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Testimony on
"TAPPING AMERICA'S UNCONVENTIONAL OIL RESOURCES FOR JOB CREATION AND AFFORDABLE DOMESTIC ENERGY: TECHNOLOGY AND POLICY PATHWAYS"
April 17, 2012

SUMMARY

- Our major concerns should be about **replenishment** and **deliverability**.
- The essential industry capability to maintain a long term, reasonably steady balance between reserves and production is one of the most important ingredients for U.S. energy security and long term prosperity.
- A robust resource base does not fully protect producers and customers from sharp swings in price but sustaining a robust resource base is essential to restoring market balance.

On primary economic factors that shape energy markets and prices, with a focus on oil and gasoline:

- Global oil markets are a complex daily dance
- Price level is most immediately impacted by cost of incremental supply to serve incremental demand. Unconventional resource plays sit firmly at the expensive end of the marginal cost curve for oil supply.
- Variation between domestic and international crude price and regional demand within the U.S. explains much of gasoline price differences.
- Increasing global incremental demand for oil relative to incremental supply and supply capacity create upward price pressure.

On potential impacts of supply and production on energy prices and the national economy:

- While a significant effort has been made to demonstrate economic benefits and impact from oil and gas industry operations, it is the much larger set of benefits and multipliers from overall provision and use of competitively supplied and delivered fuels and materials that underlies economic value.
- Hydrocarbons provide a greater measure of energy density, yielding environmental benefits that are usually not measured.
- Competitively supplied and priced energy can provide enormous economic benefits. Natural gas and gas-fired electricity have provided relief from more expensive oil and oil products. Industrial growth is more strongly linked to gross domestic product (GDP) than any other factor; the trucking industry provides a good example of constraints.

On impacts on energy markets of regulatory and supply chain hurdles faced by energy exploration and production firms:

- "Debottlenecking" the oil and gas transportation and storage system requires transparent, sensible, and timely certification of facilities.
- Unconventional plays are helping to insulate against GOM issues, but GOM production must continue.
- Sustaining socioeconomic benefits will require a competitive tax and business environment and thoughtful and flexible environmental regulatory oversight. Reducing cycle time is a key consideration.

On the role of and potential for technology advances in driving current and future energy production and impacting prices:

- Technology development and deployment is crucial to ensuring competitive supply and pricing but entails long lead times.

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April 17, 2012

Mr. Chairman and members of the Committee on Science, Space, and Technology, I am Michelle Michot Foss, Chief Energy Economist, and Head of the Bureau of Economic Geology's Center for Energy Economics, based in the Jackson School of Geosciences at The University of Texas. I am pleased and honored to be selected as a witness for the Committee.

My testimony today follows on similar testimony presented almost exactly one year ago, on March 17, 2011, before the Committee on Natural Resources (CNR). In that previous testimony, I laid out a "high altitude" case for the economic and environmental benefits of hydrocarbons, touching on markets, technology, policy, and regulation, and offering specific ideas on what can be done to harvest domestic energy resources for the betterment of our society.

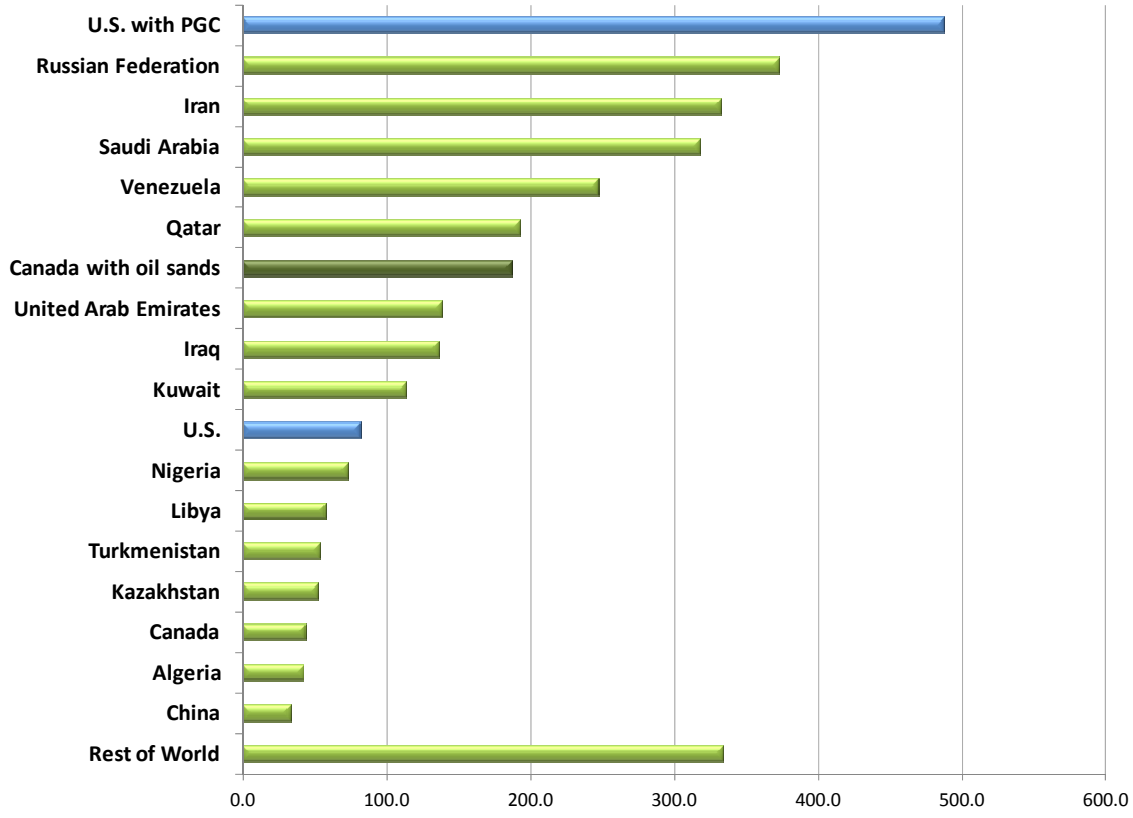
During the intervening year, nothing has happened to alter my views regarding the underlying, fundamental forces impacting prices of the major energy commodities. Indeed, all of the work I and my colleagues have done simply reinforces our opinions regarding the intrinsic and extrinsic forces that impact commodity markets and prices.[1] However, since spring a year ago, there are added complexities and nuances, new challenges, new ideas, and new consequences, unintended or otherwise, to consider.

One of the key "known knowns" is the richness of our domestic natural resource base. To make that point, I've repeated a chart from the 2011 testimony. This chart illustrates data on proved reserves of oil and natural gas (in barrel of oil equivalent terms). As before, I've added the estimated total U.S. natural gas supply (proved reserves plus total natural gas resources, deemed technically recoverable) from the Potential Gas Committee's 2010 report. I've also added an estimate of Canadian oil sands reserves. When we consider technically recoverable resources estimated by PGC, our hydrocarbons endowment tops the known and understood worldwide distribution of hydrocarbon wealth. In fairness, if other

[1] Dr. Michot Foss and CEE researchers were selected by U.S. Energy Information Administration (USEIA) to provide an independent expert memo on oil market dynamics and pricing. Our final report was submitted in April 2011.

countries in this list provided the same kind of transparent scrutiny of their resource endowments, some could easily top the U.S. It also is not possible to say whether all of the total future natural gas supply of some 2,100 trillion cubic feet (TCF) will ever be produced. To a large extent, how much of that future supply could be realized in annual production is the subject of this hearing. Of importance is that we are learning, once again, **the same lesson** we've learned many times but can't seem to accept: we have a **rich resource endowment**, and a **nimble, inventive, and deep industry bench**. Whenever supply-demand conditions yield an **attractive price signal** that suggests imbalance, companies and investors **respond quickly**. **Private land and minerals holdings** enable fast response for leasing and testing new play concepts. **Technology and service providers** combine with operating savvy to push the envelope yet again in a way that **challenges preconceived notions about U.S. productivity and longevity**. As the cycle progresses, **research and development** are mobilized to tackle the next tranche of resource recovery challenges. The outcome is **downward pressure** on both of our major commodity price indexes (Henry Hub for natural gas, West Texas Intermediate for crude oil). Spreads have widened between our domestic prices and international indexes. This reality, along with the large price premium of oil against natural gas, is unleashing disruptive forces that could lead to long term shifts in how we develop and use these resources and in international trade patterns.

Top Reserve Holders (Billion Barrels of Oil Equivalent)

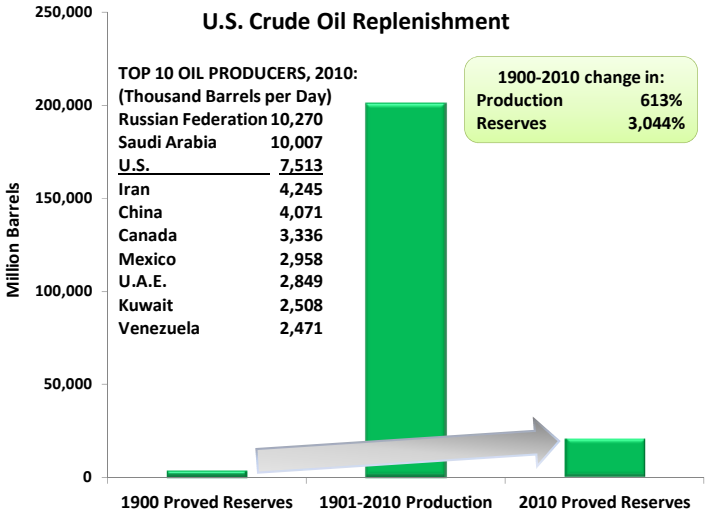


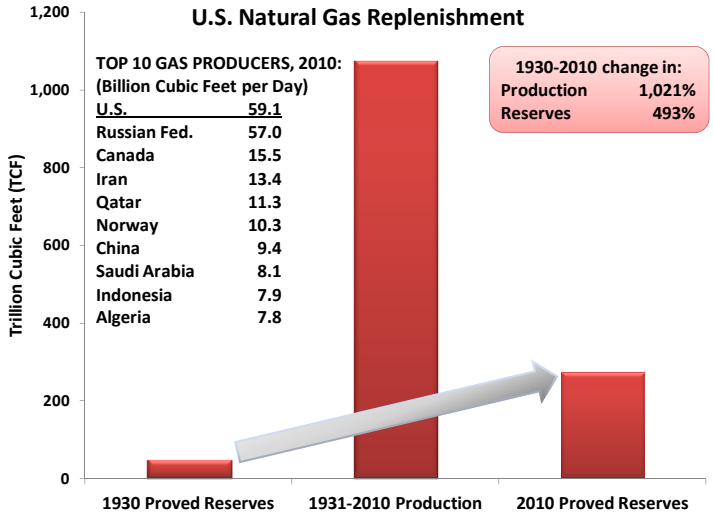
CEE-UT analysis based on BP Annual Statistical Review, Potential Gas Agency and industry reports.

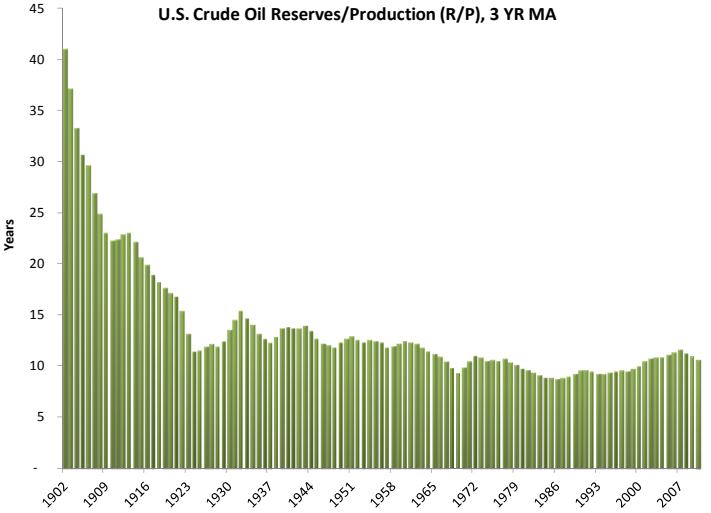
I've also updated and included charts from May 2010 testimony before the CNR on oil and natural gas reserves replacement in the U.S. (see top charts, next page). Our major concerns should be about **replenishment** and **deliverability**. Replenishment is the vital activity of finding new resources and proving up new reserves that enables sustained production going forward. Deliverability is the amount of supply that can enter the market at any time to meet demand. The questions posed regarding potential regulatory and supply chain hurdles hit home most squarely on our ability to sustain a base of hydrocarbon reserves and deliver production from those reserve on an ongoing basis. The long view I've provided on reserves to production (R/P), using a three-year moving average, demonstrates industry responsiveness (see bottom charts, next page). R/P provides a rough measure of performance. Wartime needs and post-war economic growth diminished R/Ps for both crude oil and natural gas (as did increased industry efficiency and improved inventory management). Our vibrant industry and markets have allowed operators to stabilize and, when robust business conditions exist, increase R/P ratios. **This essential capacity – industry capability to maintain a long term, reasonably steady balance between reserves and production – is one of the most important ingredients for U.S. energy security and long term prosperity.**

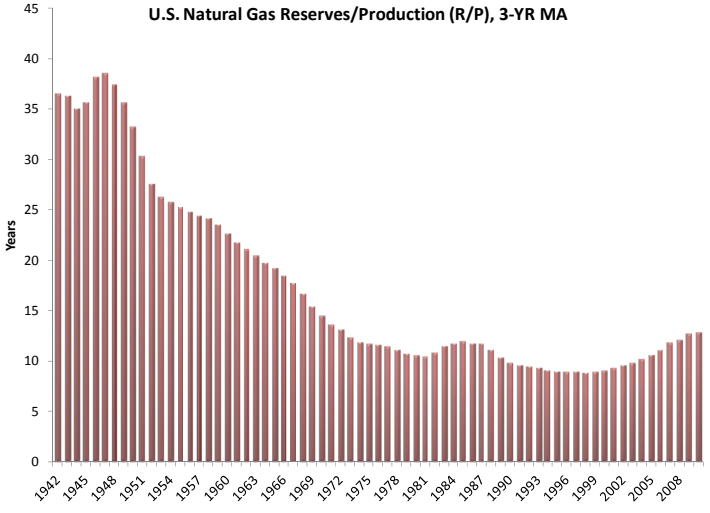
Importantly, **a robust resource base does not fully protect producers and customers from sharp swings in price**. Short and mid-term deliverability can be impacted by any number of factors, ranging from natural disasters to operational events to pronounced business cycles. Oil and natural gas are commodities for which we are all price takers. However, **sustaining a robust resource base is essential to restoring market balance.** Coupled with operational and market flexibility, ever advancing technology, and a more elastic policy and regulatory environment, a robust resource base can help mitigate swings in price. We are entering a phase in which continued deliverability of natural gas from dry (nonassociated) producing locations, which constitute the bulk of natural gas supply capacity, will be challenged by the low price environment. In testimony last year, I emphasized the shift in drilling already taking place as higher oil prices lure capital investment away from pure natural gas plays and into locations that are "liquids rich". We continue to receive pipeline imports of natural gas from Canada, and as liquefied natural gas (LNG) from other locations. But at some point, natural gas prices will rise; increased demand for low priced natural gas and stronger economic recovery will hasten that adjustment. The expectation is that the robust shale gas resource base that has been proved up along with conventional play opportunities will facilitate responsiveness. Constraints to responsiveness, such as midstream bottlenecks or policy and regulatory hurdles, would exacerbate imbalances. **In the history of our natural gas industry, the U.S. has had plenty of experience with policy and regulatory induced imbalances.** On the oil side, going forward, the Gulf of Mexico remains a critical component of our replenishment and deliverability system. Midstream bottlenecks are preventing cheaper crude oil and liquids from entering the market. These bottlenecks could impact dry gas deliverability since, in the low natural gas price environment, associated gas production would become more important for deliverability. Refining remains a challenging business segment.

U.S. Crude Oil and Natural Gas Replenishment, U.S. Production Rankings, and R/P Ratios









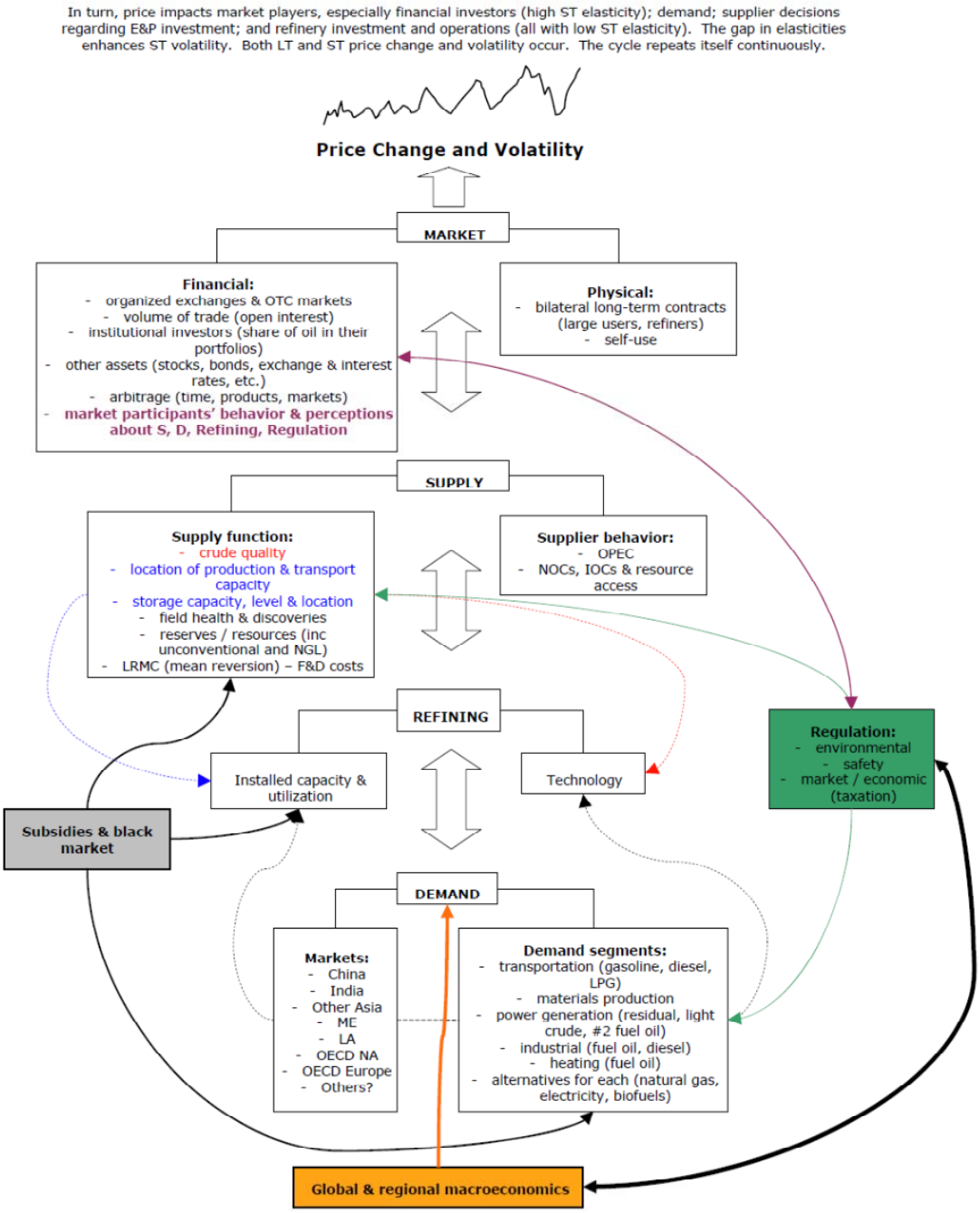
CEE analysis using USEIA and industry data.

With this background, I turn to the four key questions posed by the Chairman and Committee.

1. *Primary economic factors that shape energy markets and prices, with a focus on oil and gasoline.*

In our expert opinion to USEIA on oil markets, we provided the chart shown below.

Conceptual Organization of the Global Oil Marketplace



CEE, 2011.

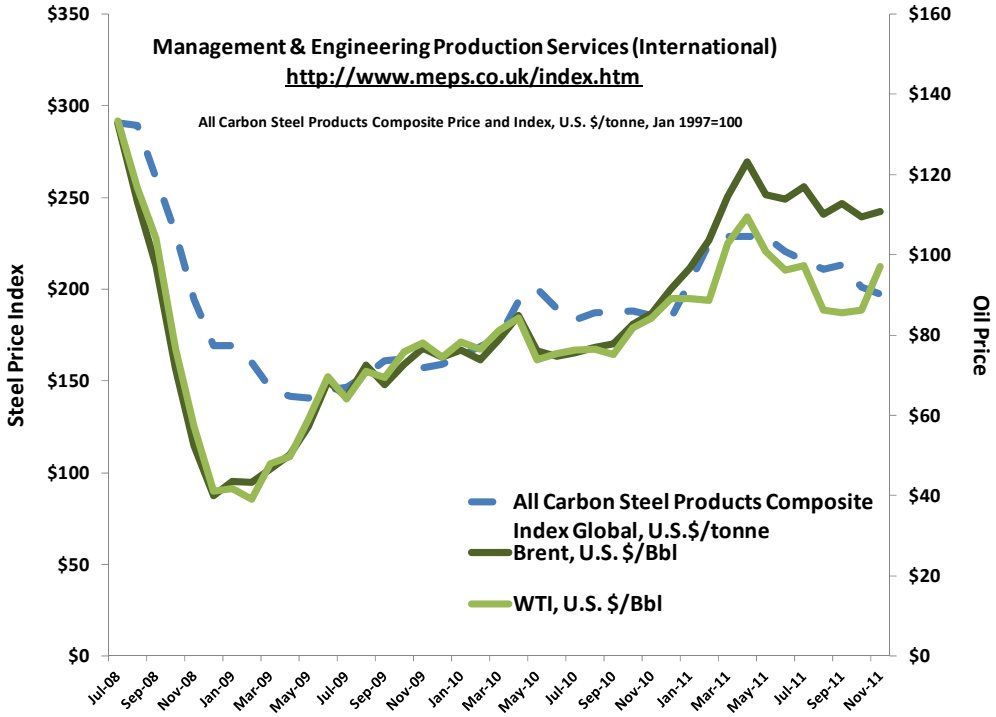
Global oil markets are a complex daily dance between supply and demand, involving large infrastructure systems (producing fields, storage facilities, shipping, pipelines, refineries). Numerous commercial (entities engaged in oil operations) and noncommercial participants engage in a huge financial market in which "paper" barrels facilitate the exchange of "physical" barrels and provide a means of price risk management. We feel that the most important drivers of oil and gasoline prices are the following.

- **Cost of incremental supply**

Price level is most immediately impacted by cost of incremental supply to serve incremental demand. As demand grows, oil supplies are delivered from ever more expensive supply sources. When demand falls, with commensurate drops in oil prices, the most expensive supply sources are abandoned first. In our work for EIA, we showed that **oil price and full, breakeven finding and development (F&D) cost are highly correlated**; price can be predicted from F&D cost in systematic ways. On average, depending upon other conditions, price needs to be 3-4 times greater than F&D cost to cover all expenses and provide a sufficient return on investment to spur drilling.

A coincident indicator of F&D cost is steel, a major input for oil and gas operations. The chart below illustrates, the strong, roughly 74 percent correlation between oil price and a common steel products price index. Higher demand for steel, and thus higher prices, impact oil and gas extraction cost. Higher oil and gas prices impact the cost of making steel.

Steel Price Index and Oil Prices – A Coincident Link



Unconventional resource plays sit firmly at the expensive end of the marginal cost curve for oil supply. Subsurface conditions are more rigorous; specialized technology and manpower are costly. To guarantee success, and to be able to operate through price cycles, operators must continually strive to reduce cost on a unit (barrel) basis. They can do this by scaling up production volumes, so long as business conditions and other constraints (like policy and regulation) permit. Technology adaptations can help to eventually improve recovery rates, a target for sustainability and future pathways in unconventional plays, thus lowering costs and supporting profitability.

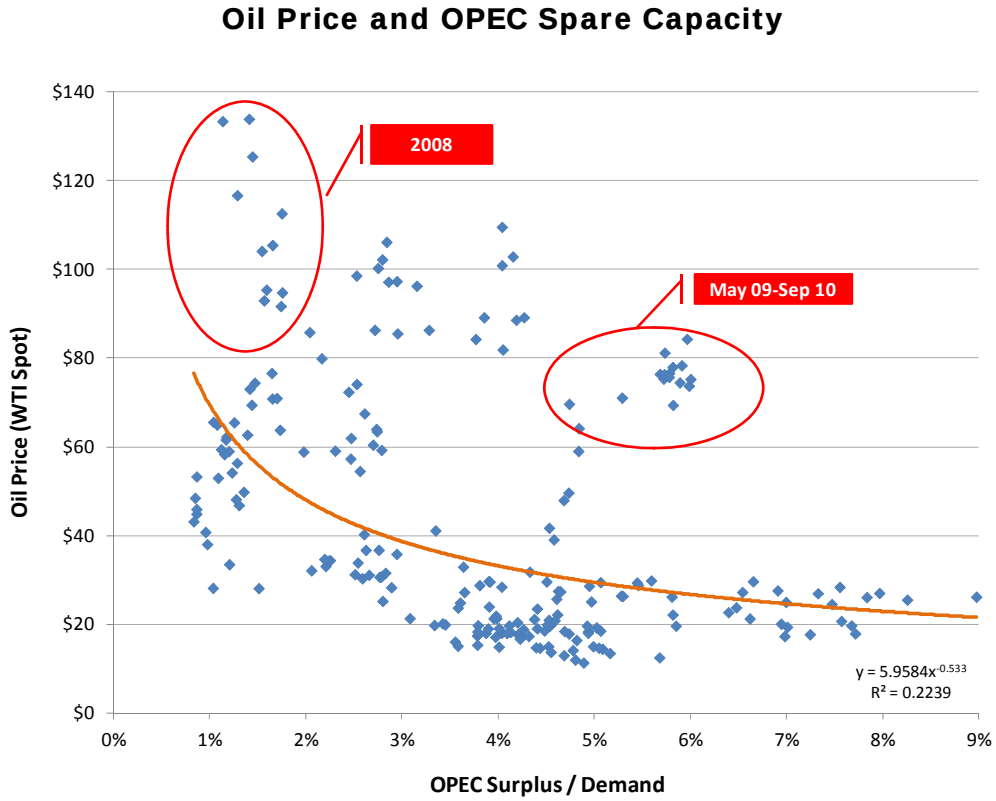
- **Variation between domestic and international crude prices and regional demand within the U.S.**

The preceding chart also serves to capture the **increasing differential** between Brent oil price, an international index, and WTI, our domestic index. Normally very closely linked, WTI has been heavily influenced by domestic exploration and production success and midstream, midcontinent bottlenecks that have created a **persistent surplus** at the Cushing, Oklahoma price point and within PADD 2 (Petroleum Administration Defense District). Refineries in our heavily populated coastal areas typically import crude feedstock priced on Brent. The disparity between WTI and Brent contributes to variation in gasoline prices (other major contributors being environmental regulations and various state rules for reformulated gasolines and differences in regional consumption patterns across the U.S.). **Prices are much higher in large coastal markets that rely on imported crude feedstock**, and much lower in the less dense U.S. midcontinent. The differential extents to natural gas liquids (NGLs) that tend to be higher valued; NGLs (propane, butane, ethane and so on) are cheaper in midcontinent locations and more expensive on the Gulf Coast where the bulk of ethane fractionation and petrochemical capacity is located.

- **Global incremental demand for oil relative to incremental supply and supply capacity.**

Also in our expert report for EIA, we adapted and modified a chart EIA typically uses to track **elasticity in global oil markets**. For the time being, and the foreseeable future, members of the Organization of Petroleum Exporting Countries (OPEC) have the best ability to maintain surplus production capacity, Saudi Arabia in particular. When global demand kicks to higher gear, or when particular geopolitical events, natural disasters or other occurrences create real or perceived disruptions, information about OPEC spare capacity can help to both dampen price movements but also send an important signal that additional increments of supply are necessary. As shown in the chart below, **when OPEC spare capacity is tight relative to demand (the OPEC surplus/demand ratio), oil price tends to be higher**. This was clearly the case at the peak of the past oil price cycle in 2008. **When spare capacity is ample relative to demand, price tends to be lower.** This was the case during the drop in oil prices from May 2009 to September 2010, largely a function of broad economic recession in the U.S. and Europe. With time and continued domestic production gains and given our status as a major oil consumer, **our resource base can help to reduce fears about chronic oil**

shortages. Consequently, replenishment and deliverability in the U.S. oil sector can contribute to greater international energy security.



CEE analysis using EIA data.

2. *Potential impacts of supply and production on energy prices and the national economy.*

Energy is essential for economic development and well-being. Hydrocarbons offer a multitude of benefits, ranging from the value associated with discreet molecules for materials and feedstocks to the energy products and services derived from them. **While a significant effort has been made to demonstrate economic benefits and impact from oil and gas industry operations, it is the much larger set of benefits and multipliers from overall provision and use of competitively supplied and delivered fuels and materials that underlies economic value.** These returns swamp those of other energy technologies, for several reasons. Hydrocarbon fuels provide a **greater measure of energy density** than other resources and technologies (more work per unit measure of energy value). They are **more easily stored**. These attributes mean that hydrocarbons offer **environmental benefits** that are not usually accorded to these fuels and related technologies. To replace a unit of energy provided by oil and natural gas, alternative energy technologies (currently available) must be scaled **orders of magnitude above** the hydrocarbons base. While renewables do not deplete, there is no commercial storage option that facilitates large scale deployment, and options for offsetting intermittency of renewable and other alternative energy forms are costly and inadequate. This does not mean that investment in alternative energy

R&D should be stopped. However, it should be **reconsidered, and targeted and focused on basic materials science** that can solve these problems before alternative energy systems are scaled up with myriad unintended consequences.

Total industry employment growth **averaged six percent per year** from early 2000s until recently with recession and soft natural gas prices. **In many states with established oil and gas production businesses, economic conditions have been somewhat better than for the nation as a whole.** Employment and other economic benefits are derived not just from direct oil and gas industry activity but many indirect and ancillary activities as well. After many years of slack spending, R&D investments by industry (which provides nearly all R&D investment in oil and gas) surged, a reflection of the deep technology and human resource needs in the shale oil and gas plays, deepwater GOM, and other frontiers. **R&D spending is a vital component of competitiveness and generates a wealth of connected economic benefits.**

Competitively supplied and priced energy can provide enormous economic benefits. Natural gas and gas-fired electricity **have provided relief** from more expensive oil and oil products. From a household perspective, higher prices can suppress spending and investment but the degree to which this happens is contingent on overall economic activity and household wealth. **Households are more sensitive to higher energy prices during slack economic periods,** thus the concern about rising gasoline costs today. For the industrial sector, energy cost, on average, is a **small part** of the U.S. manufacturing base (a bigger component for feedstock industries). During the effort to produce the 2011 NPC study, *Prudent Development*, it was clear from industrial subcommittee deliberations that many other factors drive manufacturing activity. The subcommittee concluded that **industrial growth is more strongly linked to gross domestic product (GDP) than any other factor.** Other factors include energy cost, legislation and regulation (in particular, carbon policy which adds to operational cost and risk), technology, and other considerations such as international trade competitiveness and labor and health cost and policy. Informal conclusions reached by the subcommittee were the following.[2]

- Energy intensive basic industries are important to long term economic growth because they are the base materials used to produce all other products consumed in the U.S.
- Industry has proven itself an efficient user of natural gas, responding to high prices by investing in efficiency and shutting down assets which no longer compete.
- A robust supply of natural gas that is affordable and reliable would give the industrial sector, especially energy intensive industries, a global advantage creating investment and jobs in the United States.
- Action by federal and state policymakers will have a defining impact on whether the U.S. industrial sector continues to lose jobs or whether it will thrive over the next century.

[2] From draft documents prepared by the subcommittee, of which Dr. Michot Foss was a member.

- The industrial sector use of energy creates significant value for the country.

An industrial renaissance fueled by U.S. domestic resources is as contingent on larger macroeconomic and policy conditions as on isolated influences like energy prices.

An example lies in the trucking industry.[3] The disparity between oil and natural gas prices is spurring considerable effort to explore and invest in timely options for increasing utilization of natural gas as a transportation fuel. Regional and interstate trucking operations are a target because truck fuel distribution infrastructure can move more quickly than retail distribution for the overall U.S. light duty vehicle fleet. And yet the trucking industry is struggling with a sharp decline in employment, a recession effect but, more importantly, also a function of a longer term trend as **potential drivers exit or avoid the trucking industry**. Road infrastructure, regulatory compliance (ranging from safety to environment), cost of operation – an assortment of variables is affecting one of the most vital arteries for U.S. economic activity, and one that could benefit hugely from advances in domestic production.

3. Impacts on energy markets of regulatory and supply chain hurdles faced by energy exploration and production firms.

Regulatory and supply chain hurdles can emanate from many causes. Any can impact replenishment and deliverability by creating delays, increasing costs, blocking access. I highlight a few specific concerns below.

- **A specific challenge for midstream/downstream supply chain infrastructure is posed by unconventional plays because these challenge existing fairways and processing locations.**

As oil, natural gas, and NGLs production is established in new unconventional basins, the U.S. pipeline, storage, and processing network will need to adapt. Lags in offtake of NGLs could present a drag on liquids rich production areas. Indeed, NGLs prices have been falling the past several weeks as surplus conditions emerge, a result of inadequate "offtake". Natural gas, oil, and oil product pipelines need debottlenecking and new additions. Certifying and constructing new pipelines is increasingly difficult. A lesson on future tests emanated from the Keystone pipeline slated to carry Canadian oil sands, Bakken, and other crude oil to the Gulf Coast.

Midstream developers respond most assertively to "spreads" – price differences across regions and seasons. The strong WTI/Brent spread is triggering activity to debottleneck the midcontinent region. Unusually for natural gas, spreads are absent, exacerbated by soft demand from recession and a warm winter. This is not

[3] Information from Groendyke Transport as presented to the Natural Gas and Energy Association of Oklahoma, September 2011, and provided by EnerFin, a Houston-based midstream company.

likely to be a permanent condition. Significant investments in natural gas pipeline and storage capacity already had been made, but some of this capacity may be "stranded" by shifts in production and collapsed spreads that previously had supported projects (Rockies Express to the northeast being a prime example).

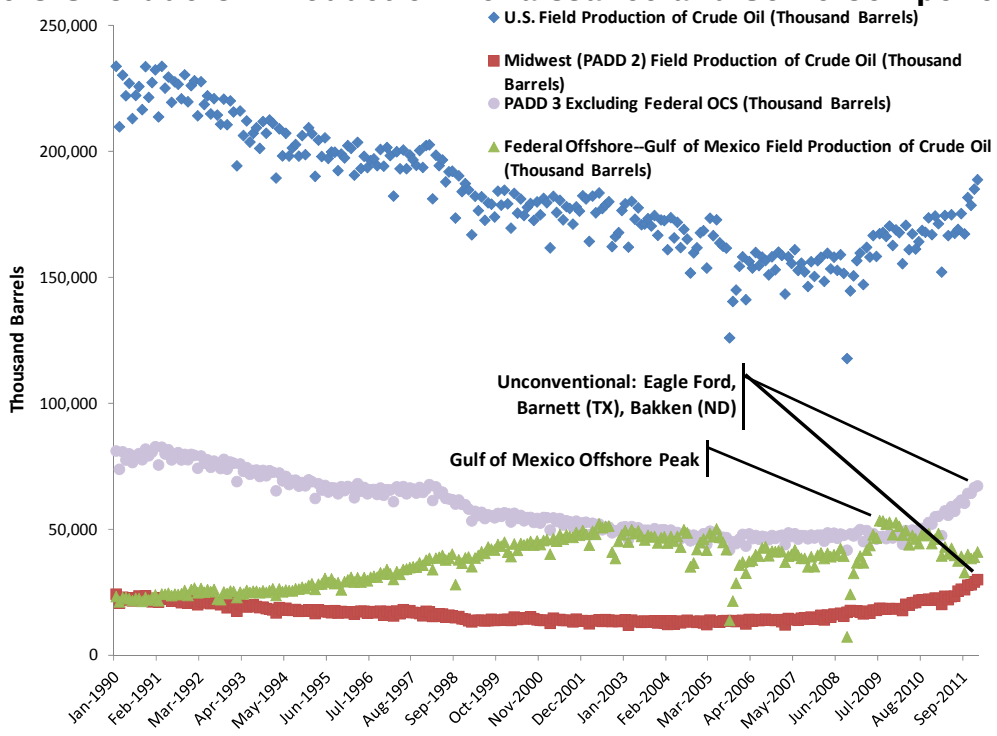
Downstream refining and petrochemical investment is under review. Some **$80 billion in new downstream spending** is anticipated for the Gulf Coast alone. Other regions and states are targeted to host additional capacity, especially in the swath of production areas from Marcellus west to the Bakken. **Timing, location, and ultimate extent of capital expenditure will hinge on many variables.** The refining industry currently is plagued by low profit margins, as high cost crude feedstock in some locations (northeast) accelerated beyond retail pricing. Soft demand, from both recession and a long term decline in gasoline consumption, undermine refining profitability, in general. Environmental risk and uncertainty complicate the picture. Expectations are that refiners and petrochemical operators will increase exports of their products if prevailing conditions continue into the future. Not much of these export volumes will reach other U.S. customers. **Review and reform of the Jones Act should be considered** to foster new, cost effective transportation routes in U.S. waters so that more Americans can benefit from our own competitively produced energy supplies.

In sum, **"debottlenecking" the oil and gas transportation and storage system requires transparent, sensible, and timely certification of facilities.** "Access" to right-of-way to build infrastructure is just as critical as access to oil and gas resources in order to sustain domestic industry and production competitiveness.

- **With regard to replenishment and deliverability, unconventional plays are helping to insulate against GOM issues, but GOM production must continue.**

Soft demand for oil products, a consequence of our deep recession, has helped to protect customers and consumers against potentially higher prices and disruptions related to Gulf of Mexico production decline. This decline has two major drivers. One – **maturity in older, shallow water fields** on the GOM shelf. Maturing and natural decline is affecting GOM natural gas deliverability much more heavily than oil. Oil production has benefitted from exploration success in oil-prone deepwater blocks. But, second – **uncertainty about policy and regulatory oversight** of the GOM Outer Continental Shelf (OCS) province is hindering investment, affecting replenishment and is, therefore, a potential factor in domestic oil reserve replenishment and supply deliverability going forward.

The U.S. Crude Oil Production Renaissance and Some Components



CEE-UT analysis based on U.S. EIA survey data.

- **Sustaining socioeconomic benefits will require a competitive tax and business environment.**

The debate on oil and gas industry taxation continues to unfold. For many, tax treatment of exploration cost and producing fields as they deplete seems unfair. However, replenishment is not simply critical, it is a matter of survivability. The oil and gas industry is **one of the most, if not <u>the</u> most, heavily taxed industries** in the U.S. when all jurisdictions – federal, state, local – are considered. In order to successfully operate through business and price cycles, navigate higher costs, continue funding and deployment of R&D and advanced technology, deal with workforce retention and recruitment, and, not least, guarantee safe and environmentally responsible operations, the industry needs a transparent and flexible fiscal regime that is consistent with fiscal policy across the economy.

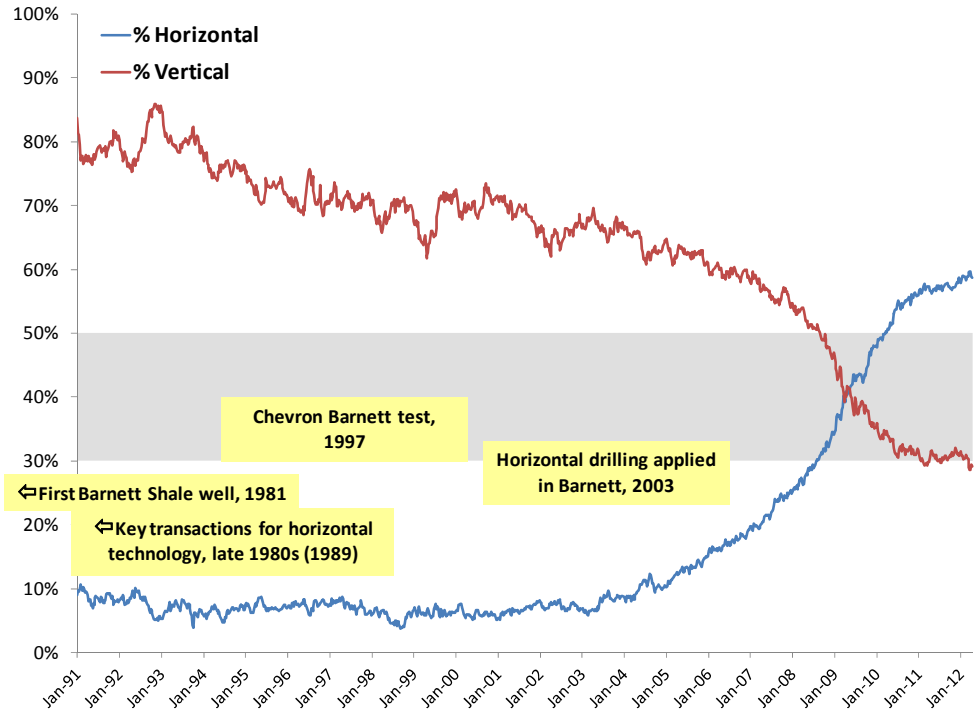
- **Sustaining socioeconomic benefits will require thoughtful and flexible environmental regulatory oversight.**

It is not easy to design and implement rules and regulations to ensure safe operations while also being cognizant of industry requirements and "cycle time" (time from origination of project concept to execution). **Reducing cycle time** helps with cost management. Public safety can be assured while also avoiding undue pressure on cycle time.

4. Role of and potential for technology advances in driving current and future energy production and impacting prices.

The biggest cost component in oil and gas supply is drilling. Consequently, drilling technology adaptation, especially in frontier applications, is **crucial to ensuring competitive supply and pricing**. For comparison, it has taken roughly 30 years for horizontal drilling to comprise more than 50 percent of the drilling market (see chart below). The oil and gas industry has one of the longest lead times for technology prove-up. Work is underway for solutions to specific problems in unconventional plays, most of which are geared toward improving recovery factors. New tools for predicting microfractures, new proppants for micro ("nano") environments, new approaches for water handling and disposal and even, perhaps, replacements for water as a drilling medium – all of these are in exciting stages of R&D. Continued investment in technology is best fostered through reasonable, coherent business and government frameworks.

Commercial Pathway for Horizontal Drilling in the U.S.



Based on Baker Hughes rig activity data.