INFRASTRUCTURE

“The basic physical and organizational structures and facilities needed for the operation of a society or enterprise.”

Oxford Lexico English Dictionary
WORLD MAP OF CCS FACILITIES IN VARIOUS STAGES OF DEVELOPMENT

66 Commercial CCS facilities around the globe

GLOBAL CCS INSTITUTE
THE LOOK OF CCS INFRASTRUCTURE

[TRANSPORT OVERVIEW]

CO₂ capture plant
Onshore transport
Buffer storage
Offshore transport
CO₂ injection
To geological storage

Provided by the Global CCS Institute
THE LOOK OF CCS INFRASTRUCTURE
THE LOOK OF CCS INFRASTRUCTURE

[OFFSHORE TRANSPORT AND STORAGE]

CO₂ transport

CO₂ pipelines

Wellheads

To geological storage

Provided by the Global CCS Institute
THE LOOK OF CCS INFRASTRUCTURE

Provided by the Global CCS Institute
CCS is secure.

220 million tonnes of CO2 stored to date
Natural Gas Infrastructure in the U.S.

Existing CO2 Pipelines

Edwards & Celia, 2018
CO2 Pipelines in the U.S.

Edwards & Celia, 2018
WORLD MAP OF CCS FACILITIES IN VARIOUS STAGES OF DEVELOPMENT

66 Commercial CCS facilities around the globe
What We Are Building

Navigator CO₂ Ventures is proposing to construct approximately 1,200 miles of new CO₂ pipeline spanning five states (Nebraska, Iowa, South Dakota, Minnesota, and Illinois) and sequestration facilities in Illinois with enough early capacity to sequester up to 8 million metric tonnes of carbon dioxide per year

- CO₂ will be sourced from different industrial sources based upon customer commitments
- Platform will be expandable to > 15 million metric tonnes of carbon dioxide per year

Project Timeline
- March 2021: Non-Binding Open Season Launch
- June 2021: Binding Open Season Launch
- 2H2021: Approximately 40 months of permitting & construction commences
- 4Q2024: Initial Phase Commissioning
- 1H2025: Full Commercial Service

Indicative Open Season Map
How We Are Commercializing CCS

- Pipeline will be offered to the market as a common carrier system consistent with FERC liquids principles
  - Shippers (versus pipeline or sponsor) will have contractual capacity rights
  - Transparent structure provides framework for new customer onramps and integration with other pipeline systems in the future
  - Fee for service model easy to understand and evaluate
- Navigator is conducting an open season process to solicit customer interest in firm capacity on the pipeline system
  - Rate grid: more capacity + longer term = lower rates
  - Project scale provides basis for attractive rate-setting
- Sequestration site(s) will be developed in parallel to accommodate open season customer responses
  - Fee for service
- Customer option for Navigator to construct and finance on-site carbon capture to minimize upfront emitter CAPEX
Why Pipelines Can Be Part of the Solution

- Pipelines represent an immensely scalable platform to aggregate and sequester carbon
- Emission sources often located at geographically disparate locations from practical carbon sequestration sites
- Engineered solutions for CO₂ capture and conditioning make pipeline systems agnostic to the emissions source
- Monitoring systems measure pressure differentials in tight distance intervals to help manage system integrity
Project Benefits

1,000

The number of trucks per day it would take to transport ~8 million mT of CO$_2$ annually

18%

Project's potential to eliminate ~18% of emissions produced by Industrial Processes and Agriculture in the state of Iowa

First step in creating multi-industry carbon hub

Substantial Economic Benefits

- Dozens of permanent fulltime jobs
- Thousands of temporary jobs
- Millions in localized tax benefits

Source: 2019 Iowa Statewide Greenhouse Gas Emissions Inventory Report
About Us

Matt Vining, CEO

“Investing in CCS allows us to be a good steward of our midstream expertise while simultaneously addressing climate change and building a more sustainable future.”

Founded in 2012, Navigator is a privately owned midstream infrastructure company with operations based in the US.

Since inception, Navigator has deployed over $1.3 billion in capital and has safely constructed and operated more than 1,000 miles of pipeline.

The company employees 52 individuals and expects to double in size over the next 36 months. Our experienced management team has over 130 years of combined experience across multiple commodities.

Matt Vining, CEO, resides in Iowa and plans to establish offices in Iowa, Nebraska and Illinois.
Infrastructure for a Net-Zero Future:
Link to Geologic Storage

Susan Hovorka
Gulf Coast Carbon Center
Bureau of Economic Geology
Jackson School of Geosciences
The University of Texas at Austin

GCCSI Carbon Capture and Storage 101 Webinar #2
May 7, 2021
Role of Storage in CCS

• To attain very large volume atmospheric CO$_2$ reductions, large volume, permanent storage is needed.
  – Much of this need can be met by injection of CO$_2$ into Deep Saline Formations
  – Initiated and augmented by use and storage of CO$_2$ via EOR.

Ritchie and Roser (2017) - "CO$_2$ and Greenhouse Gas Emissions"
$\text{CO}_2$ is captured as concentrated high pressure fluid by any methods

$\text{CO}_2$ is shipped as supercritical fluid via pipeline to a selected, permitted injection site

$\text{CO}_2$ injected via wells at pressure into pore space at depths below and isolated (sequestered) from potable water.

$\text{CO}_2$ stored in pore space over geologically significant time frames.
Multiple Stacked Storage Units

- Sandstone (Porosity indicator)
- Mudrock

Inject here

Datum: MFS 9, TSE 8, 500 ft

Amph. B zone

Datum

6000 ft
Below sea level

500 ft

7 miles

Tucker Hentz BEG
Rock Volume Occupied by CO$_2$

Porosity indicator

Micro-CT imaging

1mm sand groins

Sahar Bakhshian BEG

Burnside and Naylor 2014

Risk assessment

- Substitute underground injection for air release
- Escape of brine or CO₂ to groundwater, surface water, or air via long flowpath
- Earthquake
  - Escape of CO₂ or brine to groundwater, surface water, or air through flaws in the seal
- Failure of well cement or casing resulting in leakage
Induced Seismicity

Microseismicity for tracking pressure elevation

Illinois Basin Decatur Project, Lee et al, 2014
Leakage: likelihood is low x consequence is low = risk is low

- Available past practices
  - 80MMT stored at SACROC field, Scurry County TX
    - No detection of CO₂ in groundwater
  - 20 MMT stored at Sleipner field North Sea
    - No detection of loss by British Geologic survey
  - Well failure studies Kell 2011; Porse, Wade, Hovorka

- Controlled release experiments
  - What would happen if CO₂ leaked to air, water, soil, ocean
    - Small but detectible impacts. No massive damage.
CO$_2$ Controlled Release Experiments

ZERT experiment:

Brackenridge and SECARB experiments
Changbing Yang -- BEG

Ginninderra
http://www.ieaghg.org/docs/General_Docs/1_Combo_Mon_EnvRes/3_GinnCRFSEC.pdf

http://www.pml.ac.uk/News/CCS_controlled_leak_results

http://www.stemm-ccs.eu/
Use of CO₂ for enhanced oil recovery (EOR) process

Residual oil will not move to production wells

At reservoir pressure, CO₂ is miscible with oil
  - Viscosity decrease
  - Volume increase

Oil-CO₂ phase can migrate to production wells

30% Remaining oil is residual, immobile

Oil, CO₂, and H₂O produced

Note: Many other EOR techniques compete with CO₂
CO₂ EOR is a Closed Loop System

Capture unit

Recycle is effective in stripping CO₂ from produced fluids. All the CO₂ captured remains isolated from the atmosphere.

Separation plant

Oil to market

CO₂ emissions

Brine

Oil

CO₂
Safe and Effective Injection > 50 years

Representative projects

Water and gas injection for secondary recovery
Well management, IWR, flood surveillance

CO₂ capture from gas plants and injection for EOR
CO₂ saline storage Sleipner
Monitoring CO₂ EOR Weyburn
Monitoring CO₂ Huff-n-puff West Pearl-Queen
Monitoring CO₂ saline test Nagaoka
Monitoring CO₂ saline test Frio I and II
Monitoring Phase II EOR tests (Cranfield, Zama, SACROC
Injectivity +Monitoring Phase II saline tests
Injection+ monitoring InSalah
Injection+ monitoring Ketzin
Injection+ monitoring Mountaineer
Monitoring Phase III EOR + Saline Cranfield
Monitoring Phase III Saline Decatur
Monitoring Phase III Saline Citronelle
Monitoring Phase III EOR Michigan
NRG, QUEST, Gorgon, Air Products, Boundary Dam...

Skills in CO₂ Injection and handling

Adding Saline
Adding monitoring to demonstrate storage
Commercial storage

1940
1950
1960
1970
1980
1990
2000
2010
2020
Conclusions

• Status of geologic storage in deep saline formations and via EOR: mature, successfully underway and ready for larger scale implementation
• Challenges: convincing key stakeholders this is true
• Capacity is large but unevenly distributed
• Failure is rare, consequences ordinary, and risk manageable
Questions?

Susan Hovorka
Susan.hovorka@beg.utexas.edu
www.gulfcoastcarbon.org
The Carbon Capture and Storage 101 Webinars, May 7 2021

CCS Infrastructure for a Net-Zero Future

Jean-Philippe Hiegel, Strategy & Market Director, Northern Lights JV
Northern Lights, part of a first commercial CCS chain involving multiple emitters

→ A flexible shipping solution
  • Accommodating volumes from multiple emitters
  • Allowing the decoupling of the emitter location from the storage

→ A phased development
  • Phase 1 includes capacity to transport, inject and store up to 1.5 MTPA
  • Phase 2 will increase capacity up to 5 MTPA

→ An incentive to launch a European CCS market
  • Norwegian State subsidies during 13 years in exchange for up to 0.8 MTPA capacity reservation
  • Future revenues to be sourced from marketing of available capacity
Permanent CO2 geological storage, a return to the origins

→ Exploitation licence EL-001 “Aurora” awarded in January 2019
  • Saline aquifer located south of Troll gas field, 2,800 meters below seabed in the Johansen formation
  • Min 100 Mt expected capacity

→ “Eos” appraisal well drilled in March 2020
  • High quality sandstones
  • Sealing cap rock
  • Hydrostatic pressure regime

→ A safe and well-known operation
  • 25 yrs of expertise in CO2 injection & storage (Sleipner since 1996, Snøhvit since 2008)
  • Same natural conditions as O&G trapping for millions of years
  • Monitoring and injection control

Structural trapping → Residual trapping → Dissolution & Mineral trapping
CCS, an essential technology to reach Europe carbon neutrality by 2050

→ A necessary tool to meet Paris Agreement’s target
  • IEA Sustainable Development Scenario <2°C requires CCS growth rate analog as the O&G industry at its beginning

→ CCS at the core of the carbon neutrality virtuous circle
  • Capturing and storing residual CO₂ emitted by hard-to-abate industries (cement, steel, refining & chemicals, etc.)
  • Generating low carbon power from gas
  • Enabling carbon removal (“negative emissions”) through bioenergy with CCS (BECCS) and Direct Air Capture (DAC) with CCS

→ Fully part of the European climate-neutral ambition by 2050
  • Objective at the heart of the European Green Deal and the first European Climate Law
  • Embedded into Member States national strategies (Denmark Climate Act, Dutch Climate Agreement, Norway’s Climate Plan, French Climate Law, …)

* Source: IEA Sustainable Development Scenario <2°C
Northern Lights, part of a first commercial CCS chain involving multiple emitters

→ **A flexible shipping solution**
- Accommodating volumes from multiple emitters
- Allowing the decoupling of the emitter location from the storage

→ **A phased development**
- Phase 1 includes capacity to transport, inject and store up to 1.5 MTPA
- Phase 2 will increase capacity up to 5 MTPA

→ **An incentive to launch a European CCS market**
- Norwegian State subsidies during 13 years in exchange for up to 0.8 MTPA capacity reservation
- Future revenues to be sourced from marketing of available capacity
The dawn of a new industry

→ Northern Lights, a frontrunner in Europe
  - Phase 1 Final Investment Decision and Norwegian Parliament ratification in 2020
  - Northern Lights JV incorporated in March 2021, first company worldwide to deliver CO2 shipping and storage as a service
  - Start of injection scheduled by mid 2024

→ Subsidies and carbon pricing as short-term enablers
  - Two pillars necessary to bridge the gap between the price to emit and the cost to decarbonize

→ Next levers to create value
  - EU/State policies linking CCS and emissions targets (storage certificates, fiscal incentives, etc.)
  - Added value for zero carbon products
CCS infrastructure in the UK

Ian Hunter
Commercial Manager
Net Zero Teesside & Northern Endurance Partnership
Key roles for CCS

Carbon capture

Industry (post-combustion)

Power

Hydrogen

CO₂ usage

Transportation & storage

CO₂ usage

Industry (pre-combustion)
UK Government 10 point plan

• In 2019 UK put into law that the entire country would have Net Zero emissions by 2050

• In November 2020 UK government published its 10-point plan outlining key aims for the next decade
  • To develop four CCS clusters with two operating by the mid-2020s and two more by 2030
  • Capture 10 MtCO2 a year by 2030

• December 2020, UK’s 6th carbon budget update: CCS is essential to reach net zero:
  • >20mtpa by 2030
  • >100mtpa by 2050
UK – Key CCS Clusters

- **Scotland**
  - Hydrogen
  - Power
  - Existing infrastructure

- **Teeside**
  - Gas power
  - Bio-energy
  - Industrial CO₂
  - Hydrogen

- **North West England**
  - Hydrogen
  - Industry
  - Existing infrastructure

- **South Wales**
  - Hydrogen
  - Steel
  - Cement
  - CO₂ shipping

- **Humber**
  - Hydrogen
  - Bio-energy
  - Gas power
  - Industrial CO₂

- **Northern Endurance Partnership**
  - Transportation & offshore storage
Value for Money (1/2)

How will the project lead to decarbonisation of industrial clusters in the long term, after the ISCF investment period of March 2024? What long-term gains would be achieved through this level of public funding?
Business Models – “Split Chain” commercial structure

Gas price

Power generation

Carbon Capture

CO$_2$

NEP Transportation & Storage JV
- Transport & Storage Regulated Investment model (TRI)
- Receives T&S fee

Humber cluster

CO$_2$

T&S fee

NZT Power with CCS JV
- Dispatchable Power Agreement (DPA)
- Revenue from market & billpayer
- Pays T&S fee

Billpayer and market funding

Clean power

Electricity price

Capex / revenue support

Teesside Industry & Hydrogen

Gas

T&S fee

Govern funding