

Navigator CO₂

Heartland Greenway Project Overview

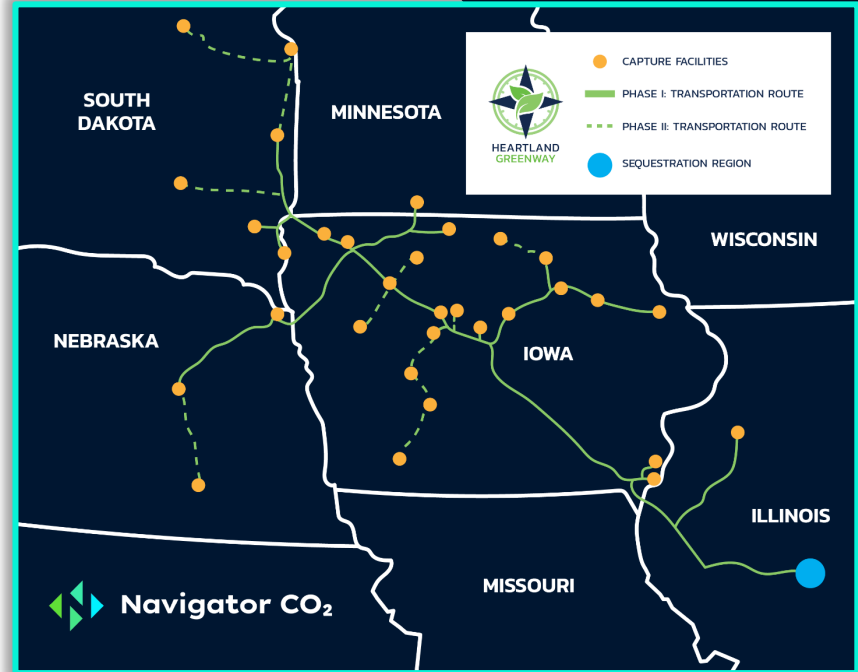
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Heartland Greenway

Project Summary

- ▶ The Heartland Greenway System (HGS) started as a 5MTPA gathering system for Valero
- ▶ In 18 months, the HGS has grown to the largest carbon capture, utilization, and sequestration (CCUS) project in active development in North America
 - ▶ 15 MTPA capacity across ~1,300 miles
 - ▶ 5 states (IA, IL, MN, NE, SD)
 - ▶ Sequestration sites located in Illinois
 - ▶ ~\$3.2 Billion capital investment
- ▶ The HGS is contracted for >11 MTPA with a growing list of high-quality customers

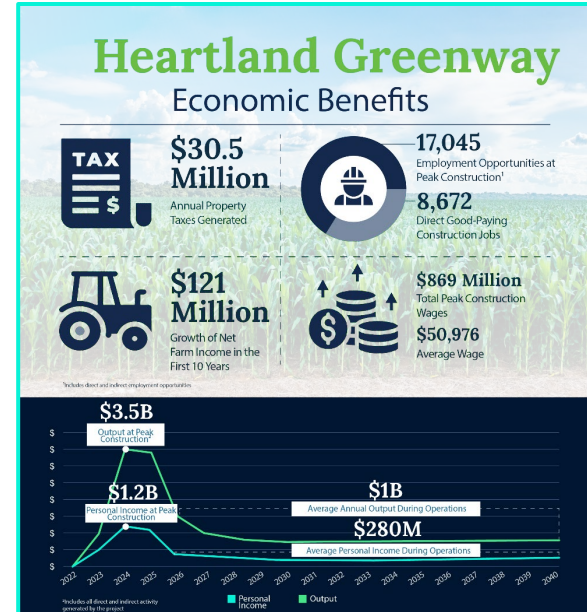


Heartland Greenway Economic Benefits

The system will provide biofuel producers in the Midwest with a cost-effective means to lower their carbon footprint

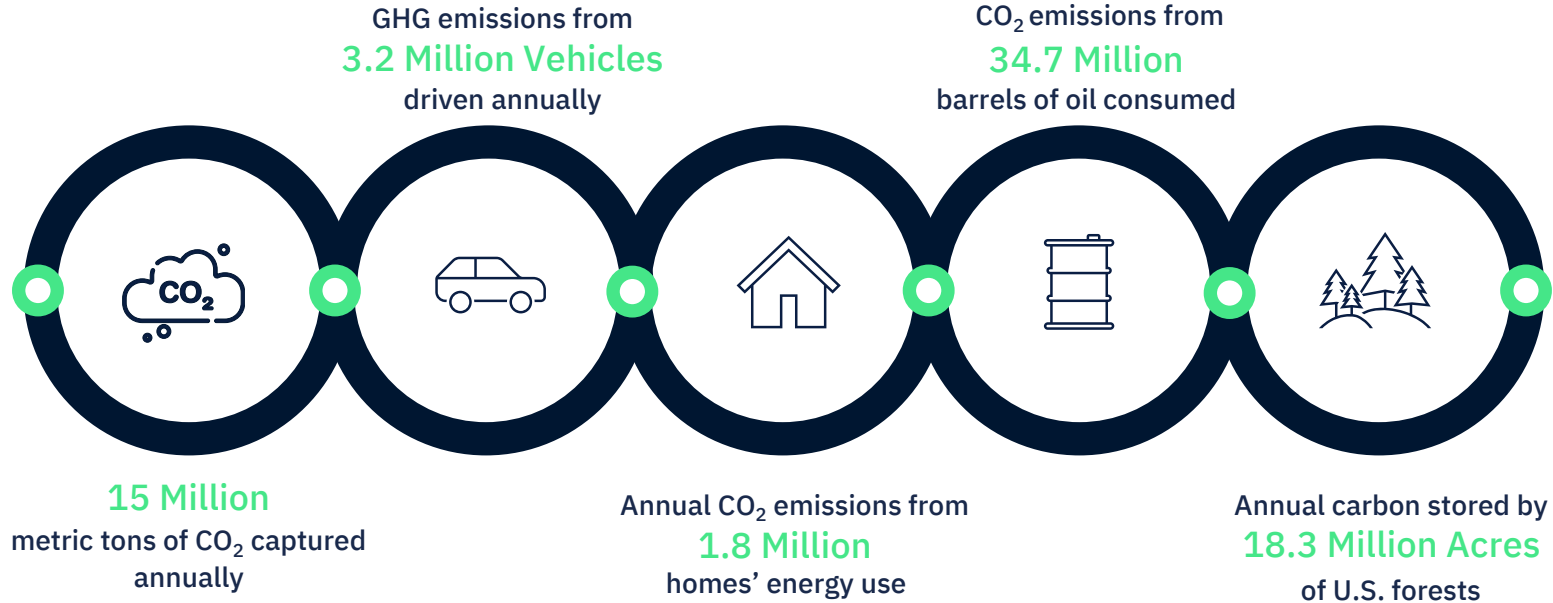
Economic Highlights

- ▶ \$30.5 Million Annual Property Taxes Generated
- ▶ \$121 Million Growth of Net Farm Income in the First 10 Years
- ▶ 17,045 Employment Opportunities at Peak Construction
 - ▶ 8,672 Direct Construction Jobs
- ▶ \$869 Million Total Peak Construction Wages
 - ▶ \$50,976 Average Wage
- ▶ \$3.5B Output at Peak Construction
 - ▶ \$1B Average Annual Output During Operations
- ▶ \$1.2B Personal Income at Peak Construction
 - ▶ \$280M Average Personal Income During Operations



Environmental Benefits

The carbon offset of the Heartland Greenway once fully expanded is equivalent to:



Source: <https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator>

Anticipated Projected Timeline



Pipeline System Specifications

- ▶ **CO₂ content will be min of 98% pure CO₂ compressed to a supercritical fluid at the receipt points to the system**
 - ▶ > 88 deg F and 1070 psig
- ▶ **Line Pipe:** steel pipe designed to mitigate the effects of fracture propagation expressly for HGS CO₂ quality with added toughness parameters (above API-5L PSL2)
- ▶ **Federal Regulation:** design, construct, operate to meet or exceed 49 CFR Part 195
 - ▶ Include best practices and recommended practices from DNV-RP-F104 as well as some components from Part 192
- ▶ **Normal Operating Pressure:** 1,300-2,100 psig (MOP by design, 2,200 psig or ANSI 900)
- ▶ **Pipe Depth:** nominal 5', 18-24" separation below existing pipelines and utilities
- ▶ **Pipe Diameter:** 6"-20" outside diameter
- ▶ **Operating Temperature:** 40-110° F
- ▶ **Mainline Valves:** strategically located per updated PHMSA-2013-0255
- ▶ **Routing to minimize the collective impact to HCAs, vulnerable places of gathering, and other stakeholder inputs (ongoing from engagement)**



49 Code of Federal Regulation Part 195

Transportation of Hazardous Liquids by Pipeline

▶ 195.1 Which pipelines are covered by this part?

(a) Covered. Except for the pipelines listed in paragraph (b) of this Section, this Part applies to pipeline facilities and the transportation of hazardous liquids or carbon dioxide associated with those facilities in or affecting interstate or foreign commerce, including pipeline facilities on the Outer Continental Shelf (OCS).

▶ 195.2 Definitions

Carbon dioxide (CO₂) means a fluid consisting of more than 90 percent carbon dioxide molecules compressed to a supercritical state.

- ▶ HGS will have a min of 98% pure CO₂ and redundant composition quality measurement and control equipment
- ▶ All receipts from CO₂ capture facilities will be at or above the supercritical state of CO₂. (88° F and 1,070 psig)
- ▶ The pressure of CO₂ will be maintained above 1,200 psig to ensure a fluid state of transportation at all times
- ▶ The temperature of the CO₂ will enter the pipeline system between 90-110° F and then achieve ground temperature

High Consequence Areas (HCA's)

Utilized 49 CFR 195.450:

- ▶ **Commercial Navigable Waterways** - which means a waterway where a substantial likelihood of commercial navigation exists
- ▶ **High Population Areas** -which means an urbanized area, as defined and delineated by the Census Bureau, that contains 50,000 or more people and has a population density of at least 1,000 people per square mile
- ▶ **Other Populated Areas** - which means a place, as defined and delineated by the Census Bureau, that contains a concentrated population, such as an incorporated or unincorporated city, town, village, or other designated residential or commercial area
- ▶ **Unusually Sensitive Area** – as defined in 195.6

HGS must take measures to prevent and mitigate the consequences of a pipeline failure that could affect a HCA. These measures include conducting a risk analysis of the pipeline segment to identify additional actions to enhance public safety or environmental protection. Such actions may include, but are not limited to:

- ▶ Implementing damage prevention best practices
- ▶ Better monitoring of cathodic protection where corrosion is a concern
- ▶ Establishing shorter inspection intervals to validate integrity of the system
- ▶ Installing Emergency Flow Restriction Devices (EFRDs) on the pipeline segment
- ▶ Enhanced systems that monitor pressure and detect unplanned releases from the system
- ▶ Providing additional training to personnel on response procedures
- ▶ Conducting drills with local emergency responders and adopting other management controls.

CO₂ Air Dispersion and Plume Modeling

Area Location of Hazardous Atmosphere's (ALOHA) Software:

- ▶ ALOHA was developed and is supported by the Emergency Response Division (ERD), a division within the National Oceanic and Atmospheric Administration (NOAA) in collaboration with the Office of Emergency Management of the U. S. Environmental Protection Agency (EPA). Its primary purpose is to provide emergency response personnel estimates of the spatial extent of some common hazards associated with chemical spills. The ALOHA development team also recognizes that the software can be an appropriate tool for training and contingency planning, but users should remain aware of its primary purpose in spill response.

DNV Phast Software Model:

- ▶ Phast is a globally adopted solution for modeling atmospheric discharge, dispersion, fires, explosions and toxic effects of a wide range of loss of containment scenarios. Process safety professionals benefit from 40 years of development and validation by industry experts and its continued use by more than 10,000 users across 1,000 organizations.

Plume buffers increase in width to increase public safety and awareness:



CO₂ Air Dispersion and Plume Modeling Cont.

Initial Routing Buffer

- ▶ Evaluation for Direct HCA impact to:
 - ▶ High Population Areas (HPAs)
 - ▶ Other Populated Areas (OPAs)
 - ▶ Unusually Sensitive Areas (USAs)
 - ▶ Drinking Water (DW)
 - ▶ Commercial Navigable Waters (CNW)
 - ▶ Vulnerable Places of Gathering
- ▶ Utilized for initial routing where possible to maximize spacing between HGS and inhabitable structures
- ▶ Included as a significant parameter to minimize the collective impacts of the Heartland Greenway System

Additional Design and Operational Mitigation Buffer

- ▶ Where pipeline falls within “Design and Operations” buffer, the following additional mitigation measures may be utilized in any combination:
- ▶ Design Enhancements:
 - ▶ Increased design factor and wall thickness of pipeline
 - ▶ Increased interval of Emergency Flow Restriction Device (EFRD) analysis for valve placement
 - ▶ Increased third party damage mitigation
 - ▶ Enhanced leak detection and air monitors
- ▶ Operational Enhancements:
 - ▶ Increased system surveillance interval
 - ▶ Redundant control, power, and communication capabilities
 - ▶ Increased integrity validations and assessments through Integrity Management Plan
 - ▶ Strategically located HGS personnel or third-party resources

CO₂ Air Dispersion and Plume Modeling Cont.

Emergency Response Buffer

- ▶ Where pipeline falls within “Emergency Response” buffer, the following additional mitigation measures utilized:
 - ▶ Indirect HCA impact to HPAs/OPAs/CNWs
 - ▶ CO₂ training and drills for HGS and First Responders
 - ▶ First Responder resources (equipment and personnel) verifications and supplements by Navigator
- ▶ Current plan is to expand the actual Emergency Response buffer once all Emergency Responder meetings are complete (Currently incorporating county plus any mutual aid partners)

Public Awareness Buffer

- ▶ Where pipeline falls within “Public Awareness” buffer, the following additional mitigation measures utilized:
 - ▶ NAV911 System will be designed to provide roll out calls based on emergency events. Yearly communications made to ensure accuracy of contact numbers.
 - ▶ Annual public awareness and training
- ▶ Current plan is to expand the actual Public Awareness buffer once all Emergency Responder meetings are complete (~1-10 miles)

HGS continues to work with external stakeholders and SMEs to develop additional models and proactive measures to enhance public safety.



HGS Line Pipe Specifications

- ▶ Navigator is working with API-5L PSL2, DNV US, and other SMEs to develop a line pipe specification for the Heartland Greenway System
- ▶ Navigator uses a conservative application of the Battelle Two-Curve Method to mitigate the effects of fracture propagation. Fracture arrest will happen when the crack velocity is below the gas velocity at the crack tip at all pressures as influenced by the pipe toughness.
- ▶ HGS Line Pipe Specification chosen to control formation of brittle microstructures:
 - ▶ Yield strengths X60M and X65M (thermo-mechanically control processed steel)
 - ▶ Tensile strength requirements are significantly stricter than API 5L PSL2 limits
- ▶ The utilization of crack arrestors will also serve as a redundant mitigation system against fracture propagation
- ▶ **ALL** materials (valves, line pipe, flanges, etc.) will be designed to withstand **ALL** pressure and temperature ranges of the Heartland Greenway System



CO₂ Odorant and Leak Detection

Odorant

- ▶ Performing research on unique odorant vs traditional oil and gas infrastructure with academic and industry partners
- ▶ Current research has a “garlic” type odor vs traditional mercaptan “rotten egg” odor to further differentiate products in the unlikely event of a release
- ▶ Evaluating potential impacts of odorant on sequestration and end use of CO₂ in demand markets (Ex. food/beverage)



Enhanced Leak Detection

Continuous Leak Detection System

- ▶ **Compensated Mass Balance** – Based on the conservation of mass principle. In a steady-state (single phase), the mass entering a leak-free pipeline will balance the mass leaving it.
- ▶ **Real Time Transient Model (RTTM)** – Uses conservation of mass, conservation of momentum, and conservation of energy principles to derive stationary and transient behavior of flow in the pipeline in real time to achieve leak detection.
- ▶ **Negative Pressure Wave** – Analysis of pressure signals. When a leak occurs, it causes a negative pressure wave propagating in both directions, upstream and downstream of a leak’s location. The pressure drop is measured at specific locations of measurement points.

Non-Continuous Leak Detection System

- ▶ **Aerial Patrol**
 - ▶ HGS plans for aerial patrols via fixed wing or other alternatives such as autonomous drones.
- ▶ **In-line Inspection Tools** (at mechanical completion of pipeline + every 3-5 years)

Pipeline Safety and Operations

Operational Philosophy

- 24/7 remote monitoring by qualified control center personnel
- SCADA analyzing pressure, temperature, flow rate
- Redundant communications to avoid outages
- Cathodic protection equipment and monitoring

Pre-Commissioning

- Hydrostatic testing above max operating pressure (1.25 x MOP)
- Coordination with local first responders
- System-wide pre-startup and safety review (PSSR)

Damage Prevention & Public Awareness

- Semi-Monthly aerial surveillance, weather permitting every ~10 days
- #811 public awareness and damage prevention
- Meetings, training drills, and communication with local liaisons

Maintenance & Response

- Routine pipeline testing, calibration, and inspection
- Annual desktop & biannual field response simulations
- Contract with private responders located along route

Thank you.

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