

For a Green and Secure Pennsylvania: Increasing Domestic Petroleum Production, Mitigating Adverse Climate Change, and Creating Green Jobs in Pennsylvania

With the change in the Administration in the White House, and with the tide of public opinion, crude oil, natural gas, and coal have become synonymous with old ways of doing business. However, oil, gas, and coal do not have to be four-letter words. While technologies traditionally considered sustainable, like solar, wind, and geothermal, will play larger and larger roles in the future, the United States cannot afford to wait until these alternative energy sources become economically sustainable. The U.S. also cannot allow climate change to go unchecked while waiting for these alternative fuels to come to commercial scale. Fortunately, there is an interim solution that would make coal more environmentally friendly, and allow the increased domestic production of oil and natural gas, all while sequestering harmful greenhouse gases. And that solution is not years or decades away – it is available today. That technology is called CO₂-enhanced oil and gas recovery. Pennsylvania should strive to become a leader in this technology, as it makes sound energy and environmental policy, and would also attract green collar jobs to the Commonwealth as well as utilize Pennsylvania's enormous wealth of natural resources. In this paper, I will argue that CO₂-EOR should be considered a “sustainable” energy resource for PA, and should qualify for the same tax, RPS, and other state incentives as do traditional renewable sources.

To illustrate the scope of the climate and energy challenge facing America, as shown in Figure 1, the Obama administration is calling for an 83% reduction in CO₂ emissions by 2050 from 2005 levels, which amounts to reducing CO₂ emissions from 5.7 billion metric tons to 2.8 billion metric tons (NETL, 2009). About 34% of the reductions must come from electricity generation, and another 27% from transportation. As shown in Figure 2, up to 51% of the U.S. electricity generation comes from coal, which accounts for 83% of CO₂ emissions, while a significant majority of CO₂ emissions in the transportation sector comes from gasoline refined from crude petroleum. Just considering Pennsylvania alone, the state accounts for 1% of the world's CO₂ emissions (Michael Morris, CEO, American Electric Power, personal communication, 2009). In order to meet the aggressive targets of the Obama

administration, it will not be sufficient to utilize existing alternative energy technologies like solar and wind, because the rate of retirement of existing coal plants and gasoline stations cannot be fast enough to meet the 2050 target. Rather, some alternative method of using coal in a way that minimizes CO₂ emissions into the atmosphere is necessary – and that alternative is CO₂-EOR.

For national security reasons, it is important to realize that not every barrel of oil is equivalent. Oil that is produced domestically improves the U.S. economy, creates local jobs that cannot be outsourced overseas, and improves the national security of the United States by reducing the amount of petroleum imports from OPEC nations, many of which are known to be supporting and/or funding terrorist cells. CO₂-EOR allows a solution out of the two national dilemmas of coal and oil/natural gas – by utilizing the CO₂ produced from coal during the generation of electricity, it is possible to sequester the CO₂ in oil and natural gas fields, and actually increasing the petroleum and natural gas production in those fields compared to the base case (see Figure 4).

The U.S. currently produces 5.1 million barrels of oil a day, down 41% from the 1970s. Domestic oil fields are declining in production because the U.S. oil industry is the oldest in the world and most fields are decades old. The U.S. DOE conducted several studies determining CO₂-EOR to be the most promising method to increase oil recovery. In fact, the DOE estimates that America has over 400 billion barrels of currently unrecoverable petroleum in our own petroleum reservoirs. In order to start taking immediate advantage of America's domestic oil resources, the present Administration needs to support and encourage the application of advanced new technologies to unlock and harness this American "lazy asset." For example, the DOE estimates that 160 billion barrels of "stranded" oil can be recovered using CO₂-EOR. To that end, our Administration should introduce tax incentives for American companies using CO₂-EOR to extract domestic oil. While change at the national level can be slow, Pennsylvania should take the lead and set the example. Specifically, Pennsylvania should offer a state production tax credit (PTC) of \$4.50 for every domestic barrel of oil extracted using CO₂. This has the added side-effect of sequestering approximately 10,000 cubic feet of CO₂ for every barrel of oil extracted,

hence also contributing to our carbon reduction goals. Offering this tax incentive will spur innovation of new technologies, commercialization of existing applicable technologies, and economic investment in new CO₂-EOR operations around the state. For example, it would spur the construction of new CO₂ pipelines to carry CO₂ from industrial sources to oil fields, thus sequestering industrial CO₂. In addition, it would encourage the commercialization of promising new CO₂ separation technologies that would allow even more industrial CO₂ to be captured and sequestered economically. Finally, it would spur the development of new CO₂-EOR technologies not even conceived today. Not only would it encourage existing companies to develop and commercialize CO₂-EOR technologies, but it would give rise to many new American companies with the innovation and agility to take advantage of this market opportunity. America does not need to subsidize CO₂-EOR with tax credits forever, as natural market forces will take over after the technology learning curve plays its course.

Injection of CO₂ has been used since 1972 in the United States for significantly increasing oil production in an economic and environmentally friendly manner. Oil & Gas Journal's 2008 Survey shows CO₂-EOR accounting for 250,000 bbls/day of U.S. oil production, and rising (Larry Wikstrom et al., Ohio Geological Survey). Figure 5 shows the total estimated market for CO₂ use in EOR. Figure 7 shows areas of the country which are using CO₂-EOR extensively, primarily in the Western United States, including largely the Permian Basin of western Texas and New Mexico and the Rocky states of Wyoming, Colorado, and Utah. The large potential of CO₂-EOR in Appalachia is being entirely underutilized – a total of 100 million additional barrels are economically recoverable in the Appalachia region, while no CO₂-EOR is currently underway.

Historically, Pennsylvania has been a leader in oil production and innovation. The first oil wells in the United States were drilled in Titusville, PA (Warren County) and the first conventional oil industry was founded, accounting for more than 50% of the world's oil production in 1900. After oil was discovered in larger quantities in the west, most of the early oil industry moved to that region. Today,

while only smaller oil production companies exist in abundance in Pennsylvania, substantial oil reserves still remain.

Pennsylvania's independent oil companies produce more than 3.5 million barrels of crude oil each year. Most of the crude oil is produced at small oil fields in the counties of McKean, Warren, Forest and Venango, although production also occurs in the counties between Butler and Greene (see Figure 3). Pennsylvania oil producers operate more than 17,000 wells on small oil fields throughout the state. Additionally, Pennsylvania currently has approximately 14 million barrels of proved crude oil reserves remaining to be produced. At the current rate of production, Pennsylvania's proved reserves will be extracted in less than ten years; hence it is clear that new unconventional petroleum resources need to be explored in Pennsylvania to continue the long tradition of independent oil production in PA.

Pennsylvania has oil reserves concentrated in small fields. These fields, due to the geographic and geologic properties, are prime conditions for the CO₂ EOR process, which would dramatically increase the life and productivity of these oil fields. In these small fields that used to produce 1,000 barrels/day 20 years ago, many are now producing less than 50/day because of natural decline. Figure 8 shows a typical Appalachian oil producer, which used to produce approximately 800 bbls per day, and is now only operating marginally, producing less than 12 bbls per day. The loss of pressure and the subsequent water displacement that occurs render most wells useless after initial oil extraction. This leaves the majority of recoverable oil in the ground and dramatically limits the oil production.

In order to effectuate any change as radical as allowing traditional tax credits reserved for renewable energy to become applicable to CO₂-EOR and allowing for CO₂-EOR based electricity to count towards the state's RPS standards, a new intellectual framework is required. It is necessary, therefore, to "Think Big, Start Small, and Scale Fast." The preceding discussion took the first step of illustrating the "Big Thinking" necessary to address the challenges facing the nation and the Commonwealth of Pennsylvania. In order to succeed, it is necessary to translate the big thinking into

small, concrete actions. Therefore, the Commonwealth of Pennsylvania should adopt the policy of treating CO₂-EOR on parity with traditional renewable energy sources when it comes to state tax credits. Ideally, a domestic (in-state) production tax credit (PTC) for oil extracted from domestic sources should be set at approximately \$4.50/bbl in order to help spur CO₂-EOR, which is still considered an exotic technology most used in Western states like Texas and Wyoming. An equivalent natural gas tax credit should also be made available.

In addition, a provision may be necessary to encourage the early adopters of this technology to get the practice started and overcome some of the initial risks of bringing the technology to PA, which has slightly different geologic characteristics than where CO₂-EOR has traditionally been used. One possibility would be to allow early applicants in the first 3 years of the program to obtain an up-front payment of the PTC equal to the net-present value of the expected PTC over a 10-, 15-, or 30- year life, allowing the developer to help finance the initial deployment of the project.

Additionally, Pennsylvania has a renewable portfolio standard (RPS) of 18% renewable energy by 2020. Pennsylvania has a long way to go, as it was ranked 39th out of 50 with the percent of total state electricity generation coming from renewable sources in 2006, with only 2.4% of Pennsylvania's electricity generation coming from renewable sources (NREL, 2009). This is not surprising, giving the dearth of renewable options in Pennsylvania. CO₂-EOR would open a much larger opportunity for Pennsylvania to participate in the green revolution, as both coal and declining oil and gas fields are abundant in the state.

In general, Pennsylvania has the following policy measures for encouraging renewable resources: generation disclosure, grants, interconnection standards, net metering, and renewable portfolio standard (RPS). The central thesis of this paper is that these policy measures should be applied with parity to CO₂-EOR for the reasons cited here.

Perhaps the most interesting phenomena that is possible with “next generation” enhanced oil recovery technology occurs when the amount of carbon sequestered is equal to or greater than the amount of carbon in the oil recovered. Thus, the oil produced can be truly “green,” since it has been fully “paid for” by the carbon sequestered to get it (see Figure 6). After CO₂ is brought to an oil field, it is forced (pumped) into the oil field through an injection well. Once the CO₂ fills pore spaces within the reservoir, it preferentially mixes with and displaces the water near the well bore, leaving the more viscous oil remaining in the pore spaces. It also re-pressurizes the reservoir aiding in the extraction process. When most of the water has been displaced, the CO₂ begins mixing with the oil as well. Eventually the CO₂ becomes miscible with the oil, reducing its viscosity and allowing it to flow from the higher-pressure reservoir to the lower-pressure well bore. This will increase the productivity of the wells that are currently extracting oil and rejuvenate those wells that have been drained of their pressure and have stopped producing. Additionally, the CO₂ will eventually begin to remain in the reservoir, staying within the pore spaces vacated by the oil. Thus, CO₂ EOR has the added benefit of sequestering the CO₂.

In an average scenario where a small oil field implements CO₂-EOR, the operator would acquire one million cubic feet of CO₂ a day. In this scenario, the CO₂ is sequestered underground in the field, generating about 100 extra barrels of oil per day (NETL, 2006).

The Commonwealth should run a regional (Appalachian) workshop in Pennsylvania involving all stakeholders, including the state’s oil and natural producers, the state’s coal-fired electric generators, the utilities, and its citizens. The citizens need to be educated about the vast indigenous resource potential within the state of Pennsylvania, and the advances in technology that make this indigenous resource both economically and environmentally accessible for the benefit of its citizens. Coordination between state lawmakers and executive agencies is crucial to moving this proposal forward. Such an unconventional change in state energy regulation will no doubt require visionary leadership, probably from the Governor’s Office. The Governor has a unique opportunity to pursue an agenda that cuts across partisan lines and has appeal to both environmental, coal, and economic interests in the state.

Most importantly, CO₂-EOR fits into the Pennsylvania Energy Development plan led by Gov. Ed Rendell and DEP Sect. Kathleen McGinty, which states that “financial tools such as PEDDA [Pennsylvania Energy Development Authority] are important to the development of the clean, advanced energy sector. Ultimately, however, sustainable growth can only be achieved if the overall energy policy in Pennsylvania is favorable to the development of clean, advanced energy” (March 28, 2008). Gov. Rendell led the resurrection of PEDDA in 2005, saying “we are investing in Pennsylvania businesses and organizations that are committed to the development of clean-burning, home-grown fuels and renewable energy sources. The investment in innovative technologies and energy efficiency will help drive energy costs down, provide affordable energy, create good-paying, green jobs in communities throughout the state and reduce our dependence on foreign oil” (Gov. Rendell, press release, Oct. 10, 2008).

However, when new sources of natural gas were discovered in the Pennsylvania Marcellus Shale in 2008, Gov. Rendell stated that “we have a Pennsylvania gold rush going on in the form of drilling for natural gas along what is known as the Marcellus Shale. Scientists now estimate that if we can extract just 10% of the gas that exists below ground in the Marcellus, it would be enough to supply the natural gas needs of the entire United States for two years.” Despite the fact that this resource is still largely unproven, requires tremendous risk in order to commercialize, and drilling activity has ground to a virtual halt as a result of the collapse of crude and natural gas prices, Gov. Rendell still called for a natural gas severance tax in his annual budget measure (a severance tax is a state tax on a portion of the value of a natural resource extracted, or “severed”). He proposed a tax of 5% at the wellhead, plus 4.7 cents per thousand cubic feet of production (Nick Snow, Feb. 20, 2009). However, Stephen Rhoads, the President of the Pennsylvania Oil and Gas Association (POGAM), said that “this tax would kill Pennsylvania’s shallow gas producers. Our numbers make a strong case for an exemption for Pennsylvania’s conventional marginal gas producers and that any tax should be postponed at least until Marcellus production trends are known” (POGAM, Feb. 6, 2009).

Instead of potentially killing a fledgling domestic gas industry in Pennsylvania, Gov. Rendell and the Pennsylvania Legislature should provide CO₂-EOR with full parity alongside other renewable energy resources, and provide a financial incentive for CO₂-enhanced oil and gas recovery in Pennsylvania. At least three states have used tax incentives to increase CO₂-EOR activity in their states since the 1980s, with highly favorable results. In Louisiana, the Louisiana Revenue Statute Ann. 47:633.4 is effective as of July 1984 with no sunset with a stated goal “to provide an economic incentive to producers to invest in tertiary recovery projects to enhance Louisiana’s crude oil production, to the ultimate benefit of the state and the people.”

The provisions of the “Tertiary Recovery Statute” are that no severance tax shall be due on production from a qualified tertiary recovery project approved by the Secretary of the Department of Natural Resources until the project has reached payout. “Payout is calculated using investment costs; expenses particular to the tertiary project, not to include charges attributed to primary and secondary options on that reservoir; and interest at commercial rates. The regular state oil severance tax rate in Louisiana is 12.5% of the value of the produced oil.” As such, eliminating the severance tax until payout for CO₂-EOR projects would provide front-end risk sharing equal to \$5.46 per barrel of incrementally produced oil (assuming a sales price of \$50 per barrel of oil and a royalty rate of 12.5%). (NETL, 2005)

In Mississippi, the Mississippi Code Ann. 27-25-503(i) (1972) is effective as of April 1994 with no sunset, with a stated goal to: “encourage the use of enhanced recovery methods of production.” The “Enhanced Oil Recovery Statute” reduces the assessed severance tax rate to 3% of the value of the oil produced by an enhanced oil recovery method. “The original statute, only covering use of carbon dioxide transported by a pipeline to the oil well, was expanded to include any other enhanced oil recovery method approved and permitted by the State Oil and Gas Board on or after April 1, 1994.” The regular state oil severance tax rate in Mississippi is 6% of the value of the produced oil. Reduction of the severance tax to 3% provides a modest risk sharing equal to \$1.32 per barrel of incrementally produced oil (assuming a sales price of \$50 per barrel of oil and a royalty rate of 12.5%). (NETL, 2005)

In Texas, the Statewide Rule 50 and the Texas Tax Code Ann. 2(I), 202.054 is effective as of 1989 for new projects and 1991 for expanded projects, with a stated goals “to encourage additional recovery of the state’s oil reserves through the use of enhanced oil recovery technology, and to extend the lives of wells with the resulting benefit to the Texas economy through job creation and additional severance taxes.” (NETL, 2005)

In the “Enhanced Oil Recovery Statute”, the state severance tax is reduced by 50% (from 4.6% to 2.3%) for oil production from new enhanced oil recovery projects and incremental production from expanded projects. “A two-step Railroad Commission certification is required. First, the operator must obtain approval and area certification for the new/expanded project; second, the operator seeks Railroad Commission certification that the project evidences a positive production response (an increased rate of production attributable to the project). The application for positive production response certification must be filed within five years for a tertiary oil recovery project. The regular state oil severance tax rate in Texas is 4.6% of the value of the produced oil.” Reduction of the severance tax to 2.3% provides a modest risk sharing equal to \$1.00 per barrel of incrementally produced oil (assuming a sales price of \$50 per barrel of oil and a royalty rate of 12.5%). (NETL, 2005)

Wyoming implemented a comprehensive CO₂-EOR state incentive program, including state regulatory assistance with CO₂ pipeline construction (Gov. Dave Freudenthal, personal communication, 2009). As a result, Wyoming has experienced a boom in CO₂-EOR. For example, a coalition of ExxonMobil, Chevron, and Anadarko built the backbone of a cross-state CO₂ pipeline network, carrying CO₂ from ExxonMobil’s ethanol processing facility to numerous oil and gas fields in the state for use in EOR. For example, Anadarko Petroleum Corporation built a 125-mile CO₂ pipeline off the main trunk line to Salt Creek, WY, a 100-year old oil field. They expect to increase production from approximately 5,000 bbls per day in 2005 to approximately 30,000 bbls per day by 2010. In the process, they invested over \$500M in the state, creating hundreds of jobs (Jim Hackett, CEO, Anadarko, personal communication, 2009).

As Thomas Friedman stated, “Green is not simply a new form of generating electric power. It is a new form of generating national power – period.” Our Administration’s priority needs to be securing America’s energy independence – now. As a nation we cannot afford to wait. Since petroleum accounts for 40% of our energy use, and is the one fuel that is essential for our energy independence, our Administration’s policies should be focused on eliminating America’s dependence on foreign oil. It is imperative that this country starts taking immediate advantage of America’s domestic oil resources through the application of advanced new technologies that also sequester CO₂ from the consumption of coal and other carbon-heavy fuels like biomass. This would have the benefit of creating highly-skilled jobs in America; reducing America's dependence on imported oil; reducing America's crude oil imports from nations which may be funding terrorist cells; reducing America's “dirty” coal-fired electric generation; and reducing carbon dioxide (CO₂) emissions into the atmosphere.

Following the philosophy of “Think Big, Start Small, Scale Fast,” if the new system of recognizing CO₂-EOR as a sustainable energy source works in the state of Pennsylvania, the system can be scaled quickly to other states, regions, and perhaps even to the federal level, allowing CO₂-EOR access to federal energy tax credits and other incentives traditionally reserved to alternative energy resources. Finally, and perhaps most importantly, CO₂-EOR will provide a bridge to the carbon-constrained world of the future. When a federal cap-and-trade or a federal carbon tax is passed, it will create a price on emitting carbon into the atmosphere. Many skeptics of carbon regulation are arguing that this will cause a large and adverse effect on energy prices. However, if CO₂ may be viewed as a valuable commodity for enhanced oil and gas production, it would create a bridge and help offset the negative effects of a high price on carbon. Depending on the price of carbon, it could also have the interesting affect of making it highly profitable to capture CO₂ from the atmosphere and sequester it underground. In short, CO₂-EOR technology is in the unusually beneficial position of being immediately available, while helping reduce the environmental effects of coal and enhancing domestic oil and natural gas production, as well as

providing a bridge into the carbon constrained future. It's about time government recognize its importance and aggressively support it. Oil need not be a four-letter word in this Administration.

REFERENCES

Department of Energy (DOE): "Basin oriented strategies for CO₂ enhanced oil recovery: Onshore Gulf Coast," (2005).

Vello Kuuskraa, et al.: "Storing CO₂ and producing domestic crude oil with next generation CO₂-EOR technology." Presentation at the 8th Annual Carbon Capture and Sequestration Conference, Pittsburgh, PA (May 6, 2009).

Vello Kuuskraa, et al.: "Storing CO₂ and producing domestic crude oil with next generation CO₂-EOR technology." DOE Report DOE/NETL-2009/1350 (Jan. 9, 2009).

Robert Ferguson, et al.: "Storing CO₂ with enhanced oil recovery." Presentation at the 2008 CCS Conference, Pittsburgh, PA (May 6, 2008).

Vello Kuuskraa, et al.: "Storing CO₂ with enhanced oil recovery." DOE Report DOE/NETL-402/1312/02-07-08 (Feb. 7, 2008).

DOE: "Undeveloped domestic oil resources: The foundation for increasing oil production and a viable domestic oil industry," (2006).

Larry Wickstrom et al.: "Enhanced Oil Recovery Potential and CO₂ Sequestration in the Michigan and Northern Appalachian Basins Region," American Association of Petroleum Geologists meeting, (2008).

DOE: “Evaluating the potential for ‘Game Changer’ improvements in oil recovery efficiency,” (2006).

DOE: “New CO₂ Enhanced Oil Recovery technology could greatly boost U.S. oil supplies,” (2006).

DOE: “Project injects CO₂ to boost oil recovery; also captures emissions. DOE-funded watershed project in Kansas demonstrates new technology,” (2006).

Bob Moen, The Associated Press: “CO₂ is squeezing more oil out of Wyoming field.” Deseret News, Aug. 5, 2005.

Pennsylvania Energy Development Authority (PEDA): “The Pennsylvania Energy Development Plan,” March 28, 2008, Kathleen A. McGinty, Secretary of Environmental Protection (DEP) and Chairman of the Board of PEDA.

Commonwealth of Pennsylvania, DEP: “Governor Rendell says clean energy projects will create jobs, promote conservation, efficiency,” October 20, 2008, press release.

Nick Snow: “Pennsylvania governor’s proposed gas severance tax is hardly a surprise,” Oil & Gas Journal (OGJ) Washington Pulse (Feb. 20, 2009).

“Governor proposes severance tax on natural gas,” Pennsylvania’s Oil and Gas Producers News, Harrisburg, PA, Feb. 2, 2009.

The Climate Change Challenge

The Obama-Biden Energy agenda calls for an 83% reduction in CO₂ emissions by 2050 (from 2005 levels). To meet the challenge, domestic electric power plants may need to reduce their CO₂ emission footprint by 90%.

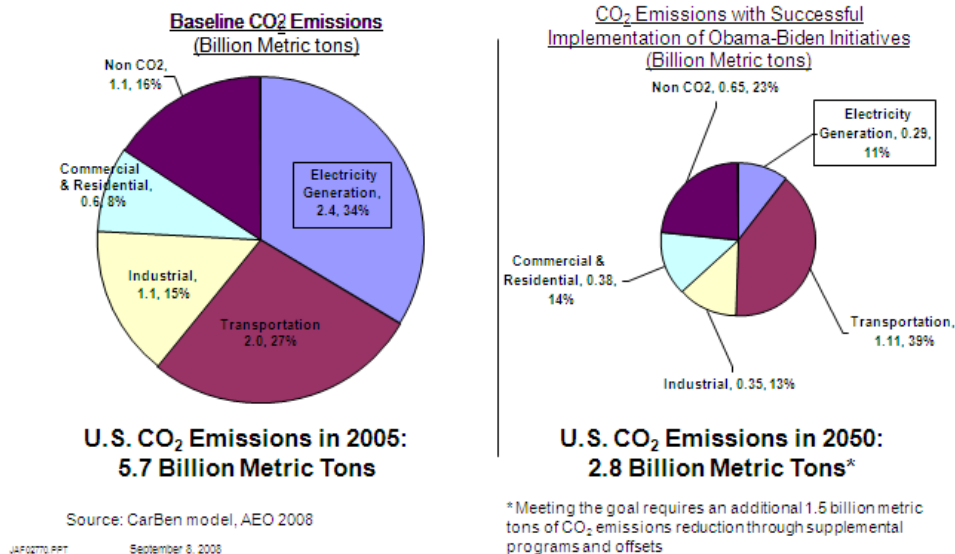


Figure 1: The Climate Change Challenge. Source: NETL.

The Climate Change Challenge

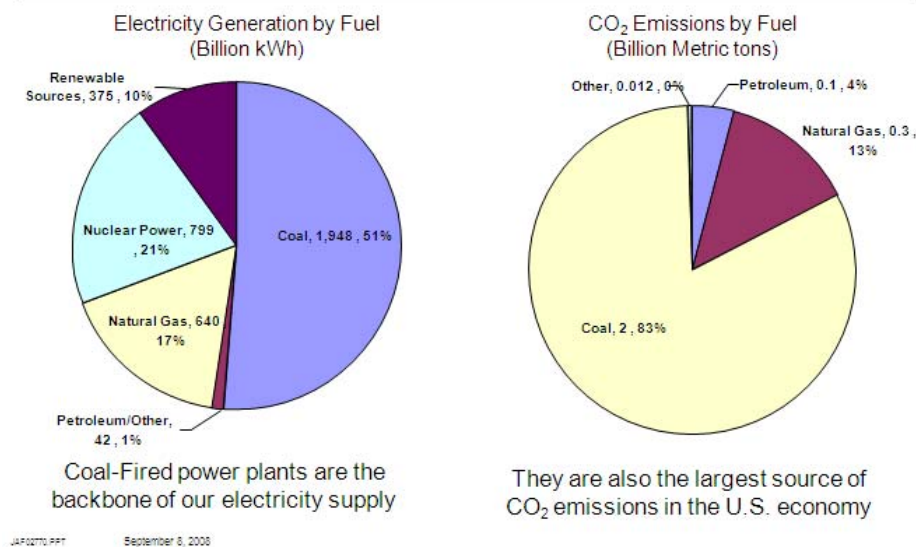


Figure 2: The Climate Change Challenge. Source: NETL.

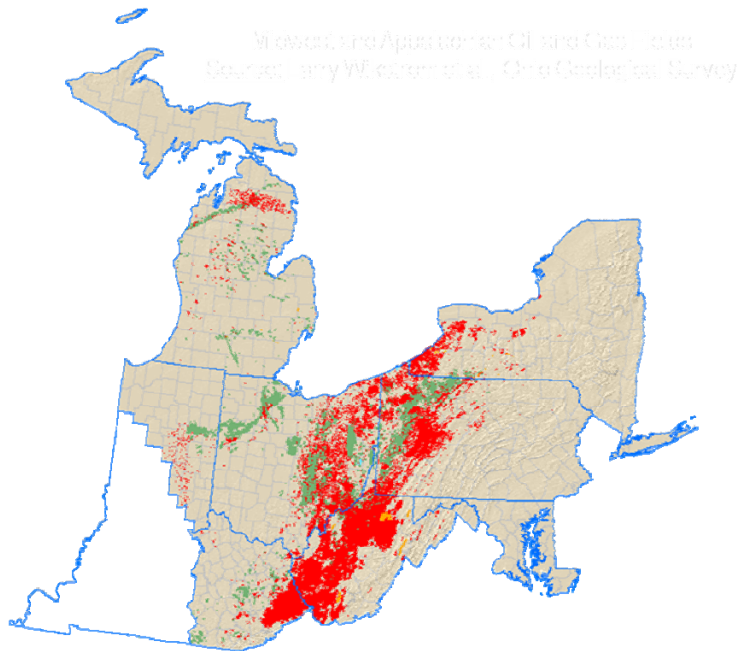


Figure 3: Midwest and Appalachian Oil and Gas Fields. Source: Larry Wikstrom et al., Ohio Geological Survey.

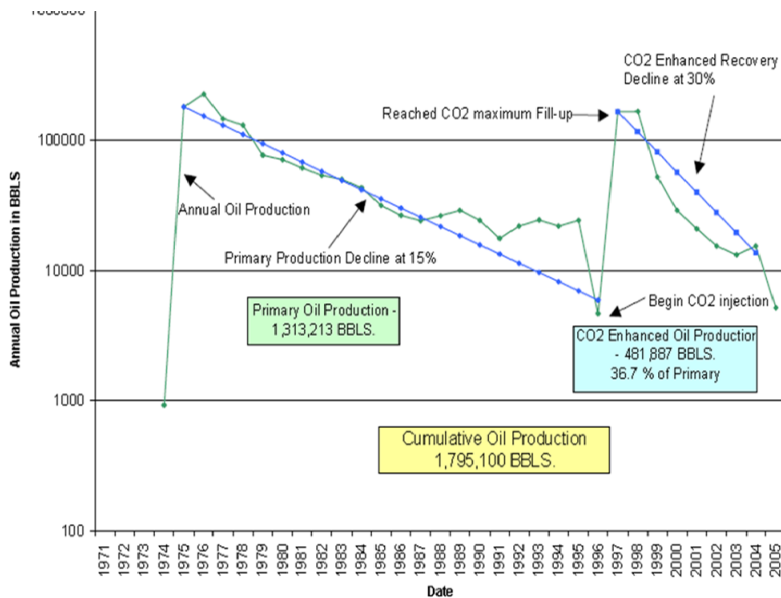


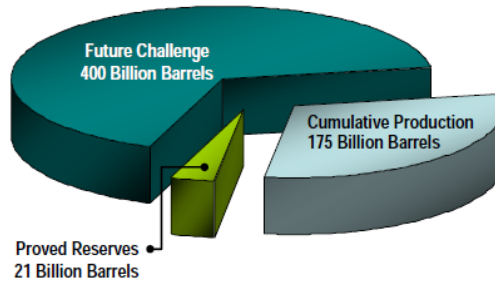
Figure 4: Enhanced Oil Recovery with CO₂ in Dover 33 Niagran Reef Field, Otsego County Michigan. Source: Larry Wikstrom et al., Ohio Geological Survey.

Storing CO₂ with EOR: A Large “Value-Added” Market for CO₂ Emissions

Large Volumes Of Domestic Oil Remain “Stranded” After Traditional Primary/Secondary Oil Recovery

Original Oil In-Place: 596 B Barrels*

“Stranded” Oil In-Place: 400 B Barrels*



*Based on field-by-field assessment of over 2,011 large U.S. oil fields accounting for 74% of domestic oil production; excludes deep-water GOM. Source: Advanced Resources International (2008)

Figure 5: National market for CO₂. Source: Advanced Projects International.

Integrating CO₂-EOR and CO₂ Storage

Integrating CO₂-EOR and CO₂ Sequestration shows that much more CO₂ can be stored, making the additional oil produced “GREEN OIL”**.

	"State of the Art"	"Next Generation"		
	(millions)	EOR	Seq.	Total
CO ₂ Storage (tonnes)	19	76	33	109
Storage Capacity Utilization	13%	52%	24%	76%
Oil Recovery (barrels)	64	180	-	180
% Carbon Neutral ("Green Oil")	70%	100%	-	160%

**Green Oil" means that more CO₂ is injected and stored underground than the volume of CO₂ contained in the produced oil, once burned.

Figure 6: “Green Oil”. Source: Advanced Projects International.

Basin/Area	Technically Recoverable (Billion Barrels)	CO ₂ -EOR Currently Underway (Billion Barrels)	Incremental Technically Recoverable (Billion Barrels)	Incremental Economically Recoverable** (Billion Barrels)
1. Alaska	12.4		12.4	9.5
2. California	10.0		10.0	8.1
3. Gulf Coast (AL, FL, MS, LA)	7.4		7.4	2.7
4. Mid-Continent (OK, AR, KS, NE)	17.1	-0.1	17.0	8.8
5. Illinois/Michigan	3.2		3.2	1.7
6. Permian (W TX, NM)	29.9	-1.9	28.0	13.2
7. Rockies (CO, UT, WY)	7.4	-0.3	7.1	3.8
8. Texas, East/Central	20.0		20.0	11.8
9. Williston (MT, ND, SD)	5.2		5.2	0.6
10. Louisiana Offshore	5.8		5.8	3.9
11. Appalachia (WV, OH, KY, PA)	2.6		2.6	0.1
Total	121.0	-2.3	118.7	64.4

*Incremental technically recoverable resources after subtracting 2.3 billion barrels already produced or proven with CO₂-EOR.

**Base Case Economics use an oil price of \$70 per barrel (constant, real) and a CO₂ cost of \$45 per metric ton (\$2.38/Mcf), delivered at pressure to the field. Economically recoverable resources from the database of large oil reservoirs are not further extrapolated to national totals. We assume that all the reservoirs with economic potential are already included in this database.

Figure 7: Economically recoverable resources from applying “Next-Generation” CO₂-EOR.

Source: NETL

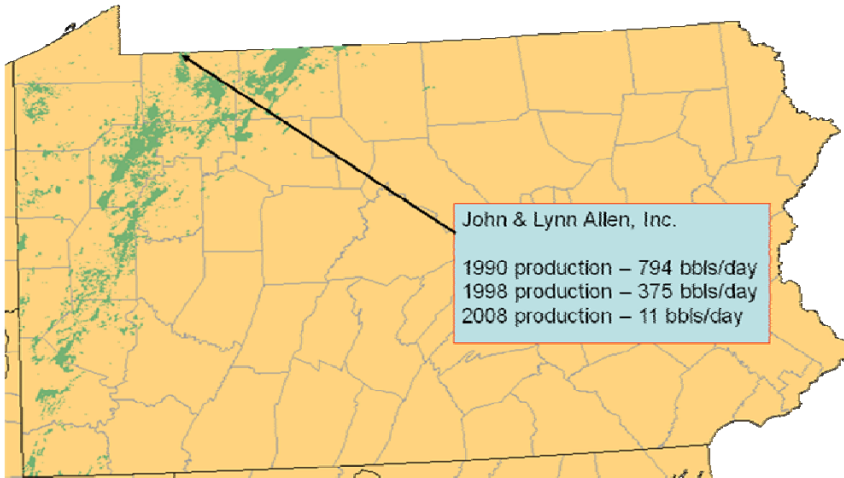


Figure 8: Typical Pennsylvania small producer. Source: J & L Allen Inc., personal conversation.