REPORT TO THE LEGISLATURE

Review of Policies Relating to Carbon Dioxide Capture from Industrial Sources and the Use and Sequestration of Captured Carbon Dioxide in Enhanced Oil Recovery

Submitted by the

Michigan Agency for Energy
in cooperation with the
Michigan Public Service Commission
In compliance with Public Act 268 of 2016

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LICENSING AND REGULATORY AFFAIRS
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Table of Contents

Figures

Tables

Executive Summary

The market response in Michigan for carbon dioxide enhanced oil recovery (CO_2-EOR) development has been limited despite enactment by the state of several financial and policy incentives and many existing federal financial incentives. The Michigan Agency for Energy (MAE) and the Michigan Public Service Commission (MPSC) reviewed policy recommendations offered by the industry to encourage CO_2-EOR investment, job growth, and low carbon energy production in Michigan.

CO_2-EOR can offer a range of energy, environmental, and economic benefits, which may include enhanced yields from existing oil infrastructure and sites; the capture and sequestration of emissions; and additional investment, tax collection, and job creation. The costs associated with a CO_2-EOR project are site and situation-specific, and are known to vary widely based on location, the geologic characteristics of the CO_2-EOR target, the state of development of the target field, and the amount of CO_2 required. Recent literature indicates the break-even price for new CO_2-EOR projects with access to low-cost CO_2 supplies is about $70 per barrel of oil. The current and projected long-term price range for a barrel of oil is $50 - $60.

This economic gap is the primary factor limiting the expansion of CO_2-EOR deployment. Thus, if the goal is to ensure expansion of CO_2-EOR deployment, proposed governmental policies will have to address this gap.

The industry has proposed a broad range of changes and additions to federal financial policies, including the following:

- strengthening the Internal Revenue Code Section 45Q production tax credit,
- enhancing the Internal Revenue Code Section 48A and 48B investment tax credits,
- establishing contracts for difference for CO_2 sold to EOR operations,
- making carbon capture eligible for master limited partnerships, and
- making carbon capture eligible for tax-exempt private activity bonds.

The industry has also proposed many state regulatory policies, which fall into in three broad categories, to allow states to provide potential support for CO_2-EOR deployment:

1) Changes in state taxes that provide incentives for the capture of CO_2 from power plants and industrial sources, and/or for the use of captured CO_2 to produce oil through EOR (note: in Michigan, even the most dramatic reduction in state taxes for CO_2-EOR operations does little to overcome the $10 – $20 price gap);
2) State portfolio requirements and mandatory power purchases for facilities that capture carbon; and
3) State regulatory and other policies and strategies to facilitate CO_2 storage, project development, and pipeline transport.

The northern Niagaran Pinnacle Reef trend, a narrow band diagonally crossing the northern portion of the Lower Peninsula, has the only active CO_2-EOR operations in Michigan. This reef trend is of most interest for further CO_2-EOR deployment as it holds over half of the CO_2-EOR potential for Michigan. Also, its relatively recent development suggests the infrastructure should

be in far better condition than older fields elsewhere in Michigan, which significantly reduces capital cost requirements for new CO_2-EOR deployment. Studies by Western Michigan University,[i] the Clinton Climate Initiative,[ii] and Schlumberger Data & Consulting Services[iii] suggest this reef trend, if fully developed, could recover over 125 million barrels of additional oil, resulting in significant new capital investment, job creation, and additional state revenues from royalties and severance taxes.

Following law changes that allow CO_2 pipeline permitting to come before the Michigan Public Service Commission (MPSC) in 2014, the MPSC has not received a permit request for CO_2 pipelines to date. Only one company remains active in the CO_2-EOR sector in Michigan, with one small-scale CO_2-EOR project initiated since 2014. This company uses captured CO_2 from a local natural gas processing plant for nine small-scale CO_2-EOR projects in Otsego County, Michigan. In total, the company produces about 500 barrels of oil per day from these CO_2-EOR wells, or about 3% of total daily oil production in Michigan. Sustained low oil prices and limited CO_2 supplies appear responsible for this minimal CO_2-EOR growth.

Another critical barrier to reaching higher levels of CO_2-EOR production in nearly all U.S. basins is the insufficient supplies of affordable CO_2. This is especially true in Michigan. Additional significant CO_2-EOR development of the northern Niagaran Pinnacle Reef trend is limited by the amount of CO_2 available in the area. Significantly larger volumes of CO_2 would be required to further develop the northern reef trend. One potential way to address these additional CO_2 needs would be through capture at power plants. As the capital costs for these carbon capture facilities is significant, favorable economics for their construction is unlikely through state action alone, and would likely require changes and additions to federal financial policies in the first instance.

There are significant structural and economic barriers to carbon dioxide capture, use, and sequestration from industrial sources for enhanced oil recovery in Michigan. The Legislature previously enacted meaningful financial and regulatory policies to address these barriers and incentivize CO_2-EOR deployment, job growth, and utilization of available oil resources in the state. Recent studies indicate that additional state policy incentives are unlikely to overcome persistent low oil prices and severely limited supplies of low cost CO_2, making further CO_2-EOR deployment uneconomical in Michigan at this time. As the CO_2-EOR sector recognizes there is a need for federal financial incentives to address current barriers facing the industry, and state tools are considerably more limited to address this gap, further changes to state policy alone are unlikely to significantly advance CO_2-EOR deployment.

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[i] Barnes, David et al., Energy Procedia, (2013), "CO_2/EOR and Geological Carbon Storage Resource Potential in the Niagaran Pinnacle Reef Trend, Lower Michigan, USA"
[ii] Clinton Climate Initiative, (February 26, 2012), CO_2-EOR Potential in the MGA Region, in collaboration with Midwest Governors Association and Great Plains Institute
[iii] Toelle, Brian et al., Society of Petroleum Engineers, (2008), "EOR Potential of the Michigan Silurian Reefs Using CO_2"

Introduction

The Michigan Legislature included in Sec. 301 of Article XIII of PA 268 of 2016 the following directive to the Michigan Agency for Energy and the Michigan Public Service Commission:

> *(1) From the funds appropriated in part 1, the Michigan agency for energy and the Michigan public service commission shall explore policies relating to carbon dioxide capture from industrial sources and the use and sequestration of captured carbon dioxide in enhanced oil recovery that improve our regulatory structure to create an environment that fosters job growth and the utilization of all available energy sources, including, but not limited to, natural gas, petroleum, and crude oil.*
>
> *(2) By April 1, the Michigan agency for energy shall report to the subcommittees, fiscal agencies, and house and senate standing committees covering energy issues its findings from the exploration under subsection (1).*

Report Development

This report was developed through an extensive literature review and interviews with individuals from various state programs and industries associated with carbon dioxide capture and use in enhanced oil recovery. Additionally, interested parties reviewed the draft report and many of the comments and suggestions were then incorporated.

This report consists of five sections. The Introduction provides the purpose and development process for the report. The Background provides the legislative context for the report. The Carbon Dioxide Enhanced Oil Recovery section reviews the technology, benefits, costs, and challenges for carbon dioxide enhanced oil recovery (CO_2-EOR) growth, especially in Michigan. The Carbon Dioxide Enhanced Oil Recovery Policies section identifies a range of CO_2-EOR policy options that are currently being promoted from within the industry sector. The final section discusses key findings and considerations for policy makers.

Background

In the November 28, 2012 **Special Message to the Legislature from Governor Rick Snyder: Ensuring our Future: Energy and the Environment**, the Governor stated, *"I am asking the Legislature to enact a law that will grant carbon dioxide pipelines the same legal standing as other pipelines in Michigan to make sure our state laws are ready for this new industry."* The Governor's request was in reference to Michigan's first successful application of using carbon dioxide (CO_2) captured from an industrial process and piping the CO_2 to old oil wells to make them productive again. This process of injecting CO_2 into an oil field to increase the amount of crude oil that can be extracted is referred to as carbon dioxide enhanced oil recovery (CO_2-EOR).

In 2014, the Legislature enacted a series of laws to remove key barriers to the deployment of CO_2-EOR.

1. Changes to assure CO_2 pipelines have the same legal standing as other pipelines in Michigan:
   - PA 83 of 2014 revised the definition of "pipeline" to include a pipeline used to transport CO_2 substances.
   - PA 84 of 2014 granted the right to authorized entities to acquire rights-of-way for transport, installation, and maintenance of CO_2 pipelines by eminent domain for CO_2 substances.
   - PA 85 of 2014 amended the title and various provisions of Public Act 16 of 1929, previously applied to crude or petroleum, so that they also apply to CO_2 substances.

2. Changes to tax laws to assure CO_2-EOR operations were categorized with higher-investment production instead of standard production.

   - PA 82 of 2014 reduced the severance tax on oil and gas production achieved through carbon dioxide enhanced recovery projects. The severance tax was capped at 4.0 percent from the existing 6.6 percent tax for oil and 5.0 percent tax for natural gas.

This report summarizes both agencies' efforts to explore and identify a range of policy options relating to carbon dioxide capture from industrial sources and the use and sequestration of captured carbon dioxide in enhanced oil recovery. The key findings and considerations discussed are intended to assist policy makers in addressing industry-wide and state-specific barriers to economic growth in an environment that fosters job growth and utilization of all available energy sources.

Carbon Dioxide Enhanced Oil Recovery

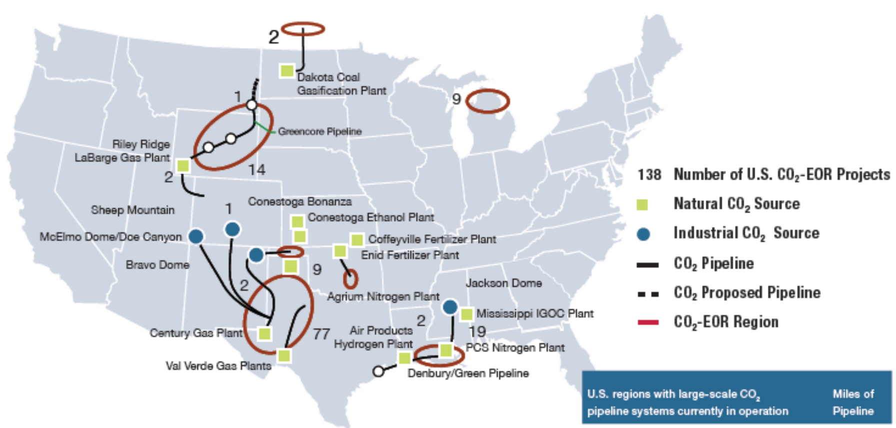
Technology Status

The capture of carbon dioxide (CO_2) from industrial sources has long been practiced as an essential requirement for various industrial operations like natural gas processing, or to make particular products such as carbonated beverages. Carbon capture and storage (CCS) is the process of capturing and preventing the release of manmade CO_2 into the atmosphere by ensuring its permanent storage in an oil and gas field, deep saline aquifer, or other geologic formation. Carbon capture, utilization, and storage (CCUS) reflects the commercial use of CO_2 prior to permanent geologic storage, while use of the captured CO_2 to recover additional crude from mature oil fields is referred to as carbon dioxide enhanced oil recovery (CO_2-EOR).

The use and storage of captured CO_2 (from industrial sources) in enhanced oil recovery (EOR) has been practiced for decades. In fact, there is nearly a half century of commercial-scale CO_2-EOR technology deployment with CO_2 successfully sourced from several industry operations, including natural gas processing, fertilizer production, hydrogen production, steam methane reforming, ethanol production, and gasification of various feedstocks.[1]

Once captured, CO_2 must be transported from its source to an EOR injection site. Pipelines like those used for natural gas are recognized as the best option for terrestrial CO_2 transport and are a commercially-proven approach.[2] The United States has approximately 4,600 miles of CO_2 pipelines used to transport CO_2 for EOR.[3] This pipeline infrastructure currently spans twelve states and five geographic regions (see Figure 1) ranging from Michigan's limited 14 mile CO_2 pipeline to a 2,470 mile integrated pipeline network in the Permian Basin.[4] Nationally, this CO_2 pipeline system as a whole supplies over 70 million tons of CO_2 per year for EOR, while Michigan's 14 mile CO_2 pipeline transports about 150,000 tons CO_2 per year.[5]

Figure 1: CO_2-EOR Operations in the U.S.



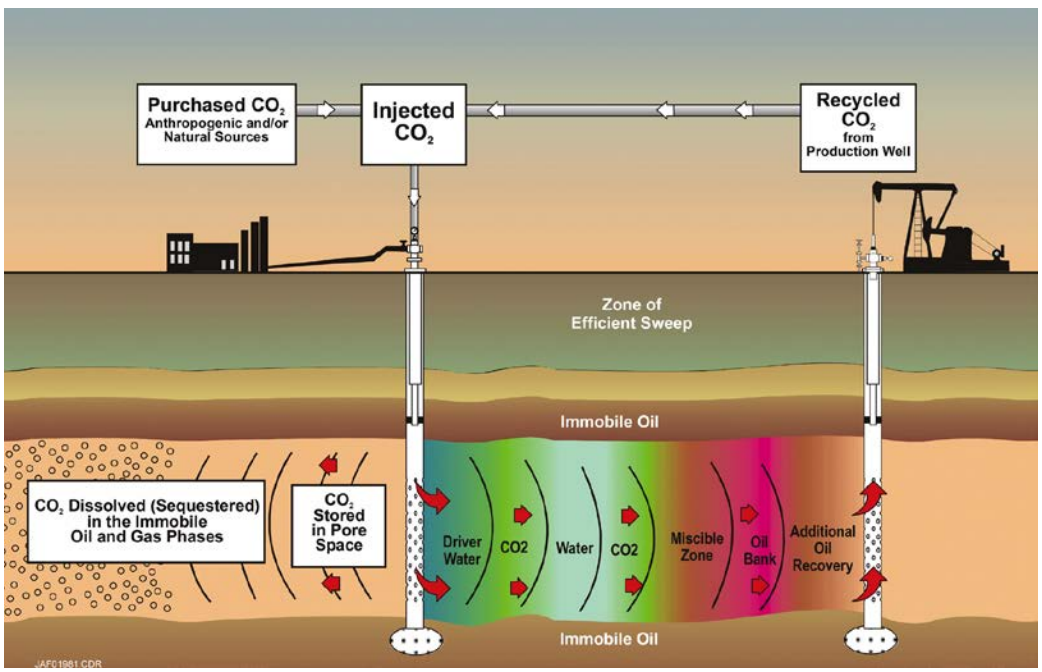
U.S. regions with large-scale CO_2 pipeline systems currently in operation	Miles of Pipeline
Permian Basin *(W. TX, NM, and S. CO)*	2,320
Rocky Mountains *(N.CO, WY and MT)*	810
Gulf Coast *(MS, LA, and ETX)*	740
Mid-Continent *(OK and KS)*	480
Other *(ND, MI, Canada)*	215

Source: Quadrennial Energy Review: Energy Transmission, Storage, and Distribution Infrastructure, April 2015.

Typically, only about 10 - 20 percent of a reservoir's original oil-in-place can be recovered without enhanced oil recovery (EOR) techniques due to declining underground pressure to drive oil to the surface (i.e. primary phase). Water injection and natural gas reinjection are usually the initial EOR techniques applied to an existing well, resulting in the recovery of an additional 20 – 40 percent of the original oil in place (i.e. secondary phase). An additional 5 – 20 percent can typically be recovered by subsequently applying thermal injection, CO_2 injection, or chemical injection EOR techniques (i.e. tertiary phase). CO_2-EOR accounts for nearly 60 percent of the tertiary phased EOR in the U.S.[6]

When injected into an existing oilfield, CO_2 lowers the viscosity of the remaining oil, reduces interfacial tension, and swells the oil, thereby allowing oil affixed to the rock and trapped in pore spaces to flow more freely and be produced through traditional means.[7] A majority of injected CO_2 remains in the reservoir and any CO_2 returning to the surface with the produced oil is then separated, compressed, and reinjected. This process results in only minor emissions from what effectively constitutes a closed-loop system.[8] Figure 2 provides a general depiction of the tertiary phased CO_2 injection process.

Figure 2: Carbon Dioxide Enhanced Oil Recovery (CO_2-EOR)



Source: Advanced Resources International and Melzer Consulting, Optimization of CO_2 Storage in CO_2 Enhanced Oil Recovery Projects, prepared for UK Department of Energy & Climate Change, November 2010.

Since the first commercially successful CO_2-EOR project in 1972, approximately 140 additional projects have been developed across the U.S., with operations present in ten states.[9] The generalized location of many of these operations are depicted in Figure 1 (pg. 6). Today, these CO_2-EOR operations produce roughly 400,000 barrels per day or about four percent of total domestic oil production.[10] In Michigan, however, there remains just one CO_2 pipeline and one company active in CO_2-EOR. Since 2003, this company has used the eleven mile White Frost pipeline to deliver captured CO_2 from the Turtle Lake Gas Processing plant to nine small-scale CO_2-EOR projects in Otsego County, Michigan.[11-13] In total, the company produces about 500 barrels of oil per day from these Michigan CO_2-EOR wells, or about 0.01% of the daily U.S. CO_2-EOR production.[14] As the total daily oil production in Michigan for 2016 was about 15,500 barrels per day, CO_2-EOR represents about 3% of Michigan's daily oil production.[15]

CO_2-EOR Benefits:

CO_2-EOR can offer a range of energy, environmental, and economic benefits:

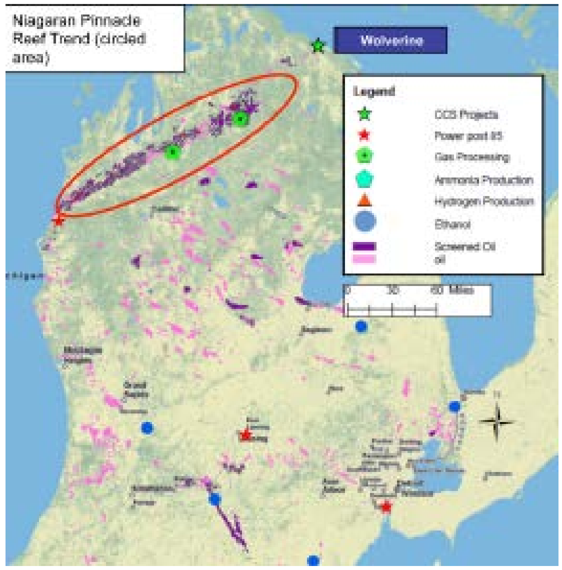
- Increases a formation's yield by up to 20 percent,
- Permanently sequesters certain emissions,
- Leads to additional investment and tax collections, and
- Creates jobs across multiple sectors.

CO_2-EOR projects offer longevity and a more complete utilization of existing assets. While CO_2 is typically injected for one to two years before a formation will yield additional oil, the resulting production may continue for up to 30 years and further increase the formation's yield by roughly 10-20 percent of the original oil in place.[16-17]

A recent study by the International Energy Agency finds that a barrel of oil produced through EOR using anthropogenic CO_2 emits 37 percent less net CO_2 (including emissions from combustion of the oil itself) than a barrel of oil produced without CO_2-EOR.[18] Current federal EPA regulations recognize CO_2-EOR as a valid and proven pathway to secure geologic storage of CO_2 emissions and the amount of CO_2 permanently sequestered can be significant.[19] As a rough rule of thumb, every 2.5 barrels of oil produced in a conventional oil field using CO_2-EOR can safely and permanently store an average of one metric ton of CO_2 underground.[20-21] In general, oil and gas reservoirs are thought to be suitable candidates for the geologic storage of CO_2 given that they have held oil and gas resources in place for millions of years.[22] Research by the University of Texas, Bureau of Economic Geology found no evidence of leakage from oil fields where CO_2-EOR has been performed since the 1970s.[23]

An economic analysis completed in 2012 determined CO_2-EOR would potentially recover over 250 million barrels of additional oil in Michigan and sequester 80 – 130 million metric tons of CO_2.[24] The area of significant interest in Michigan is the northern Niagaran Pinnacle Reef trend that diagonally crosses most of the northern portion of the Lower Peninsula (see Figure 3, Pg. 9). This reef trend holds over half of the CO_2-EOR potential for Michigan, and its relatively recent discovery and exploitation suggest the infrastructure should be in far better condition than older fields elsewhere in Michigan, thereby reducing capital cost requirements.[25]

Figure 3: Michigan northern Niagaran Pinnacle Reef trend and major CO_2 sources



Source: Clinton Climate Initiative, *CO_2-EOR Potential in the MGA Region* (Midwest Governors Association, February 26, 2012)

This same analysis suggested CO_2-EOR in Michigan could result in significant direct job creation and increased state revenues from royalties and severance taxes. In order to achieve these outcomes, CO_2-EOR will require installing carbon capture facilities, building CO_2 pipelines, and reworking mature oil fields to revitalize their production. Immediate direct benefits include investment in key energy and industrial sectors and job creation that extends across a range of sectors, including oil and gas production, pipelines and other energy infrastructure, manufacturing, construction, engineering, and other services.[26]

CO_2-EOR Costs:

Recent literature indicates the break-even price for new CO_2-EOR projects with access to low cost CO_2 supplies is about $70 per barrel.[27] However, the costs associated with a CO_2-EOR project are site and situation-specific, and are known to vary widely based on location, the geologic characteristics of the CO_2-EOR target, the state of development of the target field, and the amount of CO_2 required.[28] These CO_2-EOR costs are often grouped into capital costs, ongoing operation and maintenance costs and CO_2 purchase and transport costs. Unfortunately, specific CO_2-EOR cost data appears limited.

In general, large capital investments are required to prepare a field for a CO_2-EOR.[29-30] Upfront expenditures include mechanical integrity reviews of well bores and surface production facilities, pressure testing casing, and replacing old tubing. At minimum, wells and surface equipment need to be upgraded to handle CO_2. Larger capital investments may involve drilling new wells either to optimize flood design or to replace wells in poor condition. New wellheads, injection equipment, and changes to central production facilities where oil is separated from water (and CO_2) may all be necessary. In particular, all new CO_2 floods will require significant investment in CO_2 recycling equipment so that CO_2 produced with oil can be separated, recompressed and dehydrated to prepare it for reinjection into the reservoir. Lastly, a CO_2 distribution system is required.

Capital costs for CO_2-EOR conversion of existing wells in Ohio are estimated to average $800,000 - $940,000 for the typical 40-acre 5-spot well pattern.[31] Other studies analyzing the costs associated with CO_2-EOR of various U.S. basins found required capital costs ranged from $5.85 to $34.61 per barrel of recovered oil, with costs increasing significantly with the number of new wells required to be drilled.[32] This data suggests the CO_2-EOR capital investment to fully develop the northern Niagaran Pinnacle Reef trend totals $731 million or more.

CO_2-EOR operation and maintenance (O&M) costs include normal oil field O&M costs along with additional costs due to more frequent remedial well work, greater liquid lifting volumes, and CO_2 pipeline maintenance. The O&M costs of CO_2 recycling consist mostly of the energy required to recompress, dehydrate, and pump the recycled CO_2, with annual costs increasing over time as the volume of recycled CO_2 increases.[33] The previously mentioned studies found total O&M costs for CO_2-EOR ranged from $2.80 to $10.72 per barrel of recovered oil.

The cost of capturing CO_2 from different industrial processes varies considerably. This variation results from the relative ease of capturing CO_2 from certain industrial processes and the level of development for capture technologies. Carbon capture is easier when CO_2 is produced in high purity and high concentration streams as the byproduct of certain industrial processes, such as natural gas processing, hydrogen production, and synthetic fuel production.[34] In contrast, it is relatively more difficult to capture CO_2 from industrial flue gas emissions, as would be required from cement production, iron and steel manufacturing, and refining. As given in Table 1, the U.S. Energy Information Administration estimated industrial carbon capture and CO_2 transportation costs for applicable industrial processes.[35]

Table 1: Cost of CO_2 Capture and Transportation for Various Industrial Sources

Industrial CO_2 Source	**Cost of CO_2 Capture and Transp. ($/Metric ton)**	**Approximate Cost per Barrel of Oil Recovered***
Coal and biomass-to-liquids	36.10	14.44
Natural gas processing	36.29	14.52
Hydrogen plants	36.67 to 46.12	14.66 to 18.45
Refineries (Hydrogen)	36.67 to 46.12	14.66 to 18.45
Ammonia plants	39.69	15.88
Ethanol plants	42.15	16.86
Cement plants	81.08	32.43

* As a general rule of thumb, one metric ton of CO_2 injected will conservatively yield an incremental 2.5 barrels of oil.[36]

In reference to the above $81 per metric ton CO_2 capture and transportation cost for cement plants, the following should be noted:

- The current CO_2 capture and transportation cost for new build power plants incorporating state-of-the-art CCS technologies is \$70 - \$80 per metric ton for the Midwest.[37] The cost to retrofit existing plants is likely even greater.[38]

- A recent study evaluating the CO_2-EOR potential in Michigan found CO_2 priced at \$80 per metric ton was cost prohibitive in nearly all cases indicating CO_2 separated from flue gases is effectively cost prohibitive for EOR in the near term if oilfield operators were expected to pay the full cost of CO_2 capture from these facilities.[39] Also, a recent economic analysis of CO_2-EOR in Ohio found negative outcomes and low returns are possible at \$80 per metric ton CO_2 and oil priced at \$70 per barrel.[40]

By combining the above per barrel capital costs, ongoing O&M costs, and CO_2 purchase/transport costs (while ignoring the cement plant CO_2 cost) a ballpark range for CO_2-EOR of \$23.09 - \$63.78 per barrel of recovered oil is obtained. As data sources are limited, the cost range should be considered with much caution. Nonetheless, the upper limit is reasonably consistent with the previously mentioned \$70 per barrel breakeven price for new CO_2-EOR projects with access to low cost CO_2 supplies.

Barriers to CO_2-EOR Deployment

There are many barriers that hinder CO_2-EOR deployment and discovering which are most prevalent in Michigan can help direct policy. A recent review of the history of CO_2-EOR shows it is generally successful in fields that meet the criteria for achieving miscibility of the injected CO_2 with the oil, that have a relatively large volume of remaining unrecovered oil, and where there is a source of sustainable volumes of pure CO_2 supplies at affordable costs. Other factors that contribute to success are operator knowledge of, comfort with, and willingness to pursue, CO_2-EOR technologies; the willingness and ability of the regulatory regime to permit CO_2-EOR projects; and, often, the availability of government financial incentives to promote CO_2-EOR.[41] In contrast, where these conditions have not existed, there is a lower likelihood of successful implementation of CO_2-EOR projects.[42]

CO_2-EOR project development is also often highly dependent on the availability of investment capital, field services like drilling and work-over rigs, and materials and construction workers for development of CO_2 processing, recycling, compression, and distribution facilities.[43] Another significant technical challenge is the non-constant demand for CO_2 by an individual CO_2-EOR project. The injection profile requires much more CO_2 to be used initially than in the later stages of recovery as the reservoir becomes saturated and the CO_2 produced with the oil is recycled back into the reservoir.[44] This inherent inconsistency in the CO_2 supply required for a CO_2-EOR project often creates a dilemma in matching any one individual CO_2-EOR project with one individual source of CO_2 emissions because these sources typically generate CO_2 at a relatively constant rate.

Industrial emitters desire take-away contracts for CO_2 that guarantee continuous take away without interruption. CO_2 off-take agreements with CO_2 sources can be difficult to execute due the requirement that large volumes of CO_2 be taken on a continuous basis. The net impact is that the business case for an individual CO_2-EOR project matched with a single industrial CO_2 source may be limited.[45] A further complication is that pipeline construction for large CO_2 transport relies on contracts for firm transportation and does not now function under an "open access" or "common carrier" model. The recognized approach to overcome this dilemma is its own difficult challenge involving multiple owners capturing CO_2 from a cluster of sources matched to a cluster of CO_2-EOR prospects to provide the necessary economies of scale for successful deployment.[46]

A primary barrier to reaching higher levels of CO_2-EOR production in nearly all U.S. states is the insufficient supplies of affordable CO_2.[47-48] In aggregate, CO_2 from high purity industrial emission sources within 50 kilometers of the oil basins can meet only 4% of the CO_2 requirements for CO_2-EOR; and all CO_2 emissions from industrial sources within 100 kilometers of the oil basins can meet only 16% of the CO2 requirements for CO_2-EOR.[49] In general, substantial growth in oil production from the application of CO_2-EOR requires significantly expanded access to sources of CO_2.[50]

This same barrier exists in Michigan where further significant CO_2-EOR development is limited by the amount of CO_2 available in the northern Niagaran Pinnacle Reef trend area. The region has limited industrial development and there are limited sources of industrial CO_2 emissions. Local gas processing plants can supply only about one million metric tons of CO_2 per year in aggregate, but capacity is spread unevenly across a number of plants scattered across the northern reef trend.[51] Significantly larger volumes of CO_2 would be required to further develop the northern reef trend, and these additional CO_2 needs would have to be supported through higher cost capture at power plants.[52] It should be noted that incentives common to traditional CO_2-EOR markets, such as severance tax credits, may not be effective in catalyzing the industry in Michigan without first addressing the CO_2 supply challenge.

As noted above, CO_2 separated from flue gases is effectively cost prohibitive for EOR in nearly all cases. This cost barrier is resulting in a fundamental change in the CO_2-EOR project paradigm; that is, CO_2-EOR needs carbon capture and storage (CSS) mandates in order to ensure adequate CO_2 supplies to facilitate growth in the number of new and expanded CO_2-EOR projects.[53] This requires programs that create economic incentives for reducing emissions through emissions trading programs, carbon taxes, or other mechanisms. Furthermore, this dependent linkage leads to regulatory and liability issues and uncertainties associated with CCS that are also hindering wide-scale CO_2-EOR deployment.[54-55]

At the most fundamental level, a CO_2-EOR project must suggest favorable internal rates of returns (IRR) prior to a company moving forward with implementation. The economics associated with a CO_2-EOR project are site and situation-specific, are highly dependent on the operator's projections of oil production response to CO_2 injection, and the capital investment required in wells and surface equipment to upgrade or replace lease assets already in the field.[56] It is important to note that estimating the actual performance of CO_2-EOR operations is a complex and data intensive effort that can often take months or years to perform on a single candidate field. Moreover, it requires substantial amounts of detailed field and project-specific data, most of which is generally only available to the owner and/or operator of a field.[57] It should be noted that once an oil field has been abandoned, it is generally not economical to reopen it for CO_2-EOR.[58] As mentioned previously, this is a recognized barrier for many older fields in Michigan.[59]

Implementing a CO_2-EOR project is a capital-intensive undertaking. This alone often represents a constraint, especially for smaller producers.[60] When coupled with higher operating costs, CO_2-EOR projects are relatively slow in providing financial returns on those investments. A general rule-of-thumb is that it may take between 18 to 24 months from initial injection of CO_2 until production starts, with peak production often not occurring until year ten.[61] As a result, IRR for CO_2-EOR projects may not be as robust as other oil and gas exploration and development investments. Therefore, companies needing relatively quick payback and high rates of return may not find CO_2-EOR investments attractive without incentives.[62]

One noteworthy capital cost for CO_2-EOR projects in Michigan, given the limited amount of CO_2 available in the northern Niagaran Pinnacle Reef trend area, is the construction cost for CO_2 pipelines. A recent study evaluating the economics of CO_2-EOR in Michigan estimated this cost alone at $75,000 per inch-mile.[63] As an example, the construction cost to build a one inch CO_2 pipeline, between the ethanol plant in Caro to Grayling (about 125 miles) is estimated at $9,350,000. The same study indicates the transportation cost to deliver one million metric tons of CO_2 using this pipeline would alone be more than $11.5 million per year. These costs are based on cost estimates detailed in Table 2 below.

*Table 2: Estimated Michigan CO_2 Pipeline Costs**

Pipeline Transportation Costs ($/MT CO_2 delivered)					
Project Life	20-years		**IRR :**	15%	
Construction Costs * ($/inch – mile)	$75,000	Volume (MMT CO2/year)			
		1	*2*	*5*	*10*
Distance (mi)	*50*	$4.60	$2.90	$1.80	$1.20
	100	$11.50	$6.90	$4.20	$2.80

*Construction costs include materials, labor, right-of-ways costs, and miscellaneous (including overhead)

Source: Clinton Climate Initiative, *CO_2-EOR Potential in the MGA Region* (Midwest Governors Association, February 26, 2012)

By far, the largest impact on the economic viability of a CO_2-EOR project is the price of oil.[64] In general, it is believed potential CO_2-EOR projects begin to have unfavorable rates of return as oil prices drop below $70 per barrel.[65] As current oil prices have remained in the $50 - $60 dollar per barrel range since January 2015, and with prices expected to remain below $60 for the next two years,[66, iv] it is likely few CO_2-EOR projects will be implemented in the foreseeable future, especially given the additional barriers faced in Michigan.

[iv] NYMEX futures strip, the Lender Survey Stress Case, the Congressional Budget Office show 2020 WTI prices per barrel of $56, $41, and $56 respectively[69]

Existing federal incentives include matching grants, loan guarantees, investment tax credits and production tax credits. To date, approximately $12 billion in federal financial assistance has been made available through these existing incentives. For example, the Clean Coal Power Initiative (CCPI) has made available $2 billion in matching grants for demonstrating cleaner coal technologies at the commercial scale, including CCS.[67] Grants are awarded competitively and require private funding match of least 50% of total project costs, with demonstrations required to meet technical requirements set forth in the Energy Policy Act of 2005.[68]

A second federal incentive established under Section 1703 of Title XVII of the Energy Policy Act of 2005 authorizes the U.S. Department of Energy to provide loan guarantees to accelerate the deployment of innovative clean energy technologies that are typically unable to obtain conventional private financing due to high risks.[70] Under the Title XVII innovative clean energy projects loan program, the federal government can guarantee 80 percent of a project's total cost. Projects must employ a new or significantly improved technology that is not a commercial technology; and eligible technologies must avoid, reduce, or sequester air pollutants or anthropogenic emissions (i.e. caused or produced by humans) of greenhouse gases. In December 2013, DOE issued the Advanced Fossil Energy Projects Solicitation, which made up to $8 billion in loan guarantees available to support innovative, advanced fossil energy projects including carbon capture technologies to selectively remove CO_2 from process streams and flue gases, and produce a concentrated stream that can be compressed and transported to a permanent storage site.[71]

The CO_2-EOR sector has found numerous shortcomings of existing federal financial incentives, with the net effect of failing to provide adequate financial value for private investors and being too cumbersome for project developers to utilize effectively.[72] Furthermore, in the case of federal tax credits and grants, most of the available incentives and funds have been used and, given the timeframe and cost to develop CO_2-EOR and CCS projects, these programs have already effectively expired and are unlikely to incent additional projects.[73] In fact, the first and only CCS project to receive a loan under the Federal Loan Guarantee program was issued in December 2016.[74]

Barriers to CO_2-EOR industry growth, especially in Michigan, appear broader than the economic challenges of low oil prices, high CO_2 costs, and inadequate CO_2 delivery and storage infrastructure. This section identified additional needs such as better data on investment costs; field data on producers' level of interest, comfort, and knowledge in using CO_2 injections for EOR and sequestration; best practices and technology demonstrations; better CO_2 procurement arrangements and more. Policy options for addressing barriers are discussed in subsequent sections.

Carbon Dioxide Enhanced Oil Recovery Policies

According to an analysis by Advanced Resources International, the U.S. has the potential to produce an estimated 28 billion barrels of economically recoverable oil from conventional oil fields with today's CO_2-EOR industry best practices, while next generation techniques have the potential to yield an estimated 81 billion barrels of economically recoverable oil.[75] The same analysis estimates 11 to 24 billion metric tons of CO_2 is required to achieve this EOR.

In recognition of the enormous energy, economic, and carbon emissions management potentials, a broad range of regional, national, and international efforts have formed to study barriers and develop policies to encourage financial investment in, and accelerate commercial deployment of, CO_2-EOR technologies. A brief listing of these organizations and collaborative efforts include:

Center for Climate and Energy Solutions (C2ES**)**[v]
Great Plains Institute (GPI)[vi]
International Energy Agency (IEA)[vii]
Midwestern Governors Association (MGA)[viii]
Midwest Regional Carbon Sequestration Partnership
National Enhanced Oil Recovery Initiative
Plains CO_2 Reduction Partnership
National Association of Regulatory Utility Commissioners (NARUC)[ix]
National Enhanced Oil Recovery Initiative
Southeast Regional Carbon Sequestration Partnership (SECARB)
U.S. DOE Office of Fossil Energy (OFE)[x]

In recent years, some state officials have endorsed the need for federal action to provide incentives to accelerate commercial deployment of carbon capture, utilization, and storage. In 2015, the Western Governors Association and the Southern States Energy Board adopted resolutions in support of CO_2-EOR, and in early 2016 the National Association of Regulatory Utility Commissioners (NARUC) adopted a similar resolution. It's worth noting that the Midwestern Governors Association previously issued federal policy recommendations under the association's Carbon Capture and Storage Policy Principles Statement.

Collectively these organizations propose a comprehensive range of policy reforms intended to:

- Overcome the high financial barrier inhibiting further meaningful deployment of CO_2-EOR projects (with access to low cost CO_2 supplies) in an era of extended low oil prices.
- Scale the economic wall preventing the market place from investing in flue gas carbon capture technologies critical to achieving the enormous CO_2 supplies required for further significant CO_2-EOR deployment absent strong CCS policy drivers.

[v] CCUS Initiative
[vi] State CO_2-EOR Deployment Work Group
[vii] CO_2-EOR Program
[viii] CCS Task Force
[ix] Subcommittee on Clean Coal and Carbon Management
[x] CCS Research Program

- Achieve policy parity between zero and low carbon energy technologies through state regulatory reforms intended to reduce regulatory uncertainties that have inhibited financial investment in economically favorable CO_2-EOR projects.

Federal Policy Incentives

Existing federal incentives include matching grants, loan guarantees, investment tax credits, and production tax credits. The CO_2-EOR sector has found numerous shortcomings with these existing incentives (outlined previously), and has proposed significant changes and additional incentives, including:

- strengthening the Internal Revenue Code Section 45Q production tax credit,
- establishing contracts for difference for CO_2 sold to EOR operations,
- enhancing the Internal Revenue Code Section 48A and 48B investment tax credits,
- making carbon capture eligible for master limited partnerships, and
- making carbon capture eligible for tax-exempt private activity bonds.

Legislation has been introduced in Congress to make these changes.

The first two listed federal incentives directly apply to CO_2-EOR projects, while the remaining three federal incentives are primarily directed to advancing deployment of CCS technologies at power plants and industrial facilities with significant flue gas emissions. While these facilities may or may not involve CO_2-EOR operations, they all have the potential to provide significant quantities of CO_2 needed to expand the CO_2- EOR sector.

Section 45Q Tax Credit for CO_2 Sequestration

The federal incentive most directly benefiting CO_2-EOR operations is the production tax credit codified in Section 45Q of the Internal Revenue Code by the Energy Improvement and Extension Act of 2008 (as amended).[76] The tax credit is a performance-based incentive for carbon disposal in secure geological storage through EOR and non-EOR applications of $10 and $20 per ton of CO_2, respectively. Total credits are limited to 75,000,000 metric tons of CO_2, with the credits made available to the owner of the facility that produces a CO_2 stream that would otherwise be released into the atmosphere as industrial emission of greenhouse gases. To qualify, the facility must capture and sequester at least 500,000 metric tons of qualified CO_2 during the taxable year.

The Section 45Q production tax credit is the focus of intense industry efforts encouraging Congress to significantly enhance these credits, specifically:

- Extending and uncapping the program. This reform not only continues the tax credit, but also provides the needed financial certainty investors require to move projects forward.
- Increasing the tax credit up to $35 per ton CO_2 sequestered. This amount is highly significant relative to the generally accepted minimum price of $70 per barrel of oil for deploying new CO_2-EOR projects with access to low cost CO_2 supplies.
- Reducing the facility's annual minimum CO_2 capture amount from 500,000 to 100,000 tons per year. This reduction would enable most ethanol and fertilizer plants to participate in the program, likely leading meaningful new quantities of high purity CO_2 supplies readily available for CO_2-EOR; and

- Specify that the entity claiming the credit is the owner of the carbon capture equipment. This allows tax-exempt municipal utilities and electric cooperatives to use the credit, and provides developers flexibility to involve outside investors that can utilize the tax credits.

These reforms would clearly overcome current and anticipated $50 - $60 per barrel oil prices preventing the deployment of many CO_2-EOR projects (with low cost access to CO_2). To estimate the potential impacts of these reforms on deployment of carbon capture projects at existing power plants, rigorous financial modeling was conducted by Stanford University.[77] The capital cost for these projects is $250 - $350 per metric ton of annual CO_2 capture capacity, with the average value ($300) used in the modeling efforts.[78] Under existing conditions, it was determined the project would secure only about 15% of the required capital amount. However, the modeling demonstrated the above Section 45Q reforms would cover up to 67% of the financial gap needed to implement the carbon capture project.[79]

As previously discussed, significant future CO_2-EOR deployment is critically linked to commercially successful deployment of flue gas carbon capture projects required to deliver the massive amounts of CO_2 needed. The significant impacts of the above Section 45Q tax credit changes clearly illustrate why many of the above organizations consider these reforms the highest priority for enactment by Congress.[80]

Contracts for Difference

A significant new federal financial incentive being promoted is establishing federal price stabilization contracts (i.e. contracts for difference or CfDs) for CO_2 sold from capture facilities to EOR operations. Traditionally, CO_2 prices in contracts with enhanced oil recovery operations have been indexed to the price of oil. Historic volatility in oil prices, coupled with current and projected low market prices, creates market risk and earnings uncertainty for EOR and carbon capture projects, keeping potential lenders and investors on the sidelines. Contracts for difference would provide a single uniform oil price over the term of the contract, based on Congressional Budget Office or Energy Information Agency forecasts.[81] The financial modeling by Stanford University indicates these CfDs can cover up to 30% of the financial gap needed to cover the capital cost of installing carbon capture equipment at a typical existing power plant.

Section 48A and 48B Investment Tax Credits

The Energy Policy Act of 2005 codified Section 48A of the Internal Revenue Code (IRC) to provide investment tax credits for integrated gasification combined cycle (IGCC) projects and other advanced coal-based electricity generation technologies (ACBGT).[82] The Act codified a second clean coal investment tax credit under Section 48B of the IRC for qualified gasification projects. The tax credits are awarded on a competitive basis, and projects must meet specific technical and operating requirements and be completed within five years. The Energy Improvement and Extension Act of 2008 modified Sections 48A and 48B to require qualifying IGCC and ACBGT projects to include equipment that separates and sequesters at least 65% of the project's total CO_2 emissions, while gasification projects must separate and sequester 75% of total CO_2 emissions.[83] These modifications included $1.25 billion in investment tax credits for IGCC and ACBGT projects, and an additional $250 million for qualified gasification projects. Finally, the tax credit rate for all qualified clean coal investments was increased to 30%.

Enhancements to the Section 48A and 48B investment tax credits proposed by the sector include:

- Extending the program by appropriating additional funding.
- Replacing the competitive award process by using a defined eligibility requirement, and
- Reestablishing the credits as refundable investment tax credits (i.e. refundable for cash).

The tax credit rate would remain at 30% of eligible project costs. The financial modeling performed by Stanford University indicates these reforms would cover up to 33% of the financial gap needed to cover the capital cost of installing carbon capture equipment at typical existing power plants.

Master Limited Partnerships

A second significant new federal financial incentive being promoted is to extend eligibility for master limited partnerships (MLP) to carbon capture projects in order to help reduce the cost of equity. MLPs are tax efficient as they do not pay taxes themselves. At the same time, MLPs can list on a stock exchange and sell units to the public to raise private capital. Combined, this allows the MLP / project to raise larger amounts of money on more favorable terms from equity investors. This reform additionally helps build a long-term foundation for the industry as it does not involve a sunset or binding limit. The financial modeling performed by Stanford University indicates this MLP incentive would cover up to 15% of the financial gap needed to cover the capital cost of installing carbon capture equipment at typical existing power plants.[84]

Private Activity Bonds

A third significant new federal financial incentive being promoted is to make tax-exempt private activity bonds (PABs) available to power plants and industrial facilities that capture CO_2 emissions and store them through EOR or other geologic storage. Obtaining fixed rate long-term debt for these projects from commercial investors is extremely difficult as they suffer from construction and single asset project risk and are unlikely to be considered investment grade.[85] The federal government currently allocates to the states permission to issue approximately $33 billion of private activity bonds (PAB) annually, making the PAB tax-exempt bond market large, well-understood, and accepted by financial markets and investors. If carbon capture projects were allowed to participate in the PAB market, a long-term debt market for loans to these projects will be created, especially as this reform does not include a sunset or restrictive binding limit. The financial modeling performed by Stanford University indicates this PAB incentive would cover up to 10% of the financial gap needed to cover the capital cost of installing carbon capture equipment at typical existing power plants.[86]

Combined Impact of Federal Policy Incentives

As previously discussed, CO_2 priced at $80 per metric ton was cost prohibitive in nearly all cases indicating CO_2 separated from flue gasses is effectively cost prohibitive for EOR if oilfield operators were expected to pay for the full cost. The potential impact of the proposed federal incentives was illustrated by the rigorous financial modeling performed by Stanford University. When combined, the incentives exceeded the financial gap needed to cover the capital cost of installing carbon capture equipment at typical existing power plants - a critical requirement before significant, wide-spread CO_2-EOR deployment can be achieved. A similar analysis of the proposed federal incentives by the DOE using the National Energy Modeling System indicated an additional 200 million metric tons of CO_2 captured per year by 2040, with daily EOR production increasing by a factor of five over existing conditions.[87]

State Policy Incentives

The MGA, SECARB, C2ES, and others have previously evaluated state CCUS policies, and the GPI is currently undertaking additional efforts with recommendations expected in the near future.[xi] However, no studies were identified directly quantifying the economic or investment impacts of these incentives other than those associated with state taxes. Therefore, these policies are reviewed in brief. Collectively these organizations have proposed three broad policy categories to allow states to provide potential support for CO_2-EOR deployment:

1) Changes in state taxes that provide incentives for the capture of CO_2 from power plants and industrial sources, and/or for the use of captured CO_2 to produce oil through EOR;
    - Sales taxes on equipment purchased to build a carbon capture facility;
    - Property taxes on the carbon capture facility;
    - Sales taxes on equipment acquired to adapt an oilfield to CO_2-EOR operations; and
    - Oil and gas taxes, such as production and severance taxes.

2) State portfolio requirements and mandatory power purchases for facilities that capture carbon; and
    - Adoption of clean energy standards that include CCUS as an eligible technology or resource
    - Authorize long-term off-take agreements from a CCS facility

3) State regulatory and other policies and strategies to facilitate CO_2 storage, project development and pipeline transport.
    - CO_2 storage is declared to be in the public interest
    - Establish a CO_2 storage trust fund
    - Specified rules for CO_2 ownership
    - Establish requirements for CO_2 responsibilities
    - Establish rules regarding pore space
    - Establish rules for CO_2 pipelines and/or eminent domain
    - Clarified rules on CO_2 injection for EOR and geologic storage
    - State assumption of long-term liability for sequestered CO_2

State Financial Incentives

Currently promoted state financial incentives are directed to reducing or eliminating state taxes applied to carbon capture from power plants and industrial sources and the use of captured CO_2 to produce oil through EOR. These include severance taxes, property taxes, and sales taxes. To evaluate the potential impact associated with making these state financial reforms, the GPI study identified the highest rate applied by oil producing states for each of the four tax applications listed above. The study then determined the maximum possible reduction in the price for a barrel of oil by assuming the highest tax rates were being applied, then reducing the severance tax rate to 1.25% while eliminating the sales and property taxes. The analysis determined the maximum

[xi] To date, the State of Michigan participated in the MGA CCS Task Force.

cost reduction possible was $5 per barrel for the typical CO_2-EOR operation (i.e. one that does not also own the CO_2 capture operation).[88]

The impact in Michigan would be less as the state severance tax rate was previously reduced by PA 82 of 2014 and the remaining state tax rates are all lower than the maximum rates assumed in the study. Nonetheless, even assuming the $5 per barrel potential impact, new CO_2-EOR deployment (with access to low cost CO_2 supplies) is unlikely given the current and anticipated $50 - $60 per barrel price range and the generally accepted $70 per barrel threshold needed for economic feasibility. Again, this is in line with the MGA study conclusion that incentives to operators in Michigan CO_2-EOR markets, such as severance tax credits, may not be effective in catalyzing the industry.[89]

It is worth noting the potential impact of the combined federal financial incentives is eight times (8X) greater than the potential impact of the combined state financial incentives. In particular, the proposed Section 45Q tax credit reforms are nearly five times (5X) the potential impact of the combined state financial incentives.

Eligibility of CCUS in electricity generation portfolio standards or voluntary goals can facilitate utility cost recovery approval of projects critical for financing, and may even allow utilities to earn saleable compliance credits. Michigan had incorporated this policy reform under PA 295 of 2008, but CCS eligibility is removed effective April 20, 2017 under PA 342 of 2016. However, a cost recovery mechanism for CCS projects remains in effect. No evidence was identified indicating the adoption of this policy contributed to the very limited CO_2-EOR deployment that occurred in Michigan since 2009, or that removing the policy will inhibit future deployment. Ohio is known to have adopted this policy.

Authorization of long-term off-take agreements from a CCS facility guarantees a buyer will purchase the electricity or output from a given project, which helps secure financing due to a guaranteed revenue stream. This policy has been adopted by Illinois and Indiana.

State Regulatory Policy Reforms

The remaining promoted state regulatory reforms are directed to achieving greater policy parity between zero and low carbon energy technologies. The literature is consistent in referencing the benefit of these reforms as mitigating the regulatory uncertainties that have inhibited financial investment in CO_2-EOR.[90-92] However, no studies were identified directed to quantifying the magnitude of this impact, or even the analysis of real world examples. As clearly indicated by the GPI study, the current priority facing the industry is an urgent need to provide financial incentives to help CCUS projects bridge the current cost gap and secure private financing.

A number of bills were introduced in the Michigan Legislature in prior legislative sessions that addressed or partially addressed many of the regulatory policies listed below, in particular House Bill 4942 (2013), House Bill 4943 (2013), House Bill 5252 (2009), and Senate Bill 775 (2009). None were enacted by the Legislature.

Declaring CO_2 storage to be in the public interest can provide clarity in other state-level rule making including tools and authorities (e.g. eminent domain) that are otherwise available to public utilities, which can enable and facilitate project development. This policy has been adopted by Kentucky, Louisiana, North Dakota, Oklahoma, and West Virginia.

Establishing a CO_2 storage trust fund can pay for a state's project permitting activities to long-term site stewardship, including monitoring, remediation and enforcement. Kansas, Louisiana, Montana, North Dakota, Texas and Wyoming has established these trust funds.

Specifying rules for CO_2 ownership in law clarifies who is considered the legal owner of captured CO_2 and how parties can transfer ownership. This policy has been adopted by Illinois, Louisiana, Montana, North Dakota, Oklahoma, Texas, and Wyoming.

Establishing requirements for CO_2 responsibilities allows the state to designate specific pathways for projects to meet federal EPA Class VI Underground Injection Control rules. This policy has been adopted by Mississippi and Wyoming.

Establishing rules regarding pore space provide project developers options for acquiring pore space rights or leasing rights including compensation to the owners, eminent domain, and unitization/or aggregation of rights in an area (as is used in oil and gas projects). In some states, compensation has been provided to pore space owners to obtain the right to store CO_2. This policy has been adopted by Kentucky, Louisiana, Mississippi, Montana, North Dakota, Texas, and Wyoming.

Establishing rules for CO_2 pipelines and eminent domain were addressed in Michigan under PA 83 to 85 of 2014, as noted previously.

Clarifying rules on CO_2 injection for EOR and geologic storage allows the state to declare that CO_2-EOR projects do not have to meet the same federal EPA Class VI Underground Injection Control projects solely for geologic storage. This policy has been enacted by many states.

State assumption of long-term liability for sequestered CO_2 can reduce the long-term costs of CO_2 injection for private project developers. This policy is always linked to establishing a CO_2 storage trust fund due to ongoing costs and significant financial risks to the state. At a minimum, operators will generally be held liable during project development and operations. Many have assumed that states or the federal government will likely take liability for long-term CO_2 storage once the storage project reaches a determined point beyond the injection phase (e.g., closure, post-closure, completion, etc.). States may take on a limited role in liability, such as providing long-term monitoring and verification or other stewardship over the site while others may take full liability. This policy has been adopted by Illinois, Kansas, Louisiana, Montana, North Dakota, Texas, and Wyoming.

At both the federal and state levels, a range of financial and regulatory policies are promoted to address the many barriers faced by, and encourage growth and investment in, the CO_2-EOR industry. The prior section reviewed the barriers, and this section discussed corresponding policies and their impacts, if identified, noting limited data between regulatory uncertainties and financial investment in CO_2-EOR. Key findings and CO_2-EOR policy options for Michigan based on a review of this information are discussed in the next section.

Key Findings, Conclusions, and Options for Michigan

The market response in Michigan for CO_2-EOR development has been limited despite passage of several Michigan financial and policy incentives (i.e. P.A. 82 to 85 of 2014) in combination with pre-existing federal financial incentives. The Michigan Public Service Commission (MPSC) has not received a permit request for CO_2 pipelines to date; and, only one company remains active in the CO_2-EOR sector in Michigan, with one small-scale CO_2-EOR project initiated since 2014. The Michigan Agency for Energy (MAE) and MPSC reviewed these efforts and the policy recommendations offered by the industry to encourage investment, job growth, and low carbon energy production through CO_2-EOR.

The current and projected long-term \$50 - \$60 price range for a barrel of oil is the primary barrier inhibiting deployment of new CO_2-EOR projects which have access to low cost CO_2 supplies (e.g. nearby gas processing operations). These projects typically reach economic feasibility at the \$70 per barrel or higher price level. Even then, financial incentives may be needed to catalyze the industry. Proposed state regulatory policy reforms are unlikely to address these economic realities without accompanying federal action. Even the most dramatic reduction in state taxes for CO_2-EOR operations does little to overcome the \$10 – \$20 price gap. For instance, the proposed reforms to the Section 45Q tax credit alone offers a \$14 per barrel incentive.

The northern Niagaran Pinnacle Reef trend, a narrow band diagonally crossing the northern portion of the Lower Peninsula, has the only active CO_2-EOR operations in Michigan. This reef trend is of most interest for further CO_2-EOR deployment as it holds over half of the CO_2-EOR potential for Michigan. Also, its relatively recent development suggests the infrastructure should be in far better condition than older fields elsewhere in Michigan, which significantly reduces capital cost requirements for new CO_2-EOR deployment. Published CO_2-EOR studies suggest the northern reef trend, if fully developed, could recover over 125 million barrels of additional oil and result in significant new capital investment, job creation, and additional state revenues from royalties and severance taxes. However, access to low cost CO_2 supplies is severely limited in the region, likely requiring construction of flue gas carbon capture facilities and extensive CO_2 pipelines to address the shortfall. As the capital costs for these carbon capture facilities is significant, favorable economics for their construction can only be achieved through a combination of Section 45Q tax credit reforms and most of the remaining federal financial incentives discussed above (see previous section). Due to economic and technical challenges, carbon capture from flue gases is effectively a high risk investment for the CO_2-EOR industry, and remaining uncertainties in CCUS regulatory policies may inhibit financial investors from investing in these types of projects.

In Michigan, there are additional structural and economic barriers to carbon dioxide capture, use, and sequestration from industrial sources for enhanced oil recovery in Michigan. The Legislature previously enacted meaningful financial and regulatory policies to address these barriers and incentivize CO_2-EOR deployment, job growth, and utilization of available oil resources in the state. There has been minimal market response to date. Recent work completed by the sector indicates additional state policy incentives alone are unlikely to overcome persistent low oil prices and severely limited, low cost CO_2 supplies making further CO_2-EOR deployment uneconomical in Michigan at this time.

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Glossary and Abbreviations

Anthropogenic CO_2	Anthropogenic refers to carbon dioxide that is produced or released as a result of human activity, as distinct from naturally-occurring CO_2 that is released or obtained from geologic sources.
Bbl	The abbreviation for barrel, a unit of volume for crude oil / petroleum products.
CfD	A contract for difference (CfD) creates a contract between two parties based on the movement of an asset price. Parties execute a contract to exchange the difference in value of a particular currency, commodity or index between the time at which a contract is opened and the time at which it is closed. If the asset rises in price, the buyer receives cash from the seller, and vice versa. In the context of this report, a CfD would establish a target price for oil (to which the CO_2 prices is contractually linked) based on an oil price projection over the life of the contract. If the oil price were to fall below the target price, the federal government would provide the difference to a CO_2 capture project, and if the price of oil were to rise above the target price, the CO_2 capture project would pay the federal Treasury the difference.
CCS	Carbon capture and storage, or CCS, describes the process of capturing and preventing the release of man-made or anthropogenic CO_2 into the atmosphere and then ensuring its permanent storage in an oil and gas field, deep saline aquifer or other geologic formation.
CCUS	Carbon capture, utilization and storage, or CCUS, reflects the commercial use of CO_2 prior to permanent geologic storage through its injection into oil fields to recover additional crude through CO_2-EOR.
CO_2	Abbreviation for Carbon dioxide.
CO_2-EOR	Carbon dioxide enhanced oil recovery, or CO_2-EOR describes the process of injecting CO_2 into an oil field, usually in a tertiary phase of production, to increase the amount of crude oil that can be extracted. The commercial purpose of CO_2-EOR is to increase oil production, but permanent geologic storage of the injected CO_2 in the formation is an incidental result of the process.
EOR	Enhanced oil recovery techniques applied to an existing well encompassing secondary and tertiary production operations.
EPA	U.S. Environmental Protection Agency.
Gasification	Gasification is a long-established process of applying heat and pressure to an organic or fossil fuel-based carbonaceous feedstock, transforming it into carbon monoxide and hydrogen, with a pure stream of carbon dioxide ultimately resulting as a chemical byproduct that can readily be compressed and transported.
Geologic storage	Geologic formations can serve as storage sites for carbon dioxide, which is captured from large point sources, such as fossil fuel power plants and industrial facilities, transported by pipeline to a storage site and injected into the geologic formation. CO_2 has been injected into geological formations for nearly a half century for various purposes, including enhanced oil recovery.

Industrial CO_2	For the purposes of this report, industrial is meant to distinguish anthropogenic carbon dioxide generated from a wide range of industrial processes and activities from CO_2 produced through electric power generation.
ITC	An investment tax credit (ITC) helps defray upfront capital costs by providing a federal tax credit for investments in the development of a qualified project.
MAE	Michigan Agency for Energy
Manmade CO_2	See anthropogenic CO_2 definition.
MLP	In the U.S., a master limited partnership (MLP) is a limited partnership that is publicly traded on an exchange qualifying under Section 7704 of the Internal Revenue Code. It combines the tax benefits of a limited partnership with the liquidity and ability to raise capital of publicly-traded securities.
MPSC	Michigan Public Service Commission
Natural	CO_2 Naturally occurring carbon dioxide is CO_2 that is released or obtained from geologic sources, as distinct from CO_2 that is produced or released as a result of human activity.
O&M	Operations and maintenance
PA	Michigan Public Act
Primary production	Primary production refers to the production of oil in the initial or primary recovery stage, when production of oil and gas is assisted by natural reservoir pressures. Only about 10-20 percent of a reservoir's original oil in place is typically produced during primary recovery.
Secondary production	Secondary production refers to the production of oil that follows in a second phase following the primary recovery stage. Over the life of a producing well, the pressure will fall due to declining underground pressure to drive oil to the surface. At that point, a secondary recovery method (water injection, natural gas reinjection, etc.) is used to drive oil to the surface, resulting in the recovery of an additional 20-40 percent of the original oil in place.
Section 48A and 48B Investment Tax Credits	Section 48A and 48B reference sections of the Internal Revenue Code of 1986, authorizing federal programs that provide an investment tax credit to defray the upfront capital costs of clean coal projects (48A) and gasification projects (48B). The Section 48A and 48B programs prioritize carbon capture projects.
Section 45Q Credit For CO_2 Sequestration	26 USC §45Q provides a federal production tax credit of $10 per metric ton of carbon dioxide through enhanced oil recovery or $20 per ton for other geologic storage. Section 45Q was enacted by § 115 of the Energy Improvement and Extension Act of 2008.
Tertiary production	Enhanced, or tertiary production, follows the secondary phase and increases the mobility of the oil in order to increase extraction. Tertiary (or enhanced)

production typically begins when secondary recovery declines to the point where production no longer generates sufficient economic return. There are three major categories of enhanced recovery that have found varying degrees of commercial success: thermal injection, gas injection and chemical injection. Gas injection (including CO_2-EOR) accounts for nearly 60 percent of the enhanced oil production in the U.S.