



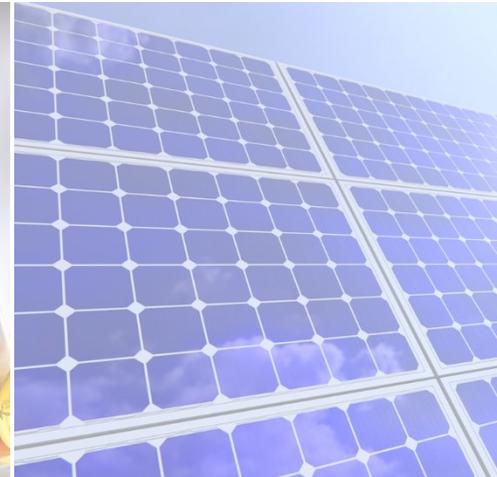
Company Overview

CARBON SOLUTIONS LLC

Richard Middleton
CEO

CARBON SOLUTIONS

richard.middleton@carbonsolutionsllc.com





CARBON SOLUTIONS



Vision: Solutions for a net-zero carbon economy

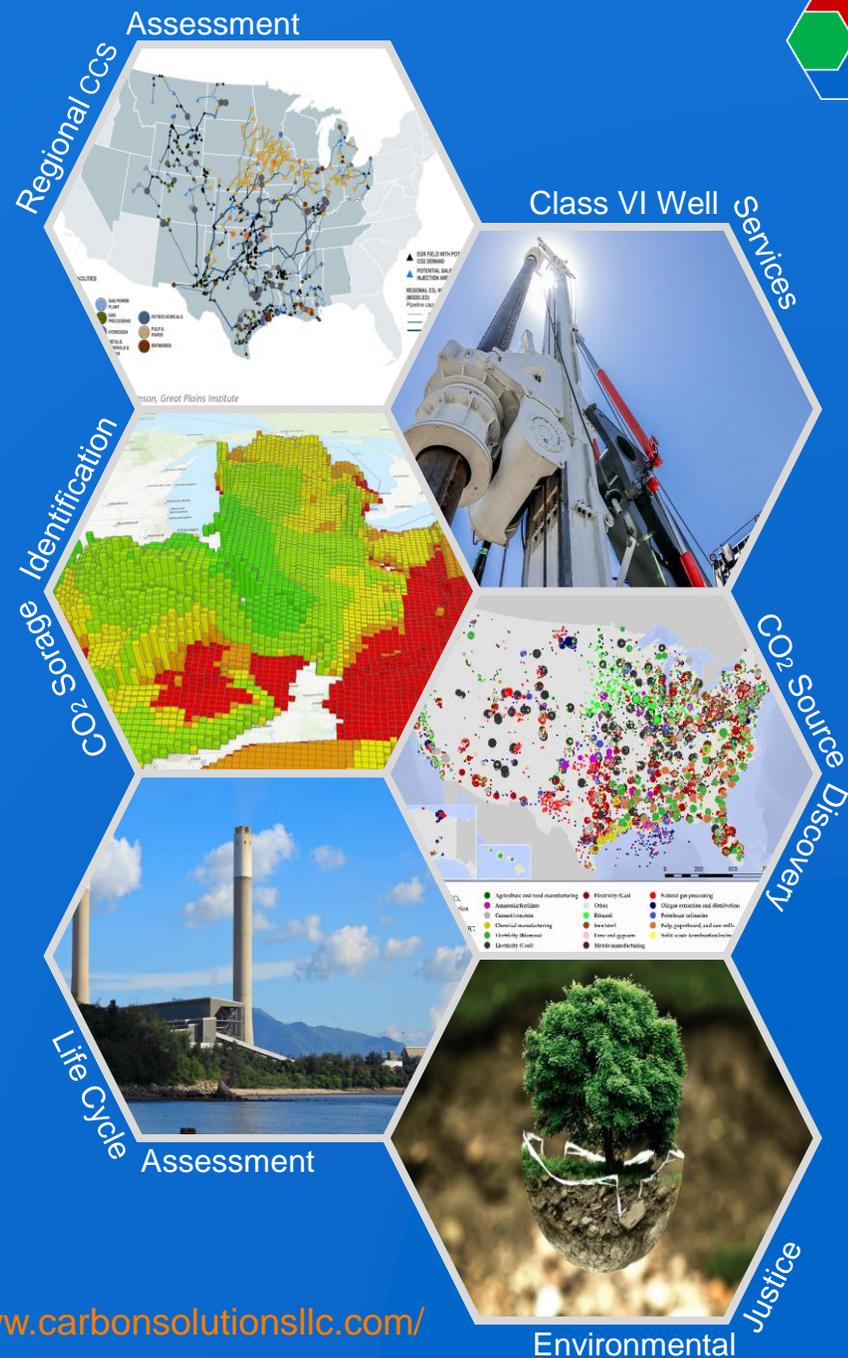
- *CARBON SOLUTIONS works with industry, government, non-profits, researchers, & other stakeholders to identify & implement real-world solutions for low-carbon energy challenges.*
- **HISTORY:** Launched 2021 | 30+ employees (15 PhD's) | 75+ projects.
- **FUNDING:** 65% Government | 20% NGOs | 15% Industry.
- **FOUNDATION:** Development of *SimCCS*.

Energy applications

- CO₂ capture-transport-utilization-storage, hydrogen, direct air capture, geothermal, wind, energy storage, grid modeling, electric vehicles, energy equity...

Data analytics

- Optimization, reservoir simulation, ML/AI, LCA, TEA, econometrics, GIScience...





RICHARD MIDDLETON

Chief Executive Officer | CARBON SOLUTIONS LLC

PROFILE

Dr. Richard Middleton is CEO and co-founder of CARBON SOLUTIONS LLC, a startup focusing on low-carbon energy Research & Development and Software & Services, including CO₂ capture and storage (CCS), energy storage, geothermal energy, and wind energy. His work focuses on two major research areas: (1) energy & infrastructure modeling, including CCS, unconventional fossil fuels (such as shale gas and CO₂-enhanced fracturing & hydrocarbon recovery), geothermal exploration, wind energy optimization, and bioenergy planning and landscape design; and (2) climate impacts on natural & engineered systems including climate extremes, hydrology, ecosystem dynamics, and the energy-water nexus. He has been ranked as the US' third-most productive CCS researcher (1997–2017) as well as Los Alamos' most-published Earth science first-author from 2010–2018. He is the lead developer of SimCCS, a research- and industry-leading decision support framework for understanding how, where, and when CCS infrastructure could and should be deployed.

CONTACT

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LinkedIn: www.linkedin.com/in/richardmiddleton
Website: www.carbonsolutionsllc.com
Blog: chartedterritory.us

EDUCATION & TRAINING

- Ph.D.** | Geography/Operations Research | University of California Santa Barbara 2001–2006 | GPA: 4.0
- M.Sc.** | Geographical Information Science (GIScience) | University of Leicester 1998–1999 | Distinction
- B.Sc.** | Geography | Lancaster University 1993–1996 | 2:1

PROFESSIONAL EXPERIENCE

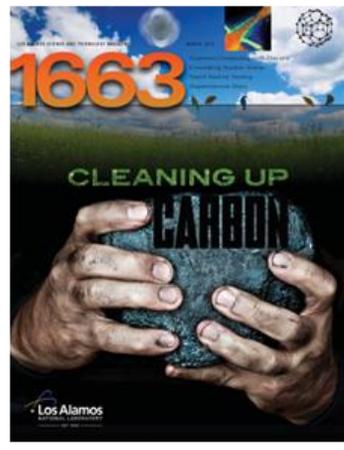
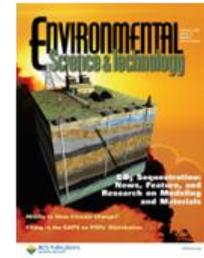
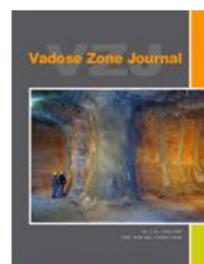
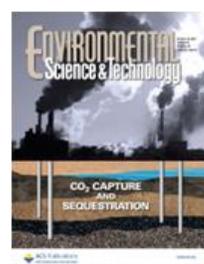
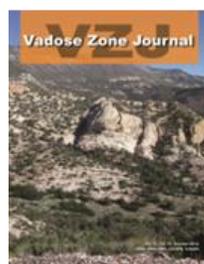
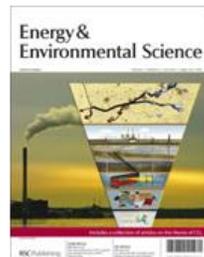
- Chief Executive Office/Co-founder** | CARBON SOLUTIONS LLC | 2021–Present
Develop & manage multi-million dollar annual portfolio | Principal analyst | Strategic development | Long-term operational management
- Manager** | Los Alamos National Laboratory | 2016–2020
Manage, guide, & mentor 50 researchers, postdoctoral fellows, & students | Manage \$15M/yr group budget | Oversee multi-million dollar projects
- Senior Scientist** | Los Alamos National Laboratory | 2016–2021
Major project development | Strategic planning | Energy-water nexus lab lead
- Research Scientist** | Los Alamos National Laboratory | 2009–2016
CO₂ capture & storage | Climate/disturbances | Energy-water nexus | Geothermal exploration | Shale gas/fracturing | Water resource management
- Senior Infrastructure Modeler** | Oak Ridge National Laboratory | 2007–2009
Biofuels | Geospatial modeling | Transportation | Supply chain
- Postdoctoral Researcher** | Los Alamos National Laboratory | 2006–2007
CO₂ capture & storage | Water resources management | Geospatial optimization

AWARDS

- Double R&D 100 Award winner | Quic-Fire | 2020
- Highest-impact Earth science pub., Los Alamos (2017–2020) | 2020
- POWER Magazine Award, Finalist | SimCCS | 2020
- Double R&D 100 Award winner | SimCCS | 2019
- World "Top 10 most-cited" CCS researcher (1997–2017) | 2019
- #1 First-author for Earth Science, Los Alamos (2011–2018) | 2018
- Distinguished Mentor Award, Los Alamos | 2017

MEDIA & INTERVIEWS

- Scientific American | Carbon Capture: Solved by Software? | 2020
- Albuquerque Journal | AI pinpoints renewable energy resources | 2020
- Reuters | Startups strive to recycle emissions for 'new carbon economy' | 2019
- Le Monde | Au Texas, on exploite le gaz de schiste en pleine ville | 2018
- Albuquerque Journal | New approach to extracting fossil fuels | 2018
- Physics Today | Refracturing may not be all it's cracked up to be | 2017



LEADERSHIP TEAM

Richard Middleton

Education

- **PhD:** Operations Research | UCSB
- **MSc:** GIScience | Univ. Leicester
- **BSc:** Geography | Lancaster Univ.

Professional

- **CARBON SOLUTIONS** | 2021– | CEO.
- **LANL** | 2009–21 | Sen. Scientist, Mgr.
- **ORNL** | 2007–09 | Geospatial Model.

Research

- **ENERGY:** CCS, wind, geothermal, hydropower.
- **CLIMATE:** Extremes, drought, wildfire, hydrologic impacts.
- **MACHINE LEARNING:** COVID, shale gas, wildfire.

Awards

- Global top-ten CCS researcher.
- Four R&D 100 Awards.
- Most-published, cited Los Alamos Earth Scientist.



JEFF BENNETT

Research Engineer | CARBON SOLUTIONS LLC

PROFILE

Dr. Jeffrey Bennett is a Research Engineer at CARBON SOLUTIONS LLC, a startup focusing on low-carbon energy Research & Development and Software & Services, including CO₂ capture and storage (CCS), energy storage, geothermal energy, and wind energy. His work focuses on using modeling tools to identify opportunities to reduce the environmental impact of emerging energy technologies. His dissertation explored the trade-offs between emissions, cost and resilience in emerging technologies supporting deep decarbonization of the electric grid. His research has focused in the areas of energy system modeling, distributed electric grids, supercritical carbon dioxide power plants, offshore compressed air energy storage, and bioenergy with carbon capture and storage.

CONTACT

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Website:
<https://www.carbonsolutionsllc.com/>
GitHub:
<http://www.github.com/EnergyModels/>

EDUCATION & TRAINING

- Ph.D.** | Civil Engineering
University of Virginia | 2021
- M.S.** | Mechanical Engineering
University of Texas at San Antonio | 2017
- M.Sc.** | Turbomachinery Aeromechanics University Training
Royal Institute of Technology and University of Liège | 2012
- B.Sc.** | Mechanical Engineering
Virginia Polytechnic Institute and State University | 2010

PROFESSIONAL EXPERIENCE

- Research Engineer** | CARBON SOLUTIONS LLC | 2021–Present
Graduate Research Assistant | University of Virginia | 2017–2021
Life cycle assessment of carbon capture and power plant technologies for bioenergy | Analyzed impact of Puerto Rico's electric grid options on cost and emissions | Developed simulations of hybrid (solar photovoltaic and gas turbine) energy systems
- Research Engineer** | Southwest Research Institute | 2014–2017
Managed projects related to power generation for government and industry clients | Optimized the efficiency of power plant thermodynamic models using advanced working fluids
- Engineer** | Southwest Research Institute | 2012–2014
Simulated critical pump and compressor station transients to ensure safe operation in the field
- Summer Intern** | General Electric Wind | 2011
- Summer Intern** | General Electric | 2008, 2009

CERTIFICATIONS

- Professional Engineer**, State of Michigan, License No. 6201310270, Commonwealth of Virginia, License No. 0402058338
- LEED Green Associate**, U.S. Green Building Council

SELECTED PUBLICATIONS

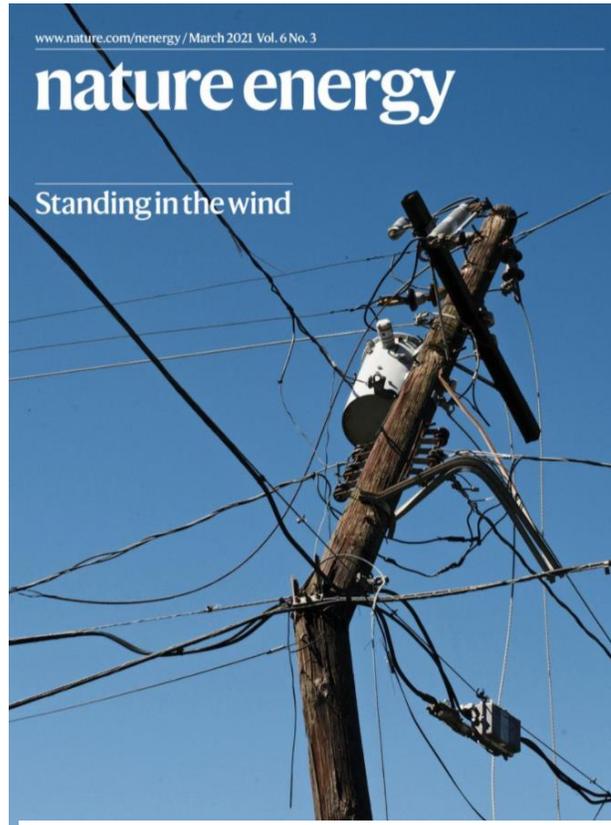
- Bennett, J.A.**, Trevisan, C.N., DeCarolis, J.F., Ortiz Garcia, C., Pérez-Lugo, M., Etienne, B.T., Clarens, A.F., (2021), Extending energy system modelling to include extreme weather risks and application to hurricane events in Puerto Rico, *Nature Energy*, 6, 240–249, doi.org/10.1038/s41560-020-00758-6
- Bennett, J.A.**, Simpson, J.G., Qin, C., Fittro, R., Koenig, G.M., Clarens, A.F., Loth, E., (2021), Techno-economic analysis of offshore isothermal compressed air energy storage in saline aquifers co-located with wind power, *Applied Energy*, 303, 117587, doi.org/10.1016/j.apenergy.2021.117587



Life cycle meta-analysis of carbon capture pathways in power plants: Implications for bioenergy with carbon capture and storage

Jeffrey A. Bennett^a, Mohammad Abotalib^b, Fu Zhao^c, Andres F. Clarens^{a,*}

^a Department of Engineering Systems and Environment, University of Virginia, Charlottesville, Virginia, United States
^b Department of Earth and Environmental Sciences, Kuwait University, Safat, Kuwait
^c Department of Mechanical Engineering, Purdue University, West Lafayette, Indiana, United States



Techno-economic analysis of offshore isothermal compressed air energy storage in saline aquifers co-located with wind power

Jeffrey A. Bennett^{a,*}, Juliet G. Simpson^b, Chao Qin^b, Roger Fittro^b, Gary M. Koenig Jr.^c, Andres F. Clarens^b, Eric Loth^b

^a Department of Engineering Systems and Environment, University of Virginia, Charlottesville, VA, United States
^b Department of Mechanical and Aerospace Engineering, University of Virginia, Charlottesville, VA, United States
^c Department of Chemical Engineering, University of Virginia, Charlottesville, VA, United States

LEADERSHIP TEAM

Jeff Bennett

Education

- **PhD:** Civil Engineering | UVA
- **MS:** Mechanical Engineering | UTSA
- **MSc:** Turbomachinery Aeromechanics | KTH & ULg
- **BS:** Mechanical Engineering | VT

Professional

- **CARBON SOLUTIONS** | 2021– | Research Engineer
- **UVA** | 2017–2021 | Graduate Research Assistant
- **SwRI** | 2012–2017 | Research Engineer

Research

- **Life Cycle Assessment:** Bio-Energy with Carbon Capture and Storage (BECCS)
- **Energy System Modeling:** Compressed Air Energy Storage (CAES), Capacity Expansion, CCS
- **Software development:** Tools to evaluate novel energy technologies



ERIN MIDDLETON

Research Scientist | CARBON SOLUTIONS LLC

EDUCATION & TRAINING

- Ph.D. | Geography**
University of California at Santa Barbara | 2004–2007
- MA | Geography**
University of California at Santa Barbara | 2001–2004
- BS | Major: Environmental Geoscience Minor: Political Science**
Purdue University | 1996–2000

PROFESSIONAL EXPERIENCE

- Research Scientist | CARBON SOLUTIONS LLC | 2021–Present**
Integrate social, physical, and environmental health characteristics in routing and siting energy-related infrastructure.
- Spatial Analyst & Demographer | Community Data Platforms | 2021–Present**
Develop procedures for flexible data analysis and survey weighting on a range of topics for use by community leaders across the United States.
- Data Analyst | Los Alamos Public Schools, Los Alamos, NM | 2019–2020**
Performed data analysis of demographic and student assessment data, developed dashboards for teachers and administrators, created databases of formal and informal student assessments, created school board reports, and developed, administered, and analyzed a variety of district surveys.
- Consultant | New Mexico | 2016–2020**
Worked with school and community organizations to create reports for their respective boards, including Los Alamos Public Schools (data analysis, continuous improvement, and equity), Magdalena Public Schools (school climate surveys), and United Way of Northern New Mexico (community health access).
- Visiting Researcher | University of Tennessee - Knoxville | 2008–2009**
Developed state-wide population projections at the Center for Business and Economic Research. Taught undergraduate course in Environmental Geography and a graduate course in Population Geography.
- Postdoctoral Researcher | Oak Ridge National Laboratory | 2007–2008**
Worked on projects related to evaluation planning, electrical grid failure, and agent-based modeling of voting behavior.

VOLUNTEER WORK AND OTHER PROJECTS

- Los Alamos Public Schools Equity Council | 2019–2020
- New Mexico Public Education Department, Assessment and Accountability Working Group | 2018–2020
- Assessment and Accountability Community of Practice | 2018–2020
- Parent Teacher Association at Mountain Elementary, Los Alamos, NM | 2018–2020
- Jemez Valley Public Schools, School Board Member | 2012–2015

PROFILE

Erin is passionate about using data and visualization tools to guide stakeholders to make informed decisions aligned to their strategic goals. While the bulk of her recent experience has been in developing metrics, models, and dashboards related to student well-being and achievement in public schools, she also has experience with projects related to community health, program evaluation, educational equity, evacuation planning, population forecasts, and predicting voting behavior. At Carbon Solutions LLC, she is excited to explore how social, health, and physical data can be integrated to address low-carbon energy challenges.

CONTACT INFORMATION

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CARBON SOLUTIONS LLC Website:
www.carbonsolutionsllc.com/

Education

- PhD:** Geography | Univ. California, Santa Barbara
- MS:** Geography | Univ. California, Santa Barbara
- BS:** Env. Geoscience | Purdue University

Professional

- CARBON SOLUTIONS** | 2021– | Dir. Equity
- Comm. Data Platform** | 2021 | Analyst
- Los Alamos Schools** | ‘19–’21 | Data Analyst
- Consulting** | ‘16–’19 | Consultant.
- Univ. Tennessee** | ‘08–’09 | Visiting Faculty
- ORNL** | ‘07–’09 | Postdoctoral Researcher

Research

- ENERGY:** Hydrogen, wind CCS.
- ENERGY EQUITY:** Environmental justice, outreach, community engagement.
- DATA ANALYTICS:** GIScience, demography, geostatistics.



JONATHAN OGLAND-HAND

Research Scientist | CARBON SOLUTIONS LLC

PROFILE

Dr. Jonathan Ogland-Hand is a Research Scientist at CARBON SOLUTIONS LLC, a startup focusing on low-carbon energy Research & Development and Software & Services, including CO₂ capture and storage (CCS), energy storage, geothermal energy, and wind energy. He researches topics including energy storage, geothermal energy, CO₂ transportation and geologic storage, utilization of geologically stored CO₂, and renewable energy integration. To do this, he has built, used, and integrated tools such as capacity expansion models, economic dispatch models, cost models, coupled plant-level models of wells and power plants, dynamic programs, and reservoir simulation. Personal values he seeks to incorporate into his work-life include teamwork, reflection, direct communication, diligence, and patience.

CONTACT

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LinkedIn:
<https://www.linkedin.com/in/j-ogland-hand>
Website:
<https://www.carbonsolutionsllc.com/>
Google Scholar Profile:
[Link](#)

EDUCATION

- Ph.D. | Environmental Science**
The Ohio State University | 2014-2019
- M.Sc. | Environmental Science**
The Ohio State University | 2014-2017
- B.Sc. | Mechanical Engineering**
Valparaiso University | 2010-2014

PROFESSIONAL EXPERIENCE

- Research Scientist | CARBON SOLUTIONS LLC | 2021-Present**
- Postdoctoral Associate | ETH Zurich | 2019-2021**
Improved the Sequestration of CO₂ Tool (SCO₂T) with Richard Middleton and Ryan Kammer | Added geologic CO₂ storage to NREL's Regional Energy Deployment System model (ReEDS) with Stuart Cohen | Assisted Ben Adams in his development and application of the generalizable GEothermal techno-economic simulator (genGEO) | Managed an interdisciplinary team for a 2019 Siemens Next47 project
- Doctoral Student | The Ohio State University | 2014-2019**
Under the guidance of Jeffrey Bielicki, Ramteen Sioshansi, and Thomas Buscheck, developed and valued approaches for using geologically stored CO₂ for energy storage and created a natural resource economic model for geothermal heat resources | Mentored undergraduate researchers | Procured ~\$42k through grant writing
- Academic Cooperation Participant | Lawrence Livermore National Laboratory | Summer 2015**
Gained proficiency in running the Non-isothermal Unsaturated Flow and Transport Simulator (NUFT) under the guidance of Thomas Buscheck
- Undergraduate Research Intern | Valparaiso University | 2013-2014**
Under the guidance of Robert Palumbo, Luke Venstrom, and Scott Duncan, worked with other engineering and chemistry undergraduate students on two concentrating solar power projects: 1) funded by NSF to produce hydrogen from metal oxides; 2) funded by DOE to produce magnesium from magnesium oxide.

AWARDS

- Geothermal Resource Council Graduate Scholarship Award | 2018
- The Ohio State University Preparing Future Faculty Fellow | 2018
- NSF Graduate Research Fellowship Honorable Mention | 2016
- NSF Graduate Research Fellowship Honorable Mention | 2015
- The Ohio State University Graduate School Fellow | 2014
- Valparaiso University Outstanding Senior Award | 2014

Education

- **PhD:** Environmental Science | OSU
- **MS:** Environmental Science | OSU
- **BS:** Mech. Engineering | Valpo

Professional

- **CARBON SOLUTIONS** | 2021- | Director of Energy Systems Analysis
- **ETH Zurich** | 2019-2021 | Postdoc
- **Lawrence Livermore National Lab** | Summer Student | Summer 2015

Research

- **ENERGY SYSTEM MODELING:** Capacity expansion, Dispatch, Dynamic Programming.
- **TECHNO-ECONOMIC ASSESSMENT:** CCS, geothermal, energy storage
- **CCS:** CO₂ Storage, carbon dioxide removal.
- **RENEWABLE ENERGY INTEGRATION:** CPG, energy storage.



Staffing

- 25 employees.

Background

- 13 PhDs.
- Geoscience, Engineering (Chemical, Civil, Electrical, Environmental, Mechanical, Petroleum), Geology, Computer Science, Policy Analysis, Geography, Economics...

							
Richard Middleton CEO, Science Leader	Benjamin Adams Mechanical Engineering	Jeff Bennett Engineering, LCA, Software Development	Bjorn Brooks Climatology, Geology	Juan C. Duque Spatiotemporal Analysis	Kevin Ellett Geoscience, Reservoir Simulation	Chris Gilhooley GIScience, Urban Planning	Andrew Harrison Economics
							
Monica Hernandez-Lara Business Management	Peter Johnson Geoscience, Reservoir Simulation	Amy Jordan Hydrogeology, Software Development	Qasim Mehdi Env. Justice, Env. Policy & Engineering	Erin Middleton Energy Equity & Env. Justice	Marcos Miranda Infrastructure Optimization	Jonathan Ogland-Hand Energy Systems, TEA, Software	Jonathon Prehn GIScience
							
Daniel Rodriguez LCA, GIScience	Kat Sale Chemical Engineering	Eric Schroeder Finance & Administration	Carl Talsma Software Engineering	Jacqueline Taylor Environment, Policy	Chris Upchurch Transportation Planning, Optimization	Tracey Ziev Mechanical Engineering	

Award-winning CCS Science & Software

Company foundation

- Founded on award-winning CCS science & software.

SimCCS^{PRO}

- Decision-support framework for designing CO₂ capture, transportation, & storage (CCS) infrastructure.
- Industry- & research-leading CCS infrastructure tool.
- Dozens of scientific papers, thousands of citations.
- Two R&D 100 Awards (2019).

Decision discovery & support

- Integrated capture, transport, & storage economics.
- End-to-end techno-economic assessment (TEA).
- Policy analysis.
- System-wide life cycle assessment (LCA).

CARBON SOLUTIONS

- Leveraging decades of carbon *research* to help industry, stake-holders, and the Nation develop carbon *solutions*.

Joint 2019 R&D 100 Entry

SimCCS^{2.0}

Los Alamos National Laboratory,
Montana State University, and
Indiana University

Open-source software for designing CO₂ capture,
transport, and storage infrastructure

- Designs complex infrastructure to optimally link CO₂ sources and storage sites
- Identifies real-world routes for CO₂ pipeline networks and trunk lines
- Maximizes industry revenues from carbon tax credits and enhanced oil production while reducing carbon footprints
- Runs on laptops, the web, and supercomputers
- Enhances collaboration through customization and shareability

SPECIAL RECOGNITION

2019

R&D 100

SILVER

2019

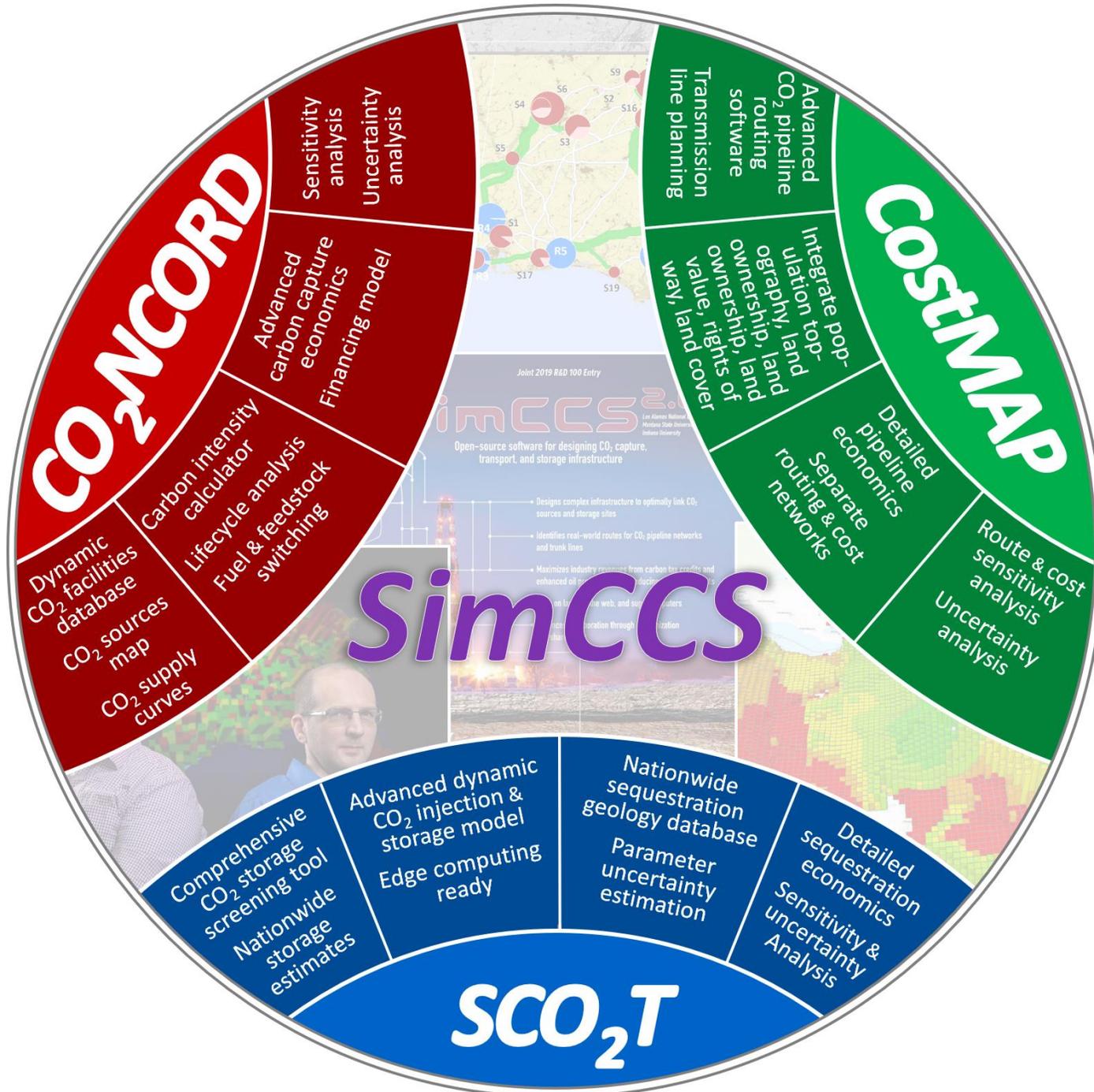
R&D 100

WINNER

Los Alamos NATIONAL LABORATORY EST. 1943

MONTANA STATE UNIVERSITY

INDIANA UNIVERSITY

**SimCCS^{PRO} (system analysis)**

- Decision support across the CCS value chain.
- Leading sub-models for CO₂ capture, transport, & storage.

CO₂NCORD (capture)

- Dynamic, customizable CO₂ capture database.
- 10,000+ sources.

CostMAP^{PRO} (transport)

- Advanced, multiscale, multi-attribute pipeline routing.

SCO₂T^{PRO} (storage)

- World's most advanced & accurate tool for dynamic CO₂ storage & costs.

CCS Decision Support

Integrated CCS assessment

- Simultaneously understand capture, transport, & storage of CO₂.

Capture

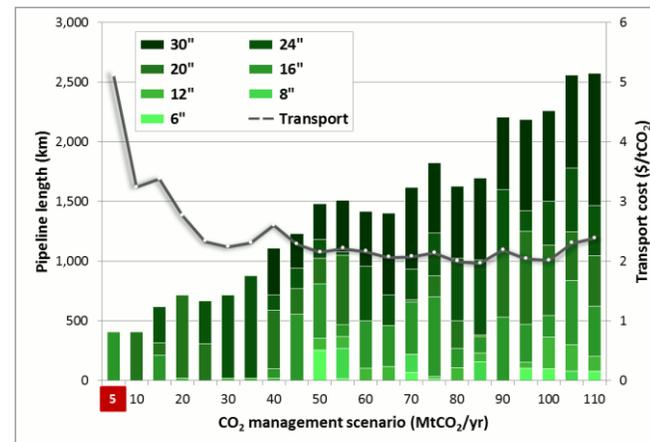
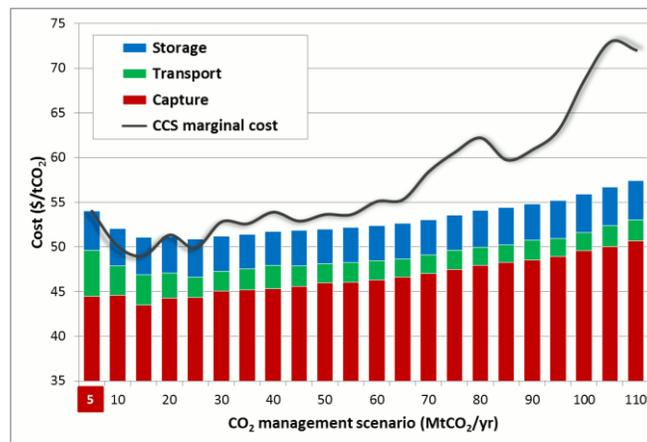
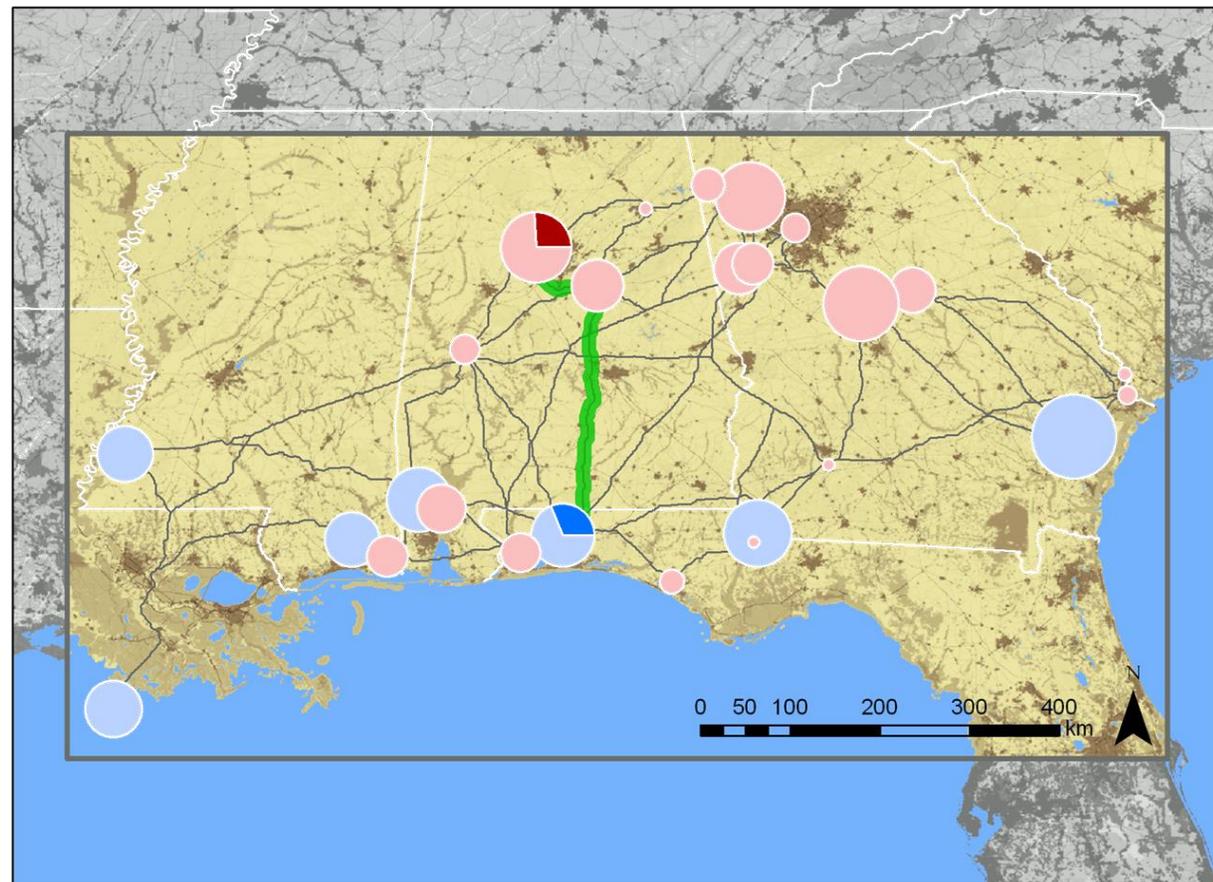
- CO₂ emissions, capturable CO₂, CO₂ purity by multiple streams, economics over space & time.

Transport

- **ROUTES:** Potential routes considering multi-dimensional geographies.
- **PIPELINES:** Capacities, trunklines to aggregate CO₂, economics (capital, fixed & variable O&M).

Storage:

- **STORAGE:** Identify ideal sites, dynamic CO₂ injection & storage, life-time reservoir costs (injection, storage, & PISC).
- **UTILIZATION:** Oil, shale gas, geothermal, & materials.



CO₂NCORD

Description

- **SOFTWARE:** Most advanced screening-level CO₂ capture database.

Motivation

- Rapidly characterize individual CO₂ sources.
- Directory of CO₂ opportunities.

Customer discovery

- Capture technologies.
- Investment banks.
- Technology companies.
- CO₂ storage.
- Government/NGOs.

CO₂NCORD

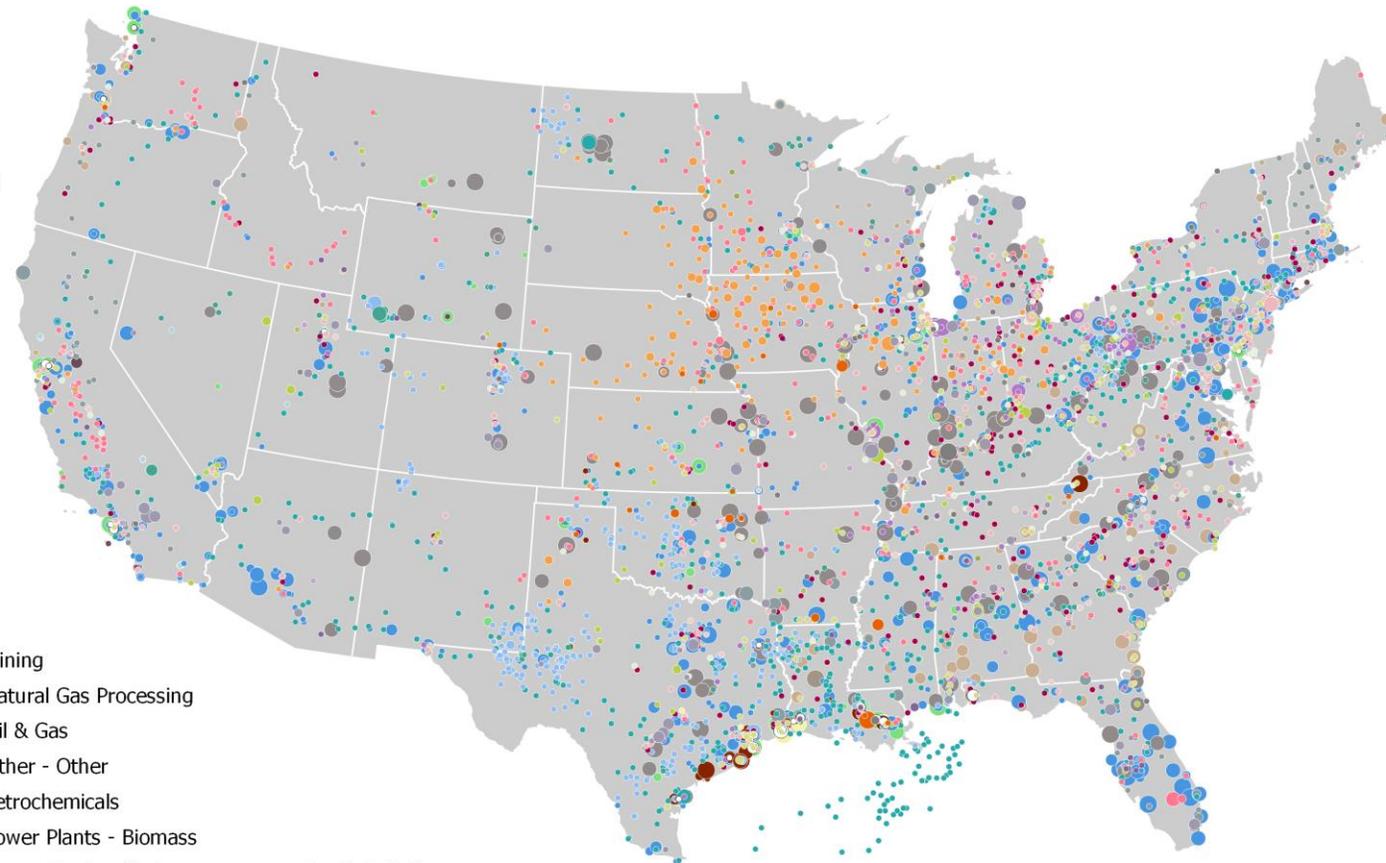
The CO₂ National Capture Opportunities and Readiness Database

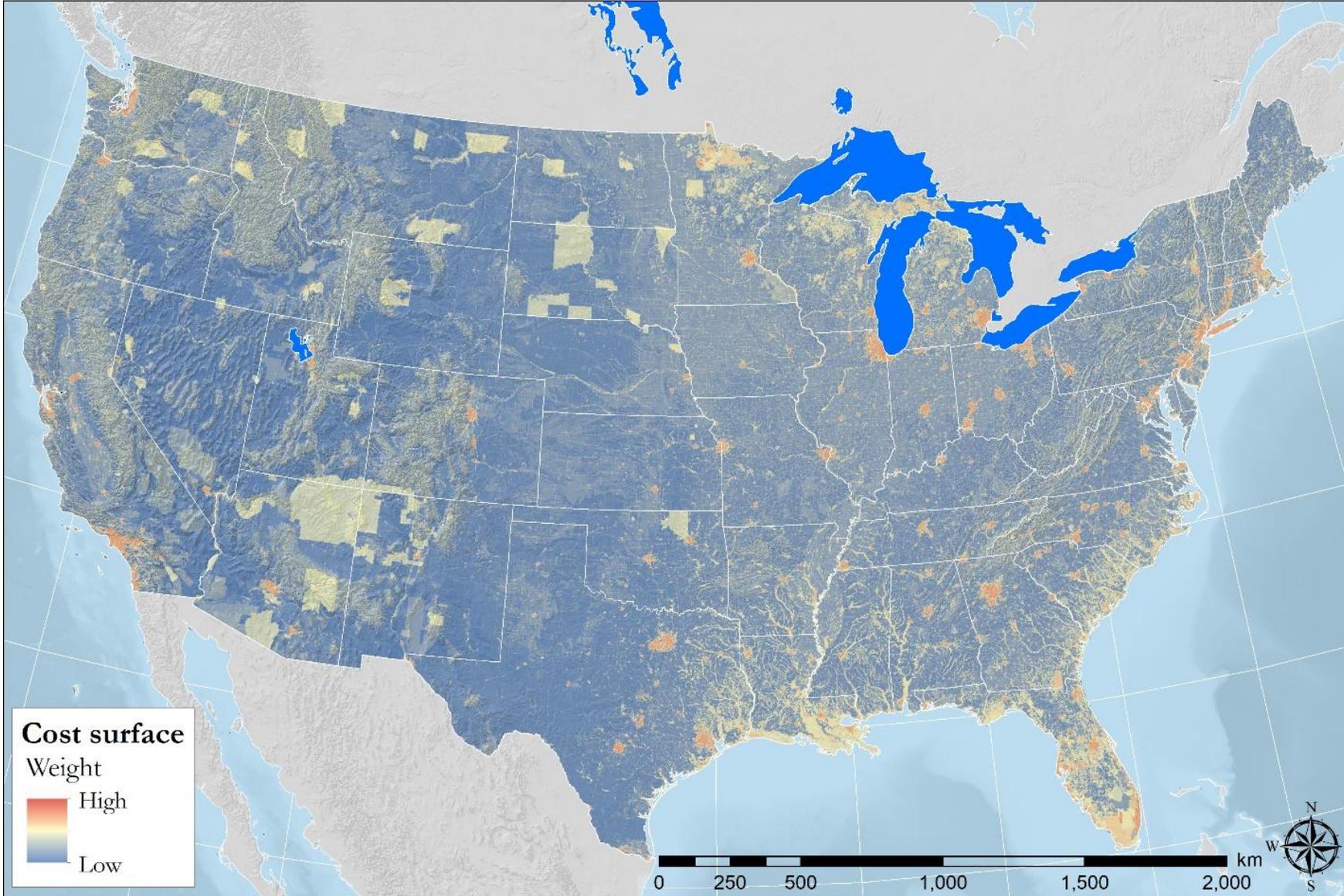
Capturable Emissions (MtCO₂)

- 0.00 - 0.50
- 0.50 - 0.85
- 0.85 - 1.50
- 1.50 - 3.00
- 3.00+

Industry Category

- | | | |
|---------------------|-------------------------------|--------------------|
| ○ Aluminum | ● Mining | ● Pulp & Paper |
| ● Ammonia | ● Natural Gas Processing | ● Refineries |
| ● Cement | ● Oil & Gas | ● Solid Waste |
| ● Chemicals | ● Other - Other | ● Waste - Landfill |
| ● Chemicals - Other | ● Petrochemicals | ● Waste - Other |
| ● Ethanol | ● Power Plants - Biomass | |
| ● Facilities | ● Power Plants - Coal | |
| ● Food & Ag | ● Power Plants - Gas | |
| ● Glass | ● Power Plants - Other | |
| ● Hydrogen | ● Power Plants - Other Fossil | |
| ● Iron & Steel | ● Power Plants - Pet Coke | |
| ● Lime & Gypsum | | |
| ● Manufacturing | | |
| ● Metals - Other | | |
| ● Minerals - Other | | |





Description

- **SOFTWARE:** Most advanced screening-level **CO₂ transportation** & routing model (or any pipelines, transmission lines).

Motivation

- Identify corridors that balance connectivity, cost, environmental impact, community engagement, and landowners.
- Customer interaction.
- Identify multiple routes.

Customer discovery

- Utilities.
- CCS projects.
- Oil & gas.
- Government/NGOs.

Description

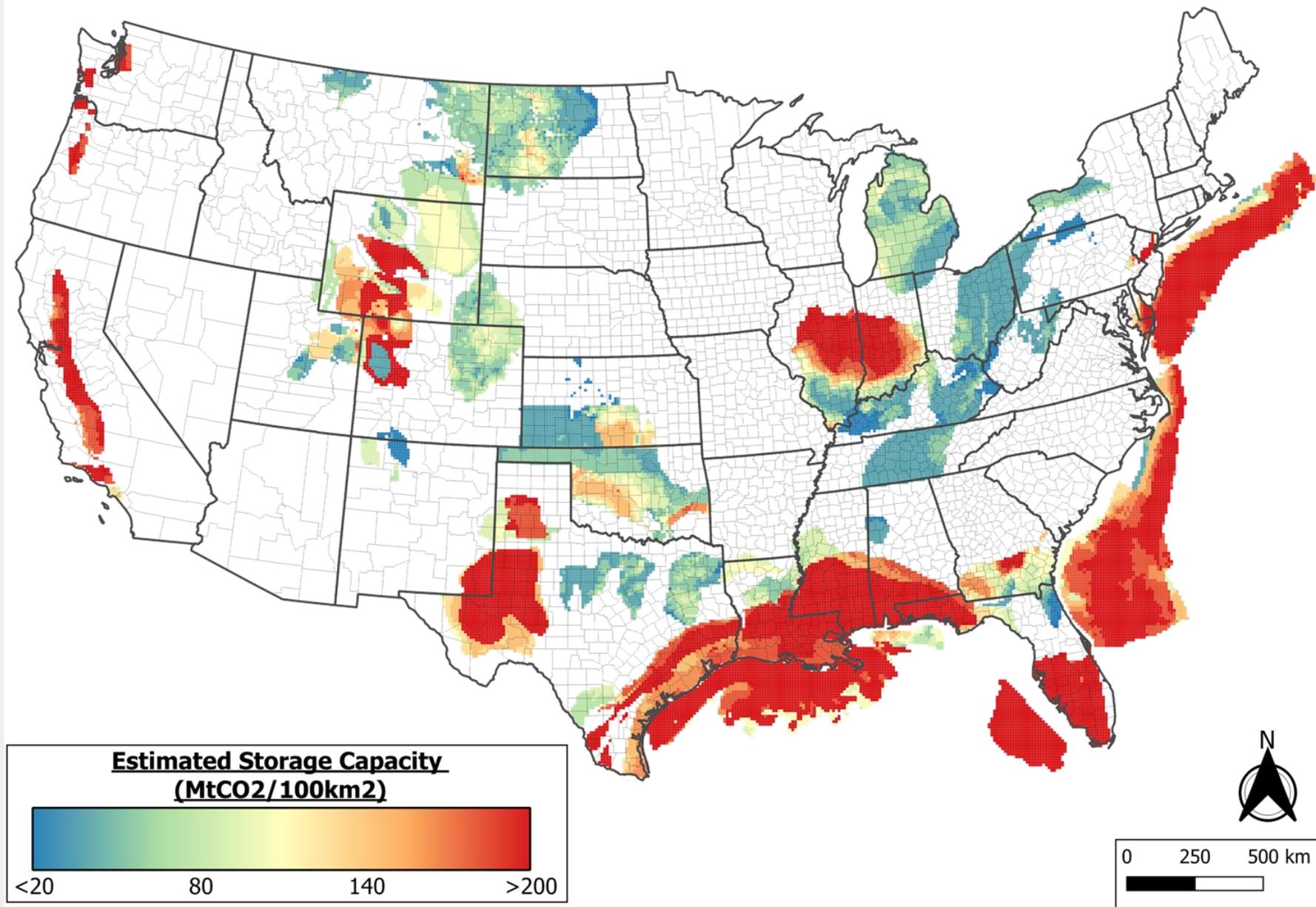
- **SOFTWARE:** Most advanced screening-level **CO₂ storage** model & database.

Motivation

- Capture complex CO₂ storage with fast-running models.
- Rapidly characterize individual storage reservoirs.
- Regional/national assessment of CO₂ storage potential.

Customer discovery

- CCS projects.
- CO₂ facilities.
- Investment banks.
- Government/NGOs.





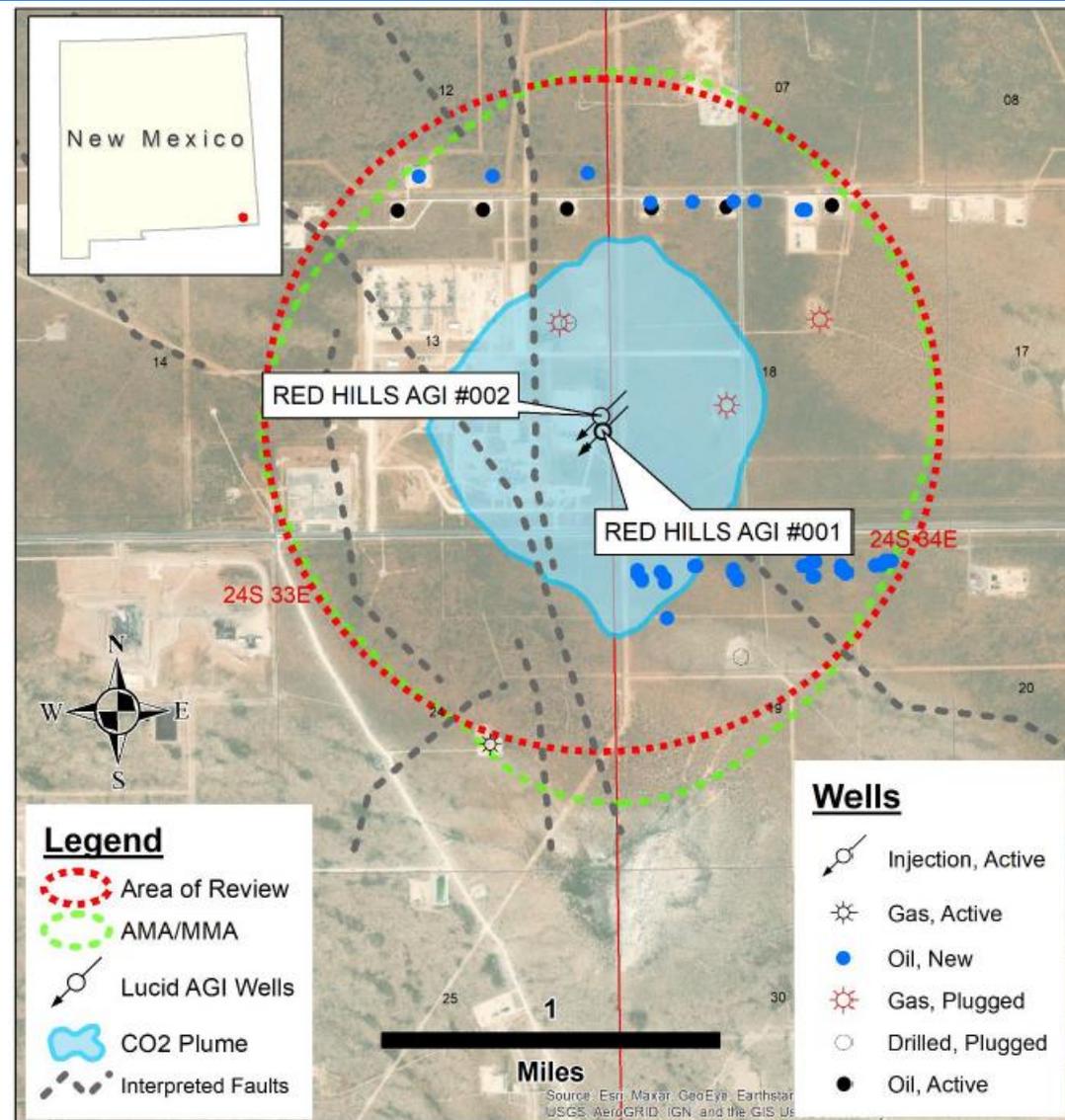
MRV Plan Development & Class VI Well Support

Monitoring, Reporting & Verification (MRV)

- **PIÑON MIDSTREAM:** End-to-end development—data, simulation, writing—of the MRV plan.
- Geological framework development.
- Reservoir modeling to delineate the Maximum Monitoring Area (MMA) & Active Monitoring Area (AMA).
- Geological review of local stratigraphy.
- Additional team of industry-leading consultants experienced with MRV plans support.

Class VI Well simulation & support

- Multiple industry clients.
- In-house $SCO_2 T^{PRO}$ tool to assist with site screening.
- Expert hydrogeologists developing reservoir models using models (e.g., STOMP, TOUGH, FEHM) to simulate the injection & migration of CO_2 .
- Reservoir model results delineate the Area of Review (AoR) for Class VI Well applications.



Example Delineation of Area of Review and AMA/MMA

Source: <https://www.epa.gov/ghgreporting/subpart-rr-geologic-sequestration-carbon-dioxide>



Class VI Applications

DIRECT SKILLS

- Management of application.
- Geological framework development.
- Reservoir modeling to delineate the Maximum Monitoring Area (MMA) & Active Monitoring Area (AMA).
- Social Licensing

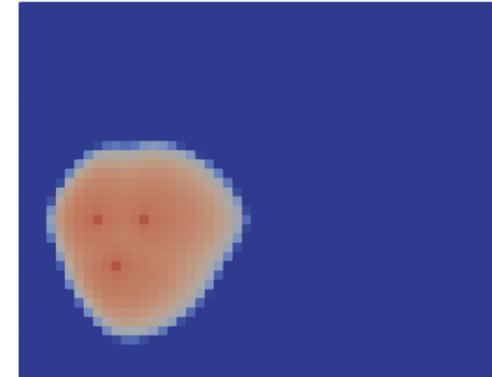
INDIRECT SKILLS

- Additional team of industry-leading consultants experienced with MRV plans support.
- Field characterization (collecting and processing wellbore and seismic data)

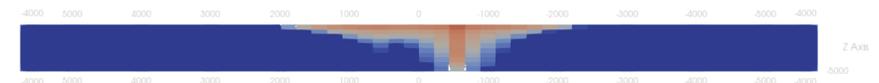
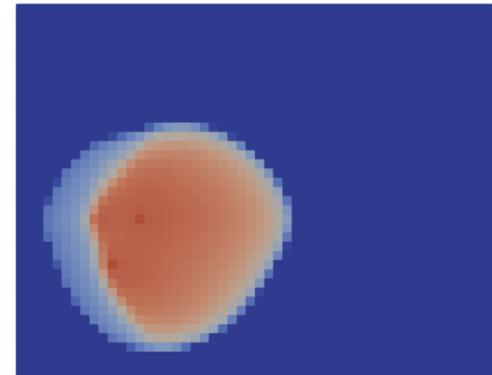
Phase 1a Simulations

- Easily Deployable
- Simulation results ready in a matter of minutes
- Accounts for primary features (e.g., depth, petrophysical properties dipping angles)
- Cost estimate with you now on adding coupled wellbore model.
- Basis for Class-VI quality models

30 years (end of injection):



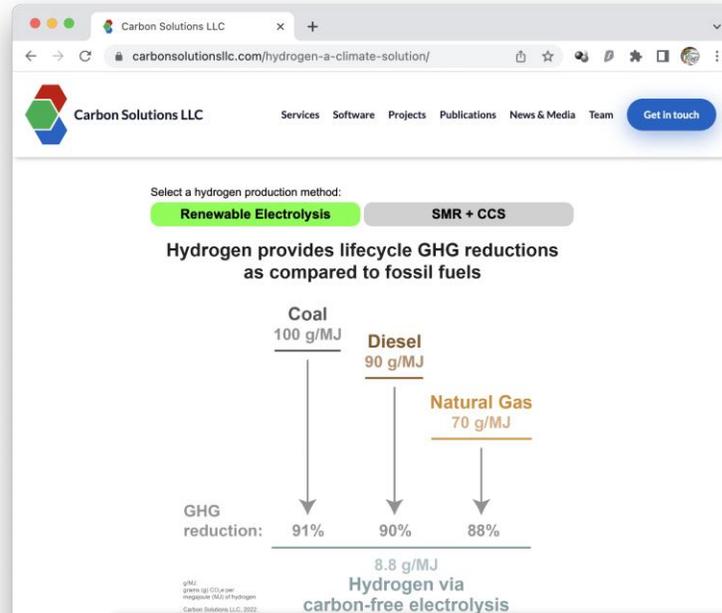
50 years (20-yrs post injection):





Capabilities

- Policy analysis.
- Lifecycle assessment.
- Cross-sector decarbonization strategy.
- Advanced GIS analysis & cartography.
- Graphic design.
- Interactive media.
- Online map applications.
- Web calculators.
- Interactive visualizations.
- Software development.
- Javascript, Python, R, C#, HTML/CSS.
- Leaflet, ArcGIS Online.

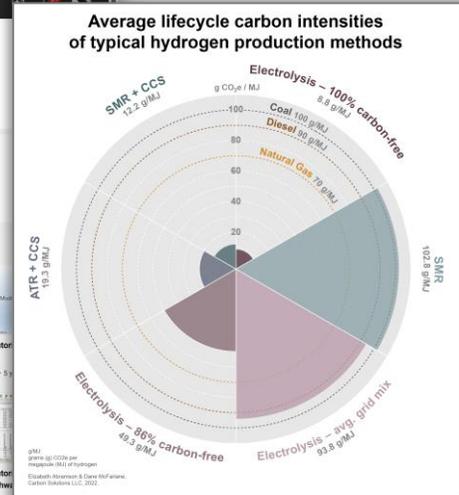


Argonne NATIONAL LABORATORY **GREET** LIFE-CYCLE MODEL

GREET Model Tutorial Videos
642 subscribers

Uploads

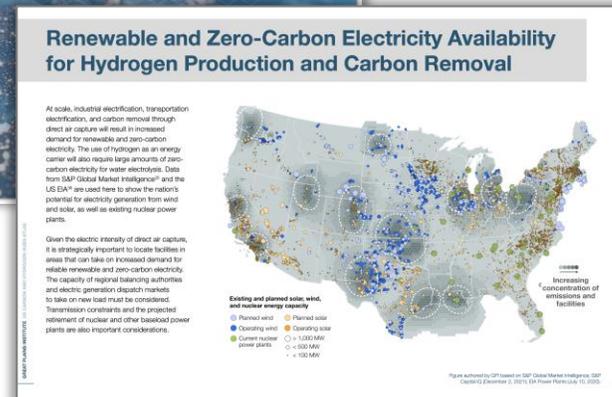
- Introduction to GREET (6:46 views - 2 years ago)
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Hydrogen production and use in the United States

An Atlas of Carbon and Hydrogen Hubs for United States Decarbonization

February 2022



Clean Hydrogen Clusters Are a Key to Industrial Decarbonization

Clean hydrogen clusters could provide decarbonized energy for US industry

As shown in the map below, hydrogen-producing facilities are often located near other industrial and power facilities. Those facilities could potentially replace or supplement their fuel supply with hydrogen, enabling them to lower their emissions. For example, the Gulf Coast is home to many hydrogen-producing facilities and many facilities that rely on fossil fuels to power their operations.

These existing clusters of hydrogen production and fossil fuel demand can serve as natural launching points for a broader transition to hydrogen in the industrial and power sectors.

Click on individual facilities for more information about their energy consumption.

Zero-carbon pathways needed for clean hydrogen

For hydrogen to be an effective decarbonization solution, it must be produced with a zero-carbon pathway, which can be costly compared to conventional hydrogen production. Today, most hydrogen is produced with steam methane reforming. The process uses high-temperature steam to isolate hydrogen atoms in a methane source such as natural gas.

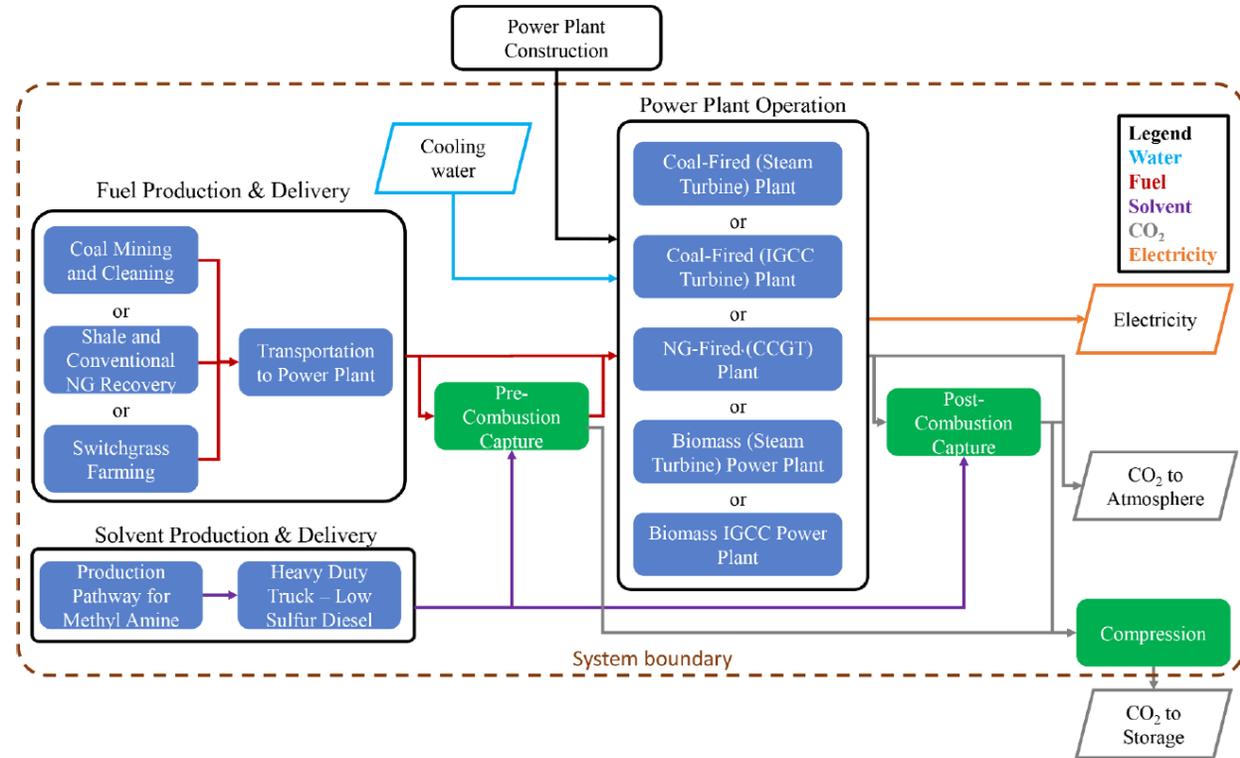


Goal

- **FULL LCA:** Quantify environmental impact of low-carbon energy systems.
- **METRICS:** Carbon intensity or global warming potential, water use, energy use, land use.
- **GHG Reporting:** Greenhouse gas (GHG) emission reporting.
- **Examples:** Power plants with CCS, bioenergy with CCS (BECCS) for power & fuels.

Approach

- **Custom:** Customer-specific Excel-based models.
- **EXISTING TOOLS:** OpenLCA.
- **DATA:** Build models published & available data.
- **Uncertainty:** Use tools such as Oracle Crystal Ball to quantify the impact of model assumptions.
- **BEST PRACTICES:** Follow best practices outlined in ISO 14040 and ISO 14041.



Life Cycle Assessment of BioEnergy with Carbon Capture and Storage

Source: Bennett et al. 2021 <https://doi.org/10.1016/j.ijggc.2021.103468>



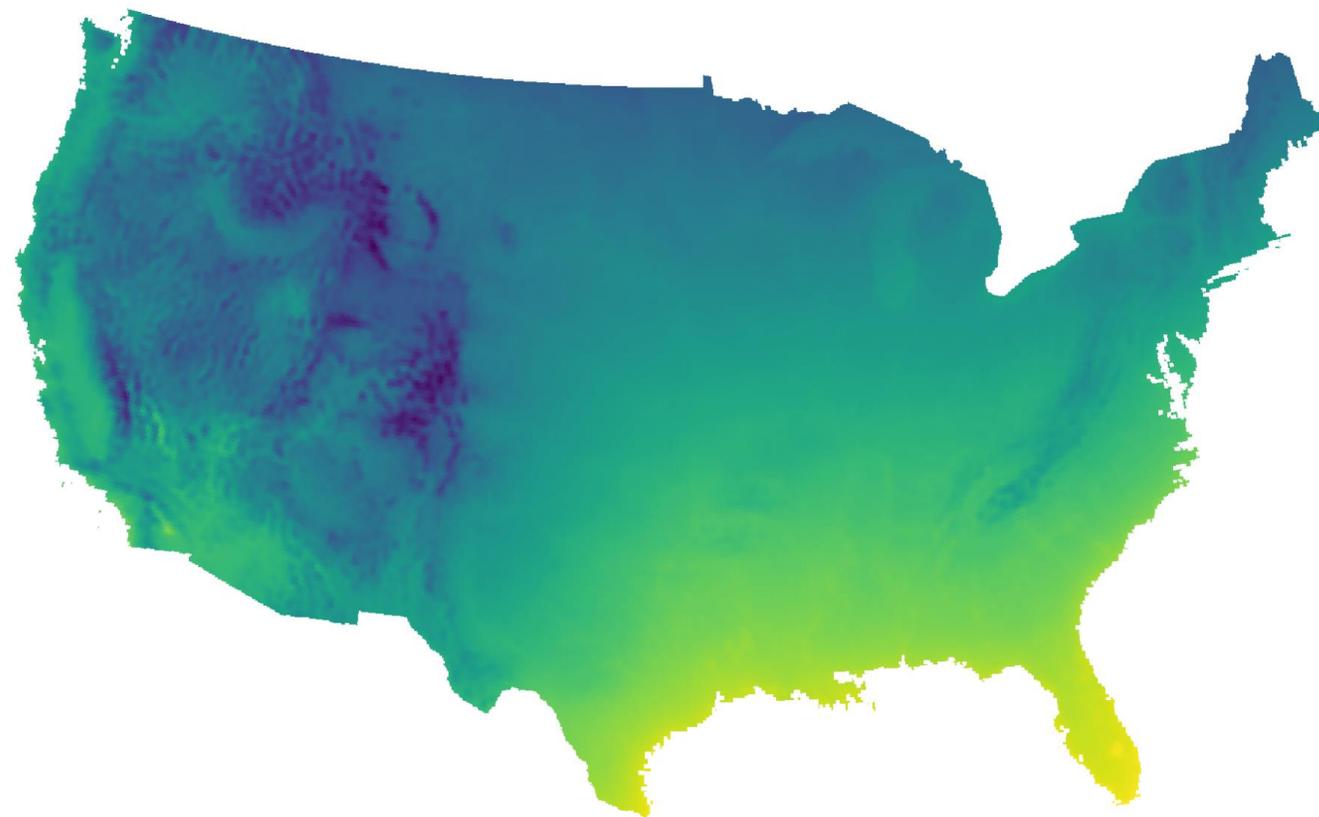
Negative CO₂ Emission Roadmap (NECTAR): CDR Removal Siting Tool

Goal

- Provide quantitative geospatial data to guide CDR siting
- Current technologies of focus:
 - High-temperature direct air capture
 - Low-temperature direct air capture
 - Bioenergy CCS (BECCS)

Example Capabilities

- DAC performance as a function of weather
- Quantity and carbon footprint of heat
 - Geothermal
 - Heat pumps
 - Waste-heat
 - Concentrated solar
- Biomass availability and cost
- Include (yes/no) disadvantaged communities?



CO₂ Captured by High-temperature DAC [Mt/yr]
(Yellow is High, Purple is Low)



Wind siting

- Wind resources represented by capacity available & average capacity factor.
- Costs based on NREL annual technology baseline.

Transmission routing

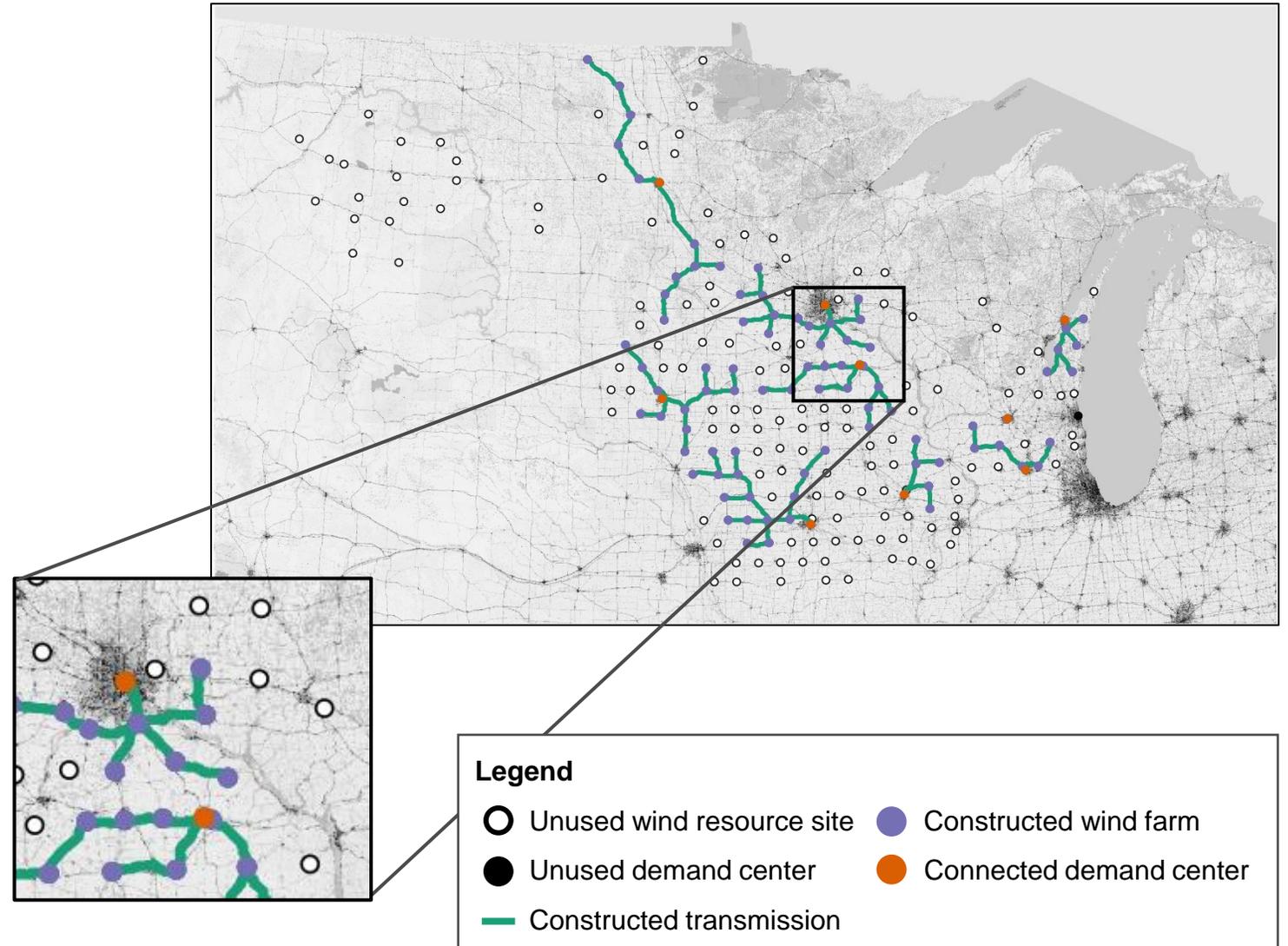
- Applies *CostMAP^{PRO}* to optimally route transmission lines.
- Uses trends based on historic costs to represent transmission costs.

Energy Equity & Env. Justice

- Include/exclude wind sites based on user-specified categories:
 - Historic fossil fuel communities.
 - Site Renewables Right.

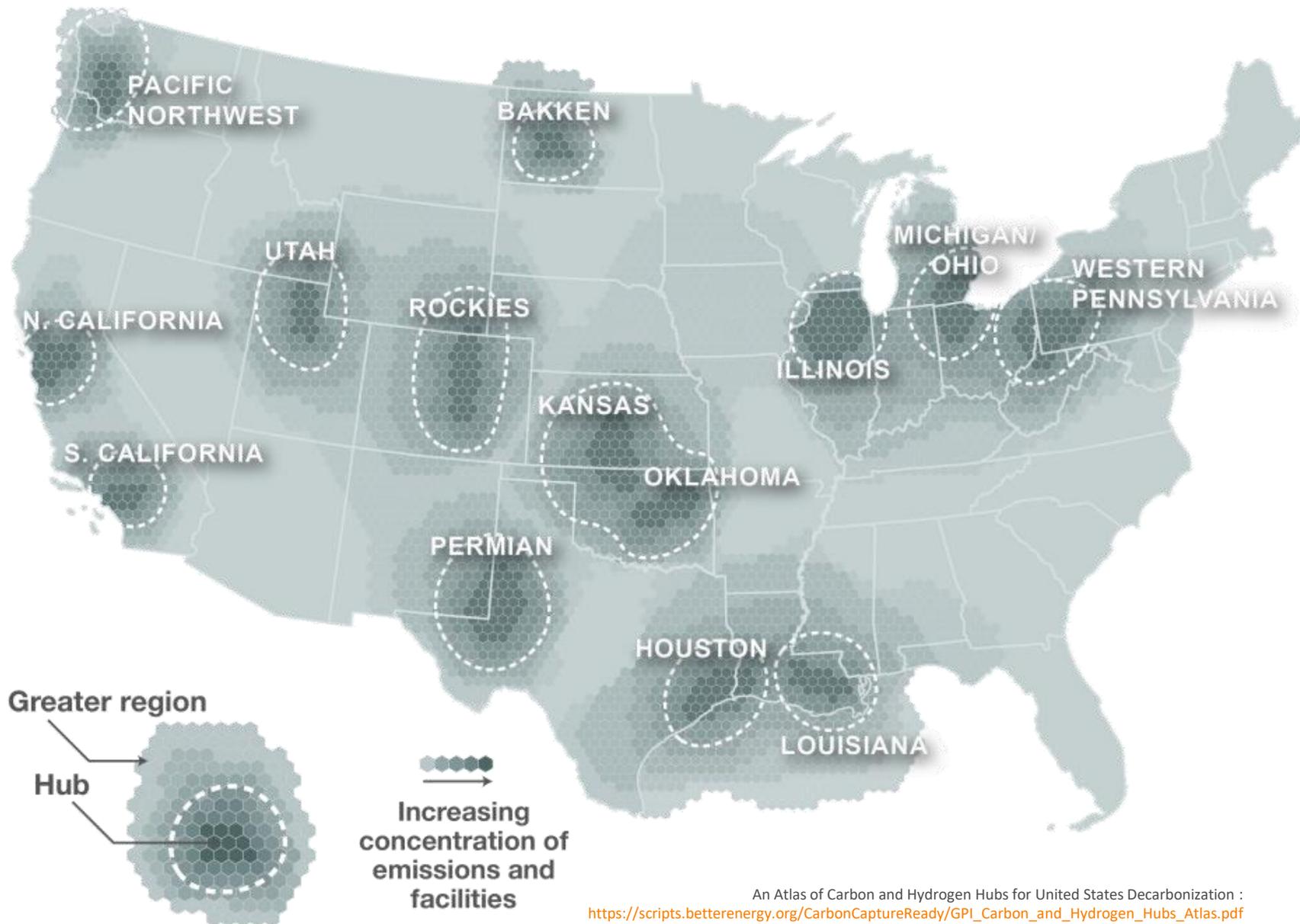
Grid connection

- Supply to demand centers or substations.





Hydrogen Economy & Infrastructure



Hydrogen Planning

- Hydrogen & carbon hubs planning.
- CO₂ storage development.
- Lifecycle assessment.
- H₂ & CO₂ pipelines.
- Fuel & feedstock switching.

Projects

- **#1:** Interactive hydrogen economy atlas that supports net zero goals & the advancement of environmental justice.
- **#2:** Identify facility-level hydrogen switching opportunities that balance carbon intensity, economics, & environmental justice.



CARBON SOLUTIONS