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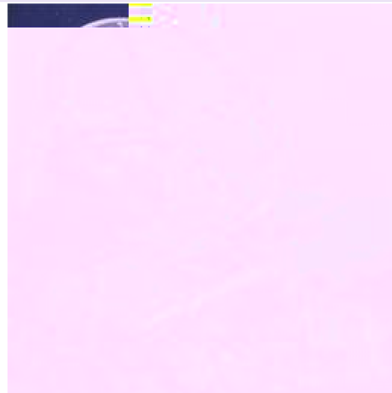

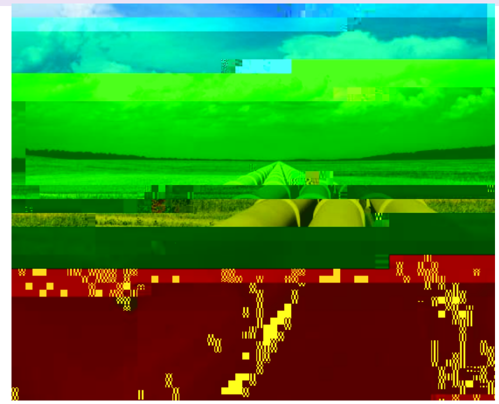

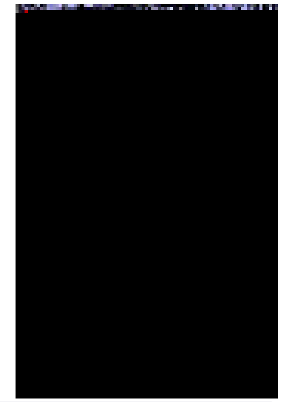

Integrated carbon capture, utilization and storage in the Louisiana chemical corridor.

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

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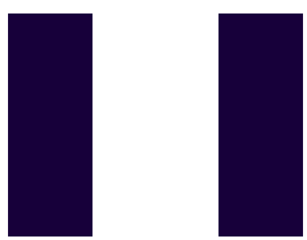

Source: IEA, Energy Technology Perspectives (2015).

Energy-Related Emissions by State, 2014

At just under 220 million metric tons of CO_2 emissions, Louisiana ranks seventh in the U.S.

Louisiana Stationary CO2 Emissions, 2014

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

Task 1.0: Project management

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.

Economic feasibility analysis

- **2.1: Identifying industrial carbon sources**
- **2.2: Estimating carbon mitigation costs.**

Public acceptance analysis

- **2.3: Developing a CCS project advisory group**
- **2.4: Public outreach and acceptance analysis**

2.2 Estimating carbon system costs and feasibility

Surveying literature on likely system

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

Summary

Operating Assumptions — [Company Name]

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	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	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																			

Financial Projections

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	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	$ 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	$ 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]	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	-
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[Variable Cost #7]																				

[Variable Cost #7] $ - $ - $ -

[Variable Cost #6]
[Variable Cost #7]

[Variable Cost #7]
[Variable Cost #7]

Illustrative feasibility analysis pro-forma model drivers

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:		

Total Capex:	$	666,150,000.00
Debt (%):		80%
Equity (%):		20%
Useful Life:		240 months
Loan Fees (%):		0.0%
Loan Fees ($):	$	-
Libor Increment		eno22 Tc (5229(e)531 Tw TD1s6 cs

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)

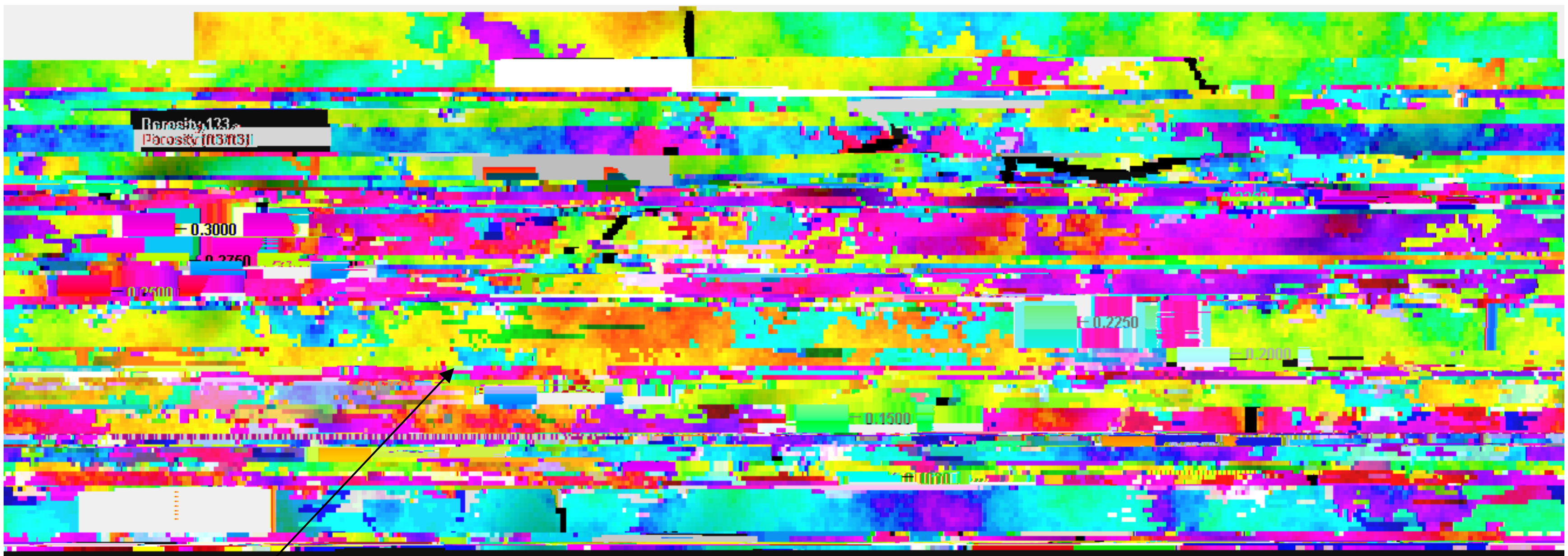
Site Specific Information

- 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



North

Major fault with 300 ft throw

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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

Studies

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

World Stress Map

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Project Schedule

Major Task/Milestone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Phase 1: identification phase																		
Screening and identification of anpÀ identification of q"$Žá™ ™ and identification of i `p ,•'•Â€																		

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Questions, comments and discussion

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