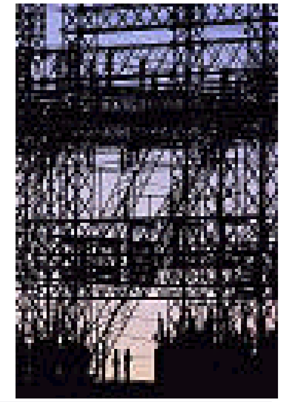
LSU | Center for Energy Studies





Integrated carbon capture, utilization and storage in the Louisiana chemical corridor.

National Energy Technology Labs, CarbonSAFE kick-off meeting, Pittsburgh, PA, March 14, 2017.

David E. Dismukes, Ph.D.
Center for Energy Studies &
College of the Coast and Environment
Louisiana State University

Presentation Outline

1. Introduction
2. Project overview and tasks
3. Team members & organization chart
4. Deliverables, milestones & schedule
5. Conclusions & anticipated benefits

Introduction

Project motivations

The **goals of this project are consistent** with those articulated in the mission of the Office of Fossil Energy (“FE:”) which is to help the United States meet is continual need for secure, affordable and environmentally-sound fossil energy supplies.

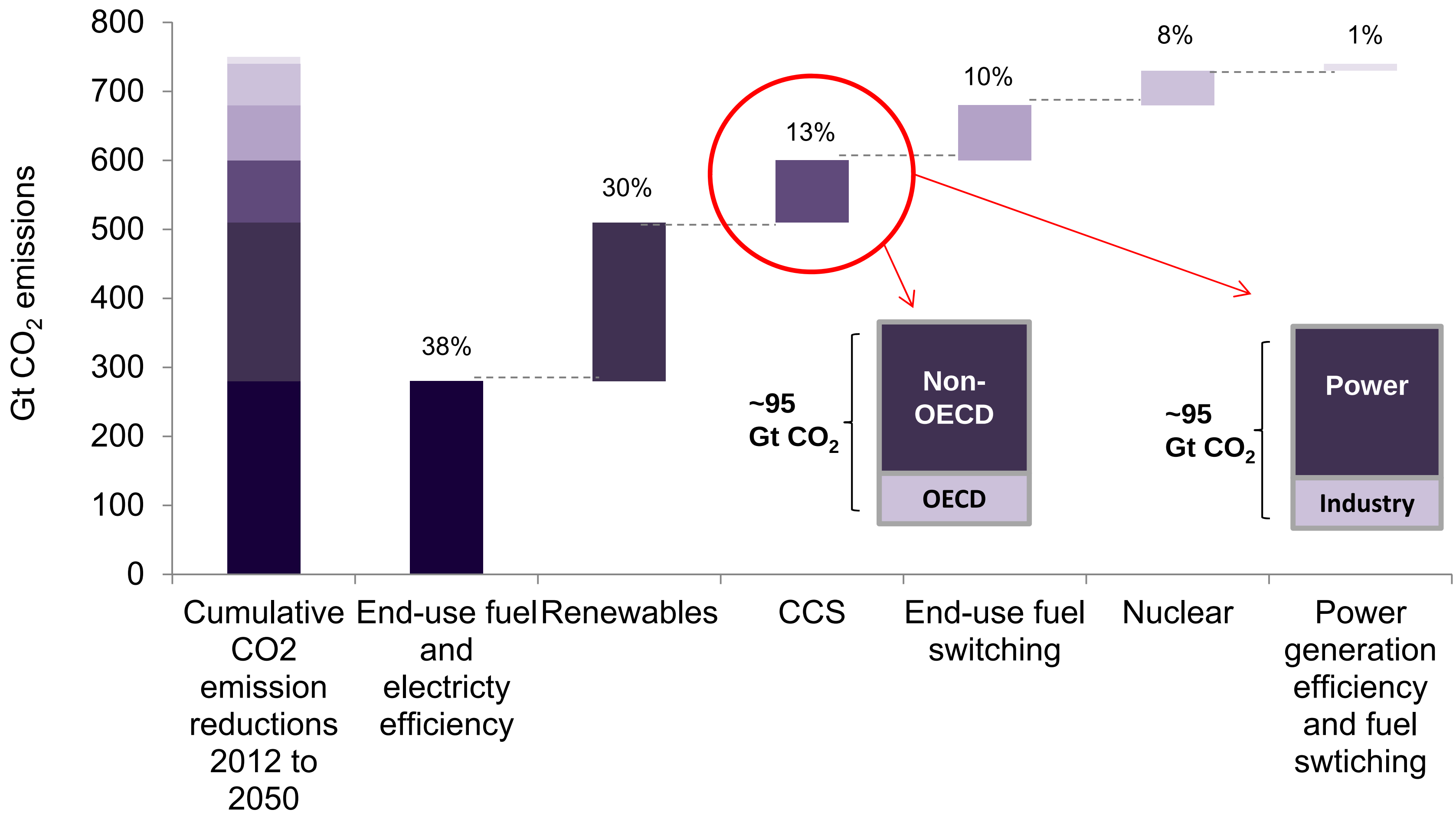
The motivation for funding this, and other similar research projects, is based upon the **recognition that several current and proposed federal and state regulations will severely limit the ability of current and future fossil energy sources to emit carbon to the atmosphere**.

Further, **public demand for energy from low-carbon sources** is growing and will continue to grow in the foreseeable future.

Concurrently, **many major energy-intensive industries**, that span various aspects of the energy value chain, **already recognize these constraints** and public pressures, particularly those energy companies that have an international footprint. Many are also looking at international solutions to this challenge, irrespective, in some instances, of domestic requirements.

Technical potentials for carbon emissions reductions (global).

CCUS is often recognized as an important and considerable means of addressing the carbon emissions problems from fossil fuels.



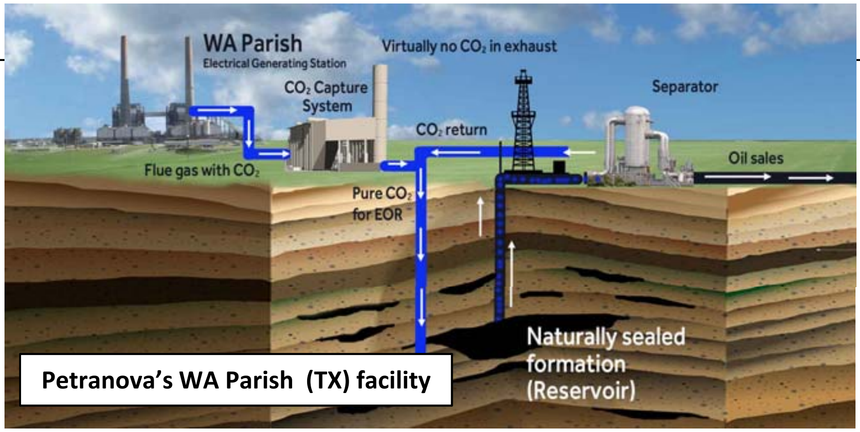
Source: IEA, Energy Technology Perspectives (2015).

Current challenges

One of the **key gaps** in the critical path towards the development of commercial-scale CCS applications in the U.S. has been in **identifying the commercial opportunities and challenges associated with a commercial application** (50 plus million metric ton of storage).

As a result, industrial/commercial applications will **bear a considerable amount of project development risk.**

While there have been some **limited investigations** associated with CCUS applications, they have been **restricted primarily to power applications and not completely with industrial applications** – this is particularly true along the GOM where the two leading applications are based upon the capture of carbon from solid fuel power generation.



Petranova's WA Parish (TX) facility

Southern Company's Kemper MS facility

CarbonSAFE goals

Phase 1 CarbonSAFE goals are to provide funding to research groups capable of (1) **formulating a team** to address the **technical and non-technical challenges** specific to commercial-scale deployment of the CO_2 industrial storage project; (2) development of a **plan encompassing technical requirements** as well as both **economic feasibility and public acceptance** of an eventual storage project; and (3) **high-level technical evaluations of the sub-basin and potential CO_2source(s)**.

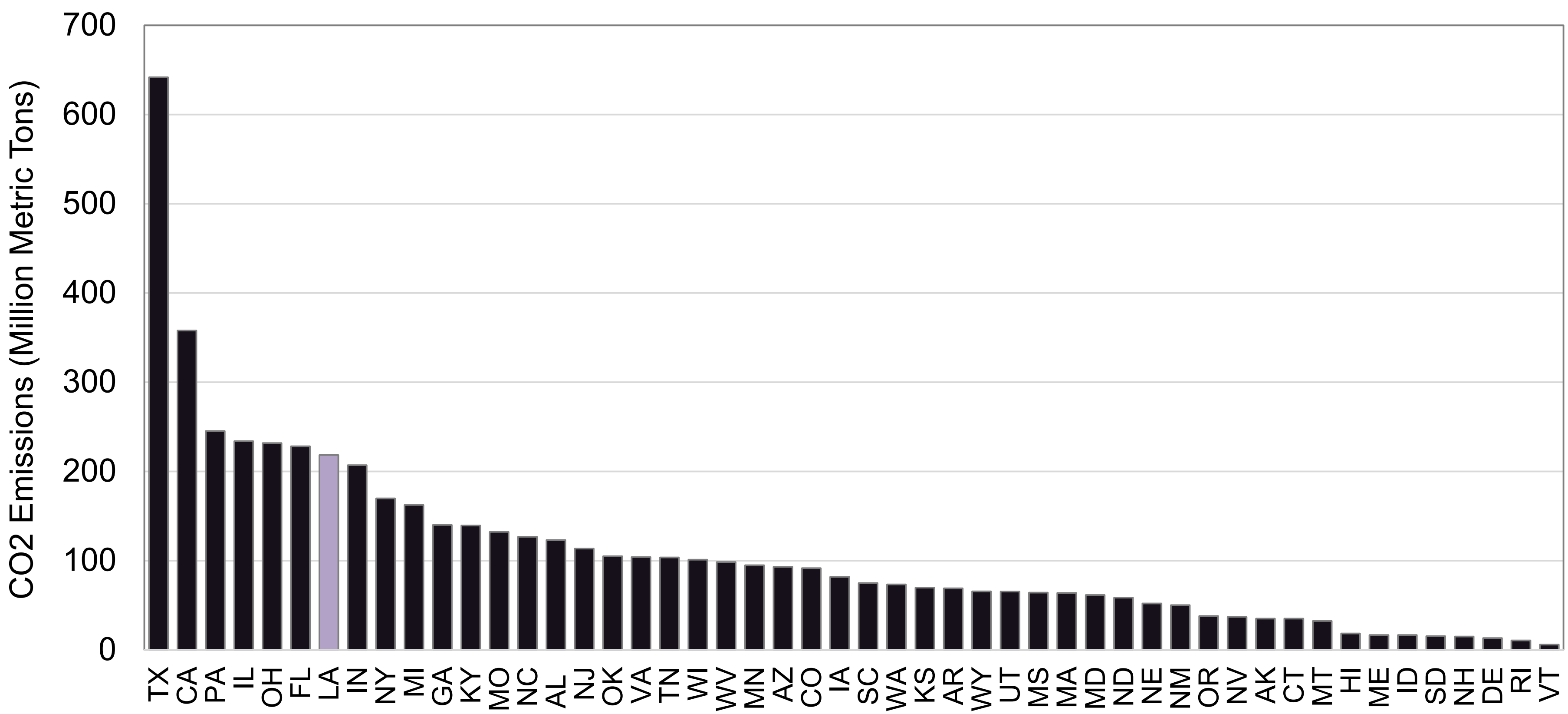
From a business development perspective, having a **geographically-concentrated** physical location with **diversified sources** will be critical in developing positive feasibility outcomes.

Our group believes that the **Louisiana industrial corridor is a well-suited location** to focus these feasibility study efforts, and generate positive results, since:

1) There are a **large number of** geographically-concentrated and diversified **sources** of CO2.
2) There are a **large number of** geographically-concentrated and diverse **storage locations (or "sinks").**
3) There are sufficient number of opportunities to develop **transportation infrastructure linking supply to storage** in these areas.
4) This is a region with a **long history and commercial experience in moving and storing a number of different hydrocarbons**, as well as other hydrocarbon wastes, into underground geological formations.

Energy-Related Emissions by State, 2014

At just under 220 million metric tons of CO2 emissions, Louisiana ranks seventh in the U.S.

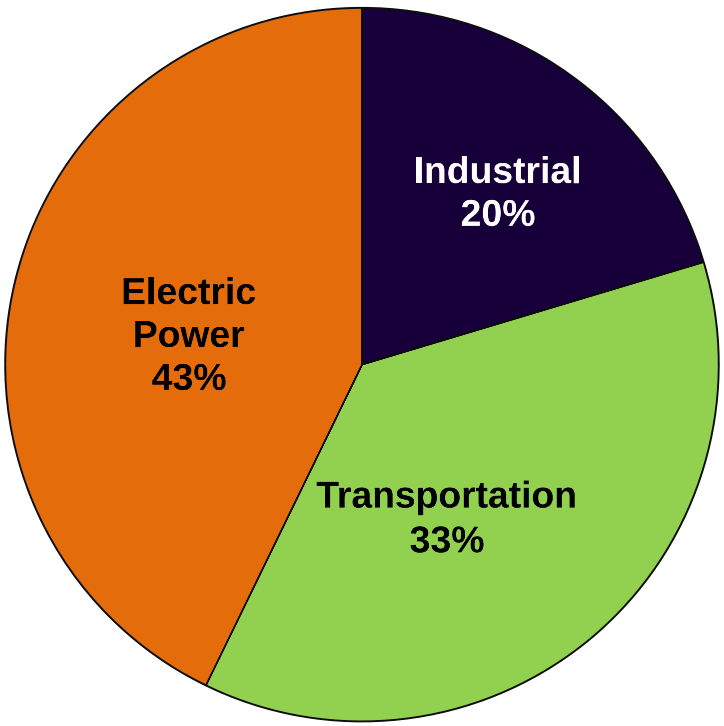


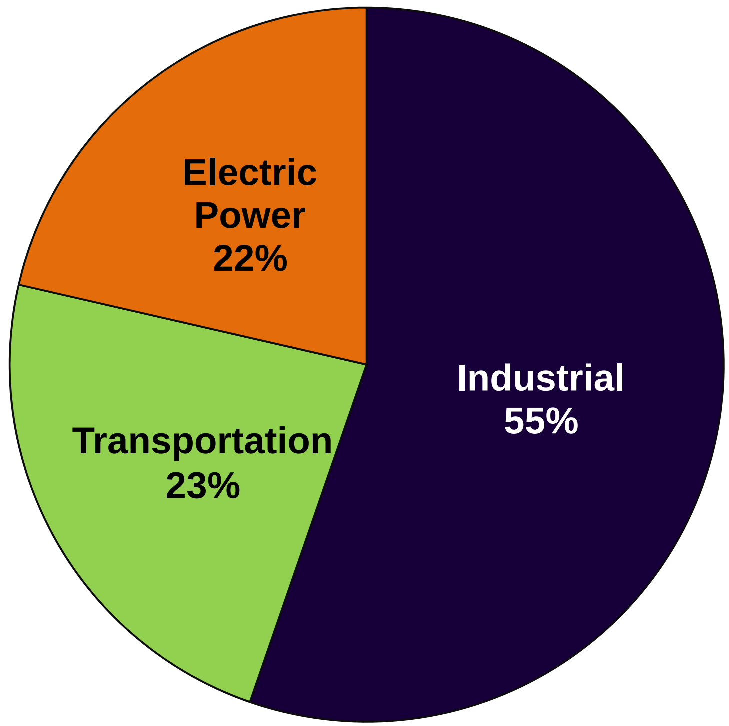
Source: Energy Information Administration, U.S. Department of Energy.

U.S. and Louisiana CO_2 Emissions per Sector, 2013

In the U.S., power generation comprises over 40 percent of overall national emissions.

In Louisiana, power generation comprises about 22 percent of overall state emissions. Louisiana's primary source of CO_2 emissions comes from industry.

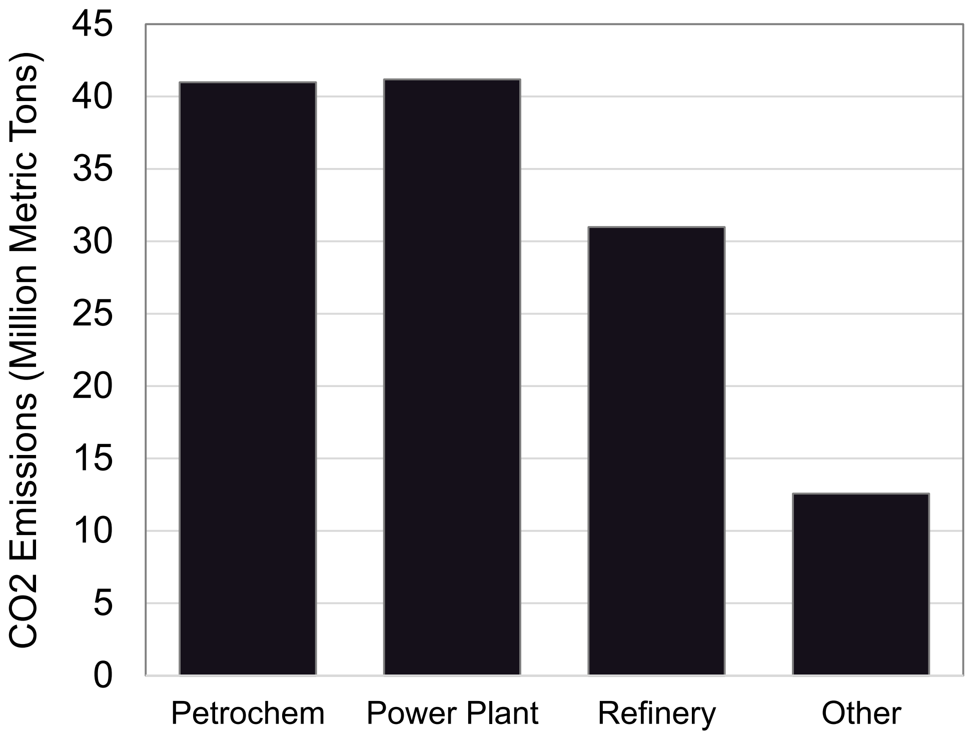


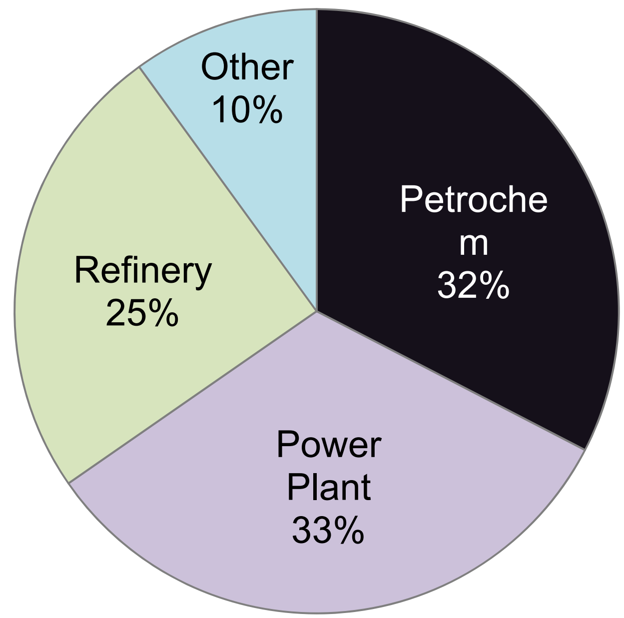


Source: Energy Information Administration, U.S. Department of Energy.

Louisiana Stationary CO2 Emissions, 2014

Petrochem facilities are the larger Louisiana carbon emission sources, followed by power plants and then refineries.

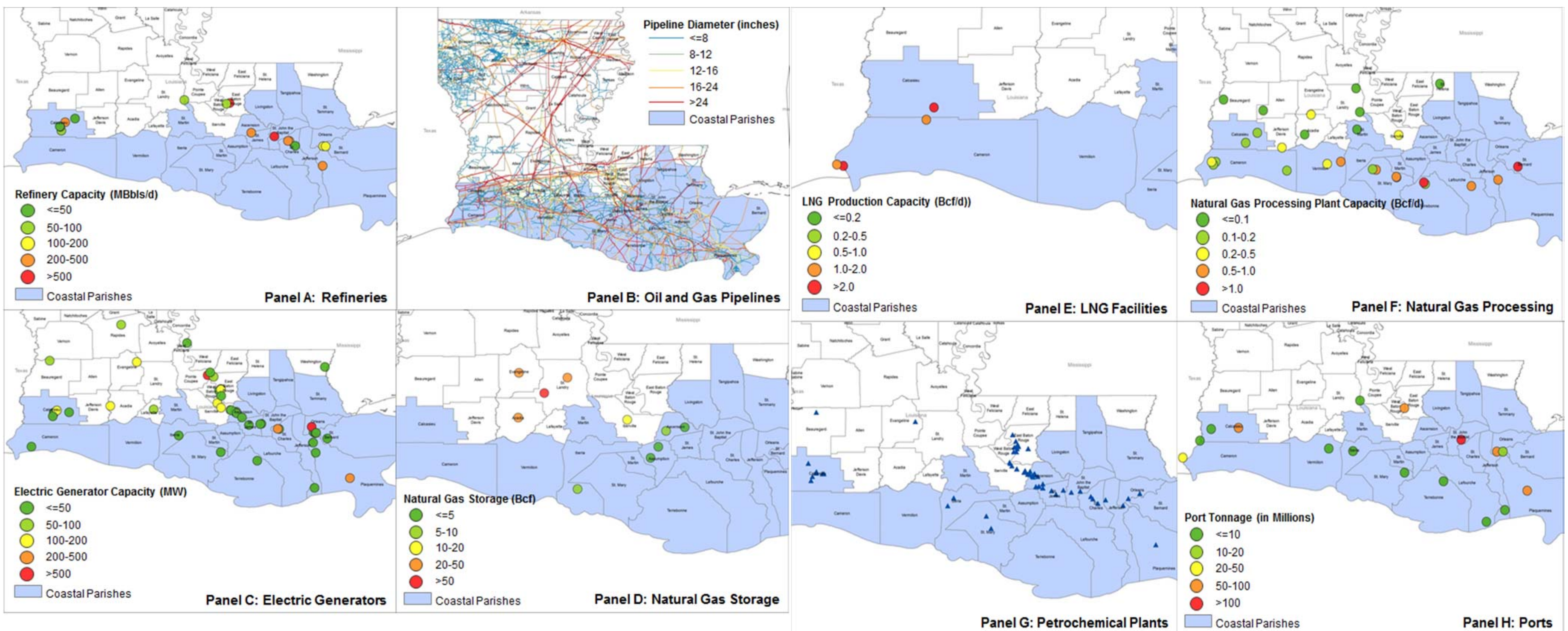




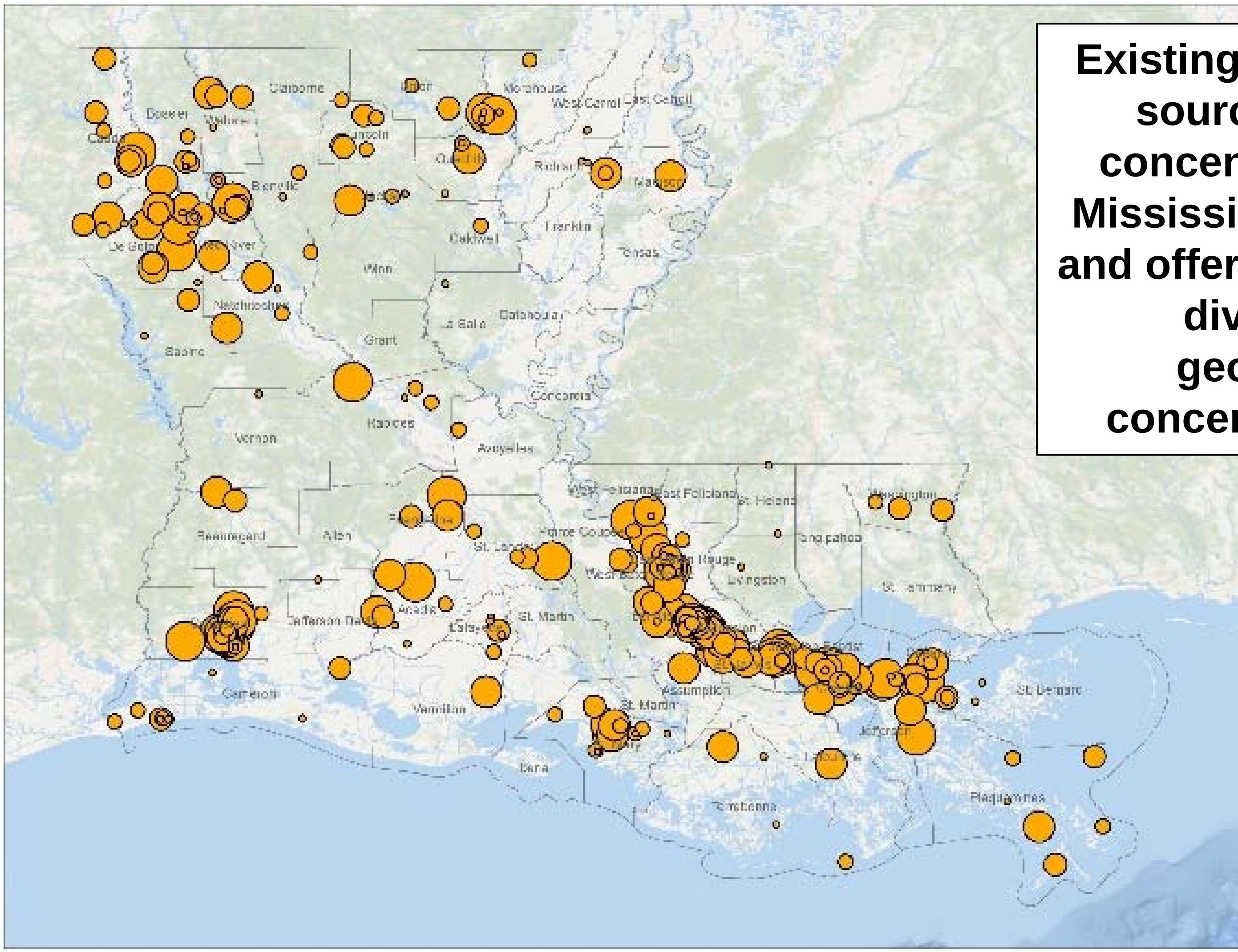
Source: Energy Information Administration, U.S. Department of Energy.

Louisiana's critical energy infrastructure.

Louisiana has a plethora of critical energy infrastructure. Refineries, certain petrochemical facilities, and gas processing facilities can serve as important carbon sources. The existing pipeline and storage infrastructure underscores opportunities for linking potential sources and sinks.



Louisiana industrial emission sources.



Existing carbon emission sources are heavily concentrated along the Mississippi River corridor and offer a large number of diversified and geographically-concentrated sources.

Project overview & tasks

Project overview

The project is comprised of **six key topical areas** – each with their own set of sub-tasks.

Task 1: Project management.

Task 2: Economic feasibility and public acceptance.

Task 3: Geological and engineering analysis.

Task 4: Geological capacity estimation.

Task 5: Baseline seismicity monitoring.

Task 6: Legal issues.

Task 1.0: Project management

Project management will include the necessary **activities to ensure coordination and planning of the project with DOE/NETL and other project participants**. These activities include, but are not limited to, the monitoring and controlling of project scope, cost, schedule, and risk, and the submission and approval of required National Environmental Policy Act (NEPA) documentation.

The project management phase includes all work elements required to maintain and revise the **Project Management Plan**, and to manage and report of activities in accordance with the plan and to maintain and revise the **Data Management Plan**.

Task 2.0: Economic feasibility and public acceptance

This section of the project will be decomposed into several tasks associated with estimated the economic feasibility of the project in addition to attempting to ascertain what the public acceptance regarding a project of this nature.

2.1: Identifying industrial carbon sources

2.2: Estimating carbon mitigation costs.

→ Economic feasibility analysis

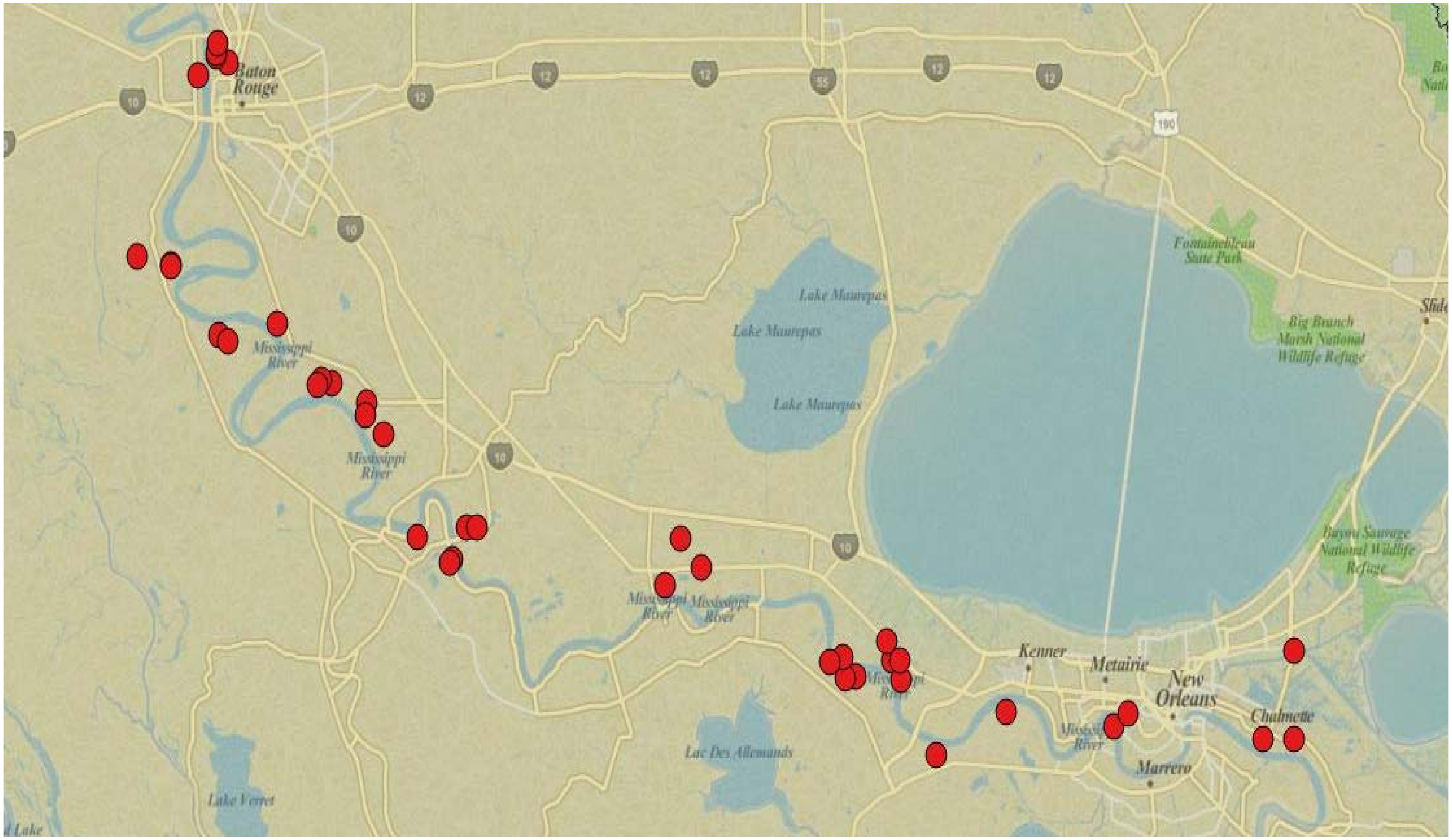
2.3: Developing a CCS project advisory group

2.4: Public outreach and acceptance analysis

→ Public acceptance analysis

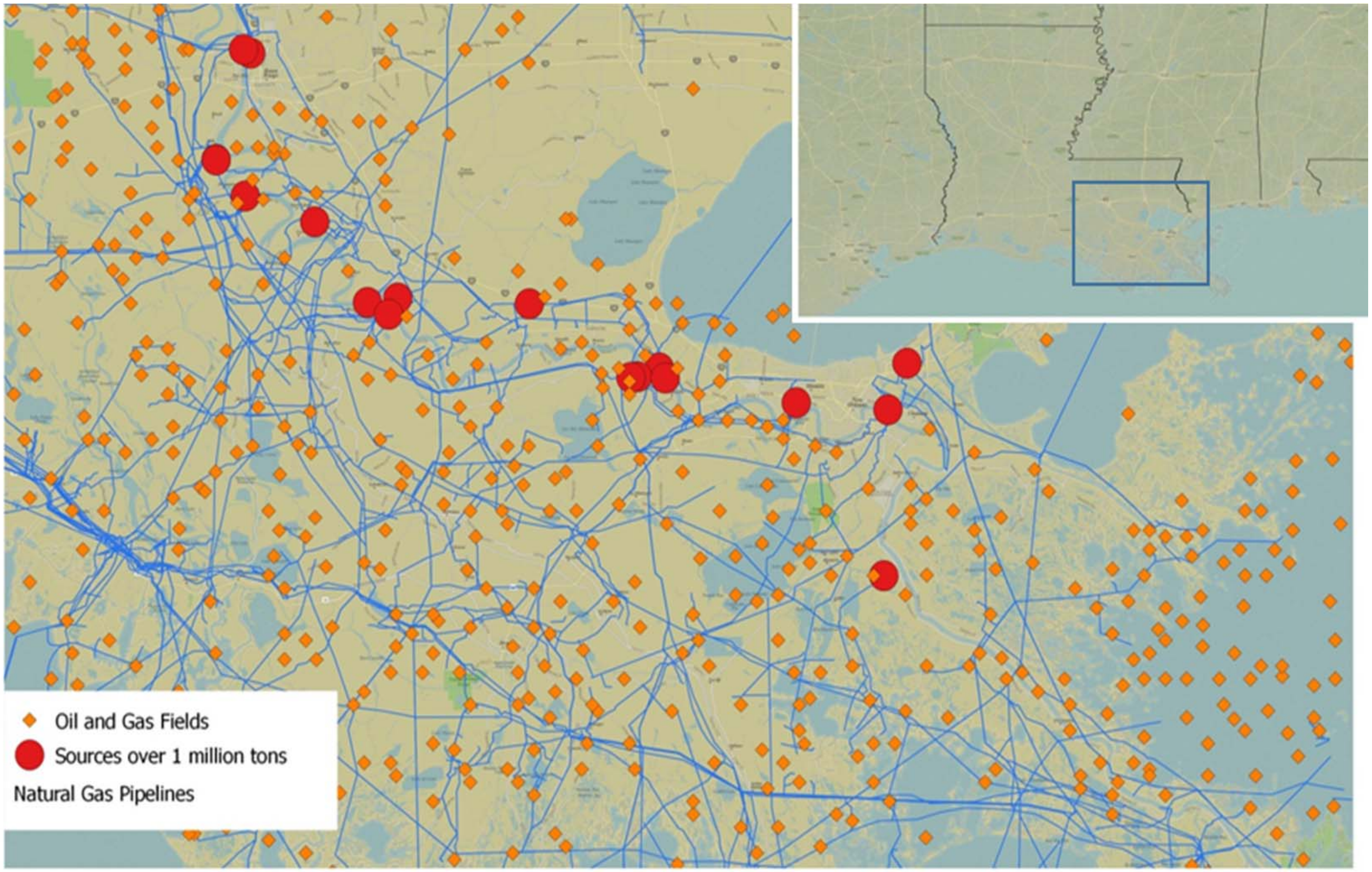
2.1 Identifying carbon sources and emissions levels

Preliminary analysis shows there are considerable potential industrial sources (250,000 metric tons or greater) in a geographically-concentrated area.

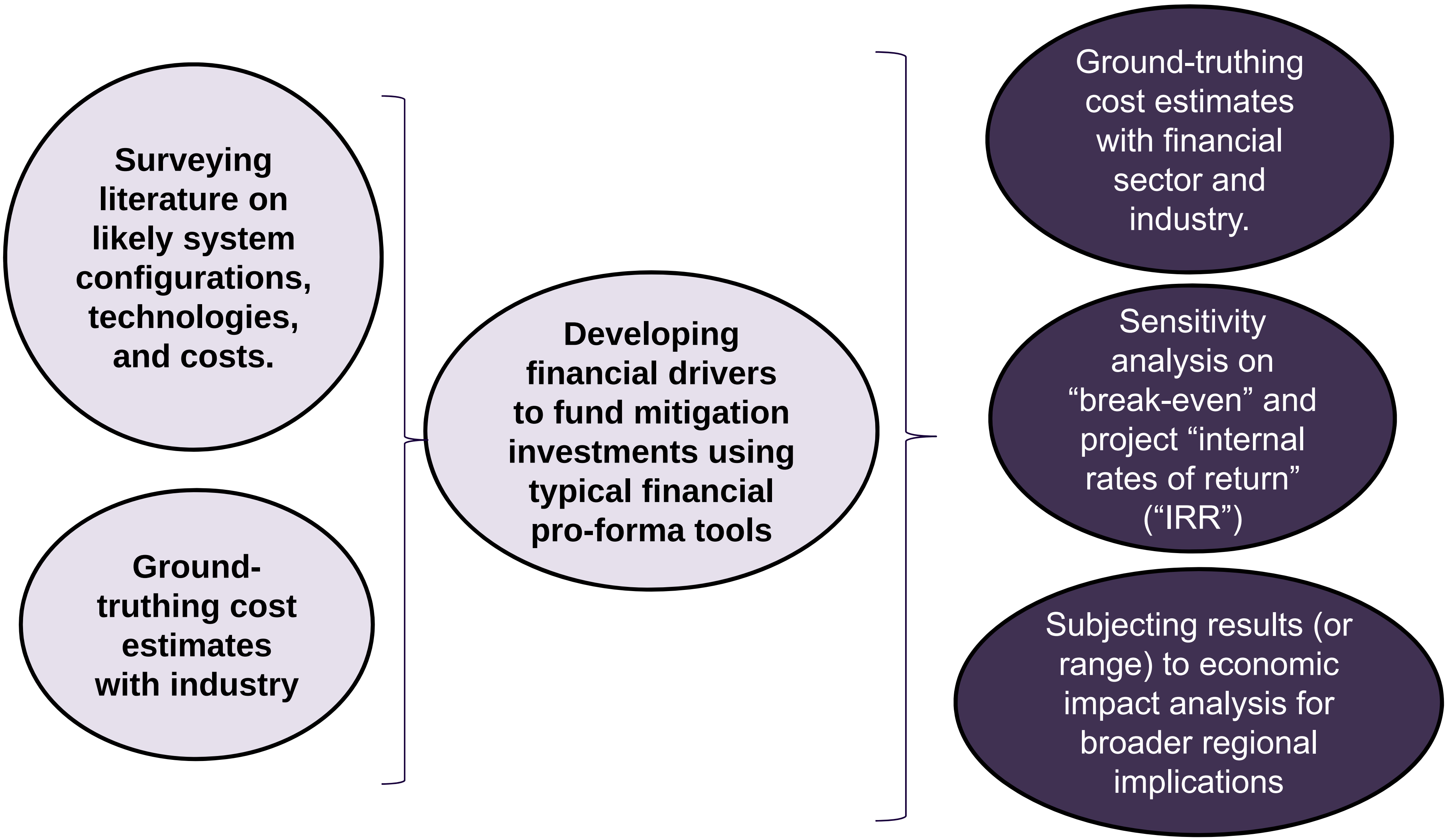


Potential sinks and transportation alternatives

There are a number of oil and gas production reservoirs, some of which are depleted, that could be used as sources with considerable co-located transport infrastructure.



2.2 Estimating carbon system costs and feasibility



Utilizing prior cost-benefit/pro-forma models for feasibility analysis

LSU-CES has developed a number of differing financial pro-forma models for examining energy infrastructure project feasibility as well as economic impact analyses for overall societal project impacts -- this is an illustrative analysis showing how a multi-year feasibility analysis will be conducted in this project.

Summary

Operating Assumptions — [Company Name]

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Total Tonnes of CO_2 Captured	3,000,000	3,000,000	3,000,000	3,000,000	3,000,000	3,000,000	3,000,000	3,000,000	3,000,000	3,000,000
Industrial Facility Type	Ammonia									
Capital Cost (Ammonia)	$ 222.05									
Capital Cost (Hydrogen)	$ 836.00									
Capital Cost (Ethylene Oxide)	$ 295.00									

	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
Total Tonnes of CO_2 Captured	3,000,000	3,000,000	3,000,000	3,000,000	3,000,000	3,000,000	3,000,000	3,000,000	3,000,000	3,000,000

Financial Projections

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Revenue										
CO_2 Capture Revenue	$ 96,000,000	$ 96,000,000	$ 96,000,000	$ 96,000,000	$ 96,000,000	$ 96,000,000	$ 96,000,000	$ 96,000,000	$ 96,000,000	$ 96,000,000
45Q Tax Credit	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Revenue	$ 96,000,000	$ 96,000,000	$ 96,000,000	$ 96,000,000	$ 96,000,000	$ 96,000,000	$ 96,000,000	$ 96,000,000	$ 96,000,000	$ 96,000,000
Variable Costs - Collection										
[Variable Cost #1]	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
[Variable Cost #2]										
[Variable Cost #3]										
[Variable Cost #4]										
[Variable Cost #5]										
[Variable Cost #6]										
[Variable Cost #7]										
Total Variable Costs - Collection										
Variable Costs - Treatment										
[Variable Cost #1]										
[Variable Cost #2]										
[Variable Cost #3]										
[Variable Cost #4]										
[Variable Cost #5]										
[Variable Cost #6]										
[Variable Cost #7]										
Total Variable Costs - Treatment										
Total Variable Costs										
Gross Margin										
Gross Margin %										
Corporate Overhead Allocation - G&A										
Fixed Costs - Collection										
Rent/Lease Expense (Equipment)										
[Fixed Cost #2]										
[Fixed Cost #3]										
[Fixed Cost #4]										
[Fixed Cost #5]										
[Fixed Cost #6]										
[Fixed Cost #7]										
Total Fixed Costs - Collection										
Fixed Costs - Treatment										
Rent/Lease Expense (Equipment)										
[Fixed Cost #2]										
[Fixed Cost #3]										
[Fixed Cost #4]										
[Fixed Cost #5]										
[Fixed Cost #6]										
[Fixed Cost #7]										
Total Fixed Costs - Treatment	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Fixed Costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
CO_2 Emission Tax										
EBITDA	$ 48,600,000	$ 48,126,000	$ 47,647,260	$ 47,163,733	$ 46,675,370	$ 46,182,124	$ 45,683,945	$ 45,180,784	$ 44,672,592	$ 44,159,318
EBITDA %	*51%*	*50%*	*50%*	*49%*	*49%*	*48%*	*48%*	*47%*	*47%*	*46%*
Interest Expense	$ 12,701,451	$ 13,829,418	$ 14,765,534	$ 15,551,606	$ 16,062,213	$ 16,422,776	$ 16,591,487	$ 16,613,847	$ 16,353,356	$ 15,946,514
Depreciation Expense	$ 33,307,500	$ 33,307,500	$ 33,307,500	$ 33,307,500	$ 33,307,500	$ 33,307,500	$ 33,307,500	$ 33,307,500	$ 33,307,500	$ 33,307,500
Amortization Expense	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Net Income Before Taxes (NBT)	$ 2,591,049	$ 989,082	$ (425,774)	$ (1,695,374)	$ (2,694,343)	$ (3,548,152)	$ (4,215,042)	$ (4,740,563)	$ (4,988,264)	$ (5,094,696)
Income Tax Expense	$ 1,036,420	$ 395,633	$ (170,310)	$ (678,150)	$ (1,077,737)	$ (1,419,261)	$ (1,686,017)	$ (1,896,225)	$ (1,995,306)	$ (2,037,878)
Net Profit	$ 1,554,629	$ 593,449	$ (255,465)	$ (1,017,224)	$ (1,616,606)	$ (2,128,891)	$ (2,529,025)	$ (2,844,338)	$ (2,992,959)	$ (3,056,818)

	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
Revenue										
CO_2 Capture Revenue	$ 96,000,000	$ 96,000,000	$ 96,000,000	$ 96,000,000	$ 96,000,000	$ 96,000,000	$ 96,000,000	$ 96,000,000	$ 96,000,000	$ 96,000,000
45Q Tax Credit	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Revenue	$ 96,000,000	$ 96,000,000	$ 96,000,000	$ 96,000,000	$ 96,000,000	$ 96,000,000	$ 96,000,000	$ 96,000,000	$ 96,000,000	$ 96,000,000
Variable Costs - Collection										
[Variable Cost #1]	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
[Variable Cost #2]										
[Variable Cost #3]										
[Variable Cost #4]										
[Variable Cost #5]										
[Variable Cost #6]										
[Variable Cost #7]										
Total Variable Costs - Collection									$ -	$ -
Variable Costs - Treatment										
[Variable Cost #1]									$ -	$ -
[Variable Cost #2]										
[Variable Cost #3]										
[Variable Cost #4]										
[Variable Cost #5]										
[Variable Cost #6]										
[Variable Cost #7]										
Total Variable Costs - Treatment									$ -	$ -
Total Variable Costs									$ 56,697,390	$ 57,264,364
Gross Margin									$ 39,302,610	$ 38,735,636
Gross Margin %									*41%*	*40%*
Corporate Overhead Allocation - G&A									$ -	$ -
Fixed Costs - Collection										
Rent/Lease Expense (Equipment)									$ -	$ -
[Fixed Cost #2]										
[Fixed Cost #3]										
[Fixed Cost #4]										
[Fixed Cost #5]										
[Fixed Cost #6]										
[Fixed Cost #7]										
Total Fixed Costs - Collection									$ -	$ -
Fixed Costs - Treatment										
Rent/Lease Expense (Equipment)										
[Fixed Cost #2]										
[Fixed Cost #3]										
[Fixed Cost #4]										
[Fixed Cost #5]										
[Fixed Cost #6]										
[Fixed Cost #7]										
Total Fixed Costs - Treatment	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Fixed Costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
CO_2 Emission Tax										
EBITDA	$ 43,640,911	$ 43,117,320	$ 42,588,494	$ 42,054,379	$ 41,514,922	$ 40,970,072	$ 40,419,772	$ 39,863,970	$ 39,302,610	$ 38,735,636
EBITDA %	*45%*	*45%*	*44%*	*44%*	*43%*	*43%*	*42%*	*42%*	*41%*	*40%*
Interest Expense	$ 15,347,821	$ 14,598,059	$ 13,574,880	$ 12,400,633	$ 11,034,535	$ 9,504,242	$ 7,726,785	$ 5,785,133	$ 3,651,630	$ 1,332,396
Depreciation Expense	$ 33,307,500	$ 33,307,500	$ 33,307,500	$ 33,307,500	$ 33,307,500	$ 33,307,500	$ 33,307,500	$ 33,307,500	$ 33,307,500	$ 33,307,500
Amortization Expense	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Net Income Before Taxes (NBT)	$ (5,014,409)	$ (4,788,239)	$ (4,293,887)	$ (3,653,755)	$ (2,827,113)	$ (1,841,671)	$ (614,513)	$ 771,337	$ 2,343,480	$ 4,095,740
Income Tax Expense	$ (2,005,764)	$ (1,915,296)	$ (1,717,555)	$ (1,461,502)	$ (1,130,845)	$ (736,668)	$ (245,805)	$ 308,535	$ 937,392	$ 1,638,296
Net Profit	$ (3,008,646)	$ (2,872,943)	$ (2,576,332)	$ (2,192,253)	$ (1,696,268)	$ (1,105,002)	$ (368,708)	$ 462,802	$ 1,406,088	$ 2,457,444

Financial Covenants

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
EBITDAR	$ 48,600,000	$ 48,126,000	$ 47,647,260	$ 47,163,733	$ 46,675,370	$ 46,182,124	$ 45,683,945	$ 45,180,784	$ 44,672,592	$ 44,159,318
Fixed Charges										
Current Maturities of Long Term Debt	$ 26,646,000	$ 26,646,000	$ 26,646,000	$ 26,646,000	$ 26,646,000	$ 26,646,000	$ 26,646,000	$ 26,646,000	$ 26,646,000	$ 26,646,000
Interest Expense	$ 12,701,451	$ 13,829,418	$ 14,765,534	$ 15,551,606	$ 16,062,213	$ 16,422,776	$ 16,591,487	$ 16,613,847	$ 16,353,356	$ 15,946,514
Rent/Lease Expense	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Distributions	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Unfinanced Capex	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Current Portion of Capital Lease Obligations	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Fixed Charges	$ 39,347,451	$ 40,475,418	$ 41,411,534	$ 42,197,606	$ 42,708,213	$ 43,068,776	$ 43,237,487	$ 43,259,847	$ 42,999,356	$ 42,592,514
Fixed Charge Coverage Ratio	1.24	1.19	1.15	1.12	1.09	1.07	1.06	1.04	1.04	1.04
In Compliance? (Min. 1.25x)	No	No	No	No	No	No	No	No	No	No
Covenant Cushion ($)	$ (467,451)	$ (1,974,618)	$ (3,293,726)	$ (4,466,620)	$ (5,367,917)	$ (6,123,077)	$ (6,690,331)	$ (7,115,220)	$ (7,261,283)	$ (7,265,060)

	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
EBITDAR	$ 43,640,911	$ 43,117,320	$ 42,588,494	$ 42,054,379	$ 41,514,922	$ 40,970,072	$ 40,419,772	$ 39,863,970	$ 39,302,610	$ 38,735,636
Fixed Charges										
Current Maturities of Long Term Debt	$ 26,646,000	$ 26,646,000	$ 26,646,000	$ 26,646,000	$ 26,646,000	$ 26,646,000	$ 26,646,000	$ 26,646,000	$ 26,646,000	$ 26,646,000
Interest Expense	$ 15,347,821	$ 14,598,059	$ 13,574,880	$ 12,400,633	$ 11,034,535	$ 9,504,242	$ 7,726,785	$ 5,785,133	$ 3,651,630	$ 1,332,396
Rent/Lease Expense	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Distributions	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Unfinanced Capex	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Current Portion of Capital Lease Obligations	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Fixed Charges	$ 41,993,821	$ 41,244,059	$ 40,220,880	$ 39,046,633	$ 37,680,535	$ 36,150,242	$ 34,372,785	$ 32,431,133	$ 30,297,630	$ 27,978,396
Fixed Charge Coverage Ratio	1.04	1.05	1.06	1.08	1.10	1.13	1.18	1.23	1.30	1.38
In Compliance? (Min. 1.25x)	No	No	No	No	No	No	No	No	Yes	Yes
Covenant Cushion ($)	$ (7,081,092)	$ (6,750,203)	$ (6,150,085)	$ (5,403,130)	$ (4,468,597)	$ (3,374,185)	$ (2,036,967)	$ (539,957)	$ 1,144,458	$ 3,010,113

Illustrative feasibility analysis pro-forma model drivers

Economic and operating assumptions for capture investments

Operating Assumptions
Tonnes of Ammonia / Hydrogen Produced
CO_2 Emissions Per Ton
CO_2 Capture Efficiency
Tonnes of CO_2 Captured
Price of CO_2 ($) / tonne
45Q Tax Credit ($) / tonne
Carbon Tax (%) / tonne
Operating Costs / tonne (Ammonia)
Operating Costs / tonne (Hydrogen)
Operating Costs / tonne (Ethylene Oxide)
Variable Cost #1 [Collection]
Variable Cost #1 [Treatment]
Variable Cost #2
Variable Cost #2
Income Tax Rate
Inflation (CPI)

Economic and operating assumptions for transport investments

Operating Assumptions
CO_2 Transported per year / tonnes
System Capacity (Million Metric Tons / year)
Pipeline Distance (Miles)

Debt and equity finance assumptions for all project components

Loan Summary

Loan Amount:	$ 532,920,000.00	
Loan Pricing	Variable	
Annual Interest Rate:	4.00%	
Credit Spread	1.75%	
Start Date:	12/31/2016	
Loan Periods:	240	months
Maturity:	60	months
Total Monthly Pmt:	$ -	
Total Loan Cost:	$ -	
Total Interest:		

Capital Expenditure

Total Capex:	$ 666,150,000.00	
Debt (%):	80%	
Equity (%):	20%	
Useful Life:	240	months
Loan Fees (%):	0.0%	
Loan Fees ($):	$ -	
Libor Increment	0.030%	
1-month Libor	0.52528%	

2.3. Developing a CCS project advisory panel

Table 1. Potential members of the LCCCT.

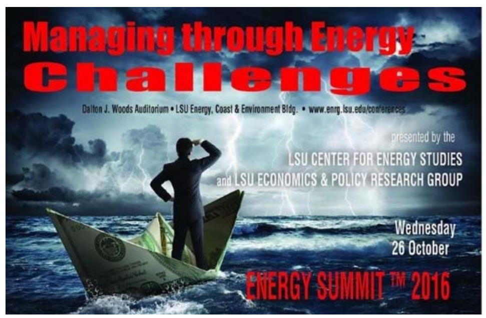
Collaborator	Role	
Center for Energy Studies, LSU	Lead Agency	X
Shell	Industrial Partner	X
Louisiana Landowners Association	Sink Partner	
Louisiana Chemical Association	Industrial Partner	X
Air Products	Industrial Partner	
Praxair	Industrial Partner	
CF Industries	Industrial Partner	
PCS Nitrogen	Industrial Partner	
Occidental Petroleum	Industrial Partner	
Cornerstone Chemical	Industrial Partner	
Mosaic	Industrial Partner	
BASF	Industrial Partner	
NRG Energy	Electricity Industry Partner	X
Jones Walker	Legal Partner	
Williams Company	Transportation Partner	
Enterprise Product Partners	Transportation Partner	X
Louisiana Office of Conservation	Government Agency	X
Louisiana Geological Survey	Academic	X
Environmental Sciences, LSU	Academic	X
Petroleum Engineering, LSU	Academic	X
Geology, LSU	Academic	X
Law School, LSU	Academic	X

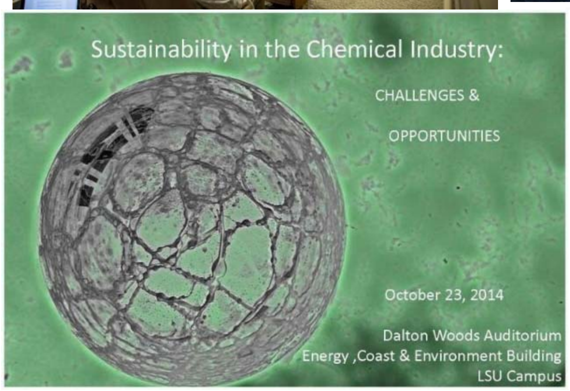
Other State Agencies

Dept. of Natural Resources (State Lands)
Dept. of Natural Resources (SEO)
Dept. of Economic Development

2.3 Public outreach and acceptance

Project team members will work with **federal, state and local community groups to ascertain issues** associated with the public acceptance of carbon capture and storage in the Louisiana industrial corridor. We will also **work at disseminating the results of this research, and its importance, on an ongoing basis**.





Emerging Issues at the **Intersection of Energy and Water**

Women's Energy Network™

Current CCUS Initiatives/Partnerships

ENERGY BAR ASSOCIATION®

SOUTHERN STATES ENERGY BOARD

Transcending Boundaries

Task 3.0: Geological and engineering analysis

The geological and engineering analysis will focus on defining candidates sites for carbon storage, the characteristics of those sites and their suitability for large-scale commercial storage. Technical information about the storage location will feed into the economic feasibility analysis as well.

- **2.1: Site identification**
- **3.2: Data collection and literature review**
- **3.3: Data evaluation relative to engineering requirements**
- **3.4: Candidate site mapping**
- **3.5: Sands evaluation**
- **3.6: Geological storage reporting for candidate sites.**

Site Selection

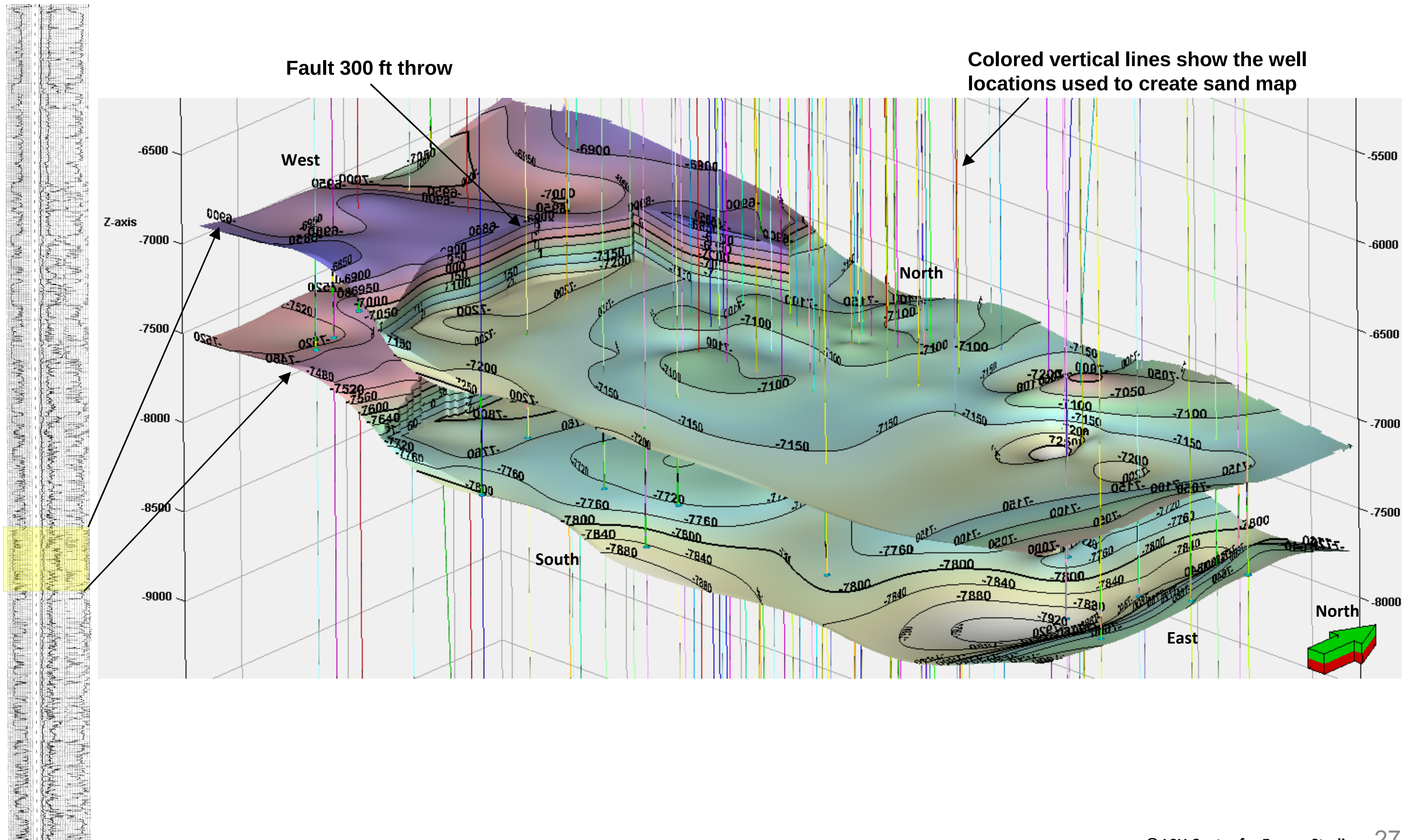
- **Site selection criteria**:
  - Proximity to CO_2 sources
  - Potential for CO_2 containment
  - Potential for large storage capacity
- **Initial site screening by LGS (Louisiana Geological Survey)***
- **Site specific data collection from public source (SONRIS)**
  - Field production history (initial site potential)
  - Well data (active and abandoned)
  - Well logs (to estimate pore space)
  - Well history data:- cement tops, plugged data etc (to estimate leakage risk)

Source: *Chacko John, Warren Schulingkamp, Bobby Jones, Brian Harder & Reed Bourgeois, (2011). "Potential for Carbon Dioxide Sequestration in Five Fields along the Mississippi River Industrial Corridor in Louisiana", LGS, LSU.

Site Specific Information

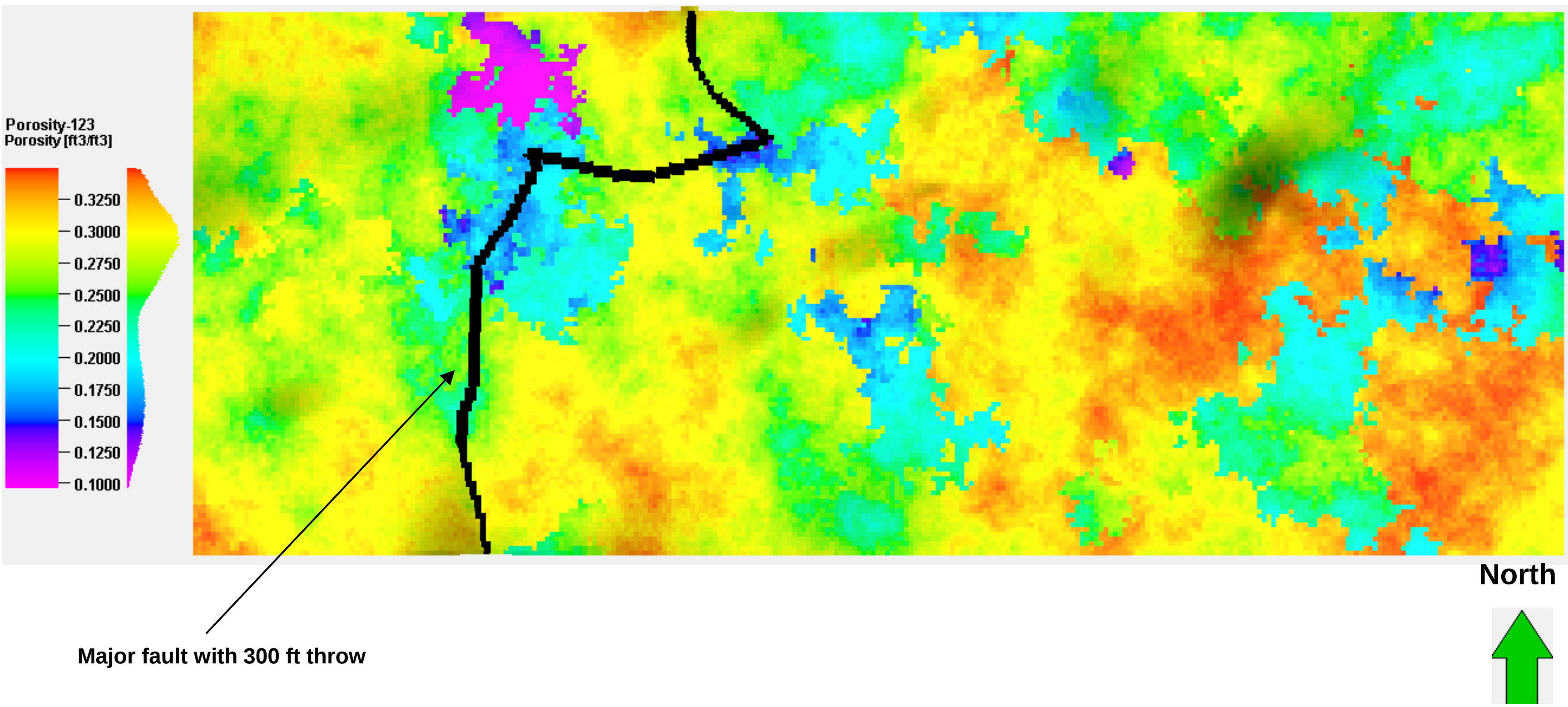
- **Bayou Sorrel**
  - Total number of drilled wells is 159 out of which 2 are water disposal wells and 3 are producing wells from oil reservoir at depth ≥12,000 ft
  - Total areal extent of the field is ~8 $mile^2$
  - A thick sand is identified at a depth of 7100 ft with 500-700 ft thickness
  - The sand is overlain by a thick shale layer with 200-600 ft thickness
  - The bottom shale is 40-100 ft thick
- **Paradis**
  - Total number of wells is 387 out of which 7 are injection wells and 16 are producing wells from reservoir at depth ≥ 8,000 ft
  - Total areal extent of the field is ~ 23 $mile^2$
  - A thick sand interval is identified at a depth of 4100 ft with 400-700 ft thickness
  - The sand is overlain by a thick shale layer with 100-200 ft thickness
  - The bottom shale is 30-100 ft thick

Preliminary Assessment, Bayou Sorrel



Preliminary Assessment, Porosity Distribution

Top view of 7100 sand package



Task 4.0: Geological capacity estimation

Distribution, potential volume, and cost to develop CO_2 geological storage have received increased emphasis in recent years. **Accurate and clearly understandable capacity assessment is crucial** in order to help government and industry make informed decisions about CO_2 geological storage. **Only a fraction of the existing pore space is available for CO_2 storage and accessible to injected CO_2**. This fraction is referred to as storage efficiency (coefficient). The project team anticipates **utilizing a number of different methods** at estimating these storage potentials and the **sensitivities influencing the robustness of the storage estimates**.

4.1: Static capacity estimation.

4.2: Dynamic capacity estimation.

4.3: Storage efficiency sensitivity.

4.4: NRAP tools

Storage Capacity Estimation

Two techniques for CO_2 storage capacity estimation:

1. Static
2. Dynamic

1. Static CO_2 storage capacity
   - Pore volume estimates (mainly based on well log data)
   - Initial temperature and pressure
   - Supercritical CO_2 volume estimates as discounted pore volume (using storage efficiency factor)
   - Capacity estimation for multiple geological model realizations

Storage Capacity Estimation (continued)

2. Dynamic CO_2 storage capacity estimate
   - Reservoir numerical simulations (CMG software, 2016)
   - Boundary conditions sensitivity
   - Injection scheme sensitivity
   - Monitorability of injected CO_2
   - NRAP tools will be used wherever they could provide additional information

- Well leakage risk assessment
  - From available well data (completion date, cement tops)
  - Leakage model using NRAP well leakage analysis tools

Expected Outcomes – Subsurface Modeling

- Site specific static and dynamic CO_2 storage capacity estimates
- Quantitative Risk Assessment (QRA) of leakage potential
- The comparison of results from static and dynamic storage capacity estimates will provide representative storage efficiency factors for this region
- The QRA framework developed for leakage risk assessment may be adopted for other sites

Task 5.0: Baseline seismicity monitoring

In the US, **recent increases in the numbers of induced seismic events** accompanying the subsurface storage of fluid waste **has created public concern** and cast a shadow over the use of CO_2 storage technology. **We propose to apply a key lesson learned from public perceptions to hydraulic fracturing**, to provide open information on the potential seismic risk and occurrence of natural seismic activity.

Our proposed CO_2 sequestration site(s) in **Louisiana have a great natural advantage because of their low chance of natural earthquake damage and activity.** Reviews of natural and induced seismicity across Louisiana for the period April 2010 and July 2012 confirm **the low level of natural seismicity** but also highlight nearby sources of induced seismic activity possibly associated with wastewater injection.

Without baseline monitoring, if seismic events become more noticeable during the sequestration phase, the exact cause of these seismic events is harder to evaluate. A baseline evaluation of natural seismicity is required to facilitate later analysis of potentially induced events during sequestration phase.

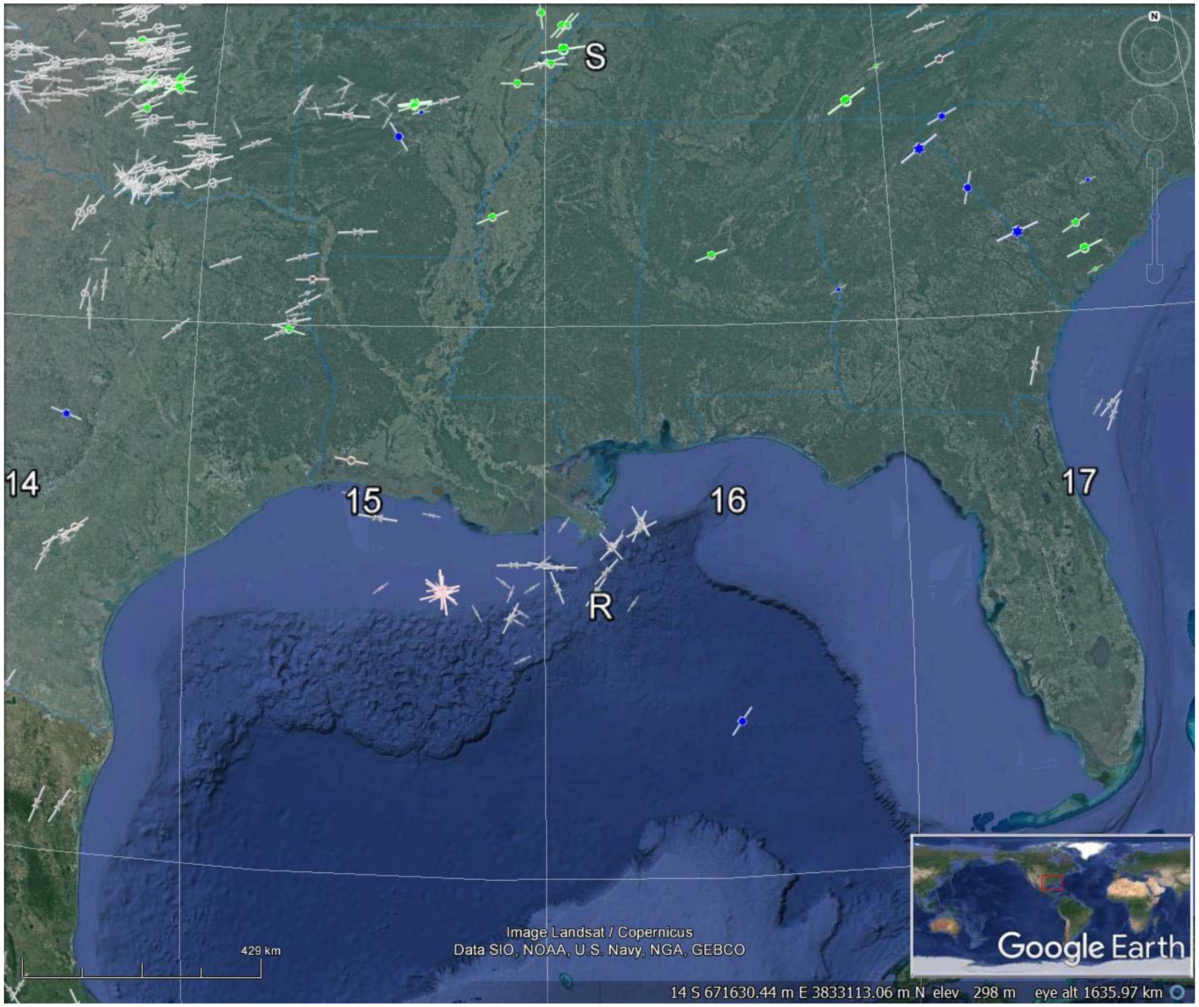
5.1: Collection and characterization of relevant data and storage methods.

5.2: Model development.

5.3: Ongoing on-line seismic catalogue and mapping

World Stress Map

Map shows Class A and B stress orientations (classes C and D omitted)



Source: Heidbach et al., 2016

Task 6.0: Legal analysis

The use of the subsurface to permanently store captured carbon emissions is replete with a **number of legal and public policy issues**. **Liability** is one issue that often comes to mind. This phase of the project will examine **a wide range of issues associated with underground carbon storage as well as transport (eminent domain)** that will have to be addressed clearly before any commercial application can be determined as being feasible.

- **6.1: Subsurface ownership analysis**
- **6.2: Subsurface eminent domain analysis.**
- **6.3: Surface eminent domain analysis.**
- **6.4: Production/CCS conflicts analysis**
- **6.5: Permitting issues and requirements**
- **6.6: Liability claims analysis.**

Project team & organization

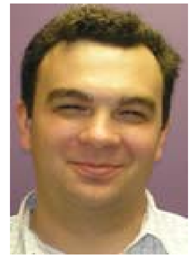
Project Team

David E. Dismukes, Economist
Professor & Exe. Director,
Center for Energy Studies &
Department of Environmental Sciences

Juan Lorenzo, Geologist
Assc. Professor
Department of Geology

Chacko John, State Geologist
Director and Professor
Louisiana Geological Survey (CES)

Brian Harder, Petroleum Engineer
Research Associate
Louisiana Geological Survey (CES)
(estimated recent photo)



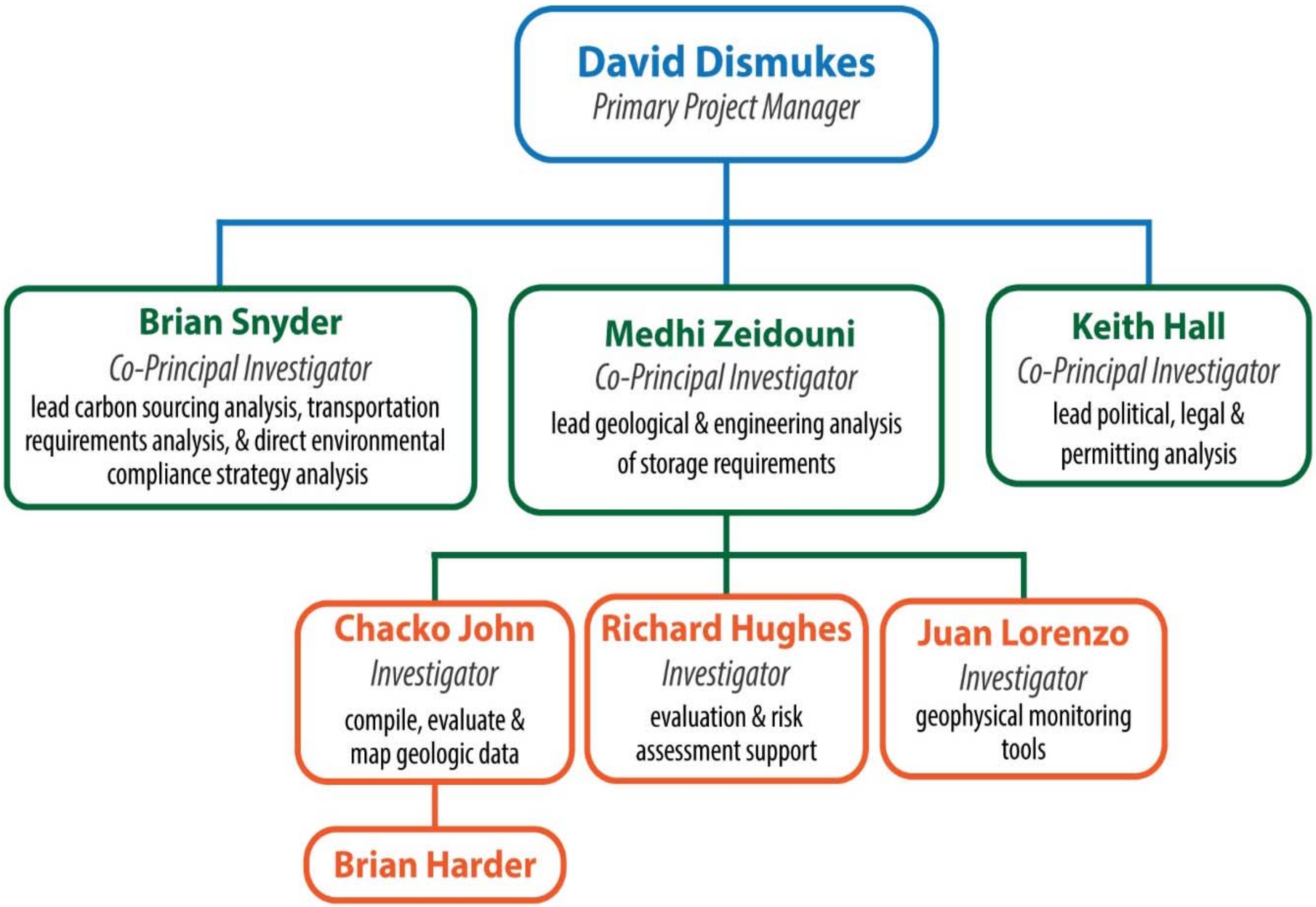
Brian Synder, Ecologist
Asst. Professor
Department of Environmental Sciences

Keith Hall, Attorney
Assc. Professor & Director
Laborde Energy Law Institute

Mehdi Zeidouni, Petroleum Engineer
Asst. Professor
Department of Petroleum Engineering

Richard Hughes, Petroleum Engineer
Professional-in-Residence
Department of Petroleum Engineering

Project Organizational Chart



Project schedule

Project Schedule

Conclusions

Conclusions

Louisiana has a **confluence of factors** that should lead to a **successful development of a CCS feasibility analysis**.

The state has several **large emission sources and sinks and is a great test location**.

These sources and sinks are **geographically concentrated**, yet **diversified** across a number of different industrial facilities.

The feasibility study arises from this work, therefore, will likely have **broad applicability in the industrial corridor** between **Baton Rouge and New Orleans** as well as from **Lake Charles to Cameron Parish.**

The **project team is already making progress** on our initial tasks and see **no near term barriers to successfully completing this project.**

Questions, comments and discussion

dismukes@lsu.edu

www.enrg.lsu.edu