54.9	45.4	41.8	39.2	46.3
MON	44.6	40.9	44.7	38.7	52.4	51.9	43.8	42.7	31.1	47.4
Sulfur (wt %)	1.95	1.09	1.26	0.01	0.00	0.09	0.28	0.04	0.02	0.08
K Factor	12.32	11.39	12.00	12.38	12.09	11.81	12.22	12.06	12.13	11.88
N+2A	53.3	76.5	52.6	34.7	63.8	57.4	48.6	37.4	61.7	52.8
Kerosene (330-470 F)	**10.0%**	**9.2%**	**8.3%**	**6.0%**	**5.5%**	**5.6%**	**10.0%**	**12.0%**	**15.2%**	**12.1%**
API Gravity	39.5	38.8	40.2	41.0	32.9	40.8	45.2	46.3	47.4	43.9
Cetane Index	29.7	35.4	36.2	47.6	31.7	36.9	42.2	47.0	47.0	40.6
Freeze Point (F)	-88.6	-79.7	-87.2	-80.8	-138.2	-68.7	-57.5	-56.1	-97.9	-67.5
Smoke Point (mm)	23.6	30.1	22.8	25.1	13.8	19.6	23.9	26.2	27.0	21.2
Sulfur (wt %)	2.63	1.80	1.06	0.03	0.17	0.88	0.72	0.29	0.05	0.30
K Factor	11.39	11.31	11.51	11.99	11.01	11.64	11.87	11.92	11.92	11.76
Diesel (470-635 F)	**22.5%**	**19.2%**	**16.2%**	**12.3%**	**8.7%**	**13.4%**	**12.8%**	**14.1%**	**17.1%**	**14.4%**
API Gravity	25.2	26.8	27.8	27.3	24.8	28.2	33.3	35.2	40.1	32.3
Cetane Index	36.0	38.3	40.3	48.8	38.5	41.2	47.0	51.6	61.9	46.6
Cloud Point (F)	-15.1	-27.5	-16.8	-18.2	-66.4	-4.8	0.4	3.7	-1.3	-17.2
Sulfur (wt %)	3.02	2.56	2.50	0.18	1.50	1.70	1.92	1.39	0.21	0.93
K Factor	11.16	11.29	11.32	11.71	11.20	11.40	11.71	11.83	12.09	11.69
Gasoil (635-1050 F)	**44.7%**	**44.5%**	**40.5%**	**37.7%**	**28.5%**	**37.3%**	**30.1%**	**30.6%**	**29.7%**	**32.0%**
API Gravity	15.5	14.8	17.1	15.9	13.2	15.0	19.2	20.6	32.2	20.4
Sulfur (wt %)	3.8	3.6	3.3	0.4	3.5	3.3	3.2	3.1	0.7	2.1
K Factor	11.16	11.21	11.42	11.57	11.17	11.56	11.62	11.68	12.52	11.77
Concarbon (wt %)	1.08	0.87	0.55	0.28	0.39	0.33	0.82	0.38	0.15	0.46
Nitrogen (ppm)	2,752	2,876	2,420	1,168	1,567	1,183	1,966	509	559	1,564
VTB (1050+ F)	**13.6%**	**18.5%**	**25.4%**	**27.0%**	**35.0%**	**27.8%**	**31.0%**	**26.1%**	**10.3%**	**19.3%**
API Gravity	-1.5	1.4	0.2	6.1	0.8	1.8	0.1	3.6	18.9	3.7
Sulfur (wt %)	5.92	5.48	6.39	0.74	6.91	6.00	5.77	5.75	1.28	3.66
Concarbon (wt %)	25.8	27.9	41.6	24.9	27.9	32.8	27.6	25.0	11.4	20.6
Nickel (ppm)	148	99	178	65	153	110	128	202	20	52
Vanadium (ppm)	322	222	475	163	432	230	687	64	103	118
Nitrogen (ppm)	8,061	8,975	11,280	5,021	7,403	6,361	6,537	3,110	2,852	6,022

(1) Assumed to meet pipeline gravity minumum based on API gravity calculated from individual cuts.

(2) Includes 20% Diluent; Measured API Gravity is for undiluted stream

(3) API Gravity calculated from back-blending individual cuts

(4) Whole crude API gravity as measured

(5) Assay reported data for the full boiling range naphtha without differentiating between LSR and HSR

Appendix Table III-2A
Crude Pricing
$50 WTI (Cushing) Pricing Basis

All Prices in USD/BBL Unless Otherwise Noted

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
KEY BENCHMARKS													
Brent (Sullom Voe)	56.20	54.25	54.60	54.85	54.88	54.91	54.92	54.94	54.96	54.98	54.99	55.01	55.02
LLS (St. James)	55.21	53.34	53.46	53.58	53.58	53.58	53.59	53.60	53.61	53.62	53.63	53.65	53.66
WTI (Cushing)	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00
Mars (Clovelly)	50.18	49.14	50.26	51.12	51.45	51.50	51.60	51.69	51.75	51.73	51.71	51.68	51.66
Maya (FOB)	42.54	41.68	42.78	43.53	43.79	44.05	44.31	44.57	44.84	44.94	45.03	45.11	45.18
Canadian WCS (Hardisty)	25.59	25.71	27.96	29.72	31.98	32.44	32.71	32.98	33.24	33.33	33.43	33.49	33.55
AWB (Hardisty)	22.33	22.65	25.09	26.98	29.31	29.85	30.15	30.46	30.76	30.86	30.96	31.03	31.10
Dubai (FOB)	50.50	49.43	50.60	51.47	51.82	51.87	51.97	52.07	52.13	52.11	52.08	52.05	52.03
Syncrude (Edmonton)	47.43	49.63	49.56	49.59	49.54	49.55	49.56	49.57	49.59	49.58	49.58	49.59	49.60
Dilluent/Condensate (Edmonton)	52.84	50.94	50.73	50.66	50.52	50.38	50.29	50.20	50.10	50.01	49.92	49.82	49.73
Condensate (Houston)	52.14	50.43	50.61	50.79	50.84	50.83	50.84	50.85	50.85	50.86	50.86	50.86	50.85
DELIVERED CRUDE PRICING													
U.S. Gulf Coast													
WTI	52.25	52.25	52.25	52.25	52.25	52.70	52.70	52.70	52.70	52.70	52.70	52.70	52.70
Maya	43.21	42.37	43.48	44.25	44.51	44.75	45.01	45.27	45.54	45.64	45.73	45.81	45.88
WCS	43.59	42.71	43.96	44.72	44.98	45.24	45.51	45.78	46.04	46.13	46.23	46.29	46.35
Mars	50.78	49.74	50.86	51.72	52.05	52.10	52.20	52.29	52.35	52.33	52.31	52.28	52.26
Arab Heavy	46.31	45.72	46.71	47.71	48.31	48.81	48.80	49.00	49.17	49.25	49.32	49.39	49.45
U.S. Midcontinent (Chicago)													
WTI	51.50	51.50	51.50	51.50	51.50	51.50	51.50	51.50	51.50	51.50	51.50	51.50	51.50
WCS	32.59	30.51	32.76	34.52	36.78	37.24	37.51	37.78	38.04	38.13	38.23	38.29	38.35
China													
Arab Heavy	47.13	46.37	47.75	48.82	49.32	49.53	49.79	50.05	50.24	50.25	50.25	50.25	50.24

	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045
KEY BENCHMARKS													
Brent (Sullom Voe)	55.04	55.05	55.07	55.08	55.10	55.10	55.10	55.10	55.10	55.10	55.10	55.10	55.10
LLS (St. James)	53.68	53.69	53.70	53.72	53.74	53.74	53.74	53.74	53.74	53.74	53.74	53.74	53.74
WTI (Cushing)	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00
Mars (Clovelly)	51.63	51.61	51.58	51.56	51.53	51.53	51.53	51.53	51.53	51.53	51.53	51.53	51.53
Maya (FOB)	45.25	45.33	45.40	45.47	45.55	45.55	45.55	45.55	45.55	45.55	45.55	45.55	45.55
Canadian WCS (Hardisty)	33.61	33.67	33.74	33.80	33.87	33.87	33.87	33.87	33.87	33.87	33.87	33.87	33.87
AWB (Hardisty)	31.17	31.25	31.32	31.39	31.46	31.46	31.46	31.46	31.46	31.46	31.46	31.46	31.46
Dubai (FOB)	52.00	51.97	51.94	51.91	51.88	51.88	51.88	51.88	51.88	51.88	51.88	51.88	51.88
Syncrude (Edmonton)	49.61	49.63	49.64	49.66	49.66	49.66	49.66	49.66	49.66	49.66	49.66	49.66	49.69
Dilluent/Condensate (Edmonton)	49.63	49.53	49.43	49.32	49.22	49.22	49.22	49.22	49.22	49.22	49.22	49.22	49.22
Condensate (Houston)	50.85	50.85	50.84	50.84	50.83	50.83	50.83	50.83	50.83	50.83	50.83	50.83	50.83
DELIVERED CRUDE PRICING													
U.S. Gulf Coast													
WTI	52.70	52.70	52.70	52.70	52.70	52.70	52.70	52.70	52.70	52.70	52.70	52.70	52.70
Maya	45.95	46.03	46.10	46.17	46.25	46.25	46.25	46.25	46.25	46.25	46.25	46.25	46.25
WCS	46.41	46.47	46.54	46.60	46.67	46.67	46.67	46.67	46.67	46.67	46.67	46.67	46.67
Mars	52.23	52.21	52.18	52.16	52.13	52.13	52.13	52.13	52.13	52.13	52.13	52.13	52.13
Arab Heavy	49.51	49.58	49.64	49.71	49.77	49.77	49.77	49.77	49.77	49.77	49.77	49.77	49.77
U.S. Midcontinent (Chicago)													
WTI	51.50	51.50	51.50	51.50	51.50	51.50	51.50	51.50	51.50	51.50	51.50	51.50	51.50
WCS	38.41	38.47	38.54	38.60	38.67	38.67	38.67	38.67	38.67	38.67	38.67	38.67	38.67
China													
Arab Heavy	50.24	50.23	50.22	50.21	50.20	50.20	50.20	50.20	50.20	50.20	50.20	50.20	50.20

Appendix Table III-2B
Crude Pricing
$60 WTI (Cushing) Pricing Basis

All Prices in USD/BBL Unless Otherwise Noted

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045
KEY BENCHMARKS																										
Brent (Sullom Voe)	66.48	64.46	64.84	65.12	65.15	65.17	65.19	65.20	65.22	65.23	65.25	65.26	65.28	65.29	65.30	65.32	65.33	65.35	65.35	65.35	65.35	65.35	65.35	65.35	65.35	65.35
LLS (St. James)	65.41	63.47	63.60	63.73	63.73	63.73	63.74	63.75	63.76	63.77	63.78	63.79	63.81	63.82	63.83	63.85	63.86	63.88	63.88	63.88	63.88	63.88	63.88	63.88	63.88	63.88
WTI (Cushing)	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
Mars (Clovelly)	59.61	58.61	59.91	60.90	61.29	61.35	61.46	61.56	61.63	61.61	61.58	61.54	61.51	61.47	61.44	61.41	61.37	61.34	61.34	61.34	61.34	61.34	61.34	61.34	61.34	61.34
Maya (FOB)	50.98	50.15	51.38	52.23	52.52	52.82	53.12	53.42	53.73	53.84	53.96	54.04	54.12	54.21	54.29	54.38	54.46	54.55	54.55	54.55	54.55	54.55	54.55	54.55	54.55	54.55
Canadian WCS (Hardisty)	33.54	33.67	36.08	37.93	40.23	40.72	41.03	41.35	41.65	41.76	41.86	41.94	42.01	42.08	42.16	42.23	42.31	42.38	42.38	42.38	42.38	42.38	42.38	42.38	42.38	42.38
AWB (Hardisty)	30.04	30.39	33.01	34.99	37.37	37.95	38.30	38.65	39.00	39.12	39.24	39.32	39.40	39.48	39.57	39.65	39.74	39.82	39.82	39.82	39.82	39.82	39.82	39.82	39.82	39.82
Dubai (FOB)	59.87	58.85	60.18	61.17	61.58	61.63	61.75	61.86	61.93	61.90	61.87	61.83	61.79	61.76	61.72	61.68	61.64	61.61	61.61	61.61	61.61	61.61	61.61	61.61	61.61	61.61
Syncrude (Edmonton)	57.51	59.75	59.75	59.74	59.68	59.70	59.71	59.72	59.74	59.73	59.73	59.74	59.75	59.77	59.79	59.81	59.82	59.82	59.82	59.82	59.82	59.82	59.82	59.82	59.82	60.71
Dilluent/Condensate (Edmonton)	63.00	60.99	60.78	60.70	60.55	60.40	60.30	60.21	60.11	60.01	59.91	59.81	59.71	59.61	59.50	59.39	59.29	59.17	59.17	59.17	59.17	59.17	59.17	59.17	59.17	59.17
	57.51	59.75	59.75	59.74	59.68	59.70	59.71	59.72	59.74	59.73	59.73	59.74	59.75	59.77	59.79	59.81	59.82	59.82	59.82	59.82	59.82	59.82	59.82	59.82	59.82	60.71
DELIVERED CRUDE PRICING																										
U.S. Gulf Coast																										
WTI	62.25	62.25	62.25	62.25	62.25	62.90	62.90	62.90	62.90	62.90	62.90	62.90	62.90	62.90	62.90	62.90	62.90	62.90	62.90	62.90	62.90	62.90	62.90	62.90	62.90	62.90
Maya	51.68	50.86	52.10	52.97	53.27	53.57	53.87	54.17	54.48	54.59	54.71	54.79	54.87	54.96	55.04	55.13	55.21	55.30	55.30	55.30	55.30	55.30	55.30	55.30	55.30	55.30
WCS	51.94	51.07	52.48	53.33	53.63	53.92	54.23	54.55	54.85	54.96	55.06	55.14	55.21	55.28	55.36	55.43	55.51	55.58	55.58	55.58	55.58	55.58	55.58	55.58	55.58	55.58
Mars	60.25	59.25	60.55	61.54	61.93	61.99	62.10	62.20	62.27	62.25	62.22	62.18	62.15	62.11	62.08	62.05	62.01	61.98	61.98	61.98	61.98	61.98	61.98	61.98	61.98	61.98
Arab Heavy	54.90	54.43	55.55	56.71	57.41	58.00	57.99	58.21	58.42	58.50	58.59	58.66	58.74	58.81	58.88	58.96	59.03	59.10	59.10	59.10	59.10	59.10	59.10	59.10	59.10	59.10
U.S. Midcontinent (Chicago)																										
WTI	61.50	61.50	61.50	61.50	61.50	61.60	61.60	61.60	61.60	61.60	61.60	61.60	61.60	61.60	61.60	61.60	61.60	61.60	61.60	61.60	61.60	61.60	61.60	61.60	61.60	61.60
WCS	40.64	38.57	40.98	42.83	45.13	45.62	45.93	46.25	46.55	46.66	46.76	46.84	46.91	46.98	47.06	47.13	47.21	47.28	47.28	47.28	47.28	47.28	47.28	47.28	47.28	47.28
China																										
Arab Heavy	55.88	55.21	56.79	58.02	58.61	58.85	59.16	59.46	59.68	59.69	59.69	59.68	59.67	59.67	59.65	59.64	59.63	59.61	59.61	59.61	59.61	59.61	59.61	59.61	59.61	59.61

Appendix Table III-2C
Crude Pricing
$70 WTI (Cushing) Pricing Basis

All Prices in USD/BBL Unless Otherwise Noted

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
KEY BENCHMARKS													
Brent (Sullom Voe)	76.76	74.67	75.08	75.38	75.41	75.43	75.45	75.47	75.48	75.49	75.51	75.52	75.53
LLS (St. James)	75.62	73.60	73.74	73.88	73.88	73.89	73.89	73.90	73.91	73.92	73.93	73.94	73.95
WTI (Cushing)	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
Mars (Clovelly)	69.04	68.08	69.56	70.69	71.13	71.19	71.32	71.44	71.52	71.48	71.44	71.40	71.36
Maya (FOB)	59.43	58.62	59.98	60.92	61.25	61.59	61.93	62.27	62.62	62.75	62.88	62.97	63.07
Canadian WCS (Hardisty)	41.48	41.63	44.20	46.14	48.48	49.01	49.36	49.71	50.06	50.18	50.30	50.38	50.47
AWB (Hardisty)	38.00	38.31	41.04	43.09	45.47	46.05	46.45	46.84	46.88	47.12	47.33	47.48	47.62
Dubai (FOB)	69.24	68.26	69.76	70.88	71.34	71.39	71.53	71.65	71.73	71.69	71.65	71.61	71.56
Syncrude (Edmonton)	67.48	69.75	69.72	69.78	69.71	69.83	69.84	69.85	69.87	69.86	69.86	69.88	69.89
Dilluent/Condensate (Edmonton)	73.17	71.04	70.82	70.74	70.58	70.42	70.32	70.22	70.12	70.01	69.91	69.80	69.70
Condensate (Houston)	71.64	69.79	70.01	70.22	70.30	70.28	70.28	70.29	70.29	70.30	70.30	70.29	70.28
DELIVERED CRUDE PRICING													
U.S. Gulf Coast													
WTI	72.25	72.25	72.25	72.25	72.25	73.10	73.10	73.10	73.10	73.10	73.10	73.10	73.10
Maya	60.15	59.35	60.73	61.68	62.02	62.39	62.73	63.07	63.42	63.55	63.68	63.77	63.87
WCS	60.28	59.43	61.00	61.94	62.28	62.61	62.96	63.31	63.66	63.78	63.90	63.98	64.07
Mars	69.72	68.76	70.24	71.37	71.81	71.87	72.00	72.12	72.20	72.16	72.12	72.08	72.04
Arab Heavy	63.50	63.14	64.40	65.71	66.51	67.19	67.17	67.42	67.66	67.75	67.85	67.94	68.02
U.S. Midcontinent (Chicago)													
WTI	71.50	71.50	71.50	71.50	71.50	71.70	71.70	71.70	71.70	71.70	71.70	71.70	71.70
WCS	48.68	46.68	49.25	51.19	53.53	54.06	54.41	54.76	55.11	55.23	55.35	55.43	55.52
China													
Arab Heavy	64.63	64.04	65.83	67.23	67.90	68.18	68.53	68.87	69.12	69.13	69.13	69.12	69.11

	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045
KEY BENCHMARKS													
Brent (Sullom Voe)	75.54	75.55	75.57	75.58	75.59	75.59	75.59	75.59	75.59	75.59	75.59	75.59	75.59
LLS (St. James)	73.96	73.97	73.99	74.00	74.02	74.02	74.02	74.02	74.02	74.02	74.02	74.02	74.02
WTI (Cushing)	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
Mars (Clovelly)	71.32	71.27	71.23	71.19	71.15	71.15	71.15	71.15	71.15	71.15	71.15	71.15	71.15
Maya (FOB)	63.16	63.26	63.35	63.45	63.55	63.55	63.55	63.55	63.55	63.55	63.55	63.55	63.55
Canadian WCS (Hardisty)	50.55	50.64	50.72	50.81	50.89	50.89	50.89	50.89	50.89	50.89	50.89	50.89	50.89
AWB (Hardisty)	47.75	47.89	47.99	48.08	48.18	48.18	48.18	48.18	48.18	48.18	48.18	48.18	48.18
Dubai (FOB)	71.52	71.47	71.42	71.38	71.33	71.33	71.33	71.33	71.33	71.33	71.33	71.33	71.33
Syncrude (Edmonton)	69.90	69.93	69.95	69.97	69.97	69.97	69.97	69.97	69.97	69.97	69.97	69.97	69.97
Dilluent/Condensate (Edmonton)	69.59	69.48	69.36	69.25	69.13	69.13	69.13	69.13	69.13	69.13	69.13	69.13	69.13
Condensate (Houston)	70.28	70.27	70.26	70.25	70.23	70.23	70.23	70.23	70.23	70.23	70.23	70.23	70.23
DELIVERED CRUDE PRICING													
U.S. Gulf Coast													
WTI	73.10	73.10	73.10	73.10	73.10	73.10	73.10	73.10	73.10	73.10	73.10	73.10	73.10
Maya	63.96	64.06	64.15	64.25	64.35	64.35	64.35	64.35	64.35	64.35	64.35	64.35	64.35
WCS	64.15	64.24	64.32	64.41	64.49	64.49	64.49	64.49	64.49	64.49	64.49	64.49	64.49
Mars	72.00	71.95	71.91	71.87	71.83	71.83	71.83	71.83	71.83	71.83	71.83	71.83	71.83
Arab Heavy	68.10	68.19	68.27	68.35	68.44	68.44	68.44	68.44	68.44	68.44	68.44	68.44	68.44
U.S. Midcontinent (Chicago)													
WTI	71.70	71.70	71.70	71.70	71.70	71.70	71.70	71.70	71.70	71.70	71.70	71.70	71.70
WCS	55.60	55.69	55.77	55.86	55.94	55.94	55.94	55.94	55.94	55.94	55.94	55.94	55.94
China													
Arab Heavy	69.10	69.08	69.06	69.04	69.03	69.03	69.03	69.03	69.03	69.03	69.03	69.03	69.03

Appendix Table III-2D
Crude Pricing
$80 WTI (Cushing) Pricing Basis

All Prices in USD/BBL Unless Otherwise Noted

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045
KEY BENCHMARKS																										
Brent (Sullom Voe)	87.04	84.87	85.32	85.64	85.68	85.70	85.71	85.73	85.74	85.75	85.76	85.77	85.78	85.80	85.81	85.82	85.83	85.84	85.84	85.84	85.84	85.84	85.84	85.84	85.84	85.84
LLS (St. James)	85.82	83.74	83.89	84.04	84.03	84.04	84.04	84.05	84.06	84.06	84.07	84.08	84.09	84.10	84.12	84.13	84.14	84.16	84.16	84.16	84.16	84.16	84.16	84.16	84.16	84.16
WTI (Cushing)	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00
Mars (Clovelly)	78.47	77.55	79.21	80.48	80.98	81.04	81.18	81.31	81.40	81.36	81.31	81.26	81.21	81.16	81.11	81.06	81.01	80.96	80.96	80.96	80.96	80.96	80.96	80.96	80.96	80.96
Maya (FOB)	67.88	67.09	68.58	69.61	69.98	70.36	70.74	71.12	71.51	71.65	71.80	71.90	72.01	72.12	72.22	72.33	72.44	72.55	72.55	72.55	72.55	72.55	72.55	72.55	72.55	72.55
Canadian WCS (Hardisty)	49.43	49.60	52.32	54.35	56.73	57.30	57.69	58.08	58.47	58.60	58.74	58.83	58.93	59.02	59.12	59.21	59.31	59.41	59.41	59.41	59.41	59.41	59.41	59.41	59.41	59.41
AWB (Hardisty)	45.45	45.87	48.83	51.02	53.49	54.16	54.60	55.04	55.47	55.63	55.78	55.89	55.99	56.10	56.21	56.32	56.43	56.54	56.54	56.54	56.54	56.54	56.54	56.54	56.54	56.54
Dubai (FOB)	78.62	77.68	79.34	80.58	81.09	81.16	81.30	81.44	81.53	81.48	81.43	81.38	81.33	81.28	81.22	81.17	81.12	81.06	81.06	81.06	81.06	81.06	81.06	81.06	81.06	81.06
Syncrude (Edmonton)	77.53	79.83	79.77	79.80	79.81	79.94	79.95	79.96	79.99	79.98	79.98	79.99	80.01	80.02	80.05	80.08	80.10	80.10	80.10	80.10	80.10	80.10	80.10	80.10	80.10	80.10
Dilluent/Condensate (Edmonton)	83.33	81.10	80.86	80.78	80.61	80.44	80.34	80.23	80.12	80.01	79.90	79.79	79.68	79.56	79.45	79.33	79.21	79.09	79.09	79.09	79.09	79.09	79.09	79.09	79.09	79.09
Condensate (Houston)	81.38	79.48	79.71	79.94	80.02	80.00	80.01	80.01	80.02	80.02	80.02	80.01	80.00	79.99	79.98	79.96	79.95	79.94	79.94	79.94	79.94	79.94	79.94	79.94	79.94	79.94
DELIVERED CRUDE PRICING																										
U.S. Gulf Coast																										
WTI	82.25	82.25	82.25	82.25	82.25	83.30	83.30	83.30	83.30	83.30	83.30	83.30	83.30	83.30	83.30	83.30	83.30	83.30	83.30	83.30	83.30	83.30	83.30	83.30	83.30	83.30
Maya	68.62	67.85	69.35	70.40	70.78	71.21	71.59	71.97	72.36	72.50	72.65	72.75	72.86	72.97	73.07	73.18	73.29	73.40	73.40	73.40	73.40	73.40	73.40	73.40	73.40	73.40
WCS	68.63	67.80	69.52	70.55	70.93	71.30	71.69	72.08	72.47	72.60	72.74	72.83	72.93	73.02	73.12	73.21	73.31	73.41	73.41	73.41	73.41	73.41	73.41	73.41	73.41	73.41
Mars	79.19	78.27	79.93	81.20	81.70	81.76	81.90	82.03	82.12	82.08	82.03	81.98	81.93	81.88	81.83	81.78	81.73	81.68	81.68	81.68	81.68	81.68	81.68	81.68	81.68	81.68
Arab Heavy	72.10	71.85	73.24	74.70	75.61	76.38	76.35	76.64	76.90	77.01	77.12	77.21	77.30	77.40	77.49	77.58	77.68	77.77	77.77	77.77	77.77	77.77	77.77	77.77	77.77	77.77
U.S. Midcontinent (Chicago)																										
WTI	81.50	81.50	81.50	81.50	81.50	81.80	81.80	81.80	81.80	81.80	81.80	81.80	81.80	81.80	81.80	81.80	81.80	81.80	81.80	81.80	81.80	81.80	81.80	81.80	81.80	81.80
WCS	56.73	54.80	57.52	59.55	61.93	62.50	62.89	63.28	63.67	63.80	63.94	64.03	64.13	64.22	64.32	64.41	64.51	64.61	64.61	64.61	64.61	64.61	64.61	64.61	64.61	64.61
China																										
Arab Heavy	73.38	72.87	74.87	76.44	77.19	77.50	77.90	78.28	78.56	78.57	78.57	78.56	78.54	78.53	78.50	78.48	78.46	78.44	78.44	78.44	78.44	78.44	78.44	78.44	78.44	78.44

Appendix Table III-3A
Product Pricing
USGC - $50 WTI (Cushing) Pricing Basis

All Prices in USD/BBL Unless Otherwise Noted

	2020	2025	2030	2035	2040	2045
Propane	$25.13	$22.00	$20.41	$19.10	$18.58	$18.58
Propylene (Refinery Grade)	$58.61	$55.95	$55.71	$55.45	$55.34	$55.34
nButane	$30.43	$28.55	$27.53	$26.45	$26.00	$26.00
Isobutane	$31.98	$29.95	$28.96	$27.93	$27.49	$27.49
Natural Gasoline	$46.06	$43.82	$43.26	$42.67	$42.43	$42.43
CBOB Regular	$66.88	$63.61	$63.99	$63.94	$63.92	$63.92
CBOB Premium	$73.97	$72.48	$71.76	$71.10	$70.96	$70.96
RBOB Regular	$69.55	$66.06	$66.52	$66.55	$66.56	$66.56
RBOB Premium	$76.80	$75.16	$74.48	$73.87	$73.75	$73.75
Jet / Kero	$76.12	$69.14	$68.24	$68.29	$68.40	$68.40
ULSD	$77.02	$70.60	$70.12	$70.13	$70.22	$70.22
Gasoil No. 2	$72.71	$66.23	$65.30	$65.26	$65.33	$65.33
0.5% S Marine Gasoil (36 API)	$67.63	$59.91	$59.05	$59.02	$59.06	$59.06
FCC Slurry	$29.13	$35.09	$37.70	$37.72	$37.73	$37.73
0.5% S Fuel Oil (12 API)	$74.29	$65.81	$64.87	$64.82	$64.88	$64.88
3% S Fuel Oil	$30.44	$36.45	$39.03	$39.01	$39.01	$39.01
Natural Gas ($/MMBtu)	$3.08	$3.15	$3.35	$3.55	$3.64	$3.64
Electricity ($/MW-hr)	$40.81	$41.54	$43.48	$45.53	$46.39	$46.39
Sulfur ($/MT)	$56.25	$61.92	$58.07	$54.12	$52.51	$52.51
Pet. Coke Tier 1 ($/MT) - Anode Coke	$587.67	$397.69	$299.64	$292.32	$289.42	$289.42
Pet. Coke Tier 2 ($/MT) - Anode Coke	$495.25	$332.88	$248.54	$241.93	$239.30	$239.30
Pet. Coke Tier 3 ($/MT) - Fuel Grade Coke	$125.57	$132.64	$127.76	$122.84	$120.85	$120.85
Pet. Coke Tier 4 ($/MT) - Fuel Grade Coke	$47.01	$52.49	$48.78	$44.96	$43.40	$43.40
Pet. Coke Tier 5 ($/MT) - Fuel Grade Coke	$28.53	$33.63	$30.20	$26.64	$25.18	$25.18
Pet. Coke Tier 6 ($/MT) - Fuel Grade Coke	$24.83	$29.86	$26.48	$22.98	$21.53	$21.53
RVO Cost ($ per Barrel Clean Product)	$2.56	$3.19	$3.68	$3.75	$3.78	$3.78
Purchased HS VGO (3% S)	$62.93	$59.70	$59.32	$59.06	$58.97	$58.97
Purchased LS Coker Feed (1% S)	$42.84	$40.30	$39.39	$38.81	$38.62	$38.62
Purchased HS Coker Feed (5% S)	$11.95	$22.97	$26.93	$26.93	$26.89	$26.89

Appendix Table III-3B
Product Pricing
USGC - $60 WTI (Cushing) Pricing Basis

All Prices in USD/BBL Unless Otherwise Noted

	2020	2025	2030	2035	2040	2045
Propane	$32.95	$29.47	$27.83	$26.50	$25.98	$25.98
Propylene (Refinery Grade)	$69.09	$66.30	$66.02	$65.73	$65.60	$65.60
nButane	$38.67	$36.58	$35.54	$34.44	$33.98	$33.98
Isobutane	$40.35	$38.09	$37.09	$36.03	$35.59	$35.59
Natural Gasoline	$55.54	$53.14	$52.56	$51.94	$51.68	$51.68
CBOB Regular	$78.01	$74.62	$74.98	$74.89	$74.86	$74.86
CBOB Premium	$85.66	$84.23	$83.39	$82.62	$82.44	$82.44
RBOB Regular	$80.88	$77.27	$77.72	$77.70	$77.70	$77.70
RBOB Premium	$88.71	$87.13	$86.33	$85.61	$85.45	$85.45
Jet / Kero	$87.97	$80.60	$79.58	$79.59	$79.68	$79.68
ULSD	$88.95	$82.20	$81.61	$81.58	$81.65	$81.65
Gasoil No. 2	$84.30	$77.46	$76.40	$76.32	$76.37	$76.37
0.5% S Marine Gasoil (36 API)	$78.29	$70.10	$69.13	$69.05	$69.09	$69.09
FCC Slurry	$37.27	$43.67	$46.54	$46.60	$46.62	$46.62
0.5% S Fuel Oil (12 API)	$86.00	$77.00	$75.93	$75.85	$75.89	$75.89
3% S Fuel Oil	$38.69	$45.15	$47.97	$47.99	$48.00	$48.00
Natural Gas ($/MMBtu)	$3.08	$3.15	$3.35	$3.55	$3.64	$3.64
Electricity ($/MW-hr)	$40.81	$41.54	$43.48	$45.53	$46.39	$46.39
Sulfur ($/MT)	$66.50	$72.48	$68.42	$64.29	$62.60	$62.60
Pet. Coke Tier 1 ($/MT) - Anode Coke	$621.75	$424.64	$321.27	$313.09	$309.86	$309.86
Pet. Coke Tier 2 ($/MT) - Anode Coke	$525.19	$356.67	$267.78	$260.46	$257.56	$257.56
Pet. Coke Tier 3 ($/MT) - Fuel Grade Coke	$138.93	$146.65	$141.36	$136.06	$133.93	$133.93
Pet. Coke Tier 4 ($/MT) - Fuel Grade Coke	$56.85	$62.59	$58.70	$54.72	$53.09	$53.09
Pet. Coke Tier 5 ($/MT) - Fuel Grade Coke	$37.53	$42.81	$39.25	$35.58	$34.07	$34.07
Pet. Coke Tier 6 ($/MT) - Fuel Grade Coke	$33.67	$38.85	$35.36	$31.75	$30.27	$30.27
RVO Cost ($ per Barrel Clean Product)	$2.76	$3.46	$3.98	$4.05	$4.08	$4.08
Purchased HS VGO (3% S)	$73.74	$70.37	$69.93	$69.62	$69.52	$69.52
Purchased LS Coker Feed (1% S)	$52.06	$49.32	$48.37	$47.78	$47.58	$47.58
Purchased HS Coker Feed (5% S)	$18.56	$30.36	$34.72	$34.77	$34.76	$34.76

Appendix Table III-3C
Product Pricing
USGC - $70 WTI (Cushing) Pricing Basis

All Prices in USD/BBL Unless Otherwise Noted

	2020	2025	2030	2035	2040	2045
Propane	$40.78	$36.94	$35.25	$33.91	$33.38	$33.38
Propylene (Refinery Grade)	$79.56	$76.65	$76.34	$76.01	$75.86	$75.86
nButane	$46.92	$44.61	$43.55	$42.42	$41.96	$41.96
Isobutane	$48.71	$46.24	$45.21	$44.13	$43.68	$43.68
Natural Gasoline	$65.02	$62.46	$61.86	$61.21	$60.94	$60.94
CBOB Regular	$89.13	$85.62	$85.97	$85.85	$85.79	$85.79
CBOB Premium	$97.35	$95.99	$95.02	$94.14	$93.92	$93.92
RBOB Regular	$92.22	$88.48	$88.92	$88.86	$88.83	$88.83
RBOB Premium	$100.62	$99.11	$98.18	$97.35	$97.15	$97.15
Jet / Kero	$99.83	$92.07	$90.92	$90.88	$90.96	$90.96
ULSD	$100.87	$93.79	$93.11	$93.02	$93.07	$93.07
Gasoil No. 2	$95.89	$88.68	$87.50	$87.38	$87.42	$87.42
0.5% S Marine Gasoil (36 API)	$88.95	$80.29	$79.21	$79.09	$79.11	$79.11
FCC Slurry	$45.41	$52.26	$55.38	$55.48	$55.51	$55.51
0.5% S Fuel Oil (12 API)	$97.70	$88.19	$87.00	$86.87	$86.90	$86.90
3% S Fuel Oil	$46.93	$53.84	$56.92	$56.97	$56.99	$56.99
Natural Gas ($/MMBtu)	$3.08	$3.15	$3.35	$3.55	$3.64	$3.64
Electricity ($/MW-hr)	$40.81	$41.54	$43.48	$45.53	$46.39	$46.39
Sulfur ($/MT)	$76.75	$83.04	$78.78	$74.45	$72.69	$72.69
Pet. Coke Tier 1 ($/MT) - Anode Coke	$655.83	$451.58	$342.89	$333.87	$330.31	$330.31
Pet. Coke Tier 2 ($/MT) - Anode Coke	$555.12	$380.45	$287.02	$278.99	$275.81	$275.81
Pet. Coke Tier 3 ($/MT) - Fuel Grade Coke	$152.29	$160.66	$154.96	$149.28	$147.00	$147.00
Pet. Coke Tier 4 ($/MT) - Fuel Grade Coke	$66.68	$72.68	$68.62	$64.47	$62.78	$62.78
Pet. Coke Tier 5 ($/MT) - Fuel Grade Coke	$46.54	$51.98	$48.30	$44.51	$42.96	$42.96
Pet. Coke Tier 6 ($/MT) - Fuel Grade Coke	$42.51	$47.84	$44.24	$40.52	$39.00	$39.00
RVO Cost ($ per Barrel Clean Product)	$2.96	$3.73	$4.28	$4.34	$4.37	$4.37
Purchased HS VGO (3% S)	$84.56	$81.04	$80.55	$80.19	$80.07	$80.07
Purchased LS Coker Feed (1% S)	$61.29	$58.35	$57.35	$56.74	$56.54	$56.54
Purchased HS Coker Feed (5% S)	$25.17	$37.75	$42.51	$42.62	$42.63	$42.63

Appendix Table III-3D
Product Pricing
USGC - $80 WTI (Cushing) Pricing Basis

All Prices in USD/BBL Unless Otherwise Noted

	2020	2025	2030	2035	2040	2045
Propane	$48.60	$44.42	$42.68	$41.31	$40.78	$40.78
Propylene (Refinery Grade)	$90.03	$87.01	$86.65	$86.28	$86.13	$86.13
nButane	$55.16	$52.64	$51.55	$50.41	$49.93	$49.93
Isobutane	$57.08	$54.39	$53.34	$52.24	$51.77	$51.77
Natural Gasoline	$74.50	$71.79	$71.15	$70.48	$70.20	$70.20
CBOB Regular	$100.26	$96.62	$96.97	$96.80	$96.73	$96.73
CBOB Premium	$109.04	$107.74	$106.65	$105.66	$105.40	$105.40
RBOB Regular	$103.56	$99.69	$100.12	$100.02	$99.97	$99.97
RBOB Premium	$112.54	$111.09	$110.03	$109.08	$108.85	$108.85
Jet / Kero	$111.69	$103.54	$102.27	$102.18	$102.24	$102.24
ULSD	$112.80	$105.38	$104.61	$104.46	$104.50	$104.50
Gasoil No. 2	$107.47	$99.91	$98.60	$98.43	$98.46	$98.46
0.5% S Marine Gasoil (36 API)	$99.61	$90.47	$89.28	$89.12	$89.14	$89.14
FCC Slurry	$53.56	$60.84	$64.23	$64.35	$64.41	$64.41
0.5% S Fuel Oil (12 API)	$109.41	$99.38	$98.07	$97.89	$97.91	$97.91
3% S Fuel Oil	$55.18	$62.54	$65.87	$65.95	$65.98	$65.98
Natural Gas ($/MMBtu)	$3.08	$3.15	$3.35	$3.55	$3.64	$3.64
Electricity ($/MW-hr)	$40.81	$41.54	$43.48	$45.53	$46.39	$46.39
Sulfur ($/MT)	$87.01	$93.59	$89.13	$84.61	$82.77	$82.77
Pet. Coke Tier 1 ($/MT) - Anode Coke	$689.91	$478.53	$364.51	$354.64	$350.76	$350.76
Pet. Coke Tier 2 ($/MT) - Anode Coke	$585.06	$404.24	$306.26	$297.52	$294.07	$294.07
Pet. Coke Tier 3 ($/MT) - Fuel Grade Coke	$165.64	$174.67	$168.57	$162.50	$160.08	$160.08
Pet. Coke Tier 4 ($/MT) - Fuel Grade Coke	$76.52	$82.78	$78.54	$74.22	$72.47	$72.47
Pet. Coke Tier 5 ($/MT) - Fuel Grade Coke	$55.55	$61.16	$57.35	$53.45	$51.85	$51.85
Pet. Coke Tier 6 ($/MT) - Fuel Grade Coke	$51.35	$56.84	$53.12	$49.29	$47.73	$47.73
RVO Cost ($ per Barrel Clean Product)	$3.17	$4.00	$4.58	$4.64	$4.67	$4.67
Purchased HS VGO (3% S)	$95.37	$91.71	$91.16	$90.75	$90.61	$90.61
Purchased LS Coker Feed (1% S)	$70.52	$67.37	$66.33	$65.70	$65.50	$65.50
Purchased HS Coker Feed (5% S)	$31.78	$45.13	$50.29	$50.47	$50.50	$50.50

Appendix Table III-4A
Product Pricing
USMC - $50 WTI (Cushing) Pricing Basis

All Prices in USD/BBL Unless Otherwise Noted

	2020	2025	2030	2035	2040	2045
Propane	$22.54	$20.40	$18.82	$17.50	$16.97	$16.97
nButane	$27.39	$26.88	$25.83	$24.72	$24.26	$24.26
Isobutane	$30.95	$30.11	$29.14	$28.10	$27.67	$27.67
Natural Gasoline	$45.00	$43.19	$42.58	$41.95	$41.68	$41.68
CBOB Regular	$67.07	$63.60	$64.03	$64.04	$64.04	$64.04
CBOB Premium	$75.97	$72.47	$71.80	$71.20	$71.07	$71.07
RBOB Regular	$69.74	$66.05	$66.56	$66.64	$66.67	$66.67
RBOB Premium	$78.98	$74.91	$74.33	$73.80	$73.71	$73.71
Jet / Kero	$78.12	$71.19	$70.25	$70.26	$70.34	$70.34
ULSD	$78.07	$71.47	$71.03	$71.10	$71.20	$71.20
0.5% S Marine Gasoil (36 API)	$63.84	$55.88	$55.12	$55.19	$55.28	$55.28
FCC Slurry	$24.97	$30.67	$33.40	$33.54	$33.59	$33.59
0.5% S Fuel Oil (12 API)	$70.12	$61.38	$60.55	$60.63	$60.73	$60.73
3% S Fuel Oil	$26.27	$32.02	$34.71	$34.81	$34.86	$34.86
Natural Gas ($/MMBtu)	$3.08	$3.15	$3.35	$3.55	$3.64	$3.64
Electricity ($/MW-hr)	$40.81	$41.54	$43.48	$45.53	$46.39	$46.39
Sulfur ($/MT)	$56.25	$61.92	$58.07	$54.12	$52.51	$52.51
Pet. Coke Tier 1 ($/MT) - Anode Coke	$587.67	$397.69	$299.64	$292.32	$289.42	$289.42
Pet. Coke Tier 2 ($/MT) - Anode Coke	$495.25	$332.88	$248.54	$241.93	$239.30	$239.30
Pet. Coke Tier 3 ($/MT) - Fuel Grade Coke	$125.57	$132.64	$127.76	$122.84	$120.85	$120.85
Pet. Coke Tier 4 ($/MT) - Fuel Grade Coke	$47.01	$52.49	$48.78	$44.96	$43.40	$43.40
Pet. Coke Tier 5 ($/MT) - Fuel Grade Coke	$28.53	$33.63	$30.20	$26.64	$25.18	$25.18
Pet. Coke Tier 6 ($/MT) - Fuel Grade Coke	$24.83	$29.86	$26.48	$22.98	$21.53	$21.53
RVO Cost ($ per Barrel Clean Product)	$2.56	$3.19	$3.68	$3.75	$3.78	$3.78
Purchased HS VGO (3% S)	$63.93	$60.70	$60.32	$60.06	$59.97	$59.97
Purchased LS Coker Feed (1% S)	$43.84	$41.30	$40.39	$39.81	$39.62	$39.62
Purchased HS Coker Feed (5% S)	$12.95	$23.97	$27.93	$27.93	$27.89	$27.89

Appendix Table III-4B
Product Pricing
USMC - $60 WTI (Cushing) Pricing Basis

All Prices in USD/BBL Unless Otherwise Noted

	2020	2025	2030	2035	2040	2045
Propane	$30.06	$27.65	$26.02	$24.68	$24.15	$24.15
nButane	$35.31	$34.70	$33.64	$32.51	$32.03	$32.03
Isobutane	$39.21	$38.28	$37.28	$36.22	$35.78	$35.78
Natural Gasoline	$54.39	$52.45	$51.82	$51.15	$50.87	$50.87
CBOB Regular	$78.21	$74.60	$75.03	$75.00	$74.98	$74.98
CBOB Premium	$87.80	$84.22	$83.44	$82.73	$82.57	$82.57
RBOB Regular	$81.09	$77.26	$77.77	$77.81	$77.82	$77.82
RBOB Premium	$91.04	$86.87	$86.17	$85.53	$85.40	$85.40
Jet / Kero	$90.11	$82.82	$81.74	$81.69	$81.76	$81.76
ULSD	$90.07	$83.13	$82.60	$82.60	$82.69	$82.69
0.5% S Marine Gasoil (36 API)	$74.08	$65.65	$64.82	$64.87	$64.96	$64.96
FCC Slurry	$32.65	$38.79	$41.81	$42.02	$42.10	$42.10
0.5% S Fuel Oil (12 API)	$81.37	$72.11	$71.20	$71.26	$71.36	$71.36
3% S Fuel Oil	$34.06	$40.26	$43.24	$43.40	$43.47	$43.47
Natural Gas ($/MMBtu)	$3.08	$3.15	$3.35	$3.55	$3.64	$3.64
Electricity ($/MW-hr)	$40.81	$41.54	$43.48	$45.53	$46.39	$46.39
Sulfur ($/MT)	$66.50	$72.48	$68.42	$64.29	$62.60	$62.60
Pet. Coke Tier 1 ($/MT) - Anode Coke	$621.75	$424.64	$321.27	$313.09	$309.86	$309.86
Pet. Coke Tier 2 ($/MT) - Anode Coke	$525.19	$356.67	$267.78	$260.46	$257.56	$257.56
Pet. Coke Tier 3 ($/MT) - Fuel Grade Coke	$138.93	$146.65	$141.36	$136.06	$133.93	$133.93
Pet. Coke Tier 4 ($/MT) - Fuel Grade Coke	$56.85	$62.59	$58.70	$54.72	$53.09	$53.09
Pet. Coke Tier 5 ($/MT) - Fuel Grade Coke	$37.53	$42.81	$39.25	$35.58	$34.07	$34.07
Pet. Coke Tier 6 ($/MT) - Fuel Grade Coke	$33.67	$38.85	$35.36	$31.75	$30.27	$30.27
RVO Cost ($ per Barrel Clean Product)	$2.76	$3.46	$3.98	$4.05	$4.08	$4.08
Purchased HS VGO (3% S)	$74.74	$71.37	$70.93	$70.62	$70.52	$70.52
Purchased LS Coker Feed (1% S)	$53.06	$50.32	$49.37	$48.78	$48.58	$48.58
Purchased HS Coker Feed (5% S)	$19.56	$31.36	$35.72	$35.77	$35.76	$35.76

Appendix Table III-4C
Product Pricing
USMC - $70 WTI (Cushing) Pricing Basis

All Prices in USD/BBL Unless Otherwise Noted

	2020	2025	2030	2035	2040	2045
Propane	$37.57	$34.90	$33.22	$31.86	$31.33	$31.33
nButane	$43.22	$42.53	$41.44	$40.29	$39.81	$39.81
Isobutane	$47.47	$46.45	$45.43	$44.35	$43.90	$43.90
Natural Gasoline	$63.78	$61.72	$61.05	$60.36	$60.06	$60.06
CBOB Regular	$89.35	$85.60	$86.03	$85.96	$85.93	$85.93
CBOB Premium	$99.63	$95.97	$95.07	$94.25	$94.06	$94.06
RBOB Regular	$92.44	$88.46	$88.97	$88.97	$88.97	$88.97
RBOB Premium	$103.10	$98.83	$98.01	$97.27	$97.10	$97.10
Jet / Kero	$102.10	$94.44	$93.23	$93.12	$93.18	$93.18
ULSD	$102.07	$94.79	$94.16	$94.11	$94.19	$94.19
0.5% S Marine Gasoil (36 API)	$84.33	$75.41	$74.51	$74.55	$74.64	$74.64
FCC Slurry	$40.33	$46.90	$50.23	$50.50	$50.60	$50.60
0.5% S Fuel Oil (12 API)	$92.63	$82.84	$81.85	$81.89	$81.99	$81.99
3% S Fuel Oil	$41.85	$48.49	$51.77	$51.99	$52.08	$52.08
Natural Gas ($/MMBtu)	$3.08	$3.15	$3.35	$3.55	$3.64	$3.64
Electricity ($/MW-hr)	$40.81	$41.54	$43.48	$45.53	$46.39	$46.39
Sulfur ($/MT)	$76.75	$83.04	$78.78	$74.45	$72.69	$72.69
Pet. Coke Tier 1 ($/MT) - Anode Coke	$655.83	$451.58	$342.89	$333.87	$330.31	$330.31
Pet. Coke Tier 2 ($/MT) - Anode Coke	$555.12	$380.45	$287.02	$278.99	$275.81	$275.81
Pet. Coke Tier 3 ($/MT) - Fuel Grade Coke	$152.29	$160.66	$154.96	$149.28	$147.00	$147.00
Pet. Coke Tier 4 ($/MT) - Fuel Grade Coke	$66.68	$72.68	$68.62	$64.47	$62.78	$62.78
Pet. Coke Tier 5 ($/MT) - Fuel Grade Coke	$46.54	$51.98	$48.30	$44.51	$42.96	$42.96
Pet. Coke Tier 6 ($/MT) - Fuel Grade Coke	$42.51	$47.84	$44.24	$40.52	$39.00	$39.00
RVO Cost ($ per Barrel Clean Product)	$2.96	$3.73	$4.28	$4.34	$4.37	$4.37
Purchased HS VGO (3% S)	$85.56	$82.04	$81.55	$81.19	$81.07	$81.07
Purchased LS Coker Feed (1% S)	$62.29	$59.35	$58.35	$57.74	$57.54	$57.54
Purchased HS Coker Feed (5% S)	$26.17	$38.75	$43.51	$43.62	$43.63	$43.63

Appendix Table III-4D
Product Pricing
USMC - $80 WTI (Cushing) Pricing Basis

All Prices in USD/BBL Unless Otherwise Noted

	2020	2025	2030	2035	2040	2045
Propane	$45.08	$42.15	$40.42	$39.04	$38.51	$38.51
nButane	$51.14	$50.36	$49.25	$48.08	$47.59	$47.59
Isobutane	$55.73	$54.61	$53.57	$52.47	$52.01	$52.01
Natural Gasoline	$73.17	$70.98	$70.29	$69.56	$69.26	$69.26
CBOB Regular	$100.50	$96.60	$97.02	$96.92	$96.87	$96.87
CBOB Premium	$111.45	$107.72	$106.70	$105.78	$105.55	$105.55
RBOB Regular	$103.80	$99.67	$100.17	$100.14	$100.12	$100.12
RBOB Premium	$115.16	$110.79	$109.85	$109.00	$108.80	$108.80
Jet / Kero	$114.10	$106.07	$104.72	$104.56	$104.60	$104.60
ULSD	$114.07	$106.45	$105.72	$105.62	$105.68	$105.68
0.5% S Marine Gasoil (36 API)	$94.57	$85.18	$84.21	$84.23	$84.32	$84.32
FCC Slurry	$48.01	$55.01	$58.65	$58.98	$59.11	$59.11
0.5% S Fuel Oil (12 API)	$103.88	$93.57	$92.50	$92.52	$92.62	$92.62
3% S Fuel Oil	$49.65	$56.73	$60.30	$60.58	$60.69	$60.69
Natural Gas ($/MMBtu)	$3.08	$3.15	$3.35	$3.55	$3.64	$3.64
Electricity ($/MW-hr)	$40.81	$41.54	$43.48	$45.53	$46.39	$46.39
Sulfur ($/MT)	$87.01	$93.59	$89.13	$84.61	$82.77	$82.77
Pet. Coke Tier 1 ($/MT) - Anode Coke	$689.91	$478.53	$364.51	$354.64	$350.76	$350.76
Pet. Coke Tier 2 ($/MT) - Anode Coke	$585.06	$404.24	$306.26	$297.52	$294.07	$294.07
Pet. Coke Tier 3 ($/MT) - Fuel Grade Coke	$165.64	$174.67	$168.57	$162.50	$160.08	$160.08
Pet. Coke Tier 4 ($/MT) - Fuel Grade Coke	$76.52	$82.78	$78.54	$74.22	$72.47	$72.47
Pet. Coke Tier 5 ($/MT) - Fuel Grade Coke	$55.55	$61.16	$57.35	$53.45	$51.85	$51.85
Pet. Coke Tier 6 ($/MT) - Fuel Grade Coke	$51.35	$56.84	$53.12	$49.29	$47.73	$47.73
RVO Cost ($ per Barrel Clean Product)	$3.17	$4.00	$4.58	$4.64	$4.67	$4.67
Purchased HS VGO (3% S)	$96.37	$92.71	$92.16	$91.75	$91.61	$91.61
Purchased LS Coker Feed (1% S)	$71.52	$68.37	$67.33	$66.70	$66.50	$66.50
Purchased HS Coker Feed (5% S)	$32.78	$46.13	$51.29	$51.47	$51.50	$51.50

Appendix Table III-5A
Product Pricing
China - $50 WTI (Cushing) Pricing Basis

All Prices in USD/BBL Unless Otherwise Noted

	2020	2025	2030	2035	2040	2045
Propane	$26.36	$23.38	$21.76	$20.43	$19.90	$19.90
Propylene (Refinery Grade)	$59.64	$57.34	$57.08	$56.77	$56.64	$56.64
nButane	$31.63	$29.94	$28.89	$27.78	$27.31	$27.31
Isobutane	$33.17	$31.33	$30.33	$29.25	$28.80	$28.80
Natural Gasoline	$47.25	$45.29	$44.72	$44.09	$43.82	$43.82
Regular Gasoline (93 RON / 87 AKI)	$66.55	$63.65	$64.04	$63.98	$63.95	$63.95
Premium Gasoline (98 RON / 93 AKI)	$73.60	$72.51	$71.82	$71.14	$70.98	$70.98
Jet / Kero	$75.73	$69.17	$68.30	$68.33	$68.42	$68.42
ULSD	$76.63	$70.63	$70.18	$70.17	$70.24	$70.24
Gasoil No. 2	$72.35	$66.27	$65.35	$65.30	$65.36	$65.36
0.5% S Marine Gasoil (36 API)	$67.30	$59.94	$59.10	$59.05	$59.09	$59.09
FCC Slurry	$29.08	$35.16	$37.80	$37.81	$37.82	$37.82
0.5% S Fuel Oil (12 API)	$73.93	$65.84	$64.92	$64.86	$64.90	$64.90
3% S Fuel Oil	$30.38	$36.52	$39.12	$39.10	$39.09	$39.09
Natural Gas ($/MMBtu)	$8.08	$8.15	$8.35	$8.55	$8.64	$8.64
Electricity ($/MW-hr)	$50.81	$51.54	$53.48	$55.53	$56.39	$56.39
Methanol	$56.33	$56.08	$55.57	$54.88	$54.60	$54.60
Sulfur ($/MT)	$56.22	$61.95	$58.12	$54.18	$52.56	$52.56
Pet. Coke Tier 1 ($/MT) - Anode Coke	$585.76	$397.75	$299.76	$292.37	$289.44	$289.44
Pet. Coke Tier 2 ($/MT) - Anode Coke	$493.67	$332.94	$248.64	$241.99	$239.33	$239.33
Pet. Coke Tier 3 ($/MT) - Fuel Grade Coke	$125.29	$132.68	$127.82	$122.89	$120.89	$120.89
Pet. Coke Tier 4 ($/MT) - Fuel Grade Coke	$47.01	$52.52	$48.83	$45.01	$43.45	$43.45
Pet. Coke Tier 5 ($/MT) - Fuel Grade Coke	$28.59	$33.66	$30.24	$26.69	$25.23	$25.23
Pet. Coke Tier 6 ($/MT) - Fuel Grade Coke	$24.90	$29.89	$26.52	$23.03	$21.59	$21.59
Purchased HS VGO (3% S)	$60.46	$62.44	$62.02	$61.68	$61.55	$61.55
Purchased LS Coker Feed (1% S)	$42.71	$40.39	$39.51	$38.92	$38.72	$38.72
Purchased HS Coker Feed (5% S)	$11.74	$22.87	$26.79	$26.72	$26.67	$26.67

Appendix Table III-5B
Product Pricing
China - $60 WTI (Cushing) Pricing Basis

All Prices in USD/BBL Unless Otherwise Noted

	2020	2025	2030	2035	2040	2045
Propane	$34.33	$30.95	$29.27	$27.91	$27.38	$27.38
Propylene (Refinery Grade)	$70.37	$67.78	$67.47	$67.14	$66.99	$66.99
nButane	$40.04	$38.06	$36.99	$35.85	$35.37	$35.37
Isobutane	$41.71	$39.57	$38.54	$37.44	$36.98	$36.98
Natural Gasoline	$56.95	$54.72	$54.10	$53.45	$53.17	$53.17
Regular Gasoline (93 RON / 87 AKI)	$77.86	$74.62	$75.00	$74.91	$74.87	$74.87
Premium Gasoline (98 RON / 93 AKI)	$85.49	$84.24	$83.41	$82.64	$82.45	$82.45
Jet / Kero	$87.80	$80.61	$79.60	$79.61	$79.69	$79.69
ULSD	$88.77	$82.20	$81.64	$81.59	$81.66	$81.66
Gasoil No. 2	$84.13	$77.46	$76.42	$76.34	$76.39	$76.39
0.5% S Marine Gasoil (36 API)	$78.14	$70.10	$69.15	$69.07	$69.10	$69.10
FCC Slurry	$37.27	$43.73	$46.62	$46.67	$46.70	$46.70
0.5% S Fuel Oil (12 API)	$85.83	$77.00	$75.96	$75.87	$75.90	$75.90
3% S Fuel Oil	$38.68	$45.20	$48.05	$48.07	$48.08	$48.08
Natural Gas ($/MMBtu)	$8.08	$8.15	$8.35	$8.55	$8.64	$8.64
Electricity ($/MW-hr)	$50.81	$51.54	$53.48	$55.53	$56.39	$56.39
Methanol	$62.91	$62.69	$62.07	$61.29	$60.97	$60.97
Sulfur ($/MT)	$66.49	$72.48	$68.44	$64.31	$62.63	$62.63
Pet. Coke Tier 1 ($/MT) - Anode Coke	$620.89	$424.65	$321.31	$313.12	$309.87	$309.87
Pet. Coke Tier 2 ($/MT) - Anode Coke	$524.47	$356.68	$267.82	$260.49	$257.57	$257.57
Pet. Coke Tier 3 ($/MT) - Fuel Grade Coke	$138.80	$146.66	$141.39	$136.08	$133.95	$133.95
Pet. Coke Tier 4 ($/MT) - Fuel Grade Coke	$56.84	$62.59	$58.72	$54.74	$53.12	$53.12
Pet. Coke Tier 5 ($/MT) - Fuel Grade Coke	$37.56	$42.81	$39.27	$35.60	$34.10	$34.10
Pet. Coke Tier 6 ($/MT) - Fuel Grade Coke	$33.70	$38.86	$35.38	$31.77	$30.30	$30.30
Purchased HS VGO (3% S)	$71.26	$73.32	$72.82	$72.43	$72.29	$72.29
Purchased LS Coker Feed (1% S)	$52.04	$49.40	$48.47	$47.87	$47.68	$47.68
Purchased HS Coker Feed (5% S)	$18.50	$30.40	$34.72	$34.71	$34.68	$34.68

Appendix Table III-5C
Product Pricing
China - $70 WTI (Cushing) Pricing Basis

All Prices in USD/BBL Unless Otherwise Noted

	2020	2025	2030	2035	2040	2045
Propane	$42.30	$38.51	$36.78	$35.40	$34.86	$34.86
Propylene (Refinery Grade)	$81.10	$78.22	$77.87	$77.50	$77.34	$77.34
nButane	$48.45	$46.18	$45.08	$43.92	$43.44	$43.44
Isobutane	$50.24	$47.81	$46.75	$45.63	$45.16	$45.16
Natural Gasoline	$66.65	$64.14	$63.49	$62.81	$62.52	$62.52
Regular Gasoline (93 RON / 87 AKI)	$89.16	$85.60	$85.96	$85.85	$85.79	$85.79
Premium Gasoline (98 RON / 93 AKI)	$97.38	$95.97	$95.00	$94.14	$93.92	$93.92
Jet / Kero	$99.87	$92.05	$90.91	$90.88	$90.96	$90.96
ULSD	$100.91	$93.77	$93.10	$93.02	$93.07	$93.07
Gasoil No. 2	$95.92	$88.66	$87.49	$87.38	$87.42	$87.42
0.5% S Marine Gasoil (36 API)	$88.98	$80.27	$79.19	$79.09	$79.12	$79.12
FCC Slurry	$45.47	$52.29	$55.43	$55.54	$55.58	$55.58
0.5% S Fuel Oil (12 API)	$97.74	$88.17	$86.99	$86.87	$86.90	$86.90
3% S Fuel Oil	$46.98	$53.88	$56.97	$57.03	$57.06	$57.06
Natural Gas ($/MMBtu)	$8.08	$8.15	$8.35	$8.55	$8.64	$8.64
Electricity ($/MW-hr)	$50.81	$51.54	$53.48	$55.53	$56.39	$56.39
Methanol	$69.49	$69.30	$68.58	$67.70	$67.34	$67.34
Sulfur ($/MT)	$76.76	$83.01	$78.77	$74.45	$72.69	$72.69
Pet. Coke Tier 1 ($/MT) - Anode Coke	$656.01	$451.54	$342.86	$333.87	$330.31	$330.31
Pet. Coke Tier 2 ($/MT) - Anode Coke	$555.27	$380.42	$287.00	$278.99	$275.82	$275.82
Pet. Coke Tier 3 ($/MT) - Fuel Grade Coke	$152.31	$160.64	$154.95	$149.28	$147.01	$147.01
Pet. Coke Tier 4 ($/MT) - Fuel Grade Coke	$66.68	$72.66	$68.61	$64.47	$62.78	$62.78
Pet. Coke Tier 5 ($/MT) - Fuel Grade Coke	$46.54	$51.96	$48.29	$44.51	$42.97	$42.97
Pet. Coke Tier 6 ($/MT) - Fuel Grade Coke	$42.51	$47.82	$44.23	$40.52	$39.00	$39.00
Purchased HS VGO (3% S)	$82.06	$84.19	$83.61	$83.18	$83.02	$83.02
Purchased LS Coker Feed (1% S)	$61.37	$58.41	$57.42	$56.83	$56.63	$56.63
Purchased HS Coker Feed (5% S)	$25.26	$37.92	$42.64	$42.70	$42.69	$42.69

Appendix Table III-5D
Product Pricing
China - $80 WTI (Cushing) Pricing Basis

All Prices in USD/BBL Unless Otherwise Noted

	2020	2025	2030	2035	2040	2045
Propane	$50.27	$46.08	$44.29	$42.89	$42.35	$42.35
Propylene (Refinery Grade)	$91.83	$88.67	$88.26	$87.86	$87.70	$87.70
nButane	$56.85	$54.30	$53.17	$51.99	$51.50	$51.50
Isobutane	$58.78	$56.05	$54.95	$53.82	$53.34	$53.34
Natural Gasoline	$76.36	$73.56	$72.87	$72.17	$71.87	$71.87
Regular Gasoline (93 RON / 87 AKI)	$100.47	$96.57	$96.92	$96.78	$96.72	$96.72
Premium Gasoline (98 RON / 93 AKI)	$109.27	$107.69	$106.60	$105.64	$105.39	$105.39
Jet / Kero	$111.93	$103.50	$102.22	$102.16	$102.24	$102.24
ULSD	$113.05	$105.34	$104.56	$104.44	$104.49	$104.49
Gasoil No. 2	$107.71	$99.86	$98.55	$98.42	$98.45	$98.45
0.5% S Marine Gasoil (36 API)	$99.82	$90.43	$89.24	$89.11	$89.13	$89.13
FCC Slurry	$53.66	$60.86	$64.25	$64.40	$64.46	$64.46
0.5% S Fuel Oil (12 API)	$109.64	$99.33	$98.02	$97.88	$97.90	$97.90
3% S Fuel Oil	$55.29	$62.56	$65.90	$66.00	$66.04	$66.04
Natural Gas ($/MMBtu)	$8.08	$8.15	$8.35	$8.55	$8.64	$8.64
Electricity ($/MW-hr)	$50.81	$51.54	$53.48	$55.53	$56.39	$56.39
Methanol	$76.08	$75.91	$75.08	$74.10	$73.72	$73.72
Sulfur ($/MT)	$87.03	$93.54	$89.09	$84.58	$82.75	$82.75
Pet. Coke Tier 1 ($/MT) - Anode Coke	$691.13	$478.44	$364.41	$354.61	$350.75	$350.75
Pet. Coke Tier 2 ($/MT) - Anode Coke	$586.07	$404.15	$306.17	$297.49	$294.06	$294.06
Pet. Coke Tier 3 ($/MT) - Fuel Grade Coke	$165.82	$174.61	$168.51	$162.48	$160.06	$160.06
Pet. Coke Tier 4 ($/MT) - Fuel Grade Coke	$76.52	$82.73	$78.50	$74.20	$72.45	$72.45
Pet. Coke Tier 5 ($/MT) - Fuel Grade Coke	$55.51	$61.11	$57.32	$53.42	$51.83	$51.83
Pet. Coke Tier 6 ($/MT) - Fuel Grade Coke	$51.31	$56.79	$53.08	$49.27	$47.71	$47.71
Purchased HS VGO (3% S)	$92.86	$95.07	$94.41	$93.93	$93.76	$93.76
Purchased LS Coker Feed (1% S)	$70.69	$67.41	$66.38	$65.78	$65.58	$65.58
Purchased HS Coker Feed (5% S)	$32.01	$45.45	$50.56	$50.69	$50.70	$50.70

Appendix Table III-6A
Crude Transportation Assumptions

All prices in $US per Barrel for 2025 and beyond

Canadian Heavy Crude Overland Transportation Costs

	Hardisty to		Hardisty to		Edmonton to	Edmonton to
	USMC - P/L (1)	USMC - Rail (2)	USGC - P/L (1)	USGC - Rail (2)	Vancouver - P/L (3)	Vancouver - Rail (2)
$50 WTI	4.80	10.30	12.80	17.30	6.40	13.00
$60WTI	4.90	10.70	13.20	17.70	6.60	13.50
$70 WTI	5.05	11.10	13.60	18.10	6.80	14.00
$80WTI	5.20	11.50	14.00	18.50	7.20	14.50

Marine Transportation Costs

	USGC to China (4)	Vancouver to China (5)
$50 WTI	4.15	2.40
$60WTI	4.50	2.60
$70 WTI	4.80	2.75
$80WTI	5.05	2.90

Other Transportation Costs

	WTI - Cushing		Mars (Clovelly)	Maya (FOB)	China - Port to	Edmonton to
	to USMC	to USGC	to USGC	to USGC	Refinery	Hardisty
$50 WTI	1.50	2.70	0.60	0.70	0.24	0.56
$60WTI	1.60	2.90	0.64	0.75	0.26	0.60
$70 WTI	1.70	3.10	0.68	0.80	0.28	0.64
$80WTI	1.80	3.30	0.72	0.85	0.30	0.68

(1) Assumes KXL is completed before 2025. Tariff rates are estimated.

(2) Rail costs are estimated and are all inclusive (loading, unloading and transport).

(3) Assumes TMX expansion is complete. Tariff rates are estimated.

(4) Light crude

(5) Heavy crude

Appendix Table III-6B
Transportation Costs
$50 WTI (Cushing) Pricing Basis

All prices in $US per Barrel for 2025 and beyond

		Transportation Cost to Refinery Gate in:		China	
	Pricing Basis	USMC	USGC	Pipeline	Rail
Canadian Heavy Crudes					
PUBs	Hardisty	4.80	12.80		
PUBs	Edmonton			9.04	15.64
WCS	Hardisty	4.80	12.80		
AWB	Edmonton	5.36	13.36	9.04	15.64
Maya	FOB Mexico		0.70		
WTI	Cushing	1.50	2.70	7.09	
Mars	Clovelly		0.60		
Arab Heavy	FOB China			0.24	

Appendix Table III-6C
Transportation Costs
$60 WTI (Cushing) Pricing Basis

All prices in $US per Barrel for 2025 and beyond

		Transportation Cost to Refinery Gate in:		China	
	Pricing Basis	USMC	USGC	Pipeline	Rail
Canadian Heavy Crudes					
PUBs	Hardisty	4.90	13.20		
PUBs	Edmonton			9.46	16.36
WCS	Hardisty	4.90	13.20		
AWB	Edmonton	5.50	13.80	9.46	16.36
Maya	FOB Mexico		0.75		
WTI	Cushing	1.60	2.90	7.66	
Mars	Clovelly		0.64		
Arab Heavy	FOB China			0.26	

Appendix Table III-6D
Transportation Costs
$70 WTI (Cushing) Pricing Basis

All prices in $US per Barrel for 2025 and beyond

		Transportation Cost to Refinery Gate in:		China	
	Pricing Basis	USMC	USGC	Pipeline	Rail
Canadian Heavy Crudes					
PUBs	Hardisty	5.05	13.60		
PUBs	Edmonton			9.83	17.03
WCS	Hardisty	5.05	13.60		
AWB	Edmonton	5.69	14.24	9.83	17.03
Maya	FOB Mexico		0.80		
WTI	Cushing	1.70	3.10	8.18	
Mars	Clovelly		0.68		
Arab Heavy	FOB China			0.28	

Appendix Table III-6E
Transportation Costs
$80 WTI (Cushing) Pricing Basis

All prices in $US per Barrel for 2025 and beyond

		Transportation Cost to Refinery Gate in:		China	
	Pricing Basis	USMC	USGC	Pipeline	Rail
Canadian Heavy Crudes					
PUBs	Hardisty	5.20	14.00		
PUBs	Edmonton			10.40	17.70
WCS	Hardisty	5.20	14.00		
AWB	Edmonton	5.88	14.68	10.40	17.70
Maya	FOB Mexico		0.85		
WTI	Cushing	1.80	3.30	8.65	
Mars	Clovelly		0.72		
Arab Heavy	FOB China			0.30	

Appendix Table III-7A
Refinery Yields - USGC
10 MBPD Case

Yields assume 100 MBPD of crude/PUB feed
All units in BPD unless otherwise noted

	PUB 1	PUB 2	PUB 3	PUB 4	AWB	WCS	MYA	ARH	Mars	WTI
Light Ends										
Propane	2,865	2,740	2,995	3,005	2,960	3,175	3,300	3,170	3,335	3,560
Propylene	2,830	2,850	3,050	3,150	2,690	2,990	2,940	3,100	3,090	3,360
nButane	520	320	300	590	585	1,550	870	735	1,600	320
Isobutane	-2,125	-2,250	-2,485	-2,135	-1,860	-1,695	-1,940	-1,945	-1,570	-1,740
Naphtha Sales										
Total Gasoline	**39,705**	**39,610**	**40,805**	**48,500**	**49,085**	**44,180**	**44,940**	**47,635**	**51,440**	**58,950**
Conv/BOB Regular	27,110	27,045	27,865	33,125	39,725	30,170	30,685	32,530	35,125	40,255
Conv/BOB Premium	2,185	2,180	2,245	2,665	2,735	2,430	2,475	2,620	2,830	3,245
RBOB Regular	9,175	9,155	9,430	11,210	5,840	10,210	10,385	11,010	11,890	13,620
RBOB Premium	1,235	1,230	1,265	1,500	785	1,370	1,395	1,475	1,595	1,830
Middle Distillates	**54,490**	**50,295**	**44,165**	**40,445**	**34,980**	**39,320**	**42,610**	**46,285**	**47,330**	**51,400**
Jet 54	11,660	11,130	10,310	8,150	7,530	7,620	11,870	13,920	14,030	16,990
ULSD	42,830	39,165	33,855	32,295	27,450	31,700	30,740	32,365	33,300	34,410
Slurry Oil	**2,520**	**2,580**	**2,180**	**1,870**	**2,130**	**2,010**	**1,690**	**1,700**	**1,690**	**970**
Sulfur (LT/D)	**470**	**410**	**400**	**40**	**370**	**350**	**340**	**320**	**230**	**150**
Pet Coke (LT/D)	**1,910**	**1,970**	**2,640**	**1,840**	**2,070**	**2,250**	**2,050**	**1,850**	**1,710**	**1,580**
HS VGO Purchases	**-10,970**	**-10,530**	**-5,030**	**-4,420**	**2,100**	**-4,110**	**1,470**	**2,530**	**420**	**3,460**
LS Resid Purchases	**0**	**0**	**0**	**2,040**	**0**	**0**	**0**	**0**	**0**	**0**
HS Resid Purchases	**15,360**	**10,550**	**3,580**	**0**	**-5,980**	**1,180**	**-2,000**	**2,860**	**9,680**	**18,730**

Appendix Table III-7B
Refinery Yields - USMC
10 MBPD Case

Yields assume 100 MBPD of crude/PUB feed
All units in BPD unless otherwise noted

	PUB 1	PUB 2	PUB 3	PUB 4	AWB	WCS	MYA	ARH	WTI
Light Ends									
Propane	2,410	2,270	2,455	2,420	2,530	2,655	2,835	2,725	3,140
Propylene	0	0	0	0	0	0	0	0	0
nButane	-765	-815	-865	-715	-820	450	-275	-585	-1,310
Isobutane	-4,375	-4,500	-5,025	-4,860	-3,765	-4,245	-4,355	-4,605	-5,025
Naphtha Sales									
Total Gasoline	**44,200**	**43,990**	**45,595**	**53,940**	**53,080**	**49,190**	**49,550**	**53,375**	**67,690**
Conv/BOB Regular	35,000	34,835	36,105	42,720	42,035	38,955	39,235	42,270	53,605
Conv/BOB Premium	2,430	2,420	2,510	2,965	2,920	2,705	2,730	2,935	3,725
RBOB Regular	6,060	6,030	6,250	7,395	7,275	6,745	6,790	7,315	9,275
RBOB Premium	710	705	730	860	850	785	795	855	1,085
Middle Distillates	**49,905**	**45,465**	**39,515**	**35,415**	**29,880**	**34,555**	**36,865**	**40,625**	**44,940**
Jet 54	7,590	8,860	8,840	6,510	2,385	6,080	9,800	11,740	14,070
ULSD	42,315	36,605	30,675	28,905	27,495	28,475	27,065	28,885	30,870
Slurry Oil	**3,200**	**3,250**	**2,860**	**2,560**	**2,840**	**2,620**	**2,230**	**2,310**	**1,380**
Sulfur (LT/D)	**400**	**330**	**330**	**30**	**290**	**280**	**270**	**240**	**100**
Pet Coke (LT/D)	**1,320**	**1,350**	**2,000**	**1,190**	**1,420**	**1,590**	**1,430**	**1,230**	**950**
HS VGO Purchases	**-7,980**	**-7,350**	**-1,440**	**-700**	**4,620**	**-40**	**3,370**	**5,170**	**6,670**
LS Resid Purchases	**0**	**0**	**0**	**-8,460**	**0**	**0**	**0**	**0**	**0**
HS Resid Purchases	**5,710**	**410**	**-7,040**	**0**	**-16,540**	**-9,980**	**-12,080**	**-7,200**	**8,650**

Appendix Table III-7C
Refinery Yields - China
10 MBPD Case

Yields assume 100 MBPD of crude/PUB feed
All units in BPD unless otherwise noted

	PUB 1	PUB 2	PUB 3	PUB 4	AWB	WCS	MYA	ARH	WTI
Light Ends									
Propane	2,065	1,975	2,290	2,230	2,350	2,510	2,685	2,560	2,940
Propylene	1,560	1,590	1,750	1,860	1,530	1,780	1,750	1,840	2,000
nButane	3,140	2,705	3,015	3,785	3,855	4,900	4,095	4,250	4,530
Isobutane	0	0	0	0	0	0	0	0	0
Naphtha Sales									
Total Gasoline	**31,330**	**31,570**	**31,735**	**35,205**	**40,655**	**33,565**	**35,985**	**37,520**	**45,195**
Conv/BOB Regular	31,330	31,570	30,855	35,185	40,645	33,565	35,985	37,520	45,185
Conv/BOB Premium	0	0	880	20	10	0	0	0	10
Middle Distillates	**57,770**	**53,300**	**47,290**	**43,650**	**37,730**	**42,490**	**45,980**	**49,620**	**55,240**
Jet 54	0	0	0	0	0	0	11,290	15,980	19,710
ULSD	34,070	38,000	42,400	42,050	24,410	38,920	34,690	33,640	35,530
No. 2 Oil	23,700	15,300	4,890	1,600	13,320	3,570	0	0	0
Slurry Oil	**2,000**	**1,980**	**1,760**	**1,440**	**1,690**	**1,510**	**1,420**	**1,400**	**960**
Sulfur (LT/D)	**450**	**390**	**380**	**30**	**350**	**330**	**320**	**290**	**120**
Pet Coke (LT/D)	**1,460**	**1,520**	**2,190**	**1,380**	**1,620**	**1,810**	**1,600**	**1,410**	**1,130**
HS VGO Purchases	**-9,930**	**-9,730**	**-4,270**	**-3,510**	**3,190**	**-2,900**	**3,160**	**3,550**	**4,260**
LS Resid Purchases	**0**	**0**	**0**	**-4,960**	**0**	**0**	**0**	**0**	**0**
HS Resid Purchases	**8,360**	**3,550**	**-3,420**	**0**	**-12,980**	**-5,820**	**-9,000**	**-4,140**	**11,730**

Appendix Table III-7D
Refinery Yields - USGC
40 MBPD Case

Yields assume 100 MBPD of crude/PUB feed
All units in BPD unless otherwise noted

	PUB 1	PUB 2	PUB 3	PUB 4	AWB	WCS	MYA	ARH	Mars	WTI
Light Ends										
Propane	2,825	2,690	2,970	3,020	2,960	3,175	3,300	3,170	3,335	3,560
Propylene	2,730	2,725	2,980	3,130	2,690	2,990	2,940	3,100	3,090	3,360
nButane	545	345	315	605	585	1,550	870	735	1,600	320
Isobutane	-2,030	-2,140	-2,410	-2,100	-1,860	-1,695	-1,940	-1,945	-1,570	-1,740
Naphtha Sales										
Total Gasoline	**38,675**	**38,410**	**40,075**	**48,195**	**49,085**	**44,180**	**44,940**	**47,635**	**51,440**	**58,950**
Conv/BOB Regular	26,410	26,230	27,370	32,920	39,725	30,170	30,685	32,530	35,125	40,255
Conv/BOB Premium	2,125	2,110	2,205	2,650	2,735	2,430	2,475	2,620	2,830	3,245
RBOB Regular	8,940	8,880	9,260	11,135	5,840	10,210	10,385	11,010	11,890	13,620
RBOB Premium	1,200	1,190	1,240	1,490	785	1,370	1,395	1,475	1,595	1,830
Middle Distillates	**54,115**	**49,880**	**43,910**	**40,360**	**34,980**	**39,320**	**42,610**	**46,285**	**47,330**	**51,400**
Jet 54	11,610	11,080	10,280	8,140	7,530	7,620	11,870	13,920	14,030	16,990
ULSD	42,505	38,800	33,630	32,220	27,450	31,700	30,740	32,365	33,300	34,410
Slurry Oil	**2,430**	**2,480**	**2,110**	**1,860**	**2,130**	**2,010**	**1,690**	**1,700**	**1,690**	**970**
Sulfur (LT/D)	**470**	**400**	**400**	**40**	**370**	**350**	**340**	**320**	**230**	**150**
Pet Coke (LT/D)	**1,910**	**1,970**	**2,640**	**1,840**	**2,070**	**2,250**	**2,050**	**1,850**	**1,710**	**1,580**
HS VGO Purchases	**-12,380**	**-12,150**	**-6,020**	**-4,720**	**2,100**	**-4,110**	**1,470**	**2,530**	**420**	**3,460**
LS Resid Purchases	**0**	**0**	**0**	**2,040**	**0**	**0**	**0**	**0**	**0**	**0**
HS Resid Purchases	**15,360**	**10,550**	**3,580**	**0**	**-5,980**	**1,180**	**-2,000**	**2,860**	**9,680**	**18,730**

Appendix Table III-7E
Refinery Yields - USMC
40 MBPD Case

Yields assume 100 MBPD of crude/PUB feed
All units in BPD unless otherwise noted

	PUB 1	PUB 2	PUB 3	PUB 4	AWB	WCS	MYA	ARH	WTI
Light Ends									
Propane	2,370	2,225	2,425	2,420	2,530	2,655	2,835	2,725	3,140
Propylene	0	0	0	0	0	0	0	0	0
nButane	-675	-725	-810	-695	-820	450	-275	-585	-1,310
Isobutane	-4,105	-4,240	-4,865	-4,815	-3,765	-4,245	-4,355	-4,605	-5,025
Naphtha Sales									
Total Gasoline	**42,430**	**42,305**	**44,545**	**53,645**	**53,080**	**49,190**	**49,550**	**53,375**	**67,690**
Conv/BOB Regular	33,600	33,505	35,275	42,480	42,035	38,955	39,235	42,270	53,605
Conv/BOB Premium	2,335	2,325	2,450	2,955	2,920	2,705	2,730	2,935	3,725
RBOB Regular	5,815	5,800	6,105	7,350	7,275	6,745	6,790	7,315	9,275
RBOB Premium	680	675	715	860	850	785	795	855	1,085
Middle Distillates	**49,425**	**45,010**	**39,240**	**35,325**	**29,880**	**34,555**	**36,865**	**40,625**	**44,940**
Jet 54	7,730	8,940	8,830	6,500	2,385	6,080	9,800	11,740	14,070
ULSD	41,695	36,070	30,410	28,825	27,495	28,475	27,065	28,885	30,870
Slurry Oil	**3,060**	**3,110**	**2,770**	**2,540**	**2,840**	**2,620**	**2,230**	**2,310**	**1,380**
Sulfur (LT/D)	**390**	**330**	**330**	**30**	**290**	**280**	**270**	**240**	**100**
Pet Coke (LT/D)	**1,320**	**1,350**	**2,000**	**1,190**	**1,420**	**1,590**	**1,430**	**1,230**	**950**
HS VGO Purchases	**-9,980**	**-9,270**	**-2,630**	**-1,050**	**4,620**	**-40**	**3,370**	**5,170**	**6,670**
LS Resid Purchases	**0**	**0**	**0**	**-8,460**	**0**	**0**	**0**	**0**	**0**
HS Resid Purchases	**5,710**	**410**	**-7,040**	**0**	**-16,540**	**-9,980**	**-12,080**	**-7,200**	**8,650**

Appendix Table III-7F
Refinery Yields - China
40 MBPD Case

Yields assume 100 MBPD of crude/PUB feed
All units in BPD unless otherwise noted

	PUB 1	PUB 2	PUB 3	PUB 4	AWB	WCS	MYA	ARH	WTI
Light Ends									
Propane	2,045	1,955	2,280	2,220	2,350	2,510	2,685	2,560	2,940
Propylene	1,520	1,540	1,710	1,860	1,530	1,780	1,750	1,840	2,000
nButane	3,090	2,650	2,985	3,770	3,855	4,900	4,095	4,250	4,530
Isobutane	0	0	0	0	0	0	0	0	0
Naphtha Sales									
Total Gasoline	**30,720**	**30,860**	**31,305**	**34,725**	**40,655**	**33,565**	**35,985**	**37,520**	**45,195**
Conv/BOB Regular	30,720	30,860	30,520	34,700	40,645	33,565	35,985	37,520	45,185
Conv/BOB Premium	0	0	785	25	10	0	0	0	10
Middle Distillates	**57,320**	**52,850**	**47,020**	**43,550**	**37,730**	**42,490**	**45,980**	**49,620**	**55,240**
Jet 54	0	0	0	0	0	0	11,290	15,980	19,710
ULSD	33,700	37,630	42,230	41,940	24,410	38,920	34,690	33,640	35,530
No. 2 Oil	23,620	15,220	4,790	1,610	13,320	3,570	0	0	0
Slurry Oil	**1,950**	**1,920**	**1,720**	**1,430**	**1,690**	**1,510**	**1,420**	**1,400**	**960**
Sulfur (LT/D)	**450**	**380**	**380**	**30**	**350**	**330**	**320**	**290**	**120**
Pet Coke (LT/D)	**1,460**	**1,520**	**2,190**	**1,380**	**1,620**	**1,810**	**1,600**	**1,410**	**1,130**
HS VGO Purchases	**-11,020**	**-10,920**	**-5,020**	**-3,710**	**3,190**	**-2,900**	**3,160**	**3,550**	**4,260**
LS Resid Purchases	**0**	**0**	**0**	**-4,960**	**0**	**0**	**0**	**0**	**0**
HS Resid Purchases	**8,360**	**3,550**	**-3,420**	**0**	**-12,980**	**-5,820**	**-9,000**	**-4,140**	**11,730**

Appendix Table III-7G
Refinery Yields - USGC
100 MBPD Case

Yields assume 100 MBPD of crude/PUB feed
All units in BPD unless otherwise noted

	PUB 1	PUB 2	PUB 3	PUB 4	AWB	WCS	MYA	ARH	Mars	WTI
Light Ends										
Propane	2,750	2,600	2,915	3,015	2,960	3,175	3,300	3,170	3,335	3,560
Propylene	2,530	2,490	2,830	3,090	2,690	2,990	2,940	3,100	3,090	3,360
nButane	580	390	335	615	585	1,550	870	735	1,600	320
Isobutane	-1,835	-1,910	-2,270	-2,055	-1,860	-1,695	-1,940	-1,945	-1,570	-1,740
Naphtha Sales										
Total Gasoline	**36,765**	**36,220**	**38,730**	**47,795**	**49,085**	**44,180**	**44,940**	**47,635**	**51,440**	**58,950**
Conv/BOB Regular	25,105	24,735	26,450	32,640	39,725	30,170	30,685	32,530	35,125	40,255
Conv/BOB Premium	2,025	1,990	2,130	2,630	2,735	2,430	2,475	2,620	2,830	3,245
RBOB Regular	8,495	8,370	8,950	11,045	5,840	10,210	10,385	11,010	11,890	13,620
RBOB Premium	1,140	1,125	1,200	1,480	785	1,370	1,395	1,475	1,595	1,830
Middle Distillates	**53,460**	**49,175**	**43,490**	**40,215**	**34,980**	**39,320**	**42,610**	**46,285**	**47,330**	**51,400**
Jet 54	11,540	11,020	10,250	8,120	7,530	7,620	11,870	13,920	14,030	16,990
ULSD	41,920	38,155	33,240	32,095	27,450	31,700	30,740	32,365	33,300	34,410
Slurry Oil	**2,260**	**2,280**	**1,990**	**1,820**	**2,130**	**2,010**	**1,690**	**1,700**	**1,690**	**970**
Sulfur (LT/D)	**460**	**400**	**400**	**30**	**370**	**350**	**340**	**320**	**230**	**150**
Pet Coke (LT/D)	**1,910**	**1,970**	**2,640**	**1,840**	**2,070**	**2,250**	**2,050**	**1,850**	**1,710**	**1,580**
HS VGO Purchases	**-14,960**	**-15,090**	**-7,810**	**-5,250**	**2,100**	**-4,110**	**1,470**	**2,530**	**420**	**3,460**
LS Resid Purchases	**0**	**0**	**0**	**2,040**	**0**	**0**	**0**	**0**	**0**	**0**
HS Resid Purchases	**15,360**	**10,550**	**3,580**	**0**	**-5,980**	**1,180**	**-2,000**	**2,860**	**9,680**	**18,730**

Appendix Table III-7H
Refinery Yields - USMC
100 MBPD Case

Yields assume 100 MBPD of crude/PUB feed
All units in BPD unless otherwise noted

	PUB 1	PUB 2	PUB 3	PUB 4	AWB	WCS	MYA	ARH	WTI
Light Ends									
Propane	2,290	2,140	2,375	2,400	2,530	2,655	2,835	2,725	3,140
Propylene	0	0	0	0	0	0	0	0	0
nButane	-500	-565	-710	-670	-820	450	-275	-585	-1,310
Isobutane	-3,600	-3,765	-4,565	-4,730	-3,765	-4,245	-4,355	-4,605	-5,025
Naphtha Sales									
Total Gasoline	**39,195**	**39,260**	**42,650**	**53,110**	**53,080**	**49,190**	**49,550**	**53,375**	**67,690**
Conv/BOB Regular	31,040	31,090	33,775	42,055	42,035	38,955	39,235	42,270	53,605
Conv/BOB Premium	2,155	2,160	2,345	2,925	2,920	2,705	2,730	2,935	3,725
RBOB Regular	5,375	5,380	5,845	7,280	7,275	6,745	6,790	7,315	9,275
RBOB Premium	625	630	685	850	850	785	795	855	1,085
Middle Distillates	**48,570**	**44,205**	**38,735**	**35,190**	**29,880**	**34,555**	**36,865**	**40,625**	**44,940**
Jet 54	8,030	9,075	8,810	6,500	2,385	6,080	9,800	11,740	14,070
ULSD	40,540	35,130	29,925	28,690	27,495	28,475	27,065	28,885	30,870
Slurry Oil	**2,780**	**2,850**	**2,610**	**2,490**	**2,840**	**2,620**	**2,230**	**2,310**	**1,380**
Sulfur (LT/D)	**390**	**320**	**320**	**30**	**290**	**280**	**270**	**240**	**100**
Pet Coke (LT/D)	**1,320**	**1,350**	**2,000**	**1,190**	**1,420**	**1,590**	**1,430**	**1,230**	**950**
HS VGO Purchases	**-13,630**	**-12,740**	**-4,780**	**-1,670**	**4,620**	**-40**	**3,370**	**5,170**	**6,670**
LS Resid Purchases	**0**	**0**	**0**	**-8,460**	**0**	**0**	**0**	**0**	**0**
HS Resid Purchases	**5,710**	**410**	**-7,040**	**0**	**-16,540**	**-9,980**	**-12,080**	**-7,200**	**8,650**

Appendix Table III-7I
Refinery Yields - China
100 MBPD Case

Yields assume 100 MBPD of crude/PUB feed
All units in BPD unless otherwise noted

	PUB 1	PUB-2	PUB 3	PUB 4	AWB	WCS	MYA	ARH	WTI
Light Ends									
Propane	2,015	1,925	2,255	2,220	2,350	2,510	2,685	2,560	2,940
Propylene	1,430	1,430	1,650	1,850	1,530	1,780	1,750	1,840	2,000
nButane	3,020	2,580	2,935	3,755	3,855	4,900	4,095	4,250	4,530
Isobutane	0	0	0	0	0	0	0	0	0
Naphtha Sales									
Total Gasoline	**29,735**	**29,650**	**30,580**	**34,560**	**40,655**	**33,565**	**35,985**	**37,520**	**45,195**
Conv/BOB Regular	29,735	29,650	29,965	34,535	40,645	33,565	35,985	37,520	45,185
Conv/BOB Premium	0	0	615	25	10	0	0	0	10
Middle Distillates	**56,730**	**52,220**	**46,620**	**43,430**	**37,730**	**42,490**	**45,980**	**49,620**	**55,240**
Jet 54	0	0	0	0	0	0	11,290	15,980	19,710
ULSD	33,410	37,360	42,130	41,840	24,410	38,920	34,690	33,640	35,530
No. 2 Oil	23,320	14,860	4,490	1,590	13,320	3,570	0	0	0
Slurry Oil	**1,850**	**1,810**	**1,640**	**1,410**	**1,690**	**1,510**	**1,420**	**1,400**	**960**
Sulfur (LT/D)	**440**	**380**	**370**	**30**	**350**	**330**	**320**	**290**	**120**
Pet Coke (LT/D)	**1,460**	**1,520**	**2,190**	**1,380**	**1,620**	**1,810**	**1,600**	**1,410**	**1,130**
HS VGO Purchases	**-12,660**	**-12,850**	**-6,220**	**-3,980**	**3,190**	**-2,900**	**3,160**	**3,550**	**4,260**
LS Resid Purchases	**0**	**0**	**0**	**-4,960**	**0**	**0**	**0**	**0**	**0**
HS Resid Purchases	**8,360**	**3,550**	**-3,420**	**0**	**-12,980**	**-5,820**	**-9,000**	**-4,140**	**11,730**

Appendix Table III- 8A
PUB and Competitive Crude Refining Values
10 MBPD Case
$50 WTI (Cushing) Pricing Basis

All Refining Values in USD/BBL

	2020	2025	2030	2035	2040	2045
USGC						
PUB 1	$73.28	$65.81	$64.44	$64.14	$64.07	$64.07
PUB 2	$70.40	$63.79	$62.66	$62.37	$62.30	$62.30
PUB 3	$64.11	$58.93	$58.12	$57.81	$57.73	$57.73
PUB 4	$76.00	$67.59	$65.27	$64.95	$64.86	$64.86
Acces Western Blend (AWB)	$59.46	$55.98	$55.66	$55.38	$55.30	$55.30
Western Canadian Select (WCS)	$63.01	$58.28	$57.60	$57.29	$57.20	$57.20
Maya	$62.56	$58.19	$57.64	$57.37	$57.29	$57.29
Arabian Heavy	$65.84	$60.63	$59.86	$59.60	$59.54	$59.54
Mars	$70.06	$63.73	$62.66	$62.39	$62.33	$62.33
WTI	$74.96	$67.18	$65.72	$65.47	$65.42	$65.42
USMC						
PUB 1	$69.49	$63.30	$62.50	$62.33	$62.30	$62.30
PUB 2	$66.38	$61.15	$60.61	$60.45	$60.43	$60.43
PUB 3	$60.09	$56.35	$56.15	$55.97	$55.93	$55.93
PUB 4	$71.45	$64.31	$62.71	$62.49	$62.44	$62.44
Acces Western Blend (AWB)	$55.29	$53.23	$53.53	$53.38	$53.34	$53.34
Western Canadian Select (WCS)	$58.75	$55.55	$55.51	$55.33	$55.28	$55.28
WTI	$71.47	$55.74	$55.78	$55.63	$55.59	$55.59
China						
PUB 1	$68.67	$62.91	$62.14	$61.88	$61.82	$61.82
PUB 2	$66.25	$61.31	$60.80	$60.55	$60.49	$60.49
PUB 3	$59.98	$56.46	$56.27	$55.99	$55.91	$55.91
PUB 4	$71.42	$64.71	$63.11	$62.79	$62.69	$62.69
Acces Western Blend (AWB)	$55.59	$53.73	$54.00	$53.75	$53.66	$53.66
Western Canadian Select (WCS)	$58.95	$55.86	$55.80	$55.51	$55.42	$55.42
Arabian Heavy	$62.29	$58.72	$58.58	$58.35	$58.30	$58.30
WTI	$71.11	$65.12	$64.34	$64.13	$64.08	$64.08

Appendix Table III- 8B
PUB and Competitive Crude Refining Values
10 MBPD Case
$60 WTI (Cushing) Pricing Basis

All Refining Values in USD/BBL

	2020	2025	2030	2035	2040	2045
USGC						
PUB 1	$85.04	$77.13	$75.61	$75.25	$75.16	$75.16
PUB 2	$81.90	$74.91	$73.65	$73.31	$73.22	$73.22
PUB 3	$74.93	$69.47	$68.56	$68.21	$68.11	$68.11
PUB 4	$87.61	$78.81	$76.32	$75.94	$75.83	$75.83
Acces Western Blend (AWB)	$70.00	$66.34	$65.98	$65.66	$65.56	$65.56
Western Canadian Select (WCS)	$73.81	$68.83	$68.07	$67.71	$67.61	$67.61
Maya	$73.33	$68.73	$68.11	$67.80	$67.71	$67.71
Arabian Heavy	$76.89	$71.38	$70.52	$70.22	$70.14	$70.14
Mars	$81.52	$74.83	$73.64	$73.31	$73.22	$73.22
WTI	$86.66	$78.43	$76.80	$76.48	$76.41	$76.41
USMC						
PUB 1	$80.91	$74.37	$73.48	$73.26	$73.21	$73.21
PUB 2	$77.52	$72.00	$71.39	$71.19	$71.15	$71.15
PUB 3	$70.55	$66.62	$66.38	$66.17	$66.12	$66.12
PUB 4	$82.77	$75.29	$73.56	$73.29	$73.22	$73.22
Acces Western Blend (AWB)	$65.45	$63.32	$63.63	$63.46	$63.41	$63.41
Western Canadian Select (WCS)	$69.17	$65.83	$65.76	$65.56	$65.50	$65.50
WTI	$82.89	$66.03	$66.05	$65.87	$65.82	$65.82
China						
PUB 1	$80.52	$74.20	$73.33	$73.03	$72.95	$72.95
PUB 2	$77.88	$72.44	$71.85	$71.57	$71.49	$71.49
PUB 3	$70.92	$67.02	$66.78	$66.48	$66.39	$66.39
PUB 4	$83.20	$75.94	$74.22	$73.85	$73.74	$73.74
Acces Western Blend (AWB)	$66.21	$64.10	$64.38	$64.11	$64.02	$64.02
Western Canadian Select (WCS)	$69.86	$66.42	$66.32	$66.01	$65.92	$65.92
Arabian Heavy	$73.44	$69.48	$69.29	$69.04	$68.97	$68.97
WTI	$82.86	$76.30	$75.39	$75.14	$75.08	$75.08

Appendix Table III- 8C
PUB and Competitive Crude Refining Values
10 MBPD Case
$70 WTI (Cushing) Pricing Basis

All Refining Values in USD/BBL

	2020	2025	2030	2035	2040	2045
USGC						
PUB 1	$96.81	$88.46	$86.78	$86.36	$86.25	$86.25
PUB 2	$93.39	$86.03	$84.64	$84.24	$84.14	$84.14
PUB 3	$85.75	$80.00	$79.00	$78.60	$78.48	$78.48
PUB 4	$99.22	$90.03	$87.36	$86.93	$86.80	$86.80
Acces Western Blend (AWB)	$80.53	$76.70	$76.30	$75.94	$75.83	$75.83
Western Canadian Select (WCS)	$84.62	$79.37	$78.53	$78.14	$78.02	$78.02
Maya	$84.10	$79.27	$78.58	$78.22	$78.12	$78.12
Arabian Heavy	$87.93	$82.14	$81.19	$80.83	$80.74	$80.74
Mars	$92.98	$85.93	$84.61	$84.23	$84.12	$84.12
WTI	$98.36	$89.68	$87.88	$87.50	$87.40	$87.40
USMC						
PUB 1	$92.33	$85.45	$84.45	$84.18	$84.13	$84.13
PUB 2	$88.65	$82.85	$82.17	$81.93	$81.87	$81.87
PUB 3	$81.00	$76.89	$76.62	$76.37	$76.31	$76.31
PUB 4	$94.09	$86.27	$84.41	$84.09	$84.01	$84.01
Acces Western Blend (AWB)	$75.61	$73.41	$73.73	$73.54	$73.48	$73.48
Western Canadian Select (WCS)	$79.60	$76.11	$76.02	$75.79	$75.72	$75.72
WTI	$94.31	$76.31	$76.32	$76.11	$76.06	$76.06
China						
PUB 1	$92.38	$85.49	$84.51	$84.17	$84.09	$84.09
PUB 2	$89.50	$83.57	$82.90	$82.58	$82.50	$82.50
PUB 3	$81.87	$77.58	$77.30	$76.96	$76.86	$76.86
PUB 4	$94.98	$87.18	$85.32	$84.92	$84.79	$84.79
Acces Western Blend (AWB)	$76.84	$74.48	$74.75	$74.46	$74.37	$74.37
Western Canadian Select (WCS)	$80.77	$76.98	$76.85	$76.52	$76.41	$76.41
Arabian Heavy	$84.59	$80.24	$80.00	$79.73	$79.65	$79.65
WTI	$94.61	$87.47	$86.45	$86.15	$86.08	$86.08

Appendix Table III- 8D
PUB and Competitive Crude Refining Values
10 MBPD Case
$80 WTI (Cushing) Pricing Basis

All Refining Values in USD/BBL

	2020	2025	2030	2035	2040	2045
USGC						
PUB 1	$108.57	$99.79	$97.96	$97.47	$97.34	$97.34
PUB 2	$104.89	$97.15	$95.64	$95.18	$95.05	$95.05
PUB 3	$96.58	$90.54	$89.44	$89.00	$88.86	$88.86
PUB 4	$110.83	$101.25	$98.41	$97.92	$97.76	$97.76
Acces Western Blend (AWB)	$91.07	$87.06	$86.61	$86.22	$86.10	$86.10
Western Canadian Select (WCS)	$95.42	$89.92	$89.00	$88.56	$88.42	$88.42
Maya	$94.87	$89.81	$89.05	$88.65	$88.54	$88.54
Arabian Heavy	$98.97	$92.90	$91.85	$91.45	$91.34	$91.34
Mars	$104.43	$97.03	$95.58	$95.15	$95.02	$95.02
WTI	$110.06	$100.93	$98.96	$98.51	$98.39	$98.39
USMC						
PUB 1	$103.75	$96.53	$95.43	$95.11	$95.04	$95.04
PUB 2	$99.78	$93.71	$92.95	$92.66	$92.59	$92.59
PUB 3	$91.46	$87.16	$86.85	$86.58	$86.50	$86.50
PUB 4	$105.41	$97.24	$95.25	$94.89	$94.79	$94.79
Acces Western Blend (AWB)	$85.77	$83.50	$83.84	$83.62	$83.55	$83.55
Western Canadian Select (WCS)	$90.03	$86.39	$86.28	$86.01	$85.94	$85.94
WTI	$105.74	$86.60	$86.59	$86.35	$86.29	$86.29
China						
PUB 1	$104.23	$96.78	$95.69	$95.32	$95.22	$95.22
PUB 2	$101.13	$94.70	$93.94	$93.59	$93.50	$93.50
PUB 3	$92.81	$88.14	$87.81	$87.45	$87.34	$87.34
PUB 4	$106.76	$98.41	$96.42	$95.98	$95.84	$95.84
Acces Western Blend (AWB)	$87.46	$84.85	$85.13	$84.82	$84.72	$84.72
Western Canadian Select (WCS)	$91.68	$87.54	$87.38	$87.02	$86.91	$86.91
Arabian Heavy	$95.73	$91.00	$90.71	$90.41	$90.33	$90.33
WTI	$106.36	$98.65	$97.50	$97.17	$97.09	$97.09

Appendix Table III- 8E
PUB and Competitive Crude Refining Values
40 MBPD Case
$50 WTI (Cushing) Pricing Basis

All Refining Values in USD/BBL

	2020	2025	2030	2035	2040	2045
USGC						
PUB 1	$73.17	$65.69	$64.32	$64.02	$63.95	$63.95
PUB 2	$70.26	$63.64	$62.51	$62.22	$62.15	$62.15
PUB 3	$64.03	$58.85	$58.03	$57.72	$57.64	$57.64
PUB 4	$75.94	$67.53	$65.20	$64.89	$64.80	$64.80
Acces Western Blend (AWB)	$59.46	$55.98	$55.66	$55.38	$55.30	$55.30
Western Canadian Select (WCS)	$63.01	$58.28	$57.60	$57.29	$57.20	$57.20
Maya	$62.56	$58.19	$57.64	$57.37	$57.29	$57.29
Arabian Heavy	$65.84	$60.63	$59.86	$59.60	$59.54	$59.54
Mars	$70.06	$63.73	$62.66	$62.39	$62.33	$62.33
WTI	$74.96	$67.18	$65.72	$65.47	$65.42	$65.42
USMC						
PUB 1	$69.34	$63.14	$62.34	$62.16	$62.13	$62.13
PUB 2	$66.25	$61.01	$60.47	$60.30	$60.27	$60.27
PUB 3	$60.01	$56.26	$56.06	$55.88	$55.84	$55.84
PUB 4	$71.43	$64.30	$62.69	$62.47	$62.42	$62.42
Acces Western Blend (AWB)	$55.29	$53.23	$53.53	$53.38	$53.34	$53.34
Western Canadian Select (WCS)	$58.75	$55.55	$55.51	$55.33	$55.28	$55.28
WTI	$71.47	$55.74	$55.78	$55.63	$55.59	$55.59
China						
PUB 1	$68.54	$62.77	$62.01	$61.75	$61.68	$61.68
PUB 2	$66.10	$61.14	$60.64	$60.38	$60.32	$60.32
PUB 3	$59.90	$56.37	$56.17	$55.89	$55.81	$55.81
PUB 4	$71.33	$64.62	$63.02	$62.69	$62.59	$62.59
Acces Western Blend (AWB)	$55.59	$53.73	$54.00	$53.75	$53.66	$53.66
Western Canadian Select (WCS)	$58.95	$55.86	$55.80	$55.51	$55.42	$55.42
Arabian Heavy	$62.29	$58.72	$58.58	$58.35	$58.30	$58.30
WTI	$71.11	$65.12	$64.34	$64.13	$64.08	$64.08

Appendix Table III- 8F
PUB and Competitive Crude Refining Values
40 MBPD Case
$60 WTI (Cushing) Pricing Basis

All Refining Values in USD/BBL

	2020	2025	2030	2035	2040	2045
USGC						
PUB 1	$84.92	$77.00	$75.47	$75.11	$75.02	$75.02
PUB 2	$81.74	$74.74	$73.48	$73.14	$73.05	$73.05
PUB 3	$74.84	$69.37	$68.46	$68.11	$68.01	$68.01
PUB 4	$87.54	$78.74	$76.24	$75.87	$75.76	$75.76
Acces Western Blend (AWB)	$70.00	$66.34	$65.98	$65.66	$65.56	$65.56
Western Canadian Select (WCS)	$73.81	$68.83	$68.07	$67.71	$67.61	$67.61
Maya	$73.33	$68.73	$68.11	$67.80	$67.71	$67.71
Arabian Heavy	$76.89	$71.38	$70.52	$70.22	$70.14	$70.14
Mars	$81.52	$74.83	$73.64	$73.31	$73.22	$73.22
WTI	$86.66	$78.43	$76.80	$76.48	$76.41	$76.41
USMC						
PUB 1	$80.74	$74.20	$73.30	$73.07	$73.02	$73.02
PUB 2	$77.37	$71.85	$71.23	$71.02	$70.98	$70.98
PUB 3	$70.45	$66.52	$66.28	$66.07	$66.01	$66.01
PUB 4	$82.75	$75.27	$73.54	$73.27	$73.20	$73.20
Acces Western Blend (AWB)	$65.45	$63.32	$63.63	$63.46	$63.41	$63.41
Western Canadian Select (WCS)	$69.17	$65.83	$65.76	$65.56	$65.50	$65.50
WTI	$82.89	$66.03	$66.05	$65.87	$65.82	$65.82
China						
PUB 1	$80.38	$74.05	$73.17	$72.87	$72.80	$72.80
PUB 2	$77.70	$72.25	$71.66	$71.38	$71.30	$71.30
PUB 3	$70.83	$66.92	$66.68	$66.37	$66.28	$66.28
PUB 4	$83.10	$75.85	$74.12	$73.75	$73.64	$73.64
Acces Western Blend (AWB)	$66.21	$64.10	$64.38	$64.11	$64.02	$64.02
Western Canadian Select (WCS)	$69.86	$66.42	$66.32	$66.01	$65.92	$65.92
Arabian Heavy	$73.44	$69.48	$69.29	$69.04	$68.97	$68.97
WTI	$82.86	$76.30	$75.39	$75.14	$75.08	$75.08

Appendix Table III- 8G
PUB and Competitive Crude Refining Values
40 MBPD Case
$70 WTI (Cushing) Pricing Basis

All Refining Values in USD/BBL

	2020	2025	2030	2035	2040	2045
USGC						
PUB 1	$96.66	$88.31	$86.63	$86.21	$86.09	$86.09
PUB 2	$93.22	$85.84	$84.45	$84.05	$83.94	$83.94
PUB 3	$85.65	$79.89	$78.89	$78.49	$78.37	$78.37
PUB 4	$99.14	$89.95	$87.28	$86.85	$86.71	$86.71
Acces Western Blend (AWB)	$80.53	$76.70	$76.30	$75.94	$75.83	$75.83
Western Canadian Select (WCS)	$84.62	$79.37	$78.53	$78.14	$78.02	$78.02
Maya	$84.10	$79.27	$78.58	$78.22	$78.12	$78.12
Arabian Heavy	$87.93	$82.14	$81.19	$80.83	$80.74	$80.74
Mars	$92.98	$85.93	$84.61	$84.23	$84.12	$84.12
WTI	$98.36	$89.68	$87.88	$87.50	$87.40	$87.40
USMC						
PUB 1	$92.14	$85.26	$84.25	$83.97	$83.91	$83.91
PUB 2	$88.49	$82.68	$81.99	$81.74	$81.68	$81.68
PUB 3	$80.90	$76.78	$76.50	$76.26	$76.19	$76.19
PUB 4	$94.07	$86.24	$84.38	$84.07	$83.98	$83.98
Acces Western Blend (AWB)	$75.61	$73.41	$73.73	$73.54	$73.48	$73.48
Western Canadian Select (WCS)	$79.60	$76.11	$76.02	$75.79	$75.72	$75.72
WTI	$94.31	$76.31	$76.32	$76.11	$76.06	$76.06
China						
PUB 1	$92.22	$85.32	$84.34	$84.00	$83.92	$83.92
PUB 2	$89.31	$83.36	$82.68	$82.37	$82.28	$82.28
PUB 3	$81.76	$77.46	$77.18	$76.84	$76.75	$76.75
PUB 4	$94.87	$87.07	$85.21	$84.80	$84.68	$84.68
Acces Western Blend (AWB)	$76.84	$74.48	$74.75	$74.46	$74.37	$74.37
Western Canadian Select (WCS)	$80.77	$76.98	$76.85	$76.52	$76.41	$76.41
Arabian Heavy	$84.59	$80.24	$80.00	$79.73	$79.65	$79.65
WTI	$94.61	$87.47	$86.45	$86.15	$86.08	$86.08

Appendix Table III- 8H
PUB and Competitive Crude Refining Values
40 MBPD Case
$80 WTI (Cushing) Pricing Basis

All Refining Values in USD/BBL

	2020	2025	2030	2035	2040	2045
USGC						
PUB 1	$108.41	$99.62	$97.78	$97.30	$97.17	$97.17
PUB 2	$104.70	$96.94	$95.42	$94.96	$94.84	$94.84
PUB 3	$96.47	$90.42	$89.32	$88.87	$88.74	$88.74
PUB 4	$110.74	$101.16	$98.32	$97.83	$97.67	$97.67
Acces Western Blend (AWB)	$91.07	$87.06	$86.61	$86.22	$86.10	$86.10
Western Canadian Select (WCS)	$95.42	$89.92	$89.00	$88.56	$88.42	$88.42
Maya	$94.87	$89.81	$89.05	$88.65	$88.54	$88.54
Arabian Heavy	$98.97	$92.90	$91.85	$91.45	$91.34	$91.34
Mars	$104.43	$97.03	$95.58	$95.15	$95.02	$95.02
WTI	$110.06	$100.93	$98.96	$98.51	$98.39	$98.39
USMC						
PUB 1	$103.54	$96.31	$95.21	$94.88	$94.81	$94.81
PUB 2	$99.60	$93.52	$92.76	$92.46	$92.39	$92.39
PUB 3	$91.34	$87.04	$86.73	$86.44	$86.37	$86.37
PUB 4	$105.39	$97.22	$95.23	$94.87	$94.76	$94.76
Acces Western Blend (AWB)	$85.77	$83.50	$83.84	$83.62	$83.55	$83.55
Western Canadian Select (WCS)	$90.03	$86.39	$86.28	$86.01	$85.94	$85.94
WTI	$105.74	$86.60	$86.59	$86.35	$86.29	$86.29
China						
PUB 1	$104.05	$96.59	$95.50	$95.13	$95.03	$95.03
PUB 2	$100.91	$94.47	$93.71	$93.36	$93.27	$93.27
PUB 3	$92.69	$88.01	$87.68	$87.32	$87.21	$87.21
PUB 4	$106.65	$98.30	$96.31	$95.86	$95.72	$95.72
Acces Western Blend (AWB)	$87.46	$84.85	$85.13	$84.82	$84.72	$84.72
Western Canadian Select (WCS)	$91.68	$87.54	$87.38	$87.02	$86.91	$86.91
Arabian Heavy	$95.73	$91.00	$90.71	$90.41	$90.33	$90.33
WTI	$106.36	$98.65	$97.50	$97.17	$97.09	$97.09

Appendix Table III- 8I
PUB and Competitive Crude Refining Values
100 MBPD Case
$50 WTI (Cushing) Pricing Basis

All Refining Values in USD/BBL

	2020	2025	2030	2035	2040	2045
USGC						
PUB 1	$72.97	$65.46	$64.09	$63.78	$63.71	$63.71
PUB 2	$70.05	$63.41	$62.27	$61.98	$61.90	$61.90
PUB 3	$63.89	$58.69	$57.87	$57.56	$57.48	$57.48
PUB 4	$75.88	$67.47	$65.14	$64.83	$64.74	$64.74
Acces Western Blend (AWB)	$59.46	$55.98	$55.66	$55.38	$55.30	$55.30
Western Canadian Select (WCS)	$63.01	$58.28	$57.60	$57.29	$57.20	$57.20
Maya	$62.56	$58.19	$57.64	$57.37	$57.29	$57.29
Arabian Heavy	$65.84	$60.63	$59.86	$59.60	$59.54	$59.54
Mars	$70.06	$63.73	$62.66	$62.39	$62.33	$62.33
WTI	$74.96	$67.18	$65.72	$65.47	$65.42	$65.42
USMC						
PUB 1	$69.09	$62.89	$62.07	$61.88	$61.85	$61.85
PUB 2	$66.02	$60.77	$60.22	$60.04	$60.01	$60.01
PUB 3	$59.86	$56.11	$55.89	$55.71	$55.66	$55.66
PUB 4	$71.40	$64.26	$62.65	$62.43	$62.38	$62.38
Acces Western Blend (AWB)	$55.29	$53.23	$53.53	$53.38	$53.34	$53.34
Western Canadian Select (WCS)	$58.75	$55.55	$55.51	$55.33	$55.28	$55.28
WTI	$71.47	$55.74	$55.78	$55.63	$55.59	$55.59
China						
PUB 1	$68.34	$62.56	$61.79	$61.52	$61.46	$61.46
PUB 2	$65.88	$60.91	$60.39	$60.14	$60.08	$60.08
PUB 3	$59.76	$56.21	$56.02	$55.74	$55.65	$55.65
PUB 4	$71.30	$64.59	$62.98	$62.65	$62.55	$62.55
Acces Western Blend (AWB)	$55.59	$53.73	$54.00	$53.75	$53.66	$53.66
Western Canadian Select (WCS)	$58.95	$55.86	$55.80	$55.51	$55.42	$55.42
Arabian Heavy	$62.29	$58.72	$58.58	$58.35	$58.30	$58.30
WTI	$71.11	$65.12	$64.34	$64.13	$64.08	$64.08

Appendix Table III- 8J
PUB and Competitive Crude Refining Values
100 MBPD Case
$60 WTI (Cushing) Pricing Basis

All Refining Values in USD/BBL

	2020	2025	2030	2035	2040	2045
USGC						
PUB 1	$84.68	$76.74	$75.21	$74.85	$74.75	$74.75
PUB 2	$81.50	$74.47	$73.21	$72.86	$72.77	$72.77
PUB 3	$74.68	$69.19	$68.28	$67.92	$67.82	$67.82
PUB 4	$87.47	$78.67	$76.17	$75.80	$75.69	$75.69
Acces Western Blend (AWB)	$70.00	$66.34	$65.98	$65.66	$65.56	$65.56
Western Canadian Select (WCS)	$73.81	$68.83	$68.07	$67.71	$67.61	$67.61
Maya	$73.33	$68.73	$68.11	$67.80	$67.71	$67.71
Arabian Heavy	$76.89	$71.38	$70.52	$70.22	$70.14	$70.14
Mars	$81.52	$74.83	$73.64	$73.31	$73.22	$73.22
WTI	$86.66	$78.43	$76.80	$76.48	$76.41	$76.41
USMC						
PUB 1	$80.46	$73.91	$72.99	$72.75	$72.70	$72.70
PUB 2	$77.11	$71.58	$70.95	$70.73	$70.68	$70.68
PUB 3	$70.28	$66.34	$66.09	$65.87	$65.82	$65.82
PUB 4	$82.72	$75.23	$73.49	$73.23	$73.15	$73.15
Acces Western Blend (AWB)	$65.45	$63.32	$63.63	$63.46	$63.41	$63.41
Western Canadian Select (WCS)	$69.17	$65.83	$65.76	$65.56	$65.50	$65.50
WTI	$82.89	$66.03	$66.05	$65.87	$65.82	$65.82
China						
PUB 1	$80.15	$73.80	$72.92	$72.62	$72.55	$72.55
PUB 2	$77.46	$71.99	$71.39	$71.10	$71.03	$71.03
PUB 3	$70.67	$66.74	$66.50	$66.19	$66.10	$66.10
PUB 4	$83.06	$75.81	$74.07	$73.71	$73.59	$73.59
Acces Western Blend (AWB)	$66.21	$64.10	$64.38	$64.11	$64.02	$64.02
Western Canadian Select (WCS)	$69.86	$66.42	$66.32	$66.01	$65.92	$65.92
Arabian Heavy	$73.44	$69.48	$69.29	$69.04	$68.97	$68.97
WTI	$82.86	$76.30	$75.39	$75.14	$75.08	$75.08

Appendix Table III- 8K
PUB and Competitive Crude Refining Values
100 MBPD Case
$70 WTI (Cushing) Pricing Basis

All Refining Values in USD/BBL

	2020	2025	2030	2035	2040	2045
USGC						
PUB 1	$96.40	$88.02	$86.33	$85.91	$85.79	$85.79
PUB 2	$92.94	$85.53	$84.14	$83.74	$83.63	$83.63
PUB 3	$85.47	$79.69	$78.69	$78.28	$78.16	$78.16
PUB 4	$99.07	$89.87	$87.20	$86.77	$86.64	$86.64
Acces Western Blend (AWB)	$80.53	$76.70	$76.30	$75.94	$75.83	$75.83
Western Canadian Select (WCS)	$84.62	$79.37	$78.53	$78.14	$78.02	$78.02
Maya	$84.10	$79.27	$78.58	$78.22	$78.12	$78.12
Arabian Heavy	$87.93	$82.14	$81.19	$80.83	$80.74	$80.74
Mars	$92.98	$85.93	$84.61	$84.23	$84.12	$84.12
WTI	$98.36	$89.68	$87.88	$87.50	$87.40	$87.40
USMC						
PUB 1	$91.83	$84.93	$83.91	$83.62	$83.56	$83.56
PUB 2	$88.20	$82.38	$81.68	$81.41	$81.35	$81.35
PUB 3	$80.71	$76.58	$76.30	$76.04	$75.97	$75.97
PUB 4	$94.03	$86.20	$84.34	$84.02	$83.93	$83.93
Acces Western Blend (AWB)	$75.61	$73.41	$73.73	$73.54	$73.48	$73.48
Western Canadian Select (WCS)	$79.60	$76.11	$76.02	$75.79	$75.72	$75.72
WTI	$94.31	$76.31	$76.32	$76.11	$76.06	$76.06
China						
PUB 1	$91.96	$85.04	$84.05	$83.72	$83.63	$83.63
PUB 2	$89.04	$83.07	$82.38	$82.06	$81.98	$81.98
PUB 3	$81.58	$77.27	$76.98	$76.65	$76.55	$76.55
PUB 4	$94.83	$87.03	$85.16	$84.76	$84.63	$84.63
Acces Western Blend (AWB)	$76.84	$74.48	$74.75	$74.46	$74.37	$74.37
Western Canadian Select (WCS)	$80.77	$76.98	$76.85	$76.52	$76.41	$76.41
Arabian Heavy	$84.59	$80.24	$80.00	$79.73	$79.65	$79.65
WTI	$94.61	$87.47	$86.45	$86.15	$86.08	$86.08

Appendix Table III- 8L
PUB and Competitive Crude Refining Values
100 MBPD Case
$80 WTI (Cushing) Pricing Basis

All Refining Values in USD/BBL

	2020	2025	2030	2035	2040	2045
USGC						
PUB 1	$108.11	$99.29	$97.46	$96.97	$96.84	$96.84
PUB 2	$104.39	$96.60	$95.08	$94.62	$94.49	$94.49
PUB 3	$96.26	$90.20	$89.10	$88.64	$88.51	$88.51
PUB 4	$110.66	$101.08	$98.23	$97.74	$97.59	$97.59
Acces Western Blend (AWB)	$91.07	$87.06	$86.61	$86.22	$86.10	$86.10
Western Canadian Select (WCS)	$95.42	$89.92	$89.00	$88.56	$88.42	$88.42
Maya	$94.87	$89.81	$89.05	$88.65	$88.54	$88.54
Arabian Heavy	$98.97	$92.90	$91.85	$91.45	$91.34	$91.34
Mars	$104.43	$97.03	$95.58	$95.15	$95.02	$95.02
WTI	$110.06	$100.93	$98.96	$98.51	$98.39	$98.39
USMC						
PUB 1	$103.19	$95.95	$94.83	$94.49	$94.41	$94.41
PUB 2	$99.28	$93.18	$92.40	$92.10	$92.02	$92.02
PUB 3	$91.13	$86.82	$86.50	$86.21	$86.13	$86.13
PUB 4	$105.34	$97.17	$95.18	$94.81	$94.71	$94.71
Acces Western Blend (AWB)	$85.77	$83.50	$83.84	$83.62	$83.55	$83.55
Western Canadian Select (WCS)	$90.03	$86.39	$86.28	$86.01	$85.94	$85.94
WTI	$105.74	$86.60	$86.59	$86.35	$86.29	$86.29
China						
PUB 1	$103.76	$96.28	$95.18	$94.81	$94.72	$94.72
PUB 2	$100.61	$94.14	$93.38	$93.02	$92.93	$92.93
PUB 3	$92.50	$87.80	$87.46	$87.10	$87.00	$87.00
PUB 4	$106.59	$98.25	$96.25	$95.81	$95.67	$95.67
Acces Western Blend (AWB)	$87.46	$84.85	$85.13	$84.82	$84.72	$84.72
Western Canadian Select (WCS)	$91.68	$87.54	$87.38	$87.02	$86.91	$86.91
Arabian Heavy	$95.73	$91.00	$90.71	$90.41	$90.33	$90.33
WTI	$106.36	$98.65	$97.50	$97.17	$97.09	$97.09

Appendix Table III-9A
Refining Value Correlation Equations (RVCEs) Assumptions

(1) Output of the Equation is the expected refining value of the crude/PUB after accounting for MARGINAL refining costs (excluding labor and other fixed costs)

(2) Actual crude/PUB market price will vary based on expected transporation costs, refining margin, and other market factors

(3) The equations do not apply ANY market discount for TAN; a TAN market discount must be applied externally

(4) The refining values are best used to compare the relative values of different, but similar, crudes/PUBs with a known/forecast market price. It can then be assumed that the differece in market price of the two crudes/PUBs will be in line with the expected difference in refining values after accounting for transporation costs and other market factors, as supplied in Appendix V.

(5) Resid yield defined as 1050+ F volume fraction as decimal (Ex. 10% Vol Yield = 0.1 Vol Fraction)

(6) Resid CCR defined as resid (1050+) concarbon in wt %

(7) Resid sulfur defined as resid (1050+) sulfur in wt %

(8) VGO yield defined as 635-1050 F volume fraction as decimal (Ex. 10% Vol Yield = 0.1 Vol Fraction)

(9) Resid K Factor defined as UOP K factor of gasoil fraction (635-1050 F)

(10) VGO CCR defined as VGO (635-1050 F) concarbon in wt %

(11) Diesel + Jet yield defined as 330-635 F volume fraction as decimal (Ex. 10% Vol Yield = 0.1 Vol Fraction)

(12) Naphtha yield defined as C5-330 F volume fraction as decimal (Ex. 10% Vol Yield = 0.1 Vol Fraction)

(13) WTI price in USD/BBL

Appendix Table III-9B
Refining Value Correlation Equations (RVCEs)
10 MBPD Case

USGC

[Resid Yield * (-1.2 + Resid CCR * -0.028) * ((MIN (Resid Sulfur , 3.693) ^ 1.88 + MAX (Resid Sulfur - 3.693 , 0)) * 43.01 + 386.5) + VGO Yield * 363.7 + (Diesel + Jet Yield) * (221)] * [(WTI Price) * 0.0001362696 + 0.00933858] + [(WTI Price) * 1.106 + 9.27]

USMC

[Resid Yield * (-351.1 + Resid CCR * -2.513) * ((Resid Sulfur ^ 0.96) * 18.95 + 66.9) + VGO Yield * -8438.6 + (Diesel + Jet Yield) * (16168)] * [(WTI Price) * 0.0000036886 + 0.0002645] + [(WTI Price) * 1.105 + 10.22]

China

[Resid Yield * (-515.4 + Resid CCR * -15.651) * ((MIN (Resid Sulfur , 4.491) ^ 2.38 + MAX (Resid Sulfur - 4.491 , 0)) * 0.17 + 4.6) + VGO Yield * 1000 + (Diesel + Jet Yield) * (3312)] * [(WTI Price) * 0.0000221206 + 0.00194191] + [(WTI Price) * 1.103 + 7.25]

Appendix Table III-9C
Refining Value Correlation Equations (RVCEs)
40 MBPD Case

USGC

[Resid Yield * (-1.9 + Resid CCR * -0.043) * ((MIN (Resid Sulfur , 3.693) ^ 1.82 + MAX (Resid Sulfur - 3.693 , 0)) * 64.81 + 623.6) + VGO Yield * 868.6 + (Diesel + Jet Yield) * (115)] * [(WTI Price) * 0.0000597501 + 0.00412279] + [(WTI Price) * 1.112 + 9.75]

USMC

[Resid Yield * (-58.2 + Resid CCR * -0.412) * ((Resid Sulfur ^ 0.96) * 13.58 + 47.8) + VGO Yield * -1000 + (Diesel + Jet Yield) * (1889)] * [(WTI Price) * 0.0000313288 + 0.00224403] + [(WTI Price) * 1.105 + 10.24]

China

[Resid Yield * (53.6 + Resid CCR * 1.491) * ((MIN (Resid Sulfur , 4.564) ^ 2 + MAX (Resid Sulfur - 4.564 , 0)) * 9.41 + 135.1) + VGO Yield * -2911.5 + (Diesel + Jet Yield) * (-10927)] * [(WTI Price) * -0.0000071244 + -0.00062325] + [(WTI Price) * 1.102 + 7.18]

Appendix Table III-9D
Refining Value Correlation Equations (RVCEs)
100 MBPD Case

USGC

[Resid Yield * (-2 + Resid CCR * -0.045) * ((MIN (Resid Sulfur , 3.693) ^ 1.82 + MAX (Resid Sulfur - 3.693 , 0)) * 66.48 + 639.6) + VGO Yield * 890.8 + (Diesel + Jet Yield) * (118)] * [(WTI Price) * 0.0000569088 + 0.00393587] + [(WTI Price) * 1.11 + 9.74]

USMC

[Resid Yield * (-78.5 + Resid CCR * -0.548) * ((Resid Sulfur ^ 0.96) * 10.09 + 35.3) + VGO Yield * -1000 + (Diesel + Jet Yield) * (1883)] * [(WTI Price) * 0.0000314799 + 0.00224755] + [(WTI Price) * 1.103 + 10.17]

China

[Resid Yield * (25.2 + Resid CCR * 0.752) * ((MIN (Resid Sulfur , 4.492) ^ 2.37 + MAX (Resid Sulfur - 4.492 , 0)) * 3.62 + 94) + VGO Yield * -999.9 + (Diesel + Jet Yield) * (-3451)] * [(WTI Price) * -0.000022032 + -0.00193302] + [(WTI Price) * 1.1 + 7.15]

Appendix Table III-9E
RVCE Factor Significance

Each value represents the expected change in crude value for a 1% absolute increase in the stated dependent variable(1)

		Resid Yield Sensitivity	Resid Sulfur Sensitivity	Resid CCR Sensitivity	VGO Yield Sensitivity	Diesel + Jet Yield Sensitivity	Overall R-Squared
USGC	**10 MBPD**	($0.247)	($0.627)	($0.088)	$0.059	$0.035	0.966
	40 MBPD	($0.258)	($0.622)	($0.091)	$0.062	$0.008	0.968
	100 MBPD	($0.245)	($0.618)	($0.091)	$0.065	$0.022	0.968
USMC	**10 MBPD**	($0.252)	($0.802)	($0.037)	($0.038)	$0.073	0.934
	40 MBPD	($0.253)	($0.802)	($0.037)	($0.038)	$0.072	0.934
	100 MBPD	($0.252)	($0.801)	($0.037)	($0.038)	$0.072	0.934
China	**10 MBPD**	($0.236)	($0.677)	($0.098)	$0.031	$0.101	0.959
	40 MBPD	($0.235)	($0.692)	($0.093)	$0.029	$0.107	0.959
	100 MBPD	($0.235)	($0.678)	($0.097)	$0.030	$0.102	0.959

(1) For example, an absolute 1% increase in resid yield would be an increase from 13% to 14%

Appendix Table III-9F
Market Value Correlation Example

Assumes High Penetration (100 MBPD) case for the USGC in 2035

PUB 2 Netback (Hardisty) = (PUB 2 Refining value - PUB 2 Transportation) - (Mars Refining Value - Mars Transportation) + Forecast Mars Spot Price

PUB 2 Properties (From Appendix Table III-1)				
Resid Yield	**Resid Sulfur**	**Resid Concarbon**	**VGO Yield**	**Diesel + Jet Yield**
18.5%	5.9%	25.8%	44.5%	28.4%

WTI Price	Predicted PUB 2 Refining Value (Using RVCE)	Mars Refining Value (From Appendix Table III-7I)
$50	$62.20	$62.39

USGC Transportation (From Appendix Table III-6A)		Forecast Mars Spot Price
PUB 2	**Mars**	**(From Appendix Table III-2A)**
$12.80	$0.60	$51.58

PUB 2 Netback at Hardisty	
Predicted Using MVCM	**Actual (From Appendix Table III-9A)**
$39.19	**$39.05**

Appendix Table III-10A
Forecast PUB Netback Market Values
$50 WTI (Cushing) Pricing Basis

FOB Edmonton/Hardisty - US $ per Barrel

	Low Penetration - 10 MBPD						Medium Penetration - 40 MBPD						High Penetration - 100 MBPD					
	2020	2025	2030	2035	2040	2045	2020	2025	2030	2035	2040	2045	2020	2025	2030	2035	2040	2045
PUB 1																		
USGC																		
vs. WCS		38.71	39.87	40.34	40.48	40.48		38.59	39.74	40.21	40.36	40.36		38.37	39.52	39.98	40.13	40.13
vs. Mars		39.37	40.63	40.63	40.58	40.58		39.25	40.51	40.51	40.45	40.45		39.03	40.28	40.27	40.22	40.22
vs. Arab Heavy		39.19	40.45	40.88	41.00	41.00		39.07	40.33	40.76	40.88	40.88		38.85	40.10	40.52	40.64	40.64
USMC vs. WCS		39.13	40.07	40.49	40.63	40.63		38.98	39.91	40.32	40.47	40.47		38.73	39.64	40.04	40.18	40.18
China vs. Arab Heavy																		
Pipeline to Vancouver		41.98	43.88	44.21	44.18	44.18		41.84	43.74	44.07	44.05	44.05		41.63	43.52	43.85	43.82	43.82
Rail to Vancouver		35.38	37.28	37.61	37.58	37.58		35.24	37.14	37.47	37.45	37.45		35.03	36.92	37.25	37.22	37.22
PUB 2																		
USGC																		
vs. WCS		37.69	38.69	39.07	39.22	39.22		37.55	38.54	38.92	39.07	39.07		37.31	38.30	38.67	38.82	38.82
vs. Mars		38.35	39.45	39.36	39.31	39.31		38.21	39.31	39.21	39.16	39.16		37.97	39.07	38.97	38.91	38.91
vs. Arab Heavy		38.17	39.27	39.61	39.73	39.73		38.03	39.13	39.46	39.58	39.58		37.79	38.88	39.22	39.33	39.33
USMC vs. WCS		37.59	38.73	39.11	39.26	39.26		37.45	38.59	38.96	39.11	39.11		37.21	38.34	38.70	38.84	38.84
China vs. Arab Heavy																		
Pipeline to Vancouver		41.58	43.24	43.37	43.35	43.35		41.41	43.07	43.21	43.18	43.18		41.18	42.83	42.96	42.94	42.94
Rail to Vancouver		34.98	36.64	36.77	36.75	36.75		34.81	36.47	36.61	36.58	36.58		34.58	36.23	36.36	36.34	36.34
PUB 3																		
USGC																		
vs. WCS		32.94	33.94	34.26	34.39	34.39		32.85	33.86	34.17	34.30	34.30		32.70	33.70	34.01	34.14	34.14
vs. Mars		33.60	34.71	34.55	34.49	34.49		33.51	34.62	34.46	34.40	34.40		33.35	34.47	34.30	34.23	34.23
vs. Arab Heavy		33.42	34.53	34.80	34.91	34.91		33.33	34.44	34.71	34.82	34.82		33.18	34.28	34.55	34.66	34.66
USMC vs. WCS		32.99	34.07	34.38	34.52	34.52		32.90	33.98	34.29	34.42	34.42		32.74	33.81	34.12	34.25	34.25
China vs. Arab Heavy																		
Pipeline to Vancouver		36.63	38.35	38.56	38.52	38.52		36.54	38.26	38.47	38.43	38.43		36.38	38.10	38.31	38.27	38.27
Rail to Vancouver		30.03	31.75	31.96	31.92	31.92		29.94	31.66	31.87	31.83	31.83		29.78	31.50	31.71	31.67	31.67
PUB 4 USGC																		
vs. WCS	45.14	42.30	41.45	41.75	41.88	41.88	45.07	42.24	41.38	41.69	41.81	41.81	45.02	42.18	41.32	41.63	41.75	41.75
vs. Mars	44.51	42.96	42.21	42.04	41.97	41.97	44.45	42.89	42.15	41.98	41.91	41.91	44.39	42.84	42.09	41.92	41.84	41.84
vs. Arab Heavy	44.26	42.78	42.03	42.29	42.39	42.39	44.20	42.72	41.97	42.23	42.33	42.33	44.14	42.66	41.91	42.17	42.27	42.27
USMC vs. WCS		40.95	40.83	41.15	41.27	41.27		40.93	40.81	41.13	41.25	41.25		40.90	40.77	41.09	41.21	41.21
China vs. Arab Heavy																		
Pipeline to Vancouver		45.98	45.80	45.71	45.65	45.65		45.89	45.71	45.61	45.55	45.55		45.85	45.67	45.58	45.52	45.52
Rail to Vancouver		39.38	39.20	39.11	39.05	39.05		39.29	39.11	39.01	38.95	38.95		39.25	39.07	38.98	38.92	38.92

Appendix Table III-10B
Forecast PUB Netback Market Values
$60 WTI (Cushing) Pricing Basis

FOB Edmonton/Hardisty - US $ per Barrel

	Low Penetration - 10 MBPD					
	2020	2025	2030	2035	2040	2045
PUB 1						
USGC						
vs. WCS		47.78	49.01	49.52	49.68	49.68
vs. Mars		49.09	50.34	50.29	50.22	50.22
vs. Arab Heavy		48.55	49.83	50.29	50.43	50.43
USMC vs. WCS		48.22	49.22	49.68	49.84	49.84
China vs. Arab Heavy						
Pipeline to Vancouver		51.41	53.37	53.67	53.63	53.63
Rail to Vancouver		44.61	46.57	46.87	46.83	46.83
PUB 2						
USGC						
vs. WCS		46.56	47.65	48.07	48.24	48.24
vs. Mars		47.86	48.98	48.84	48.78	48.78
vs. Arab Heavy		47.33	48.47	48.84	48.98	48.98
USMC vs. WCS		46.45	47.69	48.11	48.28	48.28
China vs. Arab Heavy						
Pipeline to Vancouver		50.85	52.59	52.70	52.67	52.67
Rail to Vancouver		44.05	45.79	45.90	45.87	45.87
PUB 3						
USGC						
vs. WCS		41.22	42.36	42.72	42.88	42.88
vs. Mars		42.52	43.69	43.49	43.41	43.41
vs. Arab Heavy		41.99	43.17	43.49	43.62	43.62
USMC vs. WCS		41.27	42.48	42.85	43.00	43.00
China vs. Arab Heavy						
Pipeline to Vancouver		45.33	47.18	47.36	47.31	47.31
Rail to Vancouver		38.53	40.38	40.56	40.51	40.51
PUB 4						
USGC						
vs. WCS	53.89	51.26	50.46	50.81	50.95	50.95
vs. Mars	53.74	52.57	51.80	51.58	51.49	51.49
vs. Arab Heavy	53.03	52.03	51.28	51.58	51.69	51.69
USMC vs. WCS		49.94	49.86	50.22	50.35	50.35
China vs. Arab Heavy						
Pipeline to Vancouver		55.36	55.21	55.09	55.02	55.02
Rail to Vancouver		48.56	48.41	48.29	48.22	48.22

	Medium Penetration - 40 MBPD					
	2020	2025	2030	2035	2040	2045
PUB 1						
USGC						
vs. WCS		47.65	48.87	49.38	49.54	49.54
vs. Mars		48.95	50.20	50.15	50.08	50.08
vs. Arab Heavy		48.42	49.69	50.15	50.28	50.28
USMC vs. WCS		48.05	49.04	49.49	49.65	49.65
China vs. Arab Heavy						
Pipeline to Vancouver		51.26	53.22	53.51	53.48	53.48
Rail to Vancouver		44.46	46.42	46.71	46.68	46.68
PUB 2						
USGC						
vs. WCS		46.39	47.48	47.90	48.07	48.07
vs. Mars		47.69	48.81	48.67	48.60	48.60
vs. Arab Heavy		47.16	48.30	48.67	48.81	48.81
USMC vs. WCS		46.30	47.53	47.95	48.11	48.11
China vs. Arab Heavy						
Pipeline to Vancouver		50.67	52.40	52.51	52.48	52.48
Rail to Vancouver		43.87	45.60	45.71	45.68	45.68
PUB 3						
USGC						
vs. WCS		41.12	42.26	42.62	42.78	42.78
vs. Mars		42.43	43.59	43.39	43.31	43.31
vs. Arab Heavy		41.89	43.07	43.39	43.52	43.52
USMC vs. WCS		41.17	42.38	42.74	42.89	42.89
China vs. Arab Heavy						
Pipeline to Vancouver		45.23	47.07	47.26	47.21	47.21
Rail to Vancouver		38.43	40.27	40.46	40.41	40.41
PUB 4						
USGC						
vs. WCS	53.81	51.19	50.39	50.73	50.88	50.88
vs. Mars	53.66	52.50	51.72	51.50	51.41	51.41
vs. Arab Heavy	52.96	51.96	51.21	51.50	51.62	51.62
USMC vs. WCS		49.92	49.84	50.20	50.33	50.33
China vs. Arab Heavy						
Pipeline to Vancouver		55.26	55.11	54.99	54.91	54.91
Rail to Vancouver		48.46	48.31	48.19	48.11	48.11

	High Penetration - 100 MBPD					
	2020	2025	2030	2035	2040	2045
PUB 1						
USGC						
vs. WCS		47.39	48.61	49.11	49.27	49.27
vs. Mars		48.69	49.94	49.88	49.81	49.81
vs. Arab Heavy		48.16	49.43	49.88	50.02	50.02
USMC vs. WCS		47.76	48.74	49.18	49.33	49.33
China vs. Arab Heavy						
Pipeline to Vancouver		51.01	52.96	53.26	53.22	53.22
Rail to Vancouver		44.21	46.16	46.46	46.42	46.42
PUB 2						
USGC						
vs. WCS		46.12	47.20	47.62	47.79	47.79
vs. Mars		47.43	48.54	48.39	48.32	48.32
vs. Arab Heavy		46.89	48.02	48.39	48.53	48.53
USMC vs. WCS		46.02	47.25	47.65	47.81	47.81
China vs. Arab Heavy						
Pipeline to Vancouver		50.40	52.13	52.24	52.21	52.21
Rail to Vancouver		43.60	45.33	45.44	45.41	45.41
PUB 3						
USGC						
vs. WCS		40.94	42.08	42.44	42.59	42.59
vs. Mars		42.25	43.41	43.21	43.13	43.13
vs. Arab Heavy		41.71	42.89	43.21	43.33	43.33
USMC vs. WCS		40.99	42.19	42.55	42.70	42.70
China vs. Arab Heavy						
Pipeline to Vancouver		45.05	46.89	47.08	47.03	47.03
Rail to Vancouver		38.25	40.09	40.28	40.23	40.23
PUB 4						
USGC						
vs. WCS	53.75	51.12	50.32	50.66	50.81	50.81
vs. Mars	53.60	52.43	51.65	51.44	51.34	51.34
vs. Arab Heavy	52.89	51.89	51.14	51.44	51.55	51.55
USMC vs. WCS		49.88	49.79	50.15	50.28	50.28
China vs. Arab Heavy						
Pipeline to Vancouver		55.22	55.06	54.94	54.87	54.87
Rail to Vancouver		48.42	48.26	48.14	48.07	48.07

Appendix Table III-10C
Forecast PUB Netback Market Values
$70 WTI (Cushing) Pricing Basis

FOB Edmonton/Hardisty - US $ per Barrel

Low Penetration - 10 MBPD

	2020	2025	2030	2035	2040	2045
PUB 1						
USGC						
vs. WCS		56.85	58.15	58.70	58.88	58.88
vs. Mars		58.81	60.05	59.95	59.86	59.86
vs. Arab Heavy		57.91	59.20	59.70	59.85	59.85
USMC vs. WCS		57.31	58.38	58.87	59.05	59.05
China vs. Arab Heavy						
Pipeline to Vancouver		60.90	62.91	63.18	63.13	63.13
Rail to Vancouver		53.70	55.71	55.98	55.93	55.93
PUB 2						
USGC						
vs. WCS		55.42	56.61	57.08	57.26	57.26
vs. Mars		57.37	58.51	58.33	58.24	58.24
vs. Arab Heavy		56.48	57.66	58.08	58.23	58.23
USMC vs. WCS		55.31	56.65	57.11	57.30	57.30
China vs. Arab Heavy						
Pipeline to Vancouver		60.18	62.00	62.08	62.04	62.04
Rail to Vancouver		52.98	54.80	54.88	54.84	54.84
PUB 3						
USGC						
vs. WCS		49.49	50.77	51.19	51.36	51.36
vs. Mars		51.45	52.66	52.44	52.34	52.34
vs. Arab Heavy		50.55	51.82	52.19	52.33	52.33
USMC vs. WCS		49.55	50.90	51.31	51.49	51.49
China vs. Arab Heavy						
Pipeline to Vancouver		54.09	56.05	56.22	56.16	56.16
Rail to Vancouver		46.89	48.85	49.02	48.96	48.96
PUB 4						
USGC						
vs. WCS	62.64	60.22	59.48	59.87	60.02	60.02
vs. Mars	62.96	62.18	61.38	61.11	61.00	61.00
vs. Arab Heavy	61.79	61.28	60.53	60.87	60.99	60.99
USMC vs. WCS		58.92	58.88	59.28	59.43	59.43
China vs. Arab Heavy						
Pipeline to Vancouver		64.79	64.67	64.52	64.43	64.43
Rail to Vancouver		57.59	57.47	57.32	57.23	57.23

Medium Penetration - 40 MBPD

	2020	2025	2030	2035	2040	2045
PUB 1						
USGC						
vs. WCS		56.70	57.99	58.54	58.72	58.72
vs. Mars		58.65	59.89	59.79	59.70	59.70
vs. Arab Heavy		57.76	59.04	59.54	59.69	59.69
USMC vs. WCS		57.11	58.18	58.66	58.84	58.84
China vs. Arab Heavy						
Pipeline to Vancouver		60.73	62.74	63.01	62.96	62.96
Rail to Vancouver		53.53	55.54	55.81	55.76	55.76
PUB 2						
USGC						
vs. WCS		55.23	56.42	56.89	57.07	57.07
vs. Mars		57.18	58.31	58.13	58.05	58.05
vs. Arab Heavy		56.29	57.47	57.88	58.04	58.04
USMC vs. WCS		55.14	56.47	56.93	57.11	57.11
China vs. Arab Heavy						
Pipeline to Vancouver		59.97	61.78	61.87	61.83	61.83
Rail to Vancouver		52.77	54.58	54.67	54.63	54.63
PUB 3						
USGC						
vs. WCS		49.38	50.66	51.08	51.25	51.25
vs. Mars		51.34	52.55	52.32	52.23	52.23
vs. Arab Heavy		50.44	51.71	52.07	52.22	52.22
USMC vs. WCS		49.44	50.78	51.19	51.37	51.37
China vs. Arab Heavy						
Pipeline to Vancouver		53.97	55.93	56.10	56.04	56.04
Rail to Vancouver		46.77	48.73	48.90	48.84	48.84
PUB 4						
USGC						
vs. WCS	62.55	60.14	59.40	59.78	59.94	59.94
vs. Mars	62.88	62.10	61.29	61.03	60.92	60.92
vs. Arab Heavy	61.71	61.20	60.45	60.78	60.91	60.91
USMC vs. WCS		58.90	58.86	59.26	59.41	59.41
China vs. Arab Heavy						
Pipeline to Vancouver		64.68	64.56	64.41	64.32	64.32
Rail to Vancouver		57.48	57.36	57.21	57.12	57.12

High Penetration - 100 MBPD

	2020	2025	2030	2035	2040	2045
PUB 1						
USGC						
vs. WCS		56.41	57.70	58.24	58.42	58.42
vs. Mars		58.36	59.60	59.49	59.40	59.40
vs. Arab Heavy		57.47	58.75	59.24	59.39	59.39
USMC vs. WCS		56.79	57.84	58.31	58.48	58.48
China vs. Arab Heavy						
Pipeline to Vancouver		60.45	62.45	62.72	62.68	62.68
Rail to Vancouver		53.25	55.25	55.52	55.48	55.48
PUB 2						
USGC						
vs. WCS		54.93	56.11	56.57	56.75	56.75
vs. Mars		56.88	58.01	57.82	57.73	57.73
vs. Arab Heavy		55.99	57.16	57.57	57.72	57.72
USMC vs. WCS		54.84	56.15	56.60	56.77	56.77
China vs. Arab Heavy						
Pipeline to Vancouver		59.67	61.48	61.57	61.52	61.52
Rail to Vancouver		52.47	54.28	54.37	54.32	54.32
PUB 3						
USGC						
vs. WCS		49.18	50.45	50.87	51.04	51.04
vs. Mars		51.14	52.35	52.12	52.02	52.02
vs. Arab Heavy		50.24	51.50	51.87	52.01	52.01
USMC vs. WCS		49.24	50.57	50.98	51.15	51.15
China vs. Arab Heavy						
Pipeline to Vancouver		53.78	55.73	55.90	55.84	55.84
Rail to Vancouver		46.58	48.53	48.70	48.64	48.64
PUB 4						
USGC						
vs. WCS	62.48	60.06	59.32	59.70	59.86	59.86
vs. Mars	62.81	62.02	61.22	60.95	60.84	60.84
vs. Arab Heavy	61.64	61.12	60.37	60.70	60.83	60.83
USMC vs. WCS		58.86	58.81	59.21	59.35	59.35
China vs. Arab Heavy						
Pipeline to Vancouver		64.63	64.51	64.36	64.27	64.27
Rail to Vancouver		57.43	57.31	57.16	57.07	57.07

Appendix Table III-10D
Forecast PUB Netback Market Values
$80 WTI (Cushing) Pricing Basis

FOB Edmonton/Hardisty - US $ per Barrel

	Low Penetration - 10 MBPD						Medium Penetration - 40 MBPD						High Penetration - 100 MBPD					
	2020	2025	2030	2035	2040	2045	2020	2025	2030	2035	2040	2045	2020	2025	2030	2035	2040	2045
PUB 1																		
USGC																		
vs. WCS		65.92	67.29	67.88	68.08	68.08		65.75	67.12	67.70	67.90	67.90		65.43	66.79	67.37	67.57	67.57
vs. Mars		68.53	69.76	69.61	69.50	69.50		68.35	69.58	69.43	69.32	69.32		68.03	69.25	69.10	68.99	68.99
vs. Arab Heavy		67.27	68.57	69.11	69.28	69.28		67.10	68.40	68.93	69.10	69.10		66.78	68.07	68.60	68.77	68.77
USMC vs. WCS		66.40	67.54	68.06	68.26	68.26		66.18	67.31	67.83	68.03	68.03		65.82	66.93	67.44	67.63	67.63
China vs. Arab Heavy																		
Pipeline to Vancouver		70.18	72.25	72.49	72.43	72.43		70.00	72.06	72.30	72.24	72.24		69.69	71.74	71.98	71.93	71.93
Rail to Vancouver		62.88	64.95	65.19	65.13	65.13		62.70	64.76	65.00	64.94	64.94		62.39	64.44	64.68	64.63	64.63
PUB 2																		
USGC																		
vs. WCS		64.28	65.57	66.08	66.29	66.29		64.07	65.36	65.87	66.07	66.07		63.73	65.01	65.52	65.72	65.72
vs. Mars		66.89	68.03	67.81	67.71	67.71		66.67	67.82	67.60	67.49	67.49		66.33	67.48	67.25	67.14	67.14
vs. Arab Heavy		65.63	66.85	67.31	67.48	67.48		65.42	66.64	67.10	67.27	67.27		65.08	66.30	66.75	66.92	66.92
USMC vs. WCS		64.18	65.61	66.11	66.31	66.31		63.99	65.41	65.91	66.11	66.11		63.65	65.06	65.55	65.74	65.74
China vs. Arab Heavy																		
Pipeline to Vancouver		69.30	71.20	71.26	71.21	71.21		69.07	70.97	71.03	70.98	70.98		68.75	70.63	70.70	70.64	70.64
Rail to Vancouver		62.00	63.90	63.96	63.91	63.91		61.77	63.67	63.73	63.68	63.68		61.45	63.33	63.40	63.34	63.34
PUB 3																		
USGC																		
vs. WCS		57.77	59.18	59.65	59.85	59.85		57.65	59.06	59.53	59.72	59.72		57.43	58.83	59.30	59.49	59.49
vs. Mars		60.37	61.64	61.38	61.27	61.27		60.25	61.52	61.25	61.14	61.14		60.03	61.29	61.03	60.92	60.92
vs. Arab Heavy		59.12	60.46	60.88	61.04	61.04		59.00	60.34	60.76	60.92	60.92		58.78	60.11	60.53	60.69	60.69
USMC vs. WCS		57.83	59.31	59.78	59.97	59.97		57.71	59.18	59.65	59.84	59.84		57.49	58.95	59.41	59.60	59.60
China vs. Arab Heavy																		
Pipeline to Vancouver		62.65	64.72	64.87	64.80	64.80		62.52	64.59	64.74	64.67	64.67		62.30	64.37	64.52	64.46	64.46
Rail to Vancouver		55.35	57.42	57.57	57.50	57.50		55.22	57.29	57.44	57.37	57.37		55.00	57.07	57.22	57.16	57.16
PUB 4																		
USGC																		
vs. WCS	71.38	69.18	68.50	68.92	69.10	69.10	71.29	69.09	68.40	68.83	69.01	69.01	71.21	69.01	68.32	68.74	68.92	68.92
vs. Mars	72.19	71.79	70.96	70.65	70.52	70.52	72.09	71.70	70.87	70.56	70.43	70.43	72.01	71.61	70.78	70.47	70.34	70.34
vs. Arab Heavy	70.56	70.53	69.78	70.15	70.30	70.30	70.47	70.44	69.69	70.06	70.20	70.20	70.39	70.36	69.60	69.97	70.12	70.12
USMC vs. WCS		67.91	67.91	68.34	68.51	68.51		67.89	67.89	68.32	68.48	68.48		67.83	67.83	68.26	68.43	68.43
China vs. Arab Heavy																		
Pipeline to Vancouver		74.01	73.93	73.75	73.65	73.65		73.90	73.81	73.63	73.53	73.53		73.85	73.76	73.58	73.48	73.48
Rail to Vancouver		66.71	66.63	66.45	66.35	66.35		66.60	66.51	66.33	66.23	66.23		66.55	66.46	66.28	66.18	66.18

Appendix Table V-1
WCS vs. Maya
Market Price vs. Refining Value Backcast
(US $ per Barrel)

	Feb-16	Mar-16	Apr-16	May-16	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17
Maya FOB	24.84	29.45	31.97	38.89	42.36	39.91	38.83	38.53	43.18	39.68	45.73	45.61	45.92	42.67	44.84	45.01	42.04
Transportation to Nederland	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Maya Nederland	25.54	30.15	32.67	39.59	43.06	40.61	39.53	39.23	43.88	40.38	46.43	46.31	46.62	43.37	45.54	45.71	42.74
WCS Nederland	24.25	29.86	32.95	39.35	41.06	36.20	37.00	37.49	42.06	38.08	45.08	46.24	47.20	44.77	46.83	43.99	40.92
WCS Market Discount vs. Maya	1.29	0.28	-0.28	0.24	2.01	4.41	2.53	1.74	1.83	2.29	1.34	0.07	-0.58	-1.40	-1.28	1.73	1.82
Refining Value Delta, WCS - Maya [1]	-0.24	0.05	0.05	-0.05	-0.15	-0.12	-0.07	-0.04	-0.15	-0.31	-0.15	0.00	0.03	0.12	0.04	0.03	0.07
Calculated TAN/Other Commercial Discount	**1.05**	**0.33**	**-0.23**	**0.19**	**1.86**	**4.29**	**2.46**	**1.71**	**1.68**	**1.99**	**1.19**	**0.07**	**-0.55**	**-1.28**	**-1.24**	**1.75**	**1.89**

[1] Estimated using TM&C Midcontinent delayed coking refinery model

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Appendix Table V-1
WCS vs. Maya
Market Price vs. Refining Value Backcast
(US $ per Barrel)

	Jul-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18	Annual Averages 2016	2017	2018
Maya FOB	44.39	48.77	49.42	54.85	55.25	59.61	56.70	56.84	58.04	63.44	64.67	66.60	63.11	68.72	75.53	37.58	47.08	63.33
Transportation to Nederland	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Maya Nederland	45.09	49.47	50.12	55.55	55.95	60.31	57.40	57.54	58.74	64.14	65.37	67.30	63.81	69.42	76.23	38.28	47.78	64.03
WCS Nederland	42.81	45.93	47.24	51.86	53.33	59.99	57.20	58.15	62.23	66.36	67.22	66.01	64.68	69.91	70.33	36.67	46.31	64.21
WCS Market Discount vs. Maya	2.27	3.54	2.88	3.69	2.62	0.31	0.20	-0.62	-3.49	-2.22	-1.85	1.29	-0.87	-0.48	5.90	1.61	1.48	-0.18
Refining Value Delta, WCS - Maya [1]	-0.03	-0.15	-0.09	-0.13	-0.27	0.29	0.30	0.21	0.25	0.23	0.17	0.03	0.12	0.21	0.41	-0.11	-0.04	0.22
Calculated TAN/Other Commercial Discount	**2.25**	**3.39**	**2.79**	**3.57**	**2.35**	**0.60**	**0.50**	**-0.40**	**-3.24**	**-1.99**	**-1.68**	**1.32**	**-0.75**	**-0.28**	**6.31**	**1.50**	**1.44**	**0.04**

[1] Estimated using TM&C Midcontinent delayed coking refinery model

Appendix Table V-2
AWB vs. WCS
Market Price vs. Refining Value Backcast
(US $ per Barrel)

	Jan-16	Feb-16	Mar-16	Apr-16	May-16	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17
AWB Market Discount vs. WCS [(1)]	2.32	2.23	2.51	3.40	2.75	3.20	2.80	2.57	2.51	2.19	1.88	2.08	2.39	1.97	2.43	2.09	4.23	2.10
Estimated Transportation to Hardisty	0.53	0.53	0.53	0.54	0.54	0.54	0.54	0.55	0.55	0.55	0.55	0.55	0.56	0.56	0.56	0.56	0.56	0.57
Market Discount at Hardisty	1.79	1.70	1.98	2.86	2.21	2.66	2.26	2.02	1.96	1.64	1.33	1.53	1.83	1.41	1.87	1.53	3.67	1.53
Refining Value Delta, WCS-AWB [(2)]	0.88	1.26	0.78	0.68	0.74	0.71	0.85	0.82	0.89	0.97	0.89	0.82	0.83	0.88	0.86	0.78	0.82	0.81
Calculated TAN/Other Commercial Discount	**0.91**	**0.44**	**1.19**	**2.18**	**1.47**	**1.94**	**1.41**	**1.20**	**1.07**	**0.67**	**0.43**	**0.70**	**1.01**	**0.53**	**1.01**	**0.75**	**2.85**	**0.72**

(1) AWB (Edmonton) - WCS (Hardisty) market prices

(2) Estimated using TM&C Midcontinent delayed coking refinery model

Appendix Table V-2
AWB vs. WCS
Market Price vs. Refining Value Backcast
(US $ per Barrel)

	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18	Annual Averages 2016	2017	2018
AWB Market Discount vs. WCS (1)	2.13	1.90	1.74	2.27	1.97	2.67	2.85	3.20	3.44	3.42	2.58	2.86	2.88	2.85	4.60	4.57	2.54	2.32	3.33
Estimated Transportation to Hardisty	0.57	0.57	0.57	0.58	0.58	0.58	0.58	0.59	0.59	0.59	0.59	0.60	0.60	0.60	0.60	0.60	0.54	0.57	0.59
Market Discount at Hardisty	1.56	1.33	1.17	1.69	1.39	2.09	2.27	2.61	2.85	2.83	1.99	2.26	2.28	2.25	4.00	3.97	1.99	1.76	2.73
Refining Value Delta, WCS-AWB (2)	0.84	0.88	0.99	0.97	0.96	1.04	1.09	1.06	0.81	0.81	0.93	0.86	0.93	0.98	1.00	1.40	0.86	0.89	0.99
Calculated TAN/Other Commercial Discount	**0.72**	**0.45**	**0.17**	**0.73**	**0.43**	**1.04**	**1.17**	**1.56**	**2.04**	**2.02**	**1.06**	**1.40**	**1.35**	**1.27**	**3.00**	**2.57**	**1.14**	**0.87**	**1.74**

(1) AWB (Edmonton) - WCS (Hardisty) market prices

(2) Estimated using TM&C Midcontinent delayed coking refinery model

Appendix Table V-3
CDB vs. WCS
Market Price vs. Refining Value Backcast
(US $ per Barrel)

	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18	Avg 2018
CDB Market Discount vs. WCS (1)	2.34	2.67	3.03	3.30	2.17	2.12	2.54	2.28	3.99	3.56	2.80
Estimated Transportation to Hardisty	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Market Discount at Hardisty	2.34	2.67	3.03	3.30	2.17	2.12	2.54	2.28	3.99	3.56	2.80
Refining Value Delta, WCS-WDB (2)	0.98	0.95	0.73	0.73	0.83	0.78	0.84	0.89	0.90	1.26	0.89
Calculated TAN/Other Commercial Discount	**1.36**	**1.72**	**2.30**	**2.57**	**1.34**	**1.34**	**1.70**	**1.39**	**3.09**	**2.30**	**1.91**

(1) WDB (Edmonton) - WCS (Hardisty) market prices

(2) Estimated using TM&C Midcontinent delayed coking refinery model

Appendix Table V-4
WDB vs. WCS
Market Price vs. Refining Value Backcast

(US $ per Barrel)

	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18	2018
WDB Market Discount vs. WCS (1)	3.76	4.74	4.38	4.65	3.40	3.64	3.19	3.12	4.62	4.71	4.02
Estimated Transportation to Hardisty	0.58	0.59	0.59	0.59	0.59	0.60	0.60	0.60	0.60	0.60	0.59
Market Discount at Hardisty	3.18	4.15	3.79	4.06	2.81	3.04	2.59	2.52	4.02	4.11	3.43
Refining Value Delta, WCS-WDB (2)	1.42	1.37	1.05	1.05	1.21	1.12	1.21	1.28	1.30	1.82	1.28
Calculated TAN/Other Commercial Discount	**1.76**	**2.78**	**2.74**	**3.01**	**1.60**	**1.92**	**1.38**	**1.24**	**2.71**	**2.29**	**2.14**

(1) WDB (Edmonton) - WCS (Hardisty) market prices

(2) Estimated using TM&C Midcontinent delayed coking refinery model

Appendix Table V-5
Estimated TAN and Other Commercial/Market Value Adjustments
USGC
(US $ per Barrel)

	TAN	2025	2026	2027	2028	2029	2030	2031+
Reference Crude								
WCS	0.98							
TAN Discount		(0.50)	(0.45)	(0.40)	(0.35)	(0.30)	(0.25)	(0.25)
Other Commercial/Market Discounts (2)		(0.25)	(0.10)	(0.05)	0.00	0.00	0.00	0.00
Total (Discount)/Premium		**(0.75)**	**(0.55)**	**(0.45)**	**(0.35)**	**(0.30)**	**(0.25)**	**(0.25)**
PUBs								
PUB 1	1.65							
TAN Discount		(1.00)	(0.95)	(0.90)	(0.80)	(0.70)	(0.60)	(0.50)
Other Commercial/Market Discounts (1)		(1.00)	(0.75)	(0.40)	(0.25)	(0.15)	(0.05)	0.00
Total (Discount)/Premium		**(2.00)**	**(1.70)**	**(1.30)**	**(1.05)**	**(0.85)**	**(0.65)**	**(0.50)**
vs. WCS		(1.25)	(1.15)	(0.85)	(0.70)	(0.55)	(0.40)	(0.25)
PUB 2	0.30							
TAN Discount		0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Commercial/Market Discounts (1)		(1.00)	(0.75)	(0.40)	(0.25)	(0.15)	(0.05)	0.00
Total (Discount)/Premium		**(1.00)**	**(0.75)**	**(0.40)**	**(0.25)**	**(0.15)**	**(0.05)**	**0.00**
vs. WCS		(0.25)	(0.20)	0.05	0.10	0.15	0.20	0.25
PUB 3	0.90							
TAN Discount		(0.50)	(0.45)	(0.40)	(0.35)	(0.30)	(0.25)	(0.25)
Other Commercial/Market Discounts (1)		(0.40)	(0.20)	(0.10)	(0.05)	0.00	0.00	0.00
Total (Discount)/Premium		**(0.90)**	**(0.65)**	**(0.50)**	**(0.40)**	**(0.30)**	**(0.25)**	**(0.25)**
vs. WCS		(0.15)	(0.10)	(0.05)	(0.05)	0.00	0.00	0.00
PUB 4	<0.1							
TAN Discount		0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Commercial/Market Discounts (1)		(0.70)	(0.40)	(0.25)	(0.15)	(0.10)	(0.05)	0.00
Premium for low sulfur resid (2)		0.50	0.40	0.30	0.25	0.20	0.15	0.10
Total (Discount)/Premium		**(0.20)**	**0.00**	**0.05**	**0.10**	**0.10**	**0.10**	**0.10**
vs. WCS		0.55	0.55	0.50	0.45	0.40	0.35	0.35

(1) Market entry discounts, other commercial adjustments, etc.

(2) Above and beyond model captured value.

Appendix Table V-6
Estimated TAN and Other Commercial/Market Value Adjustments
USMC
(US $ per Barrel)

	TAN	2025	2026	2027	2028	2029	2030	2031+
Reference Crude								
WCS	0.98							
TAN Discount		(0.25)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)
Other Commercial/Market Discounts (2)		0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (Discount)/Premium		**(0.25)**	**(0.25)**	**(0.25)**	**(0.25)**	**(0.25)**	**(0.25)**	**(0.25)**
PUBs								
PUB 1	1.65							
TAN Discount		(0.60)	(0.60)	(0.60)	(0.55)	(0.55)	(0.55)	(0.50)
Other Commercial/Market Discounts (1)		(0.70)	(0.50)	(0.35)	(0.25)	(0.15)	(0.05)	0.00
Total (Discount)/Premium		**(1.30)**	**(1.10)**	**(0.95)**	**(0.80)**	**(0.70)**	**(0.60)**	**(0.50)**
vs. WCS		(1.05)	(0.85)	(0.70)	(0.55)	(0.45)	(0.35)	(0.25)
PUB 2	0.30							
TAN Discount		0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Commercial/Market Discounts (1)		(0.70)	(0.50)	(0.35)	(0.25)	(0.15)	(0.05)	0.00
Total (Discount)/Premium		**(0.70)**	**(0.50)**	**(0.35)**	**(0.25)**	**(0.15)**	**(0.05)**	**0.00**
vs. WCS		(0.45)	(0.25)	(0.10)	0.00	0.10	0.20	0.25
PUB 3	0.90							
TAN Discount		(0.25)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)
Other Commercial/Market Discounts (1)		(0.25)	(0.15)	(0.05)	0.00	0.00	0.00	0.00
Total (Discount)/Premium		**(0.50)**	**(0.40)**	**(0.30)**	**(0.25)**	**(0.25)**	**(0.25)**	**(0.25)**
vs. WCS		(0.25)	(0.15)	(0.05)	0.00	0.00	0.00	0.00
PUB 4	<0.1							
TAN Discount		0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Commercial/Market Discounts (1)		(0.50)	(0.40)	(0.25)	(0.15)	(0.10)	(0.05)	0.00
Premium for low sulfur resid (2)		0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (Discount)/Premium		**(0.50)**	**(0.40)**	**(0.25)**	**(0.15)**	**(0.10)**	**(0.05)**	**0.00**
vs. WCS		(0.25)	(0.15)	0.00	0.10	0.15	0.20	0.25

(1) Market entry discounts, other commercial adjustments, etc.

(2) Above and beyond model captured value.

Appendix Table V-7
Estimated TAN and Other Commercial/Market Value Adjustments
China
(US $ per Barrel)

	TAN	2025	2026	2027	2028	2029	2030	2031	2032+
Reference Crude									
Arab Heavy	<0.1								
TAN Discount		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Commercial/Market Discounts [2]		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (Discount)/Premium		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
PUBs									
PUB 1	1.65								
TAN Discount		(1.20)	(1.10)	(1.00)	(0.90)	(0.80)	(0.70)	(0.60)	(0.50)
Other Commercial/Market Discounts [1]		(1.50)	(1.20)	(0.80)	(0.50)	(0.30)	(0.20)	(0.10)	0.00
Total (Discount)/Premium		**(2.70)**	**(2.30)**	**(1.80)**	**(1.40)**	**(1.10)**	**(0.90)**	**(0.70)**	**(0.50)**
PUB 2	0.30								
TAN Discount		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Commercial/Market Discounts [1]		(1.50)	(1.20)	(0.80)	(0.50)	(0.30)	(0.20)	(0.10)	0.00
Total (Discount)/Premium		**(1.50)**	**(1.20)**	**(0.80)**	**(0.50)**	**(0.30)**	**(0.20)**	**(0.10)**	**0.00**
PUB 3	0.90								
TAN Discount		(0.60)	(0.55)	(0.50)	(0.45)	(0.40)	(0.35)	(0.30)	(0.25)
Other Commercial/Market Discounts [1]		(1.00)	(0.70)	(0.50)	(0.40)	(0.30)	(0.20)	(0.10)	0.00
Total (Discount)/Premium		**(1.60)**	**(1.25)**	**(1.00)**	**(0.85)**	**(0.70)**	**(0.55)**	**(0.40)**	**(0.25)**
PUB 4	<0.1								
TAN Discount		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Commercial/Market Discounts [1]		(1.00)	(0.70)	(0.40)	(0.25)	(0.15)	(0.10)	(0.05)	0.00
Premium for low sulfur resid [2]		0.50	0.40	0.30	0.25	0.20	0.15	0.10	0.10
Total (Discount)/Premium		**(0.50)**	**(0.30)**	**(0.10)**	**0.00**	**0.05**	**0.05**	**0.05**	**0.10**

[1] Market entry discounts, other commercial adjustments, etc.

[2] Above and beyond model captured value.

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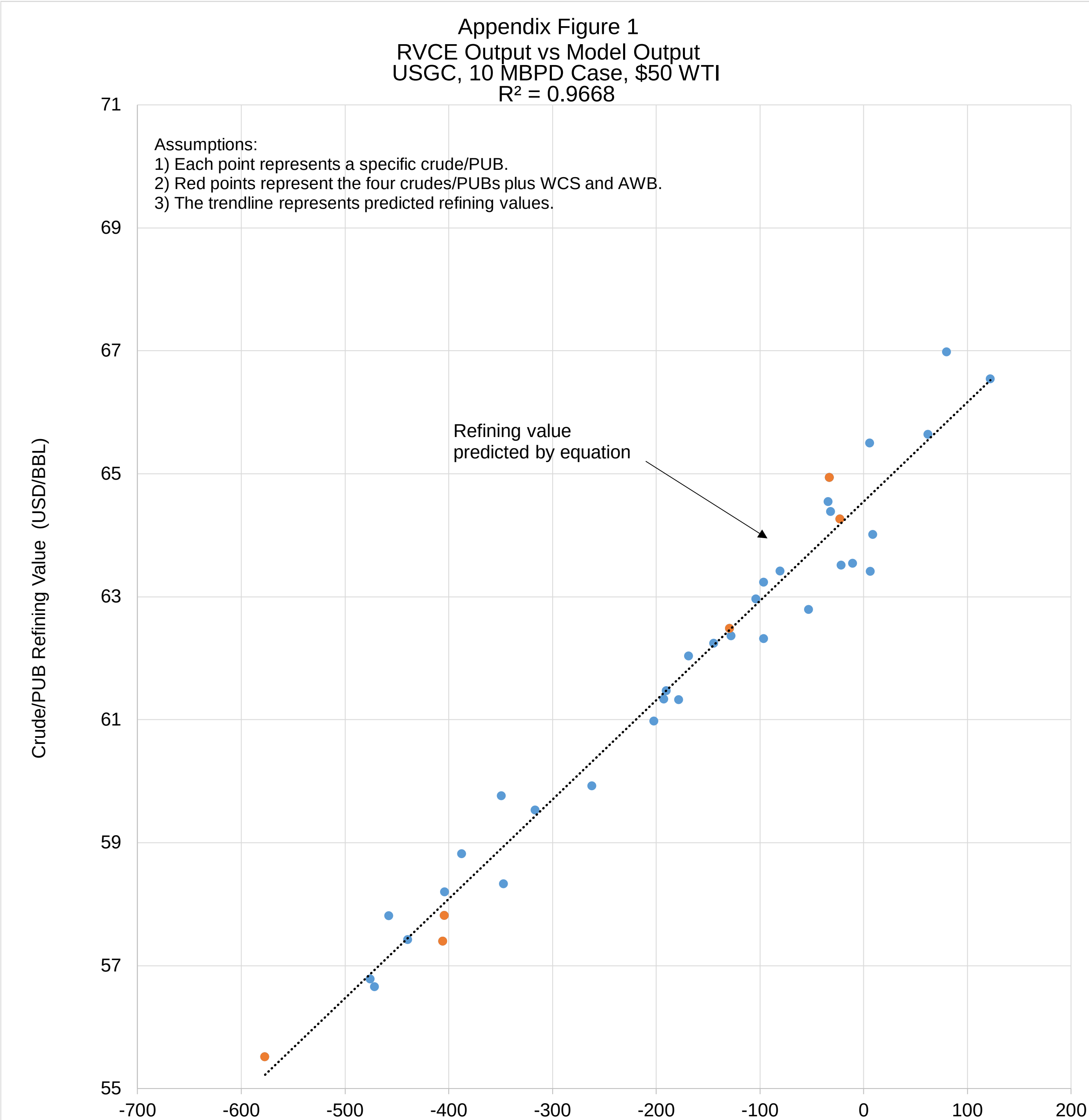
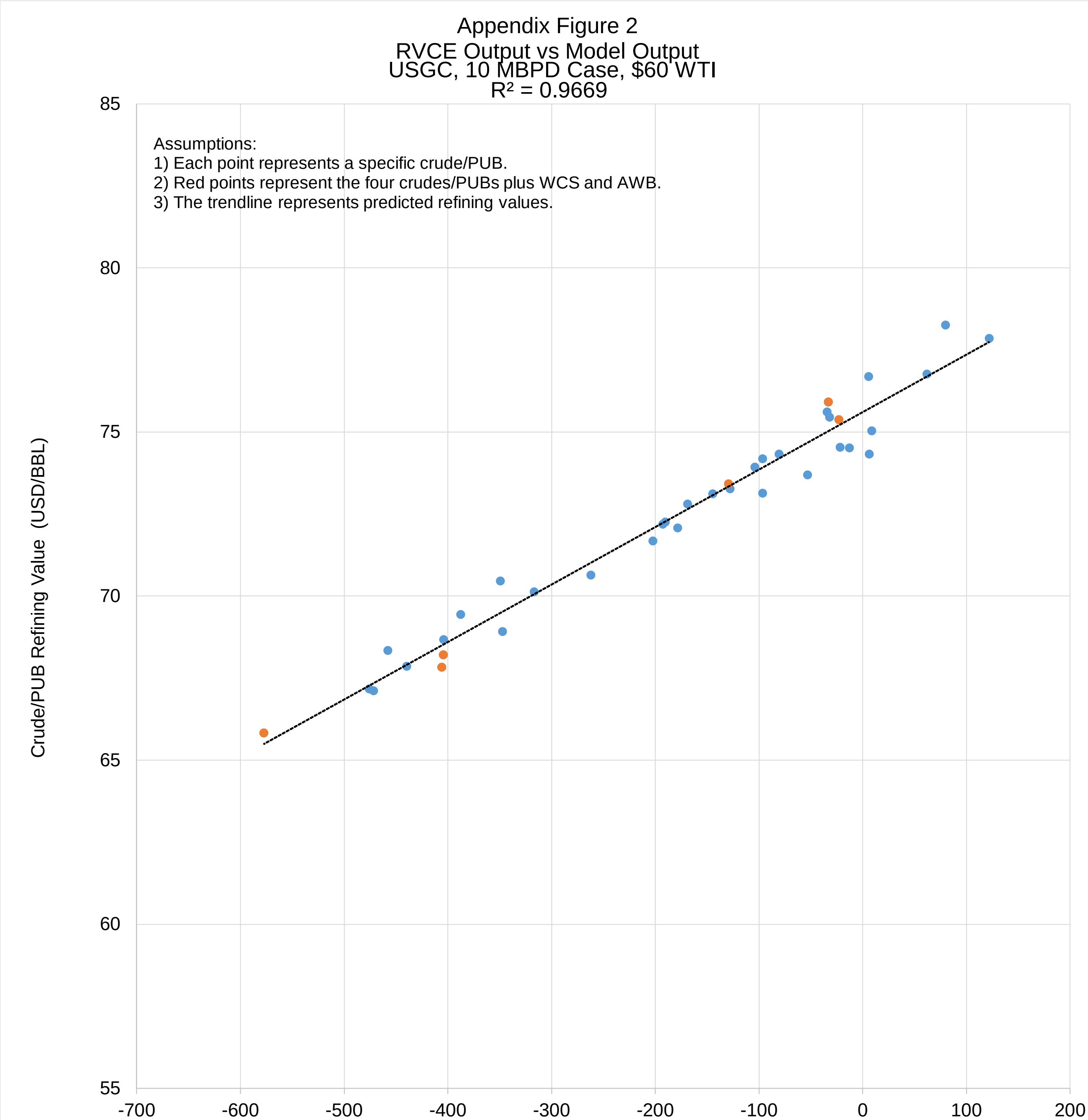
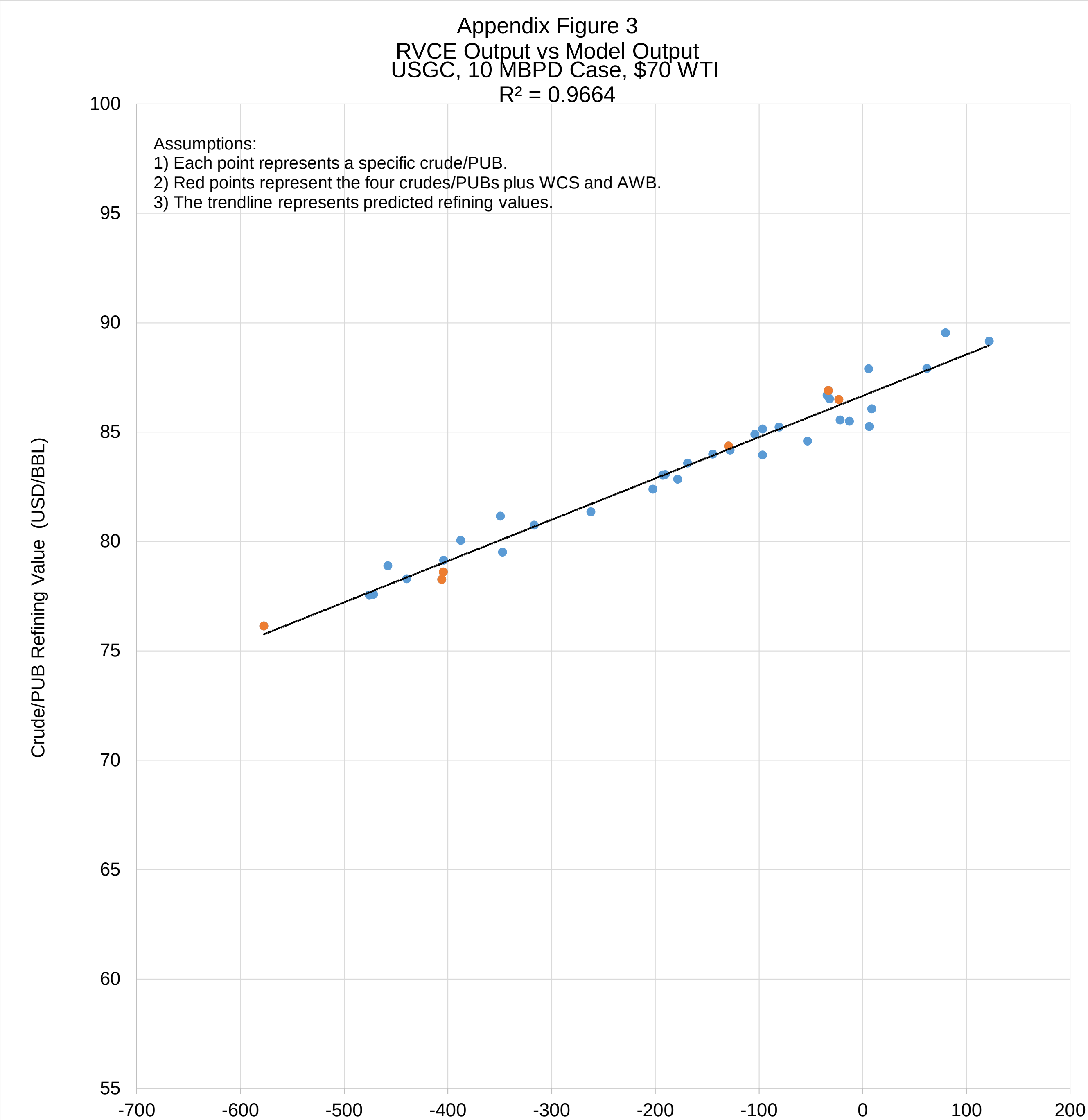
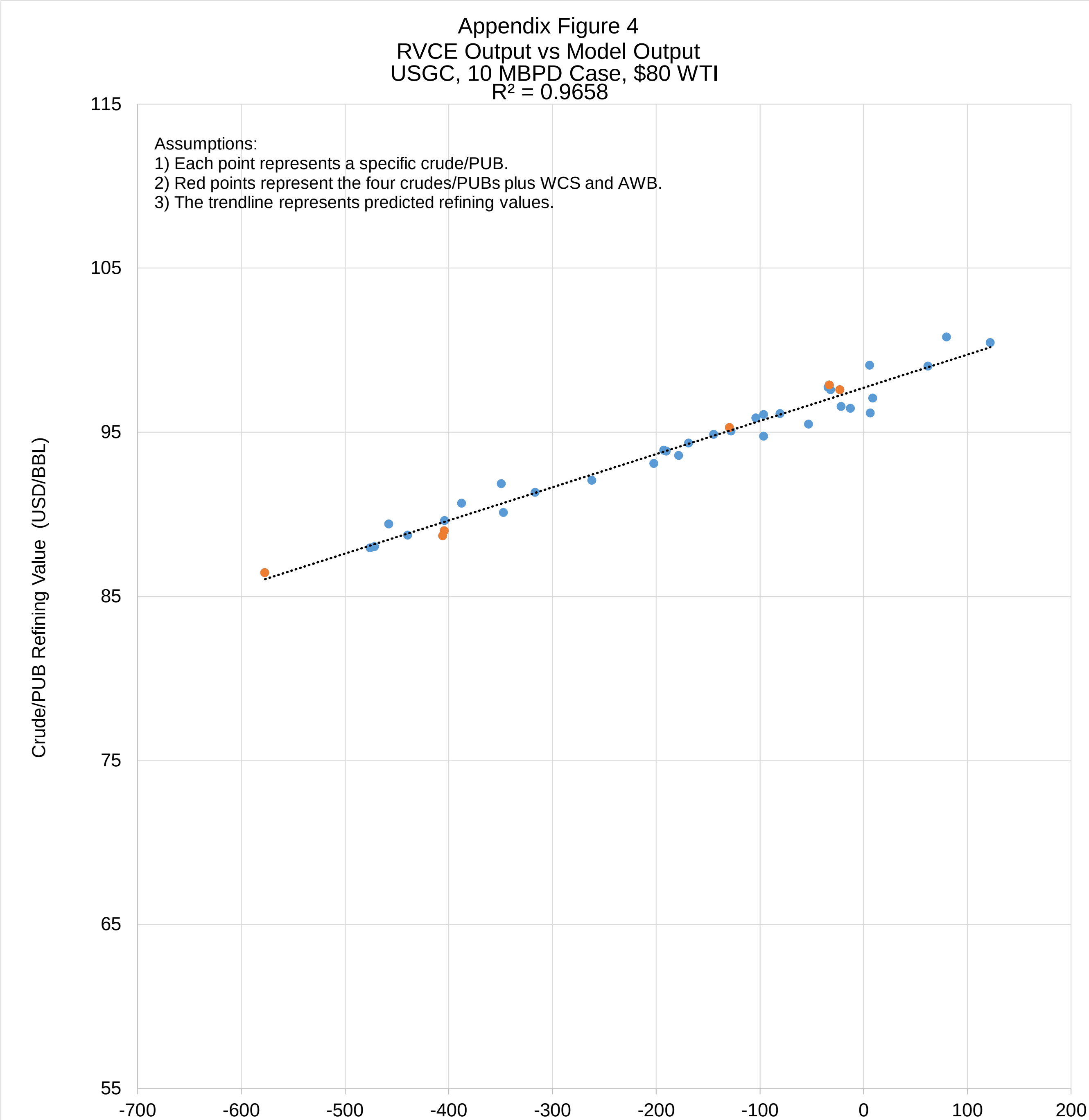
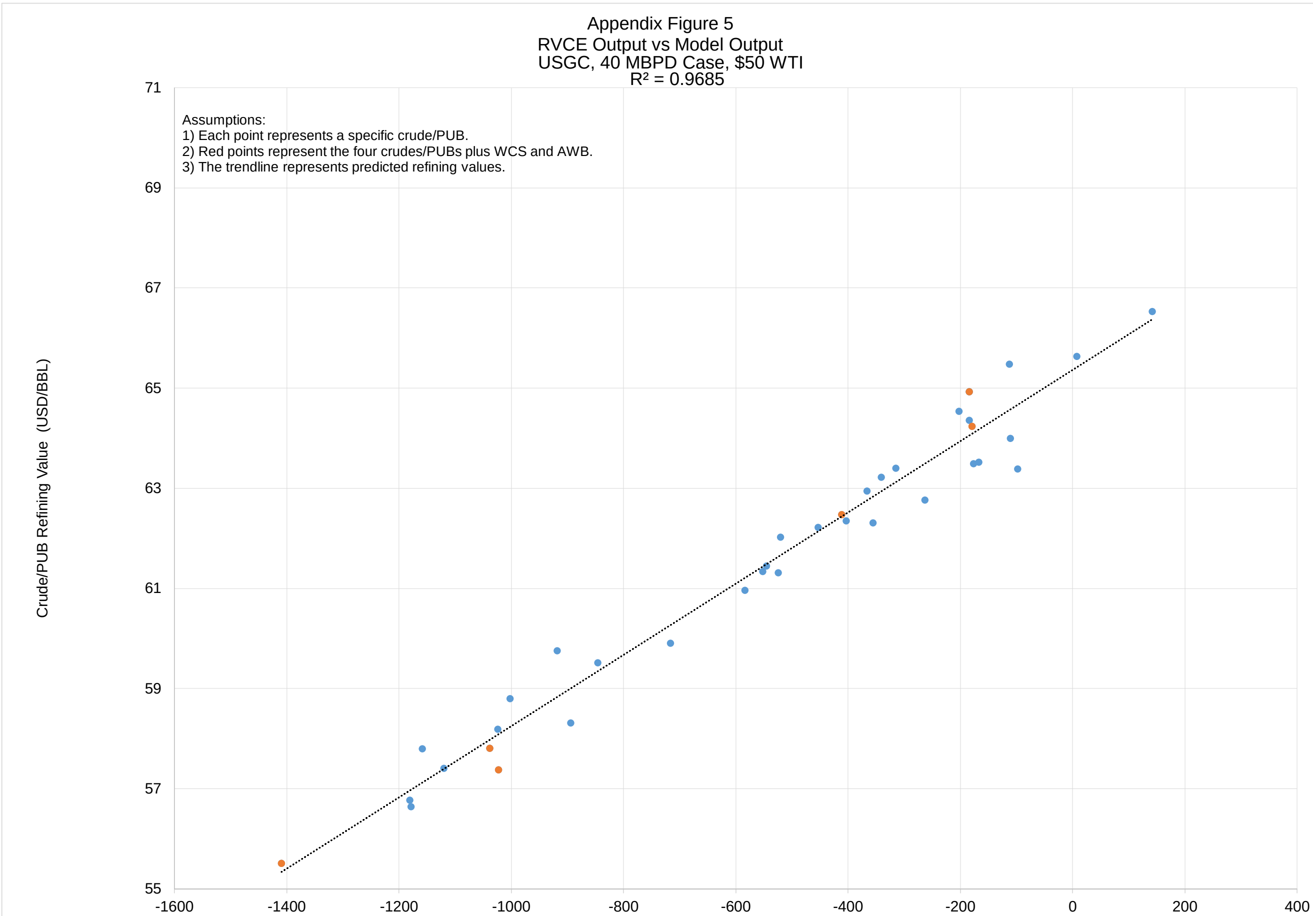


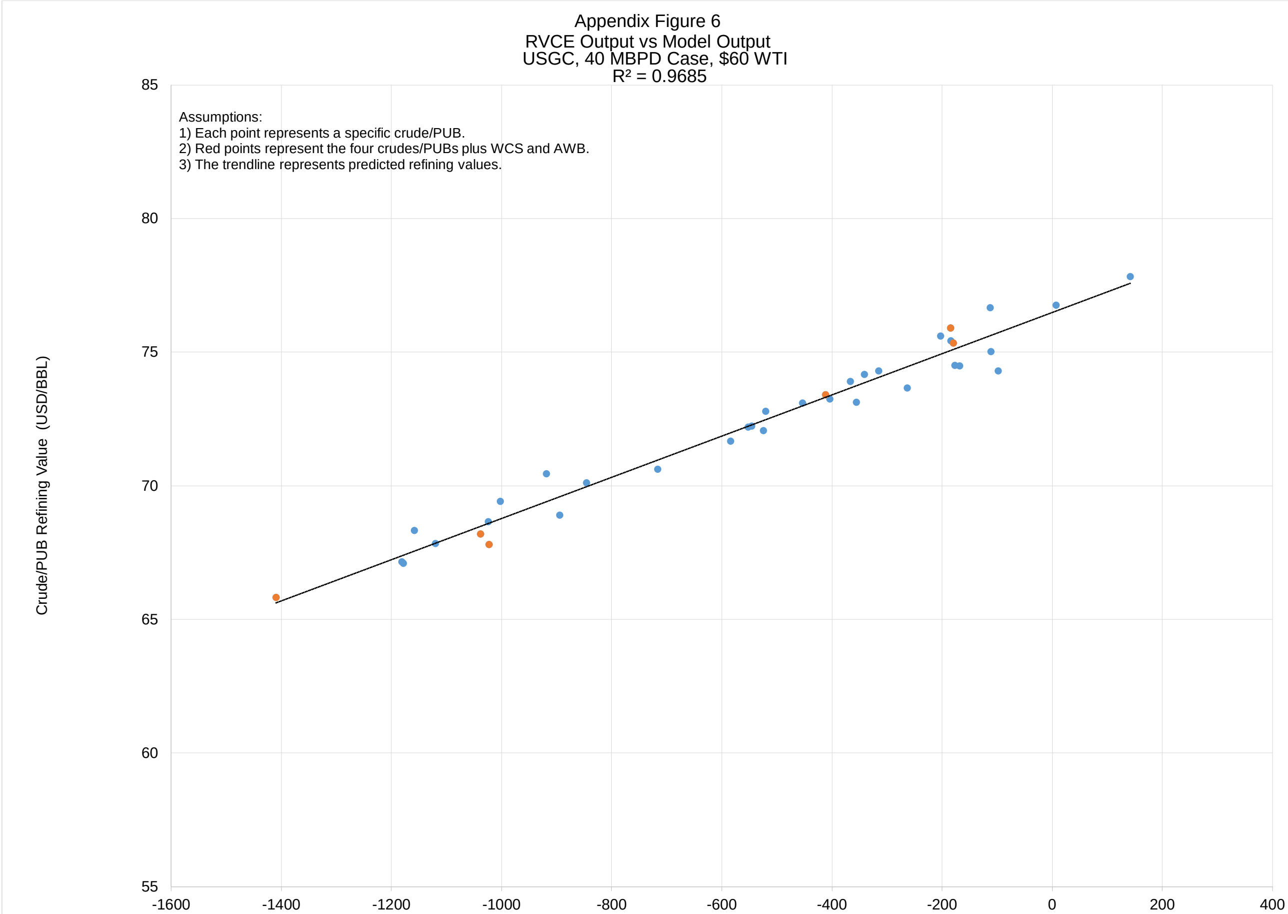
Appendix Figure 1
RVCE Output vs Model Output
USGC, 10 MBPD Case, $50 WTI
R² = 0.9668
Assumptions:
1) Each point represents a specific crude/PUB.
2) Red points represent the four crudes/PUBs plus WCS and AWB.
3) The trendline represents predicted refining values.
Refining value
predicted by equation
Crude/PUB Refining Value (USD/BBL)
71
69
67
65
63
61
59
57
55
-700
-600
-500
-400
-300
-200
-100
0
100
200

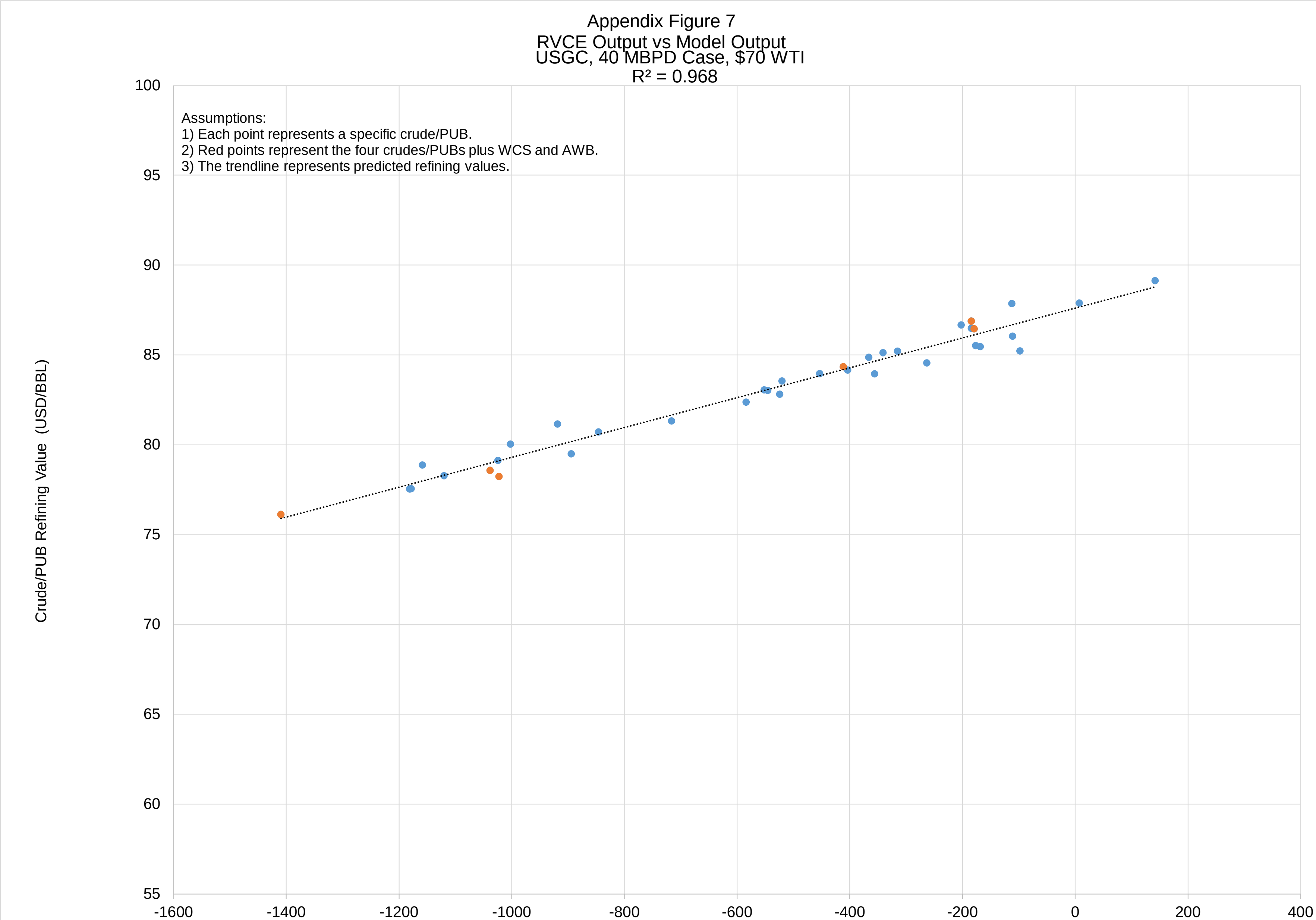

Appendix Figure 2
RVCE Output vs Model Output
USGC, 10 MBPD Case, $60 WTI
R² = 0.9669
Assumptions:
1) Each point represents a specific crude/PUB.
2) Red points represent the four crudes/PUBs plus WCS and AWB.
3) The trendline represents predicted refining values.
Crude/PUB Refining Value (USD/BBL)
85
80
75
70
65
60
55
-700
-600
-500
-400
-300
-200
-100
0
100
200


Appendix Figure 3
RVCE Output vs Model Output
USGC, 10 MBPD Case, $70 WTI
R² = 0.9664
Assumptions:
1) Each point represents a specific crude/PUB.
2) Red points represent the four crudes/PUBs plus WCS and AWB.
3) The trendline represents predicted refining values.
Crude/PUB Refining Value (USD/BBL)
100
95
90
85
80
75
70
65
60
55
-700
-600
-500
-400
-300
-200
-100
0
100
200


Appendix Figure 4
RVCE Output vs Model Output
USGC, 10 MBPD Case, $80 WTI
R² = 0.9658
Assumptions:
1) Each point represents a specific crude/PUB.
2) Red points represent the four crudes/PUBs plus WCS and AWB.
3) The trendline represents predicted refining values.
Crude/PUB Refining Value (USD/BBL)
115
105
95
85
75
65
55
-700
-600
-500
-400
-300
-200
-100
0
100
200


Appendix Figure 5
RVCE Output vs Model Output
USGC, 40 MBPD Case, $50 WTI
R² = 0.9685
Assumptions:
1) Each point represents a specific crude/PUB.
2) Red points represent the four crudes/PUBs plus WCS and AWB.
3) The trendline represents predicted refining values.
Crude/PUB Refining Value (USD/BBL)
71
69
67
65
63
61
59
57
55
-1600
-1400
-1200
-1000
-800
-600
-400
-200
0
200
400


Appendix Figure 6
RVCE Output vs Model Output
USGC, 40 MBPD Case, $60 WTI
R² = 0.9685
Assumptions:
1) Each point represents a specific crude/PUB.
2) Red points represent the four crudes/PUBs plus WCS and AWB.
3) The trendline represents predicted refining values.
Crude/PUB Refining Value (USD/BBL)
85
80
75
70
65
60
55
-1600
-1400
-1200
-1000
-800
-600
-400
-200
0
200
400



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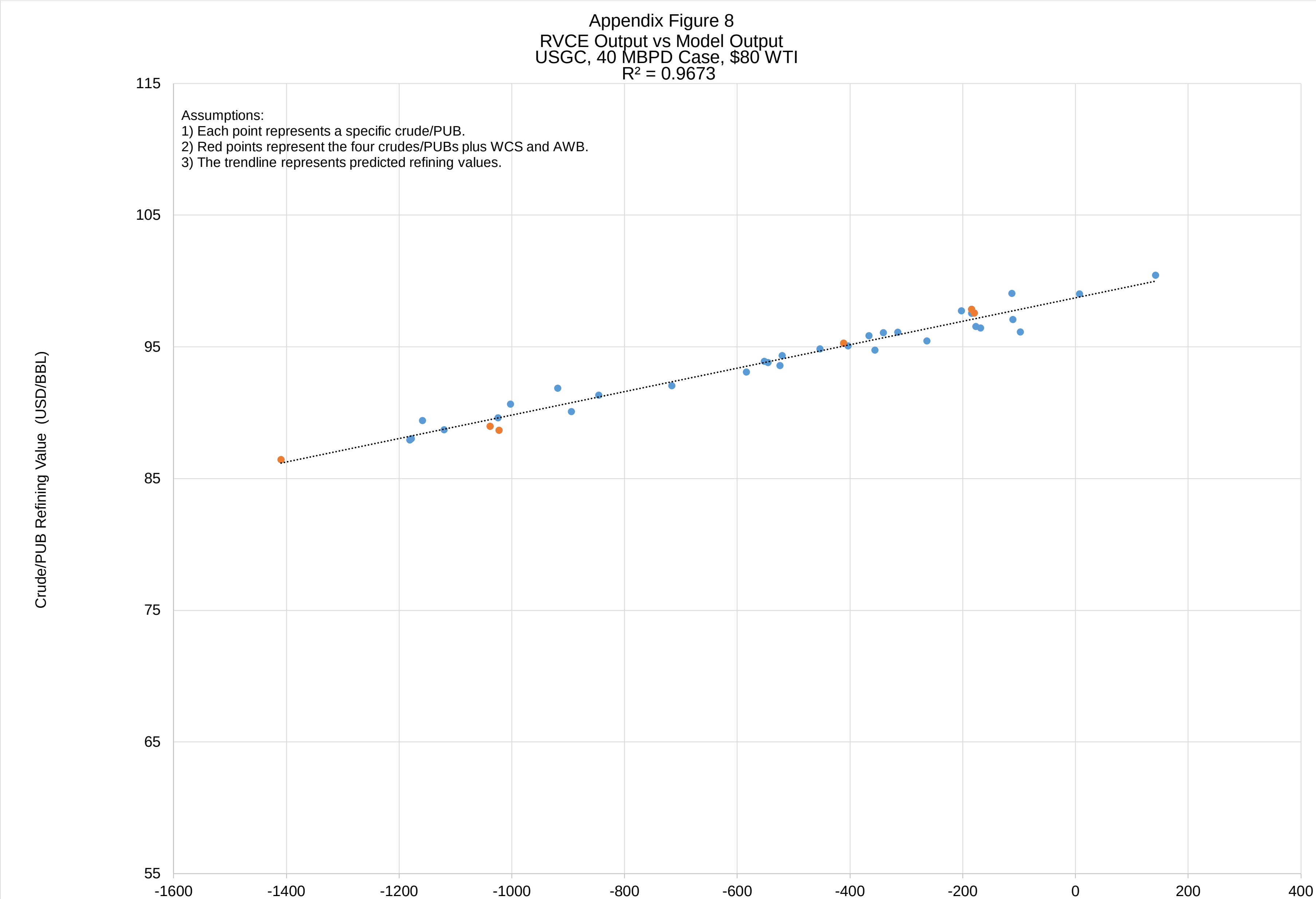

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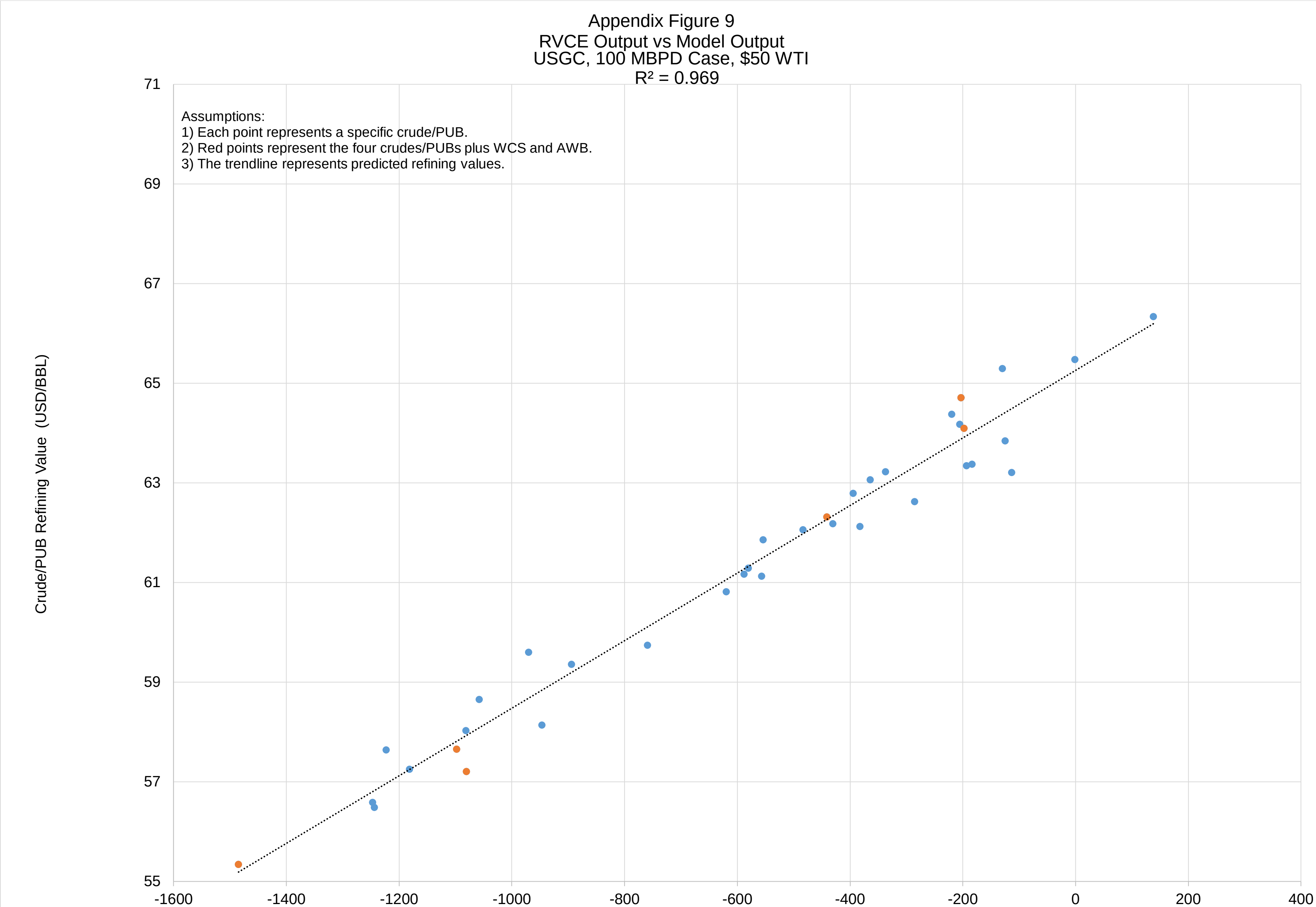
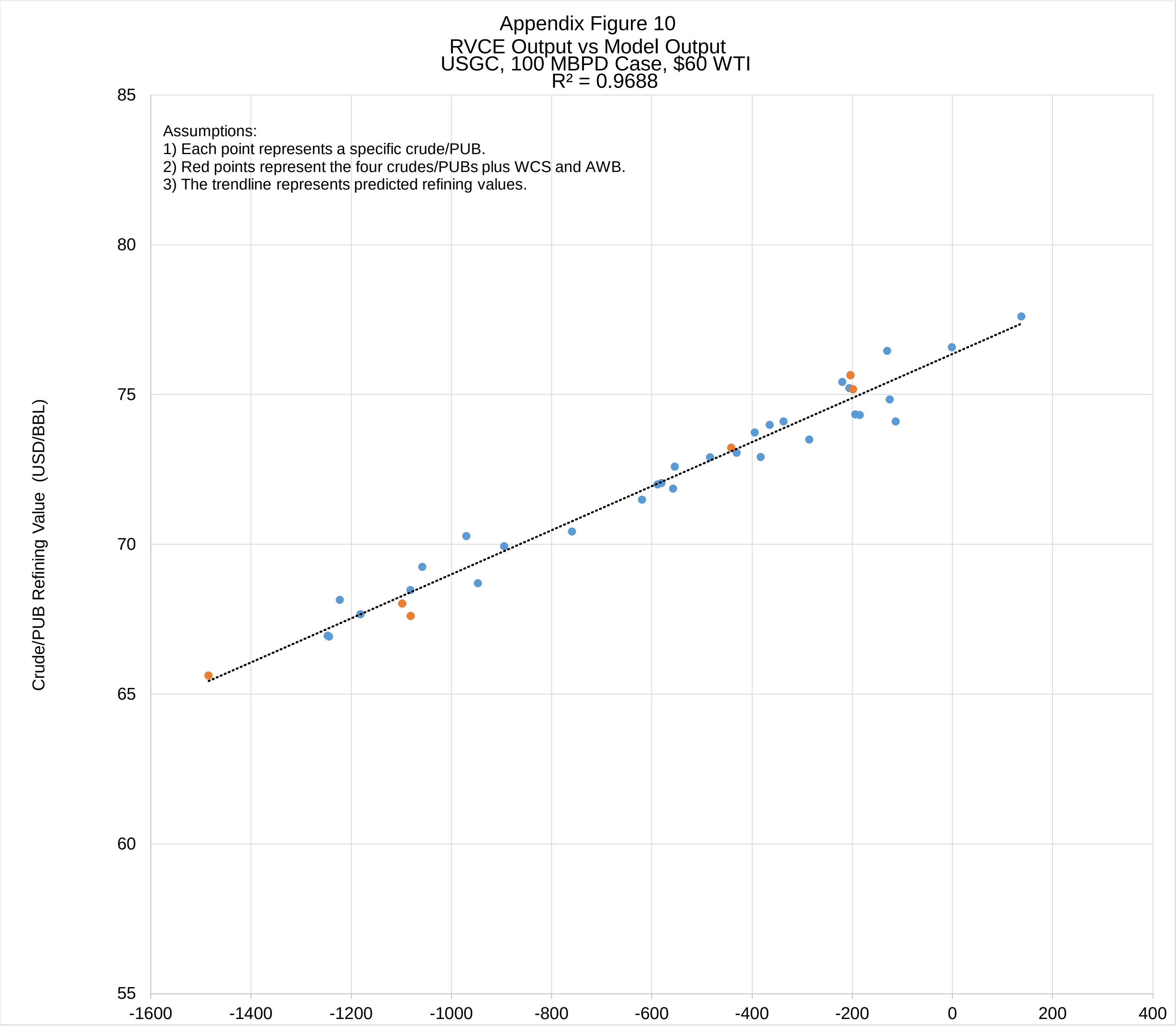


Appendix Figure 9
RVCE Output vs Model Output
USGC, 100 MBPD Case, $50 WTI
R² = 0.969
Assumptions:
1) Each point represents a specific crude/PUB.
2) Red points represent the four crudes/PUBs plus WCS and AWB.
3) The trendline represents predicted refining values.
Crude/PUB Refining Value (USD/BBL)
71
69
67
65
63
61
59
57
55
-1600
-1400
-1200
-1000
-800
-600
-400
-200
0
200
400



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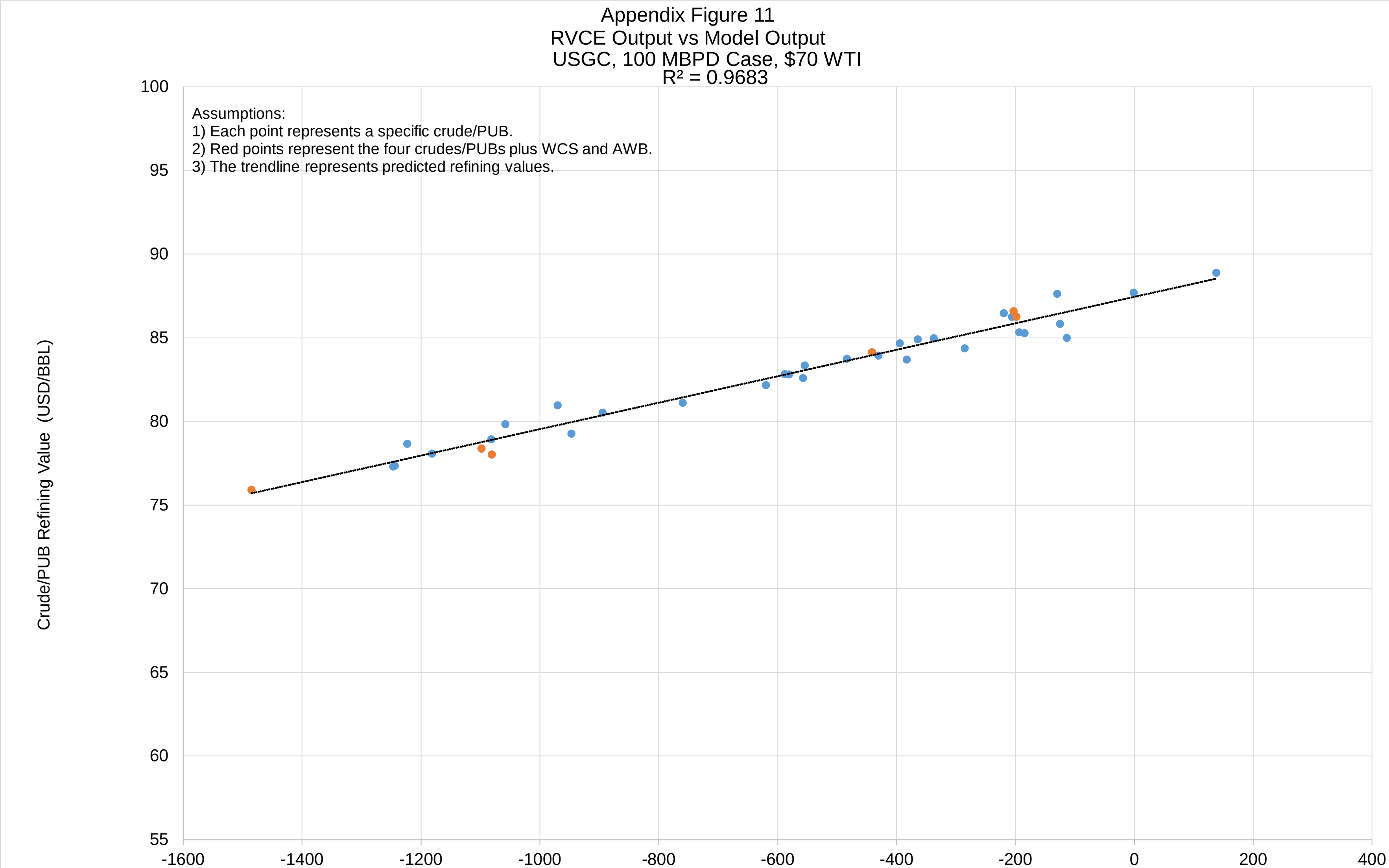
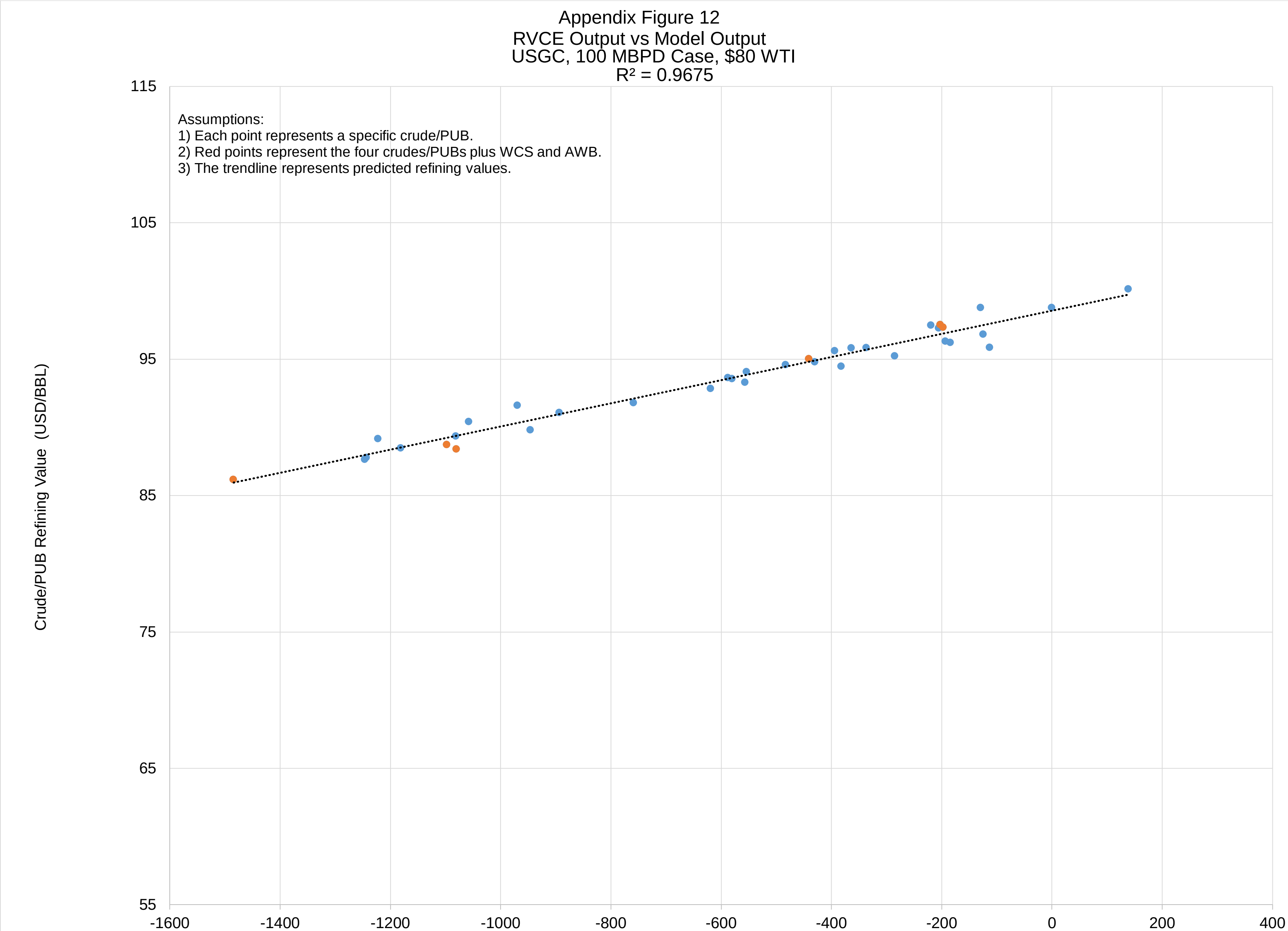
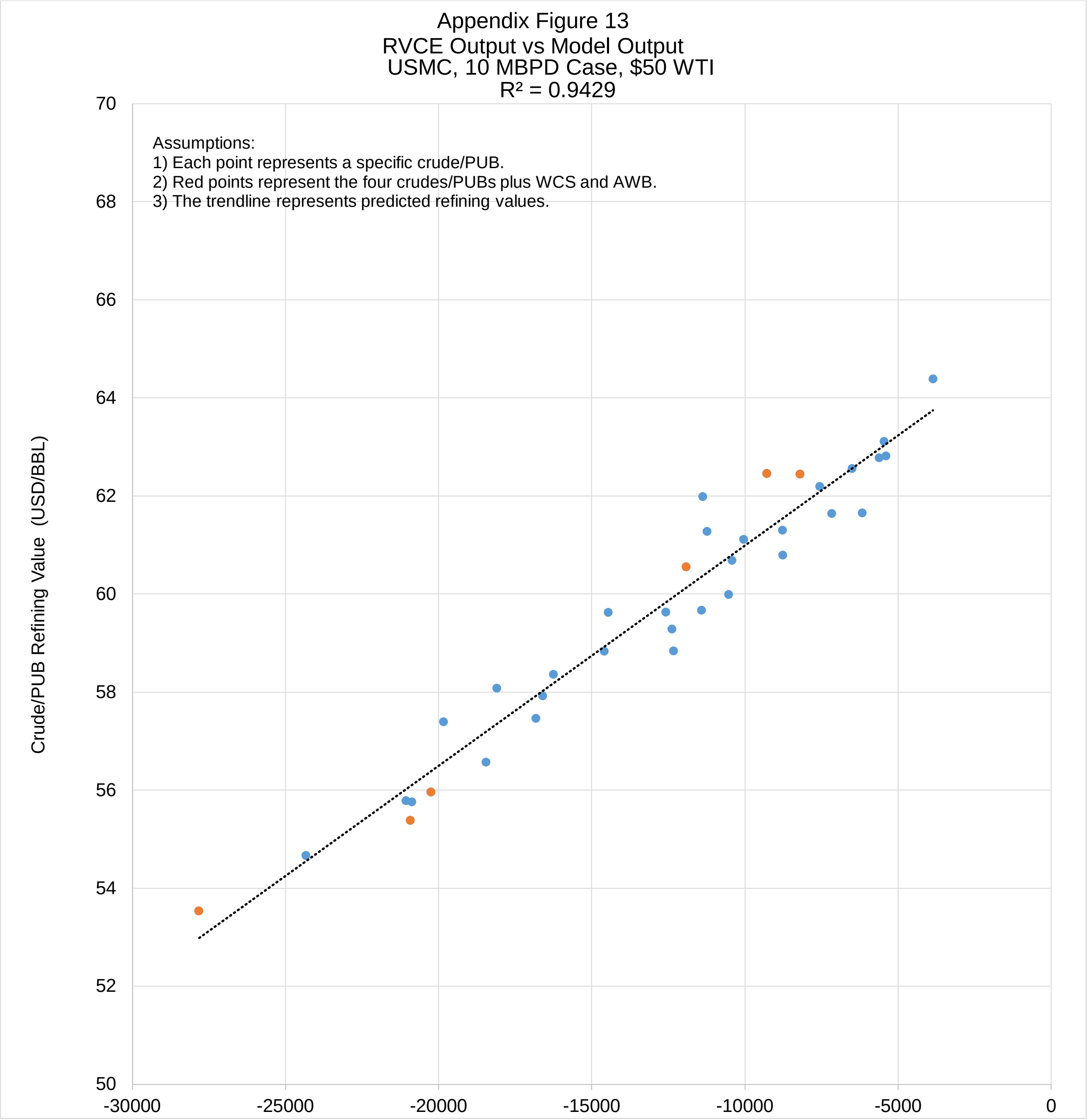

Appendix Figure 11
RVCE Output vs Model Output
USGC, 100 MBPD Case, $70 WTI
R² = 0.9683
Assumptions:
1) Each point represents a specific crude/PUB.
2) Red points represent the four crudes/PUBs plus WCS and AWB.
3) The trendline represents predicted refining values.
Crude/PUB Refining Value (USD/BBL)
100
95
90
85
80
75
70
65
60
55
-1600
-1400
-1200
-1000
-800
-600
-400
-200
0
200
400


Appendix Figure 12
RVCE Output vs Model Output
USGC, 100 MBPD Case, $80 WTI
R² = 0.9675
Assumptions:
1) Each point represents a specific crude/PUB.
2) Red points represent the four crudes/PUBs plus WCS and AWB.
3) The trendline represents predicted refining values.
Crude/PUB Refining Value (USD/BBL)
115
105
95
85
75
65
55
-1600
-1400
-1200
-1000
-800
-600
-400
-200
0
200
400



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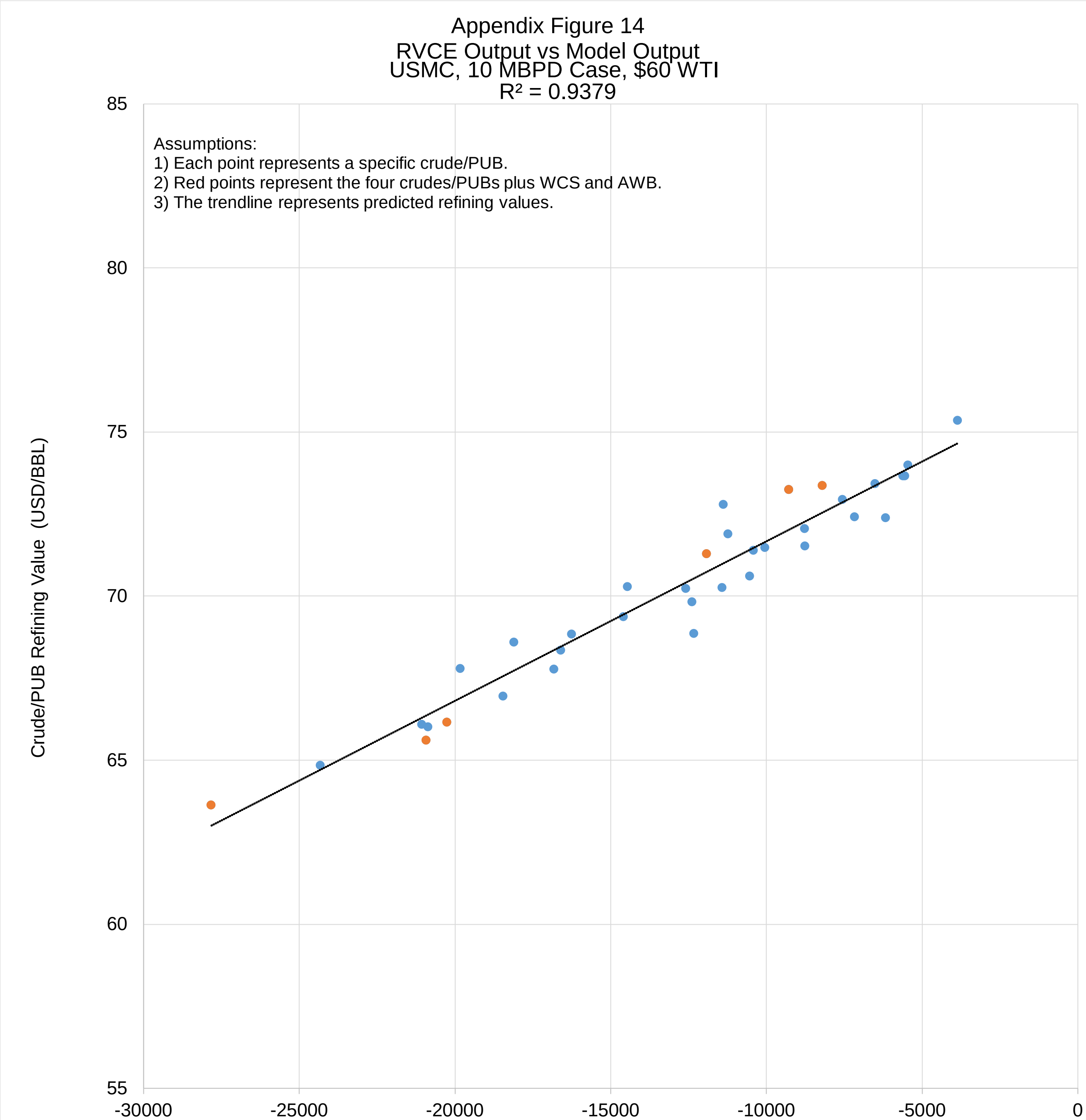
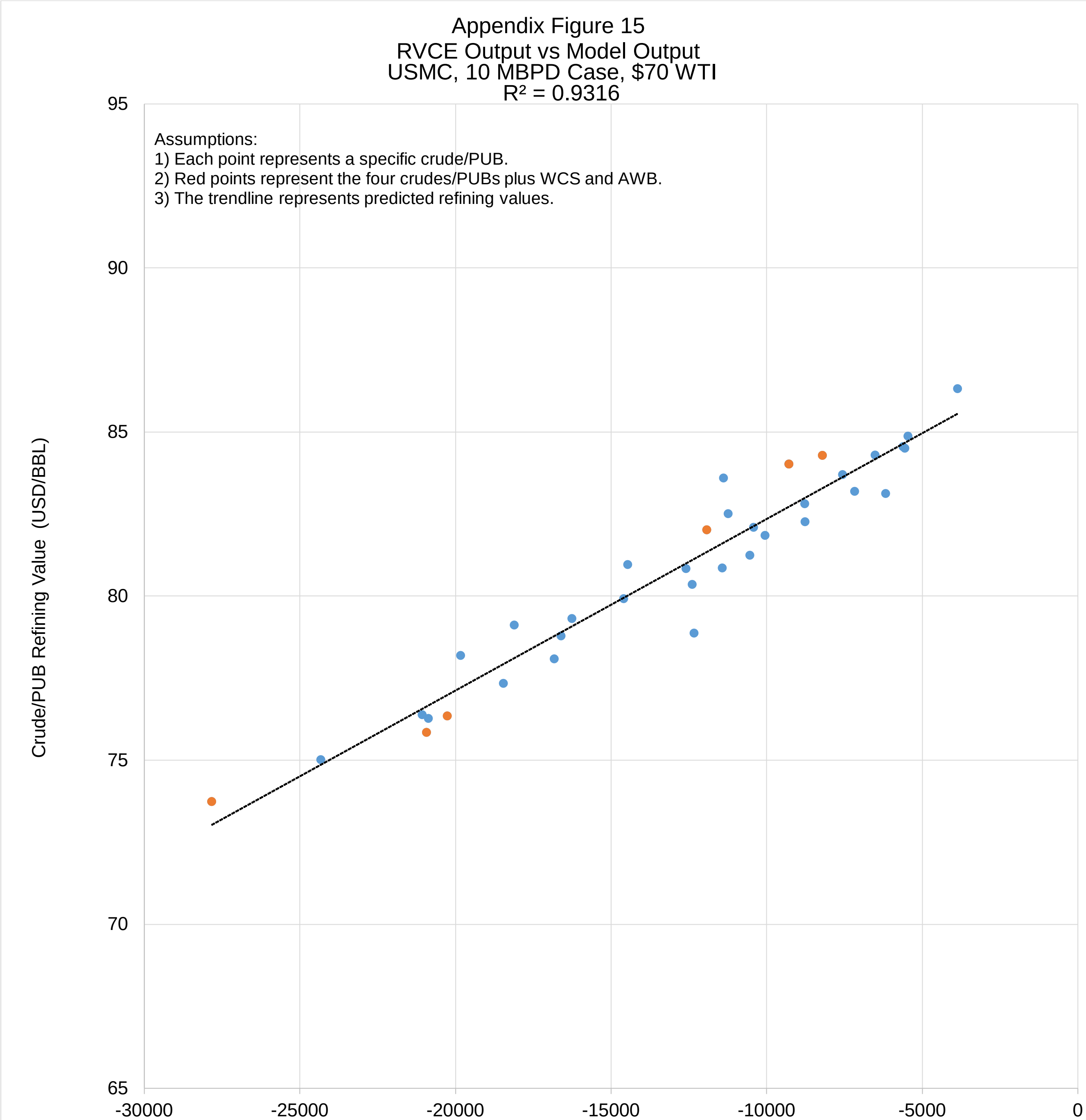
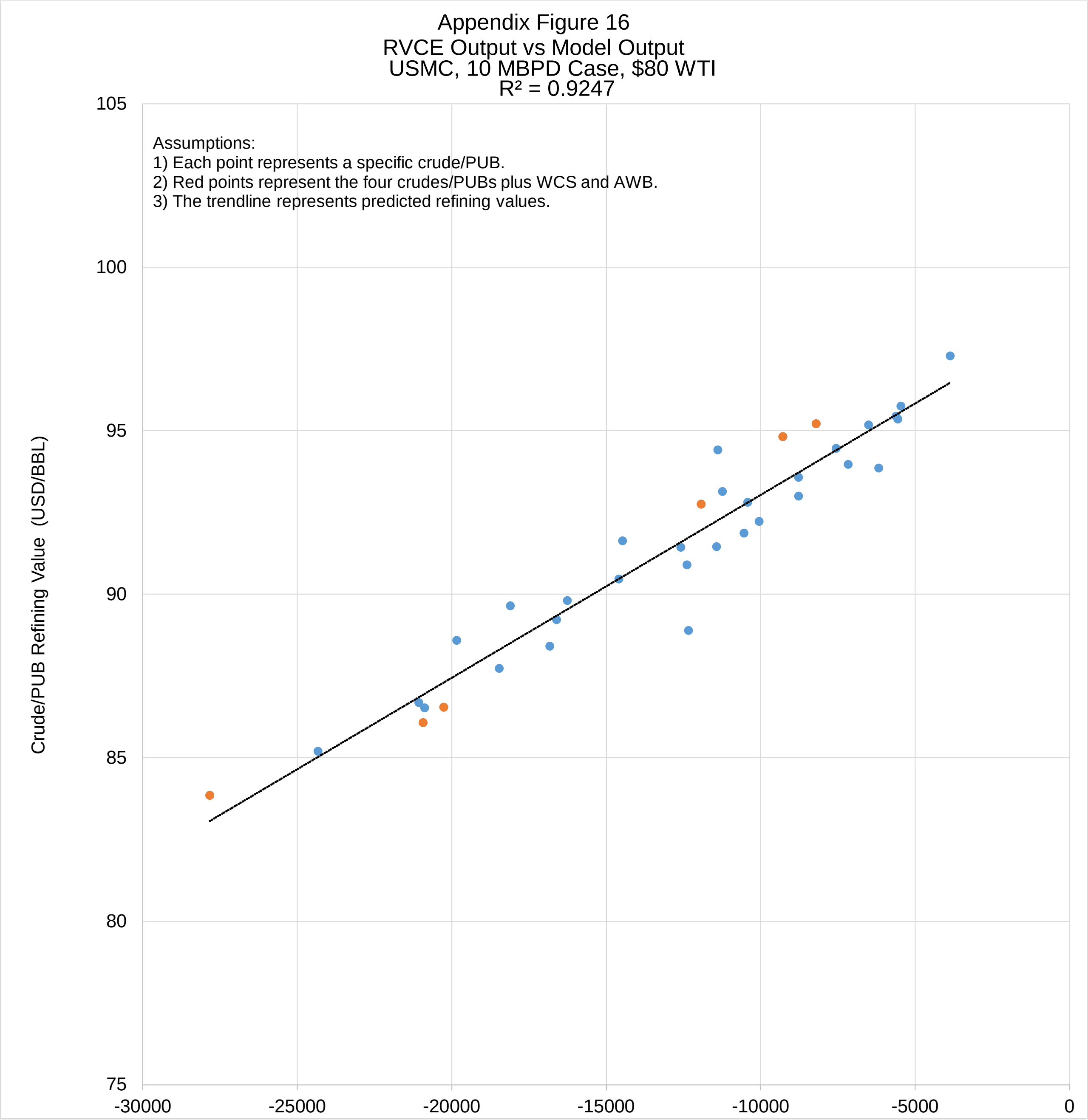
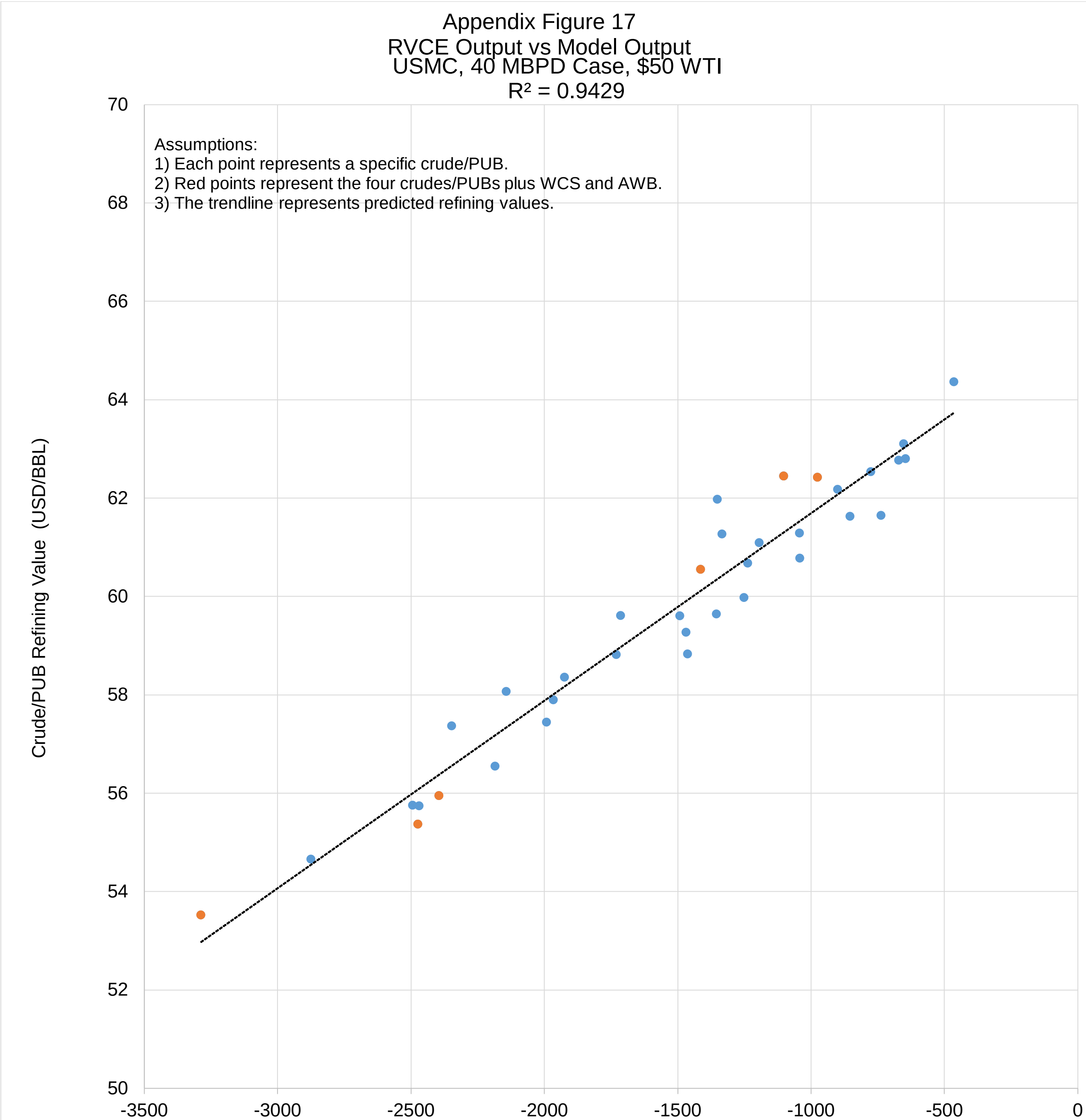
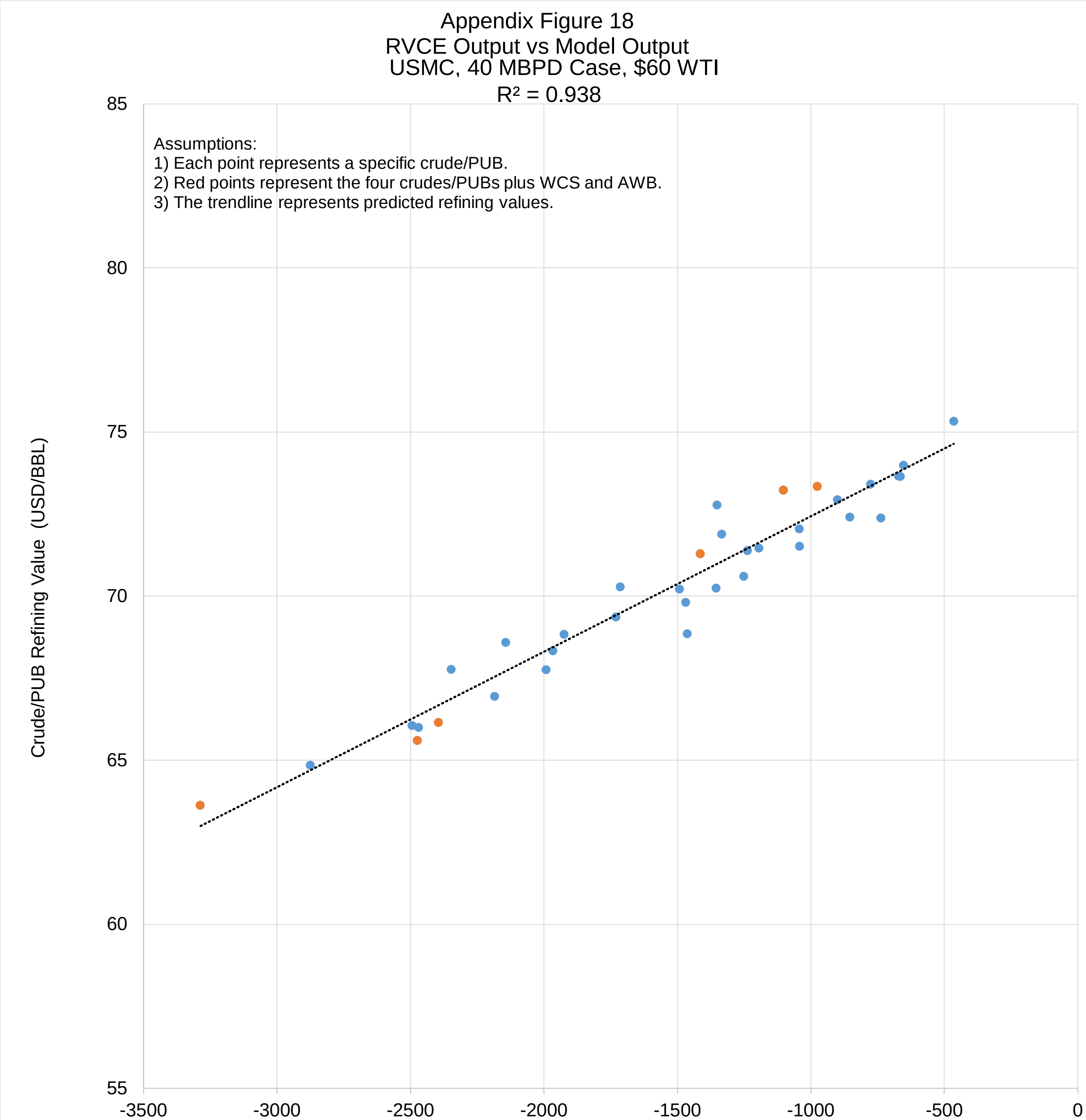

Appendix Figure 14
RVCE Output vs Model Output
USMC, 10 MBPD Case, $60 WTI
R² = 0.9379
Assumptions:
1) Each point represents a specific crude/PUB.
2) Red points represent the four crudes/PUBs plus WCS and AWB.
3) The trendline represents predicted refining values.
Crude/PUB Refining Value (USD/BBL)
85
80
75
70
65
60
55
-30000
-25000
-20000
-15000
-10000
-5000
0

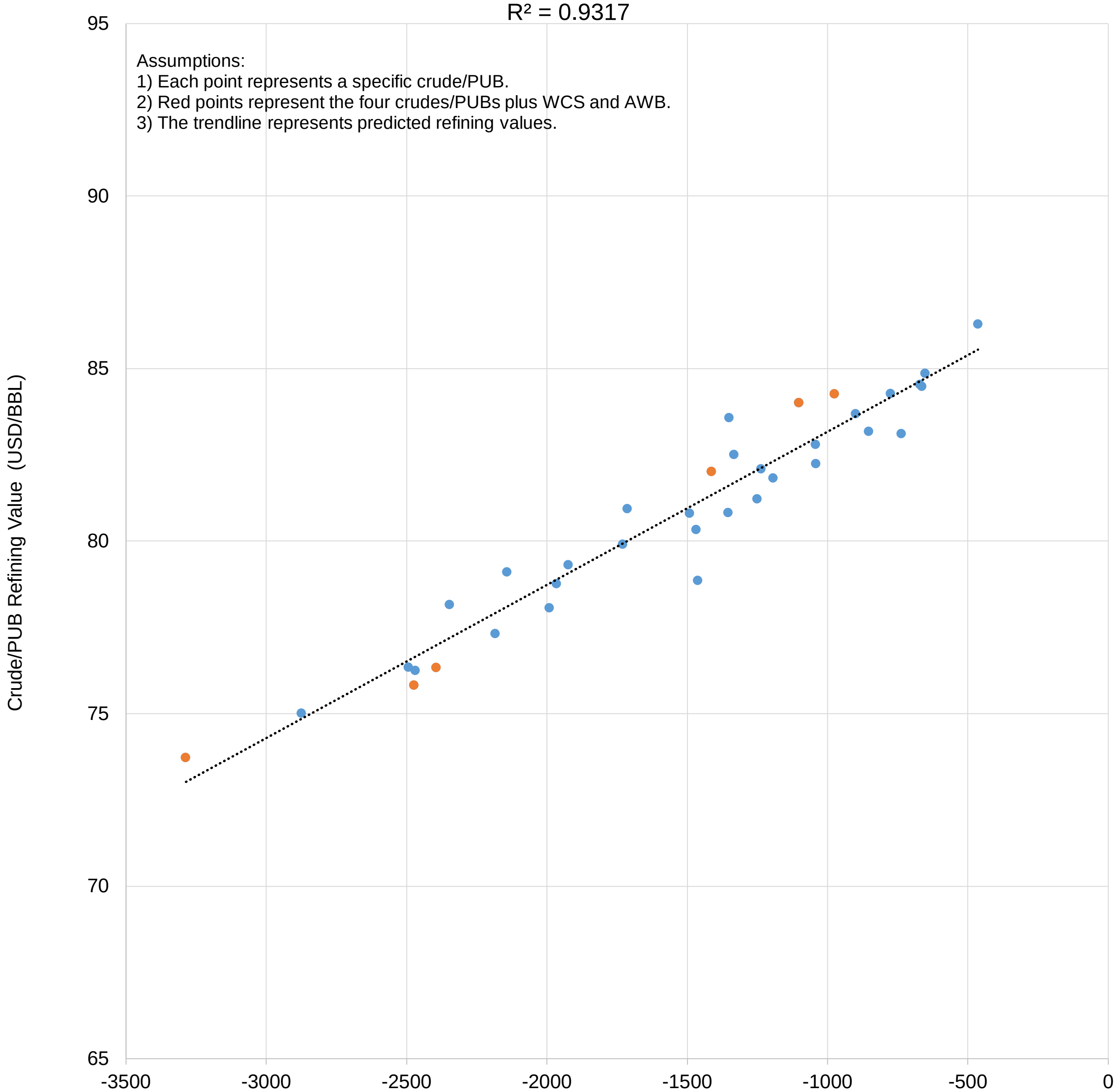

Appendix Figure 15
RVCE Output vs Model Output
USMC, 10 MBPD Case, $70 WTI
R² = 0.9316
Assumptions:
1) Each point represents a specific crude/PUB.
2) Red points represent the four crudes/PUBs plus WCS and AWB.
3) The trendline represents predicted refining values.
Crude/PUB Refining Value (USD/BBL)
95
90
85
80
75
70
65
-30000
-25000
-20000
-15000
-10000
-5000
0

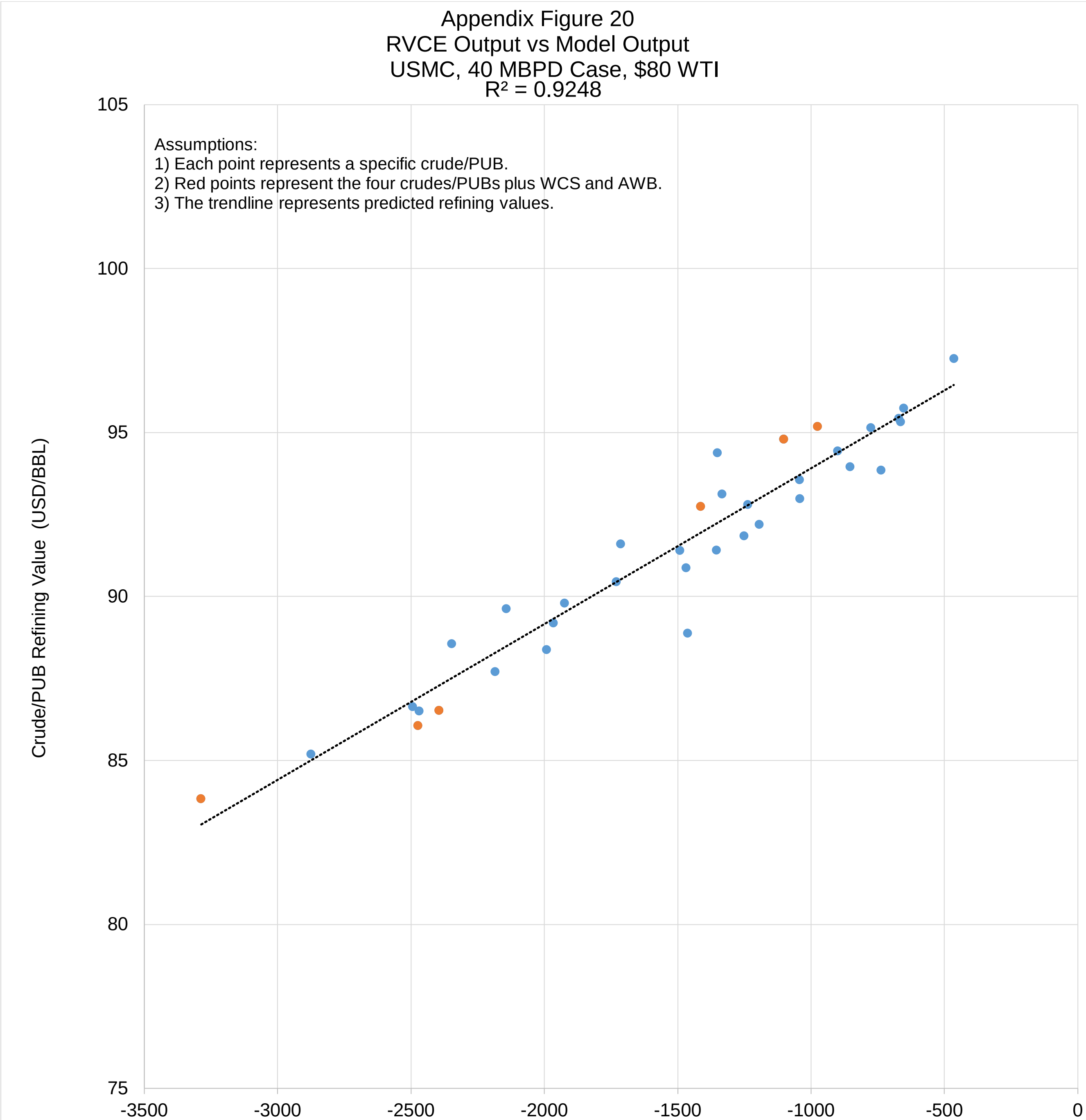

Appendix Figure 16
RVCE Output vs Model Output
USMC, 10 MBPD Case, $80 WTI
R² = 0.9247
Assumptions:
1) Each point represents a specific crude/PUB.
2) Red points represent the four crudes/PUBs plus WCS and AWB.
3) The trendline represents predicted refining values.
Crude/PUB Refining Value (USD/BBL)
105
100
95
90
85
80
75
-30000
-25000
-20000
-15000
-10000
-5000
0

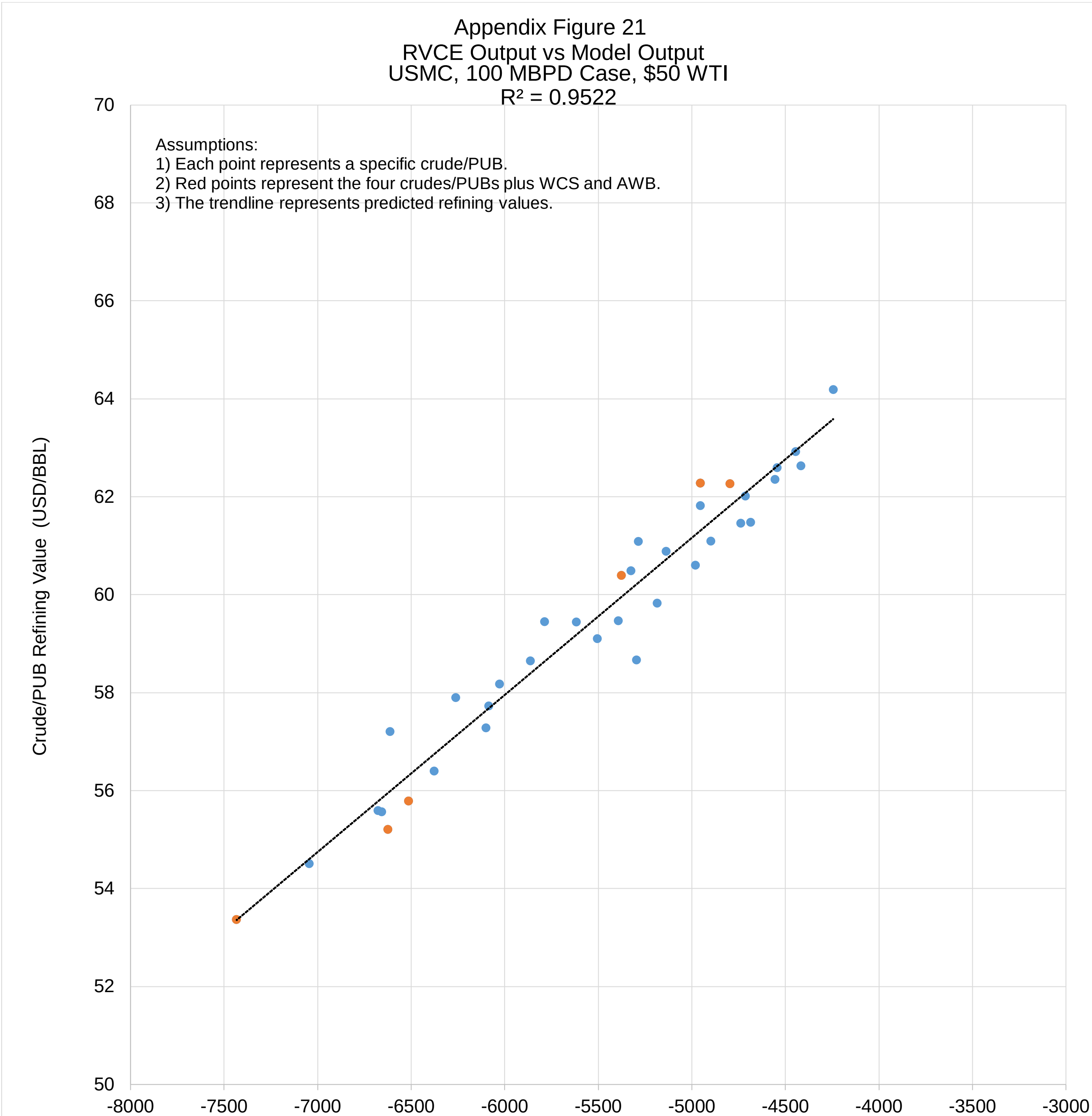

Appendix Figure 17
RVCE Output vs Model Output
USMC, 40 MBPD Case, $50 WTI
R² = 0.9429
Assumptions:
1) Each point represents a specific crude/PUB.
2) Red points represent the four crudes/PUBs plus WCS and AWB.
3) The trendline represents predicted refining values.
Crude/PUB Refining Value (USD/BBL)
70
68
66
64
62
60
58
56
54
52
50
-3500
-3000
-2500
-2000
-1500
-1000
-500
0

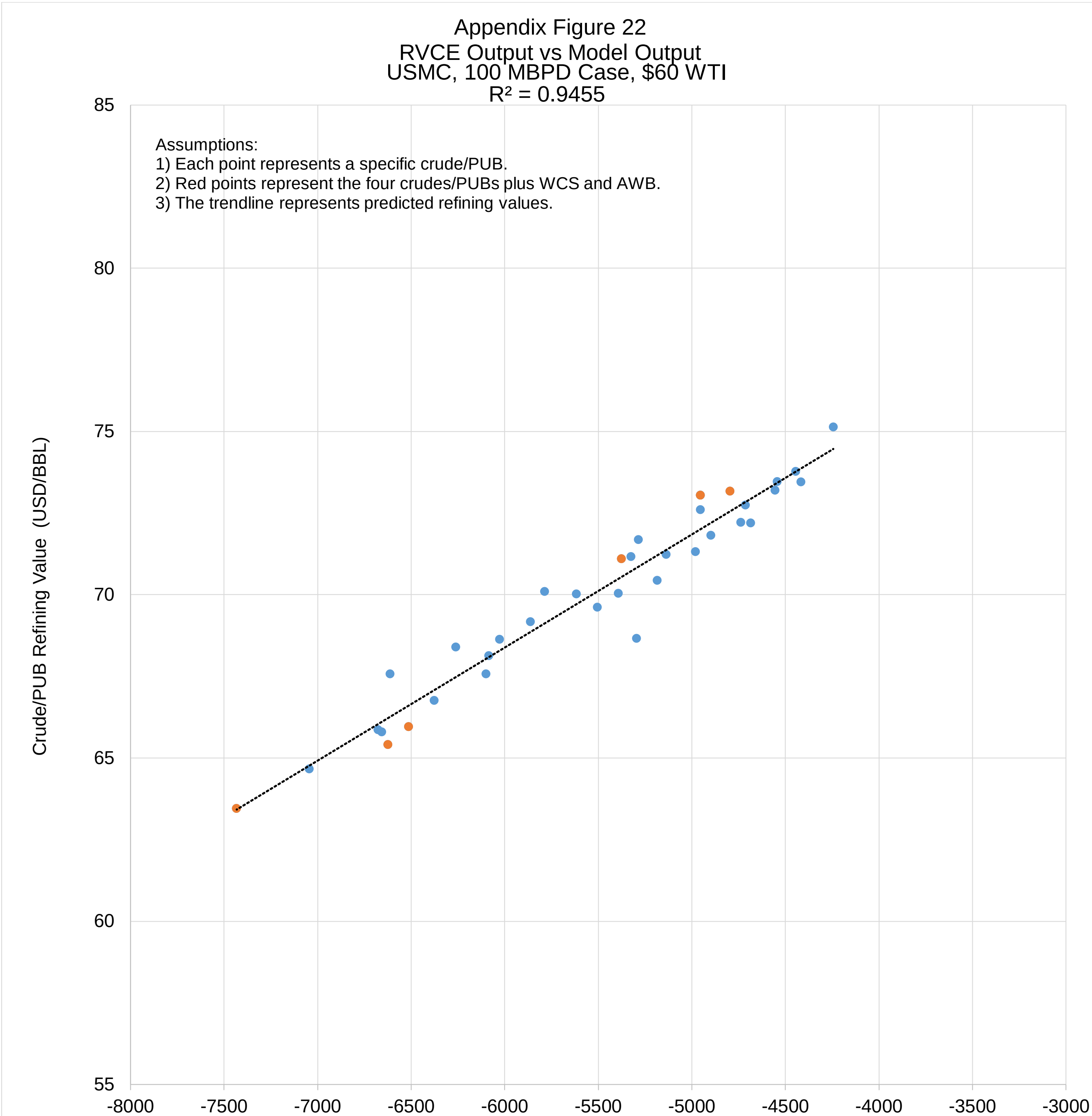

Appendix Figure 18
RVCE Output vs Model Output
USMC, 40 MBPD Case, $60 WTI
R² = 0.938
Assumptions:
1) Each point represents a specific crude/PUB.
2) Red points represent the four crudes/PUBs plus WCS and AWB.
3) The trendline represents predicted refining values.
Crude/PUB Refining Value (USD/BBL)
85
80
75
70
65
60
55
-3500
-3000
-2500
-2000
-1500
-1000
-500
0

Appendix Figure 19
RVCE Output vs Model Output
USMC, 40 MBPD Case, $70 WTI
$R^2 = 0.9317$

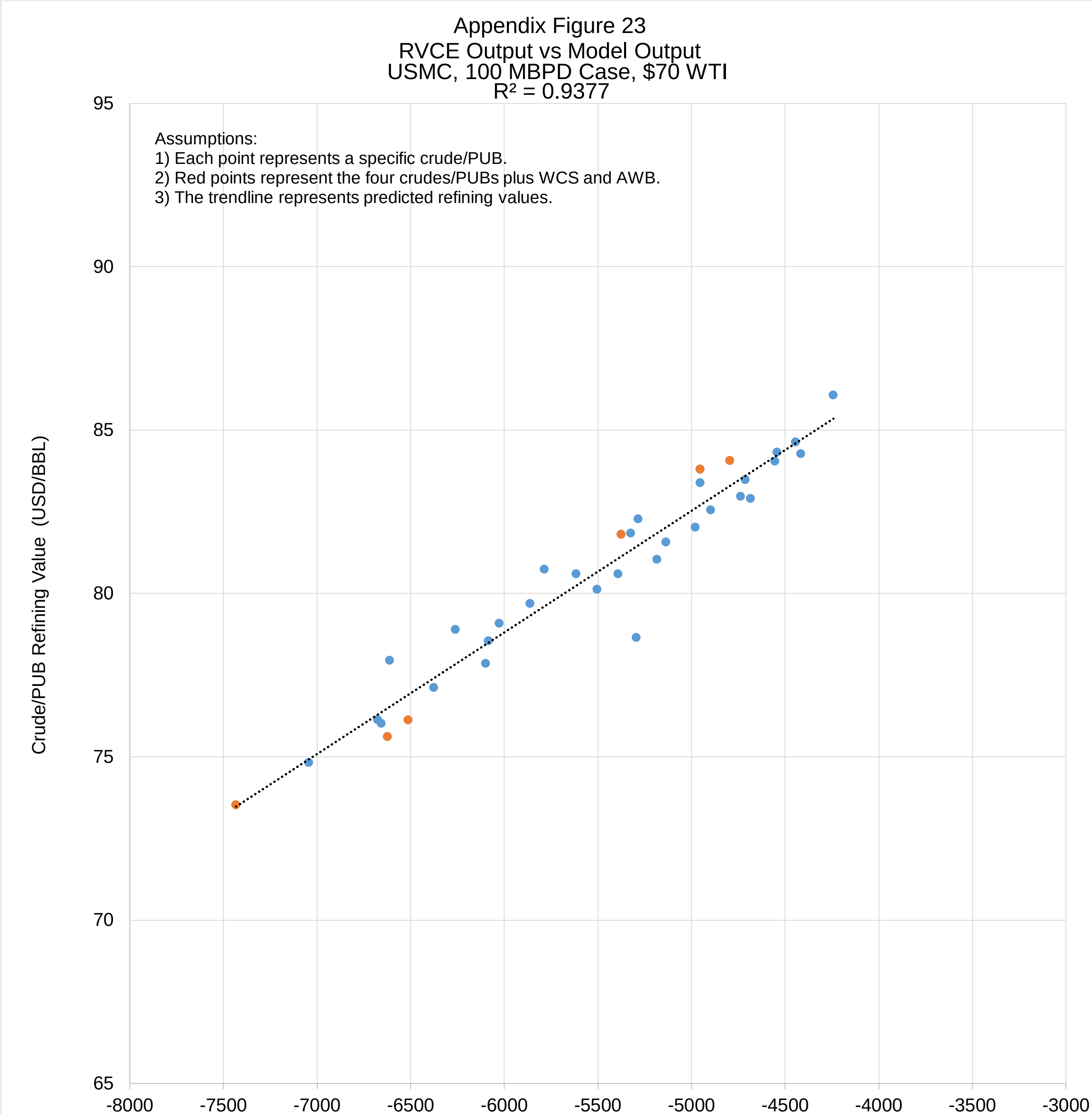



Appendix Figure 20
RVCE Output vs Model Output
USMC, 40 MBPD Case, $80 WTI
R² = 0.9248
Assumptions:
1) Each point represents a specific crude/PUB.
2) Red points represent the four crudes/PUBs plus WCS and AWB.
3) The trendline represents predicted refining values.
Crude/PUB Refining Value (USD/BBL)
105
100
95
90
85
80
75
-3500
-3000
-2500
-2000
-1500
-1000
-500
0

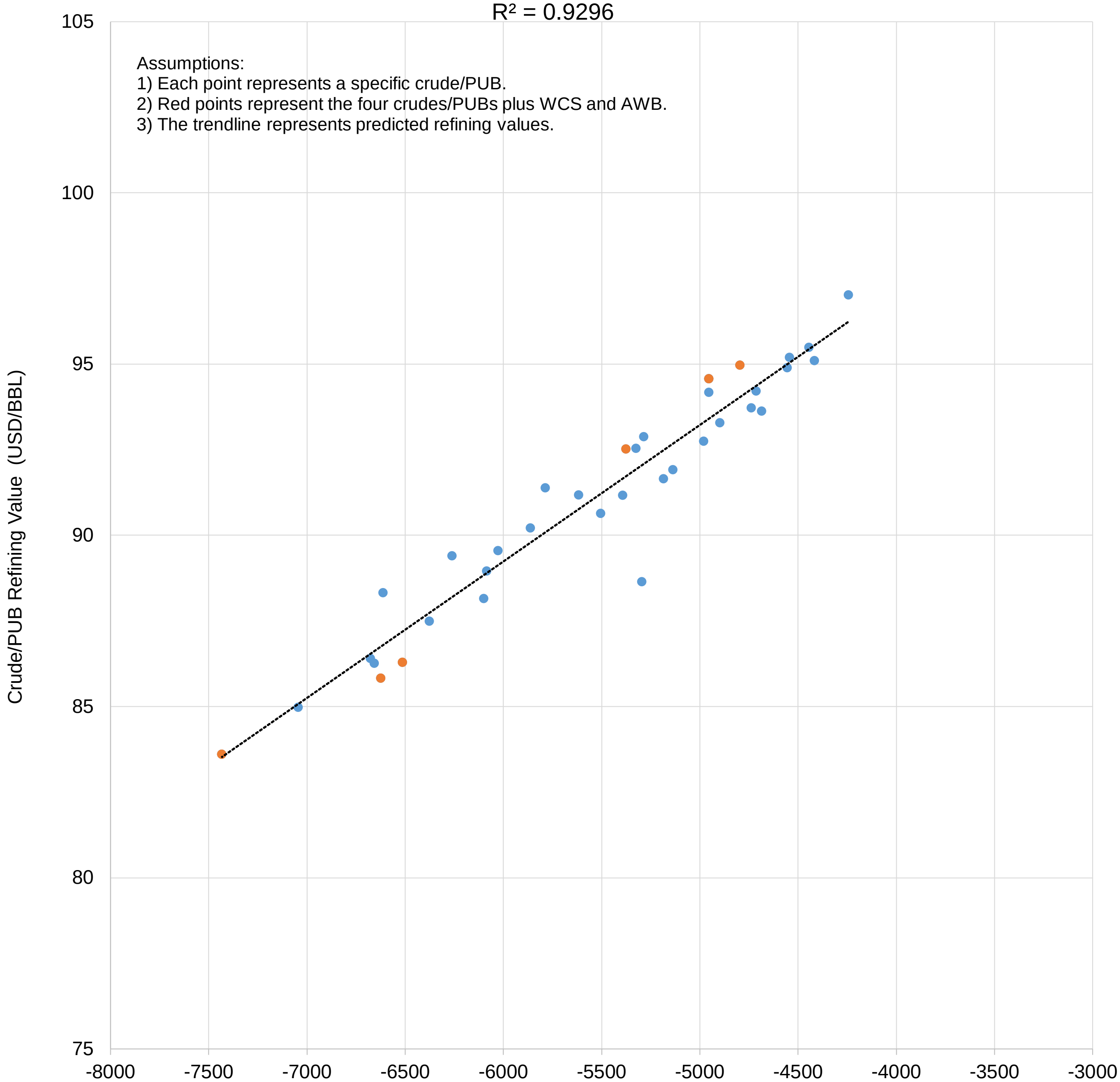

Appendix Figure 21
RVCE Output vs Model Output
USMC, 100 MBPD Case, $50 WTI
R² = 0.9522
Assumptions:
1) Each point represents a specific crude/PUB.
2) Red points represent the four crudes/PUBs plus WCS and AWB.
3) The trendline represents predicted refining values.
Crude/PUB Refining Value (USD/BBL)
70
68
66
64
62
60
58
56
54
52
50
-8000
-7500
-7000
-6500
-6000
-5500
-5000
-4500
-4000
-3500
-3000

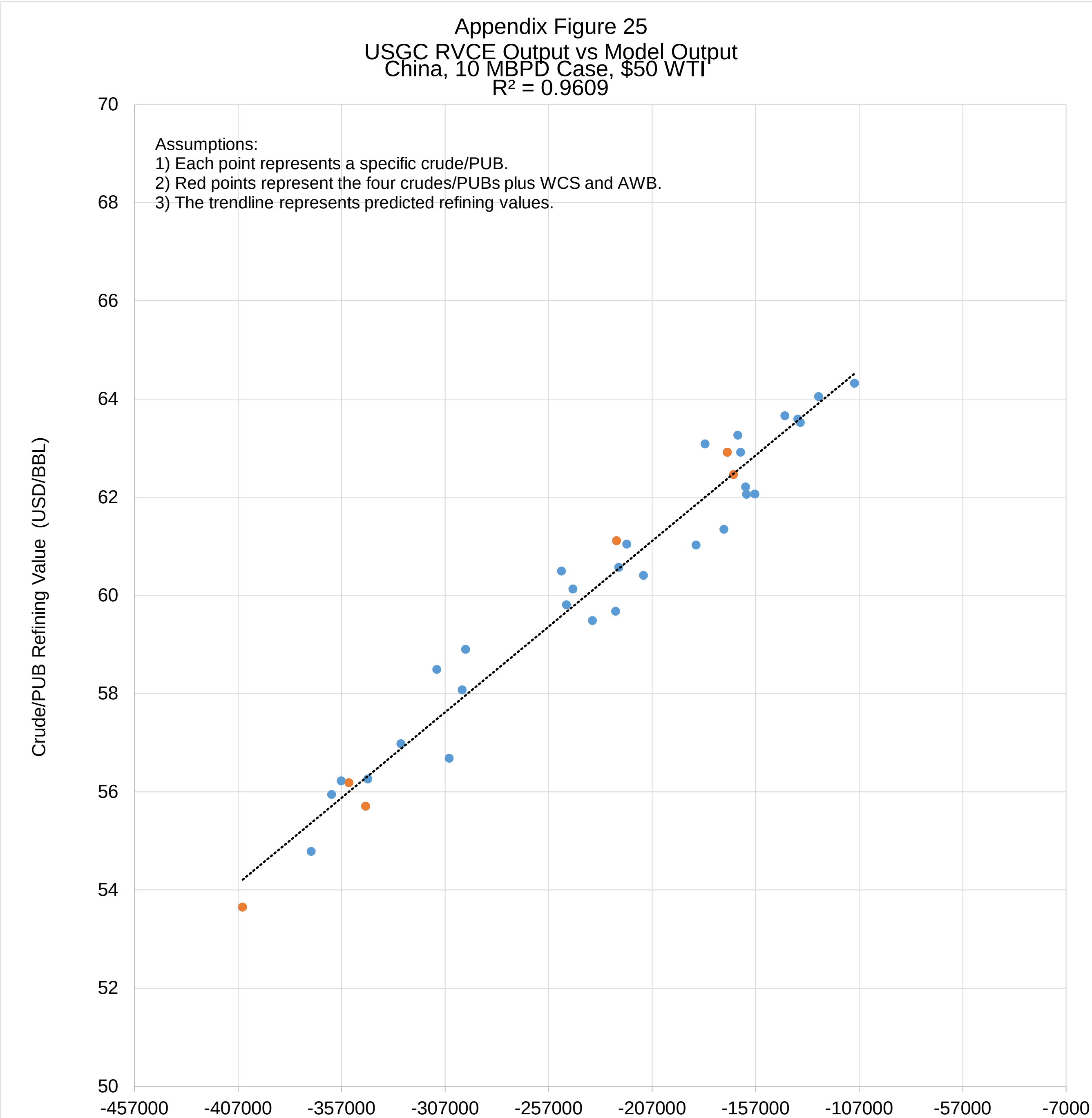


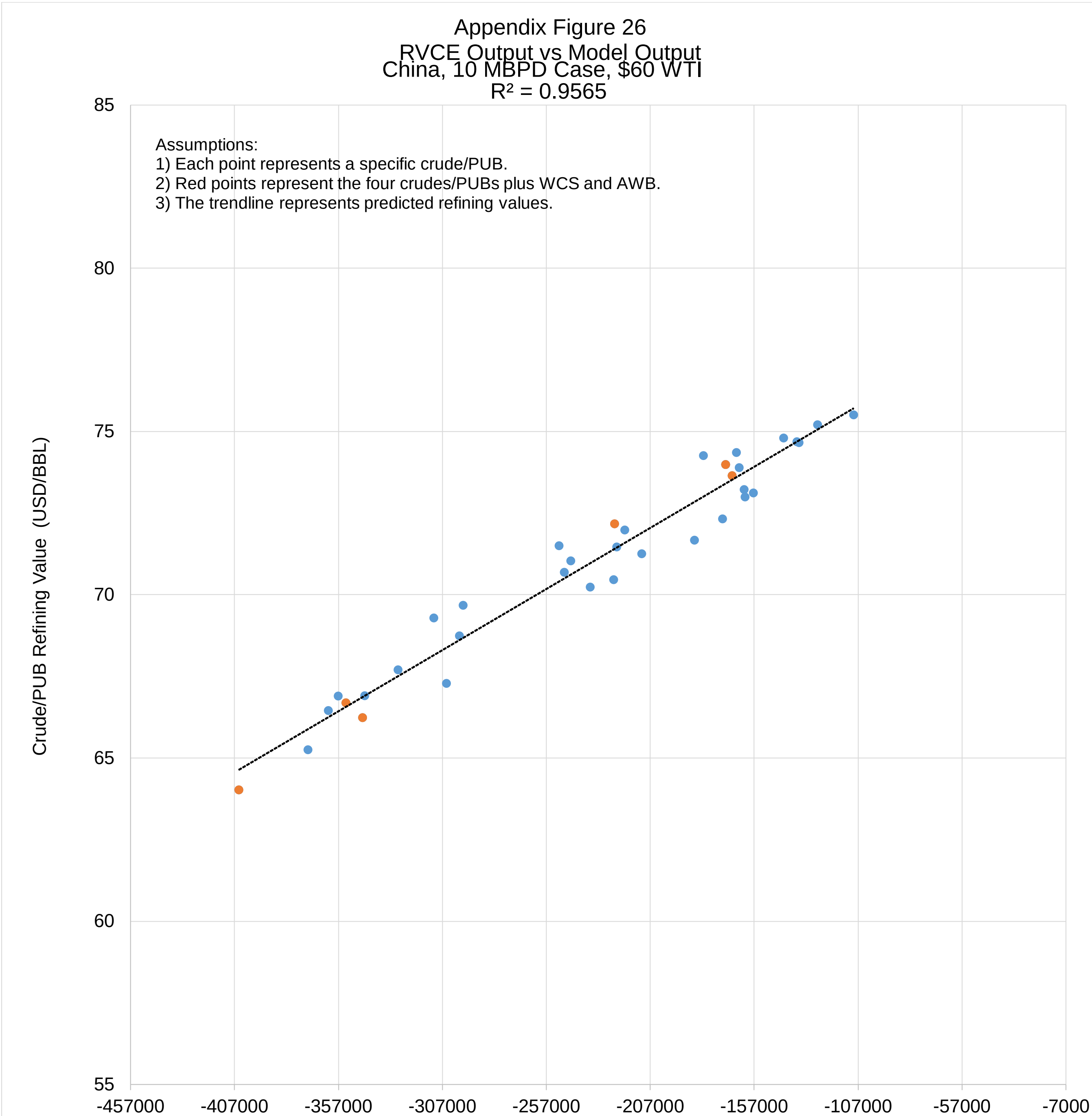
Appendix Figure 22
RVCE Output vs Model Output
USMC, 100 MBPD Case, $60 WTI
R² = 0.9455
Assumptions:
1) Each point represents a specific crude/PUB.
2) Red points represent the four crudes/PUBs plus WCS and AWB.
3) The trendline represents predicted refining values.
Crude/PUB Refining Value (USD/BBL)
85
80
75
70
65
60
55
-8000
-7500
-7000
-6500
-6000
-5500
-5000
-4500
-4000
-3500
-3000

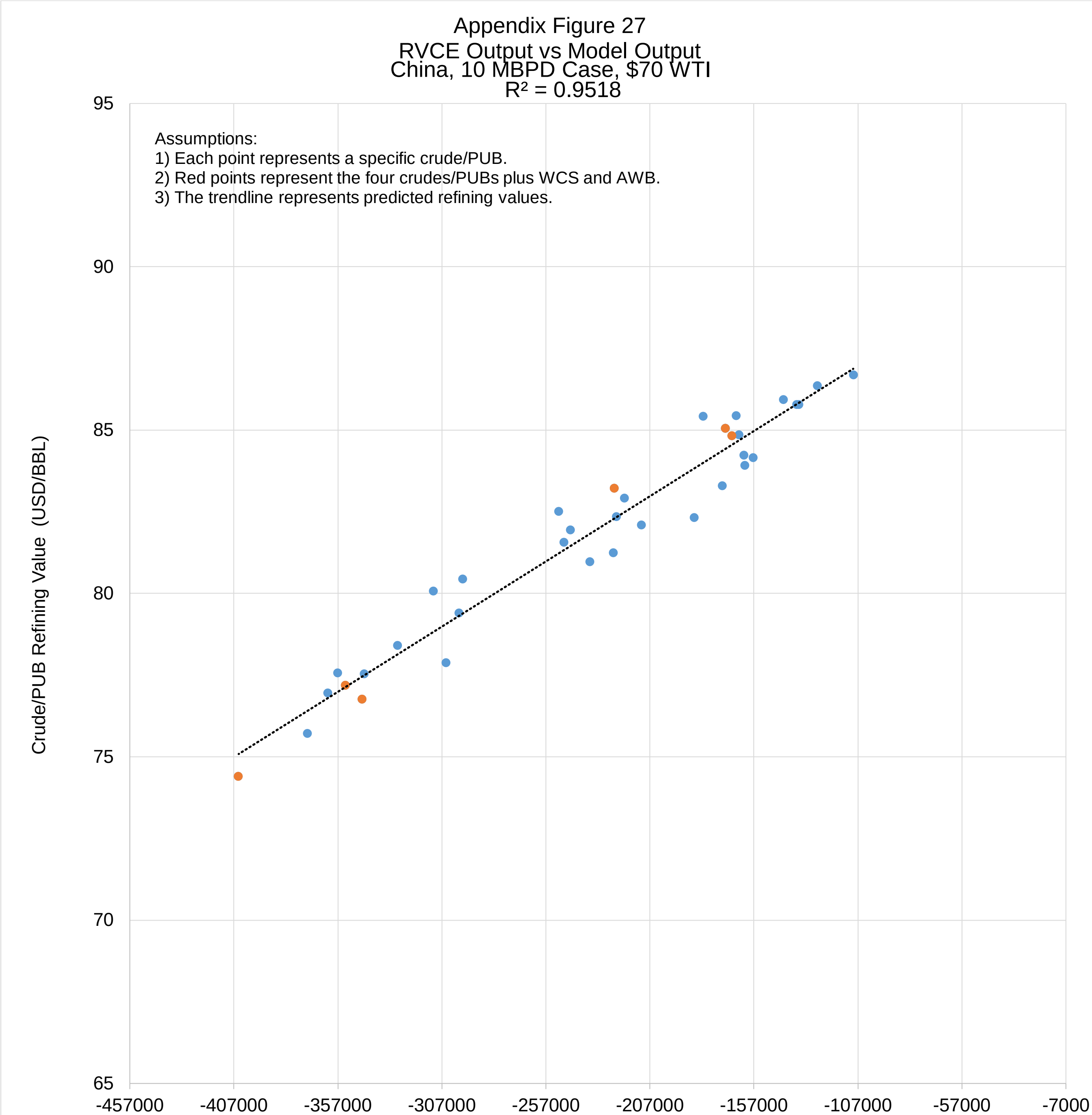

Appendix Figure 23
RVCE Output vs Model Output
USMC, 100 MBPD Case, $70 WTI
R² = 0.9377
Assumptions:
1) Each point represents a specific crude/PUB.
2) Red points represent the four crudes/PUBs plus WCS and AWB.
3) The trendline represents predicted refining values.
Crude/PUB Refining Value (USD/BBL)
95
90
85
80
75
70
65
-8000
-7500
-7000
-6500
-6000
-5500
-5000
-4500
-4000
-3500
-3000

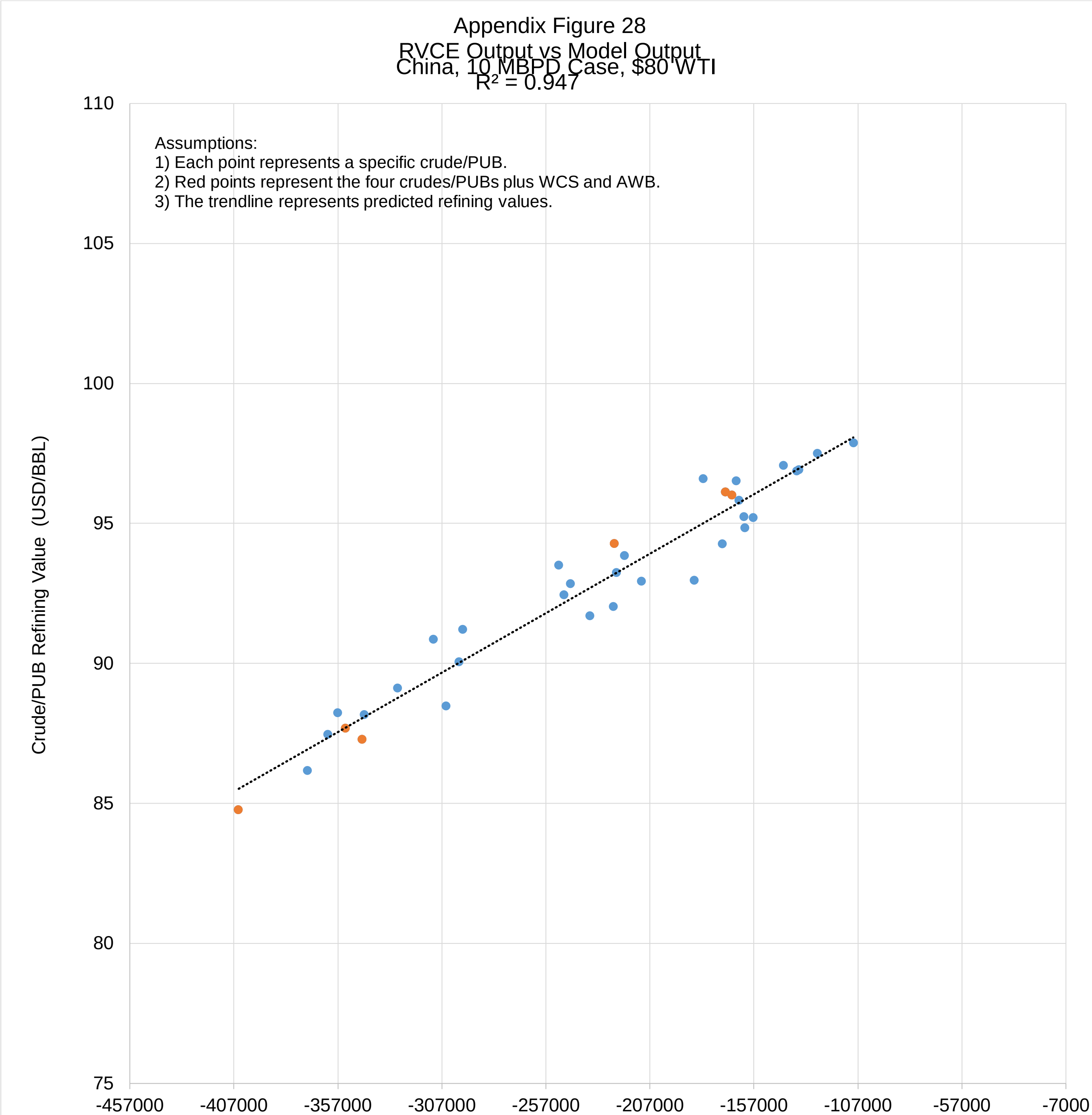
Appendix Figure 24
RVCE Output vs Model Output
USMC, 100 MBPD Case, $80 WTI
R^2 = 0.9296

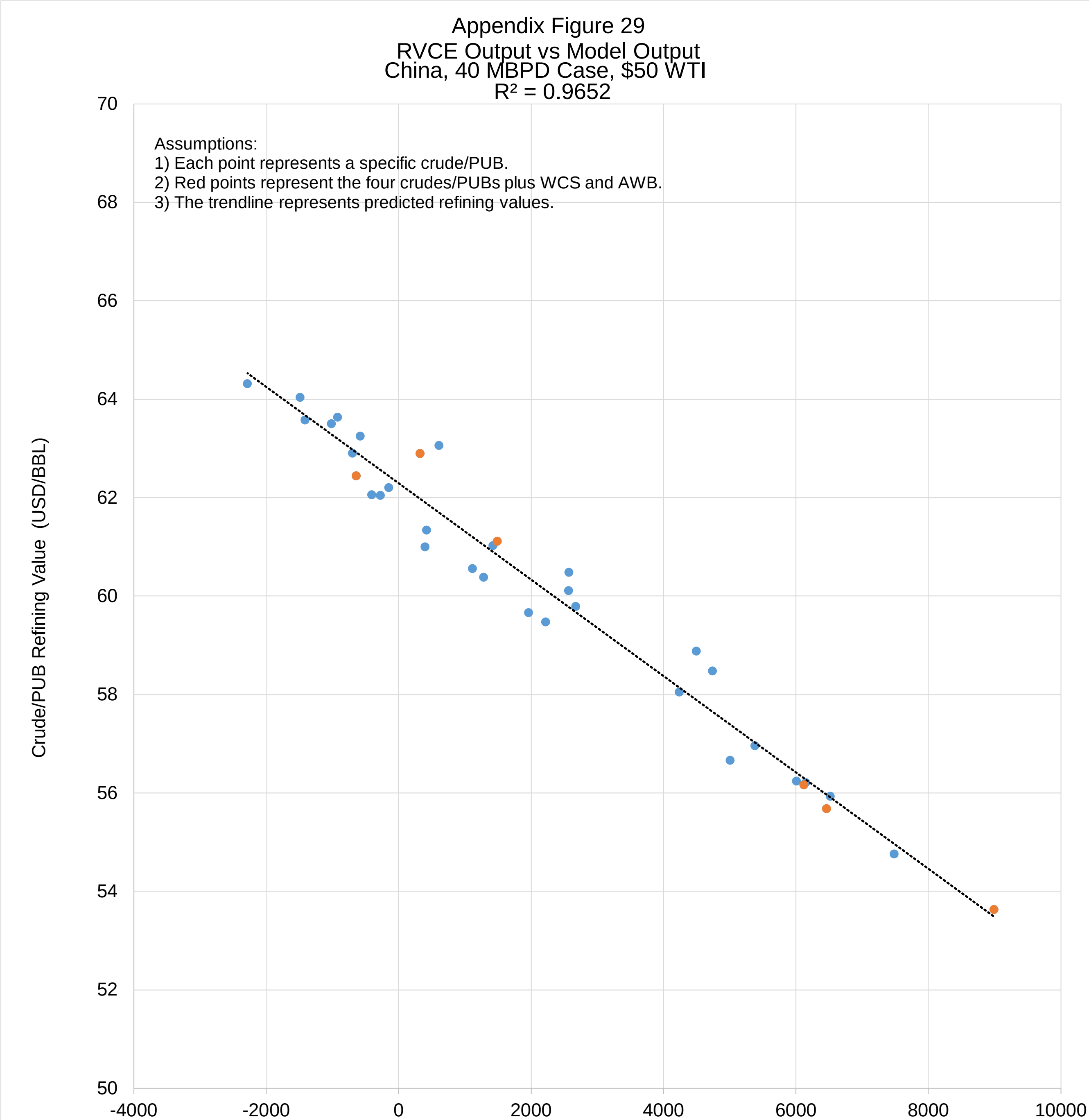


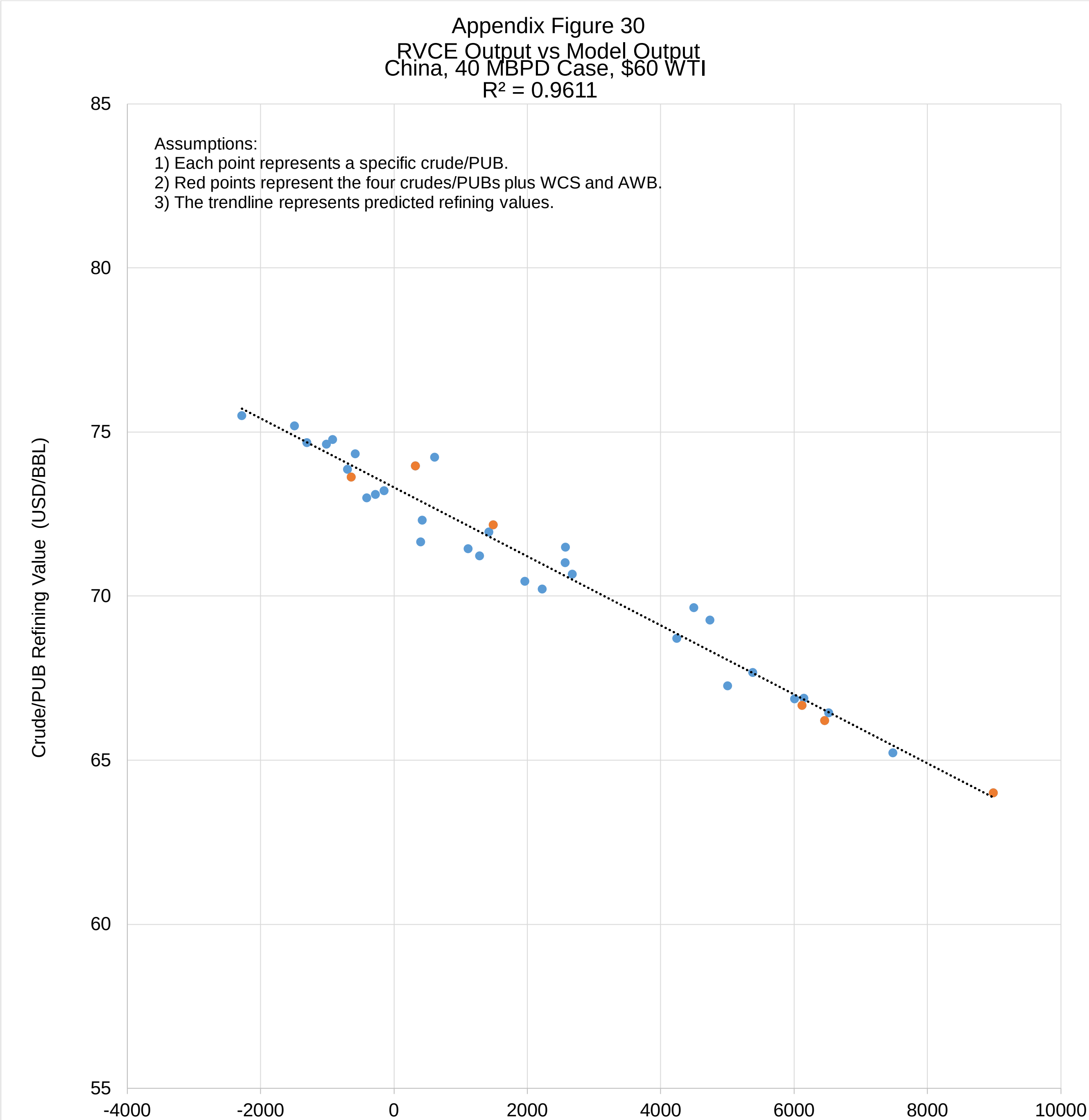

Appendix Figure 25
USGC RVCE Output vs Model Output
China, 10 MBPD Case, $50 WTI
R² = 0.9609
Assumptions:
1) Each point represents a specific crude/PUB.
2) Red points represent the four crudes/PUBs plus WCS and AWB.
3) The trendline represents predicted refining values.
Crude/PUB Refining Value (USD/BBL)
70
68
66
64
62
60
58
56
54
52
50
-457000
-407000
-357000
-307000
-257000
-207000
-157000
-107000
-57000
-7000


Appendix Figure 26
RVCE Output vs Model Output
China, 10 MBPD Case, $60 WTI
R² = 0.9565
Assumptions:
1) Each point represents a specific crude/PUB.
2) Red points represent the four crudes/PUBs plus WCS and AWB.
3) The trendline represents predicted refining values.
Crude/PUB Refining Value (USD/BBL)
85
80
75
70
65
60
55
-457000
-407000
-357000
-307000
-257000
-207000
-157000
-107000
-57000
-7000

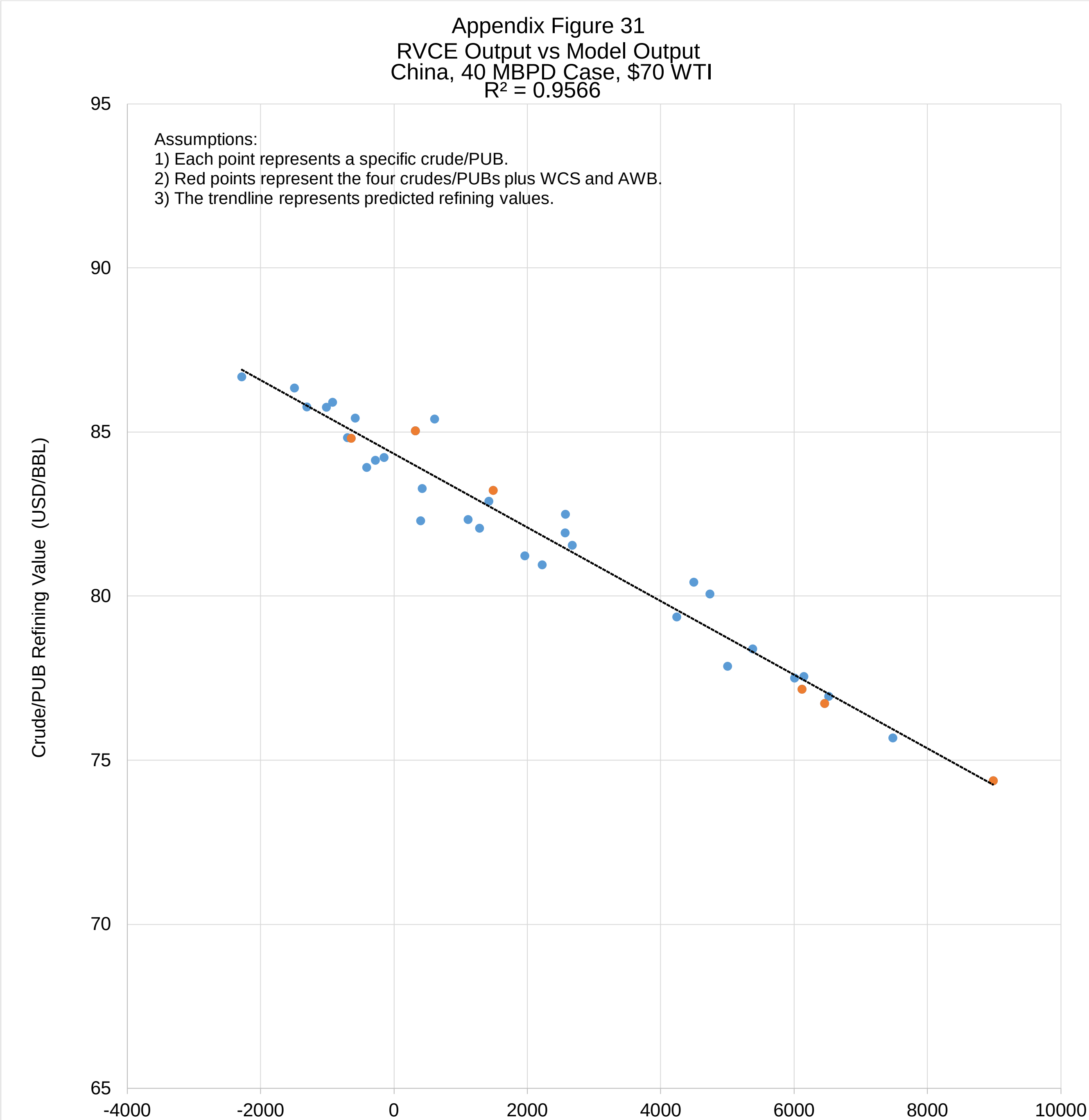

Appendix Figure 27
RVCE Output vs Model Output
China, 10 MBPD Case, $70 WTI
R² = 0.9518
Assumptions:
1) Each point represents a specific crude/PUB.
2) Red points represent the four crudes/PUBs plus WCS and AWB.
3) The trendline represents predicted refining values.
Crude/PUB Refining Value (USD/BBL)
95
90
85
80
75
70
65
-457000
-407000
-357000
-307000
-257000
-207000
-157000
-107000
-57000
-7000

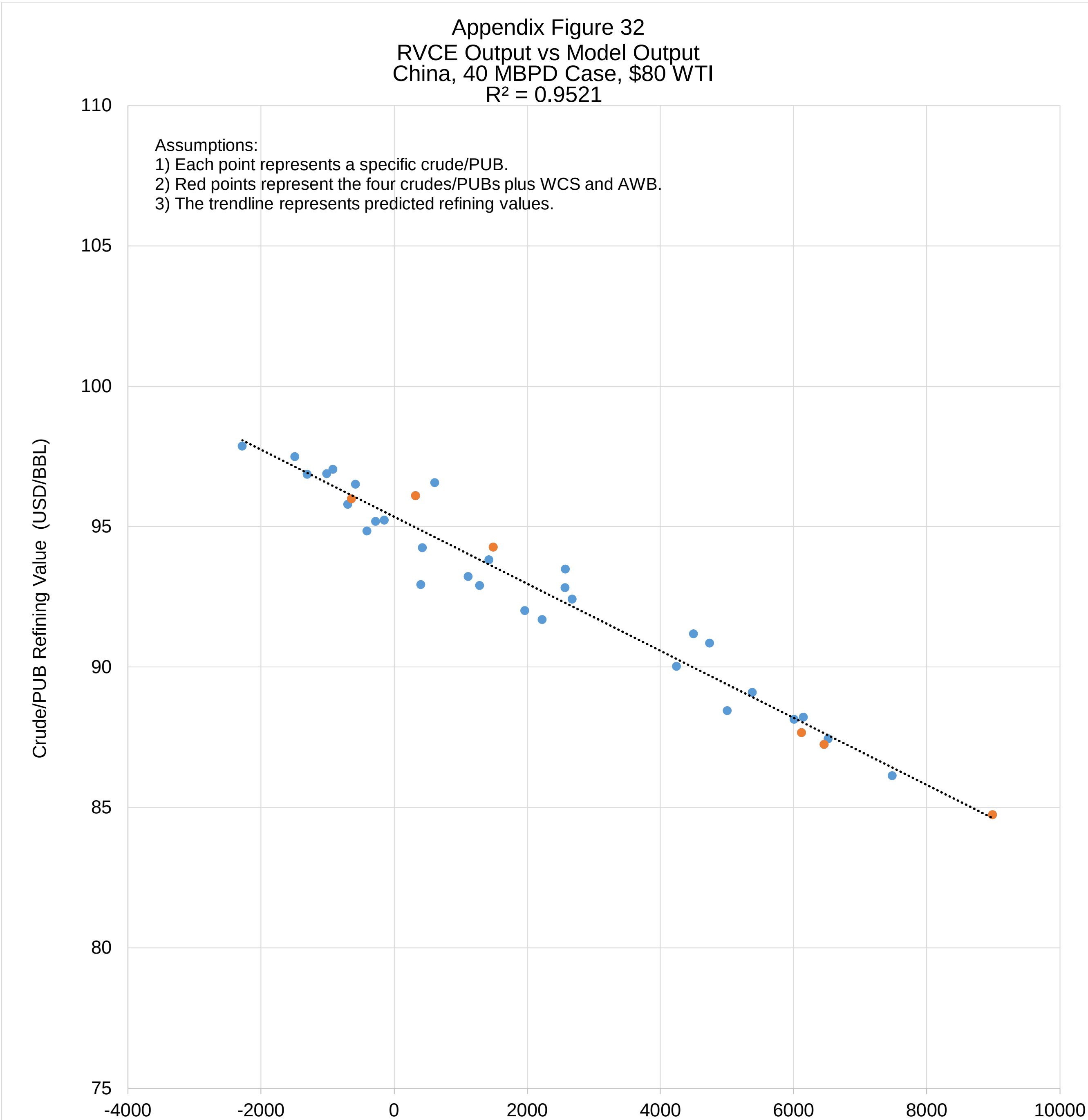

Appendix Figure 28
RVCE Output vs Model Output
China, 10 MBPD Case, $80 WTI
R² = 0.947
Assumptions:
1) Each point represents a specific crude/PUB.
2) Red points represent the four crudes/PUBs plus WCS and AWB.
3) The trendline represents predicted refining values.
Crude/PUB Refining Value (USD/BBL)
110
105
100
95
90
85
80
75
-457000
-407000
-357000
-307000
-257000
-207000
-157000
-107000
-57000
-7000


Appendix Figure 29
RVCE Output vs Model Output
China, 40 MBPD Case, $50 WTI
R² = 0.9652
Assumptions:
1) Each point represents a specific crude/PUB.
2) Red points represent the four crudes/PUBs plus WCS and AWB.
3) The trendline represents predicted refining values.
Crude/PUB Refining Value (USD/BBL)
70
68
66
64
62
60
58
56
54
52
50
-4000
-2000
0
2000
4000
6000
8000
10000



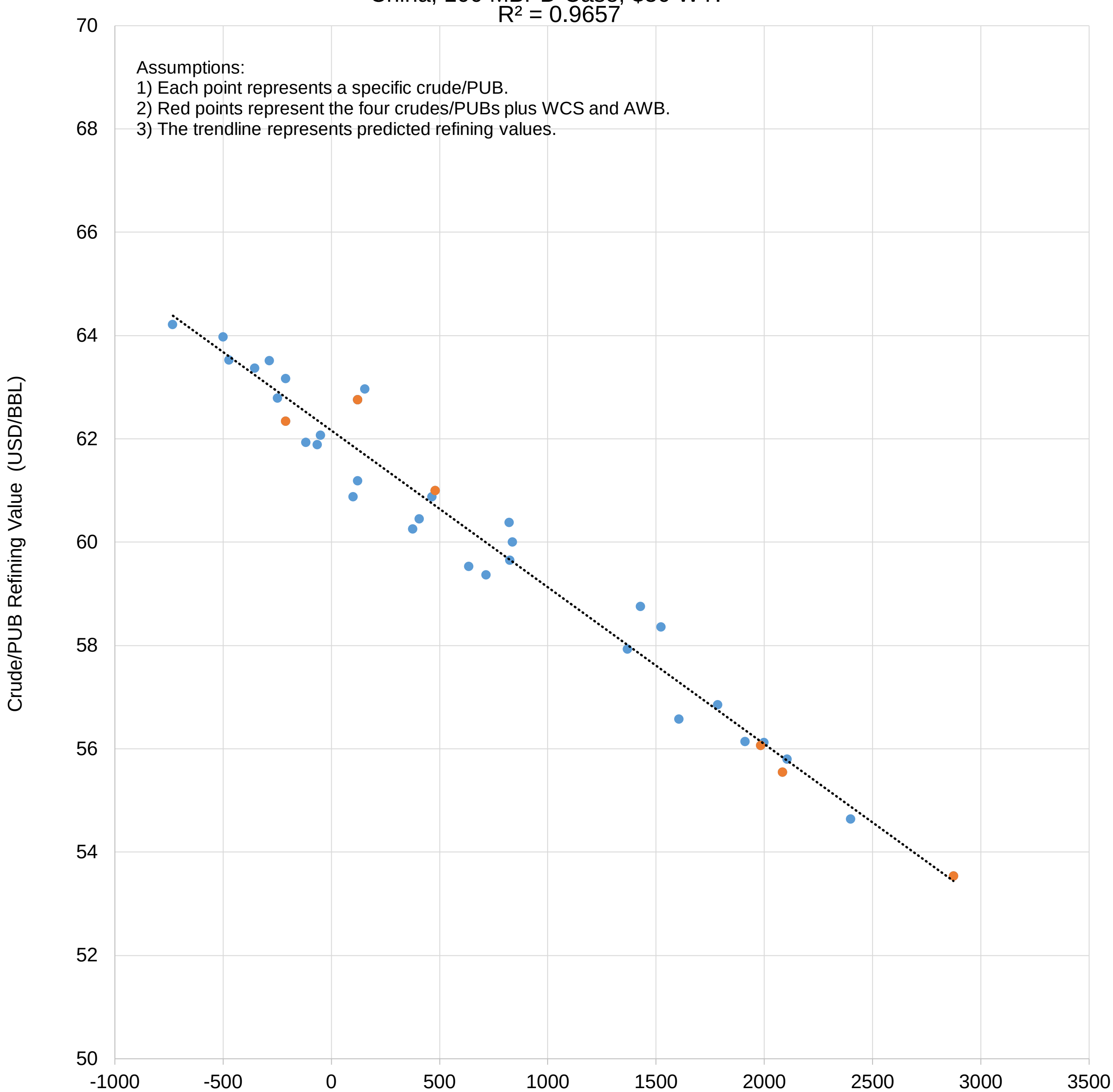
Appendix Figure 30
RVCE Output vs Model Output
China, 40 MBPD Case, $60 WTI
R² = 0.9611
Assumptions:
1) Each point represents a specific crude/PUB.
2) Red points represent the four crudes/PUBs plus WCS and AWB.
3) The trendline represents predicted refining values.
Crude/PUB Refining Value (USD/BBL)
85
80
75
70
65
60
55
-4000
-2000
0
2000
4000
6000
8000
10000

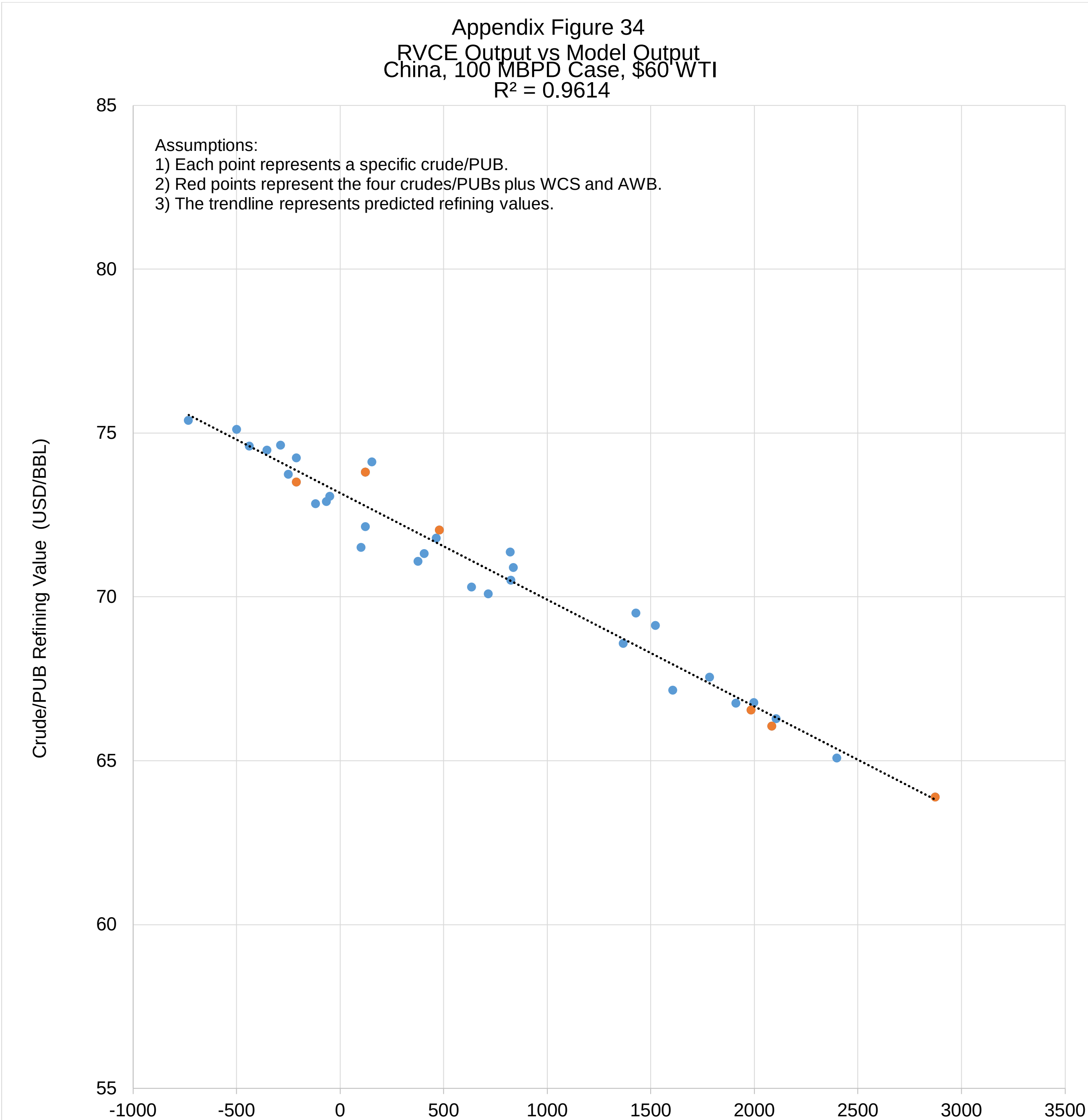

Appendix Figure 31
RVCE Output vs Model Output
China, 40 MBPD Case, $70 WTI
R² = 0.9566
Assumptions:
1) Each point represents a specific crude/PUB.
2) Red points represent the four crudes/PUBs plus WCS and AWB.
3) The trendline represents predicted refining values.
Crude/PUB Refining Value (USD/BBL)
95
90
85
80
75
70
65
-4000
-2000
0
2000
4000
6000
8000
10000

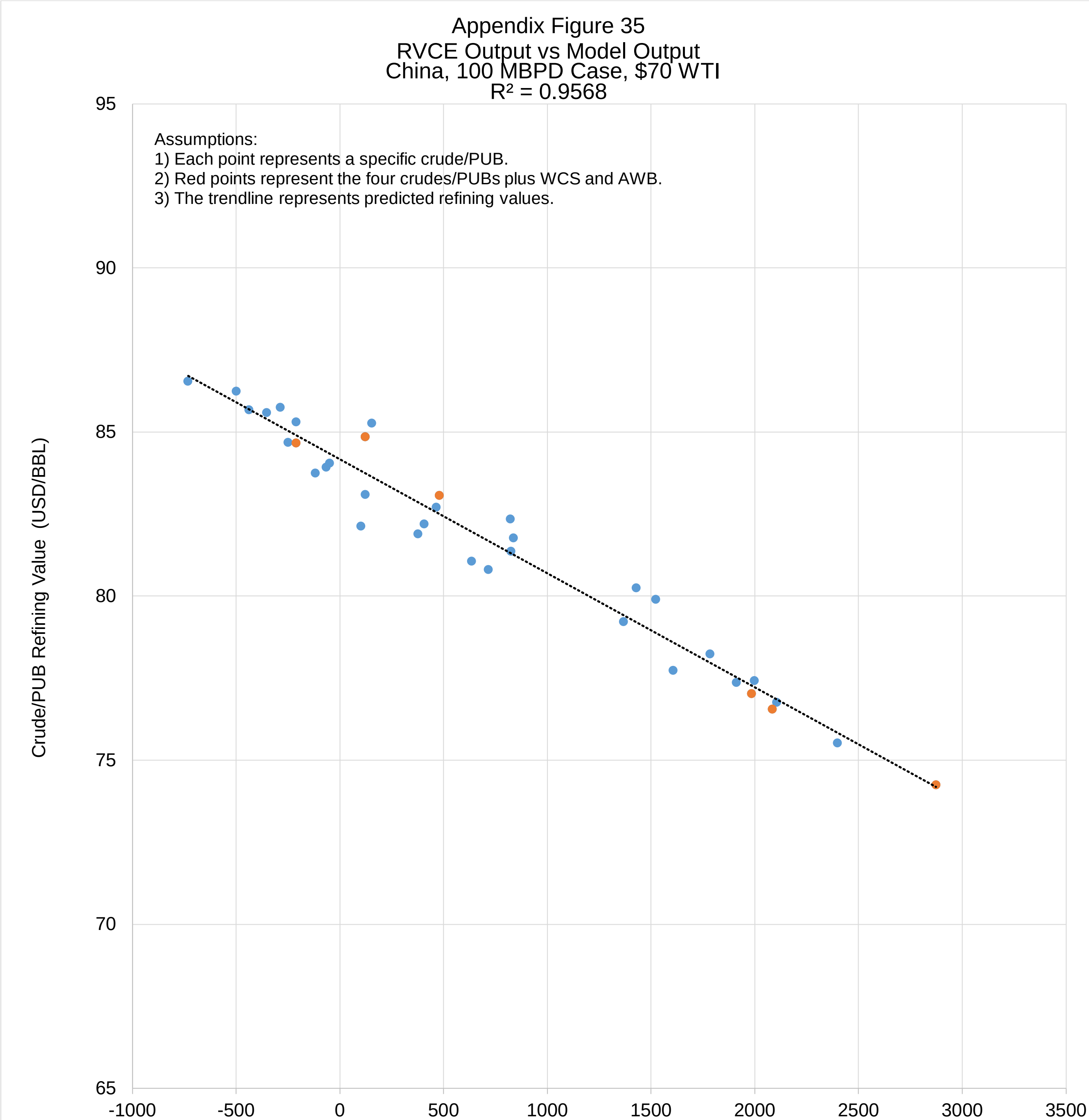


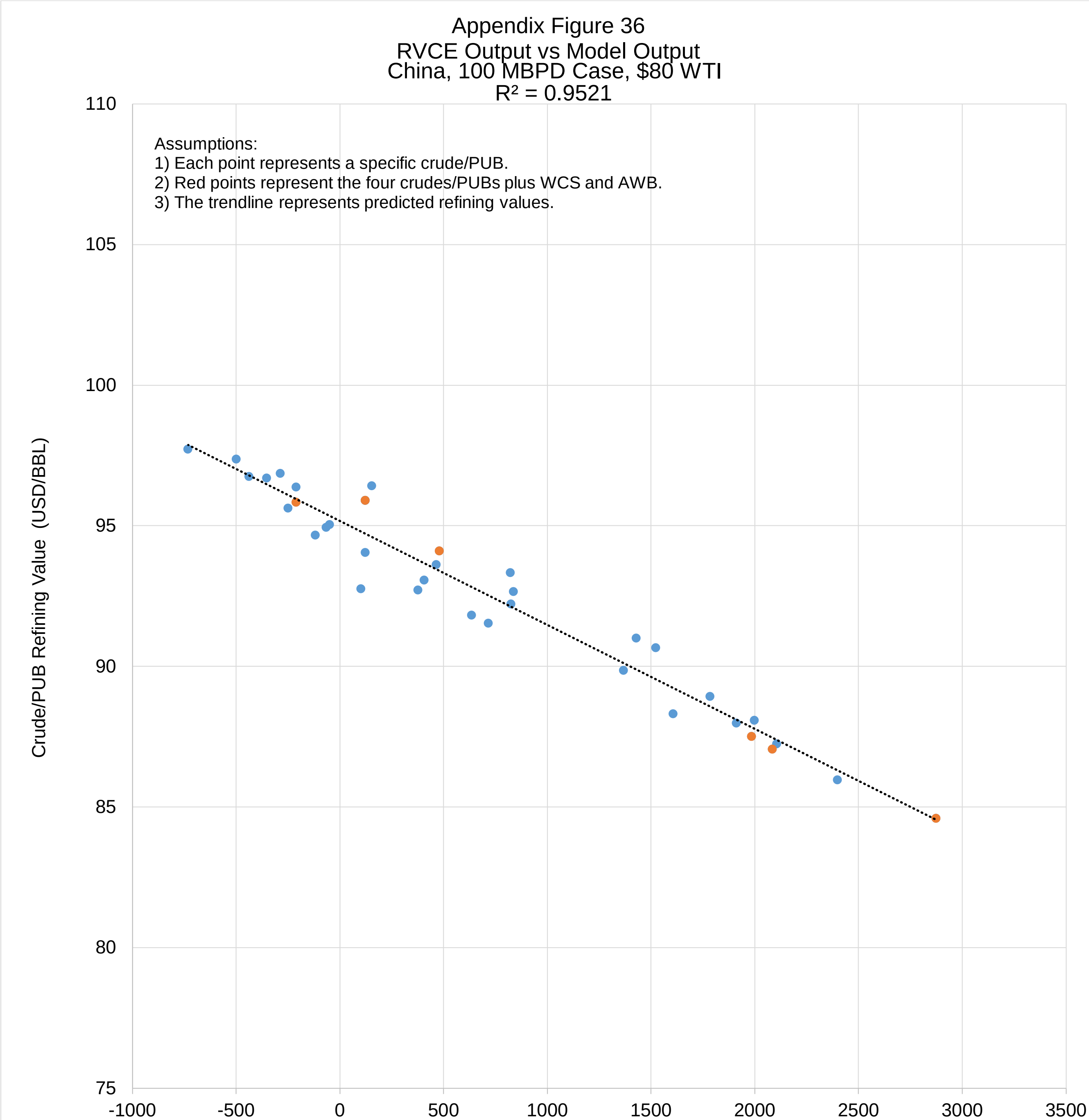
Appendix Figure 32
RVCE Output vs Model Output
China, 40 MBPD Case, $80 WTI
R² = 0.9521
Assumptions:
1) Each point represents a specific crude/PUB.
2) Red points represent the four crudes/PUBs plus WCS and AWB.
3) The trendline represents predicted refining values.
Crude/PUB Refining Value (USD/BBL)
110
105
100
95
90
85
80
75
-4000
-2000
0
2000
4000
6000
8000
10000

Appendix Figure 33
RVCE Output vs Model Output
China, 100 MBPD Case, $50 WTI




Appendix Figure 34
RVCE Output vs Model Output
China, 100 MBPD Case, $60 WTI
R² = 0.9614
Assumptions:
1) Each point represents a specific crude/PUB.
2) Red points represent the four crudes/PUBs plus WCS and AWB.
3) The trendline represents predicted refining values.
Crude/PUB Refining Value (USD/BBL)
85
80
75
70
65
60
55
-1000
-500
0
500
1000
1500
2000
2500
3000
3500


Appendix Figure 35
RVCE Output vs Model Output
China, 100 MBPD Case, $70 WTI
R² = 0.9568
Assumptions:
1) Each point represents a specific crude/PUB.
2) Red points represent the four crudes/PUBs plus WCS and AWB.
3) The trendline represents predicted refining values.
Crude/PUB Refining Value (USD/BBL)
95
90
85
80
75
70
65
-1000
-500
0
500
1000
1500
2000
2500
3000
3500



Appendix Figure 36
RVCE Output vs Model Output
China, 100 MBPD Case, $80 WTI
R² = 0.9521
Assumptions:
1) Each point represents a specific crude/PUB.
2) Red points represent the four crudes/PUBs plus WCS and AWB.
3) The trendline represents predicted refining values.
Crude/PUB Refining Value (USD/BBL)
110
105
100
95
90
85
80
75
-1000
-500
0
500
1000
1500
2000
2500
3000
3500