CO2-EOR POTENTIAL IN THE MGA REGION

February 26, 2012 | Washington D.C.

Clinton Climate Initiative in collaboration with Midwestern Governors Association and Great Plains Institute

Acknowledgements

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- Kansas Geological Survey
- Tertiary Oil Recovery Project, University of Kansas
- Michigan Department of Environmental Quality, Office of Oil, Gas, and Minerals
- Ohio Department of Natural Resources, Division of Geological Survey
- Enhanced Oil Recovery Institute, University of Wyoming

Disclaimer
The views expressed in this report do not necessarily reflect the views of those organizations listed here.

EXECUTIVE SUMMARY

CO2-EOR may be an attractive commercial opportunity for the MGA

- **Our conservative screens suggest that an estimated 2 billion barrels of oil could be added through CO2 based Enhanced Oil Recovery in the MGA region**
  - The region has large oil resources, with basins in Kansas, Illinois/Indiana, Michigan and Ohio
  - Oil production has been in long decline; CO2-EOR creates an opportunity for renewed growth in this segment
  - Wide scale implementation would require an aggregate net CO2 supply of 670 – 1,050 MMT

- **Regional stationary emissions sources emit approximately 700MMT CO2 annually**
  - About 35MMT can be sourced from potentially lower cost local ethanol plants; most additional volume would have to come from higher cost sources
  - ADM is currently capturing about 1MMT of CO2 over three years from their Decatur plant in first of two DOE/ISGS studies – demonstrating cost and feasibility of capture and geological storage

- **Our assessments in four states suggest that CO2-EOR could be economically viable, assuming oil prices remain at about current levels**
  - Reference case assumptions lead to after tax project IRR of 20% or higher
  - Economics are highly dependent on production expectation and investment cost required in wells and field equipment, making younger fields more attractive
  - In most cases a CO2 price of $80/MT renders projects uneconomic; but there is potential to develop revenue neutral approach to incentivize activity

- **State economies would benefit from extra revenue and jobs**
  - The region could add at least 6000 direct new jobs and at least 3 times as many indirect jobs
  - Additional benefits would flow through royalty, severance and income taxes

- **Next steps focus on further characterization of potential production and cost**
  - For Michigan and Ohio, CO2 sourcing would have to be confirmed

CO2-EOR could be commercially viable in Michigan

- **Analysis focused on fields in Niagaran Pinnacle Reef trend in the northern lower peninsula**
  - The potential has been proven here with Core Energy currently operating the only successful commercial CO2-EOR floods in Michigan and the MGA region.
  - The area has newer fields with infrastructure in good condition (peak production in early ’80s)
  - Small pinnacle reef fields (“cupcakes”) can be aggregated and added over time providing flexibility to investment approach
  - Over 125 million bbls in incremental EOR potential, favorable reservoir characteristics
  - Potential net CO2 demand estimated at 40 – 60 MMT

- **Representative field suggests strong operator economics**
  - The Chester 18 field was chosen for analysis, given level of data in the public domain
  - Reference case assumptions lead to an after-tax project IRR of 49%
  - Operator experience suggests that the actual production could be somewhat higher than the projections used in this analysis – further improving economics
  - Higher cost assumptions still produce returns of over 20%

- **Sourcing of “market price” CO2 may be problematic**
  - Local gas processing provides less than 1 MMT of CO2 per annum, any additional needs would require development of Wolverine project or capture at Tes Filer City Station
  - Several pipeline network scenarios possible if CO2 source can be developed

- **State could benefit also, through additional revenue and jobs**
  - Additional revenue of about $1B over 10 - 20 year period from developing Niagaran trend
    - State holds partial mineral interest in many Niagaran trend wells (~$220M royalties)
    - Severance taxes could add $750M

Illinois/Indiana area is likely to have economically viable CO2-EOR opportunities

- **Screening process suggests that the region has 500M+ bbls of miscible EOR potential**
  - The five largest fields alone have nearly 250 million bbls of EOR potential
  - Using different methodology, MGSC estimated Basin (including KY) potential of 0.8-1.3B bbls
  - We chose two representative fields for our analysis:
    - New Harmony, which straddles Illinois and Indiana, was chosen given technical data in public domain; it is typical of large fields in Illinois Basin (ILB)
    - Concord and Herald represent small field opportunity, with potentially local CO2 source
  - Potential net CO2 demand estimated at 160 - 250 MMT

- **The region has an abundance of low cost CO2**
  - There is more than 17 MMT CO2 emitted annually by ethanol fermentation process in Illinois, Indiana and Iowa – CO2 that can be captured at an estimated cost around $25/MT
  - ADM is currently injecting 1MMT of CO2 from their Decatur plant into the Mt. Simon formation, as part of a 3 year DOE project testing geological storage, CO2 may be available for EOR when project completes
  - CO2 from future gasification projects, currently planned to be transported south by the proposed Denbury pipeline, could also be used locally for regional CO2-EOR

- **Representative field economics suggest reasonable profitability for larger fields and potentially marginal results for smaller fields**
  - New Harmony project, with reference case assumptions, produces after tax IRR of 21%
  - Concord and Herald lead to smaller returns of after tax IRR of 9%. We believe returns could be better given field age and close proximity to low price CO2 source

- **State economy would benefit, adding 1,550-3,100 direct jobs**

Ohio's large resource potential could be commercially viable

- **Ohio could be a great commercial success although much work and characterization is needed in order to confirm these assessments**
  - Screens suggest approximately 500 million bbls of EOR potential in state
  - Despite Ohio's long history to beginnings of US oil industry, lack of secondary recovery means that limited data exists that operators can use to project performance and book reserves
    - Water flood performance is often used as approximate guide for CO2 floods
  - An abundance of small operators and aging/inappropriate field infrastructure adds to obstacles
  - Potential net CO2 demand estimated at 190 – 300 MMT

- **East Canton field economics suggest strong commercial potential**
  - Chosen by state geologists for 2010 pilot reservoir simulation; data in public domain
  - Strong operator concentration and relatively young infrastructure (discovered 1953) would benefit in ability to effectively implement EOR approach
  - Our reference case assumptions lead to an after tax IRR of 28%

- **While sourcing of CO2 is technically feasible through capture in many local power plants – high capture costs would likely lead to high cost of CO2**
  - CO2 from traditionally low-cost sources (ethanol, ammonia) is limited, but may be just enough to begin/test limited EOR production
  - AEP Mountaineer could have been a reliable source of CO2 if project had been approved
  - Potential future shale gas opens new source opportunities where CO2 could be produced, for example development of ammonia manufacturing

- **EOR could directly support 1,550 – 3,100 new jobs in the state of Ohio**

CO2-EOR should have commercial potential in Kansas

- **Screening process indicates 750 million barrels or more of technical CO2- EOR potential**
  - This may be conservative, reflecting adjustments to account for limited data
  - Kansas has by far largest oil resources in the MGA region
  - Kansas shares geological formations with Oklahoma, where commercial CO2 floods are proven and are serviced by existing and planned CO2 pipeline infrastructure
  - Potential net CO2 demand estimated at 240 – 370 MMT

- **Kansas has access to high volume of region's ethanol-based CO2**
  - Although the in-state supply of low cost CO2 is moderate, neighboring Nebraska produces about 6 MMT per annum of ethanol-based CO2
  - Kansas is currently exporting by pipeline CO2 from ethanol (and planned from ammonia production plants) to northern and possibly central Oklahoma for EOR

- **Our financial modeling suggests positive economics, but needs further analysis**
  - The Hall Gurney field was chosen for analysis, given level of data in the public domain and previous CO2 pilot (which proved somewhat inconclusive)
  - Our reference case economics suggest an after-tax project IRR of 22%
  - However, there are many questions around assumptions which need to be tested further: These include OOIP level, estimated production given experience in similar formations and costs associated with pattern practice. Changing assumptions can lead to wide fluctuations, with economics turning marginal or negative

- **State economy would benefit from additional jobs – direct 2,300 – 4,600**

APPROACH & ASSUMPTIONS

General assumptions – reference case and sensitivities

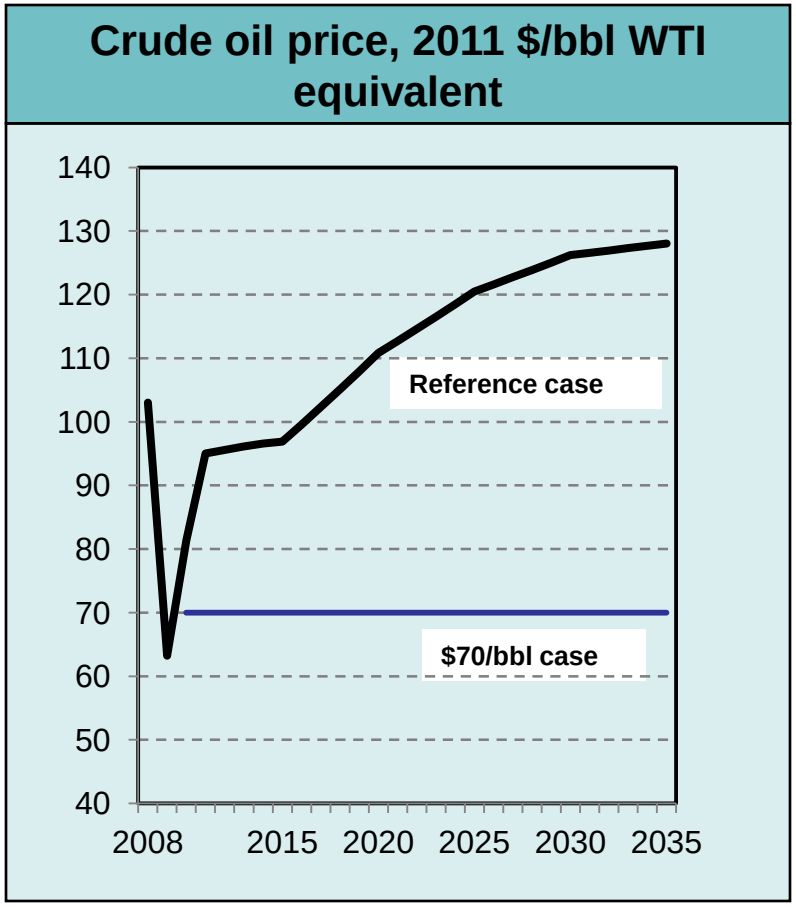
- **Crude oil and CO2 prices**
  - Crude oil prices from the latest (2011) EIA Annual Energy Outlook – WTI equivalent
  - CO2 "market price" assumed at about 2% of crude oil price, similar to recent trend
  - Sensitivities: lower crude price at $70/bbl; CO2 at fixed real $25/50/80 per metric ton

- **Production curves**
  - Projections from best available match
    - Basin specific simulations where possible
    - Incremental recovery sensitivities: IL/IN,MI,KS 15%,10%: OH 8%.14%,20%

- **Production capital and operating costs**
  - McCoy, Rubin (2008) depth dependent cost functions derived from aggregate cost indexes
  - EIA cost index to update costs to 2012 dollars

- **Other Assumptions**
  - Royalty 15% (Sensitivities: 12.5%, 17.5%, 20%)
  - Taxes: Severance tax state dependent; federal corporate tax 35%
  - Depreciation: straight line for 15 years (likely conservative)
  - Inflation: oil price escalator (~2%)
  - Discount Rate (nominal) at 20%; sensitivities: 15%, 25%
  - 45Q federal tax credits have not been applied – would have positive effect on economics

Reference case assumes US EIA 2011 oil price forecast



Crude oil market prices

Our reference case crude oil price projections reflect the latest US EIA forecast

- Prices shown for WTI equivalent in $2011/bbl
- Nominal prices used for economic projections, also based on EIA's forecast

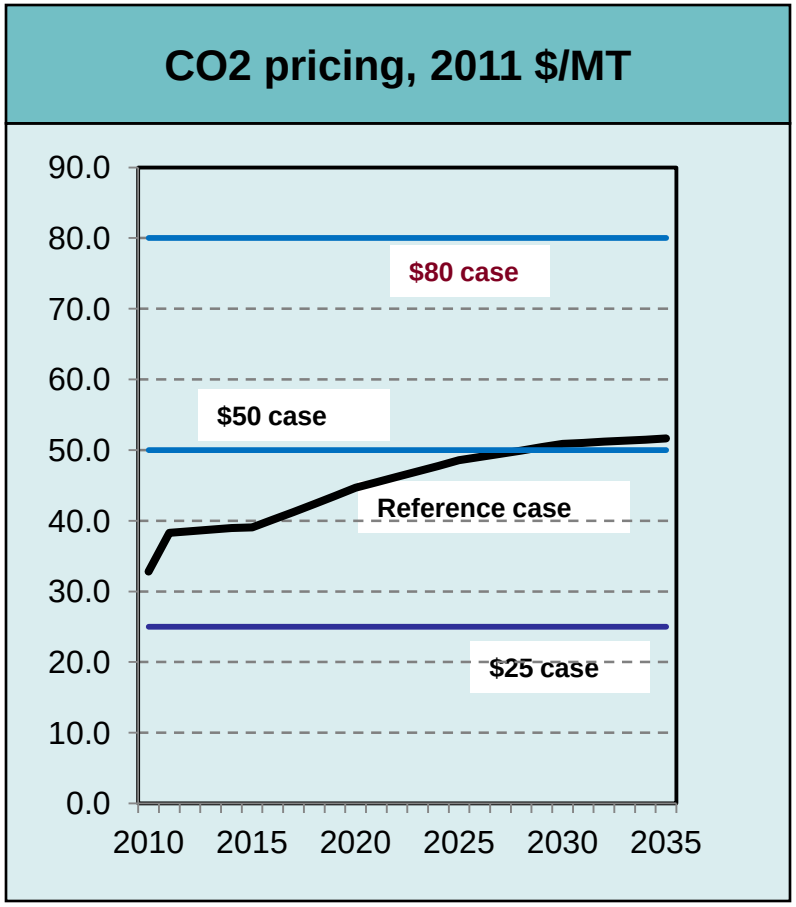
Sensitivities: lower pricing

- Assume oil price remains flat at about $70/bbl (below current level of $95/bbl), nominal assumes same multipliers

Some possibility for much higher oil prices

- EIA high case about 50% higher than reference

Reference case CO2 price is tied to the oil price



CO2 market price expectations

Future CO2 market price is likely to be set by supply/demand balances

- May be influenced by cap and trade policies, if those in place
- Naturally influenced by the cost of CO2 capture/production

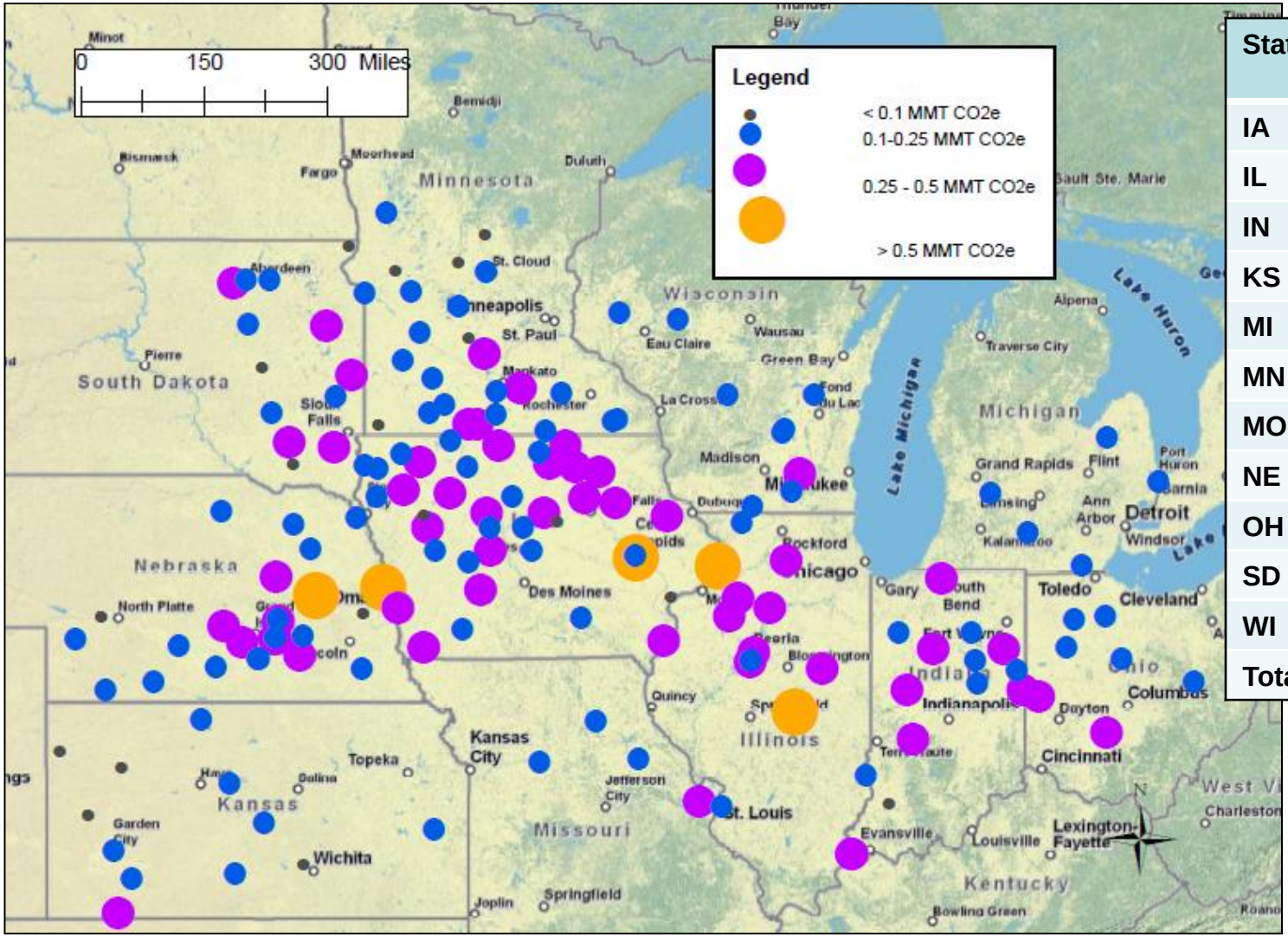
Our reference case assumes that CO2 market price will remain at about 2% of oil price (mcf)

- Recent CO2 market prices varied between 2-3% of oil price, rising to ~$1.60/mcf + (~$31/MT) over the last 4 years

Sensitivities: CO2 trades at a price close to the cost from marginal supply:

- $25/MT reflects capture at ethanol plants, natural gas processing, and ammonia
- $50/MT reflects capture at steel, cement, hydrogen, and some power plant capture
- $80/MT reflects power plant capture

Midwest is rich in ethanol based CO2…



State	MMT CO2
IA	10.3
IL	3.5
IN	3.3
KS	1.5
MI	0.8
MN	3.2
MO	0.7
NE	6.0
OH	1.5
SD	2.9
WI	1.4
Total	35.2

*MMT CO2: Million Metric Tons of CO2

Note: These are biogenic CO2 emissions from ethanol fermentation, and are currently exempt from EPA reporting requirements.

Source: RFA 2011, CCI

…hence can deliver portion of CO2 at/below "market" prices

Potential crude production estimated using best available sources

- **Analog methodology was used to predict CO2-EOR performance in representative fields:**
  - Assumes candidate field performs similar to original field once adjusted for scaling parameters
  - Reservoir simulations used as “analogs” instead of historical performance, as there is little commercial CO2-EOR history in region
  - Incremental projections include estimates for not only oil production but also water (injection and production), and CO2 (injection, production and recycling)
  - Length of field production varies, as fields assumed to produce only if economics positive

- **Midwest Geological Sequestration Consortium (MGSC) simulations for select Illinois Basin leases in “Phase I” report (2005) provided “analog” curves for IL/IN, MI and KS**
  - Production normalized over Original Oil in Place (OOIP) in the fields analyzed
  - The reference case assumes that EOR will deliver 15% of OOIP
  - Net CO2 utilization generally consistent with West Texas rules of thumb: 0.5MT/bbl at 5 years; declining to about 0.25 MT/bbl at 20 years
  - To date Michigan experience suggests better production performance – hence reference case economics may be conservative
  - Kansas fields may perform closer to Texas fields. Texas experience in similar carbonate formations suggests equivalent to higher production.

- **Ohio’s representative East Canton field production derived from Ohio Geological Survey reservoir characterization study for pilot area of the same field (2010)**
  - The reference case assumes delivery of 14% of OOIP, with low/high boundaries of 8/20%
  - Net CO2 utilization is 0.7 to 0.8MT/bbl after 20 years due to 100% CO2 use (rather than water)

Initial capital costs are significant

- **Field investment is by far the largest component of cost. Costs will vary by operator and field design strategy**
  - Spacing will affect both production volumes and capital costs inversely - traditionally 40 acre inverted five spot “patterns” are used, however Illinois and Kansas assumptions are at 20 acres
  - New production or injection wells may be needed to complement or replace existing wells, we assumed that 50% of wells will be new and 50% worked-over

- **The field investment cost is divided into three large components:**
  - Drilling and completion: number of new vs. work-over wells and well depth are key to cost
    - We assumed depth to be at average depth of EOR candidate reservoirs in field
  - Workovers & Conversions: assumed all existing wells require “workovers” for CO2 operation
    - Some may be converted from producer to injector or vice versa to optimize flood design
  - Pattern and other surface (lease) equipment will generally need upgrading due to anticipated increased production, changes require new wellheads and other production/injection equipment

- **CO2 separation and recycle equipment needs to be added as significant level of CO2 will be produced with the oil (and water)**
  - CO2 will be recycled and re-injected into the field
  - We sized the compression and dehydration equipment capacity in line with projected recycled CO2 volumes

Operating costs could be as high as 25% of gross revenue

- **Operating costs can consume as much as 25% of total gross revenues or 40-60% of total project costs, not including CO2 purchases**
  - Although total costs decrease over time, maintenance of wells continues periodically

- **The operating costs assumptions included three components:**
  - Well maintenance: assumed at fixed cost per well per year inflated nominally
  - Lifting costs: assumed at $0.25/bbl of liquids including oil, water, natural gas liquids produced
  - CO2 recycle operations: consists mostly of energy to recompress, dehydrate, and pump recycled CO2
    - Reference case assumes $0.35/mcf of recycled CO2 and hydrocarbon gas
    - Total costs increase over time as volumes of recycled CO2 increase

- **CO2 purchases are the highest cost item, especially in the early years of project life when little CO2 is recycled**
  - Could run as high as 50% of total costs

Pipeline costs are a small component of total CO2 delivery costs

Pipeline Transportation Costs ($/MT CO2 delivered)					
Project Life	20-years			**IRR** :	15%
Construction Costs * ($/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 generally include: materials, labor, right-of-way costs, and miscellaneous/other (including overhead).

- **Operating costs are a function of pipeline diameter and vary with length**
  - These were included in estimates above
- **Total transport cost is only a small portion of delivered CO2**
  - As CO2 prices expected to range from $25 - $80/MTCO2

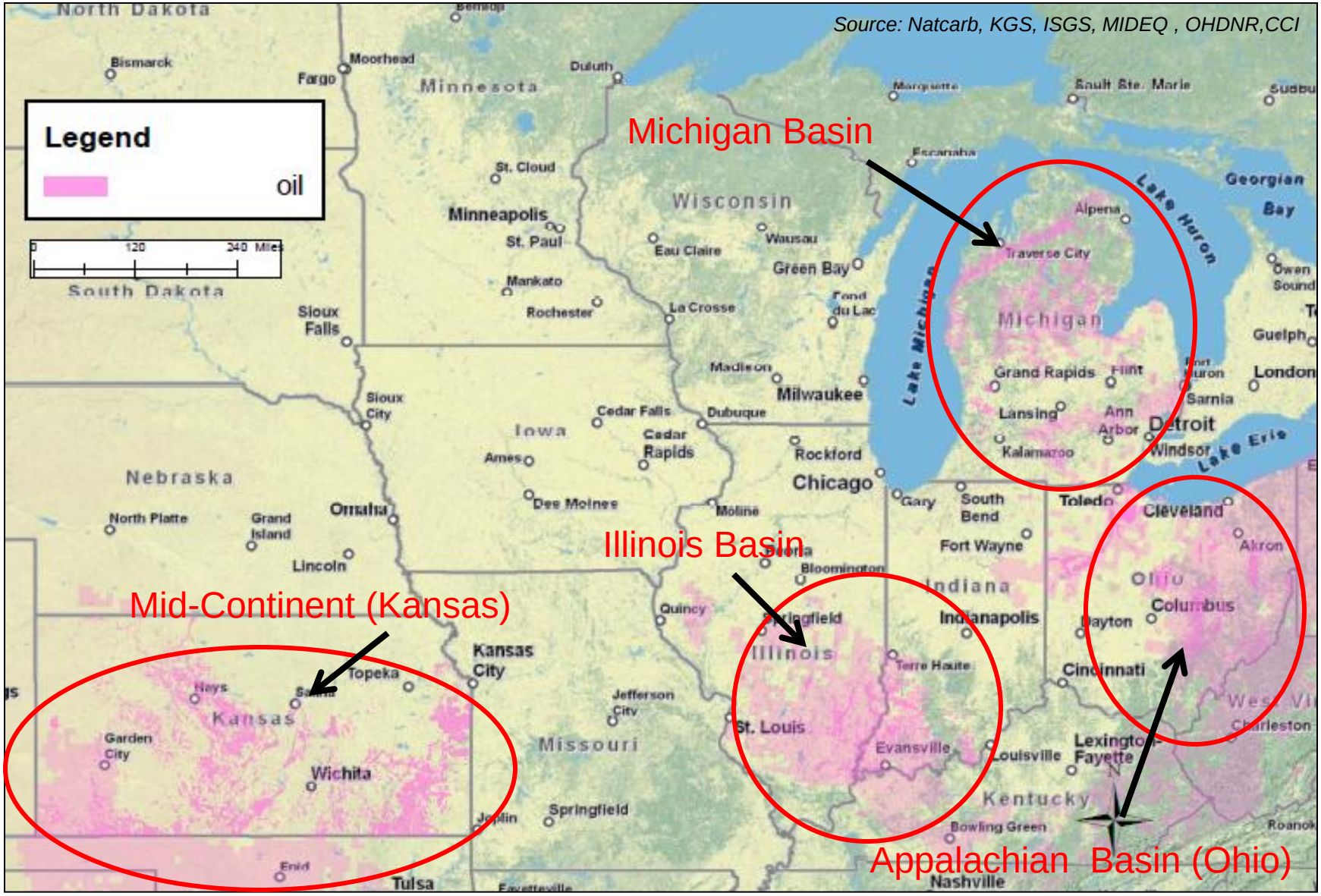
** Source: IOGCC, EPA, MGSC, CCI*

MGA REGION

Summary

- **MGA region has large oil resources**
  - With four principal oil regions in Kansas, Illinois/Indiana, Michigan and Ohio
- **However regional oil production has been in long decline**
  - Even though Kansas has reversed the trend recently
  - Many fields throughout the region produce from “stripper” wells
- **CO2-EOR creates opportunity for renewed growth in oil production**
  - The region has an abundance of stationary CO2 sources, including large volumes of potentially lower cost CO2 in Iowa and Nebraska
- **Estimated 2 billion barrels of could be added to regional economies through CO2-EOR**
  - Screens in this analysis indicate that Kansas could produce more than 0.7B bbls, Ohio about 0.5B bbls, Illinois / Indiana more than 0.5B bbls, and Michigan more than 0.2B bbls
- **Recovery would require a net CO2 supply of 670 – 1,050 MMT**

MGA region has large oil resources



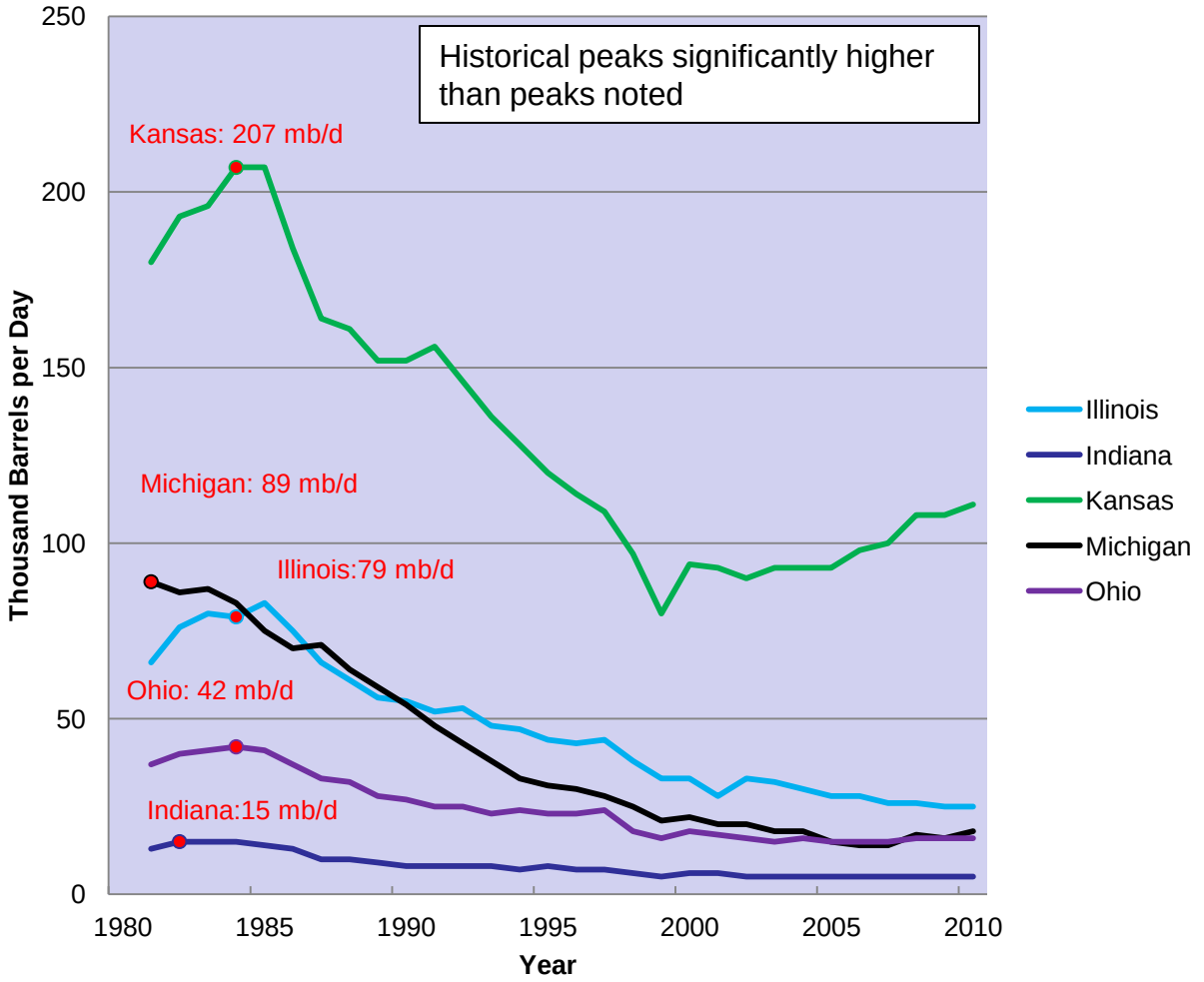
Regional crude production has been in long decline

Regional production is small

State	Cumulative Production (billion bbls) (1)	mb/d (2)(3)
IL	3.6	25
IN	0.5	5
KS	6.2	111
MI	1.2	18
OH	1.1*	16
Total	**12.6**	**175**
TX		1169
US TOTAL		**5474**

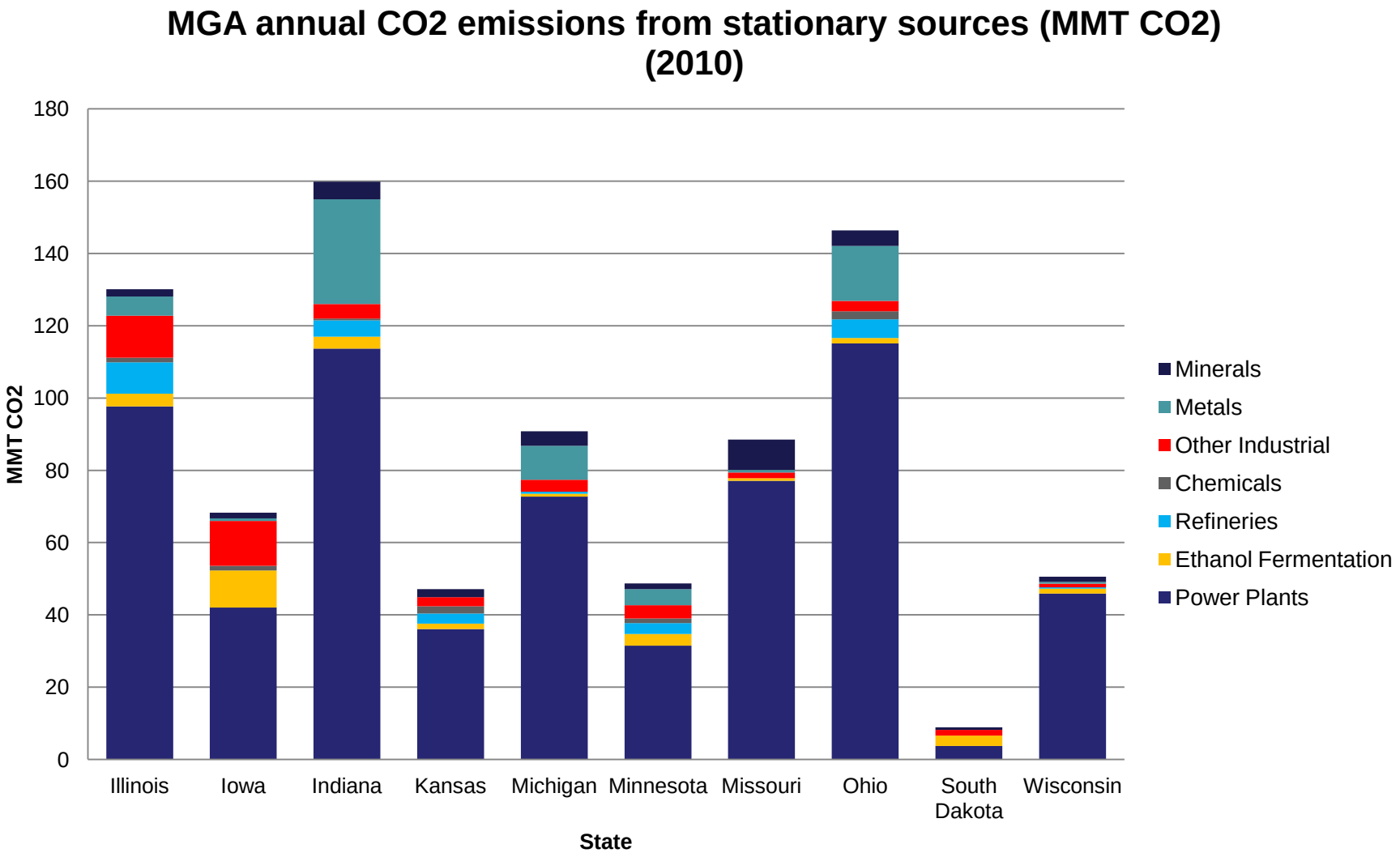
(1) O&GJ (2003)
(2) EIA 2010
(3) mb/d = thousands of barrels per day
** No secondary recovery taking place*

Production history (mb/d) of last 30 years



Source: EIA 2010

MGA region emits approximately 700 MMT CO2 annually…



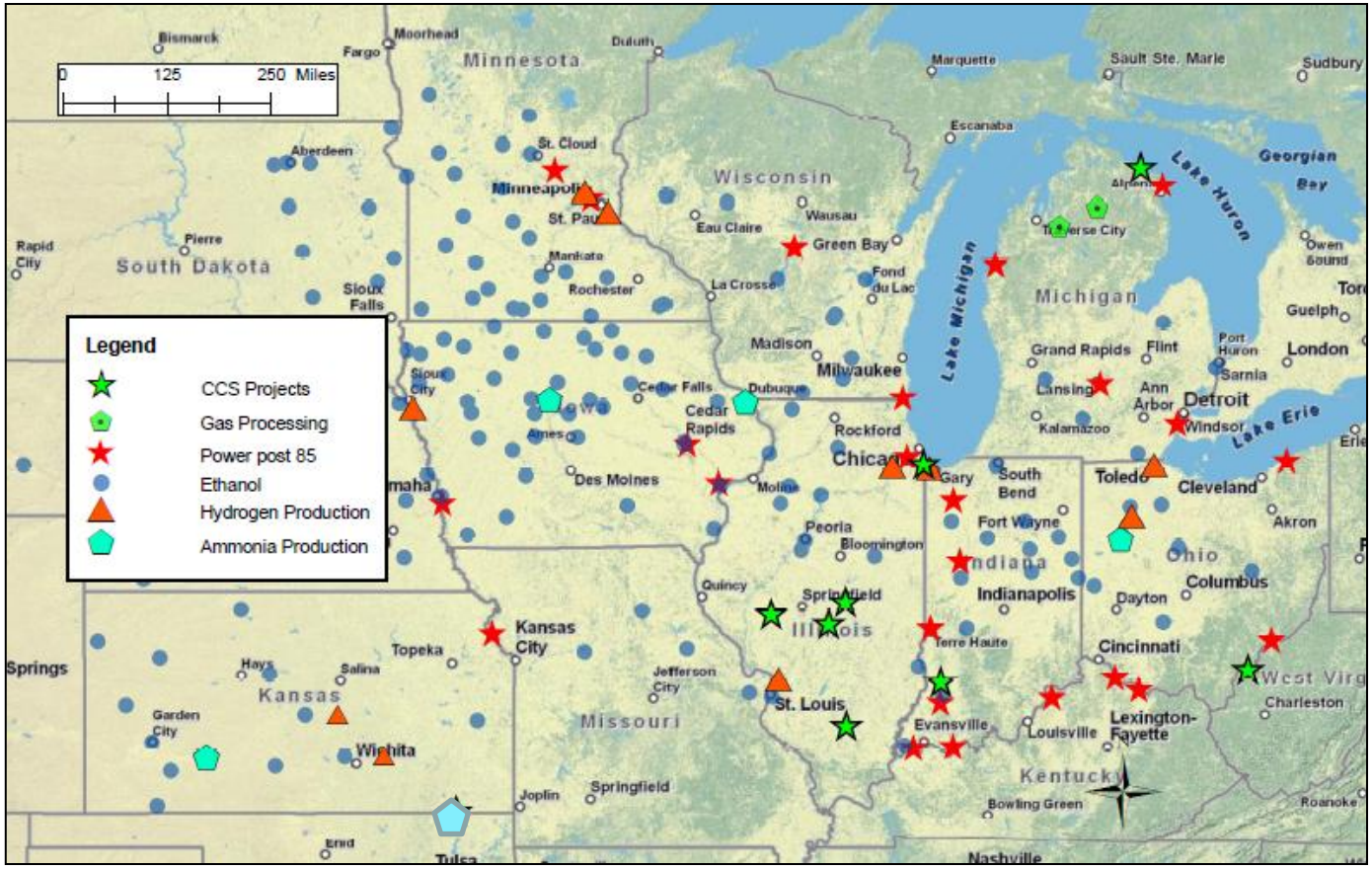
Source: EPA 2011 , RFA 2011, CCI

…with an abundance of stationary CO2 sources throughout

Potential CO2 sources were screened for EOR opportunities

A screening methodology was developed in order to narrow down the list of sources to those which are more likely to be retrofitted with a CO2 capture technology. These include:

1. **Power Plants with generating units younger than 1985**
2. **Planned / Proposed CCS projects**
3. **Plants with a high-purity CO2 stream:**
   a) Ethanol fermentation
   b) Hydrogen production
   c) Ammonia production
   d) Gas Processing



Source: Natcarb, RFA, EPA, CCI

Oil and gas basins were screened for CO2-EOR potential

A series of technical and economic screens were applied to identify where miscible CO2-EOR flooding could take place in each respective basin. Production history, reservoir depth, reservoir pressure, oil characteristics were all used to identify candidate fields.

Preliminary

1. Depth Screen

a) Producing Formation / Payzone > ***2,500 ft***.

2. **Economic Screen**

a) Cumulative Production > ***1 Million bbl***

Primary

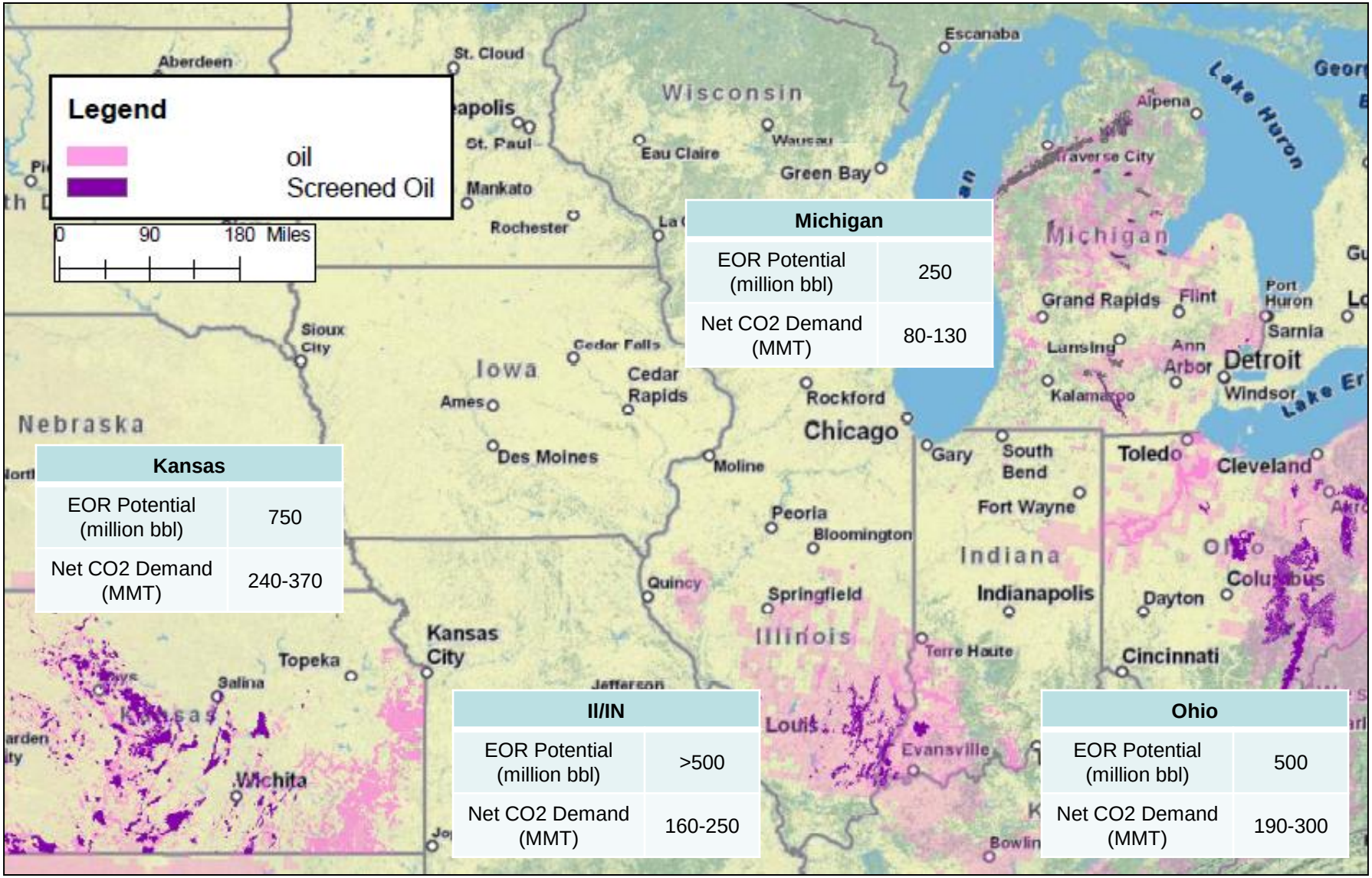
3. Miscibility Screen

a) Calculate minimum pressure required to achieve miscibility - Minimum Miscibility Pressure (MMP) and compare MMP to initial reservoir pressure

MMP = f(*Depth, temperature, pressure, oil character)*

b) Where MMP could not be calculated, it was approximated based on available data

Screens estimated 2 billion bbls of oil could be added through CO2-EOR



Source: Natcarb, KGS, ISGS, MIDEQ, OHDNR,CCI

MICHIGAN

CO2-EOR could be commercially viable in Michigan

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  - The area has newer fields with infrastructure in good condition (peak production in early ’80s)
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  - Over 125 million bbls in incremental EOR potential, favorable reservoir characteristics
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- **Sourcing of “market price” CO2 may be problematic**
  - Local gas processing provides less than 1 MMT of CO2 per annum, any additional needs would require development of Wolverine project or capture at Tes Filer City Station
  - Several pipeline network scenarios possible if CO2 source can be developed

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  - Additional revenue of about $1B over 10 - 20 year period from developing Niagaran trend
    - State holds partial mineral interest in many Niagaran trend wells (~$220M royalties)
    - Severance taxes could add $750M

Michigan state overview

CO2 Emissions Overview

Screened emissions

Source	Michigan (MMT CO2)
Power	1.7
Ethanol	0.7
Gas Processing	1.0
Total	**3.5**

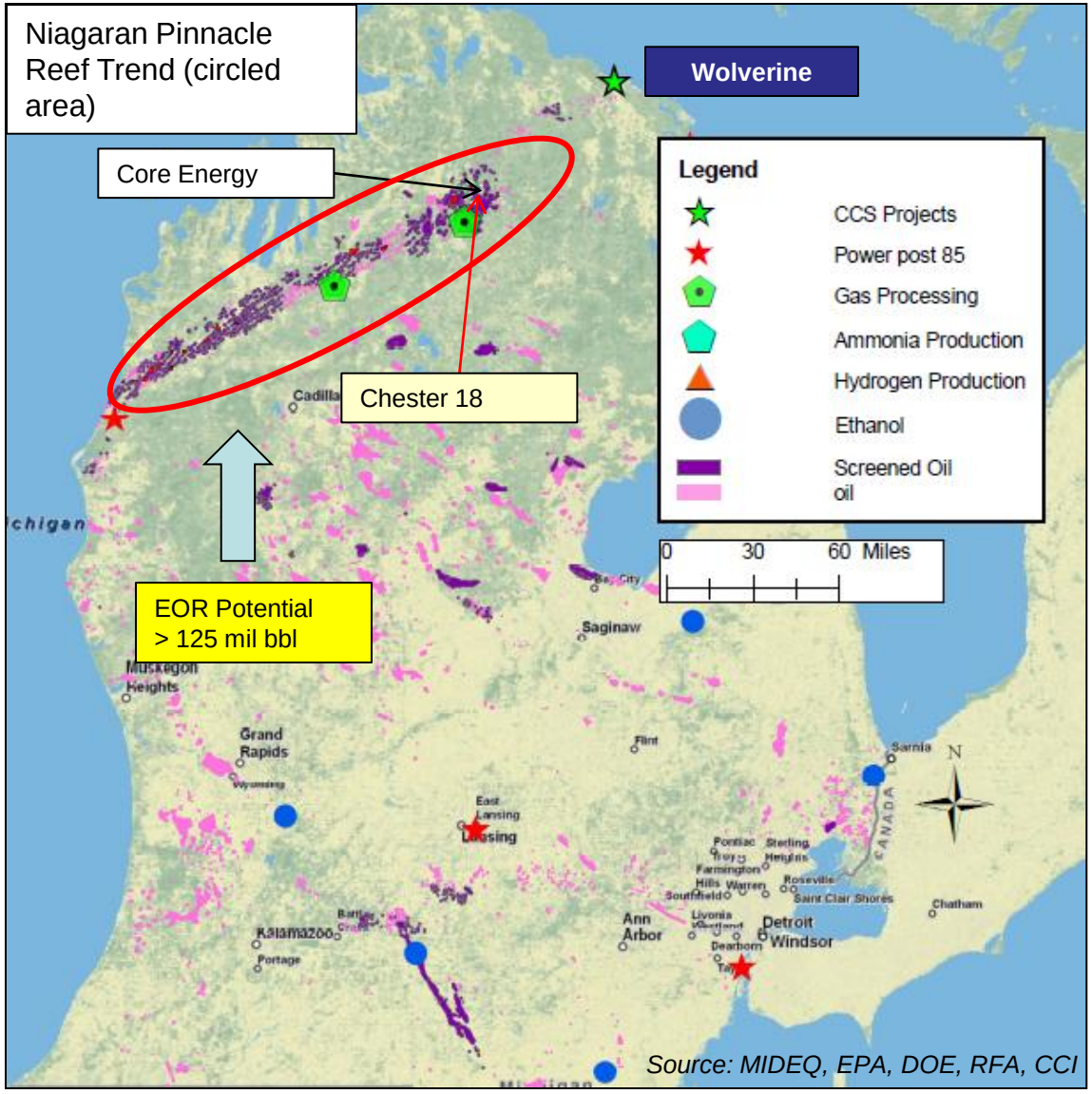
Potential CO2 Capture Projects

Wolverine Clean Energy Venture
Status: Pending (received air permit, capture unclear)
Emissions: **6 MMT CO2**

Oil Overview

Cumulative Production: 1.2 billion bbl

CO2-EOR activity taking place in Niagaran pinnacle reef trend by Core Energy.



Representative field suggest strong economics

- **Given "cup cake" structure of Niagaran trend, we used one representative field to assess potential CO2-EOR production economics for the area**
  - Chester 18 field was chosen for analysis due to technical data available in public domain
  - The field has a potential for 4.6M bbls of additional EOR production over a 20 year period
- **Our reference case assumptions lead to an after-tax project IRR of 49%**
  - Experience suggests that the actual field production could be higher than the estimates based on the simulations we used – further improving economics
  - For Chester 18, the investment of about $31M leads to an after tax $40M NPV@20%
- **Various tested sensitivities indicate that the project is likely to remain economic:**
  - The pricing and availability of CO2 will be key. If CO2 captured and delivered from Wolverine project, it would likely be priced higher than our reference case, given CO2 capture costs.

Economics (Before/After Tax)	BT IRR	AT IRR	BT NPV @ 20%	AT NPV @ 20%
Reference case	**70%**	**49%**	**$ 75 M**	**$ 40 M**
Sensitivities				
CO2 Prices				
▪ CO2 @ $25/MT	**86%**	**59%**	**$ 85 M**	**$ 50 M**
▪ CO2 @ $80/MT	**37%**	**22%**	**$ 34 M**	**$ 5 M**
Oil price 2011 $/bbl $70	**51%**	**35%**	**$ 40 M**	**$ 20 M**
Higher Cost				
▪ Investment + 20%	**60%**	**41%**	**$ 65M**	**$35 M**
▪ Higher Recycle Cost	**56%**	**39%**	**$ 65 M**	**$30 M**

The area is attractive for CO2-EOR network, but sourcing of "market price" CO2 may be problematic

- **The Niagaran reef trend represents an attractive area for a CO2-EOR network build out**
  - More than 125 million barrels of oil in EOR potential, with attractive economics
  - A series of gas processing plants and the proposed Wolverine Clean Energy Venture (WCEV) could provide CO2, and act as anchors for a 200-mile pipeline stretching the length of the trend
  - Tes Filer City Station previously had a proposal to upgrade 60MW capacity to 180MW IGCC, which may have provided an additional potential source of power plant-based CO2

- **Sourcing of "market priced" CO2 may be problematic**
  - Local gas processing provides less than 1 MMT of CO2 per annum
  - Any additional needs would require development of higher cost CO2 capture projects, either at the potential WCEV project or at Tes Filer City Station
  - Wolverine project, if built, may go forward without CO2 capture component
  - Tes Filer City proposed upgrade to IGCC plant apparently moribund, no air quality permit application has been submitted.

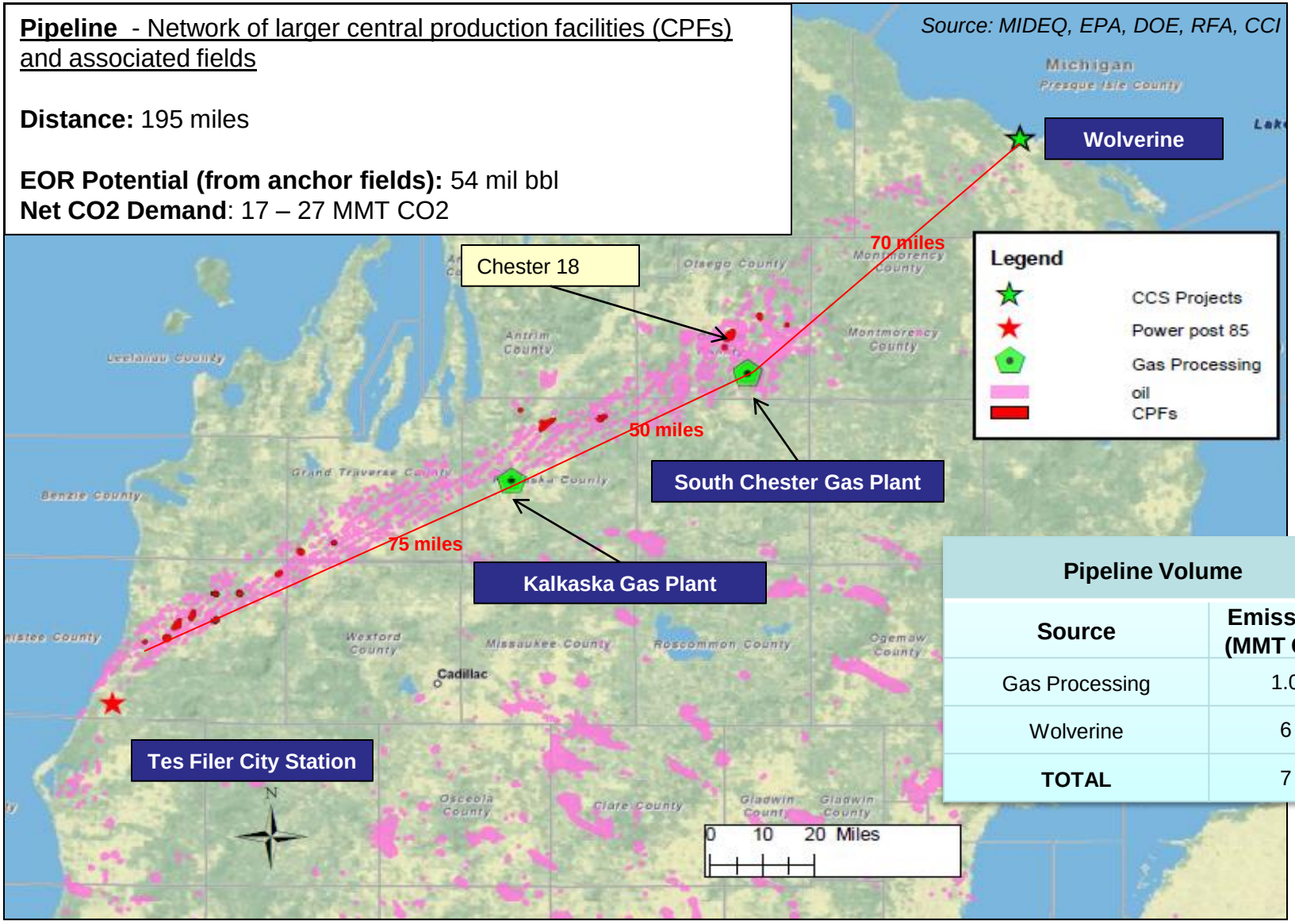
- **Several pipeline network scenarios are possible, with build out over time**
  - Large central production facilities (CPFs), processing production from multiple fields, are scattered over length of the trend. These could serve as initial sites for CO2 recycling plants and anchor the build-out of the network
  - From the Wolverine Plant in the north-east, the pipeline network would deliver CO2 to fields in Otsego and Kalkaska counties
  - The next phase would continue the pipeline to the western edge of Manistee county

Niagaran reef trend could be developed over a period of time

Pipeline - Network of larger central production facilities (CPFs) and associated fields

Distance: 195 miles

EOR Potential (from anchor fields): 54 mil bbl
Net CO2 Demand: 17 – 27 MMT CO2



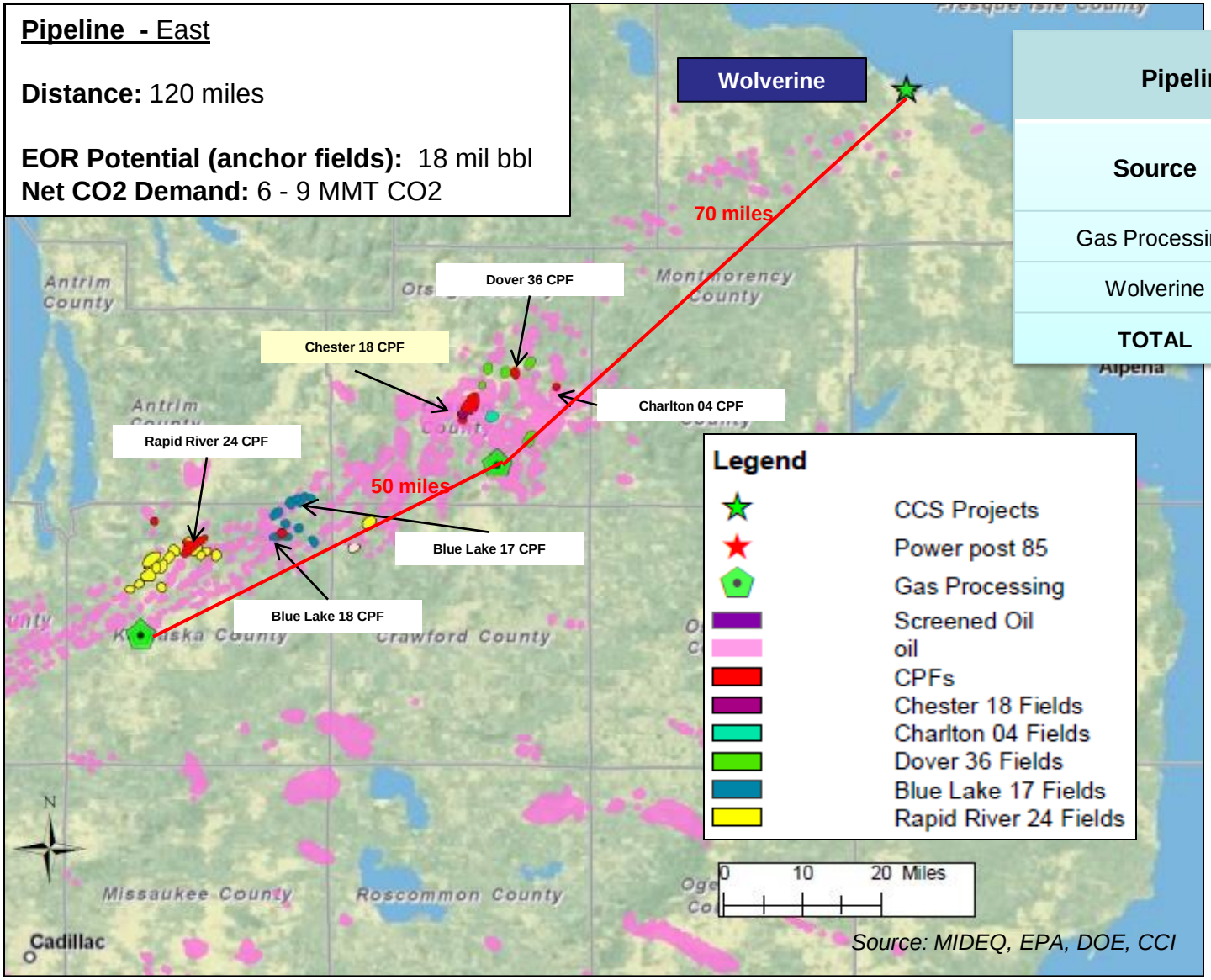
Pipeline Volume	
Source	**Emissions (MMT CO2)**
Gas Processing	1.0
Wolverine	6
TOTAL	7

Eastern Leg: Kalkaska & Otsego Counties

Pipeline - East

Distance: 120 miles

EOR Potential (anchor fields): 18 mil bbl
Net CO2 Demand: 6 - 9 MMT CO2

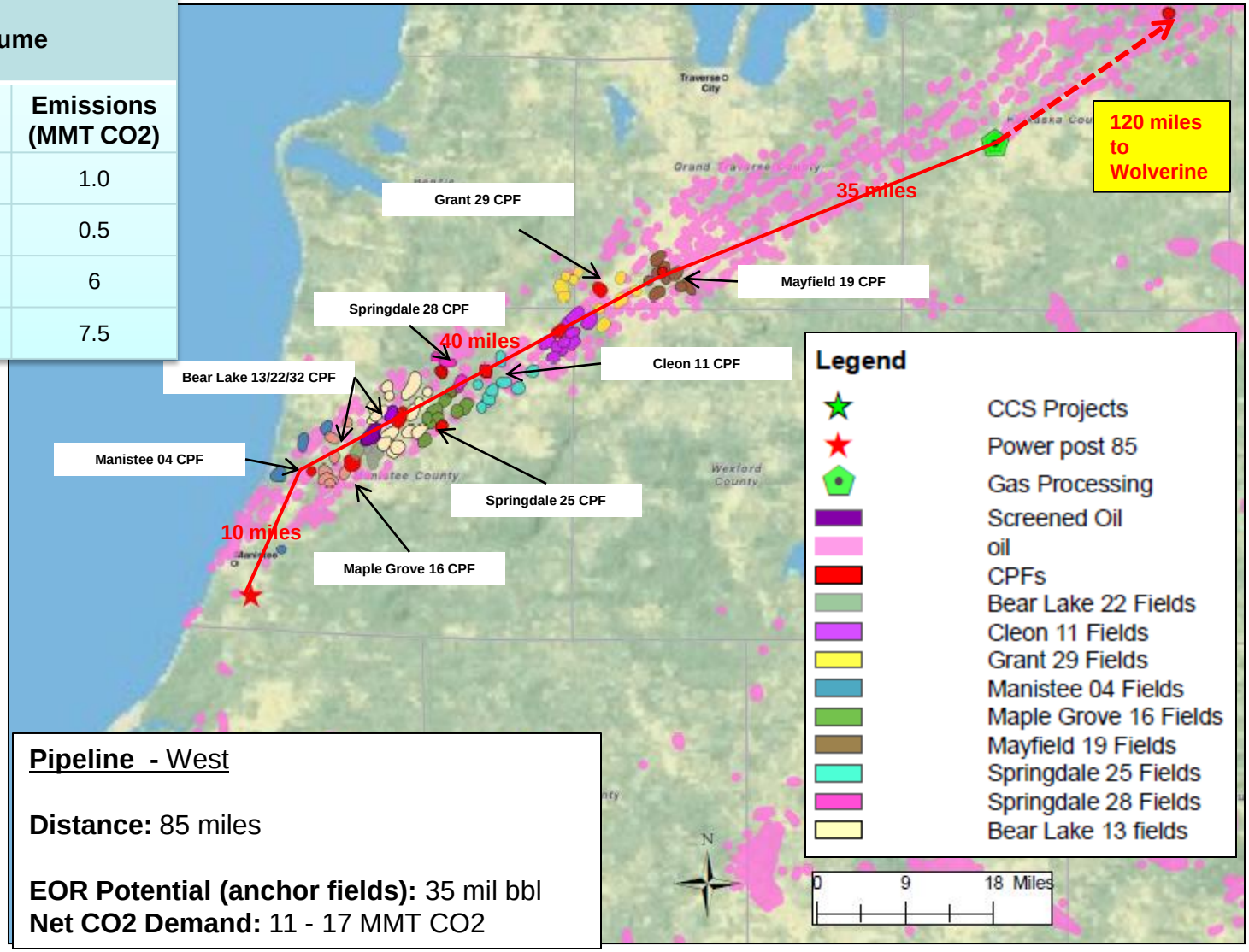


Source: MIDEQ, EPA, DOE, CCI

Pipeline Volume	
Source	**Emissions (MMT CO2)**
Gas Processing	1.0
Wolverine	6
TOTAL	7

Western Leg: Manistee & Grand Traverse Counties

Pipeline Volume	
Source	**Emissions (MMT CO2)**
Gas Processing	1.0
Tes Filer City Station	0.5
Wolverine	6
TOTAL	7.5



Pipeline - West

Distance: 85 miles

EOR Potential (anchor fields): 35 mil bbl
Net CO2 Demand: 11 - 17 MMT CO2

Source: MIDEQ, EPA, CCI

State could benefit through additional revenue and jobs

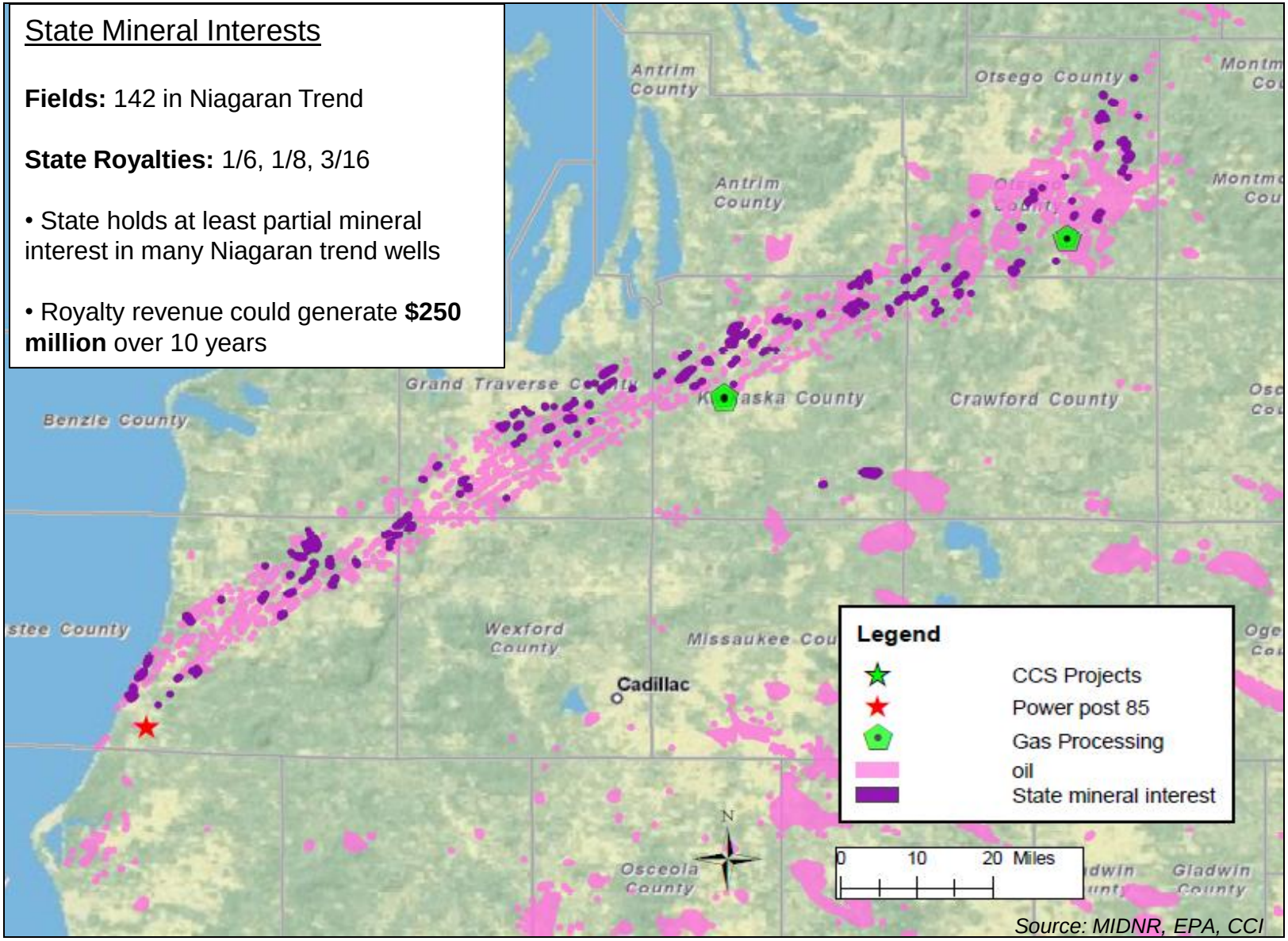
- **State holds at least a partial mineral interest in many Niagaran Trend wells**
  - Estimated EOR potential of wells at about 21M bbls of production over 10+ years. The length of production will be based on the speed of network development, given field characteristics and CO2 availability

- **With the development of Niagaran reef trend, the state could receive additional revenue of about $1 Billion**
  - Royalties could amount to > $220 million over the period of EOR development
  - Severance taxes could add an additional $750 million (based on total EOR potential of about 125 M bbls)

- **EOR development of Niagaran reef trend could add to job creation within the state**
  - EOR could directly support 400 – 800 new jobs*
  - Indirect employment could add another 1,200 – 2,400 jobs* in support industries
  - The number of jobs would be higher during the initial investment stage
  - Income taxes from these jobs would create an added state revenue stream

* Note: Estimates based on 15 - 30 year production and Wood Mackenzie job multipliers data

State owns significant level of mineral rights



Next Steps

- **Given relatively small supply of "market price" (lower cost CO2), other possibilities for sourcing CO2 and associated cost need to be evaluated**
  - Potential Wolverine Clean Energy Venture project is a natural possibility. What is the likelihood that carbon capture is reintegrated into this project and what would be the associated cost of CO2?

- **Develop additional technical geological review to increase level of data in public domain**
  - CO2-EOR has been technically proven in the northern lower peninsula by an independent operator, however there is little public domain data available for other operators in the trend

- **As possibilities become more clear, could state create revenue neutral options in support of CO2-EOR development?**

ILLINOIS

Illinois/Indiana area is likely to have economically viable CO2-EOR opportunities

- **Screening process suggests that the region has 500M+ bbls of miscible EOR potential**
  - The five largest fields alone have nearly 250 million bbls of EOR potential
  - Using different methodology, MGSC estimated Basin (including KY) potential of 0.8-1.3B bbls
  - We chose two representative fields for our analysis:
    - New Harmony, which straddles Illinois and Indiana, was chosen given technical data in public domain; it is typical of large fields in Illinois Basin (ILB)
    - Concord and Herald represent small field opportunity, with potentially local CO2 source
  - Potential net CO2 demand estimated at 160 - 250 MMT

- **The region has an abundance of low cost CO2**
  - There is more than 17 MMT CO2 emitted annually by ethanol fermentation process in Illinois, Indiana and Iowa – CO2 that can be captured at an estimated cost around $25/MT
  - ADM is currently injecting 1MMT of CO2 from their Decatur plant into the Mt. Simon formation, as part of a 3 year DOE project testing geological storage, CO2 may be available for EOR when project completes
  - CO2 from future gasification projects, currently planned to be transported south by the proposed Denbury pipeline, could also be used locally for regional CO2-EOR

- **Representative field economics suggest reasonable profitability for larger fields and potentially marginal results for smaller fields**
  - New Harmony project, with reference case assumptions, produces after tax IRR of 21%
  - Concord and Herald lead to smaller returns of after tax IRR of 9%. We believe returns could be better given field age and close proximity to low price CO2 source

- **State economy would benefit, adding 1,550-3,100 direct jobs**

Illinois / Indiana state overview

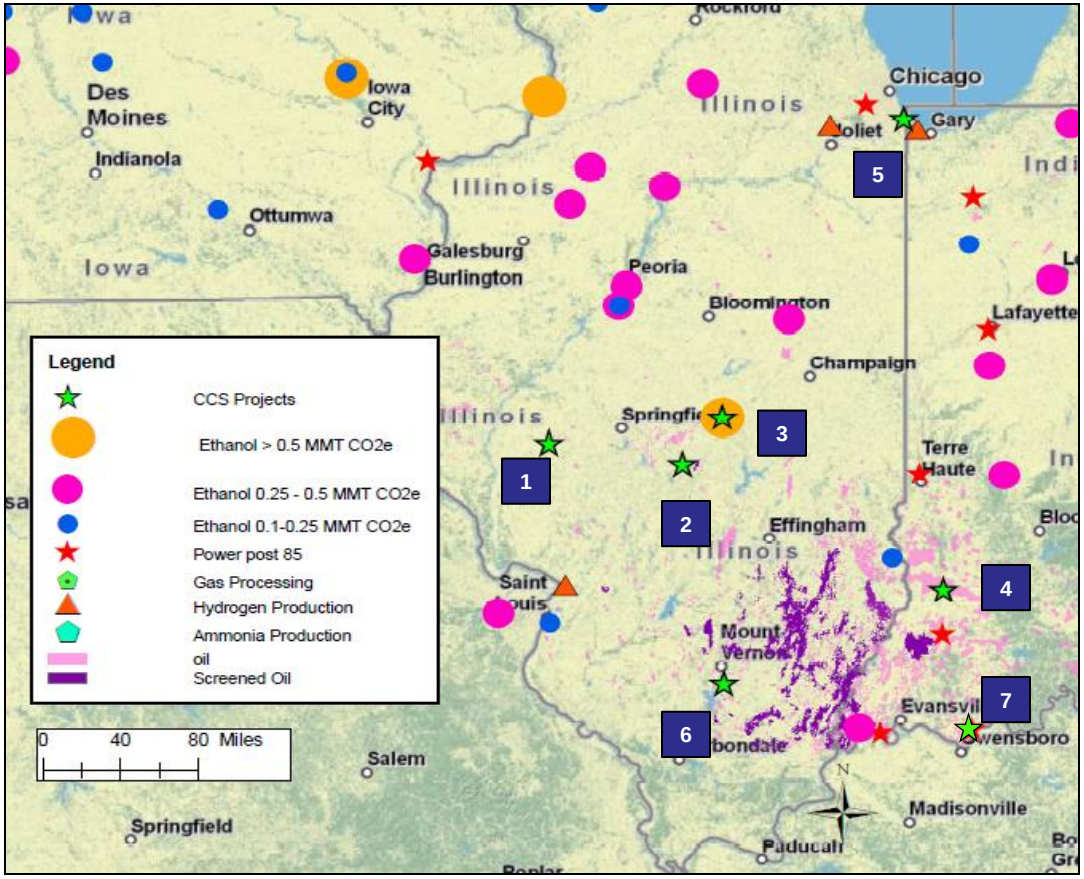
CO2 Emissions Overview

Screened sources

Source	Illinois (MMT CO2)	Indiana (MMT CO2)
Power	0.5	15.4
Ethanol	3.5	3.3
Ammonia Production	0.3	
Hydrogen Production	0.6	0.5
Total	**4.9**	**19.2**

Oil Overview

Cumulative Production: 3.5 billion bbl



Source: ISGS, IGS, EPA, DOE, RFA, CCI

Potential Projects (emissions and status)

1. FutureGen: 1.3 MMT CO2

- *Status:* Planned – Well characterization

2. Tenaska Taylorville: 3.2 MMT CO2

-*Status:* Passed Senate vote; House (2012)

3. ADM Decatur – 0.8 MMT CO2

-*Status:*

a. IBDP: Injection (1 MMT CO2 over 3-years)
b. IL- ICCS: Under Construction

4. Duke Edwardsport: 3.6 MMT CO2

-*Status:* Under Construction

***5,6.* Chicago Clean Energy & Power Holdings:** 5.5 MMT CO2

- *Status:* Legislation passed – awaiting regulator and local review

***7.* Indiana Gasification:** 4.5 MMT CO2

- *Status:* Legislation passed

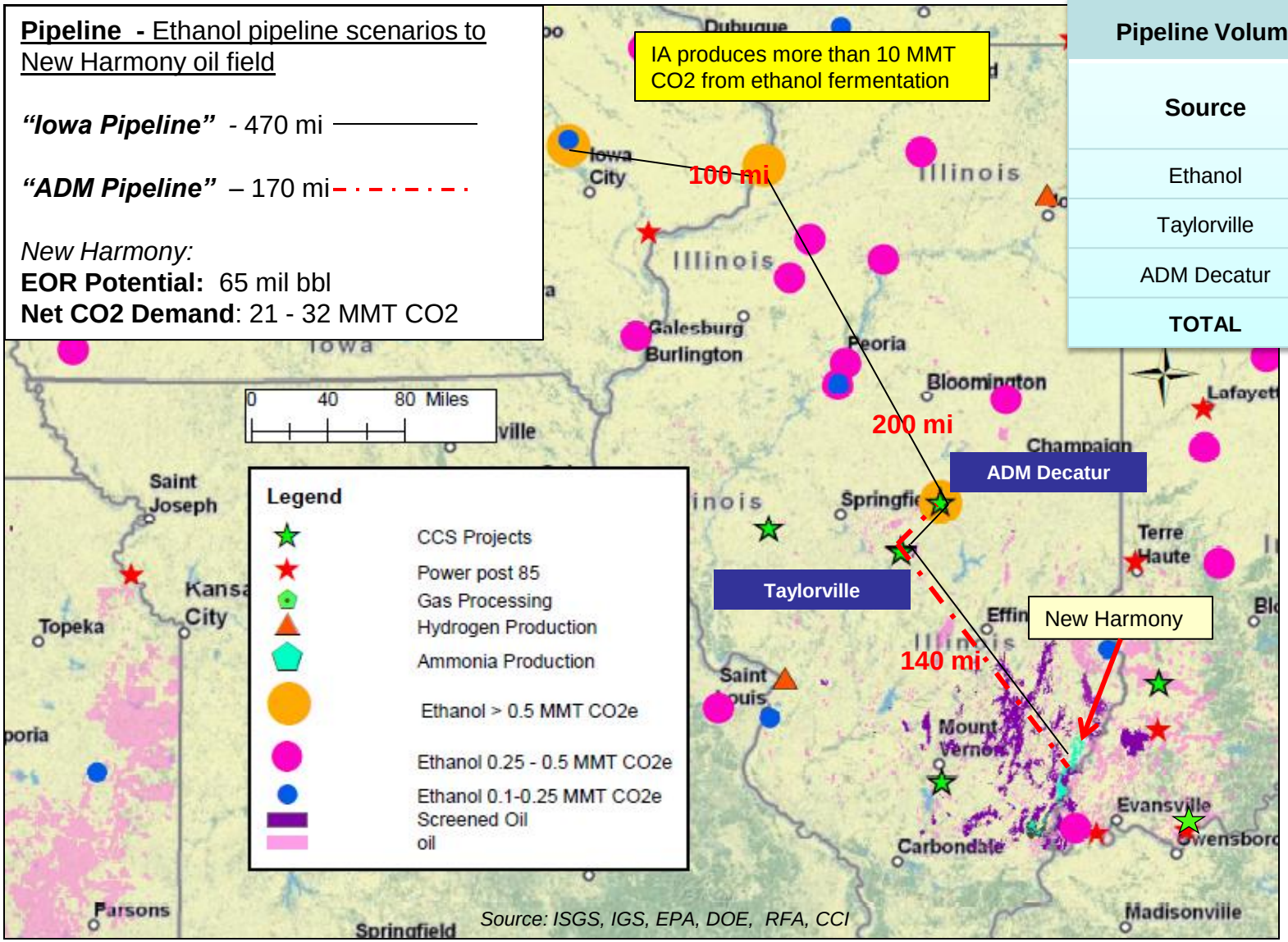
Illinois, Indiana and Iowa have an abundance of low-cost CO2 from ethanol fermentation

Pipeline - Ethanol pipeline scenarios to New Harmony oil field

"Iowa Pipeline" - 470 mi ——————

"ADM Pipeline" – 170 mi- - - - - - -

New Harmony:
EOR Potential: 65 mil bbl
Net CO2 Demand: 21 - 32 MMT CO2

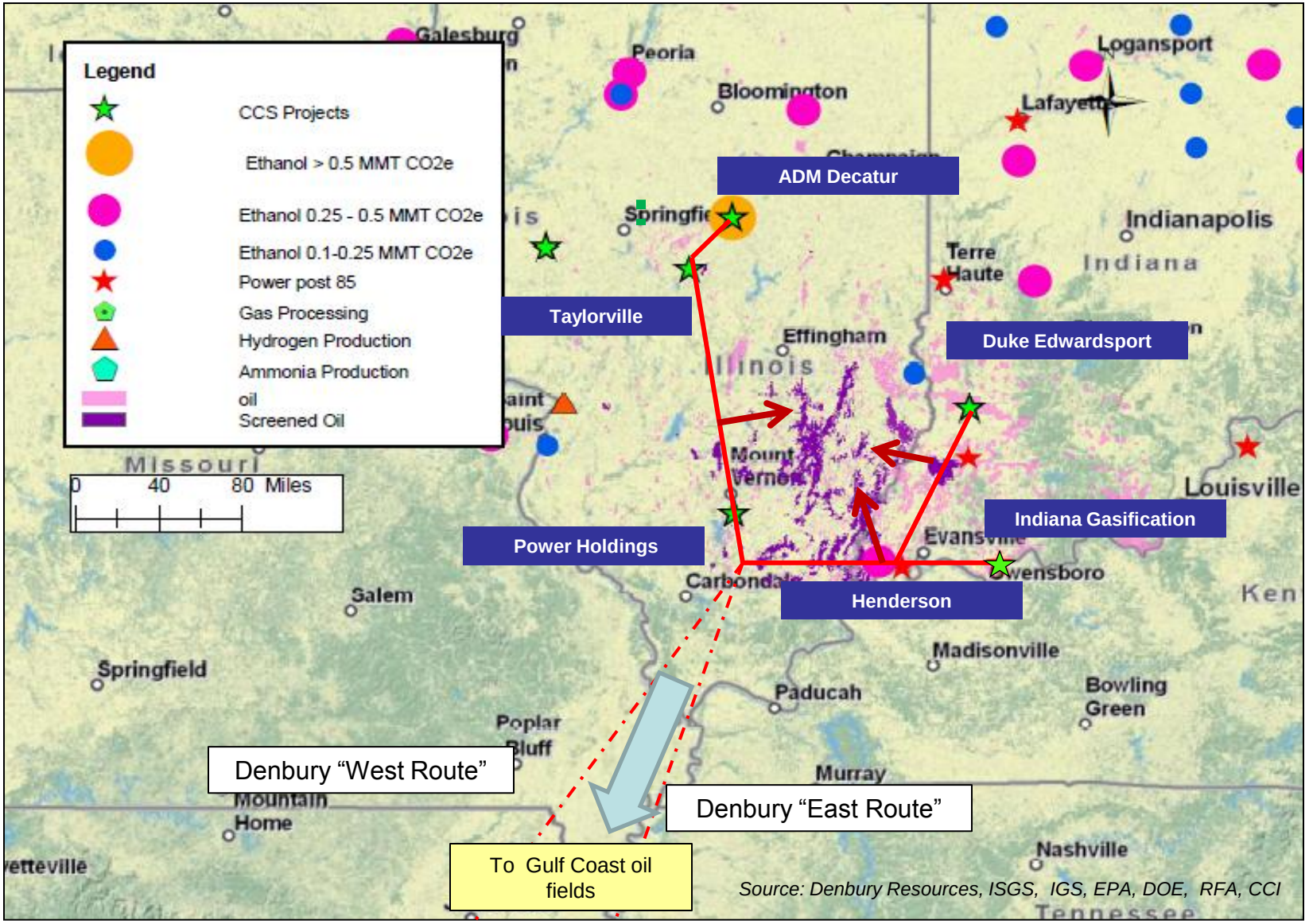


Source: ISGS, IGS, EPA, DOE, RFA, CCI

Pipeline Volume (total length)

Source	Emissions (MMT CO2)
Ethanol	3.8
Taylorville	3.2
ADM Decatur	0.8
TOTAL	7.8

Potential gasification projects could supply CO2 to Illinois Basin oil fields via spurs from prospective Denbury pipeline



Representative field economics suggest reasonable profitability for larger fields…

- **We used two representative scenarios to assess potential CO2-EOR production economics for the Illinois Basin (ILB) – New Harmony is the "large field" case**
  - New Harmony field, straddling Illinois and Indiana, was chosen for analysis due to technical data in public domain; it is typical of large fields in ILB: 10+, often stacked reservoir systems
  - The field has a potential for 50-80M bbls of additional EOR production over a 20 year period
- **Our reference case assumptions lead to an after-tax project IRR of about 21%**
  - We assumed that wells will produce from multiple reservoirs, but only OOIP estimates for reservoirs that screened miscible were included in our model
  - For New Harmony, investment of about $1.1B leads to an after tax $50M NPV@20%
- **Various tested sensitivities indicate that the project may or may not remain economic:**
  - The availability of CO2 at $25 would improve project economics significantly
  - Condition of old wells (many pre-1942) and equipment is critical. We assume 50% of wells will require re-drilling, much higher capital requirements may render project infeasible

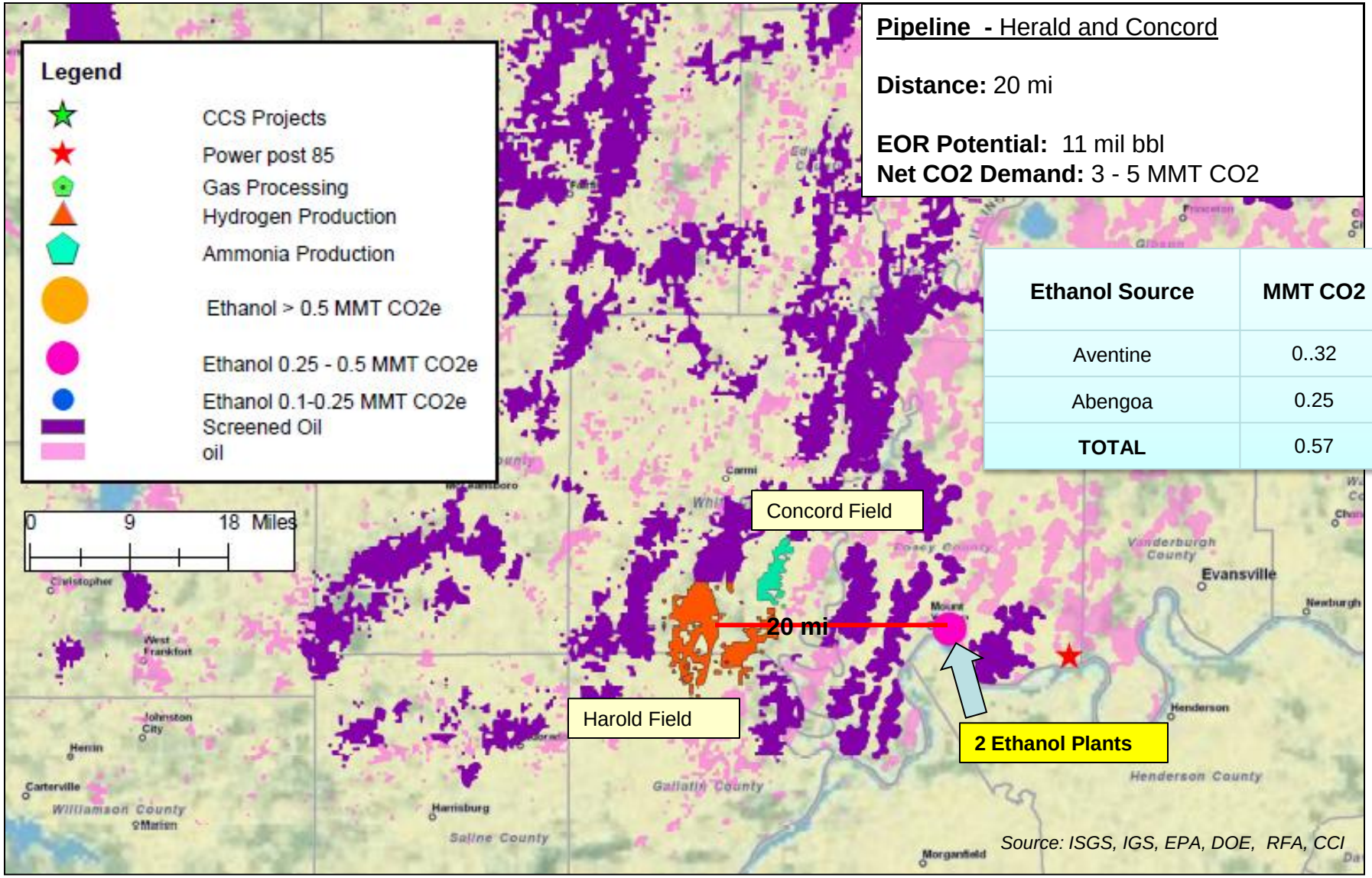
Economics, Before/After Tax	BT IRR	AT IRR	BT NPV @ 20%	AT NPV @ 20%
Reference case	**33%**	**21%**	**$ 535 M**	**$ 50 M**
Sensitivities				
CO2 Prices				
▪ CO2 @ $25/MT	**40%**	**26%**	**$ 780 M**	**$ 240 M**
▪ CO2 @ $80/MT	**16%**	**9%**	**$ (180) M**	**$ (585)M**
Oil price $/bbl 2011 $70	**16%**	**8%**	**$ (135) M**	**$ (400) M**
Higher Cost				
▪ Investment + 20%	**27%**	**16%**	**$ 315 M**	**$ (170) M**
▪ Higher Recycle Cost	**28%**	**18%**	**$ 370 M**	**$ (100) M**

…and potentially marginally positive results for smaller fields

- **Concord and Herald represents potentially attractive small field opportunity**
  - Younger fields, so assume better aggregate conditions and thus potentially less capital cost
  - Combined fields could lead to 9–13M bbls of EOR production over a 20 year period
- **Our reference case assumptions lead to an after-tax project IRR of 10%, a marginal result**
  - For these fields the investment of about $230M leads to an after tax $(70M) NPV @20%
- **Project's economics could improve, especially if linked directly to CO2 source from local ethanol plant in Indiana :**
  - A "below market" CO2 price, in combination with a 20% reduction in capital costs from our reference case in light of the age of field discoveries, leads to an after tax project IRR of 21%

Economics, Before/After Tax	BT IRR	AT IRR	BT NPV @ 20%	AT NPV @ 20%
Reference case	**18%**	**10%**	**$ (10)**	**$ (70)**
Sensitivities				
CO2 Prices				
▪ CO2 @ $25/MT	**24%**	**14%**	**$ 25**	**$ (40)**
▪ CO2 @ $80/MT	**6%**	**0%**	**$ (120)**	**$ (170)**
Oil price $/bbl 2011 $70	**1%**	**-5%**	**$ (110)**	**$ (140)**
Higher Cost				
▪ Investment + 20%	**13%**	**6%**	**$ (60)**	**$ (120)**
▪ Higher Recycle Cost	**15%**	**8%**	**$ (35)**	**$ (95)**

Smaller fields could benefit from direct CO2 sourcing



State economy would benefit from additional jobs

- **EOR development in Illinois could add to job creation within the state**
  - EOR could directly support 1,550 – 3,100 new jobs*
  - Indirect employment could add another 4,600 – 9,300 jobs* in supporting industries
  - The number of jobs would be higher during the initial investment stage

- **Income taxes from these jobs would create an added state revenue stream**

* Note: Estimates based on 15 – 30 year production and Wood Mackenzie job multipliers data

Next Steps

- **Utilize data from small pilots and simulations for further education of EOR possibilities**
  - Increase level of results from simulations into public domain
  - Availability of data could increase confidence among operators

- **Given the abundance of proposed gasification and capture projects in the region, attach one or several of the projects to large scale EOR demonstrations**
  - ADM is currently injecting for testing of geological storage in pilot scale project and has a follow-on commercial scale demonstration project:
    - After commercial scale demonstration, can CO2 be utilized for EOR purposes?
    - Can pilot project capture equipment provide truckload quantities for EOR pilots at reasonable cost?
  - A market demand for CO2 would improve economics for carbon capture projects

- **As possibilities become more clear, could state support development of incentives in support of CO2-EOR development?**

OHIO

Ohio's large resource potential could be commercially viable

- **Ohio could be a great commercial success although much work and characterization is needed in order to confirm these assessments**
  - Screens suggest approximately 500 million bbls of EOR potential in state
  - Despite Ohio's long history to beginnings of US oil industry, lack of secondary recovery means that limited data exists that operators can use to project performance and book reserves
    - Water flood performance is often used as approximate guide for CO2 floods
  - An abundance of small operators and aging/inappropriate field infrastructure adds to obstacles
  - Potential net CO2 demand estimated at 190 – 300 MMT

- **East Canton field economics suggest strong commercial potential**
  - Chosen by state geologists for 2010 pilot reservoir simulation; data in public domain
  - Strong operator concentration and relatively young infrastructure (discovered 1953) would benefit in ability to effectively implement EOR approach
  - Our reference case assumptions lead to an after tax IRR of 28%

- **While sourcing of CO2 is technically feasible through capture in many local power plants – high capture costs would likely lead to high cost of CO2**
  - CO2 from traditionally low-cost sources (ethanol, ammonia) is limited, but may be just enough to begin/test limited EOR production
  - AEP Mountaineer could have been a reliable source of CO2 if project had been approved
  - Potential future shale gas opens new source opportunities where CO2 could be produced, for example development of ammonia manufacturing

- **EOR could directly support 1,550 – 3,100 new jobs in the state of Ohio**

Ohio state overview

CO2 Emissions Overview

Screened Sources

Source	Ohio (MMT CO2)
Power	9
Ethanol	1.5
Ammonia Production	0.9
Hydrogen Production	0.7
Total	**12**

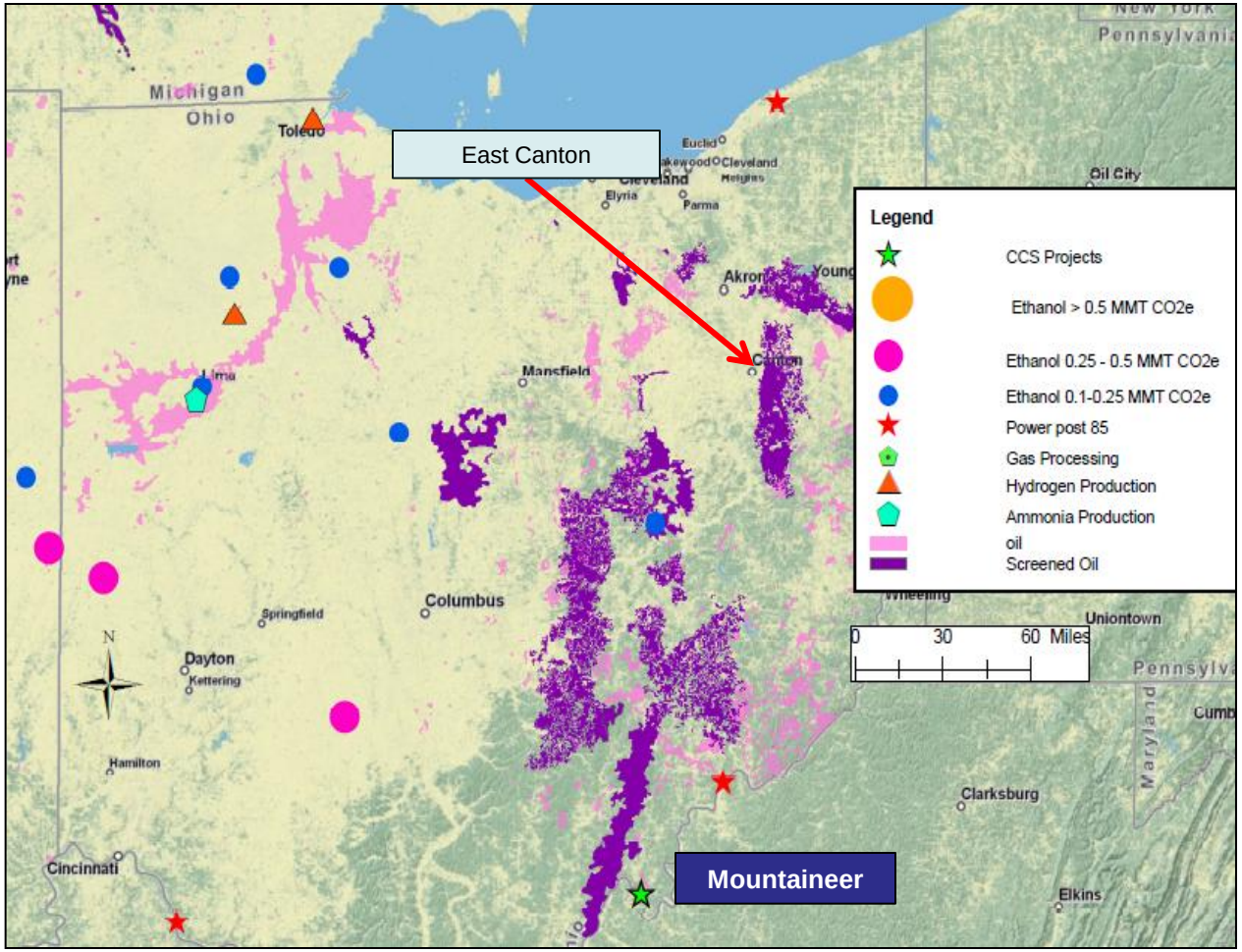
Proposed Projects

AEP Mountaineer (WV)
Status: On-hold

Oil Overview

Cumulative Production: 1.1 Billion bbls*

Very little waterflooding has taken place



Source: OHDNR, EPA, RFA, CCI

East Canton economics suggest great commercial potential

- **We chose East Canton field as it is a large resource, with recent reservoir study, and strong operator concentration for the region (~2/3 of the wells in the field owned by two operators)**
  - Publicly available pilot simulation results were scaled to entire field
  - Clinton Sandstone" reservoir in field is widespread throughout Appalachian Basin oil fields
  - The field has a potential for 75 – 280M bbls of additional EOR production
- **Our reference case assumptions lead to an after-tax project IRR of 28%**
  - For East Canton, investment of about $5B leads to an after tax $1.1B NPV@20%
- **Economics are especially sensitive to CO2 price, assumed only CO2 injection (no water)**
  - Field has never been waterflooded, a traditional precursor to EOR, due to geological constraints (low permeability) – hence continued only CO2 injection assumed
  - Relatively high net CO2 utilization rates of 0.7MT/bbl after 5 years and 0.8 after 10 years.

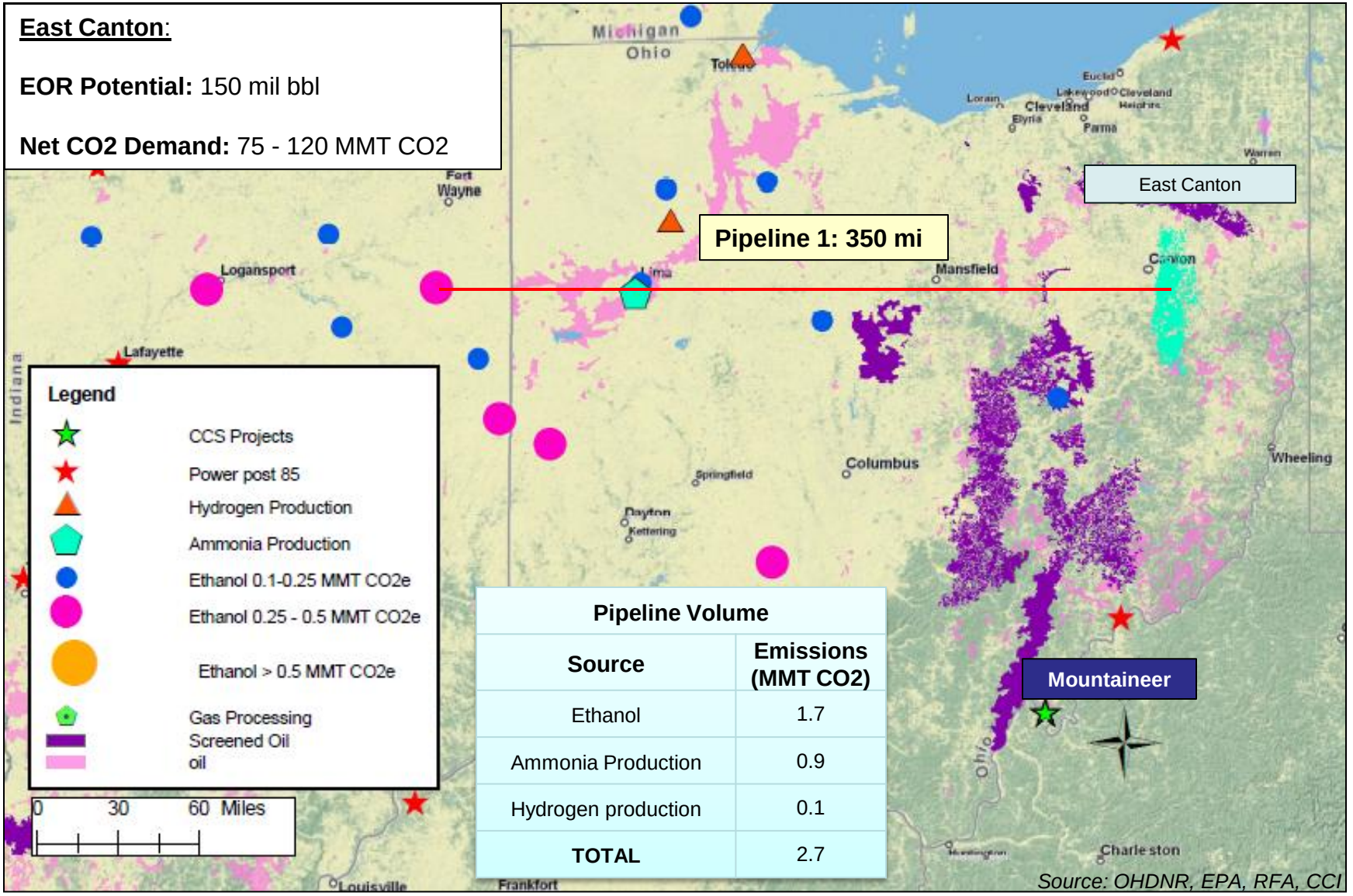
Economics, Before/After Tax	BT IRR	AT IRR	BT NPV @ 20%	AT NPV @ 20%
Reference case	**47%**	**28%**	**$ 3,660 M**	**$ 1,130 M**
Sensitivities				
CO2 Prices				
▪ CO2 @ $25/MT	**61%**	**38%**	**$ 6,110 M**	**$ 2,720 M**
▪ CO2 @ $80/MT	**-11%**	**-20%**	**$ (2,380) M**	**$(3,040) M**
Oil price $/bbl 2011 $70	**23%**	**11%**	**$ 310 M**	**$(1,090) M**
Higher Cost				
▪ Investment + 20%	**36%**	**21%**	**$2,630 M**	**$ 100 M**
▪ Higher Recycle Cost	**41%**	**24%**	**$3,160 M**	**$ 685 M**

Sourcing of CO2 technically feasible, but potentially at higher cost

East Canton:

EOR Potential: 150 mil bbl

Net CO2 Demand: 75 - 120 MMT CO2



Pipeline Volume	
Source	**Emissions (MMT CO2)**
Ethanol	1.7
Ammonia Production	0.9
Hydrogen production	0.1
TOTAL	2.7

Source: OHDNR, EPA, RFA, CCI

State economy would benefit from additional jobs

- **Commercial CO2-EOR development in Ohio could add to job creation within the state**
  - EOR could directly support 1,550 – 3,100 new jobs*
  - Indirect employment could add another 4,600 – 9,200 jobs* in support industries
  - The number of jobs would be higher during the initial investment stage

- **Income taxes from these jobs would create an added state revenue stream**

* Note: Estimates based on 15 - 30 year production and Wood Mackenzie job multipliers data

Next steps

- **Ohio and East Canton has little waterflood experience, and therefore minimal injection response data, so further studies are required to confirm reservoir properties and potential**
  - Hence current simulations assume continued pure CO2 injection rather than less costly traditional water alternating gas (WAG) approach, which uses significantly less CO2
  - Fewer than 15 fields have had any type of secondary recovery
  - Reservoir characterizations and pilot simulation in other CO2-EOR candidate field are needed (eg Morrow, Birmingham-Erie, Baltic)

- **Develop larger scale commercial CO2 flood pilot in East Canton to improve reservoir characterization data and prove technical viability in "Clinton Sandstone"**
  - Cooperation/partnership between state/federal/operator desirable

- **Lower cost CO2 supply is problematic, hence possibilities for sourcing CO2 and associated cost need to be evaluated**
  - Could we aggregate ethanol from Indiana and Western Ohio?
  - Could we create a "cost neutral" project with a power plant that would be commercial?

- **Investigate possibilities of synergy with future shale gas production**
  - Evaluate impurities in Marcellus or Utica shale gas to determine if future gas processing will extract commercial quantities of CO2
  - Would production of "low cost" shale gas lead to gas based manufacturing (for example ammonia) – with CO2 as a by-product?

KANSAS

CO2-EOR should have commercial potential in Kansas

- **Screening process indicates 750 million barrels or more of technical CO2- EOR potential**
  - This may be conservative, reflecting adjustments to account for limited data
  - Kansas has by far largest oil resources in the MGA region
  - Kansas shares geological formations with Oklahoma, where commercial CO2 floods are proven and are serviced by existing and planned CO2 pipeline infrastructure
  - Potential net CO2 demand estimated at 240 – 370 MMT

- **Kansas has access to high volume of region's ethanol-based CO2**
  - Although the in-state supply of low cost CO2 is moderate, neighboring Nebraska produces about 6 MMT per annum of ethanol-based CO2
  - Kansas is currently exporting by pipeline CO2 from ethanol (and planned from ammonia production plants) to northern and possibly central Oklahoma for EOR

- **Our financial modeling suggests positive economics, but needs further analysis**
  - The Hall Gurney field was chosen for analysis, given level of data in the public domain and previous CO2 pilot (which proved somewhat inconclusive)
  - Our reference case economics suggest an after-tax project IRR of 22%
  - However, there are many questions around assumptions which need to be tested further: These include OOIP level, estimated production given experience in similar formations and costs associated with pattern practice. Changing assumptions can lead to wide fluctuations, with economics turning marginal or negative

- **State economy would benefit from additional jobs – direct 2,300 – 4,600**

Kansas state overview

CO2 Emissions Overview

Screened Sources

Source	Kansas (MMT CO2)
Power	0
Ethanol	1.4
Ammonia Production	1.4
Hydrogen Production	0.5
Total	**3.3**

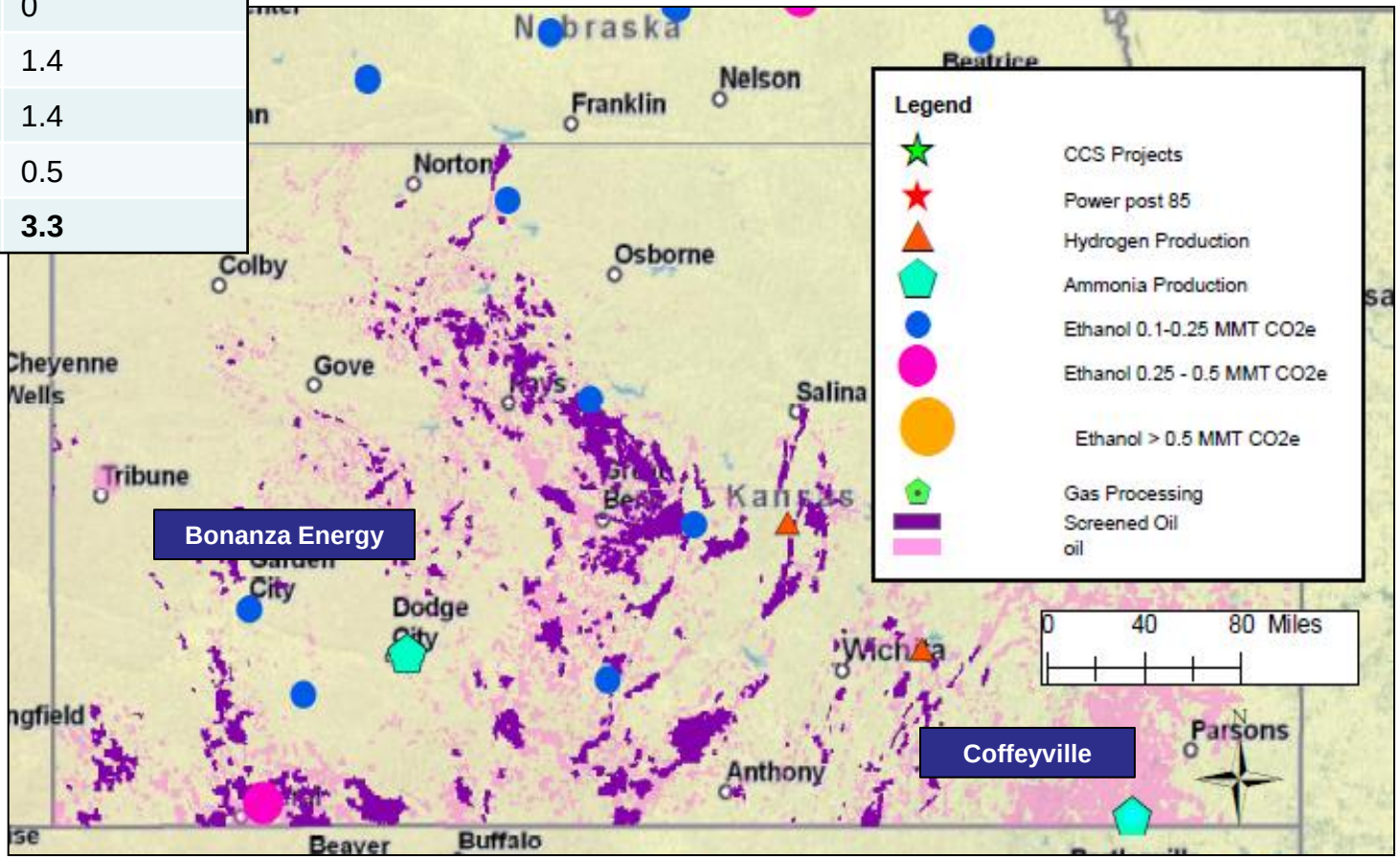
Potential / Ongoing Projects

Coffeyville Resources
Status: Chaparral to "export" to OK > 0.8 MMT CO2 for EOR in 2013

Bonanza Energy Ethanol (Garden City)
Status: PetroSantander to inject 0.15 MMT of captured CO2 into nearby Stewart Field for EOR.

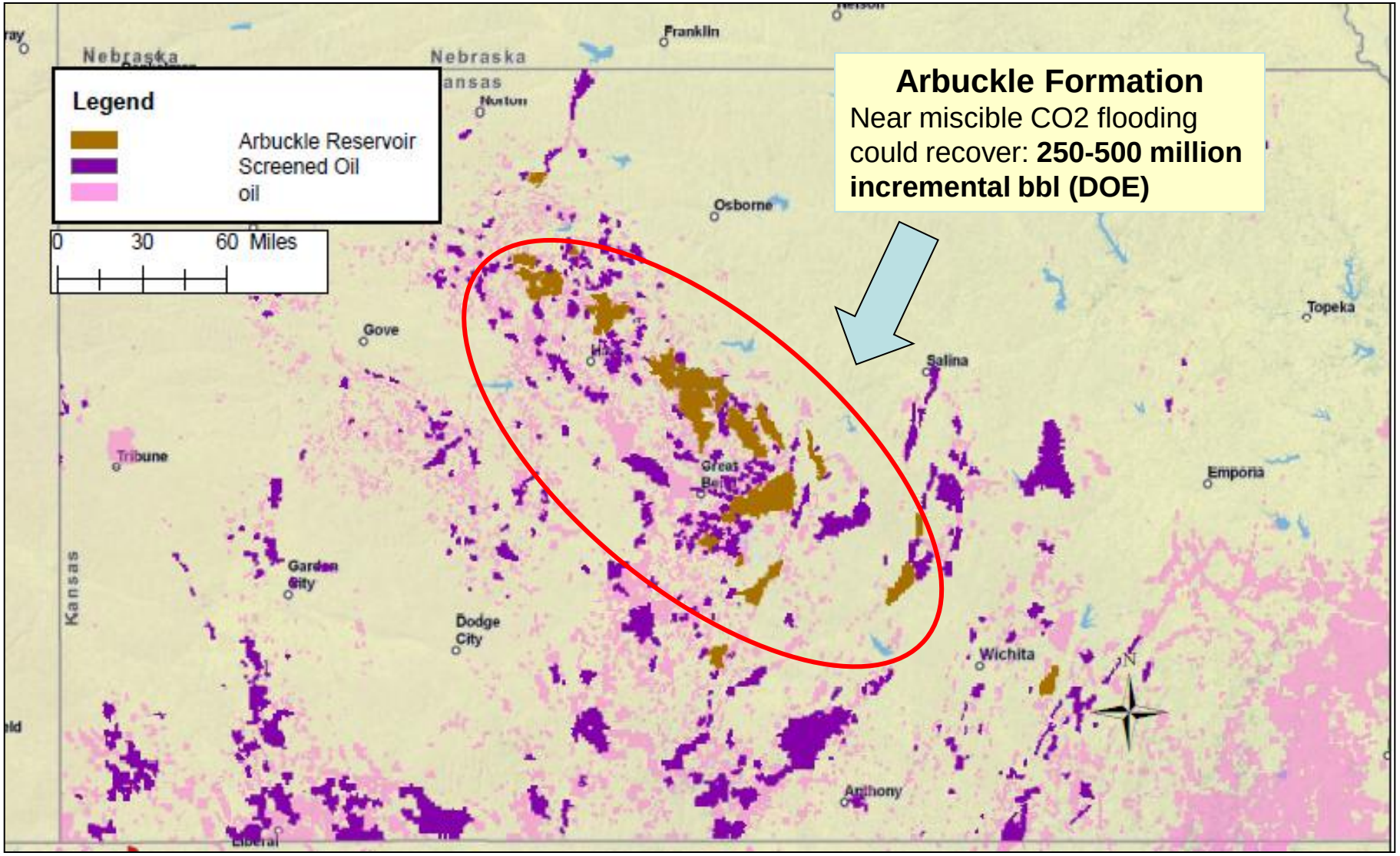
Oil Overview

Cumulative Production: 6.2 billion bbl



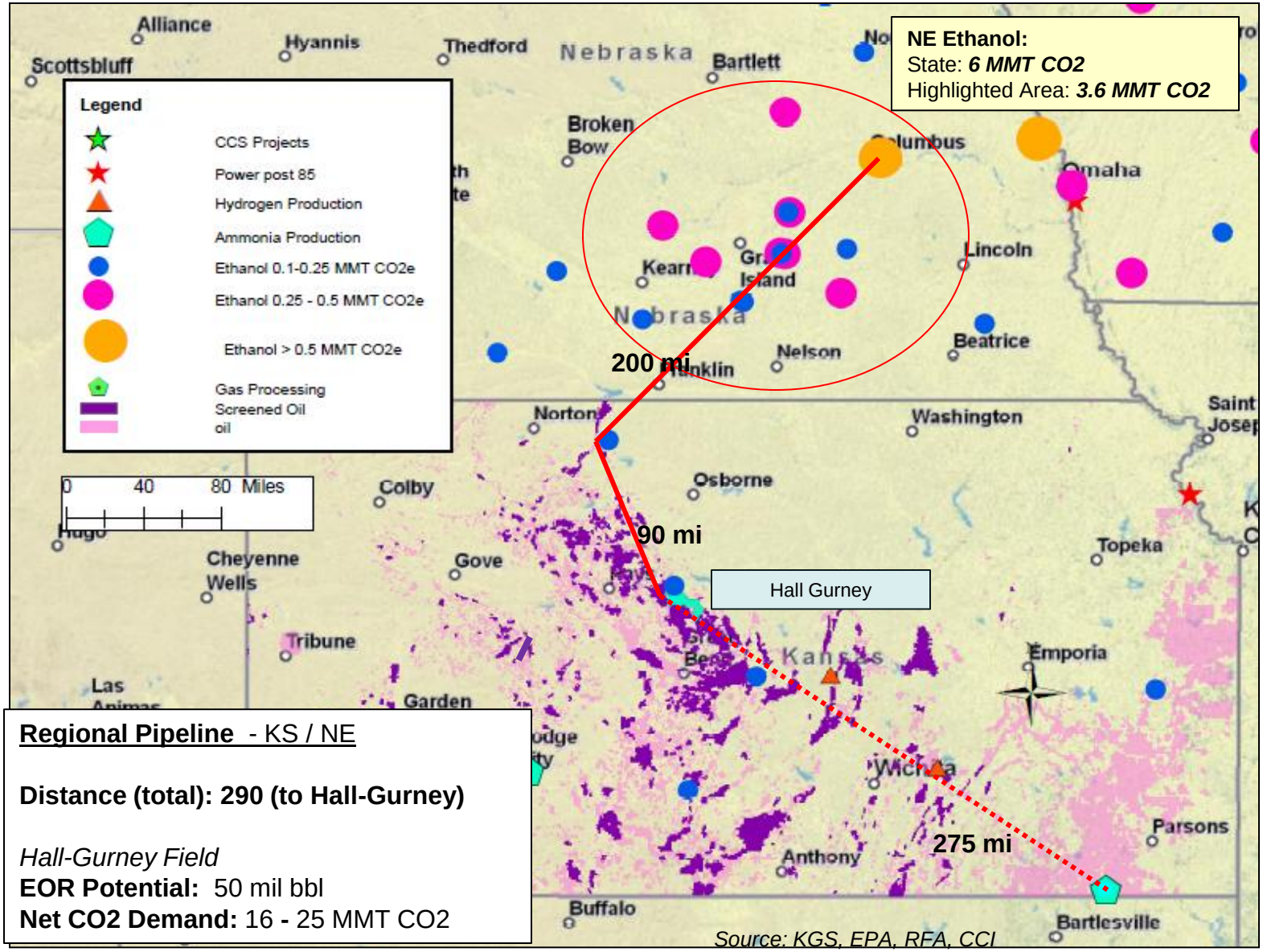
Source: KGS, EPA, RFA, CCI

Kansas has tremendous technical production potential in the Arbuckle formation



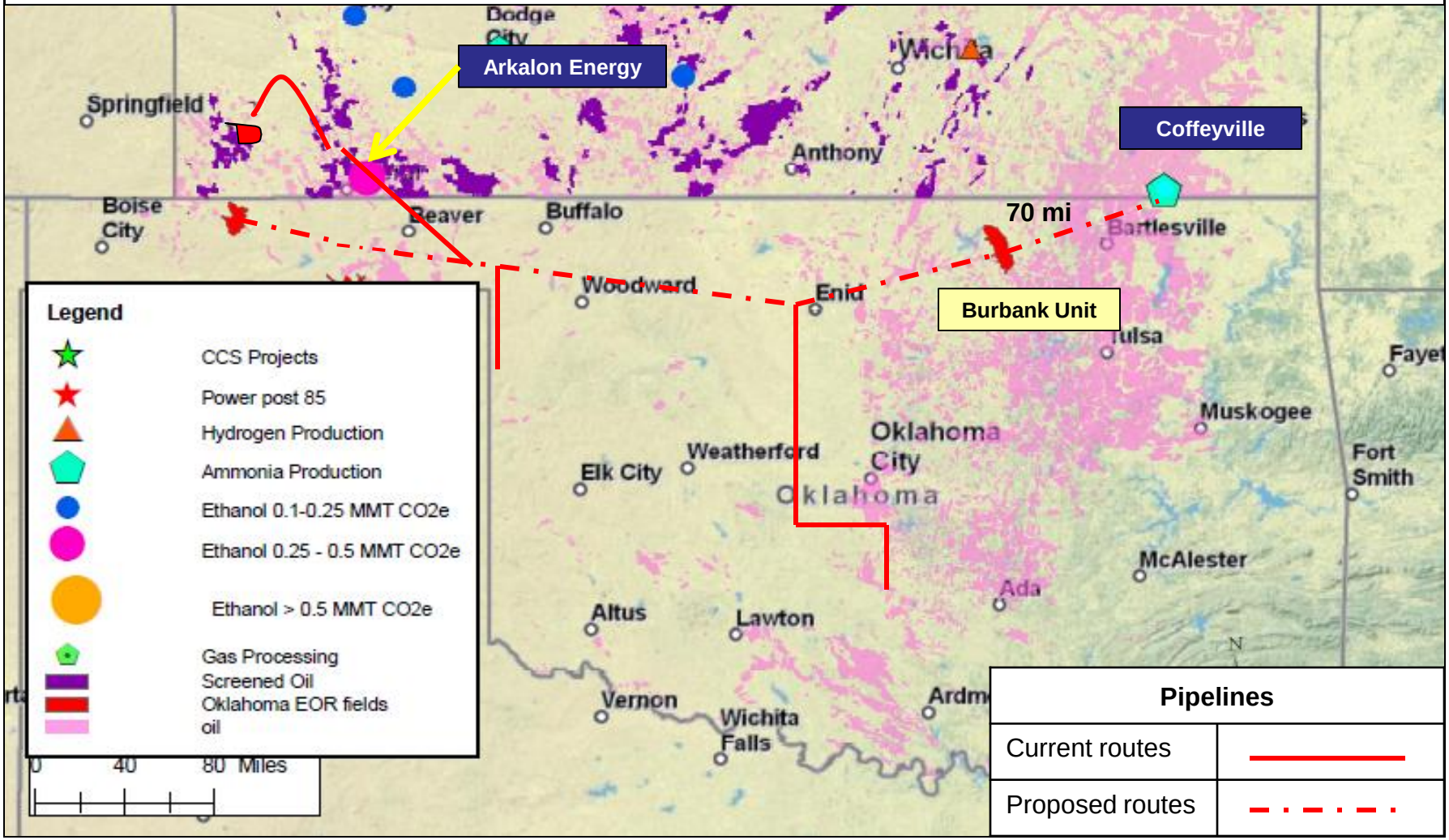
Source: KGS, DOE, CCI

State has access to high volume of region's ethanol-based CO2



Kansas is currently exporting CO2 to Oklahoma for EOR

Chaparral is currently purchasing CO2 for EOR from Arkalon Energy's ethanol plant and has contracted for an additional 0.8 MMT CO2 / year from Coffeyville Resources Nitrogen Fertilizers plant.



Source: Chaparral Energy, KGS, OGS , EPA, RFA, CCI

Our financial modeling suggests positive economics but further analysis is needed

- **We chose Hall Gurney field for our economic analysis**
  - It is historically one of the most prolific fields in Kansas; both producing reservoirs in field (Lansing-Kansas City and Arbuckle) are common throughout central Kansas
  - DOE CO2 injection pilot test proved moderately successful – even if somewhat inconclusive

- **Our reference case indicates after tax IRR of 22% - but need to test assumptions further**
  - Reference case $1.8B capital investment leads to an after tax profit of $140 M NPV@ 20%
  - Economics could be better given the following:
    - Reference capital investment (50% new wells) is on the high side due to relatively small "pattern" size assumption (assumed 20 acres vs. 40 acre in West Texas). NPV impact would be about $750M increase at 40 acre size pattern
    - Production experience in W.Texas for similar lithology (carbonate) suggests stronger performance that our Illinois simulations based assumptions indicate
  - However, economics could turn marginal or very negative given the following:
    - Capital investment (50% new wells) could be much higher if a 10 acre pattern size, typical for water floods in central Kansas, was to be utilized (more than $1B decline in NPV)
    - More conservative assumptions on OOIP would lead to NPV decline of $750M
  - Such wide fluctuations clearly indicate need for further work to tighten the range of possibilities

- **The studies currently underway in Kansas may provide some of this data**

Our financial modeling suggests positive economics but further analysis is needed (cont'd)

- **Various tested sensitivities indicate that we need further analysis:**
  - With an investment of $1.8B, a 20% reduction in capex would leads to a positive after tax NPV of more than 500M @ 20%

Economics, Before/After Tax	BT IRR	AT IRR	BT NPV @ 20%	AT NPV @ 20%
Reference case	**35%**	**22%**	**$ 955 M**	**$ 140 M**
Sensitivities				
CO2 Prices				
▪ CO2 @ $25/MT	**42%**	**27%**	**$ 1,350 M**	**$ 435 M**
▪ CO2 @ $80/MT	**17%**	**9%**	**$ (200) M**	**$ (890) M**
Oil price $/bbl 2011 $70	**18%**	**9%**	**$ (85) M**	**$ (560) M**
Highest Cost				
▪ Investment + 20%	**28%**	**17%**	**$ 595 M**	**$ (220) M**
▪ Higher Recycle Cost	**29%**	**19%**	**$ 685 M**	**$ (105) M**

Next Steps

- **More characterizations required to validate resource base and commercial production potential. Some studies already in progress**
  - TORP report on near-miscibility in technically challenging Arbuckle is based on lab work and will require follow-on pilot
  - Characterization studies are due to be published this year by KGS and a corporate consortium for CCS and EOR in southern Kansas
    - CCS-EOR for Wellington field in south-central Kansas and EOR for four fields in southwest Kansas
  - May use the field specific modeling for the Wellington and southwest Kansas studies, as well as the TORP Arbuckle study, to develop distributable "synthetic" dimensionless curves for academia and operators to use in scoping models for high level production estimates in fields and leases producing from similar formations.

- **Policy review and/or other actions are needed to address field remediation**
  - Hall Gurney and other central Kansas fields are in latter stages of secondary production and dominated by "stripper" wells, often producing less than 5 bbl per day
  - Many wells have already been plugged and abandoned, not always using modern methods
  - Field remediation costs are uncertain but large, and will prejudice economic potential
  - Fields will likely require unitization, which may take 2-3 years and also prejudice economics. Kansas has a compulsory field wide unitization law (but nothing less than field scale), with possibly high bar.

- **As Kansas proceeds towards better assessment of oil potential, "Residual Oil Zone" potential may be considered**
  - Technical advancements and research in the last 5-10 years have aided the "discovery" of significant oil resources from "residual" zones below oil-water contact (in some geological conditions) in West Texas. The Permian Basin is only region in country where ROZ oil has been booked as reserves and commercially produced, but Wyoming has also characterized significant ROZ potential in state. ROZ oil requires CO2 to produce.

APPENDIX

Abbreviations, acronyms and units of measure

Units of Measure

cf	Cubic feet
ft	Feet
bbls	Barrels
mbbls	Thousand barrels
Mbbls	Million barrels
mb/d	Thousands of barrels per day
mcf	Thousand cubic feet
mi	Miles
MMT	Million metric tons
MT	Metric tons

Abbreviations and acronyms

AT	After Tax
ADM	Archer Daniels Midland
BT	Before Tax
CCS	Carbon Capture and Storage
CO2	Carbon Dioxide

Abbreviations, acronyms and units of measure cont.

CPF	Central Production Facility
DOE	Department of Energy
EIA	Energy Information Administration
EOR	Enhanced Oil Recovery
EORI	Enhanced Oil Recovery Institute, University of Wyoming
IBDP	Illinois Basin / Decatur Project
IGS	Indiana Geological Survey
IRR	Internal Rate of Return
ISGS	Illinois State Geological Survey
KGS	Kansas Geological Survey
MGSC	Midwest Geological Sequestration Consortium
MIDEQ	Michigan Department of Environmental Quality
MRCSP	Midwest Regional Sequestration Partnership
NATCARB	National Carbon Sequestration Database and Geographic Information System

Abbreviations, acronyms and units of measure cont.

NPV	Net Present Value
OHDNR	Ohio Department of Natural Resources
OOIP	Original Oil in Place
RFA	Renewable Fuels Association
TORP	Tertiary Oil Recovery Project, Kansas University
WAG	Water Alternating Gas
WTI	West Texas Intermediate

Conversion table

Conversion table	
1 Barrel of Oil Equivalent	6000 cubic feet
1 Metric Ton	1.1 Short tons
1 Metric Ton	19 mcf


CLINTON FOUNDATION
CLINTON
CLIMATE
INITIATIVE


MGA
Midwestern Governors Association


Great Plains Institute