

Trisha Curtis describes the building blocks of the North American petroleum renaissance

In 2009, the United States became the world's largest producer of natural gas and all indications are it will remain so for the next twenty years. The shift in expectations on domestic natural gas output took place across a remarkably short time span. In June 2003, Alan Greenspan, Chairman of the U.S. Federal Reserve, testified before the Congress Committee on Energy and Commerce that the USA was in a state of crisis due to declining natural gas production. A consensus among both policy makers and much of the domestic petroleum industry led to an accelerated programme to construct facilities to import liquefied natural gas (LNG). Approximately \$30 billion was spent to construct LNG import facilities over a 3–4 year period, but the simultaneous turnaround in domestic gas output was large and quick. Today these import facilities are operating at less than 10 percent capacity. Some LNG facilities are now applying for licences to export American natural gas to world markets.

This remarkable shift in the outlook for natural gas production directly resulted from the application of two

critical advances in modern petroleum development: horizontal drilling and hydraulic fracturing. Advances in the art and science of these petroleum development technologies are now migrating to unconventional shale/tight oil plays throughout the United States.

In this article references to shale oil refer to a broad range of so-called unconventional oil development including tight and carbonate oil formations. US shale oil production has taken root in North Dakota and Texas where combined production has risen from negligible volumes to 500,000 barrels a day (b/d) in just three short years. These shale oil plays have helped raise US liquids production to its highest level in nearly a decade, more than offsetting Gulf of Mexico production losses from leasing and development delays after the Macondo spill. It is no longer unthinkable that US production alone could rise by over 2 million b/d in the next ten years.

In a period in which the US economy is suffering from high unemployment and lagging economic growth, the petroleum industry remains a bright spot. Figure 1 illustrates the ratio of national unemployment to four prominent oil- and gas-producing states. For the state of North Dakota, the benefits from oil production are widespread. Taxes on oil production and extraction have allowed the state to put millions of dollars into a legacy

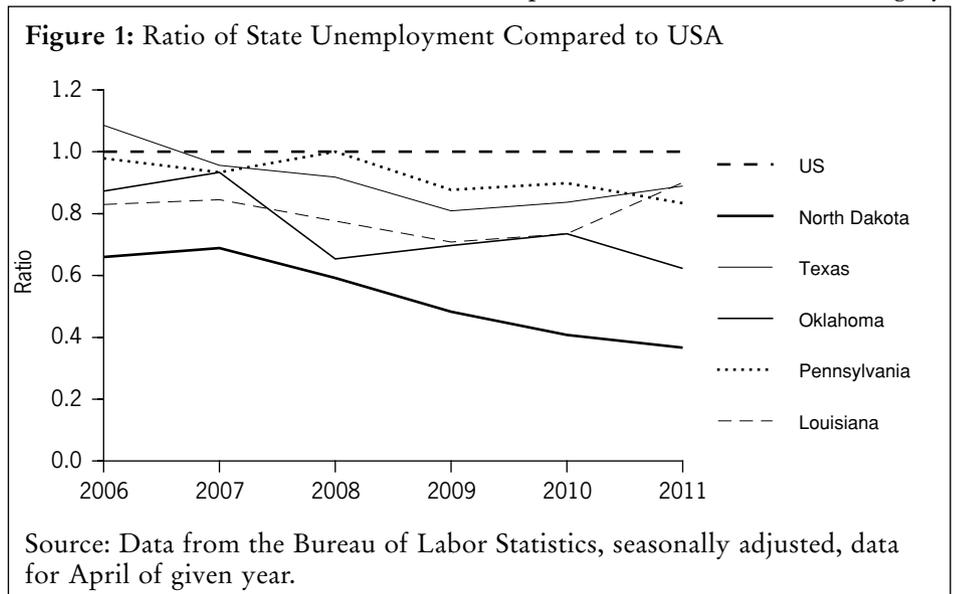
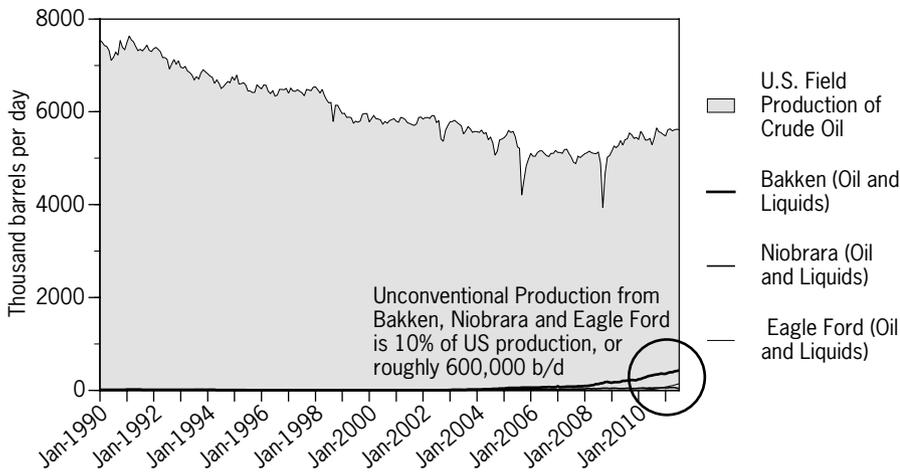


Figure 2: Unconventional Production as a Percentage of US Production



Source: HPDI and EIA Data, EPRINC Calculations (conservative)

Note: Bakken production does include some NGLs (natural gas liquids) but is primarily oil; Eagle Ford includes more NGLs and about 20,000 b/d are oil; Niobrara does include some NGLs, but is primarily oil.

fund, to invest in water resources, communities, education and research, and to lower income, corporate, and property taxes. In the fiscal year of 2011 oil taxation brought in \$977.8 million.

Beyond the direct benefits of improving the fiscal outlook for oil-producing communities and improving employment opportunities, rising oil production (both crude and natural gas liquids) provides cost-effective import substitution and new competitive opportunities for American refineries and petrochemical plants. Most of the crude oil coming out of these shale basins is of premium quality, very light and sweet. Bakken oil from North Dakota and Montana typically has an API gravity of over 43 degrees. Light sweet crude oil is well matched to the less complex refineries on the East Coast and some in the mid-continent. These refineries typically operate on very small margins and face fierce foreign competition. Most refineries on the East Coast must purchase high cost crudes from Nigeria and the Middle East – also subject to fierce competition from imports of gasoline components from European and even some Asian refineries – that can be processed in less complex facilities. This high cost and

competitive operating environment is characterised by low utilisation rates, poor margins, routine closures and maintenance, and now the threat of additional capacity losses from permanent closures. With the necessary development in infrastructure through pipeline and rail, light sweet Bakken oil could supplant portions of Middle East imports on the East Coast or other refining sectors in the United States and give refiners a potentially lower cost alternative than waterborne imports.

Due to a rise in Canadian imports overtime and the increase in US production primarily from the Bakken, the two global crude oil benchmarks, Brent and WTI, have diverged and this currently puts Brent at \$10 premium to WTI. This means that East Coast refineries that import waterborne crude are paying a higher price than Midwest refineries which have access to domestic produced crude, currently selling at a discount.

Figure 2 shows unconventional production as a percentage of US production.

The Plays

Shale oil has historically been difficult and costly to produce because it is

found in formations characterised by both low porosity and low permeability. Essentially the rock is hard and tight with minimal natural fractures; the lack of porosity (holes) and permeability (connections) prevents the oil from easily flowing out.

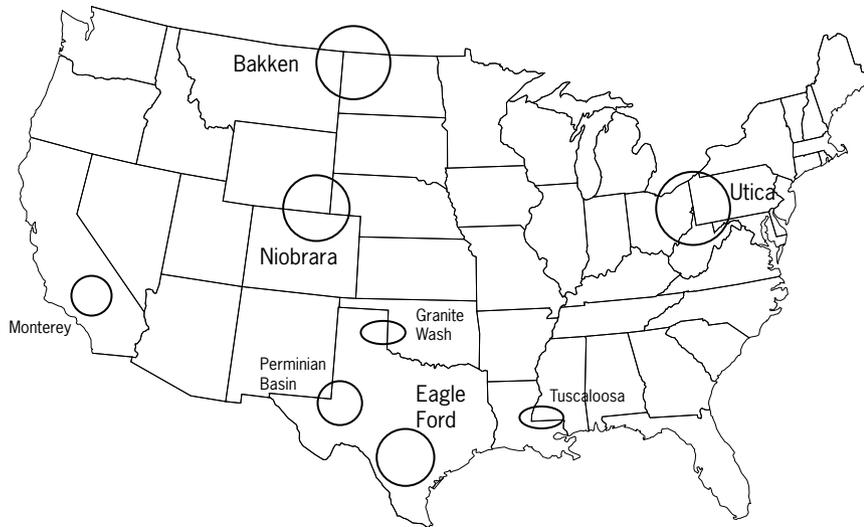
Traditional vertical well technology and production methods touched only a portion of the producible rock. This left the wellbore (the drilled hole exposed to the producing rock) exposed to only a small portion of the tight oil formation, thus not allowing it to be produced to its true potential. Attempts to access shale oil in North Dakota using horizontal drilling technology had been tried in the past, but had not advanced to longer laterals and multiple hydraulic fracturing stages in the correct layer of rock. This technique was pioneered in the shale gas revolution and applied to oil prone shale in North Dakota’s Bakken formation where its success has triggered a frenzy of investment across the country’s liquid basins. (Figure 3)

North Dakota’s Bakken

North Dakota is now the fourth largest oil-producing state with production topping 464,000 b/d in September 2011. (Figure 4) The majority of this production is Bakken oil from the Bakken and Three Forks formations. It is conventional, light-sweet crude oil, trapped 10,000 feet below the surface within shale rock. The Bakken shale play consists of three layers, an upper layer of shale rock, a middle layer of sandstone/dolomite, and a lower layer of shale rock. The middle sandstone layer is what is commonly drilled and fracked with the horizontal lateral today.

The Bakken and underlying Three Forks formations are part of the larger Williston Basin, which encompasses Saskatchewan, Manitoba, North Dakota, Montana, and South Dakota. Bakken producing zones are mainly present in Western North Dakota, Southern Saskatchewan, and Eastern Montana. Beyond the Bakken and Three Forks there are other potential rock members within the Williston

Figure 3: US Shale/Tight Oil Formations



Source: EPRINC Map. Formations are not to scale and indicate roughly their location for visual understanding. This is not inclusive of all US shale/tight oil.

Basin that could offer further oil production opportunities.

What makes the Bakken unique from other formations in the United States and the world is that it is a continuous oil accumulation, possibly the largest in the world according to the USGS. It is an over pressured system which is in part why many wells experience such high initial production. The high pressure in the formation suggests that the oil is contained within the petroleum system. This means that the oil remains in place and is tightly contained throughout the geologic structure.

While Bakken oil is of the highest quality, very light and sweet, it still suffers from a discount due to its distance to major refining markets and limited take-away capacity. This discount has substantially narrowed in recent months with significant rail and pipeline developments.

Southern Texas’ Eagle Ford

The Eagle Ford in south Texas has become something of an overnight miracle. After years of proving up the Bakken, drillers began an active exploration and development programme in the Eagle Ford around 2008. As well

as other major shale plays, the Eagle Ford is now experiencing significant investment from both major and independent oil companies, accompanied by high acreage costs, and multiple joint ventures.

The Eagle Ford is more of a carbonate than a shale, but is produced in the same manner as the Bakken with horizontal drilling and multi-stage fracking. It includes three hydrocarbon windows: oil, wet gas/condensate/

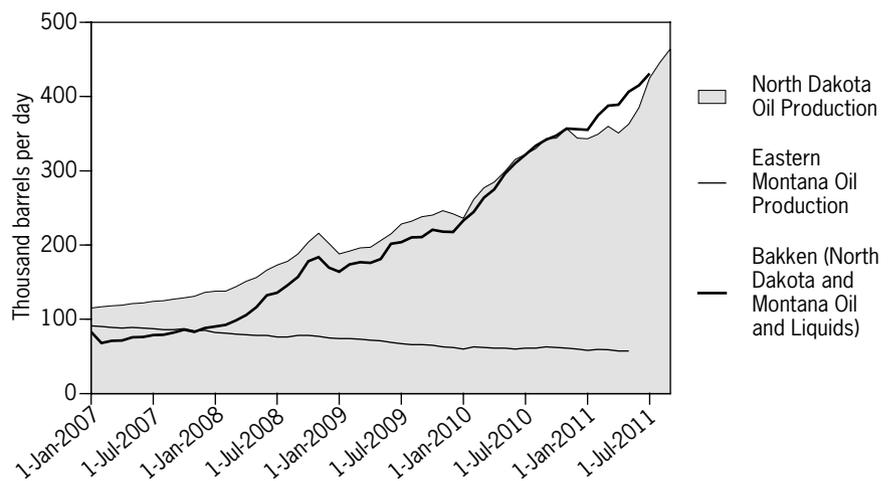
NGLs (natural gas liquids), and dry gas respectively with play zones ranging in depth from 4000 ft. to 14,000 ft. As the play moves eastward across Texas from oil to gas it increases in depth, thermal maturity, and API gravity.

Right now the most prolific part of the Eagle Ford play is the wet gas/NGL/condensate window. Condensate valuations are similar to oil and remain a major target in exploration and development efforts. Oil production is increasing in the Eagle Ford and is currently around 20,000 b/d, but will likely increase as necessary take-away infrastructure comes online. Close proximity to the Gulf Coast refinery district has helped the Eagle Ford take off quickly, but substantial infrastructure constraints still exist. Figure 5 shows liquids and gas production from 2008 to 2011.

Colorado’s Niobrara

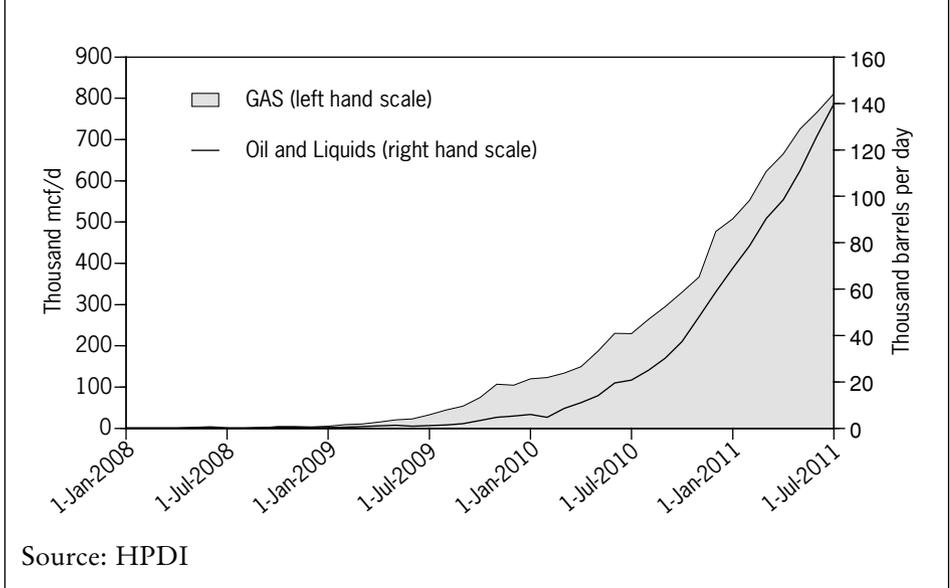
Unlike the success seen in the Bakken and the Eagle Ford, the Niobrara has proven to be more difficult to crack. Some initial well results were extremely promising, but over the past year production results have varied. Many wells being drilled in the Niobrara are still vertical and companies are still testing the prospectivity of much of the play. The most notable success has been seen in Weld County in eastern

Figure 4: North Dakota, Montana, and Bakken Oil Production



Source: State production data from North Dakota Pipeline Authority, Bakken production HPDI

Figure 5: Eagle Ford Liquids and Gas Production



Colorado, known for its historical gas production.

The Niobrara is not a pure oil play like the Bakken. Weld County for example ranges from more gas production to more oil production as you move north. The Niobrara – a broad name that actually includes multiple shales and basins – spreads across parts of Colorado and Wyoming and parts of Nebraska and is a mix of chalk, limestone, and shale. While this play is not an overnight victory, many companies are doing exceptionally well in Weld County and companies are still testing different fracking techniques.

Additionally, unlike typical shale wells in the Bakken and Eagle Ford, which have high IP (initial production) rates and substantial decline rates, some Niobrara wells indicate a moderate IP rate and a flatter decline curve. With a better understanding of the geology across the play and application of the appropriate completion methods, the Niobrara may yield increasingly positive results in the future. Figure 6 shows liquids and gas production from 1990 to 2011.

Ohio’s Utica

In the past several months notable independents and major oil companies have leased up sizeable amounts of land in Eastern Ohio. Permit activity

is accelerating and drilling is underway. Only a few well results have been released, but thus far the play looks extremely promising.

The Utica sits well below portions of the Marcellus and reaches from eastern Ohio into Pennsylvania, but the most prospective liquid prone area is eastern Ohio and parts of Western Pennsylvania. According to some images, the Utica source rock extends into New York, Virginia, West Virginia, and Kentucky as well. The Utica has received a lot of attention due to the success seen in the Bakken and Eagle Ford. It is also structurally

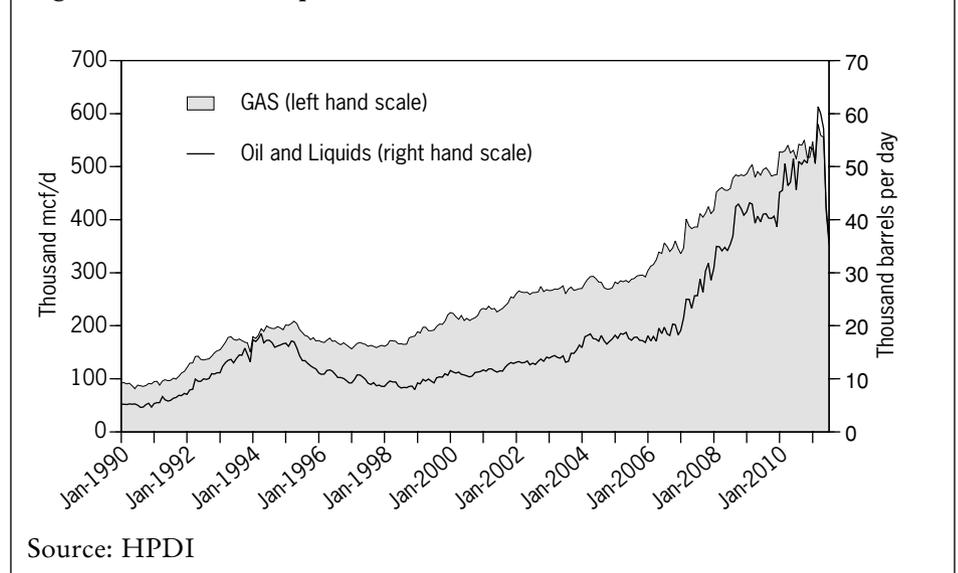
similar to the Eagle Ford in that it has three potential hydrocarbon windows for production: oil, wet gas/condensate/NGLs, and dry gas respectively (from west to east). Prospective drilling depths in Ohio range from 3500 ft. to 10,000 ft. The formation is interlayered with shale and carbonate.

Time will tell if this play is in fact similar in productive nature to the Eagle Ford and if so may have a significant economic impact on employment in the rust belt as well as the depressed refining sector on the East Coast, including refineries in Ohio and Pennsylvania.

Looking Ahead

North America is at the beginning of a turnaround in domestic crude oil production driven by the same technology that sparked the shale gas revolution. New crude oil, condensate, and natural gas liquid supplies, combined with the current surge in natural gas production, offer the promise of a renaissance in petrochemical processing and petroleum refining industries. This dramatic increase in domestic oil production from unconventional reservoirs does not come without complications and constraints. In the coming years, both industry and policy makers will face challenges to bring about essential infrastructure to expand needed takeaway capacity with the onset of new oil plays.

Figure 6: Niobrara Liquids and Gas Production



Horizontal drilling and multistage fracking technology used to unlock shale gas has been proven in the Bakken and Eagle Ford, but also has the potential to yield additional crude volumes from plays on the periphery as well as older fields. Multiple shale plays not mentioned here have the potential to yield significant oil production results with time and technology. The Granite Wash in Texas and Oklahoma, for example, was historically known for its gas production, but is now seeing drilling in multiple layers of rock beneath the gas. Oil that could not previously be reached underneath the gas is being tapped and produced and offers a prime example to the potential of new oil production from older fields across the United States. In fact, the gas is said to be helping with the production of oil in this play. Additionally, the well-known Permian Basin is seeing significant drilling activity and production with multiple shale and tight oil plays.

Rising oil and gas production can generate sustained employment growth and expand the national economy. For American policy makers the emerging paradigm shift in the outlook for North American supplies of oil and gas creates both opportunities and challenges. Embracing the new economic opportunity will provide revenue for state and local governments and much needed economic activity, but it will also require sophisticated management of the challenges to the environment and the accompanying rapid industrial development.

