GTI ENERGY

solutions that transform

2022–2023 REPORT

Energy Systems Transitions Require Systems Thinking, Innovation, and Collaboration

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We live in a time of incredible abundance for energy resources and technologies. Energy systems support historic quality of life and economic vitality for some and remain out of reach for others. Energy systems are increasingly required to be more affordable, more accessible, lower emissions, lower environmental impact, more resilient and more secure. These are the collective ambitions of the energy systems transitions envisioned that require pursuing disruptive innovation—of the scale that Vaclav Smil points out occurred in the 1880s with the discovery of electricity, the internal combustion engine, ballpoint pens and the modern bicycle. Each of these advances were applied in ways that disrupted expectations.

As attention, ambition and investment progressively focus on low-carbon and low-cost solutions, GTI Energy is serving a vital role in mapping paths and demonstrating solutions at the intersection of tradition and innovation in energy systems—in community with others.

We bring our technology and operational expertise, our systems thinking and our role in convening collaborations to our mission to help our partners continually evolve energy systems to benefit the people and economies they serve.

This 2022–2023 report surveys and celebrates our efforts, progress, success, and learnings.

We appreciate the trust that our partners place in our mission as well as the privilege of working with you to shape the future of energy systems.

Rebecca Ranich
Chair, GTI Energy
Board of Directors

Paula A Gant, PhD
President and CEO,
GTI Energy

Energy Systems Transitions Require Systems Thinking, Innovation, and Collaboration

GTI Energy is a technology development organization with 80 years of experience demonstrating solutions at the intersection of tradition and innovation in energy systems. We have executed more than $1 billion in energy research, development, and demonstration over the past decade as we work to advance the innovations needed to enable low-carbon and low-cost energy systems—economy-wide.

Our community of experts is focused on solutions that shape energy systems transitions across low-carbon gases, liquids, infrastructure, and efficiency. We take technologies and operational solutions from concept through to design, testing, piloting, demonstration, and commercial deployment.

We operate more than ten industry collaboratives—each working to develop, test, and accelerate adoption of technological and operational innovations. From the lab to the market, GTI Energy creates spaces for organizations to learn together to accelerate progress to overcome consequential challenges. Our customers and partners come to us because we are the people who know how stuff works and how all the parts and people fit together to operationalize solutions.

We are motivated by dual imperatives—the need to decarbonize energy systems and the need to strengthen the safety, reliability, and accessibility of energy to support economic vitality and quality of life. As such, we focus our work on creating positive impacts for communities, the environment, economies, and people.

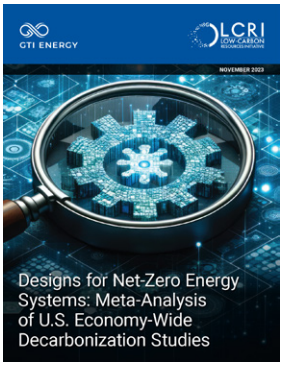
To create that impact, we keep three guiding principles front of mind in everything we do: systems thinking, innovation, and collaboration. We think about how new technologies and practices get integrated into existing energy systems; how we can move the dial on human progress through innovation; and how to activate all the people involved with shared tools, knowledge, and a mutual sense of purpose.

SYSTEMS THINKING

GTI Energy approaches energy systems transitions by taking a broad systems view—looking at energy as a "system of systems," all interconnected and interdependent.

We keep the aperture wide, by maintaining curiosity about the innovations yet to come, and the integration of those innovations with a host of other advances to shape low-carbon, low-cost energy systems. A systems thinking approach grounds our thinking about the complexity of our energy systems, and it drives our ambition to harness existing infrastructure to accelerate deep decarbonization.

Our perspective leads us to ask and answer new questions, unlocking the potential for disruptive innovations that transcend traditional boundaries. It positions us to engage a broad array of communities, stakeholders, and decision makers in advancing impactful solutions that transform lives, economies, and the environment.



GTI Energy's **Designs for Net-Zero Energy Systems: Meta-Analysis of U.S. Economy-Wide Decarbonization Studies (Meta NZ)** provides a comparative analysis of five U.S. economy-wide net-zero studies developed by the Low-Carbon Resources Initiative, Open Energy Outlook, Evolved Energy Research, Princeton University, and Decarb America. By harmonizing results across multiple studies, Meta NZ offers fresh insights into the pathways and possibilities for U.S. economy-wide decarbonization. There is no single design for net-zero energy systems. Each of these studies points to a diverse mix of solutions underpinned by innovative technologies, versatile energy carriers, and supporting infrastructure.

GTI Energy and the Electric Power Research Institute, for example, through the **Low-Carbon Resource Initiative (LCRI),** performed an integrated energy system scenario modeling exercise which evaluates alternative technology strategies for achieving economy-wide net-zero emissions of carbon dioxide in the U.S. by 2050. Findings illustrate that the future energy mix is projected to consist of an increasingly complex and integrated blend of existing and emerging technologies and infrastructure. Natural gas infrastructure, in particular, plays a crucial role in all net-zero scenarios in providing firm capacity for a transitioning power sector and delivering low-carbon fuel to industry and buildings.

GTI Energy performs **whole building and microgrid research.** Our projects enable connected and resilient energy systems by integrating electric, renewable, and gaseous fuels along with energy storage and other energy efficient technologies. These system-level solutions minimize lifecycle costs of emissions reductions from buildings, focusing on behind-the-meter and community-scale solutions.

INNOVATION

GTI Energy occupies a unique space at the intersection of tradition and innovation in energy systems. Working to develop and deploy these innovations—in collaboration with partners and the communities they serve—is core to our mission.

We organize ourselves internally as an innovation system—shaping how we work to reflect the energy systems we are seeking to influence. Innovation sets the intention to move beyond incremental improvements in technologies and operational practices to achieve meaningful change.

GTI Energy's role is to be a partner that affects change and innovation across energy systems for our customers and stakeholders seeking to solve consequential challenges in the world. As a science-based, creative problem solver, our organization has acquired hundreds of patents, products, and licensing agreements, demonstrating our expertise in taking technologies from the idea stage to market impact.

ADVANCING DIGITAL INNOVATION

Predictive analytics help us understand existing systems and simulate change so we can forecast the impacts on energy systems, people, and communities prior to implementation. To enable this type of complex analysis, GTI Energy is focused on providing more transparency in energy systems data.

For example, accounting for methane emissions requires a variety of technologies that cover different spatial and temporal resolutions, report in different units, and vary greatly depending on organizational work practices. GTI Energy has a unique opportunity to pull this information together in a single platform through funding from the Department of Energy and by collaborations with our trusted industry partners. This **project will demonstrate how filling gaps in data will enable meaningful decarbonization at scale.**

Through software automation, we have also **reduced the complexity of collecting methane emissions measurements in the field by deploying our Methane Emissions Toolbox (MET)**. These tools help create a sampling plan to determine what measurements need to be collected in the field based on user input, and also automate complicated uncertainty calculations for reporting purposes. These tools put world-class statistical analytics into an easy-to-use web-based form that can support an organization's ability to demonstrate methane emissions reductions.

Additionally, we are working with gas utilities to develop **advanced computer vision applications to identify hazardous conditions in the field accurately**. Our team is creating algorithms that can accurately detect and classify corrosion levels on Meter Set Assemblies, providing valuable support to maintain infrastructure and ensure safe operations. Similarly, we are working with industry partners to integrate algorithms into existing software applications that can provide visual inspections using drone-based technologies. The ability to remotely inspect infrastructure and to detect and classify anomalies will save time and reduce human error in the field.

COLLABORATION

There are no solo acts in energy transitions—collaboration is key. Core to GTI Energy's role is building spaces for collaboration that allow for open learning, de-risking experimentation, and building upon our successes so that we can progress solutions to proven scale and deployment faster.

GTI Energy has eight decades of experience convening partners with deep knowledge and expertise to engineer and demonstrate the next generation of innovative technologies and processes. We are proud of the billions of dollars deployed through collaborations we both lead and participate in.

Our non-profit technology development collaborations, **OTD** and **UTD**, for example, are natural gas consortiums serving gas customers in North America and Europe. These consortia fund research in operational tools, improvements, and safety, and utilization of products that deliver energy to commercial, industrial, and residential end users.

Veritas, a methane emission measurement and verification initiative led by GTI Energy with partners Highwood Emissions Management and SLR engages nearly 40 stakeholders to develop a measurement-informed approach to calculating and reporting methane emissions.

Veritas provides open-source technical protocols to measure methane emissions in a consistent, credible, and comparable way to accelerate meaningful methane emission reductions rapidly.

Following pilot demonstrations, the protocols were launched publicly in early 2023. Throughout the year, they were refined and improved, leading to the release of Version 2 streamlined protocols in December.

GTI Energy is collaborating with the Oil & Gas Methane Partnership 2.0 (OGMP 2.0) to develop a new methodology to provide stakeholders with a detailed path for meeting the requirements of OGMP 2.0 using Veritas Protocols, fostering greater comparability of global emissions data.

Through the **Open Hydrogen Initiative (OHI),** GTI Energy and S&P Global Commodity convened a group of international experts and developed a standardized emissions accounting methodology and toolkit to calculate the carbon intensity of hydrogen production at the facility level.

Founded on the technical perspectives and real-world marketplace insights of OHI's 40+ members, the comprehensive open-source hydrogen lifecycle assessment tool advances transparency to harmonize the market and support global hydrogen trade. It is being demonstrated in 13 industry projects spanning three continents.

The open-source toolkit was launched to the public at CERAWeek in March 2024.

OPEN **HYDROGEN** INITIATIVE

GTI ENERGY | S&P Global Commodity Insights

GTI Energy designed the **Net Zero Infrastructure program (NZIP)** to test and map the most practical opportunities for integrating low-carbon solutions, including hydrogen, renewable natural gas, and carbon transportation and storage, within the existing natural gas infrastructure.

With more than 30 partners, NZIP will accelerate the transition to net-zero emissions by identifying how today's infrastructure can evolve to advance the development of integrated energy systems. The first whitepaper discussing the important role of the U.S. natural gas infrastructure was published in December 2023.

GTI ENERGY NZIP Net Zero Infrastructure Program

GTI Energy Collaboratives

130+
Participating Organizations

20+
Years of Experience

10
GTI Energy-led Collaboratives

GTI ENERGY-LED COLLABORATIVES

Center for Methane Research (CMR)
Provides centralized resources that enable the natural gas industry to understand the presence, measurement, and potential impacts of methane in the atmosphere, highlighting the interconnected role of natural gas production, delivery, and use.

Emerging Technology Program (ETP)
Enables utilities to meet energy efficiency goals with less risk and more certainty by accelerating the commercialization and adoption of energy efficient technologies.

HyRes, a Hydrogen Emissions Research Consortium
Builds a foundation of sound, science-based information on hydrogen emissions and their potential atmospheric and climate impacts.

Low-Carbon Resources Initiative (LCRI)
Accelerates development, demonstration, and deployment of hydrogen and other low-carbon energy technologies and fuels at scale.

Net Zero Infrastructure Program (NZIP)
Accelerates the transition to net-zero emissions by understanding how today's natural gas infrastructure can evolve to advance the development of integrated energy systems.

Open Hydrogen Initiative (OHI)
Lays the foundation for low-carbon hydrogen marketplaces by convening industry, academics, regulators, and eNGOs from around the world to drive harmony in hydrogen carbon intensity measurements.

Operations Technology Development, NFP (OTD)
Improves safety, reliability, and operational efficiency of gas systems through innovative R&D projects.

SUSTAIN H_2 Subsurface Storage Technological Advancements & Innovation for Hydrogen

Accelerates the deployment of safe and cost-effective long-term storage of hydrogen as a viable energy transition solution by combining scientific expertise, market insights, and field experience to address the issue.

Utilization Technology Development, NFP (UTD)
Maximizes the environmental performance, affordability, efficiency, and safety of gas and renewable energy systems and processes through innovative R&D projects.

GTI ENERGY'S METHANE EMISSIONS MEASUREMENT + VERIFICATION INITIATIVE

Veritas, GTI Energy's Methane Emissions Measurement + Verification Initiative
Enables countries and companies with methane reduction targets to report reductions in a consistent, transparent, and verifiable way to help reduce economy-wide global methane emissions.

Advancing the Hydrogen Economy

Hydrogen is a versatile low-carbon gas that can play a critical role in the energy transition. Integrating hydrogen into our energy system and using it strategically to reduce emissions in hard-to-abate sectors is vital to a resilient, reliable, and sustainable clean energy future. As such, hydrogen has developed into a critical area for GTI Energy.

HyVelocity Hub

ARCH2
APPALACHIAN REGIONAL CLEAN HYDROGEN HUB

MIDWEST ALLIANCE FOR CLEAN HYDROGEN

GTI Energy is administering or partnering in **three Regional Clean Hydrogen Hubs** selected by the U.S. Department of Energy (DOE) Office of Clean Energy Demonstrations for funding.

The HyVelocity Gulf Coast Hydrogen Hub, the Appalachian Regional Clean Hydrogen Hub (ARCH2) and the Midwest Alliance for Clean Hydrogen (MachH2) Hub are poised to deploy hydrogen at scale and deliver energy, environmental, and economic benefits to surrounding communities.

GTI Energy is piloting a **low-cost, low-carbon hydrogen generation technology** under a DOE-sponsored 0.3MW project at our Des Plaines campus and in a larger 1.6MW Hydrogen Production by Sorbent Enhanced Steam Reforming (HyPER) project with Cranfield University, Doosan Babcock, and Helical Energy sponsored by the UK government. Both pilots are producing clean hydrogen at scale with inherent carbon capture.

GTI Energy's **Community Benefits Team advances our organizational mission by delivering on technology-specific positive impacts to the community** and mitigating potential risks through the development and execution of community benefit plans.

The team utilizes AI, quantitative and qualitative methods, and geospatial modeling and analysis to develop environmental impact assessments, safety, risk mitigation, emergency response, and community messaging plans. They are executing projects across the country covering R&D in hydrogen, energy efficiency, CCS/CCUS, geothermal, and methane emissions monitoring and measurement and are supporting the three Hydrogen Hubs that GTI Energy is involved in.

GTI Energy researchers are supporting **hydrogen blending demonstrations** for utilities across the nation and coordinating industry participation and funding in National Renewable Energy Laboratory's HyBlend™ project to create publicly accessible tools to characterize the opportunities, costs, and risks of blending hydrogen in the gas infrastructure. Life-cycle assessments of hydrogen blending provide valuable information on its effects on safety, leakage, durability, and material integrity.

We are investigating the implications of **blending hydrogen into conventional and advanced equipment and appliances** to determine if existing appliances can be used as-is with a hydrogen/natural gas blend, need different components, or need to be replaced with new appliances. One GTI Energy study documented the impact of hydrogen/natural gas blends on the performance, emissions, and safety of unadjusted equipment, and a California Energy Commission project underway is assessing hydrogen use in large commercial and industrial processes.

In a **DOE H2@Scale in Texas and Beyond project**—in partnership with Frontier Energy, University of Texas at Austin, and almost two dozen industry stakeholders and sponsors—GTI Energy is building an integrated renewable hydrogen network, laying the foundation for expanding hydrogen's role in decarbonizing the Gulf Coast with multiple technical demonstrations integrating energy production from renewables, on-site storage, and hydrogen end use in various applications. GTI Energy designed and built a steam methane reformer (SMR) for hydrogen generation and delivered it to the site at the UT-Austin campus, where demonstrations will begin soon.

With support from the California Energy Commission, Southern California Gas, Sacramento Metropolitan Air Quality Management District, and the Low-Carbon Resources Initiative, GTI Energy and Sierra Northern Railway lead a project team to design, build, and demonstrate a **hydrogen fuel cell switcher locomotive** that can improve air quality, reduce greenhouse gas emissions, and increase the quality of life for surrounding communities at the Port of West Sacramento.

In the Zero Emissions for California Ports (ZECAP) pilot project, GTI Energy and Frontier Energy—with support from California Air Resources Board and SoCalGas—designed, assembled, assessed, and verified the safe and reliable performance of two **zero-emission fuel cell-electric terminal tractors** in a demanding cargo-handling application at the Port of Los Angeles. This hydrogen vehicle application illustrates a pathway for significant reduction in air and noise pollution for people who work at and live near the busy port.

GTI Energy, with support from California Energy Commission, Utilization Technology Development, NFP, and SoCalGas, is leading the project team of Symbio, Michelin, and other industry partners in the Symbio H2 Central Valley Express project to **develop and demonstrate a hydrogen-fueled Class 8 truck** that matches the performance of a 15-liter diesel truck, providing a zero-emission solution for regional-haul trucking operations.

GTI Energy and partners are **creating a flexible and scalable blueprint for the nation's hydrogen fueling infrastructure** from Houston to Los Angeles (H2LA) along I-10. Leveraging a U.S. Department of Energy grant, the team will develop plans for an investment-ready, hydrogen fueling and heavy-duty freight truck network with a focus on the potential benefits to surrounding communities.

Decarbonizing with Sustainable Fuels

Looking to midcentury, we see continued robust demand for low-cost, environmentally friendly gases, fuels, and power. Biomass feedstocks are plentiful and offer a versatile portfolio of low-carbon options that can reduce greenhouse gas emissions and provide the economy with resources needed for sustainable growth.

SunGas Renewables, a spin-out of GTI Energy, is leading decarbonization of fuels by providing its S1000 renewable syngas product to third parties for renewable hydrogen and biofuels production while also developing and investing in low-carbon biofuels businesses. In June 2023, SunGas formed **Beaver Lake Renewable Energy, LLC,** to construct a 400,000 tons per year green methanol production facility in Central Louisiana, expected to provide clean fuels for A.P. Moller—Maersk's fleet of methanol-powered container vessels. SunGas was also selected as the technology supplier for ABEL Energy's Bell Bay Powerfuels Project in Australia.

BEAVER LAKE RENEWABLE ENERGY

GTI Energy is leading a DOE-supported project to expand the efficient production and use of low-carbon sustainable aviation fuel (SAF) with large-scale conversion technology. The **R-GAS™ Advanced Gasification Pre-Pilot Demonstration for Biofuels (BioRGAS) project** demonstrates how low-cost transportation fuel can be produced at a commercial scale from biomass and sorted municipal solid waste and reduce GHG emissions by more than 70%. The project uses a modular approach with pulverized biomass as a feedstock, which can lead to significant cost reductions.

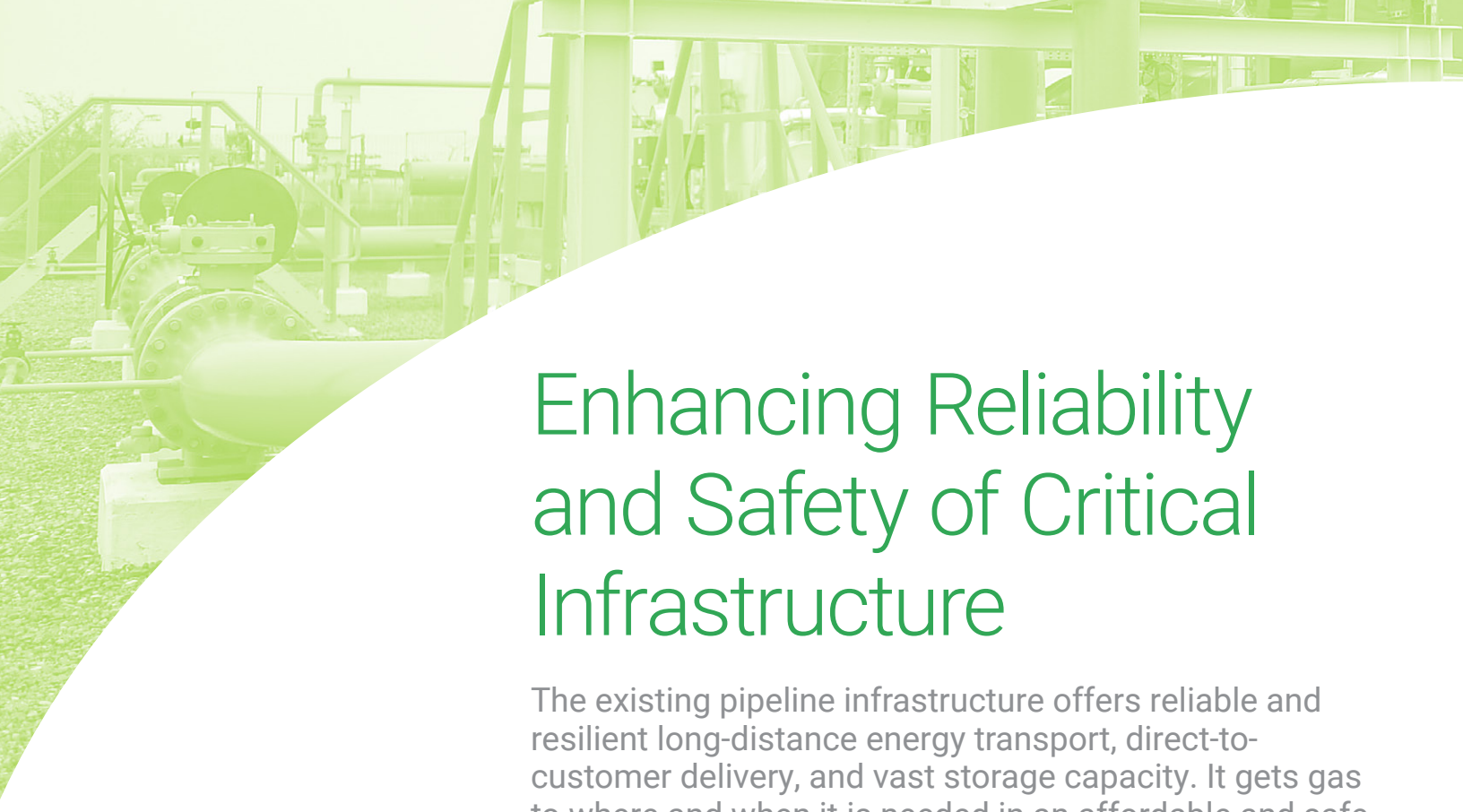
Aether Fuels

Aether Fuels and GTI Energy are partnering to **commercialize a scalable and economical solution to produce sustainable fuels for aviation and ocean shipping** from low-value and abundant waste streams. Aether has raised investment funding and is exclusively licensing technology from GTI Energy, building upon GTI Energy's original gas-to-liquid technology program initiated in 2016. An expanded relationship now accelerates commercialization through a technology transfer program, co-locating Aether's expertise to work alongside GTI Energy counterparts to run the pilot lines in their Chicago-area Campus and further scale the new solution.

GTI Energy's **Cool LPG technology converts biogas, bio-syngas, or biogenic carbon dioxide and green hydrogen into 100% renewable liquid fuels**—or renewable propane—for affordable cooking, heating, and transportation worldwide. Researchers are advancing catalyst performance and preparing for pilot-scale development under an exclusive global licensing agreement with the Global LPG Partnership (GLPGP) and BioLPG LLC.

UN-backed NGO affiliate GLPGP is helping developing countries in Africa transition to r-LPG for cooking to reduce pollutants. BioLPG LLC and consortium partners in North America, Italy, and Germany are supporting Cool LPG in rapidly developing and scaling up the technology to bring r-LPG to market.

Major advancements have been made to GTI Energy's patented Cool GTL℠ technology through DOE and industrial partner support, **producing high-quality liquid fuels that minimize greenhouse gas emissions from transportation**. The technology uses innovative approaches in chemistry (catalysts), equipment (reactors), and process flows to reduce cost and shrink the size, delivering more products at a lower cost than existing approaches. The research team demonstrated SAF production in its integrated pilot plant line producing 1.5 gallons of sustainable fuels per day.



Enhancing Reliability and Safety of Critical Infrastructure

The existing pipeline infrastructure offers reliable and resilient long-distance energy transport, direct-to-customer delivery, and vast storage capacity. It gets gas to where and when it is needed in an affordable and safe manner to serve a diverse set of customers and offers great potential to enable low-carbon renewable energy.

With Operations Technology Development support, GTI Energy is progressing **material tracking and traceability procedures and gas utility construction** with digital solutions, automating the data collection process through digital-scanning techniques, and gathering and converting it into a geographic information system (GIS) to provide traceable, verifiable, complete, and reliable information.

GTI Energy researchers are developing an easy-to-use and accessible web-based tool—**www.WEAKLINKapp.com** for OTD. The app assists industry professionals in selecting and applying "weak links" (an engineered device) for trenchless pipeline installations to ensure that a plastic gas pipe's allowable tensile stress is not exceeded during the process of pulling the pipe through the ground.

As part of the ARPA-E REPAIR program that is addressing leaks from older gas pipes and working to reduce the cost per mile of replacement, GTI Energy is providing third-party **performance assessments of systems and processes being developed to rehabilitate aging pipelines.**

Our team is analyzing data to understand how current infrastructure can be improved and optimized. Numerous efforts integrate **3D infrastructure locating and visualization techniques,** and projects for OTD and California Energy Commission are advancing high-accuracy 3D mapping technologies.

A **live gas mapping 3D technology** to help mitigate third-party pipeline damage is now available and being commercialized. It inserts a smart probe inside a live pipeline to map buried utilities and provide accurate locations. It can also directly download data to a GIS platform.

Working with the U.S. Department of Defense's Construction Engineering Research Laboratory (CERL) and other partners, GTI Energy's microbiology experts are collecting samples from infrastructure across the nation and **using advanced molecular and genetic engineering techniques to characterize and quantify corrosion-causing microorganisms,** develop improved biocorrosion detection and monitoring techniques, and identify novel control and prevention methods to maintain safety and integrity.

GTI Energy and partners are designing a **first-of-a-kind environmental chamber** at CERL's research lab in Champaign, Illinois. The chamber can simultaneously test large-scale material samples in one location, subjecting specimens to a variety of harsh environmental conditions to evaluate their resistance to corrosion caused by extreme temperature swings, salt spray, UV light, and other environmental factors that impact construction materials.

Under the support of OTD and the Center for Methane Research, GTI Energy is working on a variety of projects for critical infrastructure detection monitoring. We have **developed leak detection technologies**, and researchers are evaluating a wealth of new hardware and equipment to help utilities locate and identify leaks that need repair. Field evaluations were conducted for an advanced mobile leak detection system and a Gas Mapping LiDAR system to evaluate performance. An exploration of the potential use of satellites in the detection and quantification of leaks at the distribution level is underway. The team is also assessing applications for sensors and drones.

Leveraging Energy Efficiency for Economy-Wide Decarbonization

GTI Energy helps harness the promise of abundant gas-based energy with more efficient appliances and equipment to minimize greenhouse gas emissions and decarbonize buildings. Gas can be integrated with renewable energy sources to address energy intermittency issues and meet increasing demands for clean energy in global communities.

GTI Energy examined the **current state of space heating energy use and assessed the impacts of electrifying residential space heating across the U.S.** An interactive data viewer explores the state-by-state impacts on emissions and annual heating costs for an average single-family home and on peak electricity demand across the state. Researchers also completed a scoping study for the Air-Conditioning, Heating, and Refrigeration Institute and a DOE study concerning corrosion abatement in gas-fired heat pumps.

GTI Energy's **Carbon Management Information Center (CMIC)** offers a broad systems perspective to inform whole building standards, codes, and regulations. It develops modeling tools to deliver technical data that illustrates the potential energy, environmental, and cost benefits of all viable decarbonization pathways. CMIC developed a Carbon Reduction Calculator/RNG Blending tool that allows users to perform scenario analysis of RNG at a specified carbon intensity (CI) to reach targeted CO_{2e} reductions.

carbon [CMIC] management information center
POWERED BY GTI ENERGY

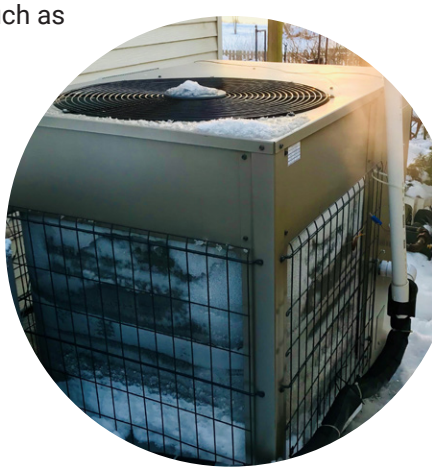
FRONTIER energy

In 2023, Frontier Energy kicked off a multi-million-dollar program to **improve the quality of installation for heating, ventilation, and air conditioning systems in California**, called Quality HVAC. The program aims to encourage industry practices that go beyond traditional equipment upgrades, help contractors differentiate higher-value services, and inspire others to improve the quality of their HVAC services through contractor incentives. Additionally, the program aims to improve the installation and maintenance services of efficient technologies to help California meet its carbon-neutrality goal by 2045.

With the support of Utilization Technology Development, NFP (UTD), GTI Energy researchers are **experimentally testing and evaluating several fuel cells** that are considering or entering the North American market to serve residential and light commercial end users.

Researchers are **evaluating emerging or commercially-available hybrid gas furnaces/electric heat pump products** in the North American market to identify the more promising hybrid systems and develop installation and operation guides that can help end users accelerate their integration of electricity derived from renewable energy with fuel-fired equipment.

UTD **accelerated the availability of more high-efficiency gas-driven heat pumps** by advancing technology developments with partners such as SMTI/ANESI, Robur, HeatAmp, Yanmar, the University of Missouri, and the University of Florida. In November 2023, SMTI started up its first manufacturing plant in TN.



Recognizing the importance of integrated systems to improve the built environment, researchers are **developing solutions for buildings as a system to optimize equipment performance and reduce carbon intensity**. To drive down annual energy loads, we are retrofitting existing homes and commercial buildings with high-efficiency envelopes and using them in new construction, paired with high-efficiency, low-capacity HVAC systems. This work also assesses improved labor productivity through envelope retrofits to incorporate advanced technologies such as vacuum-insulated panels.

GTI Energy leads the **Supercritical Transformational Electric Power (STEP) Demo project** to demonstrate clean, compact, and high-efficiency supercritical carbon dioxide (sCO_2) power cycles. This next-generation power generation technology delivers significant environmental performance across a broad slate of applications. The project successfully achieved sCO_2 fluid conditions in early 2023, was mechanically completed in October, and started system commissioning tests in December 2023. Performance testing is set to begin in May 2024.

The project team includes Southwest Research Institute (SwRI) and GE Vernova, with funding provided by the U.S. Department of Energy/National Energy Technology Laboratory (U.S. DOE/NETL) and other industry partners.

"I've worked on sCO_2 technology for the first 10 years of my career and have seen it grow from infancy being only a paper study to now having actual hardware at a 10 MW scale. GTI Energy achieving an industry "first" by successfully hot-firing the closed-loop Brayton cycle is an amazing feat, and I'm honored to be a part of that success."

Megan Herrera, GTI Energy Program Manager and System Engineering Lead for the STEP Demo project

GTI Energy's research team is redeveloping an existing gasification site with Wabash Valley Resources, LLC to be a first-of-a-kind flexible-fuel power plant that will **produce low-carbon power, net-negative hydrogen, and ammonia.** Hydrogen with net-negative carbon emissions will be produced by integrating carbon capture and sequestration. The team is producing a techno-economic analysis and design study for the site in West Terre Haute, Indiana.

Demonstrating Energy Resiliency with the U.S. Department of Defense

As the largest energy consumer in the federal government, the U.S. Department of Defense (DoD) sets the pace for increasing energy efficiency and helping emerging technology reach the market with multi-phase RD&D projects.

GTI Energy works closely with DoD through the U.S. Army Corps of Engineers Construction Engineering Research Laboratory (CERL), the Environmental Security Technology Certification Program (ESTCP), and other initiatives to assess a broad slate of technologies for their ability to cost-effectively reduce energy use and improve energy resiliency in military bases.

GTI Energy is a rising HERO of energy resiliency for the U.S. Department of Defense. GTI Energy and CERL kicked off the Hydrogen Energy Research Operation (HERO) program to **test and deploy various hydrogen technologies** to improve the energy resiliency of critical operations while advancing decarbonization goals at Army installations.

GTI Energy successfully completed a project with CERL to **evaluate the energy savings, cost-effectiveness, reliability, and resilience improvements of emerging high-efficiency natural gas-fired technologies** for heating, cooling, hot water, air compressors, and backup power generation at the U.S. Army Engineer Research and Development Center (ERDC) facilities in Vicksburg, Mississippi.

Control equipment testing for the Illinois Army National Guard delivered energy savings for **advanced boiler pump controls, retrofit advanced RTU controls, and recirculating pump controls** for central hot water.

In addition to demonstrating a new **micro combined heat and power (mCHP)** system at NSGL, GTI Energy is evaluating existing mCHP and microgrids installed at Maine Army National Guard facilities to quantify performance and economics.

Innovative gas-fired kettles and advanced warewashers with drain water energy recovery systems are being demonstrated at Naval Station Great Lakes (NSGL) dining facilities with positive results. The high-efficiency gas-fired warewashers are expected to reduce galley operating costs by over $41,000 per year, save 1.45 million gallons of water per year, and decrease energy use by almost 2,400 mmbtu.

Creating Solutions for Carbon Management

Carbon capture offers a powerful opportunity to reduce climate emissions, and it will play a prominent role in successful decarbonization strategies, especially when captured CO_2 can be put to good use. GTI Energy has a portfolio of solutions for carbon dioxide capture and removal, transport, storage, and utilization plus the relevant experience and capabilities to fully address the essential elements of integrated projects.

ROTA-CAP™ is a transformational intensified CO_2 capture process that significantly lowers emissions and carbon capture costs. The modular system has been successfully operating for over 1,600 hours under various real flue gas conditions at the National Carbon Capture Center. A follow-on project to test a 3-tonne CO_2 per day engineering-scale carbon capture system at U. S. Steel's Edgar Thomson industrial iron and steel production facility in Braddock, Pennsylvania has been selected for award of DOE funding.

We are collaborating with the National Energy Technology Laboratory, The Ohio State University, and other partners to develop a **Facilitated Transport Membrane technology** that will reduce the cost and energy penalties of carbon capture. It will be demonstrated at pilot scale at the Wyoming Integrated Test Center and also at a Holcim U. S. cement plant in South Carolina with funding from the U.S. Department of Energy.

With DOE support, GTI Energy researchers and partners are exploring options to replace traditional chemical engineering separation and reaction processes with something more environmentally friendly. The team has invented **advanced graphene oxide (GO)-based membranes** that offer step-change improvements in performance, and bench-scale membranes are being tested at the National Carbon Capture Center (NCCC) to assess performance with actual flue gas.

GTI Energy has a rich legacy of managing complex public-private field programs and developing and deploying solutions for unconventional oil and gas resources, and the team is applying that subsurface experience to underground CO_2 storage. GTI Energy's subsidiary, Projeo Corporation, complements that expertise with geotechnical competencies and operational/management services to ensure secure, efficient, and cost-effective carbon dioxide containment. Together, we are leading **DOE Carbon Storage Assurance Facility Enterprise (CarbonSAFE) projects** in Sutter County, Northern California, and in the Permian basin of West Texas, aimed at developing carbon dioxide geologic storage sites.

GTI Energy is evaluating an innovative technology that **captures carbon from building heating system exhaust directly at the point of use** for Canadian company CleanO2. CARBiN-X uses a chemical process to convert CO_2 into a stable carbonate to produce soaps and detergents for the consumer market. UTD's members are providing technology development expertise and financial support to refine and optimize a prototype.

Developing the Next-Generation Workforce

Professional development programs convene thought leaders to collaborate on solutions for low-carbon, low-cost energy systems.

GTI Energy supported the creation and launch of the **Energy Leadership Institute's Energy Generation (EnGen) Leadership Program** in 2022 to educate and empower the next generation of leaders across industry sectors. These professionals have a broad understanding of the integrated nature of energy systems and are working together to guide the evolution of the industry. GTI Energy sponsors and serves on the advisory board for the one-year, curriculum-based executive development program.

Energy Leadership INSTITUTE

enGen

Our newly launched **Energy Transition Opportunities Program (ETOP)** provides interactive science, technology, engineering, and math (STEM)-forward learning for local students and faculty at underrepresented high schools, aimed at sparking students' interest in technical fields and identifying pathways for students to pursue their interests and future career options. This kind of hands-on activity and problem-solving resource helps young people develop real-world, employable skills and knowledge in science and technology, critical thinking, creativity, and teamwork they need to make a lasting impact on communities and the environment.

As part of an LCRI project, GTI Energy is working with EPRI on a workforce development initiative to cultivate an emerging industry workforce to advance hydrogen technologies and use. The **Hydrogen Education for a Decarbonized Global Economy (H_2EDGE)** project focuses on developing newly trained personnel as well as enabling the existing labor force to migrate into the hydrogen field.

Enabling Continuous Learning with Training and Events

The new workforce wants mobile, interactive, real-life learning options. GTI Energy professionals are meeting the demand with immersive training, can't-miss conferences, and other methods to deliver relevant, engaging content.

CH4 CONNECTIONS
THE METHANE EMISSIONS CONFERENCE
GTI ENERGY
ENERGY INSTITUTE
COLORADO STATE UNIVERSITY

Hosted by GTI Energy and Colorado State University Energy Institute, the 2023 **CH4 Connections conference** attracted record attendance, with topics including measurement, mitigation, and methane emissions reduction. The event brings together leading thought leaders, academic researchers, industry experts, regulators, policymakers, and environmental advocates annually to collaborate on ideas and solutions for decarbonization.

GTI Energy's training group is developing **3D augmented reality (AR) interactive models** of gas fittings and equipment to help train employees via simulations. Putting field workers virtually hands-on with components allows them to get familiar with the equipment rapidly—and from anywhere. In addition, the team re-developed virtual reality (VR) training models to incorporate gamification features that enhance the overall training experience.

GTI Energy's hallmark bioenergy event, the **International Conference on Thermochemical Conversion Science (tcbiomass2022)**, highlighted the role of biomass in achieving net-zero carbon goals and drew global attendees to share insights and opportunities. A rich technical program complemented an outstanding lineup of keynote speakers, panel discussions, poster presentations, exhibits, and networking opportunities.

tcbiomass

Strengthening Culture, Communities, and the Environment

People are at the core of everything we do. From our team members to the communities where we work to the energy customers who benefit from the solutions we discover, we are committed to engaging with and empowering people from diverse backgrounds. We believe that bringing together a variety of perspectives creates a more innovative and inclusive culture where everyone feels valued, supported, and respected.

We have established a Strategic Plan to guide our **diversity, equity, inclusion, and accessibility (DEIA) efforts**, drive our culture, and maintain GTI Energy's status as a Top Workplace. Our new DEIA Council brings awareness to relevant topics and elevates the voices of underrepresented groups as we incorporate inclusivity concepts and practices into all areas of our business.

GTI Energy is committed to **making an impact in our local communities,** investing in STEM education initiatives and environmental justice work to support the next generation of scientists, engineers, and sustainability experts, and provide skills, knowledge, and guidance to disadvantaged high school students in various communities.

GTI Energy sponsored a school-based science and engineering program to create regional resources and talent with knowledge in hydrogen and renewable energy. We mentored a high school team from Friedrich Von Steuben Metropolitan Science Center in Chicago, which built a remote-controlled hydrogen-powered car to compete at the Horizon Hydrogen Grand Prix Midwest races in Spring 2023. Our Woodland Hills team collaborated with California Polytechnic State University students on a hands-on learning experience to bolster their mechanical design technical skills while enhancing cooling water distribution on equipment.

We also work **directly with area non-profits** to gather gifts for children as part of the U.S. Marine Corps Toys for Tots Program and support the United Way, Wounded Warrior Project, and the American Red Cross through an annual charitable giving campaign.

GTI Energy is **extending efficiency and sustainability** through all phases of technology research and development, from project management to operations in our workplace. Our Sustainability Committee finds efficient ways to use energy, responsibly manage material reuse, recycling, and disposal, and conserve natural resources through building upgrades and day-to-day activities.

GTI ENERGY
ENVIRONMENTAL
SUSTAINABILITY
PROGRAM

The Committee sponsors activities to raise awareness on environmental topics, such as recycling events that collect electronics, paint, batteries, eyeglasses, and clothing, as well as other items to divert waste from landfills.

Our Portfolio Companies

GTI International, Inc. (GTII) is a holding company and wholly owned subsidiary of GTI Energy. Through GTII, GTI Energy is investing in an efficient, clean energy future to meet ever-escalating energy, operational, and environmental challenges.

Frontier Energy, a subsidiary of GTI International, Inc., is a professional services firm with a long history of providing solutions to encourage the intelligent use of energy. The firm's expertise includes demand-side management, software development, building research and consulting, commercial foodservice efficiency, and advanced transportation and power. Frontier Energy partners with utilities, government, and private businesses to help them conserve energy, make strides toward decarbonization, and evaluate the effectiveness of large-scale initiatives.

In 2022, GTI International acquired **Projeo Corporation,** a project management, field supervision, and subsurface technical services firm for clients engaged in CO_2 storage, geothermal, hydrogen, oil/gas, and critical mineral projects. With a focus on deep subsurface and low-carbon projects, Projeo has decades of experience and a large portfolio of both commercial customers and government-funded projects across the U.S.

SunGas Renewables, a spin-out of GTI Energy, is taking a leading role in decarbonization by providing its S1000 renewable syngas product to third parties for renewable hydrogen and biofuels production while also developing and investing in low-carbon biofuels businesses. The SunGas Renewables S1000 contains pressurized fluidized bed gasification technology, originally developed by GTI Energy, integrated with other large-scale proven commercial technologies to provide an optimized and reliable green syngas manufacturing platform for the production of green methanol for marine fuel, renewable natural gas, SAF, green hydrogen, and other renewable biofuels from sustainably sourced biomass and wood fiber.

Rev Innovations, an affiliate of GTI Energy, was founded on the belief that energy transitions will require new solutions to consequential problems. Rev believes these efforts will require engagement with and transformation of today's infrastructure. Further, the team considers that solutions in successful energy transitions must be not just lower-carbon but also lower-cost. Rev seeks success for its partners, colleagues, and communities.

Larry Brand
President and CEO,
Frontier Energy
(retired April 1, 2024)

Nick Malkewicz
President, Projeo
Corporation

Robert Rigdon
CEO, SunGas
Renewables

Johanna Schmidtke, PhD
Managing Partner,
Rev Innovations

Leadership

SENIOR LEADERSHIP TEAM

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President and CEO

Quinton Ford
Senior Vice President, Technology Development, General Counsel and Secretary

Jim Ingold
Senior Vice President, Finance, Treasurer, and CFO

Ronald Snedic
Senior Vice President, Corporate Development and President, GTI International

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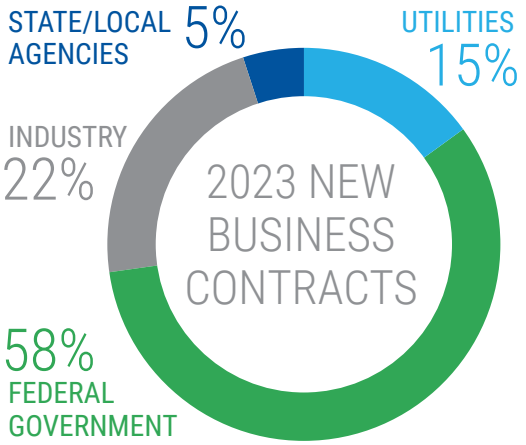
Vice President, Carbon Management & Conversion

Kristine Wiley
Vice President, Low Carbon Energy Solutions

Financial and Business Overview

FINANCIALS

In Millions	2022	2023
Project Revenue	$156.9	$172.2
Royalty/Other Revenue	$5.5	$2.9
Total Revenue	$162.4	$175.1
Total Assets	$162.8	$168.6
Total Liabilities	$86.8	$96.0
Net Assets–Unrestricted	$76.0	$72.6



LOCATIONS

GTI Energy

- Des Plaines, IL
- Agoura Hills, CA
- Woodland Hills, CA
- Davis, CA

Projeo

- Champaign, IL

SunGas Renewables

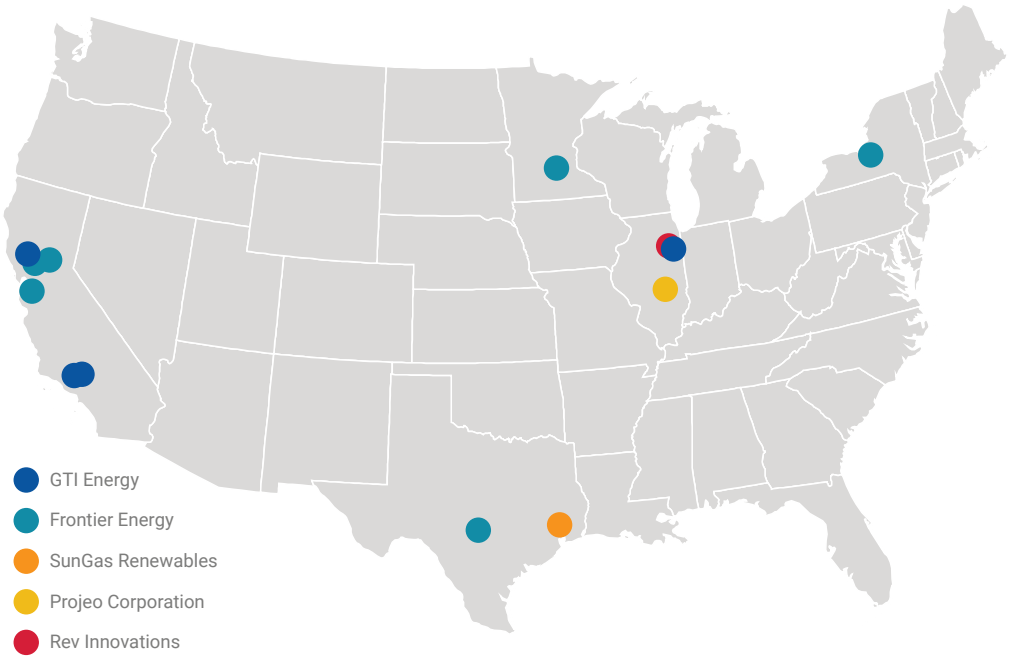
- Houston, TX

Frontier Energy

- Austin, TX
- Cazenovia, NY
- Chanhassen, MN
- Davis, CA
- Pleasanton, CA
- Sacramento, CA

Rev Innovations

- Des Plaines, IL



GTI ENERGY

solutions that transform

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