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submitted to the

Natural Resources Committee,
Subcommittee on Energy and Mineral Resources

Unites States House of Representatives

Hearing on

"Spinning Straw Into Black Gold: Enhanced Oil Recovery Using Carbon Dioxide"

June 12th, 2008

We thank the House Natural Resources Committee, Subcommittee on Energy and Mineral Resources for the opportunity to submit written testimony for its June 12th, 2008 oversight hearing on "Spinning Straw Into Black Gold: Enhanced Oil Recovery Using Carbon Dioxide". NRDC is a national, nonprofit organization of scientists, lawyers and environmental specialists dedicated to protecting public health and the environment. Founded in 1970, NRDC has more than 1.2 million members and online activists nationwide, served from offices in New York, Washington D.C., San Francisco, Los Angeles, Chicago and Beijing.

The Subcommittee's examination of the topic of Enhanced Oil Recovery using Carbon Dioxide (CO_2-EOR) is extremely topical. The United States are faced with two related challenges that demand prompt action: energy independence and climate change.

First, we must ensure that our nation can meet its energy needs securely, affordably and efficiently, without being subject to world energy price shocks or relying on unstable regions for its fuel supplies.

Second, as the developed world's largest greenhouse gas emitter – and until very recently the world's largest emitter[1] – we must also take prompt action to reduce these emissions substantially in order to avoid the worst effects of climate change on this country and the rest of the planet, as well as the significant costs associated with it, which will be significant for many regions of the country.

CO_2-EOR offers an opportunity to take positive action on both challenges by making use of an untapped domestic oil resource without the worst impacts of other production methods or proposals, while permanently sequestering CO_2 from anthropogenic sources underground. To put the opportunity in perspective, a recently updated survey of the CO_2-EOR potential in the United States prepared for the U.S. Department of Energy estimates that as much as 48 billion barrels of "stranded oil" from existing fields – more than double the approximately 22 billion barrels of proven U.S. reserves – would be economical to produce at recent years' high oil prices.[2] At $100/barrel, that amounts to $4.8 *trillion* tied to domestic oil reserves that would create a multi-decade market for more than 11.5 billion tons of CO_2, almost all of which will need to come from industrial sources that otherwise would be emitted to the atmosphere.

In our view, the urgent challenges of our national and global dependence on oil and escalating global warming pollution both demand rapid investment in efficiency and cleaner sources of energy. NRDC also believes that carbon capture and geologic storage from coal-fired power plants and other large industrial sources will be necessary to achieve the deep emission reductions that will be needed. We believe that CO_2-EOR, implemented with the appropriate measures to ensure long-term geologic sequestration, provides a very significant opportunity to advance carbon capture and storage, reduce industrial emissions and to sustain domestic oil projection without drilling in environmentally sensitive areas.

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[1] Estimates indicate that China surpassed the U.S. in emissions in 2007.
[2] "Storing CO2 with Enhanced Oil Recovery", DOE/NETL-402/1312/02-07-08, February 2008.

Our oil addiction

In his 2006 State of the Union address, President Bush famously admitted that America is addicted to oil. Indeed, the U.S. consumes oil at an astonishing rate of roughly 21 million barrels/day or a quarter of the oil produced globally, 70% of which is used in the transportation sector. According to the DOE-EIA Annual Energy Outlook, we import twice as much oil as we produce domestically, meaning that a staggering two-thirds of our oil is imported. Domestic oil production has been dropping steadily since the 1970s as the figure below shows, and the nation's dependence on imported oil is project to increase steadily according to the EIA. Depending so heavily on an imported resource so crucial to the economy is without question unwise – and the policy decisions that will affect whether this will be the case are being made today.

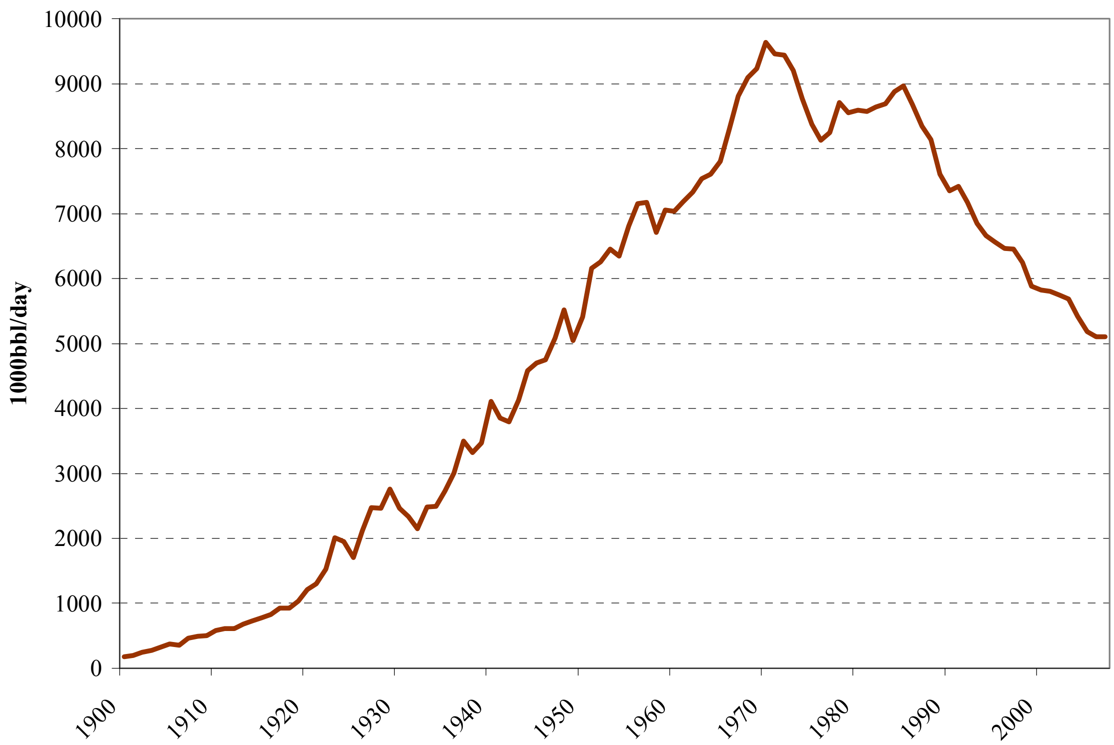


Figure 1 – Domestic crude oil production (thousands of barrels/day)

Until recently, the nation had grown complacent about oil use. The price of oil remained under $20/barrel in nominal terms for much of the 1990s, creating an illusion of an inexpensive commodity. Since 2002 however, oil prices have been climbing ever upwards, surging to almost $140/barrel in June 2008. It is clear that the era of cheap oil – and cheap fossil fuels more generally for that matter – is over in all likelihood. With strong demand in the developed world and an ever-increasing pressure coming from the developing countries, a world of high or rising oil prices is a distinct possibility and one predicted by several analysts.

The economic impacts of the recent surges are being felt worst of all by the poorest families and communities. Yet high prices have not slowed us down. Even in the context of sustained high oil prices in the last five years, fuel use trends remain largely unchanged, and our transportation fuel demand continues to rise relentlessly. Only now is evidence emerging that consumers are turning to more fuel-efficient vehicles and away from "gas-guzzlers", an effect that is making automakers resort to plant closures and shift their fleet to the kind of vehicle that ought to have been the obvious choice and the correct business decision long ago.

It does not take an expert to work out that our current path is unwise from an economic point of view, from a national security point of view, or from an environmental point of view.

A changing climate

Alongside surging oil prices and demand, the planet's climate is changing fast. Greenhouse gas emissions from the use of fossil fuels, mainly CO_2, are having a profound effect on our planet, presenting us with one of the most significant environmental and social challenges of the century.

In its most recent Assessment Report last year, the Intergovernmental Panel on Climate Change, an independent scientific body, issued the loudest warning to date, calling the warming in the climate system "unequivocal" and calling for serious emission reductions if we are to avoid truly dangerous greenhouse gas concentrations. Failure to pursue significant reductions in greenhouse gas emissions very soon will make the job much harder in the future – both the job of stabilizing atmospheric pollution concentrations and the job of avoiding the worst impacts of climate chaos.

A growing body of scientific research indicates that we face extreme dangers to human health, economic well-being, and the ecosystems on which we depend if global average temperatures are allowed to increase by more than 2 degrees Fahrenheit from today's levels. We have good prospects of staying below this temperature increase if atmospheric concentrations of CO_2 and other global warming gases are kept from exceeding 450 ppm (parts per million) CO_2-equivalent and then rapidly reduced. To make this possible requires immediate steps to reduce global emissions over the next several decades, including action to halt U.S. emissions growth within the next few years and then cut emissions by approximately 80% by mid-century. This goal is ambitious, but achievable. It can be done through an annual rate of emissions reductions that ramps up to about a 4% reduction per year. Fortunately, a wide variety of tools is available today to achieve those reductions – but we will need all the tools at our disposal. One such tool is Carbon Capture & Sequestration (CCS).

Carbon capture & sequestration (CCS)

Given the world's and the nation's dependence on fossil fuels, it is essential to have in place a technology and a strategy to reduce greenhouse gas emissions from large industrial facilities that burn these fuels, even though their complete phase-out through energy efficiency improvements and a transition to renewable fuel sources might be technically and theoretically possible. Using all available tools is a wise and necessary hedging strategy in the face of the steep emission cuts that are needed. Projections differ as to the exact portion of reductions that will be delivered by different technologies, but from a strategic point of view, CCS provides a much needed answer for fossil fuel use – which is inevitable.

Coal by itself, the most carbon-intensive of fossil fuels presents the biggest climate challenge. Since the dawn of the industrial age, human use of coal has released about 150 billion metric tons of carbon into the atmosphere – about half the total carbon emissions due to fossil fuel use in human history. Another 4 trillion metric tons of carbon are contained in the remaining global coal resources. That is a carbon pool nearly seven times greater than the amount in our pre-industrial atmosphere. Using that coal without capturing and disposing of its carbon means a climate catastrophe. And the die is being cast for that catastrophe today, not decades from now. According to the International Energy Agency, over 1800 GW of new coal plants will be built between now and 2030, a capacity equivalent to 3000 large coal plants, or an average of ten new coal plants every month for the next quarter century. This new capacity amounts to 1.5 times the total of all the coal plants operating in the world today.

Continuing with the use of coal without capturing and sequestering is fundamentally incompatible with climate stabilization. NRDC believes that CCS technology is available to us today to begin deployment.

Research on CCS has been ongoing for many years now, with major international conferences taking place since the early 1990s. Since then, knowledge on the subject has greatly expanded, to the extent that the Intergovernmental Panel on Climate Change ("IPCC") issued a special report on CCS in 2005. An extensive Massachusetts Institute of Technology ("MIT") study on the Future of Coal in 2007 also examined CCS in depth. There is a substantial body of evidence, knowledge, and peer-reviewed literature on CCS.

In many ways, CCS is not new. There are three elements to successful geologic sequestration of carbon dioxide: capture, transportation, and sequestration. All three of these elements have been demonstrated and operated in commercial, large scale installations.

The first element of CCS is the initial capture of the carbon dioxide emissions. "Pre-combustion capture" is applied to conversion processes that gasify coal, petroleum coke, or other feedstocks (such as biomass) rather than combusting them in air. In the oxygen-blown gasification process, the feedstock is heated under pressure with a mixture of pure oxygen, producing an energy-rich gas stream consisting mostly of hydrogen and carbon monoxide. Coal gasification is widely used in industrial processes around the world, such as in ammonia and fertilizer production. Hundreds of such industrial gasifiers are in operation today. In power generation applications as practiced today this "syngas" stream is cleaned of some impurities and then burned in a combustion turbine to make electricity in a process known as Integrated Gasification Combined Cycle ("IGCC"). Commercially demonstrated systems for pre-combustion capture from the coal gasification process involve treating the syngas to form a mixture of hydrogen and CO_2, and then separating the CO_2 primarily through the use of solvents. These same techniques are used in industrial plants to separate CO_2 from natural gas and to make chemicals such as ammonia out of gasified coal. However, because CO_2 can be released to the air in unlimited amounts under today's laws, except in niche applications, even plants that separate CO_2 do not capture it; rather, they release it to the atmosphere. Notable exceptions include the Dakota Gasification Company plant in Beulah, North Dakota, which captures and pipelines more than one million tons of CO_2 per year from its lignite gasification plant to an oil field in Saskatchewan (the Weyburn project described below), and ExxonMobil's Shute Creek natural gas processing plant in Wyoming, which strips CO_2 from sour gas and pipelines several million tons per year to oil fields in Colorado and Wyoming. The principal obstacle for broad application of pre-combustion capture to new power plants (and the main reason behind limited deployment of IGCC with carbon capture) is not technical, it is economic: under today's laws it is cheaper to release CO_2 to the air than capture it. Other capture technologies, including post-combustion and oxyfuel combustion are currently at the bench and/or pilot demonstration stage. The cost of CO_2 capture is by far the most expensive element in the CCS chain of operations, estimated to be in the region of 75% of total costs, depending on the geological setting and the distance of transport.

The second element of CCS is the transportation of captured carbon dioxide to the injection site, if needed. As we describe further below, CO_2 pipelines today operate as a mature market technology.

The third element of CCS is the sequestration of the carbon dioxide in geological formations. Injection of carbon dioxide has been successfully demonstrated on a large scale, not least in the context of CO_2-EOR projects, some of which like Seminole, SACROC and Wasson are injecting annual amounts of CO_2 well above the quantity that a 500MW coal plant would produce. There is also considerable scientific knowledge regarding the mechanisms for trapping carbon dioxide in sedimentary geological formations. For example, residual trapping limits carbon dioxide mobility through capillary forces. Solubility trapping occurs when injected carbon dioxide dissolves in fluids within the geological formation. Stratigraphic trapping occurs when overlying impermeable rock formations prevent upward movement of carbon dioxide from underlying reservoirs. Mineralization trapping occurs when injected carbon dioxide forms carbonate minerals and essential becomes part of the solid rock into which it was injected. Both the Intergovernmental Panel on Climate Change ("IPCC") and the interdisciplinary team from the Massachusetts Institute of Technology ("MIT") concluded that such sequestration methods in appropriately selected and operated geologic reservoirs are likely to trap over 99% of injected carbon dioxide over 1,000 years. This conclusion is based on existing project performance and a number of natural and industrial analogs. Nature itself has stored hydrocarbons and CO_2 for millions to hundreds of millions of years, and humans have successfully stored natural gas and other fluids underground.

There are several commercial and research projects that inject carbon dioxide in sedimentary geological formations for permanent sequestration. For example, the Sleipner project in Norway has been operating since 1996 and injects about 1 million tons of CO_2 annually into a deep saline formation in the North Sea. BP's In Salah project, operating in Algeria since 2004, injects a similar amount of CO_2 stripped from natural gas back into the water leg of the natural gas field. The Weyburn project receives CO_2 captured and transported from North Dakota to Saskatchewan and has been operating since 2000 and injects 1-2 million tons of CO_2 annually. All three of these projects include monitoring programs. The results of that monitoring indicate that the CO_2 is remaining sequestered in the formations and that there is no reason to expect any CO_2 leakage from these projects. These projects just mentioned give me a great deal of confidence that CO_2 can remain permanently sequestered in geological reservoirs.

All components of CCS therefore – capture, transportation and injection – have been demonstrated at commercial scale in a number of industrial applications. We believe that the barriers to CCS are not technological, but rather economic and regulatory. We are joined by leaders of major industrial corporations such as NRG Energy and BP, who have stated their case as follows:

"We're Carboholics. Make Us Stop. We are not running out of time; we have run out of time. We need to move as quickly as possible toward implementing the low-emissions ways of combusting coal that are under development or, in the case of "coal gasification" technology, are ready for commercial deployment."

[David Crane, CEO of NRG Energy; Washington Post, October 14, 2007]

"CCS cannot succeed as a commercially successful emission abatement technology without the policy or regulatory frameworks that would allow commercial entities to invest in it. New technology cannot be "pushed" into industrial-scale deployment, a market is necessary to 'pull' it. Deploying CCS at scale is not as much a question of technology availability but of economic viability. CCS is available today to play a significant role in reducing greenhouse gas emissions and addressing climate change".

[Robert Malone, Chairman and President, BP America; Written Testimony Submitted to the Select Committee on Energy Independence and Global Warming U.S. House of Representatives, September 21, 2007]

The reason that no large integrated power sector CCS project exists today is purely economic: it is simply cheaper to vent the CO_2 under today's laws instead capturing it, compressing it, transporting it to a suitable reservoir and sequestering it. However, this is not an indication of the state of readiness of the technology. The USDOE is also leading a national research program on CCS. Although we applaud the efforts of the dedicated and talented individuals involved in this program, the resources and funding available are not in line with the deployment timescale needed for CCS to reduce emissions meaningfully. Without an economy-wide cap-and-trade scheme that prices carbon emissions, and without targeted and reliably funded (such as auction revenues, as opposed to the notoriously unreliable appropriations) incentives to bring down the costs of CCS in the initial years when the carbon price is too low and volatile to spur investment, CCS is destined to linger in the background as it has done until now. We are convinced, however that, under such a policy framework, hundreds of MWs of power sector CCS would be deployed in the early years. The DOE's targets and timelines should not be seen as representative of the technology, or its program as the gateway to CCS.

Addressing energy independence and climate change

Weaning ourselves off foreign oil, while at the same time addressing climate change, is achievable if we make the right choices. In a world of climbing prices, increased dependence on imports, geopolitical instability and rising emissions, the obvious focus should be the more efficient use of energy and oil, and its replacement to the extent possible with cleaner, sustainable alternatives.

Solutions abound: more efficient vehicles, expanded use of public transport, smart city planning, low carbon fuels such as sustainably grown biofuels, plug-in-hybrid vehicles powered by low carbon electricity are all options that are available to us today. Our first priority should be to substitute oil by improving end-use efficiency, and by sustainable, low-carbon alternatives as fast as possible. These resources are cleaner, and the diversity that they will provide is our most powerful weapon against oil profiteers domestically and abroad. On the topic of domestic production, we should fully exploit the fields we have already explored and developed. America's existing oil fields hold billions of barrels of oil that we know are there and can be produced at reliable costs with no added environmental damage. CO_2-EOR is key to tapping this resource.

In order for these solutions to deliver on their potential, concerted policy efforts will be needed – and this will take decisive action, political vision and leadership. Now is the time to make the right choices on how to fuel our future growth, and to move in an efficient, low-carbon direction.

The false promises of drilling and unconventional fuels

In the face of high oil prices and energy security concerns, a number of proposals have been put on the table that would allegedly come to the rescue. These include drilling in environmentally sensitive or protected areas such as the Arctic National Wildlife Refuge (ANWR) or on the Outer Continental Shelf (OCS), or resorting to unconventional oil sources such as tar sands and oil shale.

Drilling in ANWR and on the OCS has been restricted in order to protect a few of the remaining special places in America from the industrialization that accompanies energy exploitation, and because an expansion of drilling in these areas will do precious little to benefit Americans – the U.S. can meet its energy needs without opening these areas to drilling and accompanying industrial activities. Both of these premises remain true today, even though unrelated forces have resulted in an increase in prices at the gas pump. It remains true that complete exploitation of these areas would not reduce America's transportation fuel bill. Efforts to expand drilling in those areas amount to nothing more than attempts by special interests to stockpile and secure market share. However, there are a combination of actions that can provide real and long-lasting relief while protecting these special places as part of the bargain.

The Arctic National Wildlife Refuge, a pristine area located in northeast Alaska, is the nation's second largest national wildlife refuge, comprising 19 million acres. It is home to nearly 200 wildlife species. Because of its abundant and diverse wildlife, the refuge is often likened to Africa's Serengeti. Scientists consider the coastal plain, which has been proposed for drilling, to be the biological heart of the entire refuge, containing caribou, polar bears, grizzly bears, wolves, and various migratory birds, several of which are protected by international treaties or agreements. The refuge was created in 1960 by Congress to specifically protect the region's wildlife.

In addition to the wilderness value of the refuge, drilling there will do nothing to relieve prices at the pump for a number of reasons, which are aptly summarized in a recent report by Majority staff of this Committee[3], drawing on official departmental statistics and reports:

- It is not clear exactly how much oil could be extracted. It may be possible that up to 11 billion barrels of crude oil is in place. However, the amount of this oil that can actually be recovered due to technological and economic reasons is significantly less. In a recent study, the DOE's Energy Information Administration estimated that the cumulative additional oil production from ANWR could be as low as 1.9 billion barrels, with an upper estimate of 4.3 billion barrels.[4]
- A vast acreage is open and available for leasing in Alaska outside ANWR. However, companies have leased only a fraction of this land and produced very little or no oil.[5]
- It will take a decade before oil can be produced from ANWR, and another decade before oil production reaches its peak.

[3] "The Truth About America's Energy: Big Oil Stockpiles Supplies and Pockets Profits"; A Special Report by the House Committee on Natural Resources Majority Staff, June 2008.
[4] "Analysis of Crude Oil Production in the Arctic National Wildlife Refuge". Energy Information Administration Office of Integrated Analysis and Forecasting U.S. Department of Energy; May 2008
[5] Approximately 91 million acres are currently open to leasing in the Arctic region of Alaska onshore and offshore. Oil and gas companies have leased only 11.8 million of these. Within the National Petroleum Reserve in Alaska, around 3 million acres out of 22.6 have been leased. No oil has been produced those lands and industry has drilled only 25 exploratory wells there since 2000.

- The total production from ANWR would pale in comparison with total U.S. demand, and also in comparison to the production potential from CO_2-EOR from depleted fields.

Pretty much the same realities apply to drilling on the OCS. Drilling in these areas poses unacceptable environmental risks of oil spills, air and water pollution, seismic impacts on marine mammals and onshore damage. Drilling is not necessary, given that estimates by the Minerals Management Service (MMS) show that 60% of the untapped economically recoverable oil and 80% of the untapped economically recoverable oil and/or natural gas on the OCS are located in areas that are currently open for leasing to industry.

Perhaps most importantly, feeding our addiction does nothing to decrease our dependence on oil. Moreover, oil prices are set by global markets. There is absolutely no evidence to show that increased domestic production will result in more than a few cents worth of lower prices at the pump – in fact although between 1999 and 2007, the number of drilling permits issued for development of public lands has more than tripled, oil and gasoline prices have risen to today's levels regardless. We also cannot hide the fact that the local and cumulative impacts from the expansion in leases and permits has also been significant. Many leases are located in areas where the carrying capacity for development has been, or is very close to being exceeded, and in most areas development is taking place without an overall development plan or in a phased manner. Nor is the characterization of no-go areas accurate. In some regions such as California, despite the absence of "new" drilling for some years now, there a substantial ongoing legacy program. All in all, recent years have been characterized by a fury of domestic drilling under permissive federal regulators, with plenty of unused leases still available in reserve. Despite this activity, prices have soared and the share of imports has risen.

The only sound and possible way to decrease prices and ensure a secure energy supply for the nation is to move away from the paradigm of meeting uncontrolled demand growth, use oil more efficiently and to replace it with other, low-carbon fuels. We just cannot drill our way out of our oil dependence. Attempts to mislead the public into believing that the protection of sensitive areas from drilling is responsible for today's ills are irresponsible and not in the interest of the American people, who will ultimately be the judges of the policies that come out of Congress. Increasing fuel efficiency standards for new vehicles to 40 miles per gallon would save more than ten times the likely yield of oil from ANWR. It is short-sighted and unwise to think of degrading an irreplaceable refuge to get a few cents of relief from higher gas prices, rather than encouraging Detroit to make more efficient cars and employing Americans in clean energy jobs. Fortunately we moved a step closer to the right path this past year when Congress required automakers to build cars and light trucks that average at least 35 mpg by 2020. By raising the fuel-efficiency bar even higher, we will be well on our way to beating the addiction. The public has realized that, and automakers are feeling the impacts: only recently General Motors announced that it is closing four plants that produce sport utility vehicles and pickup trucks in North America, prompted by soaring gas prices and slumping sales in the area. At the same time, GM plans a new emphasis on compact cars and is reviewing the future of the giant "Hummer".

Unconventional fuels are no exception. In the name of energy independence and lowering gas prices, proponents would have us believe that producing transportation fuels from tar sands, oil shale and coal are a sensible solution. These resources can be accessed domestically in the U.S. or in friendly Canada just across the border. The technologies to convert these unconventional resources into fuels had seen very limited application for years due to their high cost and market risk, but current high oil prices are spurring a flurry of development. Tempting though these resources might seem, they carry a host of economic and environmental problems, and unsurprisingly are not the answer to our oil addiction either.

Whether it is scouring the earth for the tar-like substance mixed with sands excavated from under the Boreal forests of Alberta, Canada, mining shale under the U.S. Rockies, or stripping coal from the mountains of the American West and Appalachia to manufacture synthetic liquid fuel, these unconventional sources constitute a heavy environmental burden to communities and ecosystems – both local and global.

Fuel production from these sources is extremely energy intensive, and the production process emits a far higher amount of greenhouse gas emissions than conventional oil production – often whole multiples of that amount. In a carbon-constrained world, these fuels will have to shoulder the additional cost of their high carbon content, and will not fare well either under cap-and-trade regimes or low carbon fuel standards that are now being legislated in a number of states and Canadian provinces and will likely be Federal policy in the U.S. soon. Producing fuel from tar sands, oil shale, and liquid coal is not only environmentally risky, but also a risky business proposition. In the near future, the United States is likely to join Europe and Japan in adopting mandatory limits on global warming pollution. Businesses developing these highly polluting fuels will likely find they are poor investments in a global market that increasingly values clean, low-carbon energy technologies. Moreover, taxpayers are being asked to share the bill for these risky deals through government subsidies and entitlements. Taxpayers and investors alike should be wary of putting their dollars into risky ventures involving carbon-intensive fuels. Extraction of all three resources also comes at enormous cost to our water, air, forests, wetlands, and wildlife and places serious burdens on community infrastructure and public health.

Destroying wildlife habitat to extract those costly resources at a significant expense to the climate is also not the way to wean ourselves off oil. Some have characterized tapping into these resources as “scraping the bottom of the barrel”, which aptly describes how little those resources would do to reduce oil consumption domestically, or affect the price we pay for oil. Supply concerns are unlikely to be eased by the growing clout of the world’s oil cartel, the Organization of Petroleum Exporting Countries (OPEC). OPEC countries hold over 75% of the world’s oil reserves according to current estimates . EIA estimates that members of OPEC earned $673 billion in net oil export revenues in 2007, a 10% increase from 2006, with Saudi Arabia earning the largest share of these earnings at $194 billion or 29% of total revenues. This immense market power enables the organization to control world oil prices effectively, leaving limited or no scope for the

U.S., which holds a meager 3% of global oil supply, to ease price pressures through additional production.

Could CO_2-EOR offer a better alternative to uncontrolled drilling in wild places and dirty fuels, alongside conservation policies and clean, sustainable fuels?

Enhanced oil recovery as an untapped domestic fuel source and CO_2 sink

Stranded oil is oil that is left in the reservoir after primary and secondary recovery techniques. Enhanced oil recovery through CO_2 flooding can reduce the amount of stranded oil significantly. Of the original oil in place (OOIP), 5-40% is usually recovered in the primary production phase. An additional 10–20% of oil in place is produced by secondary recovery that uses water flooding. Various miscible agents, among them CO_2, have been used for enhanced, or tertiary, oil recovery with an incremental recovery of 7-23% (averaging around 13.2%) of the original oil in place. The exact number is highly reservoir specific.

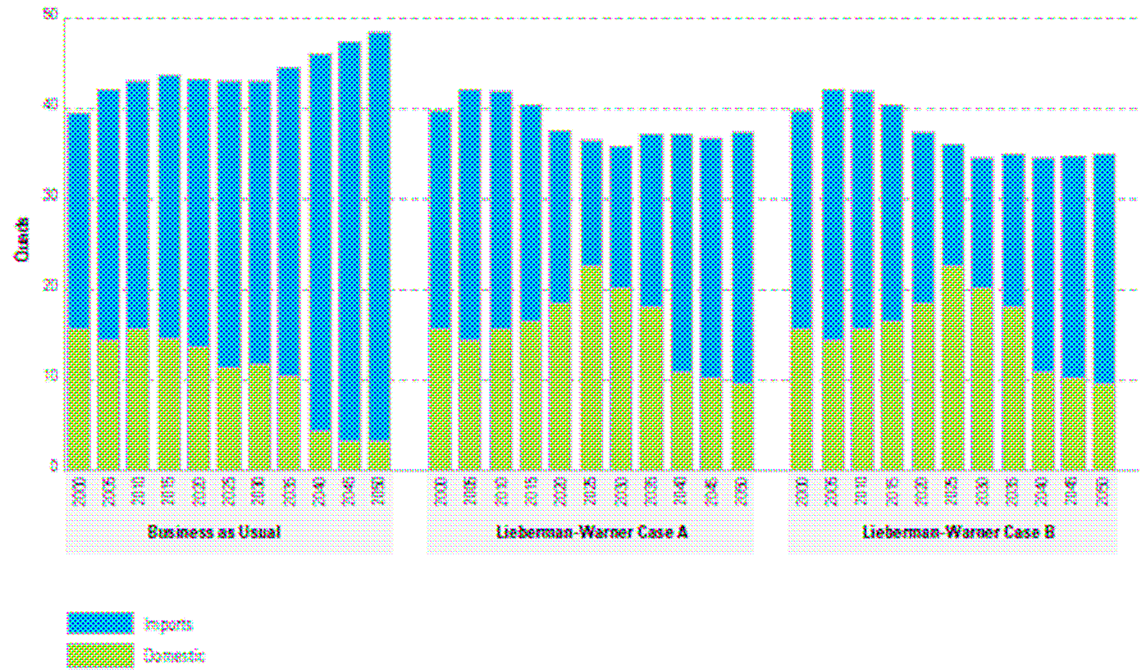
The use of CO_2 for EOR began in the U.S. in the early 1960s. Inexpensive industrial CO_2 sources, such as natural gas processing plants, were initially used, although to sustain the expansion this was quickly supplemented and eventually overshadowed by naturally occurring CO_2 discovered in Colorado, New Mexico and Mississippi. Today, there are around one hundred registered CO_2 floods worldwide, almost 90% of which are in the U.S. and Canada. Some 35 million tons of CO_2 annually are injected in mature oil reservoirs. These floods are primarily in the Permian Basin of Texas and New Mexico, but also in the Bighorn Basin of Wyoming, the Rangeley Field of Colorado and the Mississippi Salt Basin. In North Dakota CO_2 from the Great Plains Synfuels project is captured and transported across the border to Canada, and injected into the Weyburn and Midale fields in Saskatchewan. CO_2 pipelines today operate as a mature market technology and are the most common method for transporting CO_2. The first long-distance CO_2 pipeline came into operation in the early 1970s. In the United States, over 3,000 miles of pipeline transports more than 40 million tons CO_2 per year for use in CO_2-EOR.

The growth of CO_2-EOR as a technique has been contained for a number of reasons. The primary reason is the relative scarcity of high-volume sources of pure CO_2 that is needed for EOR operations. This in turn has put a premium on the cost of CO_2 to operate the floods, which can add up to half the total costs of a CO_2-EOR project. The cost of capturing anthropogenic CO_2 and using finite supplies of CO_2 that is being produced from natural domes (in much the same way as oil and gas) has thus kept projects in check. Another reason relates to lead times: it can take two years or more for the production to respond to the CO_2 being injected, delaying revenues, increasing risks and making financing less favorable. Moreover, different fields' response to CO_2 flooding can be highly variable, making successful operation a site-specific affair. Rising oil prices however, have now made CO_2-EOR economics look far more attractive. CO_2 supply for EOR is more choked than ever, and companies are pursuing aggressive business models to expand their operations using anthropogenic CO_2.

The Department of Energy (DOE) has collaborated with Advanced Resources International (ARI) to produce estimates of the volumes of oil that could be produced and the CO_2 that can be stored through CO_2-EOR in the U.S. The latest iteration of the study[6], issued in February 2008, builds on the previously issued "Basin Studies" and makes the case for a very significant domestic CO_2-EOR potential. Specifically, it evaluates the total stranded oil at roughly 400 billion barrels, 85 billion of which is "technically recoverable" using state-of-the-art CO_2-EOR techniques, with 45 billion being "economically recoverable" at an oil price of $70. At current levels, the economically and technically recoverable estimates represent approximately 5-10 full years worth of our oil consumption. The base case for the economically feasible market demand for CO_2 estimates are approximately 7.5 billion tons of CO_2 in the lower 48 states, and 9.3 billion tons of CO_2 in the whole of the U.S. – this is well in excess of the nation's annual CO_2 emissions of approximately 6 billion tons of CO_2. This is a significant sequestration potential. Even today's injection levels of approximately 35 million tons per year amount to the emission from five large coal power plants which, although would not solve our CO_2 problem still represents a significant quantity.

Easing the CO_2 supply and cost constraints would enable the much larger cited potential to be tapped. The International Resources Group recently conducted an analysis of the proposed Lieberman-Warner conducted for NRDC, using an improved and extended version of the US national MARKAL model (US-NM50) originally developed by the Environmental Protection Agency's Office of Research and Development. The reference point for the analysis is a business-as-usual (BAU) scenario calibrated to the Department of Energy's 2008 Annual Energy Outlook. The results demonstrate the power of CO_2-EOR combined with efficiency: oil imports drop to 35% of total oil supply in the middle years of the period under study due to both lower demand and through CCS using CO_2-EOR that greatly expands domestic production from existing fields. Oil imports rise again between 2035 and 2050 as the EOR resource begins to deplete, although they remain under 60% of total oil supply, as compared to more than 80% by 2050 in the BAU case. The figure below illustrates the analysis results – the two scenarios correspond to different mixes of renewable and CCS power generation:

[6] "Storing CO2 with Enhanced Oil Recovery", DOE/NETL-402/1312/02-07-08, February 2008.



CO_2-EOR in our view therefore has a substantial immediate- to long-term role to play in both increasing domestic oil production in a responsible way, and in sequestering CO_2. Although global and national CO_2 storage capacity estimates in deep saline formations dwarf those in depleted oil and gas fields, it will be several years before EOR capacity is depleted in the U.S. In this interim period, the added revenues from oil production can help offset the costs of capturing CO_2 from industrial sources and the costs of expanding the pipeline network for CO_2.

Key questions and recommendations

We conclude by answering some of the key questions around CO_2-EOR as a domestic source of oil and a CO_2 abatement technology.

Why pursue further drilling when we should be breaking our dependence on oil?

Breaking the dependence on foreign oil – and oil in general – should be the first priority as this testimony has argued. However, America will continue to depend to some extent on oil for some years to come. Sourcing this oil domestically is advantageous over importing it. Oil produced from CO_2-EOR in already drilled, mature fields is far preferable to oil that would be produced from ecologically sensitive areas of the country. Existing wells and pads can be used, reducing the need for further disruptions. The CO_2 pipeline network for EOR can provide the backbone for a national sequestration pipeline network. Moreover, an expansion in the CO_2-EOR business can have more direct beneficial effects to local and state economies and workforces, as operators are almost entirely small- to medium-size independent producers as opposed to the majors.

What about the CO_2 emissions from the produced oil?

The oil produced from CO_2-EOR will emit CO_2 when refined and combusted. The key factor in determining whether these emissions are additional, however, is to look at overall oil demand. If the quantity of oil produced through CO_2-EOR is substantial enough to reduce prices and induce an increase in national consumption, then the emissions are additional. In practice, however, CO_2-EOR oil would be limited in quantity would simply be displacing imported oil without resulting in additional emissions.

Regarding the suggested notion of "green oil", which has been suggested to capture the fact that oil from CO_2-EOR might have resulted in the sequestration of anthropogenic CO_2, we feel that it is simpler and more appropriate to account for the reduced emissions at the source of the CO_2, whether this is a power plant, refinery, ethanol plant or other facility that would be regulated under climate legislation.

How is business-as-usual CO_2-EOR different to CCS?

CO_2-EOR is not tantamount to CCS. In the former, the objective of the process is to maximize oil yields using the least amount of CO_2, which has to be bought in as a resource, often at some expense. The objective of sequestration on the other hand is to maximize the amount of CO_2 stored in the geological formation, and to ensure permanence of storage. However, the extensive body of technical expertise gained from CO_2-EOR practices is directly related to CCS. Conventional injection techniques used in EOR in combination with a few simple additions can ensure permanent storage and provide the assurances needed for a CO_2-EOR project to qualify as sequestration.

Specifically, these steps would be:

- A more extensive geological site characterization that establishes the containment characteristics and mechanisms present in potential reservoirs.
- Proven monitoring and verification systems capable of tracking the evolution of CO_2 in the subsurface and either verify containment or provide triggers for remedial action.
- Mitigation or remediation actions to ensure that CO_2 remains contained underground without endangering underground sources of drinking water or being released to the atmosphere.
- Appropriate accounting provisions.

All of these steps and techniques can be performed today by research and commercial entities alike at a small fraction of the cost of capturing the CO_2.

A geological site characterization assesses the ability of a reservoir to retain CO_2 for long periods of time, or indefinitely for all intents and purposes. It assesses the capacity and injectivity of the reservoir, the effectiveness of the trapping mechanisms, the integrity of the caprock, as well as other risk factors. The presence of oil in reservoirs is itself evidence that they have the ability to trap fluids over long periods. However, a more careful study of the specific reservoir characteristics is needed to pick secure, non-leaky reservoirs with the desirable injection and retaining characteristics. Geologists and the oil industry have the necessary tools at the disposal to perform this evaluation at a modest cost, especially in fields that have been drilled and operated for years. The impact of existing wells at the proposed site, as well as their construction standards, should be evaluated as an integral part of the site characterization.

A robust program for monitoring CO_2 in the subsurface is an integral component of sequestration. Such a program, typically referred to as Monitoring, Measuring, and Valuation ("MMV"), has the role of tracking the evolution of CO_2 in the subsurface and either verifying containment or providing triggers for remedial action, while serving as a continuous source of data feedback for the reservoir models that should be used to predict CO_2 behavior. A number of monitoring techniques and tools are readily available. Selection of the appropriate ones and specifics of their use is very site- and medium-specific, and should follow directly from the information that the site characterization study would reveal. The monitoring regime should also include methods to detect potential leakage from wells, which are the more likely conduits for migration as opposed to geological pathways in well-selected reservoirs. This is particularly important in areas of high drilling and well density.

In addition to monitoring, mitigation and remediation procedures need to be studied and specified prior to injection to ensure that CO_2 will remain contained underground without endangering underground sources of drinking water or being released to the atmosphere. That said, experience and research indicate that the risk of such leaks are minimal in properly selected and operated reservoirs. We are not aware of any cases or studies in the history of CO_2-EOR that point towards groundwater contamination or other adverse impacts.

Should the use of naturally sourced CO_2 in EOR be discontinued or CO_2-EOR regulated differently?

It is somewhat paradoxical that in a world that desperately needs to reduce its CO_2 emissions, we are producing CO_2 from geological formations in order to re-inject it. The reasons, or course, are economic. We do not believe that the use of naturally sourced CO_2 should be discontinued. With the right incentives for capturing anthropogenic CO_2 in place, we believe that future growth in CO_2-EOR will be done primarily on the back of anthropogenic CO_2. As this becomes widely available and economical, the use of naturally sourced CO_2 can and should be phased out.

We also do not believe that it is necessary to alter the EPA's or the states' Class II Underground Injection Control (UIC) requirements for the purposes of business-as-usual EOR. If CO_2-EOR is to qualify as sequestration, however, we do believe that additional provisions are required – as we outline below.

Recommendations

Cap-and-trade: the most far-reaching measure that will not only reduce our greenhouse gas emissions but also reduce our dependence on foreign oil, is an economy-wide cap-and-trade scheme, such as that proposed by the Lieberman-Warner legislative proposal that was recently debated in the Senate. Recognizing that the initial price of CO_2 is likely to be too low and/or too unstable to stimulate sufficient investment in CCS, the bill included a set of targeted incentives for carbon sequestration. As the MARKAL analysis described earlier in this testimony shows, the bill would provide a significant boost to CO_2-EOR by making significant supplies of CO_2 available at affordable prices, greatly reducing oil imports.

Tax treatment for anthropogenic CO_2 pipelines: pipelines that carry natural CO_2 currently qualify for favorable tax treatment as master limited partnerships. It is not yet clear whether pipelines carrying anthropogenic CO_2 would qualify. The tax code should be modified explicitly to extend at least as favorable a treatment, and preferably favorable, to the pipelines carrying anthropogenic CO_2.

Requirements for conversion of EOR to CCS: we believe that appropriately modified CO_2-EOR projects should be allowed to earn carbon allowances under a cap-and-trade scheme. EPA should be required to write the relevant accounting protocols for sequestration facilities. In addition, we propose the inclusion of conversion provisions or a new injection class under the EPA's UIC program that will clearly outline how a CO_2-EOR project can be converted to and classified as a CCS project. The characterization, monitoring and remediation/mitigation considerations discussed above, together with the accounting protocol, provide a basis for the conversion.

Subsurface property rights: states have different laws for mineral and pore-space rights (which usually belong to the surface owner). With very few exceptions, such as Wyoming that recently passed a clarifying law, conflicts are resolved through case law, with the mineral estate usually being dominant over the surface estate. Sequestration could results in conflicts between occupying the pore space with CO_2 and minerals that might be present in the same reservoirs, all between many different owners. We urge that states clarify these properly issues, and that the relevant Federal agencies clarify provisions for lands under their jurisdiction.

We would like to thank the Subcommittee again for the opportunity to submit written testimony, and stand ready to assist in any way possible.