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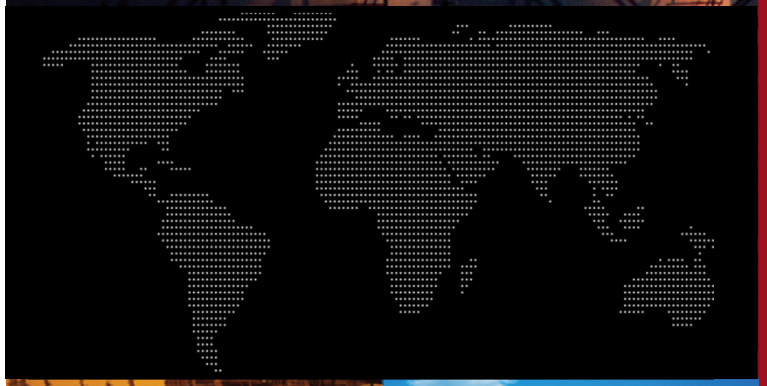


An Analysis of U.S. Light Tight Oil Absorption Capacity

September 24, 2014

CONFIDENTIAL

Study Outline

- **Introduction**
  - Study Objectives / Approach
  - Key Premises
- **Summary of Results**
- **LTO Absorption Mechanisms**
  - Fully utilize existing LTO processing capacity
  - Displace imports
  - Expand capacity to process LTO
- **Appendix**

Study Objective/Approach

- **Study Objective:** Estimate the capability of the U.S. to absorb incremental light tight oil (LTO) production.

- **Study Approach:** Considered the potential to absorb incremental LTO by each of the following mechanisms:
  - Full utilization of existing U.S. refinery light ends handling capacity.
  - Displacement of crude oil imports into the U.S.
    - Light
    - Medium
    - Heavy
  - Capacity Expansions
    - Announced
    - Additional

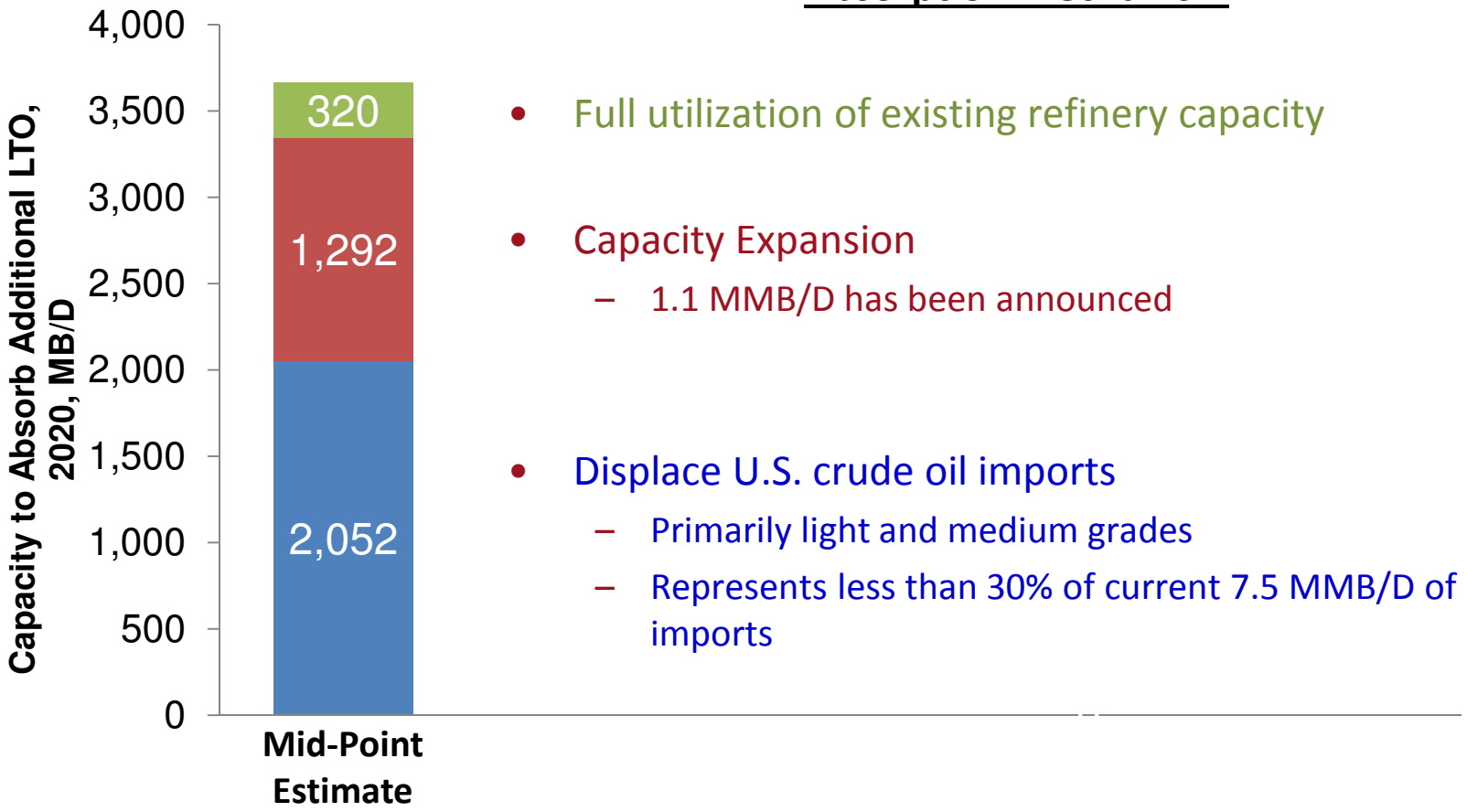
Key Premises

- Refineries have limited capabilities for processing naphtha and lighter material (hydrocarbons boiling below 350°F). LTO processing is constrained due to its relatively high naphtha and lighter content.
  - LTO processing constraints vary by refinery, and the nature of such constraints are generally not publically available. Such constraints may include the amount of traffic that the crude atmospheric distillation unit (CDU) can handle, refinery light ends handling capacity, CDU-fired heater capacity, the CDU pre-heat train configuration, and various other factors.
- Political, strategic, or other factors will not limit displacement of crude oil imports with additional LTO.
- Transportation of LTO to U.S. refineries will not be prohibitively constrained.
- Additional heavy crude supply is limited to that forecast for Canada by the Canadian Association of Petroleum Producers (CAPP).
- The analysis is focused on technical feasibility. No attempt has been made to assess refinery economics.
- Crude oil classification:

Classification	API Gravity
Light	>35°
Medium	26° – 35°
Heavy	<26°

U.S. LTO Absorption Capacity

- By 2020, the U.S. will have capacity to absorb **3.1 to 4.3 MMB/D** of **additional** U.S. (LTO) production versus that consumed in Q4 2013. The following chart depicts the absorption mechanisms corresponding to the mid-point of this range.



Absorption Mechanism

- Full utilization of existing refinery capacity
- Capacity Expansion
  - 1.1 MMB/D has been announced
- Displace U.S. crude oil imports
  - Primarily light and medium grades
  - Represents less than 30% of current 7.5 MMB/D of imports

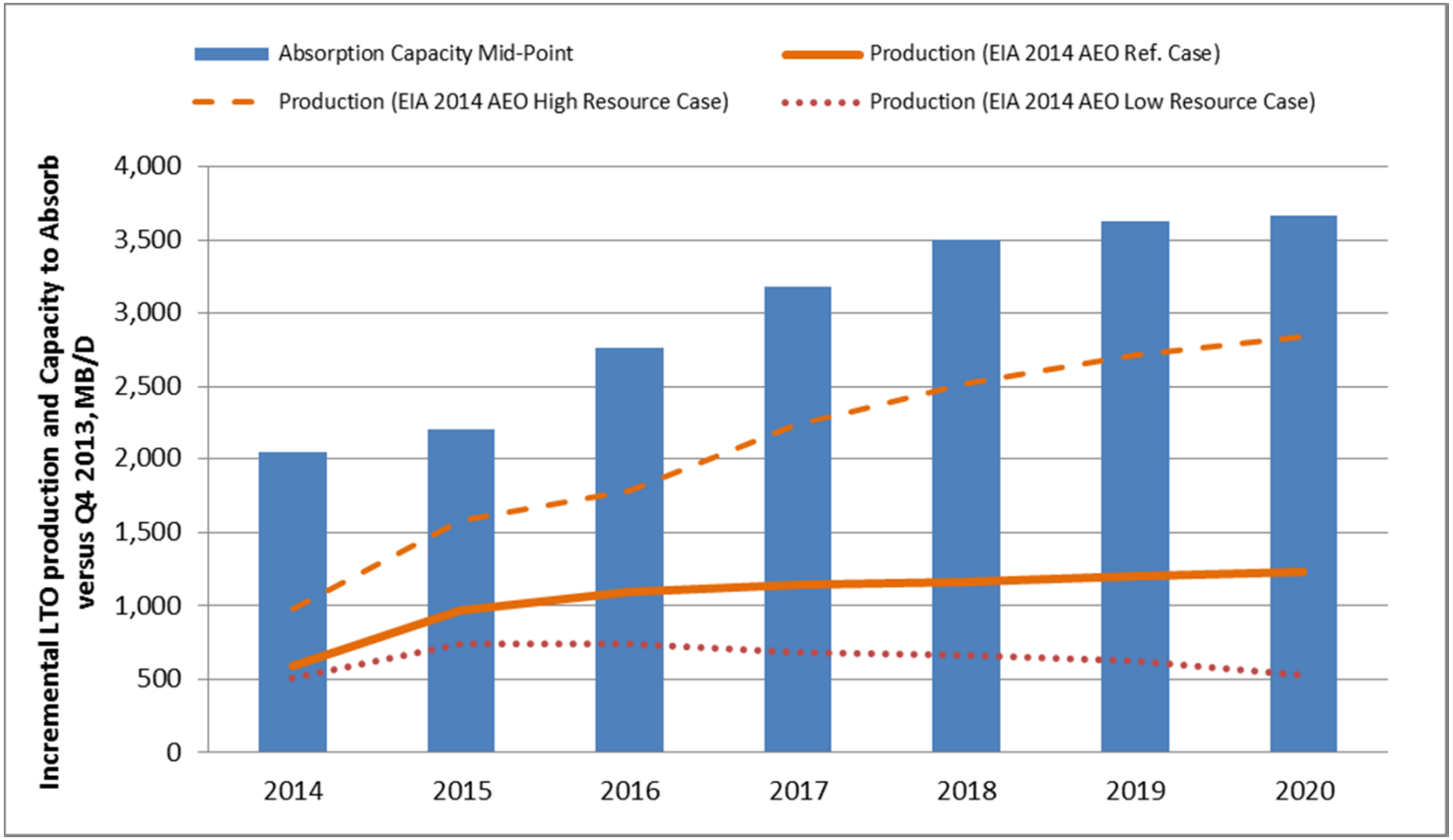
U.S. LTO Absorption Capacity Additional Detail

- By 2020, the U.S. will have capacity to absorb 3.1 to 4.3 MMB/D of incremental U.S. LTO production versus that consumed in Q4 2013.

Absorption Mechanism	U.S. Capacity to Absorb Incremental LTO, MB/D (2020 vs. Q4 2013)		
	Low	High	**Mid Point**
Fully utilize existing refinery capability	320	320	**320**
Displace light crude oil imports	661	661	**661**
Displace medium crude oil imports	977	1,382	**1,180**
Displace heavy crude oil imports	148	276	**212**
Announced expansion projects	844	1,129	**986**
Unannounced expansion projects	108	503	**306**
Total	3,057	4,270	**3,664**

Capacity to Absorb Additional LTO vs. Incremental LTO Production

- Using the mid-point of the high and low absorption capacity estimates, the U.S. is expected to have capacity to process all incremental LTO production through 2020, assuming EIA production forecasts.



Note: Incremental production is calculated using EIA's forecast for Lower 48 onshore crude oil production minus Q4 2013 actual production.

LTO Naphtha and Lighter Yield

- Given the premise that U.S. refineries are generally constrained by their naphtha and lighter handling capacity, it is important to understand the naphtha and lighter content of LTO as compared to grades for which they might substitute.
- It is assumed that the quality of incremental LTO production can be reasonably represented by the quality of a mix of 46% WTI, 27% Bakken, and 27% Eagle Ford crude oil.*
- Using Baker & O'Brien's proprietary crude oil assay library, the volume yield of naphtha and lighter material contained in incremental LTO supply was estimated at 36.5%.

	Naphtha and Lighter, Vol.%	% of Blend*
WTI	32.8%	46%
Bakken	35.7%	27%
Eagle Ford	43.6%	27%
Avg. LTO	36.5%	100%

*Based in part on the EIA's near-term crude oil production forecast by quality. See Appendix for details as to how the quality mix was estimated. Includes crude oil and condensates.

Underutilized Refinery Capability

- U.S. refiners appear to have underutilized their naphtha and lighter processing capacity in Q4 2013. The reasons underlying this untapped capacity can generally be categorized as follows:
  - **Low crude throughput**, due to maintenance activity, economics, or other factors. To the extent that naphtha and lighter processing capacity was underutilized because of reduced crude oil throughput, refiners should have capability to process additional LTO through incremental crude runs.
  - **Crude slate oriented more towards medium and/or heavy crude oil,** due to economics, contractual obligation, proximity to competing crude oil grades, or other factors. To the extent that naphtha and lighter processing capacity was underutilized because of crude slate, refiners should generally be able to process additional LTO by direct displacement of medium and/or heavy crude oil, on roughly a one-to-one basis.

- It is estimated that U.S. refineries can process an additional 432 MB/D of LTO by utilizing existing refinery capacity, with a breakdown as follows:*
  - 320 MB/D of incremental refinery crude runs.
  - 112 MB/D through direct displacement of medium crude oil.

* See Appendix for details.

US Crude Oil Import Displacement

- The U.S. imported 7.5 MMB/D of crude oil in Q4 2013.

Imported Crude Oil Type	Q4 2013 Imports, MB/D	Naphtha and Lighter, Vol.%*
Light	758	31.8%
Medium	2,852	23.3%
Heavy	3,916	14.2%
Total	**7,526**	

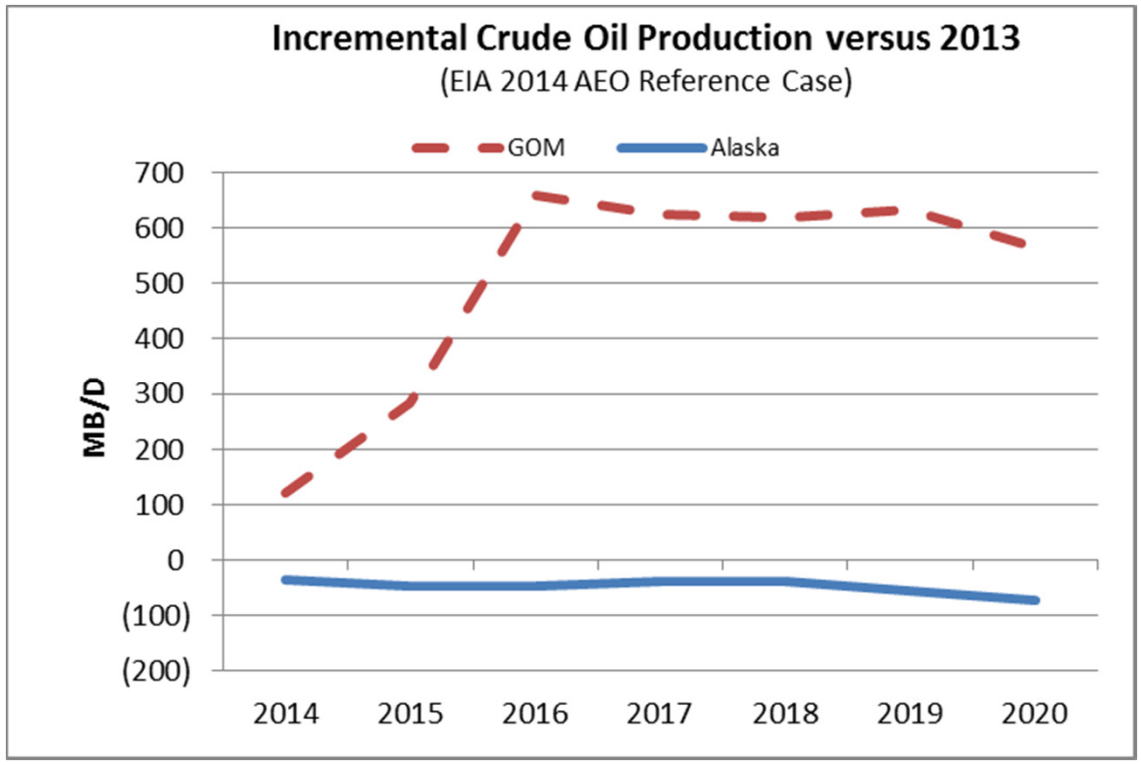
- Given that the naphtha and lighter content of imported crude oil is lower than that of LTO (36.5%) and given a premise that refineries are constrained by naphtha and lighter handling capacity, one barrel of imported crude oil would be displaced by less than 1 barrel of LTO.
  - For instance, 0.87 barrels of LTO can be processed in lieu of 1 barrel of imported light crude oil (31.8/36.5 = 87%)

- **661 MB/D** of LTO can be processed in lieu of the 758 MB/D of imported light crude oil.

* Estimated using Baker & O'Brien crude oil assays and EIA company level import statistics.

Imported Medium Crude Oil Displacement

- A net increase in domestic medium crude oil production, primarily from the Gulf of Mexico (GOM), is expected to displace a portion of imported medium crude oil.
  - All incremental GOM production is assumed to be medium crude oil.



Source: EIA 2014 AEO Reference Case.

Displacement of Medium/Heavy Crude Oil Imports

- Some refineries have excess naphtha and lighter processing capacity and can substitute LTO for imported medium crude oil on a one-for-one basis. As discussed previously in this report, it is estimated that 112 MB/D of LTO can be absorbed in such refineries.
- Several companies have announced plans to modify refineries to process LTO in lieu of imported medium and/or heavy crude oil. In these instances, it is assumed that a barrel of LTO can displaces 0.5 barrels of imported medium crude oil and 0.5 barrels of imported heavy crude oil. These refinery modifications are estimated to allow processing of 85 MB/D of LTO in lieu of 42.5 MB/D each of medium and heavy crude oil imports.

U.S. Refinery Modifications to Process LTO versus Medium/Heavy Crude Oil

Owner	Location	Estimated Capacity, B/CD	Estimated Start-Up
Marathon Petroleum	Robinson, IL	30,000	2016
Flint Hills Resources	Corpus Christi, TX	15,000	2016
LyondellBasell	Houston, TX	40,000	2016
Total		**85,000**	

Source: Baker & O'Brien Estimates, Company Reports.

Displacement of Medium Crude Oil Imports

- Medium crude oil imports can be displaced with a blend of LTO and heavy crude oil (or heavy intermediates).[1]
- A blend of 41% LTO and 59% imported heavy crude oil would provide the same naphtha and lighter volume as imported medium crude oil.

Crude Type	Naphtha and Lighter, Vol.%	Distillates	AGO[2] and Heavier
Imported Medium	23%	30%	47%
Synthetic Medium (41% LTO, 59% Imported Heavy)	23%	27%	50%
Imported Heavy	14%	22%	64%
Average LTO	37%	34%	29%

- LTO/heavy blends containing higher portions of LTO may also be viable, despite their potential for reducing total crude throughput. See Appendix for further analysis.

1 - There have been reports of asphaltene precipitation in some LTO/heavy oil blends which have led to equipment fouling. It is understood that this issues is being resolved in part through the use of chemical additives. In any event, it is assumed that there are no constraints on blending LTO and heavy crude oil.

2 - Atmospheric Gas Oil.

Displacement of U.S. Medium Crude Oil Imports Conclusions

- It is estimated that **1.0** to **1.3** MM**B/D** of LTO can be absorbed through displacement of imported medium crude oil.
  - **Low Case**: 41%/59% LTO/heavy crude oil blends, no impact on crude throughput.
  - **High Case**: 70%/30% LTO/heavy crude oil blends, 22% reduction in crude throughput. Additional atmospheric tower bottoms generated from additional crude runs is used in conjunction with LTO to displace imports.
- Through 2016, 41% LTO blends are assumed to be limited by heavy crude oil availability.
- 350 MB/D of medium crude oil imports are assumed as a floor for lube oil production, declining to 200 MB/D by 2020.

Import Displacement Mechanism	Medium Crude Oil Imports Displaced MB/D	LTO Absorbed Low Case MB/D	LTO Absorbed High Case MB/D
Replace medium crude oil imports with incremental domestic medium crude oil production.	491	0	0
Replace medium crude oil imports with LTO on a one-for-one basis using excess naphtha and lighter processing capacity.	112	112	112
Modify refineries to process LTO in lieu of medium crude oil with no loss in crude throughput.	43	43	43
Replace medium crude oil imports with LTO/heavy blends.	2,006	822	1,227
Total - 2020	**2,652**	**977**	**1,382**

Potential Mechanisms for Displacement of Heavy Crude Imports

- **Displace heavy crude oil imports with a blend of LTO and either rawbit or railbit.***
  - Allows refinery to maintain crude throughput and downstream unit utilization rates.
  - A blend of 33% LTO and 67% rawbit or 17% LTO and 83% railbit, would provide the same naphtha and lighter yield as imported heavy crude oil.

C rude Type	Naphtha and Lighter, Vol.%	Distillates, Vol. %	AGO and heavier, Vol.%
Imported Heavy	14	22	64
33% LTO/ 67% rawbit	14	24	62
17% LTO/ 83% railbit	14	21	65
Bitumen	3	19	78
Railbit	10	18	72
Average LTO	36	34	29

- **Direct substitution of LTO for imported heavy crude oil.**
  - Potential reduction in crude throughput and low utilization of conversion units (e.g., FCC, hydrocrackers, cokers) depending on feedstock market balances.
  - Some refineries are being modified to avoid a loss in refinery throughput when substituting LTO for heavy crude oil.

*Rawbit refers to raw bitumen and Railbit refers to a blend of raw bitumen and approximately 15% diluent.

Displacement of U.S. Heavy Crude Oil Imports Conclusions

- It is estimated that by 2020, **148** to **276** MMB/D of LTO can be absorbed through displacement of imported heavy crude oil.
  - **Low Case**: Assumes 200 MB/D of additional railbit availability and no additional rawbit availability.
  - **High Case**: Assumes 400 MB/D of additional railbit availability and 100 MB/D of additional rawbit availability.

Import Displacement Mechanism	Low Case		High Case	
	Imported Crude Oil Displaced	LTO Absorbed	Imported Crude Oil Displaced	LTO Absorbed
Modify refineries to process LTO in Lieu of heavy crude oil	43	43	43	43
Replace 0-100 MB/D of heavy crude oil imports with a 33%/67% LTO/rawbit blend	0	0	100	33
Replace 200 to 400 MB/D of heavy crude oil imports with a 17%/83% LTO/railbit blend	200	34	400	68
Replace 5% to 10% of remaining heavy crude oil imports with LTO, sacrificing crude runs.	183	71	337	132
Total	**426**	**148**	**880**	**276**

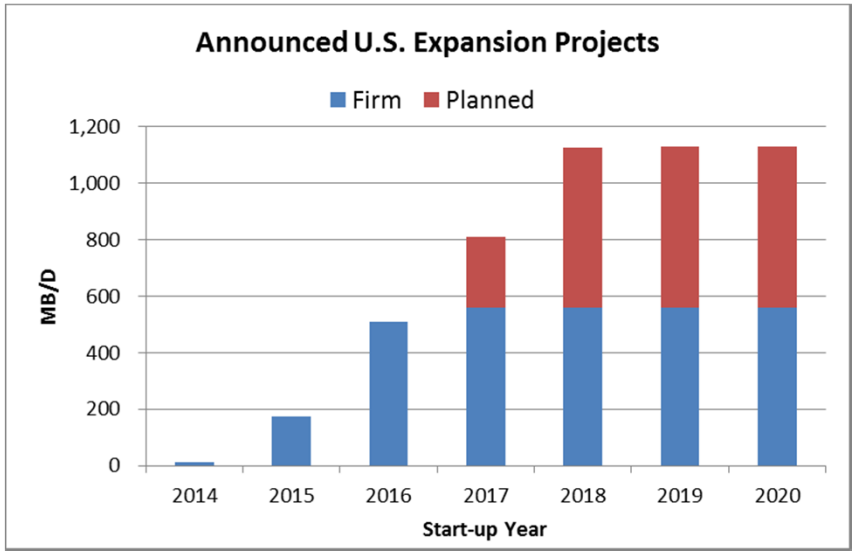
Displacement of Crude Oil Imports Summary

- It is estimated that 1.8 to 2.3 MMB/D of LTO can be absorbed through displacement of a portion of U.S. crude oil imports.

Crude Oil Type	U.S. Q4 2013 Imports, MB/D	LTO Absorption Potential, MB/D (vs. Q4 2013)		
		Low	High	Mid Point
Light	758	661	661	661
Medium	2,852	977	1,382	1,180
Heavy	3,916	148	276	212
Total	**7,526**	**1,786**	**2,318**	**2,052**

Announced Projects to Increase U.S. Crude Throughput

- Announced projects are expected to provide capacity to absorb **0.8 to 1.1** MMB/D of LTO.
- Roughly 1.1 MMB/D of crude oil and condensate expansion projects are under construction or are being considered.
- The high case assumes that all projects will be completed. For the low case, a 100% probability of completion was assigned to those projects assessed as firm. For others, a 50% probability was used.



Owner	Location	Estimated Capacity, B/CD	Estimated Start-Up	Firm
Delek	El Dorado, AR	10,000	2014	Y
Alon	Big Spring, TX	3,000	2014	Y
Calumet	San Antonio, TX	3,000	2015	Y
Delek	Tyler, TX	15,000	2015	Y
Kinder Morgan	Galena Park, TX	50,000	2015	Y
Marathon	Catlettsburg, KY	35,000	2015	Y
Tesoro	Salt Lake City, UT	4,000	2015	Y
Valero	McKee, TX	25,000	2015	Y
HollyFrontier Phase 1	Salt Lake City, UT	14,000	2015	Y
Marathon	Canton, OH	15,000	2015	Y
Flint Hills Resources	Corpus Christi, TX	10,000	2016	Y
Magellan	Corpus Christi, TX	50,000	2016	Y
Valero	Houston, TX	90,000	2016	Y
Valero	Corpus Christi, TX	70,000	2016	Y
Buckeye	Corpus Christi, TX	50,000	2016	Y
Dakota Prairie Refining	Dickinson, ND	20,000	2016	Y
CHS	McPherson, KS	15,000	2016	Y
Ergon	Newell, WV	5,000	2016	Y
Dakota Oil Processing	Trenton, ND	20,000	2016	Y
Phillips 66	Santa Maria, CA	4,500	2016	Y
Alon	Bakersfield, CA	60,000	2017	
HollyFrontier Phase 2	Salt Lake City, UT	15,000	2017	
Kinder Morgan	Galena Park, TX	50,000	2017	Y
Martin Midstream	Corpus Christi, TX	50,000	2017	
Targa	Channelview, TX	35,000	2017	
Phillips 66	Sweeny, TX	70,000	2017	
Three Tribes	Makoti, ND	20,000	2017	
Western Refining	El Paso, TX	25,000	2018	
Castleton	Corpus Christi, TX	100,000	2018	
Magellan	Corpus Christi, TX	50,000	2018	
Quantum Energy	Various	80,000	2018	
American Energy Holdings	Devils Lake, ND	20,000	2018	
Quantum energy	East Fairview, ND	20,000	2018	
Rock River Resources	Green River, UT	10,000	2018	
WEC	Gardendale, TX	10,000	2018	
CHS	Laurel, MT	5,000	2019	
Total		**1,128,500**		

Additional LTO Capacity Increases

- U.S. refiners are likely to implement additional projects to process LTO, beyond those announced.
  - Not all companies announce their intentions to increase capability to process LTO; particularly when little investment is required.
  - Companies are still assessing their options for processing additional LTO.

- For relatively moderate capital, it is expected that many refiners could debottleneck their facilities to process 10% to 20% more naphtha and lighter material.

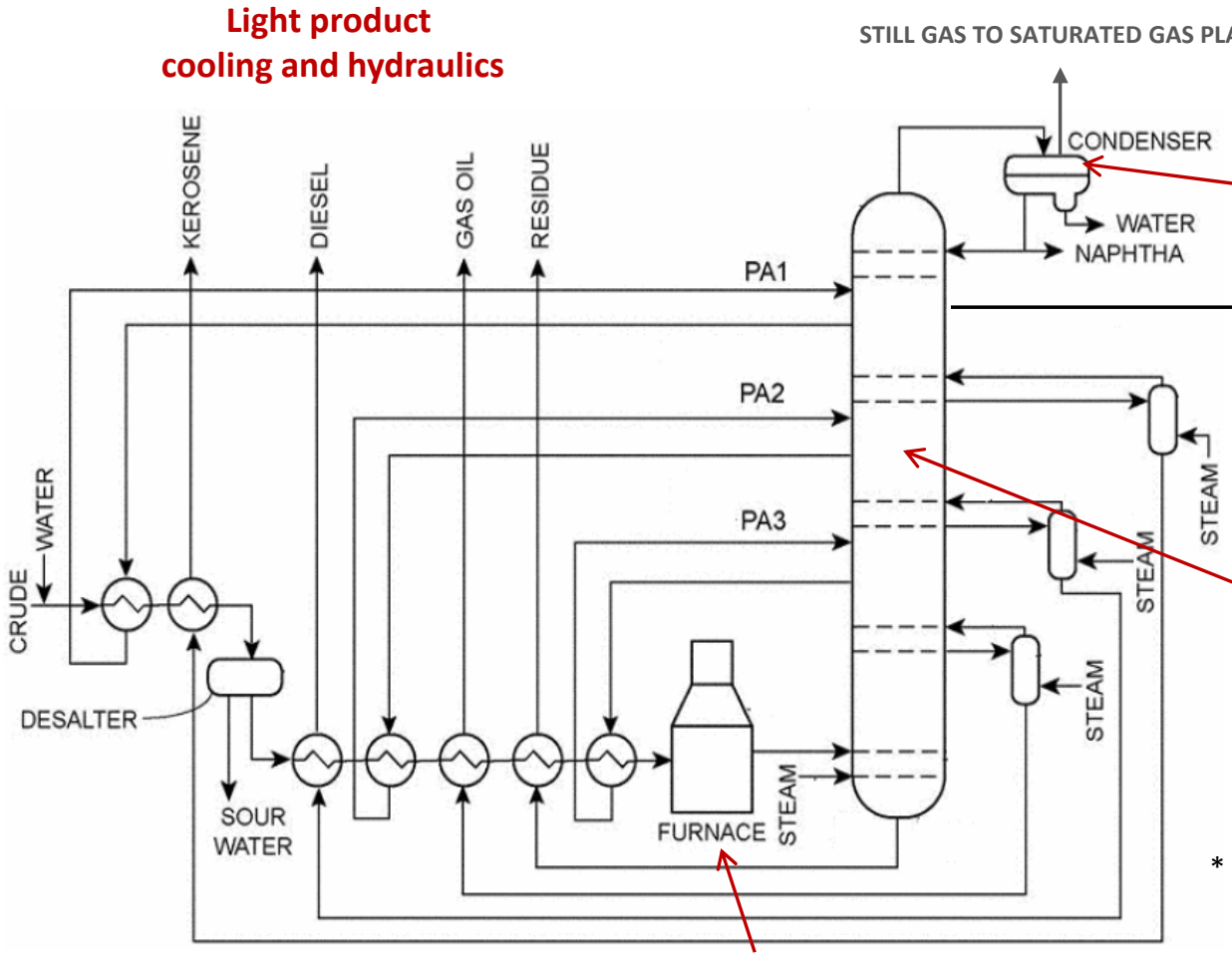
- By 2020 it is estimated that refiners will implement additional projects that will absorb 108 to 503 MB/D of LTO, at an average industry cost of $50 to $240 million per year (over five years).

- The following pages provide an overview of typical bottlenecks and potential debottleneck/expansion options for overcoming these bottlenecks.

*Oil and Gas Journal, E&P capital spending to rebound in North America, March 3, 2014.

Typical LTO Handling Constraints

- **Physical constraints to processing LTO vary by refinery but are generally centered around crude oil distillation and light ends handling.**



Light product cooling and hydraulics

Saturated gas plant capacity

Overhead hydraulics and cooling

Naphtha treating and processing

Crude column diameter

Preheat train configuration

Crude vaporization capacity

* Note: "PA" = pumparound circuit

Source: Petroleum Fractionation Overview, University of Oklahoma and Baker & O'Brien.

Estimated Capital Costs for Expanding LTO Capability

Refinery Area	Replacement Cost New, $MM[1]	+10% Expansion Costs, $MM[2]	+20% Expansion Costs, $MM[3]
Light Product Cooling & Hydraulics	6 – 12	2	4
Preheat Train	15 – 30	5	9
Crude Furnace/Vaporization	25 – 30	8	15
Column Overhead Hydraulics/Cooling	13 – 23	4	7
Sat Gas Plant – Compression/Cooling	20 – 40	6	12
Naphtha Hydrotreating	70 – 110	18	36
Naphtha Reforming	150 – 250	40	80
Crude Column Diameter (new column)	50 – 100	N/A	N/A
New Pre-Flash Tower	60 – 110	N/A	N/A
New Distillation Tower + Supporting Facilities (excluding tankage)	160 – 300	N/A	N/A
Additional Tankage	20-60	N/A	N/A

Notes:

1. Approximate, order of magnitude costs, mid-point sizing assumes 100 MB/D tower; 40 MB/D reformer/hydrotreater; costs do not include lost profits during shutdown.
2. 10% expansion costs estimated at 20% of replacement cost new.
3. 20% expansion costs estimated at 40% of replacement cost new; additional expansion beyond 20% assumed uneconomic vs. new facility.
4. Cost effective expansions may not be possible for one or more items shown

Hypothetical LTO Expansion Projects: 100 MB/D Distillation Train

Hypothetical Projects Shown:

$23 MM – 10% debottleneck of furnace, cooling, hydraulics, gas plant

$47 MM – 20% expansion of same

$82 MM – 10% debottleneck, including naphtha treating and reforming

$180-360 MM "mega project" for new distillation column and additional tankage

Refinery Area	Replacement Cost New, $MM	+10% Expansion Costs, $MM	+20% Expansion Costs, $MM
Light Product Cooling & Hydraulics	6 – 12	2	4
Preheat Train	15 – 30	5	9
Crude Furnace/Vaporization	25 – 30	8	15
Column Overhead Hydraulics/Cooling	13 – 23	4	7
Sat Gas Plant – Compression/Cooling	20 – 40	6	12
Naphtha Hydrotreating	70 – 110	18	36
Naphtha Reforming	150 – 250	40	80
Crude Column Diameter (new column)	50 – 100	N/A	N/A
New Pre-Flash Tower	60 – 110	N/A	N/A
New Distillation Tower + Supporting Facilities (excluding tankage)	160 – 300	N/A	N/A
Additional Tankage	20-60	N/A	N/A

$23 MM

$47 MM

$82 MM

$180 - 360 MM

Criteria for Estimating Additional Expansion Capacity

Certain refineries were assessed as more likely to expand than others, given a set of criteria:

- Refineries in PADDs 2 and 4 Less Likely to Expand Further
  - Refineries in the Mid-Continent and Rocky Mountain regions have enjoyed access to price-discounted crude oil for several years now, and pipeline bottlenecks have been relieved to some extent, reducing margin incentives (PADD 2); thus, it might be reasonable to expect that refineries in these areas are not likely to expand beyond the projects that have already been announced.
- Refineries in PADD 5 Not Likely to Expand
  - Refineries (especially in CA) have limited refined product supply disposition choices, lack existing pipeline infrastructure to LTO basins (relatively high logistical costs), and face continuing state regulatory and permitting pressures.
- Refineries in PADD 1 Will be Slower to Expand (or won't expand at all)
  - Historical profit performance and recent closures;
  - Relatively high logistical costs to access LTO basins; and
  - Uncertainty about long-term LTO volume availability.
- Refineries in PADD 3 are Primary Candidates for Expansion
  - Low-cost (pipeline) access to Eagle Ford and Permian Basin and, via connecting pipelines from Cushing, other LTO plays.
- Refineries that have already announced expansion projects or have recently implemented expansion projects are less likely to expand further.

Additional Refinery Projects Recap

- **Criteria Recap and Key Assumptions**
  - Only PADD 3 refineries are assumed to expand going forward.
  - Refineries with recent or projected expansion projects excluded.
  - Estimated total aggregate naphtha and lighter processing volume.
  - Evaluated range of refineries actually completing projects: 30%, 50%, 70%.
  - Evaluated range of capacity growth: +10%, +20%
  - Calculated expanded naphtha and lighter volumes and convert into LTO equivalent volume.

- **Results**
  - Range of **108 – 503 MB/D** of additional LTO absorption capacity.

Population of Refineries	Naphtha and Lighter, MB/D
Total U.S.	3,815
PADD 3 Only	1,961
PADD 3 Excluding Projects	1,301

Naphtha and Lighter, MB/D	Average Expansion Achieved	
Scenario	10%	20%
Projects completed for 30% of capacity	39	78
Projects completed for 50% of capacity	65	130
Projects completed for 70% of capacity	91	182

LTO Basis, MB/D	Average Expansion Achieved	
Scenario	10%	20%
Projects completed for 30% of capacity	108	216
Projects completed for 50% of capacity	180	359
Projects completed for 70% of capacity	251	503

Capacity to Absorb Additional LTO Annual Summary

Capacity to Absorb Additional LTO Production

MB/D

	Low Case						
	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Import Displacement	1,089	1,254	1,621	1,773	1,728	1,750	1,786
Processing Capacity Expansion	13	174	545	756	949	952	952
Utilize Existing Capacity	320	320	320	320	320	320	320
Total	**1,422**	**1,748**	**2,485**	**2,849**	**2,997**	**3,021**	**3,057**

	High Case						
	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Import Displacement	2,328	2,160	2,091	2,164	2,231	2,270	2,318
Processing Capacity Expansion	13	174	620	1,032	1,459	1,632	1,632
Utilize Existing Capacity	320	320	320	320	320	320	320
Total	**2,661**	**2,654**	**3,032**	**3,516**	**4,009**	**4,222**	**4,270**

	Mid-Point						
	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Import Displacement	1,709	1,707	1,856	1,969	1,980	2,010	2,052
Processing Capacity Expansion	13	174	582	894	1,204	1,292	1,292
Utilize Existing Capacity	320	320	320	320	320	320	320
Total	**2,042**	**2,201**	**2,759**	**3,182**	**3,503**	**3,622**	**3,664**

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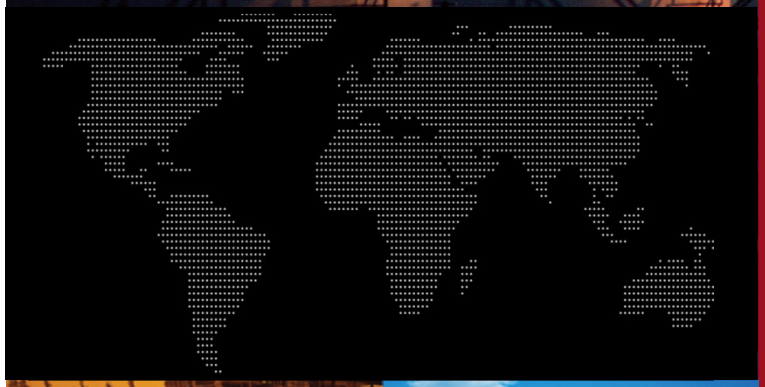


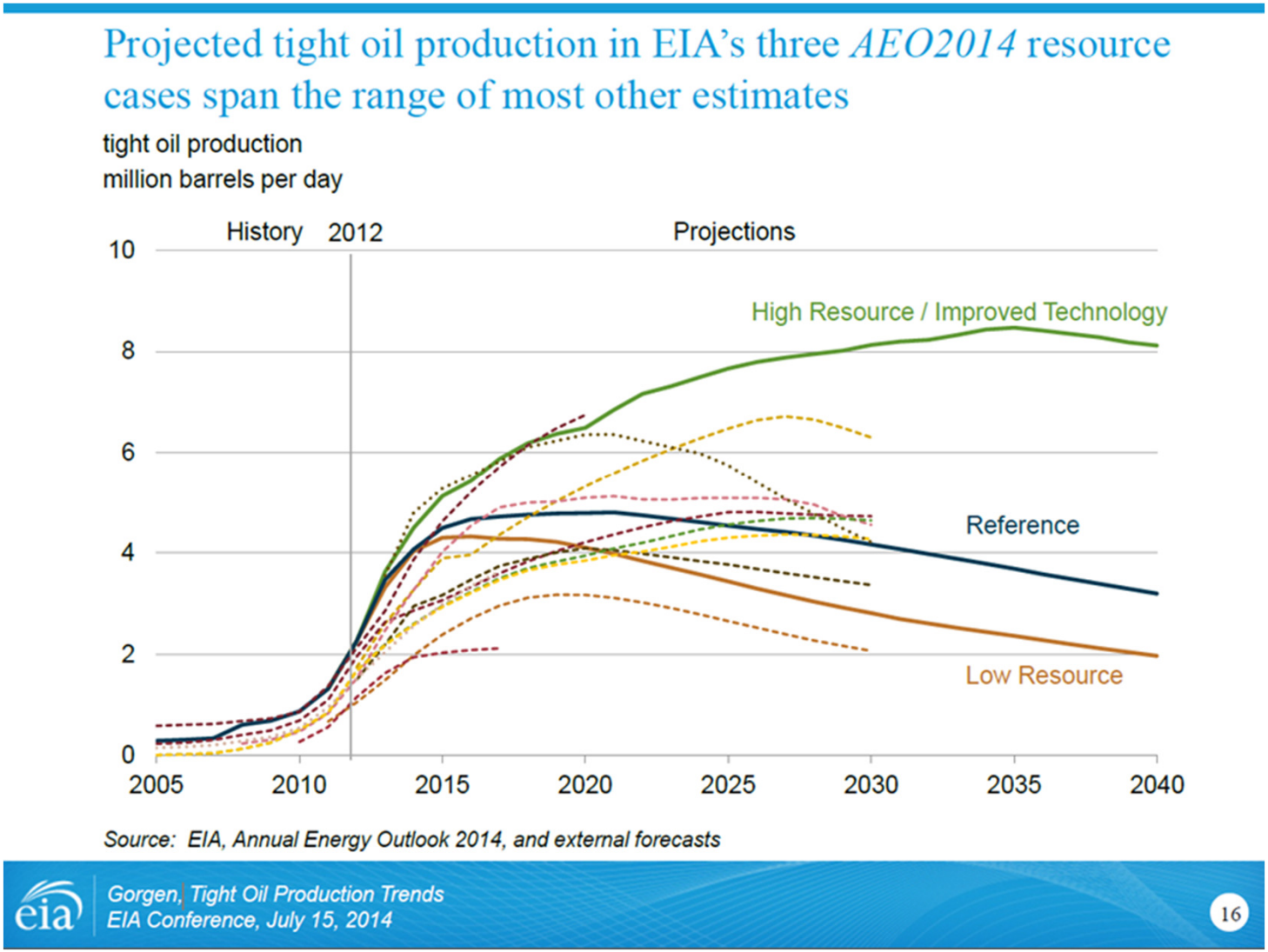
Appendix

EIA and CAPP Crude Oil Production Forecasts

	Production or Supply, Million B/D						
Million Barrels per Day	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
EIA 2014 AEO reference case							
Tight Oil[1]	4.07	4.49	4.67	4.72	4.76	4.78	4.79
Lower 48 Onshore	6.57	6.94	7.07	7.12	7.14	7.18	7.21
Lower 48 Offshore Gulf	1.41	1.57	1.95	1.92	1.91	1.92	1.85
Alaska	0.47	0.46	0.46	0.47	0.47	0.45	0.44
EIA 2014 AEO high oil and gas resource case							
Tight Oil[1]	4.50	5.13	5.43	5.88	6.19	6.37	6.49
Lower 48 Onshore	6.96	7.56	7.76	8.21	8.50	8.69	8.82
EIA 2014 AEO low oil and gas resource case							
Tight Oil[1]	4.04	4.30	4.33	4.28	4.27	4.22	4.11
Lower 48 Onshore	6.49	6.72	6.72	6.66	6.64	6.60	6.50
CAPP W. Canadian Crude Oil Supply Forecast							
Total W. Canada heavy crude supply	2.16	2.39	2.75	2.96	3.15	3.38	3.64

1 - Tight oil represents resources in low-permeability reservoirs, including shale and chalk formations. The specific plays included in the tight oil category are Bakken/Three Forks/Spanish, Eagle Ford, Woodford, Austin Chalk, Spraberry, Niobrara, Avalon/Bone Springs, and Monterey.

EIA Tight Oil Production Forecast Comparison with Other Forecasts



Source: Review of EIA oil production outlooks for 2014 EIA Energy Conference, July 15, 2014, Samuel Gorgen.

Estimation of Underutilized Refinery Capability Methodology

- For each U.S. fuels refinery operating during Q4 2013, estimates of quarterly refinery crude runs and the volume of naphtha and lighter material processed were tabulated for 2005 through 2013.
- For each refinery, maximum sustainable crude throughput (per calendar day) and maximum sustainable naphtha and lighter handling capacity (per calendar day) were estimated by multiplying the second highest observed quarterly performance by a 90% utilization factor.
  - The second highest month rather than the highest month was selected in order to be conservative.
  - The 90% utilization rate is intended to account for planned and unplanned reductions in throughput.
- Q4 2013 performance was compared to maximum sustainable performance to determine the amount of underutilized processing capacity.
  - During Q4 2013 some refineries were operating above their maximum sustainable performance and others were operating below maximum. The net effect was a 320 MB/D underutilization of crude throughput capacity and 158 MB/D underutilization of naphtha and lighter capacity utilization.
- Using 320 MB/D LTO to fill out the underutilized crude capacity would consume 117 MB/D (320*36.5%) of the underutilized naphtha and lighter capacity.
- It is assumed that the remaining 41 MB/D of underutilized naphtha and lighter capacity would be filled by processing 112 MB/D LTO (41/36.5%) in place of 112 MB/D of imported medium crude oil.

Estimating the Quality of Average Incremental LTO Production - Methodology

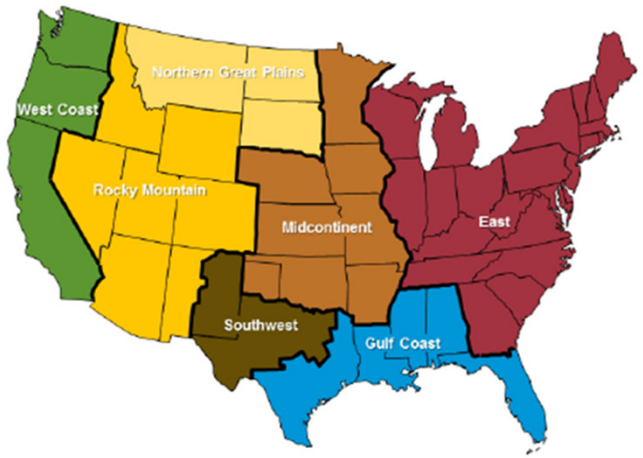
- EIA's May 29, 2014 forecast of U.S. crude oil production by quality and by region formed a basis for the analysis.
- It was assumed that all crude oil production outside of the West Coast, Alaska, and Gulf of Mexico was 100% LTO.
- Production volume from each region was assigned to one of three crude oil assays as shown in the table below.

EIA Production Region	Production Change[1] 12/15 vs 12/13, MB/D	% LTO[2]	Volume Corresponding to the Various Assays Used to Characterize Oil Quality,[2] MB/D			
			Eagle Ford	Bakken	WTI	Total
Northeast	3	100%	3			3
Gulf Coast	326	100%	326			326
Midcontinent	68	100%			68	68
Southwest	432	100%			432	432
Rocky Mountains	67	100%			67	67
West Coast	55	0%				-
N. Great Plains	331	100%		331		331
Gulf of Mexico	360	0%				-
Alaska	(80)	0%				-
Total			**329**	**331**	**567**	**1,227**
% of Total LTO			***27%***	***27%***	***46%***	

[1] EIA, "U.S. Crude Oil Production Forecast-Analysis of Crude Types", May 29, 2014

[2] EIA, Baker & O'Brien Assumption

Map 1. U.S. onshore lower-48 production regions



Source: EIA, Short-Term Energy Outlook.

LTO / Heavy Crude Oil Blends - Illustration #1

- Base Case: A refinery processing 100 MB/D of imported medium crude oil, constrained by the volume of naphtha and lighter material that can be processed.
- As LTO becomes a higher portion of the LTO/heavy blend, total crude throughput becomes constrained and production of feedstock for downstream conversion units declines.
- Minimum unit turndown constraints become a concern below roughly 70% of the Base Case, suggesting in this example a maximum 65% LTO in an LTO/heavy blend.
  - A portion of the decline in conversion unit feedstock may be filled by increasing supply of atmospheric tower bottoms from new condensate splitters and refinery investments.

Case	% LTO in L/H Blend	Medium Crude	Heavy Crude	LTO	Total Crude	Naphtha and Lighter	Distillates		AGO and Heavier	
		MB/D	MB/D	MB/D	MB/D	MB/D	MB/D	% of Base	MB/D	% of Base
Base		**100**			**100**	**23**	**30**	**-**	**47**	**-**
1	40%		60	40	101	23	28	92%	50	107%
2	50%		46	46	92	23	26	87%	43	91%
3	60%		34	51	84	23	25	83%	36	77%
4	70%		23	55	78	23	24	80%	31	66%
5	80%		15	58	73	23	23	78%	26	56%
6	90%		7	61	68	23	22	75%	22	47%

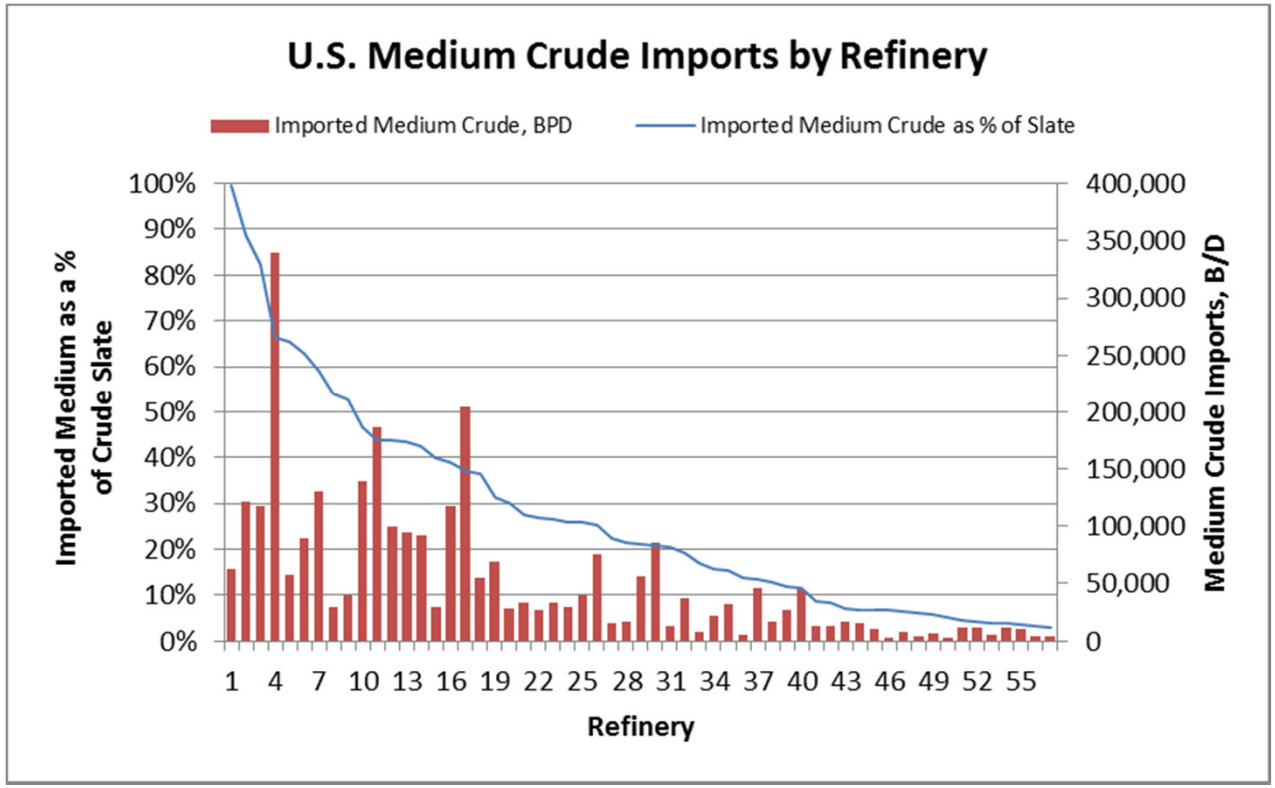
LTO / Heavy Crude Blends - Illustration #2

- Base Case: A refinery processing 50 MB/D of domestic medium and 50 MB/D of imported medium crude oil, constrained by the volume of naphtha and lighter material that can be processed. Assume domestic medium is the same quality as imported medium crude oil.
- Compared to the previous illustration, a higher LTO percentage in the blend can be tolerated before reaching downstream conversion unit turndown constraints.
- In this instance, substituting a 90% LTO blend for imported medium crude oil may be feasible.

Case	% LTO in L/H Blend	Medium Crude	Heavy Crude	LTO	Total Crude	Naphtha and Lighter	Distillates		AGO and heavier	
		MB/D	MB/D	MB/D	MB/D	MB/D	MB/D	% of Base	MB/D	% of Base
Base		**100**			**100**	**23**	**30**	**-**	**47**	**-**
1	40%	50	30	20	100	23	28	96%	49	103%
2	50%	50	23	23	96	23	28	94%	45	95%
3	60%	50	17	25	92	23	27	92%	42	89%
4	70%	50	12	27	89	23	27	90%	39	83%
5	80%	50	7	29	86	23	26	89%	37	78%
6	90%	50	3	31	84	23	26	88%	35	74%

U.S. Medium Crude Oil Imports

- It appears that there are only nine U.S. refineries in which imported medium crude oil comprises more than 50% of their crude slate.
- These nine refineries account roughly one-third of U.S. medium crude imports.



Source: EIA, Baker & O'Brien Analysis

Mechanisms for Displacement of Heavy Crude Oil Imports

- **Illustration: Direct substitution of LTO for heavy crude oil imports.**
  - Base Case: A refinery processing 100 MB/D of imported heavy crude oil, constrained by the volume of naphtha and lighter material that can be processed.
  - In order to process 10 MB/D of LTO, crude throughput is limited to 84 MB/D, and AGO and heavier production is 79% of the Base Case. 10 MB/D of LTO backs out 26 MB/D of heavy imports.
  - At 20 MB/D of LTO, AGO and heavier volume declines to 58% of the Base Case, creating potential issues with respect to minimum turndown on conversion units.
    - A portion of the decline in conversion unit feedstock may be filled by increasing supply of atmospheric tower bottoms from new condensate splitters and refinery investments.

Scenario	Heavy Crude	LTO	Total Crude	Naphtha and Lighter	Distillates		AGO and Heavier	
	MB/D	MB/D	MB/D	MB/D	MB/D	% of Base	MB/D	% of Base
Base	100	0	100	14	22	-	64	-
1	74	10	84	14	20	90	50	79
2	49	20	69	14	18	79	37	58
3	23	30	53	14	15	69	23	37
4	0	39	39	14	13	59	11	18

Capital Cost Estimating Framework for Expanding LTO Capability

- **The following approach was used to estimate potential capital costs for expanding LTO handling capability**
  - Estimated replacement cost new (RCN) for various components of the crude distillation train as well as for a standalone new distillation unit
  - Assumed that components can be expanded at a cost of:
    - 20% of RCN for 10% increase in capacity
    - 40% of RCN for 20% increase in capacity
  - Established investment scenarios
  - Calculated unit capital costs for investment scenarios