



WHITE PAPER

# Finding the Best Upstream Investment Opportunities in a Low Oil Price World: North American Tight Oil Resource Economics and Implications for Oil Markets

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Acknowledgements: This paper could not have been completed without the efforts of Doug Elliott and Thu Nguyen.



## The Bottom Line

- U.S. and Canadian tight oil resources have emerged as a world-scale oil resource that is widely distributed, complex, and highly variable. ICF has assessed and evaluated this resource using geologic and well production data.
- In the U.S. Lower-48 states, the assessed technically recoverable tight oil resource base is 76 billion barrels, the equivalent of 24 years of 2014 U.S. oil production.
- Understanding tight oil well economics is key to identifying the most promising upstream investment opportunities.
- While a protracted period of low oil prices would have a large impact on tight oil development and production, ICF has determined that a large fraction of recent wells would have been economic at relatively low oil prices. For example, 68 percent of resources developed by new tight oil wells in 2013 would have been economic to drill at a wellhead price of \$60 per barrel, and 37 percent would have been economic at \$40 per barrel.

## Executive Summary

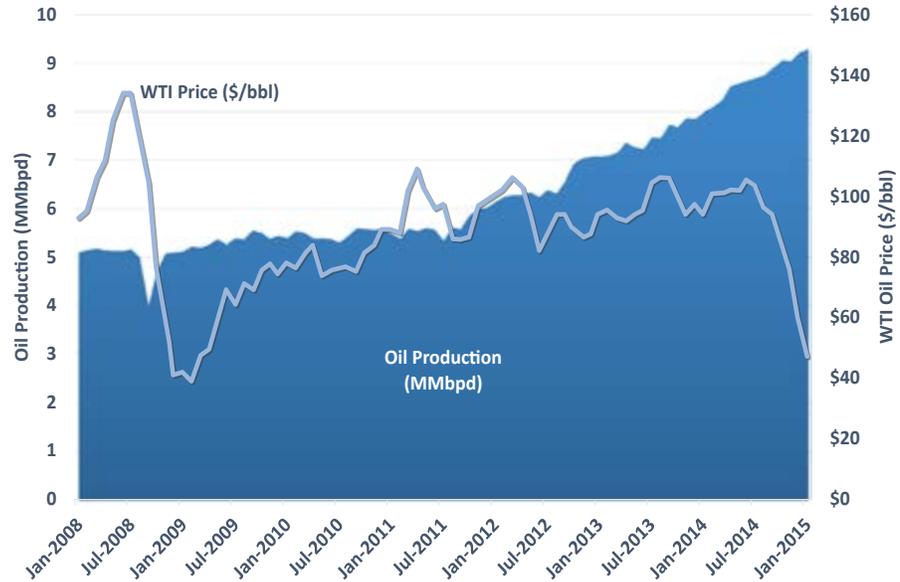
West Texas Intermediate (WTI) oil prices dropped 54 percent between July 2014 and January 2015. Despite this drop, U.S. oil production rose 7 percent to 9.3 million barrels per day (MMbpd) in January 2015, a level above which production is expected to be maintained for several months, (Exhibit 1) even with sustained low price forecasts and dramatically lower rig counts. The U.S. tight oil landscape is varied, although significant opportunities exist in the face of low oil prices. With global oil prices expected to remain low over the next couple of years, highly leveraged independent U.S. oil and gas producers are at significant risk, some potentially facing bankruptcy. The sustained low price environment creates new challenges for the U.S. upstream industry and also investment opportunities for those with a medium- to long-term investment horizon.

## Tight Oil

Tight oil is light crude oil or condensate contained in petroleum-bearing formations of low permeability, particularly shales. Economic tight oil production often involves horizontal well drilling and multi-stage hydraulic fracturing technologies also used to produce shale gas.



**Exhibit 1: Historical U.S. Oil Production and Prices**



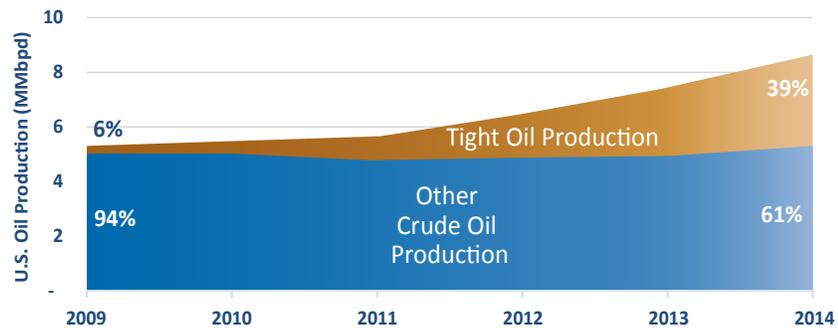
Source: EIA

Key factors in evaluating such opportunities include the identification of production “sweet spots” relative to company acreage, determination of individual well and overall play economics, evaluation of the risk of geological variability in sparsely drilled areas, and a thorough understanding of potential infrastructure constraints.

### Tight Oil Production Gains

Tight oil unconventional resources are driving upstream U.S. oil activity. The U.S. and Canadian tight oil resource base has emerged as a world-scale resource that has significantly impacted world oil markets, while generating thousands of high quality jobs in the United States and Canada. Because of activity in these plays, U.S. oil production has increased greatly and has had a large impact on the use of and investment in oil transportation infrastructure.

**Exhibit 2: U.S. Oil Production**



Source: EIA and ICF International

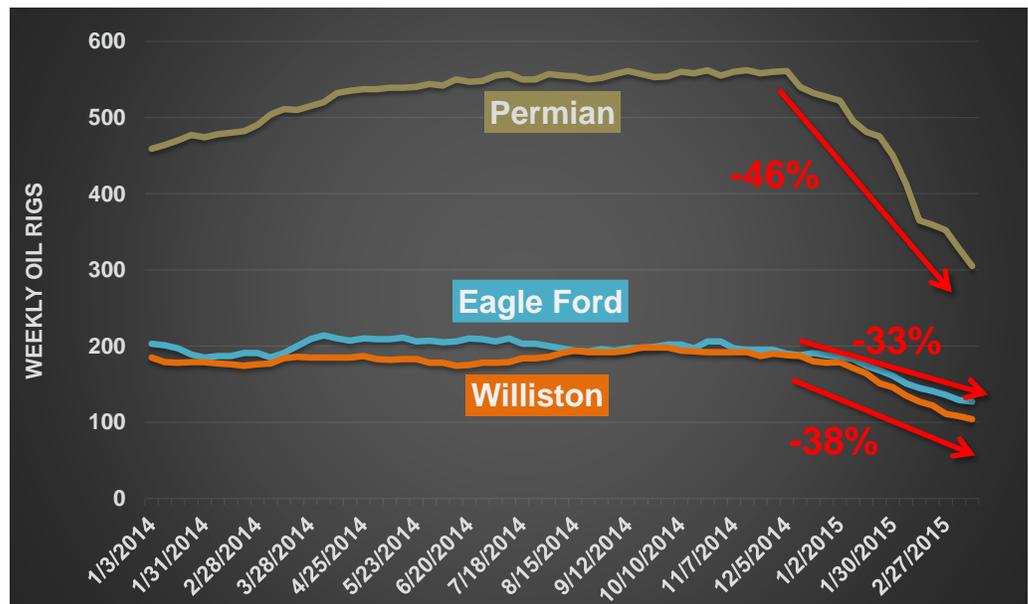


U.S. large-scale horizontal tight oil development began ramping up in the mid-2000s at a time when world oil prices hovered around \$100 per barrel. After the 2008 price drop caused by the global economic recession, oil prices rebounded back to that level and were sustained around \$100 per barrel through the summer of 2014, contributing to a high rate of return for producers. U.S. annual tight oil production reached 3.3 MMbpd in 2014, comprising nearly 40 percent of total U.S. production, up from 6 percent in 2009, as shown in [Exhibit 2](#).

The surge in tight oil activity put millions of barrels per day of new oil into the world supply. This U.S. production growth, combined with other factors such as slowing global economic demand and continued production from the Organization of Petroleum Exporting Countries, has resulted in a 54 percent drop in world oil prices since July 2014 and a global oil supply glut.

The U.S. oil and gas industry has since experienced a large pullback in drilling activity as shown in [Exhibit 3](#). How long these market conditions will persist is unclear. At issue is the expected impact of sustained low oil prices on the development of tight oil. Although many factors will play a role in future tight oil activity and production, the key issue over time will be the distribution of resources by quality and resource costs.

**Exhibit 3: Play-Level Oil-Directed Rigs**  
(as of March 13, 2015)



Source: Baker Hughes

### Well Productivity and Economics

Productivity from U.S. tight oil wells is high, compared with conventional onshore oil wells. Drilling and completion costs also are high because of the need to drill horizontal laterals and substantial stimulation required for production. As a result, tight oil is a relatively high-cost resource, compared with many available world oil resources. To date, little work has been published on assessing the scope and economic distribution of this resource. A large amount of information has been published on individual plays with respect to geology, drilling activity, well costs, economics, and prospectivity of company acreages. However, a need exists for a much better understanding of the scope of the recoverable resource, recovery per well, and development costs.

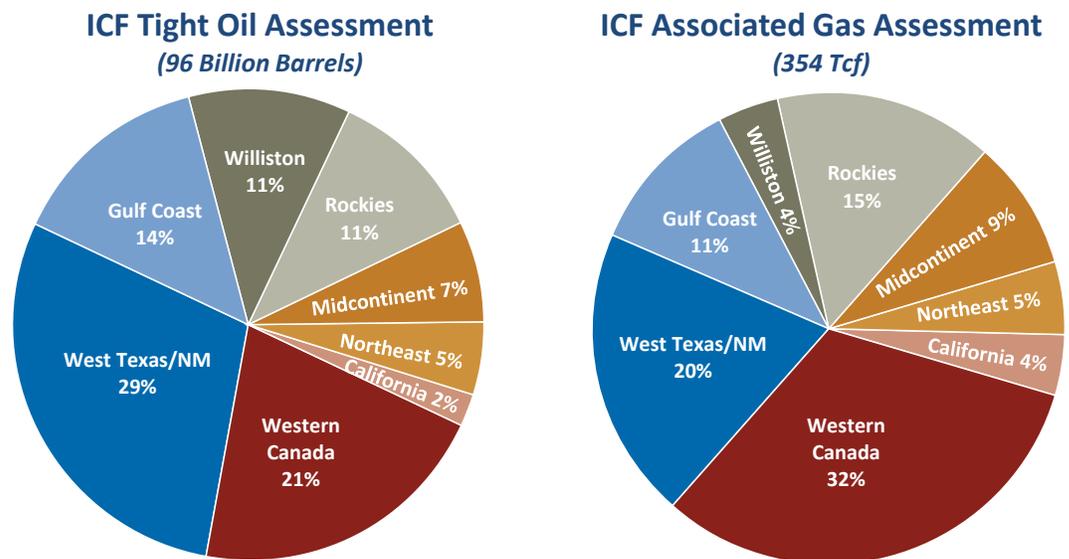


To this end, ICF has developed a play- and subplay-level assessment of the technically and economically recoverable tight oil resource base of the United States and Canada. In addition, ICF has extensively evaluated historical tight oil drilling results, using commercial well-level data. The resource assessment is based primarily upon analysis of public domain maps and data, with the information processed through geographic information system (GIS) and cell-level tight oil assessment and economic models. The models and database allow a detailed look at the economics of tight oil and the identification of production sweet spots. Tight oil production is dominated by three areas: the Williston Bakken, the Texas Gulf Coast Eagle Ford, and the Permian Basin. These areas produce both crude oil and lease condensate. Much of the Eagle Ford Shale liquids production to date has been condensate. Almost all of the U.S. tight oil production is considered “light” (relatively high API gravity) and “sweet” (low sulfur).

### Resource Assessment

As shown in Exhibit 4, the assessed recoverable resources of North American tight oil are 354 trillion cubic feet (Tcf) of gas and 96 billion barrels of liquids (crude oil and condensate).

Exhibit 4: U.S. and Canadian Assessment Summary



Source: ICF International

The U.S. portion is assessed at 76 billion barrels of liquids and 239 Tcf of natural gas. Canada is assessed at 20 billion barrels of liquids and 114 Tcf of gas. The natural gas portion of the assessment shown here consists of both associated and dissolved gas in the crude oil portions of plays and gas well gas in the wet gas portions. Gas is reported on a dry basis, and gas plant liquids are in addition to the liquids volumes shown. A large fraction of the gas resource comes from wet gas areas of plays such as the Eagle Ford, Utica, and Duvernay.

The assessment shown represents technically recoverable resources from the initial well spacing only (which varies by play) and assumes current technology constraints. ICF develops unconventional oil and gas assessments as a function of ultimate assumed well spacing. Both primary spacing and subsequent potential infill assessments are assumed to be potentially developed.



### Resource Assessment Approach

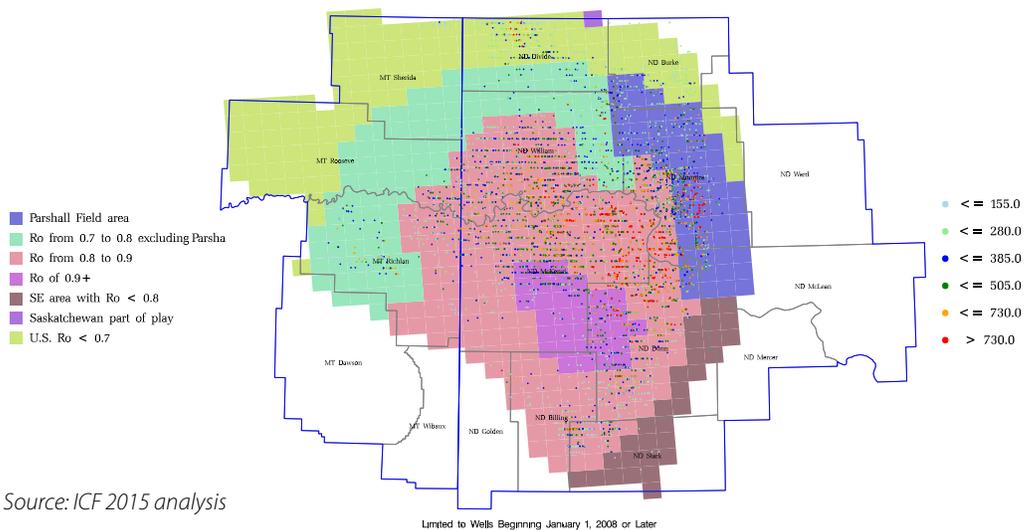
A total of 40 North American plays have been evaluated. Twenty-nine plays have been assessed by using the models. Resource estimates based on area and assumed well recovery were developed for 11 additional plays. A risking approach is applied to the process to compensate for uncertainty in productivity and resource quality. In general, higher risk is applied to outlying areas of plays that have yet to be developed significantly.

For each play, geologic information was mapped, including depth, net thickness, thermal maturity, and other factors. The information for each play was input into the model to develop estimates of original oil in place and original gas in place and of recoverable resources. The output includes technically recoverable crude and condensate, dry gas, and gas plant liquids on both a risked and unrisked basis. The Bakken tight oil play in the Williston Basin contains a large fraction of U.S. tight oil resources—about 9 billion barrels of recoverable resource. The play was assessed at the cell level by using the cells shown in [Exhibit 5](#).

### Key Questions

- How has tight oil production affected U.S. oil markets?
- How much tight oil resource is available?
- How is tight oil assessed and what are the production uncertainties?
- What is the distribution of tight oil economics?
- What do current wells indicate in terms of resource quality and distribution?
- What are the economics of current wells?
- How will tight oil development be impacted by low oil prices?

**Exhibit 5: EUR Th.Boe/well in Horizontal Wells in Williston Bakken (Gas and Oil Production)**



The cell boundaries were primarily based upon thermal maturity. Overlaid on the cell map are the locations of horizontal Bakken wells for which ICF has estimated ultimate recovery. A resource assessment was developed using mapped geologic data combined with engineering data and various assumptions. Once the risked recoverable resource and recovery per well were assessed, the information was input into a discounted cash flow model to estimate typical well economics for each area.



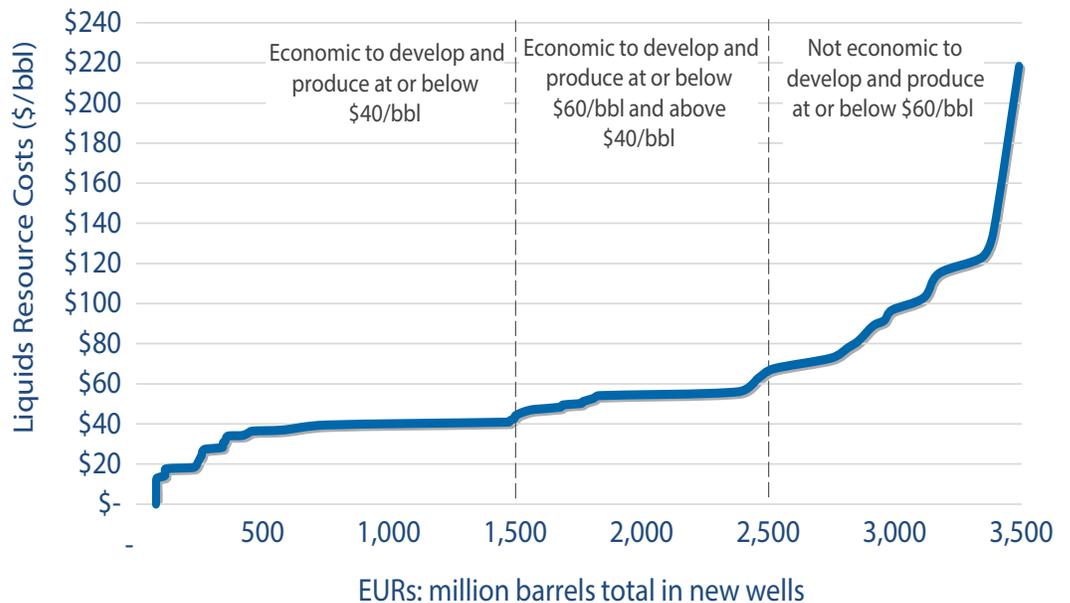
### Tight Oil Well Proven Recovery and Economics

ICF has evaluated ultimate recovery per well and production decline parameters for all identified U.S. and Canadian conventional and unconventional oil and gas plays. The analysis is based upon historical monthly oil and gas production at the well level and incorporates reservoir engineering principles and fitted decline curve parameters. Vertical and horizontal wells are evaluated separately, resulting in more than 950 play/direction units.

The “resource cost” of a unit of analysis is the wellhead price, typically on a dollars-per-MMBtu or dollars-per-barrel basis, that is needed to meet the specified rate of return. Factors influencing wellhead economics include vertical depth; lateral length; number of stimulation stages; drilling costs; completion costs; initial production potential; production decline parameters; ultimate recovery; mix of gas, oil, and natural gas liquids (NGL) production; rate of return requirement; taxes and royalties; and the future oil, natural gas, and NGL prices.

The ICF play-level economic model was developed to estimate the annual resource costs of the 950 play units. Using this model, ICF can evaluate the oil and gas reserves added by well vintage (year of completion). Exhibit 6 shows the resource cost distribution for all Lower-48 oil well completions in 2013. The 2013 liquids reserve additions totaled 3.5 billion barrels. Of that amount, approximately 68 percent, or 2.4 billion barrels, was from wells deemed to have been economic at \$60 per barrel; and 37 percent of the developed resources was from wells that were economic at \$40 per barrel.

**Exhibit 6: 2013 Lower 48 Onshore Cost Distribution of New Well Crude and Condensate EURs**



Source: ICF 2015 analysis

The results of the analysis of 2013 drilling represent a mix of wells drilled in sweet spots and fringe areas. Thus, the curve for 2013 wells presented here is not representative of the entire undrilled resource base. The supply curve for the entire resource base would have a much lower percentage of the resource economic at \$60 per barrel, because it would include large fringe areas. The difference in the underlying resource curve and the drilled resource curve reflects operators’ focus on the sweet spots.



### ***Technology Trends***

Although tight oil has largely been developed during just the past five years, rapid gains in technology and improved practices and efficiencies already have occurred, with concurrent reductions in resource development costs. Trends include longer laterals, more hydraulic fracturing stages, better stage placement, and improved horizontal lateral placement, all of which have all contributed to a rise in average ultimate recovery per well. Another key factor for well recovery is seismic mapping. Well placement is based upon improved predrill mapping through 3D seismic. As an example of the combined impact of these factors, the average recovery per well in the Bakken play increased from 193,000 barrels of oil-equivalent (BOE) in 2007 to 376,000 BOE in 2013, an increase of 95 percent.

Pad drilling now is commonplace in most areas. Drilling multiple wells from a single pad results in many efficiencies and cost reductions as well as reduced surface impact. Improved hydraulic fracturing water management for both sourcing and recycling also has been important, both in terms of well economics and environmental impact. Although gains in some aspects of technology such as increasing lateral length appear to have matured somewhat over the past two years, ICF expects continued improvements that will contribute to per-well cost reductions. Generally, economic analysis is based upon current technology and practices. ICF has evaluated trends in the various factors that can be input into the models for future drilling.

### ***Summary***

The ICF U.S. and Canadian tight oil assessment documents a tremendous recoverable resource, of which a large portion is economic to drill at relatively low oil prices. Tight oil plays range from oil only such as the Bakken to oil and gas transition plays such as the Eagle Ford and Niobrara. Each play has unique characteristics that impact wellhead economics, with large variability in recovery per well across the play.

In addition to assessing the resource base, ICF evaluated the economics of historical drilling by play and subplay. ICF's analysis of the economics of new 2013 Lower-48 oil completions determined that approximately 68 percent of the producing reserves added that year were added at a cost of \$60 per barrel or less, and 37 percent were economic at \$40 per barrel. The presence of large-scale known sweet spots in most plays is expected to ensure the viability of tight oil resources in specific areas even in a protracted low price environment. The identification and understanding of the economics of tight oil sweet spots is a critical aspect in evaluating upstream and midstream investment opportunities. ICF's approach to identifying the best well economics, calibrated to historical play-level data, is a valuable tool in unearthing the best upstream opportunities. This capability, combined with other ICF oil and gas modeling tools such as the Gas Market Model and the Midstream Infrastructure Report (described below) can provide a robust perspective on potential acquisition targets.



### ICF Oil and Gas Modeling Tools

**Gas Market Model (GMM®)**—The GMM is an internationally recognized North American gas market model that is capable of forecasting gas market conditions based upon actual and scenario-based changes in the market.

**Detailed Production Report (DPR)**—The DPR is a gas and oil vintage well production model that provides a complete outlook for North American natural gas, NGLs, and crude oil production. The DPR projects output for more than 50 production basins.

**Unconventional Oil and Gas GIS Assessment Model (UGIS)**—The UGIS model is used to assess North American unconventional oil and gas resources using GIS-formatted geological data and engineering principles.

**Well Decline Model (WDM)**—The WDM uses a set of algorithms applied to commercial well level-production data to generate estimates of ultimate recovery per well and to model well production profiles.

**Midstream Infrastructure Report (MIR)**—The MIR provides a granular look at regional infrastructure needs, costs, and opportunities throughout North America, including capital investment opportunities and shifts in midstream projects based on changing supply, demand, and transportation dynamics.

**Natural Gas Liquids Transport Model (NGL TM)**—The NGL TM projects the annual transport of North American NGLs at various submarkets. ICF is able to project the movement of raw mix and purity products in addition to exports and imports of the commodities.

**Crude Oil Transport Model (COTM)**—The COTM allows ICF to project the movement of crude oil around North America based on existing and projected crude oil infrastructure. In tandem with ICF's DPR, the COTM solves for crude oil balances at more than 32 submarket regions.

**Propane Database and Forecasting Model (PDFM)**—The PDFM provides detailed forecasts of U.S. propane demand by sector and state.



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**Harry Vidas** is a recognized authority on energy markets and forecasting. He leads a team of geologists, engineers, and economists to analyze North American and world natural gas and oil supply, transportation, and end use. He has directed projects related to international oil and natural gas supply, gas processing, and liquefied natural gas (LNG) production; shipping, pipeline transmission, underground storage, and gas-to-liquids processes; and synthetic fuels and end-use markets. He has worked in electric utility fuel use, price and capacity forecasting, and design and implementation of management information and planning systems. He has designed and implemented models to estimate expected future energy price distributions and optimum commodity sales portfolios. Mr. Vidas holds a master's degree in International Relations and Economics from the School of Advanced International Studies at Johns Hopkins University and a bachelor's degree in History and Economics from Dartmouth College.

**Robert Hugman** has more than 30 years of experience in the upstream energy industry as an oil and gas consultant and as an exploration geologist for a major oil company. He has managed a wide range of oil and gas resource-related projects in both consulting and industry environments. Since joining ICF, Mr. Hugman has authored or contributed to numerous reports on gas and oil resources, industry activity, and upstream economics in the United States, Canada, and internationally. An expert in the characteristics, assessments, and analysis of shale gas plays in North America, he was responsible for much of the gas supply research and model implementation for the landmark U.S. National Petroleum Council North American gas studies. His previous experience includes working as a senior exploration geologist with several oil and gas companies in Colorado, Texas, and Alaska. Mr. Hugman has an MS in Geology from Texas A&M and a BS in Geology from Texas Christian University.

**Briana Adams** analyzes gas-electric coordination issues, fuels economics, and infrastructure development. She is experienced in assessing gas-electric coordination issues in the U.S. Northeast and in analyzing LNG exports, Canadian gas supply access issues, North American natural gas flows and infrastructure development, and shale gas environmental issues and associated regulation. Ms. Adams also has more than seven years of international work experience in China and the Middle East. Ms. Adams has a master's degree in International Affairs from Columbia University and a bachelor's degree in Economics, International Management, and Spanish from Hamline University.

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