BAKER & O'BRIEN
INCORPORATED




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

Executive Summary

Prepared by:
Richard X. Thomas
Kevin G. Waguespack

September 24, 2014

Baker & O'Brien, Inc.
1333 West Loop South
Suite 1350
Houston, TX 77027

TABLE OF CONTENTS

1. INTRODUCTION 1

2. SUMMARY OF RESULTS 2

3. METHODOLOGY AND ANALYSIS 4

KEY PREMISES 4
LTO ABSORPTION MECHANISMS 4
DISPLACEMENT OF CRUDE OIL IMPORTS 4
UTILIZATION OF EXCESS REFINING CAPACITY 7
CAPACITY EXPANSION 7

4. ADDITIONAL INFORMATION 10

ABOUT BAKER & O'BRIEN 10
LIMITATIONS 10

APPENDIX A – EIA Tight Oil Production Forecasts Compared to Other Forecasts

1. INTRODUCTION

The United States (U.S.) produces almost 9 million barrels of crude oil per day. With the exception of some exports to Canada,[1] essentially all of the oil produced in the U.S. is consumed in the U.S. In addition to the U.S.'s own production, the U.S. imports close to 7.5 million barrels of crude oil per day from foreign sources. U.S. production of crude oil is increasing, especially light tight oil (LTO).[2] Nevertheless, the U.S. remains heavily dependent on imports of crude oil and is likely to continue to import crude oil for the foreseeable future.

The U.S. refining system is the largest, most complex and most flexible in the world. Given expectations for rising U.S. LTO production, Baker & O'Brien Inc. (Baker & O'Brien) was asked how much additional LTO the U.S. refining system can absorb.[3]

KEY FINDINGS

The U.S. refining system is expected to have capacity to process all the LTO that will be produced for the remainder of this decade, assuming LTO production within the range of forecasts prepared by the U.S. Energy Information Administration (EIA) in their 2014 Annual Energy Outlook (AEO).

- Baker & O'Brien estimates that the U.S. refining industry will have capacity to absorb an additional 3.1 to 4.3 million barrels per day (MMB/D) of LTO by 2020 (relative to the fourth quarter of 2013).
- This range of absorption capacity exceeds the EIA's AEO reference case, and even their high case, for incremental LTO production through 2020.

This document summarizes Baker & O'Brien's technical analysis of additional LTO volumes that can be absorbed in the U.S. for the remainder of the decade (to 2020), and summarizes the key assumptions and methodologies that underpin the analysis. Additional detail is provided in an accompanying presentation-style report.

[1] U.S. crude oil exports to Canada were 0.4 million barrels per day in June 2014.
[2] Includes crude oil and field condensate.
[3] Baker & O'Brien was engaged on behalf of The Consumers and Refiners United for Domestic Energy (CRUDE) to analyze the various options and mechanisms for absorbing increasing production of LTO.

2. SUMMARY OF RESULTS

From a conceptual standpoint, there is no limit to the amount of LTO that the U.S. can absorb if refining companies are given proper economic incentives and sufficient lead time to modify and/or expand processing capacity. LTO processing is relatively simple from a technical perspective and much less capital-intensive compared to processing heavier, sour crude oil that is consumed by a number of U.S. refiners. Similar to LTO production, LTO processing capacity is dynamic and is likely to respond to the changes in LTO production. If LTO production increases beyond projections, then additional LTO processing capacity is likely to be added.

In recent years, U.S. refiners have absorbed increasing LTO production through three primary mechanisms:

- Displacement of crude oil imports;
- Increased utilization of existing refinery capacity; and
- Capacity expansion

These same mechanisms are estimated to provide capacity to absorb an additional 3.1 to 4.3 MMB/D of LTO by 2020 (relative to the fourth quarter of 2013). Figure 1 depicts the relative contribution from each of these mechanisms using a year 2020 midpoint estimate.

The EIA considered a range of U.S. tight oil production forecasts in their 2014 AEO, and indicated that these cases span the range of most other estimates (see **Appendix A**). A midpoint estimate of additional LTO absorption capacity is shown annually in Figure 2, compared to incremental LTO production using three AEO cases:[4] the Reference Case, the High Oil and Gas Resource Case, and the Low Oil and Gas Resource Case. Estimates of available LTO absorption capacity of 3.1 to 4.3 MMB/D appear to be more than sufficient to absorb all incremental LTO production through 2020.

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

FIGURE 1
CAPACITY TO ABSORB ADDITIONAL LTO (2020 VS Q4 2013)

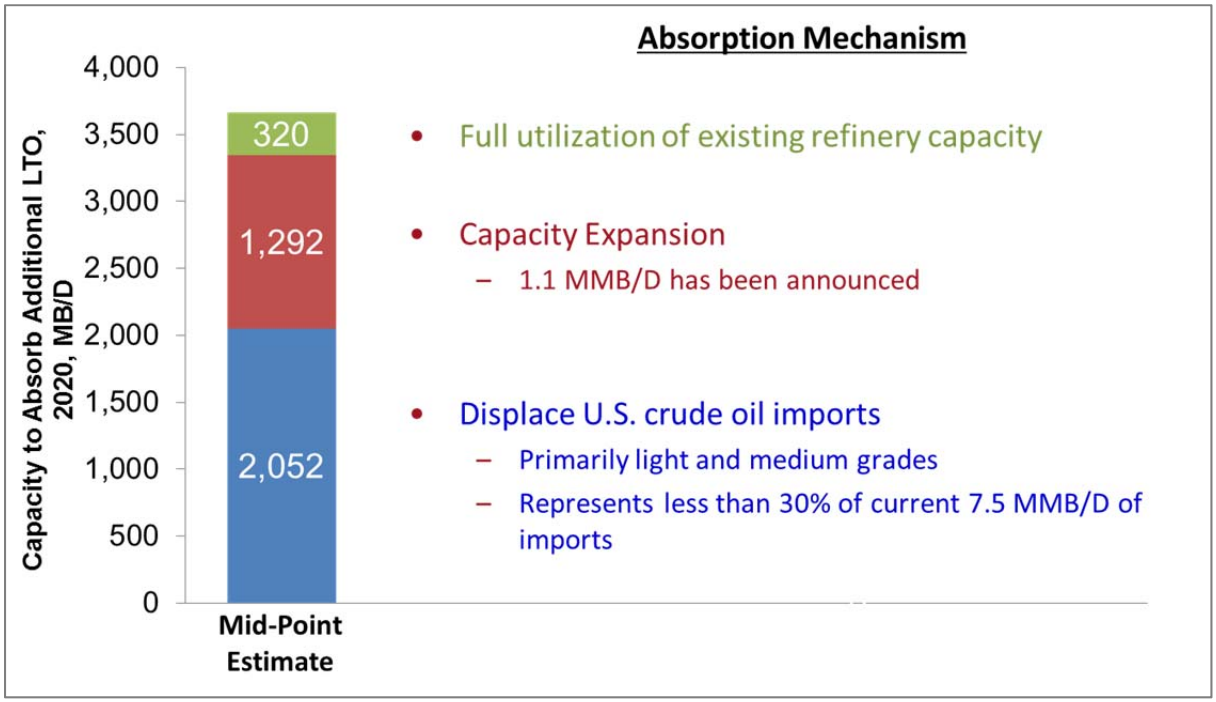
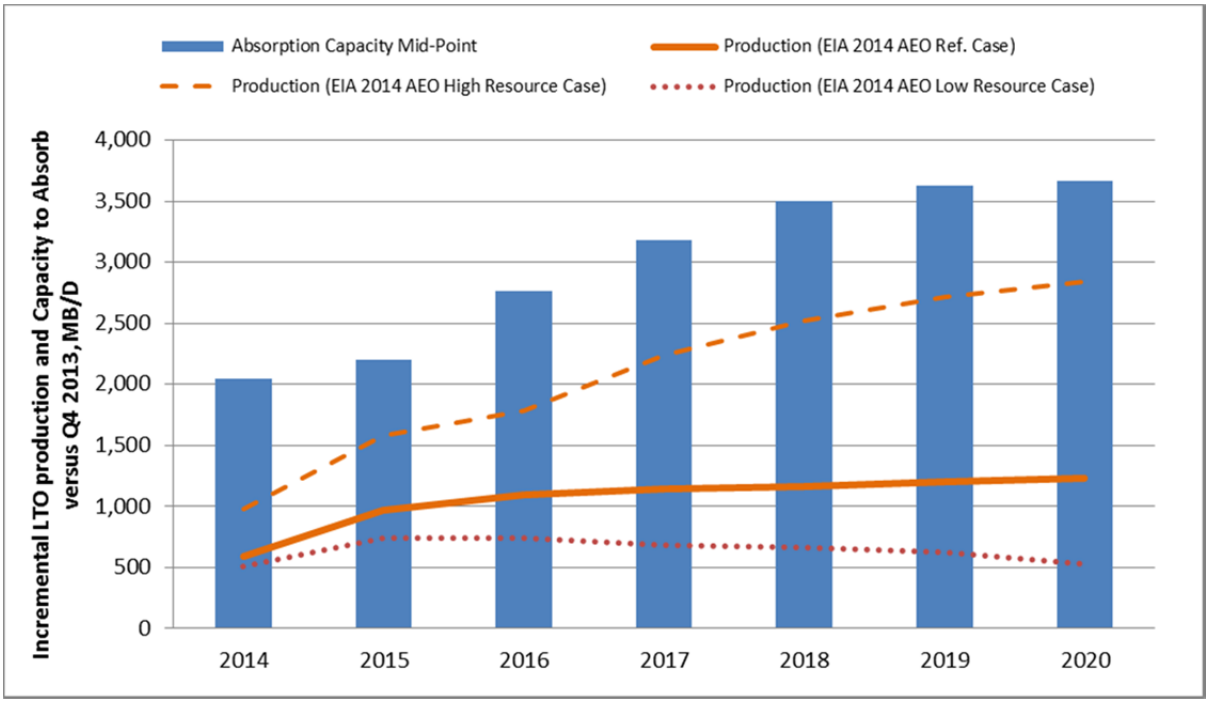


FIGURE 2
CAPACITY TO ABSORB LTO VS. INCREMENTAL PRODUCTION



3. METHODOLOGY AND ANALYSIS

KEY PREMISES

The analysis establishes a baseline using actual U.S. refinery crude throughput and crude oil imports for the fourth quarter of 2013. Starting from this baseline, estimates were made of how much additional LTO could be absorbed through each of the three absorption mechanisms referred to previously. The following key premises were used for the analysis:

- Refineries have limited capabilities for processing naphtha and lighter material (hydrocarbons boiling below 350°F).[5] LTO processing is constrained due to its relatively high content of naphtha and lighter material.
- 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 oil supply is limited to that expected to be produced in Canada.
- The analysis is focused on technical feasibility. No attempt has been made to assess refinery economics, which are dependent on numerous factors that are specific to each refinery.

LTO ABSORPTION MECHANISMS

DISPLACEMENT OF CRUDE OIL IMPORTS

The U.S. imported 7.5 MMB/D of crude oil in the fourth quarter of 2013. As summarized in Table 1, it is estimated that 1.8 to 2.3 MMB/D of additional LTO production can be absorbed by displacing all light crude oil imports and a portion of medium and heavy crude oil imports.

[5] LTO processing constraints vary by refinery, and the nature of such constraints are generally not publically available. Such constraints may include the volume of oil that the crude distillation unit (CDU) can handle, refinery light ends handling capacity, CDU fired heater capacity, CDU pre-heat train configuration, and various other factors.

TABLE 1
IMPORT DISPLACEMENT SUMMARY

Crude Oil Classification	U.S. Imports, Q4 2013, MB/D[6]	LTO Absorption Capacity MB/D (2020 vs. Q4 2013)		
		Low	High	Mid-Point
Light (> 35°API)	758	661	661	661
Medium (between 26 and 35°API)	2,852	977	1,382	1,180
Heavy (<26°API)	3,916	148	276	212
Total	**7,526**	**1,786**	**2,318**	**2,052**

Light Crude Oil Import Displacement: Displacement of light crude oil imports is relatively straightforward, given that these grades have similar qualities to LTO. A modest reduction in total refinery crude throughput may occur because the average LTO has a higher content of naphtha and lighter material (36.5 percent [%] on average) compared to the average imported light crude oil (31.8% on average[7]). Given the premise that refineries have a limited capability for handling naphtha and lighter material, 0.87 barrels of LTO can be processed in lieu of an average barrel of imported light crude oil (based on the ratio of naphtha and lighter material).

Medium Crude Oil Import Displacement: Displacement of medium crude imports is more challenging because the average imported medium grade contains only 23.3% of naphtha and lighter material, compared to LTO at 36.5%. Nonetheless, additional LTO can be absorbed through displacement of imported medium crude oil by the following means.

- Some refiners have excess naphtha and lighter handling capacity and can substitute LTO for imported medium crude oil on a barrel-for-barrel basis.
- Certain refiners are investing to provide flexibility to process LTO in lieu of imported medium crude oil on a barrel-for-barrel basis.
- Refiners can use blends of LTO and heavy crude oil (and/or heavy intermediates) as a substitute for imported medium crude oil.[8] For example, a blend of 41% LTO and 59% imported heavy crude oil contains the same amount of naphtha and lighter

[6] MB/D denotes thousand barrels per day.
[7] Estimated using Baker & O'Brien's crude oil assay library and EIA company level import data.
[8] There have been reports of asphaltene precipitation in some LTO/heavy oil blends which have led to equipment fouling. However, refiners appear to be processing these blends successfully. It is understood that this issue is being mitigated by several measures, including the use of chemical additives.

material as an average medium crude oil import. Blends containing higher portions of LTO can also be used, but would likely result in a reduction in crude throughput.

The analysis accounts for:

- Potential limitations on heavy crude oil availability;
- An increase in domestic medium crude oil production which is expected to displace a portion of medium crude oil imports that would otherwise be available for LTO absorption; and
- A base level of medium crude oil imports required to sustain current lube oil production.

Heavy Crude Oil Import displacement: Displacement of imported heavy crude oil can be challenging, because the average imported heavy crude oil contains only 14.2% of naphtha and lighter material compared to LTO at 36.5%. Nonetheless, additional LTO can be absorbed through displacement of imported heavy crude oil by the following means.

- Certain refiners are investing to provide flexibility to process LTO in lieu of imported heavy crude oil on a barrel-for-barrel basis.
- Refiners can blend LTO with rawbit[9] and/or railbit[10] as a substitute for imported heavy crude oil.[11] Blends of 34% LTO and 66% rawbit or 17% LTO and 83% railbit contain a similar amount of naphtha and lighter material as an average imported heavy crude oil.
- Refiners can directly substitute LTO for imported heavy crude oil. The volume of imports displaced is estimated to be 2.6 times as large as the volume of LTO absorbed because it is assumed that crude throughput would decline in order to maintain the same volume of naphtha and lighter material.

[9] Canadian raw bitumen containing very little diluent.
[10] A Canadian bitumen blend containing a lower diluent content (15%) than that required for pipeline transportation.
[11] Key considerations include the availability of rawbit and railbit, the capacity to load and unload heated rail cars, and new capabilities required for blending with LTO.

UTILIZATION OF EXCESS REFINING CAPACITY

U.S. refiners appear to have underutilized their naphtha and lighter processing capacity during the fourth quarter of 2013.[12] 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.

- A crude slate oriented towards medium and/or heavy crude oil, due to economics, contractual obligations, 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 throughput.

- 112 MB/D through direct displacement of medium crude oil. (This volume was accounted when estimating the amount of LTO that can be processed in lieu of medium crude oil imports.)

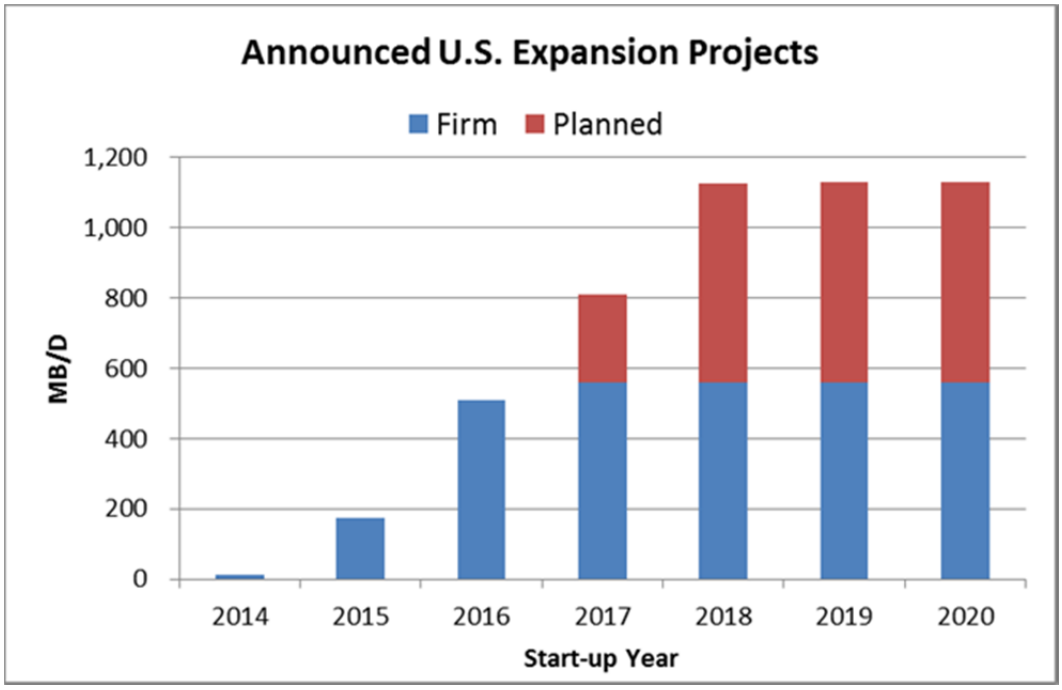
CAPACITY EXPANSION

Additional LTO can be absorbed through the expansion of LTO processing capacity. A total of 1.1 MMB/D of crude oil and condensate processing projects have been announced. In developing a low range estimate of LTO absorption capacity, an assessment was made as to the likelihood of each project being implemented. For those projects assessed as "Firm," a 100% probability of completion was assigned. For others, denoted as "Planned," a 50% probability of completion was assumed (Figure 3). The result is a range of 0.8 to 1.1 MMB/D of capacity to absorb additional LTO via announced projects.

[12] Using quarterly refinery throughput and crude slate estimates for 2005 through 2013, the amount of naphtha and lighter material processed by each U.S. refinery was calculated. The second highest quarterly volume of naphtha and lighter material was selected, and a 90% utilization factor was applied to establish the maximum naphtha and lighter processing capacity on a calendar day basis. This capacity was compared to fourth quarter 2013 performance to estimate the amount of unused capacity.

Most of these capacity expansions will help facilitate the displacement of medium and heavy crude oil, as they provide a source of heavy intermediate streams (e.g., vacuum gas oil, atmospheric residuum) that can be used by medium and heavy crude refiners to keep their heavy conversions units (fluidized catalytic cracker units, cokers) fully loaded while processing LTO.

FIGURE 3
ANNOUNCED EXPANSIONS



It is likely that U.S. refiners will implement additional projects to process LTO, beyond those announced at this time. Not all companies announce their intentions to increase capability to process LTO, particularly when relatively modest investment is required. In addition, companies are still assessing the potential for LTO production growth and their options for processing additional LTO. For relatively moderate capital, it is estimated that many refiners could debottleneck their facilities to process 10% to 20% more naphtha and lighter material leading to higher LTO absorption capability. It is estimated that refiners will implement

additional projects[13] that will absorb 108 to 503 MB/D of LTO, at an average industry cost of $50 to $240 million per year (assuming costs spread over five years).

[13] Projects currently underway that have not been announced publicly and those that will be announced in the future.

4. ADDITIONAL INFORMATION

ABOUT BAKER & O'BRIEN

Baker & O'Brien is an energy consultancy that serves a wide variety of clients with interests in the oil, gas, chemicals, and related industries. Many of the firm's clients are engaged in the production, processing, or transportation of petroleum, natural gas, and related industrial and consumer products. In addition, Baker & O'Brien frequently advises clients that provide construction, financial, risk management, and legal services to these industries.

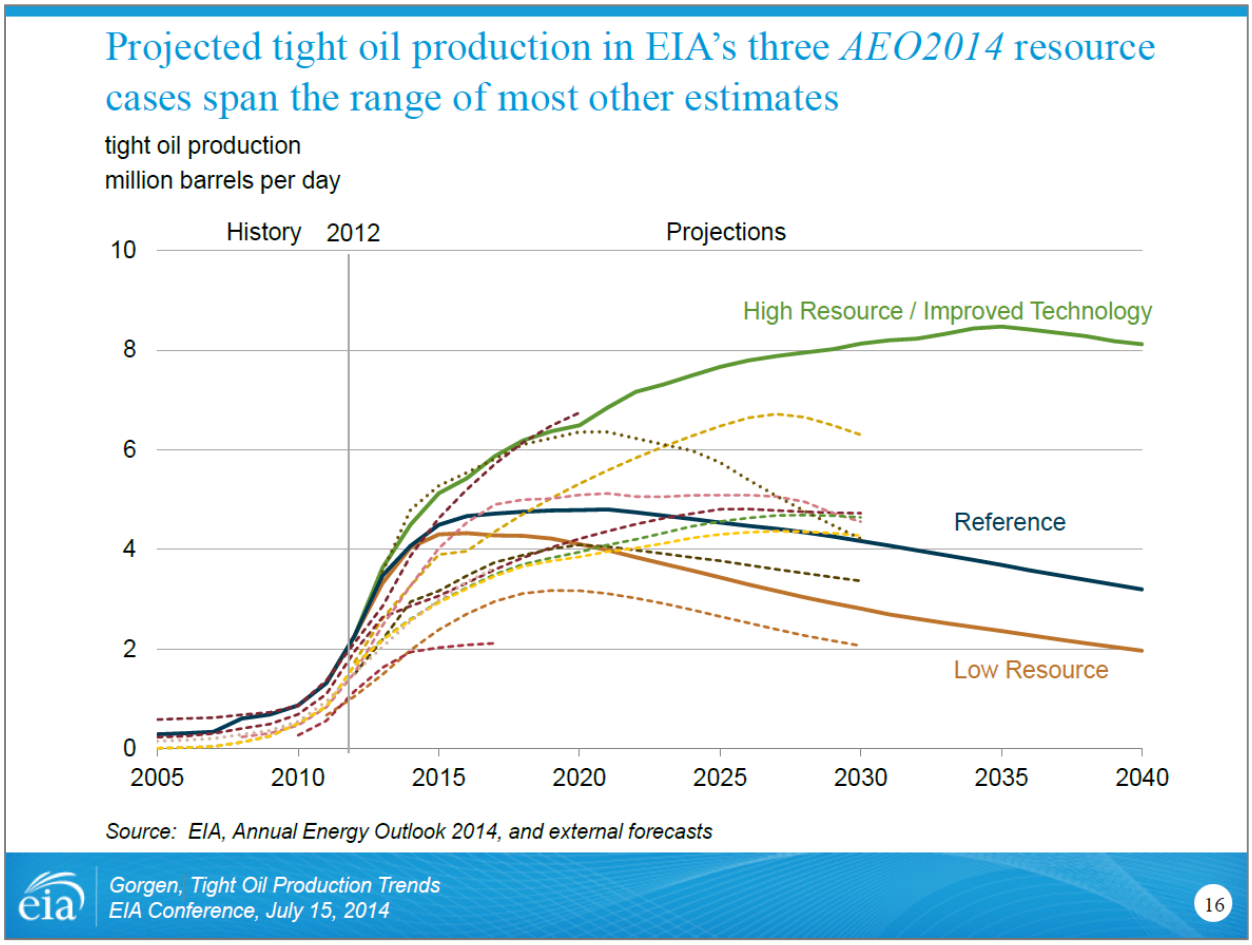
Clients rely upon Baker & O'Brien's experience and skill to understand and resolve unique business situations. The firm's consultants, primarily chemical and mechanical engineers, have extensive industrial experience and are familiar with its clients' standards and practices. Baker & O'Brien's combination of technical expertise and commercial experience has been applied to diverse issues in a variety of settings, ranging from the control room to the boardroom, and from negotiation to litigation.

LIMITATIONS

Baker & O'Brien prepared this report using reasonable care and skill, based on our education, training, experience, knowledge, and by applying methods that we believe are consistent with good industry practice for experienced engineers. No other representations or warranties, expressed or implied, are made by Baker & O'Brien. All results and observations are based on information made available at the time of preparation of this report. To the extent that additional information becomes available, or the factors or assumptions on which our analysis is based change, our opinions could change accordingly. Baker & O'Brien expressly disclaims all liability for the use, disclosure, reproduction, or distribution of this information.

APPENDIX A

EIA Tight Oil Production Forecasts Compared to Other Forecasts



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