

CONVERGENCE

gti<sup>®</sup>

2017 ANNUAL REPORT





gti®



## EXPERTISE. FACILITIES. FUNDING.

GTI is the place where it all comes together.

- Depth and breadth of knowledge across the energy spectrum integrates to achieve robust and comprehensive solutions.
- State-of-the-art labs and facilities stimulate creative thinking and drive crisp execution.
- National and global energy industry partners collaborate to leverage research funding and deliver results with impact.

HERE, ALL THE RIGHT ELEMENTS CONVERGE TO TRANSFORM RAW TECHNOLOGY INTO PRACTICAL ENERGY SOLUTIONS.

# ALL OF GTI'S INITIATIVES COALESCE AROUND AFFORDABLE AND ABUNDANT ENERGY WITH A LOW ENVIRONMENTAL FOOTPRINT

Our backlog of projects spanning efficient and prudent production to management of greenhouse gas emission, low-carbon fuels and power, safe and reliable gas delivery, energy efficiency—and everywhere in between—resonates with this consistent theme.

With a strong vision, sterling reputation, and an ever-expanding slate of relevant projects, GTI's business is healthy and growing. We had an exciting year of transformations, as we increased in size and scope and established a record-breaking backlog of new business contracts.

Our financial health is robust, achieving a new milestone in revenue. We're proud to say that we have doubled our revenue from \$54 million to almost \$113 million over the past five years. It's a testament to the hard work and dedication of our very talented staff on highly relevant energy issues.

We have a balanced mix of customer segments and technology offerings, and we bring great value to our clients, from operational efficiencies to breakthrough transformative technology. We delivered solid performance and operated safely, without any lost time accidents or recordable incidents.

GTI was awarded 14 U.S. patents and 40 foreign patents—intellectual property that can make a substantial impact on the market. Our world-class scientists and engineers de-risk technologies, bringing industry needs to the table to develop technologies that meet user requirements for performance, features, and cost. Researchers also generate and analyze factual scientific data that can be used to help guide informed decision-making.

We are leading construction of transformational demonstration facilities all around the world. Many large-scale projects have been established and will continue to grow and flourish in 2018. We also expanded our capabilities with an updated laboratory in Davis, CA and a new testing facility in Agoura Hills, CA.

GTI is well known for our connections across the energy value chain and role as a trusted partner. We will continue to expand those relationships and build effective teams that can deliver critical insight and contribute funding to support key initiatives. Collectively, we can achieve significant results.

In the coming year, our team of experts will continue to develop novel technologies to produce, create, deliver, and use environmentally friendly and affordable fuel and power from all of our resources. We hope to have the opportunity to work together with you on these important endeavors.



*David C. Carroll*  
David C. Carroll,  
President & CEO



*Terry D. McCallister*  
Terry D. McCallister,  
Chairman of the Board



# EFFICIENT AND RESPONSIBLE PRODUCTION

## Minimizing environmental impacts and increasing recovery rates with the Hydraulic Fracturing Test Site program

GTI's high-profile program on Hydraulic Fracturing Test Sites (HFTS) is developing environmentally responsible methods of optimizing production and lowering costs. The U.S. Department of Energy National Energy Technology Laboratory (DOE/NETL) provided broad support, along with cofunding from operators and service companies.

In the first collaboration—HFTS1–Midland—400+ fracture stages were completed in 11 Laredo Petroleum wells in the Wolfcamp formation of the Midland portion of the Permian Basin. **A through-fracture core sample along with comprehensive data analysis provided information to validate and improve models and design of hydraulic fracturing.**

**Air and groundwater quality evaluations indicate the HFTS well pads had minimal impact on local air emissions concentrations, and analysis of water quality did not find any evidence of natural gas or produced water migration to the groundwater aquifer.**

Based on industry interest, Phase 2 has been added to HFTS1–Midland, with a focus on enhanced oil recovery (EOR). The effort will explore injection of natural gas into a well to pressure the formation up again and potentially recover another 2–4% of the oil in place. This increased recovery would reduce the number of wells that need to be drilled, resulting in a smaller environmental footprint.

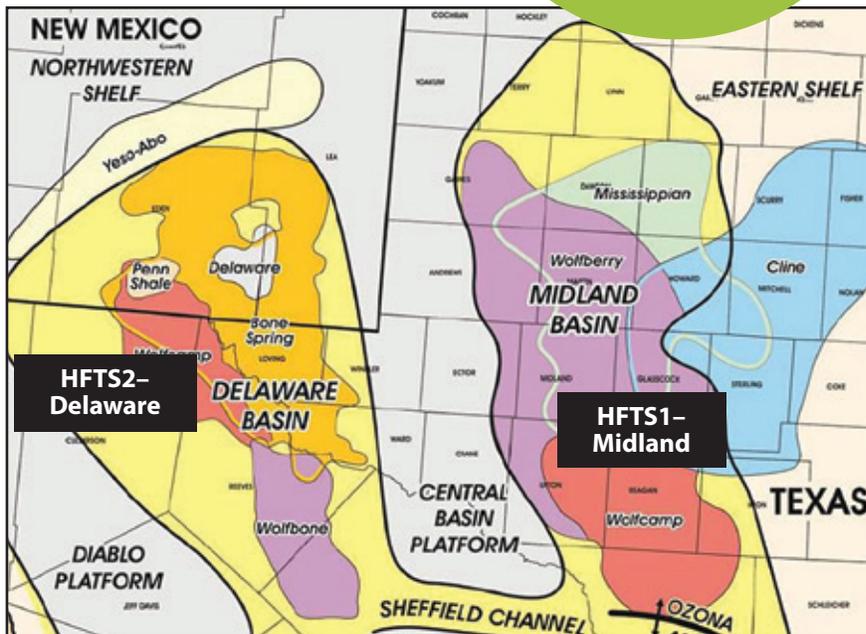
In January 2018, GTI was awarded additional funding from DOE/NETL for new cost-shared research and development on fracturing efficiency. GTI will collaborate with oil and gas majors on a new site, HFTS2–Delaware, to evaluate well completion, design optimization, and environmental impact quantification. The field test site will be located in the Wolfcamp formation of Delaware Basin portion of the Permian Basin, which features different depth, pressures, and permeability than Midland.

Anadarko Petroleum Corporation and Shell Exploration and Production Company plan to co-host the test site and other industry partners are being solicited. Work will commence in late 2018 at an Anadarko-operated location in the Delaware Basin.

GTI and the University of Calgary signed a letter of intent for HFTS-Canada in the Western Canadian Sedimentary Basin. The effort will support the University's Global Research Initiative in sustainable low carbon unconventional resources, which aims to significantly reduce the carbon footprint of unconventional resource development.



The HFTS program could fundamentally change the hydraulic fracturing process, improve reservoir recovery rates, and eliminate the need for thousands of wells.



# CLEANER FUELS AND CHEMICALS



**“Yangquan is one of the largest coal producers in China. This technology offers a step-change improvement in efficiency and cost over current gasification technology and is uniquely capable of gasifying China’s low-rank coal.**

**Coal is a leading energy choice in China, and finding the most cost-effective and environmentally friendly ways of using it will help to maintain its role as a vital contributor to our economy.”**

*Mr. Zhai Hong,  
Chairman of Yangquan Group*



## **Providing significant economic and environmental benefits in China with breakthrough gasification technology**

GTI and Yangquan Coal Industry Group, a Global Fortune 500 company, signed a contract for joint development of an Industrial Demonstration Project for the R-GAS™ gasification process in China. The installation will be located at the largest coal-to-chemicals plant in Shanxi Province.

The project follows up successful long-duration testing of high ash-fusion temperature coal using GTI’s R-GAS gasifier technology at our pilot-scale facility in Des Plaines, IL.

**The innovative technology is able to gasify the anthracite coal predominant in China. Testing validated the robustness of the R-GAS process, demonstrating the capability to achieve >99% carbon conversion even with this low-rank coal.**



The gasifier footprint is about one-tenth the size of competing entrained flow technologies, and the compact size and advanced design features drive higher efficiency and lower cost. R-GAS consumes up to 30% less water and the higher efficiency results in lower overall emissions. It can be used for coal conversion to liquid fuels and chemicals, as well as power generation.

Capital expenditures are estimated to be 15–25% lower than the most economical entrained flow technology. The Yangquan industrial demonstration will validate long-duration reliability, operability, and capital costs.

# CLEANER FUELS AND CHEMICALS

## Expanding production and use of renewable natural gas (RNG)



GTI is leading a team of technology providers and engineering experts to perform a site-specific **engineering study at a Stockton, California Biomass power facility. The goal is to quantify the costs to transform the site into a renewable natural gas (RNG) production facility and produce up**

**to 3 BCF/year of RNG from woody biomass.** It will provide both an economic and an environmental basis for future commitments to deploy large-scale RNG production in California and elsewhere. Support is being provided by a group of West Coast utilities, California public agencies, and team members including ANDRITZ, Haldor Topsoe, and Black & Veatch.

### **A report produced by GTI and Quantum Biopower is providing research-backed insights and information to enlighten policymakers and the general public about the potential of RNG.**

The study highlighted Connecticut's potential capacity for 41 MW of electricity from RNG that could displace 540,000 tons of carbon dioxide. The RNG generated from all waste sources combined could generate enough pipeline-quality natural gas to heat up to 40,000 homes or provide carbon-negative transportation fuel to thousands of passenger and heavy-duty vehicles.

With funding from Operations Technology Development, NFP (OTD), GTI is providing a fact-based, objective study on the quality, analysis, risk, and compositional variability of final end-use grade biomethane. The goal is to provide the industry with sound science and clear facts to demonstrate that biomethane is safe to inject into a distribution or transmission pipeline if properly processed.

In another project, GTI is working to identify sensor systems that can detect and analyze all trace contaminants of concern in biomethane gas on-line and offer immediate insights to gas quality. This will ensure that only fully up-graded biomethane is injected into the gas stream. Phase 1 identified several technologies that meet this criteria, and their performance will be validated in Phase 2.

Researchers are also conducting studies looking at analytical techniques, sampling methods, and sampling materials to develop a universal analytical technique for determining siloxane content in biomethane.



# MOBILITY SOLUTIONS WITH REDUCED EMISSIONS

**“The IH<sup>2</sup> technology can be one of the game changers that can make my country a net exporter of energy.”**

*Dharmendra Pradhan  
Minister of Petroleum  
and Natural Gas, India*



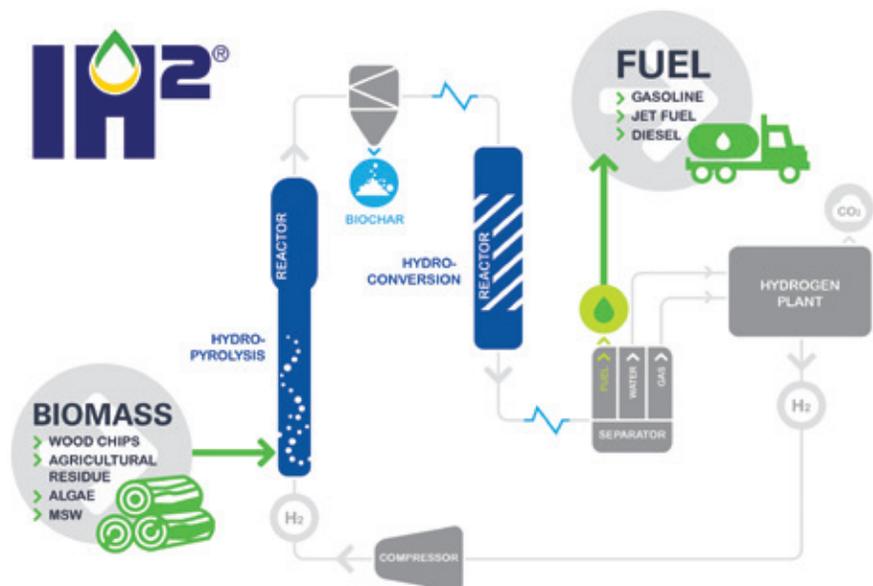
## Producing alternative transportation fuels from renewable resources

Shell India Markets Pvt Ltd (SIMPL) completed construction of a 5 TPD IH<sup>2</sup> demonstration plant at their new Technology Center in Bangalore, India. **IH<sup>2</sup> is a catalytic thermo-chemical process that converts non-food biomass feedstocks—such as wood, agricultural residues, algae, aquatic plants, and municipal waste—directly into gasoline, jet, and diesel drop-in transportation fuels with greater than 60% reduction in greenhouse gas emissions.**

GTI experts spent significant time in Des Plaines as well as Bangalore the past year assisting with plant commissioning, leading training, and supporting optimization of operating parameters. CRI Catalyst Company (CRI) and Shell will demonstrate the conversion of municipal and agriculture waste into liquid transport fuel.

GTI invented, tested, and patented the fully integrated IH<sup>2</sup> technology and has an exclusive worldwide licensing agreement with CRI. CRI has signed more than 10 licensing agreements for preliminary engineering assessments. One with New Delhi-headquartered Sunlight Fuels will develop detailed engineering on a plant that would convert sugarcane bagasse into transportation fuels.

Researchers are providing ongoing technical and commercialization support at GTI's IH<sup>2</sup> process pilot plant. To date, 10 U.S. and 72 international patents have been awarded on the technology.



## MOBILITY SOLUTIONS WITH REDUCED EMISSIONS



### Developing alternative transportation vehicles, engines, and fueling infrastructure

GTI is leading a project to design and demonstrate a **heavy-duty hybrid truck that combines an electric vehicle with a near-zero compressed natural gas (CNG) engine to extend its range.**

The Zero Emission Cargo Transport (ZECT) truck has a Kenworth chassis that integrates a BAE electric propulsion and power system. A smart charging port was designed, built, tested, and installed, and extensive operational testing is underway.

End users, support staff, and first responders will be trained and the truck will be put into service at the ports of Los Angeles and Long Beach later this year. Support for the project has been provided by DOE Office of Energy Efficiency & Renewable Energy (EERE), South Coast Air Quality Management District (SCAQMD), and Southern California Gas Company (SoCal Gas).

A project funded by the California Energy Commission with support from Utilization Technology Development, NFP (UTD) and SoCal Gas is underway to develop and demonstrate a compressed natural gas (CNG) dispensing system that safely and accurately achieves a full natural gas vehicle (NGV) fill. It will allow for cost-effective full fills, using an advanced control technology and a simple method for conditioning gas as it is dispensed into a NGV in order to effectively manage the temperature and density changes that currently prevent vehicles from getting a full fill.

GTI subsidiary Frontier Energy manages the California Fuel Cell Partnership (CaFCP), a public-private collaborative focused on bringing fuel cell electric vehicles (FCEVs) powered by hydrogen to the commercial market. At the end of 2017, 31 retail hydrogen stations were open and 2,348 FCEVs had been sold or leased in California. Three transit agencies were operating 20 fuel cell buses, and 33 more buses and shuttles are slated to be added to the fleet.

**Frontier Energy team members played an instrumental role in the California Energy Commission's award for additional hydrogen stations and Governor Brown's executive order that increased the state's commitment to hydrogen and fuel cell transportation.** Frontier Energy staff are also working with GTI on pilot projects with fuel cell trucks.



**CWI natural gas engines are 90% cleaner than the latest available diesel engine.**

GTI has worked with Cummins Westport Inc. (CWI) and other partners—including the California Energy Commission and SoCal Gas—on development and field testing to bring a slate of ultra-low NO<sub>x</sub> emission natural gas vehicle engines to market.

The NO<sub>x</sub> emissions from the CWI B6.7N, L9N 320-HP, and ISX12N 400-HP medium and heavy-duty truck engines are so low that they are almost immeasurable, surpassing U.S. EPA emission standards and qualifying as “near zero” NO<sub>x</sub> emission engines.

In the Michigan to Montana (M2M) Corridor project along I-94, GTI is building community-based partnerships and providing leadership to create a successful and **sustainable alternative fuel corridor for clean vehicles.** With a nearly \$5 million award from DOE and \$15 million in partner support, GTI worked with Clean Cities Coalitions and other industry leaders to facilitate the deployment of new electric charger, CNG, and propane fueling stations and accelerate the adoption of alternative fuel vehicles (AFVs). In addition, training is being provided to critical stakeholders to establish a sustainable market and continue growth beyond the project's end.

# COST-EFFECTIVE CAPTURE AND REUSE OF CARBON



GTI and Air Liquide Advanced Separations are developing a versatile **hollow fiber membrane contactor (HFMC) technology for pre- and post-combustion carbon capture**. The CarboLock™ HFMC technology offers power generation carbon capture with a smaller footprint and lower costs.

Under a DOE/NETL project, GTI installed, commissioned, and tested CarboLock at a 0.5-MWe (10 ton CO<sub>2</sub>/day) scale on a coal-derived flue gas stream at the National Carbon Capture Center (NCCC). Early testing indicate DOE's technical target (95% CO<sub>2</sub> purity) can be achieved. Continuous, steady-state operation is now underway.



## Using CO<sub>2</sub> to reduce greenhouse gas emission and generate useful products

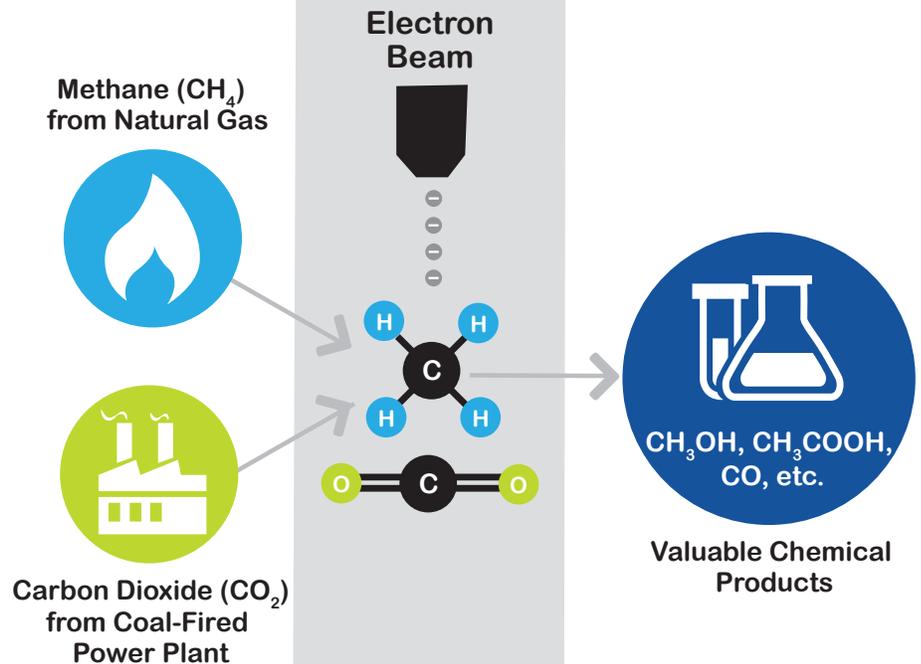
GTI has a number of early-stage research initiatives underway on carbon utilization with \$4 million in funding from DOE/NETL's Novel and Chemical Processes for Beneficial Use of Carbon program.

In a project on high-energy systems for transforming carbon dioxide (CO<sub>2</sub>) to valuable products, GTI is leading a team with IBA Industrial Inc. and the State University of New York (SUNY) to develop a **direct electron beam (E-beam) synthesis (DEBS) process to produce chemicals using CO<sub>2</sub> captured from a coal-fired power plant and methane (natural gas)**.

The DEBS low-cost, energy-efficient process uses a high-energy e-beam to break chemical bonds, allowing production of chemicals such as acetic acid, methanol, and carbon monoxide, at near-ambient pressure and temperatures that offer lower capital and operating costs.

This project will expand on the concept of DEBS to develop a commercially viable process that will minimize e-beam energy requirements and selectively control the yield of more valuable products while maximizing CO<sub>2</sub> conversion, which will mitigate CO<sub>2</sub> emissions and/or offset the cost of carbon capture and storage.

Another project is testing a catalytic membrane technology for dry reforming to transform CO<sub>2</sub> and methane into syngas.



# METHANE EMISSIONS MONITORING, MITIGATION, AND INSIGHTS

## Addressing global climate change concerns

GTI and Jet Propulsion Laboratory are developing, testing, and demonstrating a **high-efficiency integrated methane mitigation thermoelectric generator (MMTEG)/burner system for oil and gas field operations**. The thermoelectric generator provides power to compress air that is used instead of natural gas to operate the pneumatic controllers, resulting in natural gas recovery and reduced methane emissions. Initial experiments to simulate heat transfer to the thermoelectric generators have been completed.

Residential methane detectors (RMDs) augment existing safety programs and their adoption adds another layer of protection for the detection of leaks. GTI conducted a national study to evaluate the performance of methane detectors in a variety of residential settings. Based on successful outcomes, researchers are advocating reduction of the alarm limit to 10% lower explosive limit (LEL) of methane and working toward listing with the International Code Council Evaluation Services. Ongoing efforts include stakeholder education and outreach to build technology awareness and advance the product with guidance on optimal detector placement.



**Methane monitoring tools, comprised of a network of remote sensors connected wirelessly via phone or tablet to provide information about methane concentration at multiple points at a leak site**, have been developed by GTI with support from OTD. Field testing and demonstrations are underway, and researchers are engaging with potential commercializers to bring the technology to market. A utility measurement use case is assessing semi-permanent longer-range wireless access for utilities to monitor leaks over time.



Another new tool simultaneously measures CH<sub>4</sub> concentration, air flow, temperature, and humidity for improved measurement and quantification of leak classification.



A white paper developed by GTI's Center for Methane Research (CMR) outlines radiative forcing data from the National Oceanic and Atmospheric Administration (NOAA) to provide insight on trends for CO<sub>2</sub> and methane radiative forcing. The CMR is a GTI collaborative program with a focus on understanding and reducing atmospheric methane concentrations. It collects, analyzes, and synthesizes existing fact-based data to distill important information.



GTI hosted the most successful methane emissions conference to date, with over 250 participants. With a new partner and location at Colorado State University (CSU) in Fort Collins, **CH<sub>4</sub> Connections brought together industry experts and leaders to discuss and share perspectives regarding emissions-related issues, policies, and technologies.**



# SAFE AND RELIABLE GAS DELIVERY

A two-year project with U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration (DOT PHMSA) and partners was recently completed. It delivered an **integrated set of quantitative tools that provide a structured approach to evaluating the latent risk in vintage polyethylene pipes**, such as Aldyl-A, that are common in gas distribution systems.

Outcomes from the project include a prototype endoscopic structured-light inspection tool for assessing stress risers that can access pipe through keyholes, comprehensive risk models, and methods to optimize maintenance and replacement programs based on collected data.

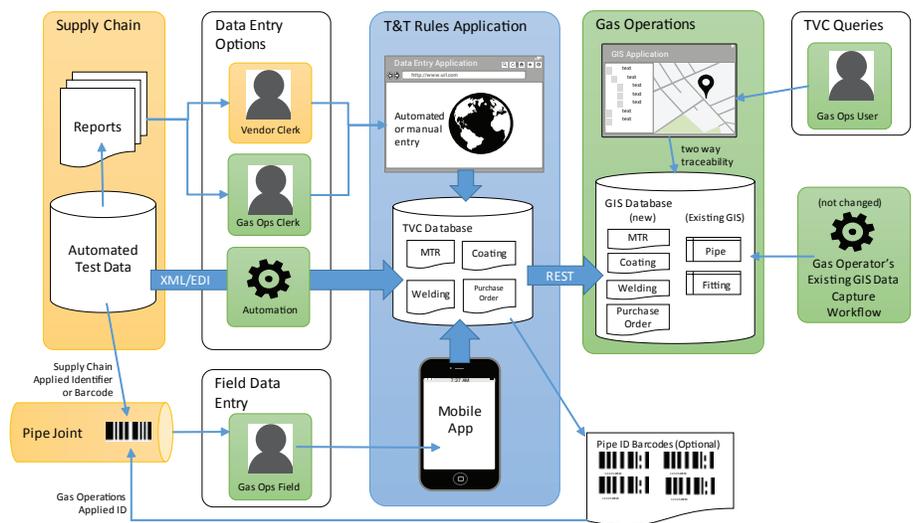
## Empowering operators to assess and manage risk

A GTI-developed Enterprise Decision Support System (EDSS) platform integrates gas-system data and knowledge from various sources into a single information source to support decision making. It utilizes diverse data sets, probabilistic reasoning, and artificial intelligence (AI) to support optimization of capital programs, risk governance, risk management, and analysis through advanced data analytics.

With OTD funding, **a full set of tools for determining fitness-for-service of vintage plastic gas distribution pipe has been integrated into a commercially available AI framework and validated against historic data sets.**

GTI is making continued progress in developing a **multi-pronged, programmatic approach to bring tracking and traceability solutions to high-pressure pipe systems.** The objective is to develop a consistent methodology and implementation protocols that will allow natural gas system operators to more effectively manage operations data and improve the decision-making process. The effort includes work with pipe suppliers and development of a consensus marking standard.

Operators will have the ability to factor the quality and reliability of data into the decision-making process, ranking which inputs have the most leverage on the calculation of risk. Gaps, consistency, integrity, default value rationale, and similar attributes of data will be quantified. A set of guidelines for implementing a quality standard for managing and documenting data will also be created. A comprehensive Business Process Model and Notation (BPMN) architecture will map out the protocols and work processes to ensure easy integration.



# SAFE AND RELIABLE GAS DELIVERY

## Digitization and data analytics drive informed decisions

**In a GTI-developed excavation encroachment notification (EEN) system, real-time GIS and sensors integrated into a tracking system are alerting pipeline operators to the potential for damage from active excavations.**

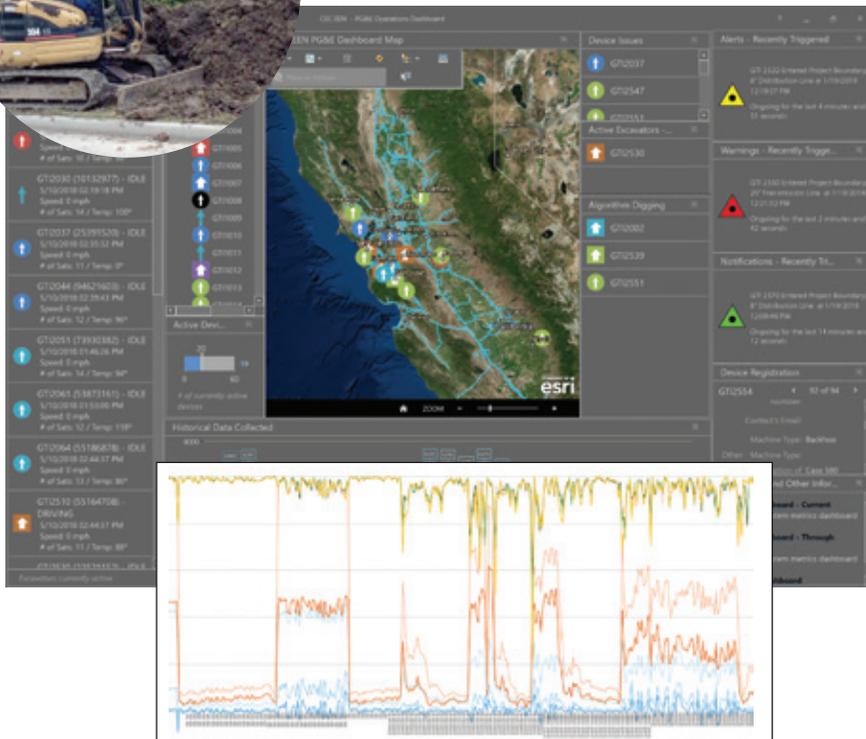
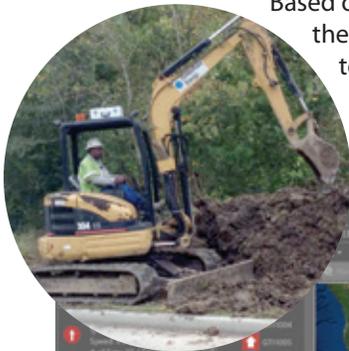
Data streams and mapping are enhancing situational awareness of activities within and outside of authorized dig areas, helping to reduce risk when digging near gas pipelines.



GTI has worked extensively with OTD, Pacific Gas & Electric (PG&E), and other utilities to develop and demonstrate the technology. A project supported by the California Energy Commission and PG&E deployed 150 devices with cellular connectivity, global positioning systems (GPS), and motion sensors on construction equipment in the state.

Researchers were able to assess excavation activity and combine GIS data to provide an accurate algorithm to significantly reduce the occurrence of false-positive results in the characterization of field activity. Historical data archiving also provides key information for analysis and trend identification.

Based on positive response, PG&E will continue to use the devices after the field test ends to help bring the technology to market. Additional pilot projects under development involve potential commercialization partners, and new utility partners are encouraged to participate.



LocusView Solutions (LVS) was launched as a Chicago start-up in 2014 by GTI International (GTI). LVS brings advanced commercial-scale mobile geospatial products and services to natural gas operators.

LVS's technology is currently deployed at over 15 operators with more than 900 users of the Digital Construction and Intelligent Inspection offerings. Large-scale deployments at Atmos, PG&E, Southern Company, Washington Gas, and Exelon/PECO and other utilities are planned in 2018.

In April 2018, LVS was sold to NortecView, Ltd., the software company who developed the mobile application platform currently utilized by LocusView.

This will position the company to accelerate the pace of product development and rapidly scale technology deployment across the country.



# SAFE AND RELIABLE GAS DELIVERY



GTI partnered with PG&E to bring pre-commercial Optimized Radar to Find Every Utility in the Street (ORFEUS) technology to the U.S. for live field evaluations. The real-time radar obstacle detection system for horizontal directional drilling (HDD) was developed in Europe with funding support from the European Union.

**During testing, the ORFEUS technology was able to successfully detect plastic and steel gas lines, electric conduit, and a sewer main. GTI is continuing to assist with further technology development to help bring the product to market.**

**“This system is a huge step forward in improving safe digging in built-up areas.”**

*Aaron Rezendez,  
Gas Engineer,  
PG&E*

## Collaborative technology development for infrastructure construction and maintenance

A myriad of exciting new tools and hardware being developed by GTI with funding from OTD are preventing damage, enhancing operational efficiency, and increasing safety.

The Gas Line Tracer and Directional Entry Tool available from Jameson addresses the issue of locating previously un-locatable plastic gas distribution lines. It enables vertical insertion of tracer rods and cameras into live gas mains, facilitating the difficult first bend at entry.



Marketed as the Kleiss MCS Flow Stopping System, new tools are used to stop the flow of gas in polyethylene, steel, cast-iron, and PVC pipes at diameters up to 18 inches and pressures up to 60 psig. The system, which is manufactured in Europe, was brought to the U.S. and optimized for North American infrastructure through an OTD project.

GTI and 3M have joined forces to develop and test a viable solution for intrinsically locatable polyethylene (PE) pipe materials. The system builds on existing 3M EMS ball marker locator technology which uses material resonators for path marking. It offers precise location without tracer wires or accurate maps. By applying the marker directly to the plastic pipe, installation time is reduced and the system offers greater accuracy, integrity, and ease of use.



A breakaway fitting to enhance gas system safety is a low-cost option to reduce risk to aboveground Meter Set Assemblies (MSAs) when impacted by outside forces, such as vehicular impact. The breakaway fitting being commercialized by OPW can be installed directly to new and existing meter sets to stop the flow of gas when impacted and reduce the risk of a leak, fire, explosion, and/or property damage. Field testing at several U.S. utilities received very positive feedback.

The Integrated Intelligent Safety System (IISS) under development will help to mitigate the risk of gas leaks due to third-party damage on commercial, multi-family, and small industrial service lines. The IISS works similarly to an excess flow valve, but has a lower shut-off threshold. It's versatility is capable of serving variable gas loads, avoiding false closures yet recognizing and reacting to smaller but significant downstream leaks.

# LOW-CARBON POWER GENERATION

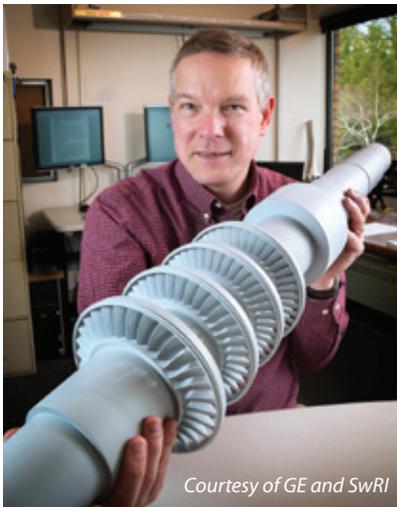


## Increasing power plant efficiency with supercritical carbon dioxide (sCO<sub>2</sub>) power cycles

Under an \$80 million contract from DOE's Supercritical Transformational Electric Power (STEP) program, GTI and partners Southwest Research Institute (SwRI) and GE Global Research are designing, building, and demonstrating a 10 megawatt electrical (MWe) supercritical carbon dioxide (sCO<sub>2</sub>) pilot power plant. This grid-connected, advanced power plant pilot will be located at the SwRI campus in San Antonio, Texas.

Compact, modular technologies that can be applied in future power plants to generate clean, low-cost power from natural gas, coal, next-generation nuclear, concentrated solar thermal, and industrial waste heat sources will be integrated and proven at this demonstration.

**The thermodynamic advantages of using sCO<sub>2</sub> as a working fluid instead of steam allows a power plant to generate electricity from less fuel which decreases CO<sub>2</sub> and other emissions, as well as overall operating costs. An additional attribute of the technology is a dramatically smaller turbine (85% reduction in size), enabling a potentially more dynamic power plant with a downsized footprint.**



*Courtesy of GE and SwRI*

This pilot power plant will be an independent platform to qualify, de-risk and mature materials, components, technologies, and power cycles, and will support power industry adoption of this technology and provide lower-cost electricity generation to consumers.

In 2017, Korean Electric Power Co. (KEPCO) joined the project as a Steering Committee member. Southern Company and Natural Resources Canada/CanmetENERGY joined as Joint Industry Program partners in 2018, and additional partnership agreements with international parties are now being defined.



Prime Contractor and System Lead



Host Site and Test Operations



Turbomachinery Technology

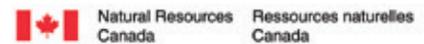


Steering Committee Member



Southern Company

Joint Industry Program Partner



Canada

Joint Industry Program Partner

# LOW-CARBON POWER GENERATION

## Simultaneously generating electricity and storable heat with a hybrid solar energy system

A hybrid solar energy system project is aimed at advancing new solar conversion and storage technology options that can enable a much higher penetration of solar energy into the U.S. energy mix.

The breakthrough technology can simultaneously generate electricity and storable heat. **It has the potential to enable production of renewable power at grid-competitive prices, along with high-quality thermal energy for power producers and industrial facility operators. The new technology maximizes the amount of heat that can be derived from solar panels and could play a role in opening the microgrid market for dispatchable electricity and solar energy use in industrial process heating.**

With funding from the Department of Energy Advanced Research Projects Agency-Energy (ARPA-E), the team composed of GTI, University of California at Merced (UC Merced), and MicroLink Devices, Inc. recently completed successful testing of the hybrid system and met critical ARPA-E project milestones. Based on cost-benefit analysis, the research team is proposing to scale up and demonstrate a 60 kW thermal (up to 600°C) collector with particle thermal energy storage for on-demand process heating at an industrial plant in California.

Financial support to develop this hybrid solar energy technology was also provided by Utilization Technology Development (UTD), a not-for-profit corporation. This collaboration of nineteen industry-leading utilities creates, develops, tests, demonstrates, and deploys new energy-efficient natural gas end-use technologies for their ratepayers, communities, and the environment.



GTI's hybrid solar energy system was featured at the 2018 Advanced Research Projects Agency-Energy (ARPA-E) Congressional Showcase. It was one of five projects from across the nation that was invited, a distinguished honor that recognizes its great potential to be transformational.



# ENERGY EFFICIENCY



## Improving energy savings with heat and water recovery



GTI's patented Transport Membrane Condenser (TMC) technology is a low-temperature device that recovers both sensible and latent waste heat and clean water from exhaust flue gas in industrial and commercial boilers. The technology has also been proven in residential markets, where the **Transport Membrane Humidifier (TMH) can simultaneously upgrade mid-efficiency furnaces (80%) to high-efficiency (95%) while also providing space humidification without an external water supply.**

In a field study, four residences in Minnesota had the TMH installed to their natural gas-fired furnaces for two years, providing heat and humidity to the host families. Analysis of performance data showed that each of the furnaces achieved significant energy gain and provided balanced humidification and indoor comfort. In addition, it has been certified by UL for field installation, paving the way for future commercialization.

The TMC technology has also been modified for power generation applications. It can recover water vapor from high moisture content flue gas and add it to the coal-fired power plant boiler feed water loop to replace costly fresh makeup water and improve energy efficiency. Starting in 2018, testing on large-scale industrial applications will get underway in conjunction with oxy-combustion systems.

Under a grant from the Minnesota Conservation Applied Research and Development (CARD) program, GTI demonstrated emerging condensing rooftop units (RTUs) at two field sites in Minneapolis—a hotel commercial kitchen make-up air unit (MAU), and a conventional RTU installed in a restaurant dining area. **Based on the study, condensing heating generated natural gas savings up to 17% compared to standard efficiency (80% thermal efficiency) systems, and both applications resulted in a positive net natural gas cost savings.** The results confirm that 100% outside air (OA) applications, such as dedicated outside-air systems (DOAS) and MAUs, are the most promising initial market entry since they provide the long, predictable run times and larger heating loads required to generate net energy savings large enough to pay back the installed cost premium.



GTI developed a case study on residential natural gas and electric use in the state of New York.



It highlights the potential impact of electrification in New York and the policy implications in terms of carbon abatement cost-effectiveness and impact on electricity demand. **The study also highlights various future natural gas pathways for up to 50% reduction in CO<sub>2</sub> emissions from gas use in homes.** The case study was presented at the 2017 NARUC Summer Policy Summit.

GTI is finalizing the development of a new analytical platform called the Energy Planning Analysis Tool (EPAT). Developed with support from the American Gas Association (AGA), American Public Gas Association (APGA), and Propane Education & Research Council (PERC), EPAT allows the comprehensive evaluation of a full-suite of residential energy uses such as space heating and cooling, water heating, cooking, drying, and lighting. It offers a detailed assessment of baseline and alternative technologies (natural gas, propane, and electricity), with output values of site and source energy, energy cost, capital cost, and emissions.

# ENERGY EFFICIENCY

GTII subsidiary Frontier Energy's Building Research and Energy Consulting group is teaming with University Student Living of New Jersey to provide energy and sustainability consulting for two major housing projects on the UC Davis campus—Orchard Park and West Village student apartments.

Leveraging decades of experience with technology evaluation and energy modeling, **Frontier Energy is working with the developer to incorporate new state-of-the-art technologies and energy efficiency measures into the buildings to optimize performance, lower the amount of energy consumed, reduce costs, and minimize environmental impacts.**

For West Village, Frontier Energy is guiding efforts to meet the Zero Net Energy (ZNE) goals for the project.



## Bringing low-cost gas-fired heat pump (GHP) technology to high-efficiency homes



GTI and strategic partner Stone Mountain Technologies demonstrated a fourth-generation gas-fired heat pump water heater (GHPWH) at a residence in Alabama, with improved reliability and performance over prior field trials.

This novel technology can meet Ultra-Low NO<sub>x</sub> requirements and has a projected Uniform Energy Factor (UEF) that is more than twice that of standard gas water heaters. **It offers the lowest operating cost and cost of ownership, with projected 50% energy savings.**

A broader, California-focused program is advancing this technology towards commercialization through technology

demonstration, market assessment, and stakeholder outreach activities.

The partners also deployed a gas-fired heat pump combined space and water heating (GHP combi) system at a residence in Tennessee. **The combi system replaced the home's furnace and water heater and is providing a projected 45% energy savings over baseline.** This system, designed to operate in mild and cold climates without backup heating, has been run for over 2,000 hours and will continue operation in 2018.

The team will install several additional GHP combi systems at subsequent field trials in Wisconsin to better understand cold climate performance and installation barriers.





# EDUCATION AND TRAINING

## Opening up career opportunities with Natural Gas Utility and Pipeline Field Skills Training Program

A new, targeted training program for displaced coal workers and others in the Appalachian region was designed and implemented by GTI. The **“From Black to Blue” field skills training program introduces participants to natural gas utility and pipeline operations careers and enables them to become stronger candidates for employment.**

**“I am a strong believer that everything happens for a reason and being in that class has reset me on a better path and provided me with more tools to ensure a successful future.”**  
*Training Graduate*

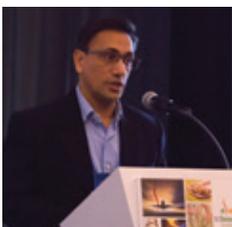


Included is four weeks of blended classroom and hands-on sessions, with a graduation celebration and job fair with regional utilities and contractors on the final day. Several students landed jobs with a local utility right away.

Funded by a grant from the Appalachian Regional Commission (ARC) to Washington Greene County Job Training

Agency, Inc. (WGCJTA), training is offered tuition-free for eligible students in southwestern Pennsylvania and southeastern Ohio. The program, managed by GTI, has been well received by students and employers alike, and classes are ongoing through 2018.

**The Northeast Gas Association (NGA) licensed GTI’s Natural Gas Field Skills Training** to prepare field workers for safe, effective performance in operations and maintenance tasks. The agreement gives access to all NGA utility and contractor members who are enrolled in their Operator Qualification (OQ) testing program. It is anticipated that around 20,000 field workers in the region will be educated using GTI’s materials, ensuring a consistent approach to safety, quality, and compliance.



tcbiomass2017 presented the latest research and innovations in bioenergy in Chicago in early September. The event, hosted by GTI, showcased substantial technical progress in producing biofuels and included expert keynote and technical presentations, poster sessions, and virtual tours from around the world. Attendees hailed from 16 different countries spanning four continents.

**GTI organized a reverse trade mission on behalf of the United States Trade and Development Agency (USTDA) to bring Chinese delegates to the U.S. to learn about heavy-duty vehicle technologies and opportunities.** In early 2018, delegates visited several Fortune 500 companies and attended the largest annual heavy-duty trucking industry event in the world in Louisville, KY.

Two additional reverse trade missions are being organized, one focused on accelerating U.S. LNG exports, and the other on small-scale natural gas infrastructure such as modular natural gas facilities.

Delegates expected from South Africa, India, Argentina, Vietnam, Panama, Jamaica, Dominican Republic, Benin, Cote d’Ivoire, Nigeria, Turkey, and Indonesia will spend 10 days in the U.S. this June. They will participate in the World Gas Conference (WGC) in Washington D.C. and travel to Houston, TX for site visits and meetings with national companies and organizations.

GTI subsidiary Frontier Energy offers online training, designed specifically to educate and certify commercial foodservice professionals in the fundamentals of energy and water efficiency. Following a successful Fe3 pilot program, the sustainability training modules have been added as a requirement for the Foodservice Management curriculum at Sacramento State University.



**Food Service Energy Efficiency Expert**

# FINANCIAL AND BUSINESS OVERVIEW

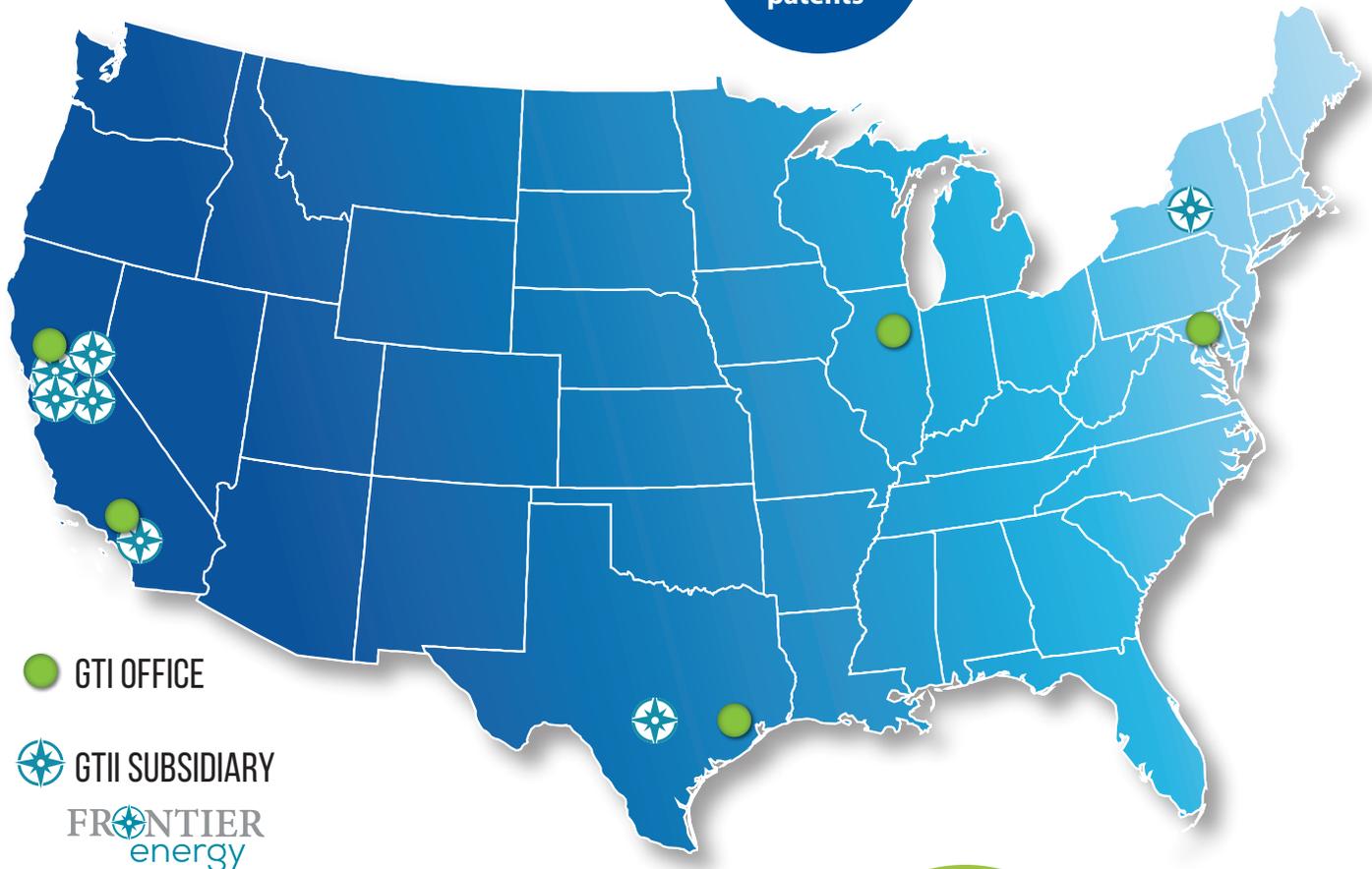
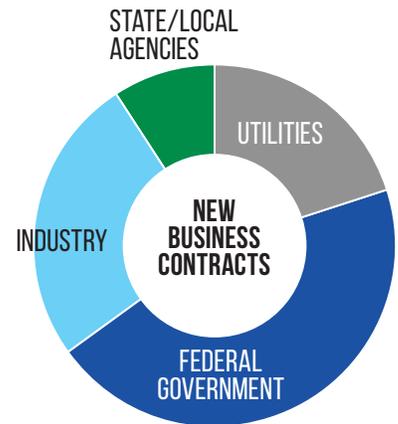
## 2017 Financials

### In Millions

|                         |          |
|-------------------------|----------|
| Project Revenue         | \$ 108.5 |
| Royalty/Other Revenue   | \$ 4.4   |
| Total Revenue           | \$ 112.9 |
| Total Assets            | \$ 135.9 |
| Total Liabilities       | \$ 46.8  |
| Net Assets—Unrestricted | \$ 89.1  |

Record level of new business contracts

14 U.S. patents and 40 foreign patents



365+ employees

Safety is a priority—no lost time accidents in 2017

## SUBSIDIARIES



Energy efficiency,  
market transformation,  
and advanced transportation

|   |   |   |
|---|---|---|
| New company.<br>30+ year history.   |  |  |
|  |  |  |
| 7 U.S. offices<br>in CA, TX, NY   | 120+ employees  | Serving utilities,<br>government agencies,<br>and private clients                 |

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

2017 was a pivotal time in bringing GTII energy efficiency subsidiaries together. Frontier Energy, Inc. was formed in January 2017 when three GTII subsidiaries, Fisher-Nickel, Inc., Davis Energy Group, Inc., and Bevilacqua-Knight, Inc., combined. Frontier Energy provides professional services in energy efficiency, market transformation, and advanced transportation. The company is fuel agnostic and works on projects involving electricity, hydrogen, biogas, and conventional fuels.

The acquisition of Frontier Associates LLC, a professional services firm located in Austin, Texas, was completed in January 2017 as well. On January 1, 2018, Frontier Associates and CDH Energy were integrated into Frontier Energy, Inc. to finalize the combination of our energy efficiency subsidiaries and increase the team's strong qualifications.

Frontier Energy has expertise in demand-side management, building research and energy consulting, commercial foodservice, transportation and power, and software solutions.

## COLLABORATIVES

GTI leads collaborative R&D programs that offer unique opportunities to leverage research funding and bring industry needs to the table.

These collaboratives continue to expand as we add new domestic and international members that recognize the benefits of participation.



Operations Technology Development's (OTD's) mission is to identify, select, fund, and oversee research projects resulting in innovative solutions and the improved safety, reliability, and operational efficiency of natural gas systems. OTD's 25 member companies contribute more than \$11+ million in annual dues to fund important research.



Utilization Technology Development (UTD) creates and advances new technologies and products to save consumers money, enable efficient fuel choices, minimize environmental impacts, further integrate natural gas with renewable energy, and address regulatory developments.

UTD's 19 member companies serve more than 45 million natural gas customers in the Americas and Europe.

# LEADERSHIP

## GTI Executive Team

- David C. Carroll, President and CEO
- Quinton B. Ford, Acting General Counsel and Corporate Secretary
- James F. Ingold, Senior Vice President of Finance, Treasurer, and CFO
- Edward B. Johnston, Senior Vice President, Research and Technology Development
- Ronald N. Snedic, Senior Vice President, Corporate Development and President, GTI International

## GTI Business Leaders

- Vann Bush, Managing Director, Supply and Conversion
- Richard M. Kaelin, Vice President, Washington Operations
- William E. Liss, Managing Director, Delivery and Utilization
- Jeremy M. Otahal, Executive Director, Corporate Development
- Rodney C. Rinholm, Executive Director, International Business
- Larry Brand, President, Frontier Energy, Inc.

## GTI Board of Directors

- Carlos A. Cabrera, Executive Chairman, Genomatica, Inc.
- David C. Carroll, President and CEO, GTI (Ex Officio Director)
- Arthur C. Corbin, President and CEO, Municipal Gas Authority of Georgia
- Marc J. Florette, Executive Digital Advisor, ENGIE (retired)
- John D. Hofmeister, Chief Executive, Citizens for Affordable Energy
- Alexander A. Karsner, Managing Partner, Emerson Collective
- J. Bret Lane, President and COO, Southern California Gas Company
- Terry D. McCallister, Chairman and CEO, WGL Holdings, Inc. and Washington Gas (Chair)
- Steven L. Mueller, Chairman and CEO, Southwestern Energy Company (retired)
- Rebecca Ranich, Director, Deloitte Consulting LLP (retired) (Vice Chair)
- David F. Smith, Chairman, National Fuel Gas Company
- John W. Somerhalder II, Chairman, President and CEO, AGL Resources (retired)
- Nick Stavropoulos, President and COO, Pacific Gas & Electric Company
- Lori S. Traweek, Chief Operating Officer, American Gas Association

## Values

**Safety.** Nothing is more important than the safety of our employees and our customers

**People.** We provide opportunities and a stimulating environment for creative employees to learn, grow and make a difference

**Integrity.** We obey the law and conduct business in a straightforward, transparent manner

**Teamwork.** GTI's ultimate success depends on our ability to work together in a manner that delights our customers

**Quality.** We have an obligation to our customers to deliver the very best product GTI can provide

**Market Focus.** We must bring solutions to customers that enable their continued success

GTI SOLVES IMPORTANT ENERGY CHALLENGES, TURNING RAW TECHNOLOGY INTO PRACTICAL SOLUTIONS THAT CREATE EXCEPTIONAL VALUE FOR OUR CUSTOMERS IN THE GLOBAL MARKETPLACE

# COMMUNITY SERVICE



GTI works to make a difference in our local community, helping others that are nearest to us. These activities are a reflection of our culture, our values, and the way we do business.

Throughout each year, GTI hosts food drives and sponsors blood drives. This past year, a group of GTI staff members visited a local organization, Northwest Compass, to help with assembling shelving, loading up items that will be distributed, and sorting boxes of food for needy families to have for their Thanksgiving dinners.

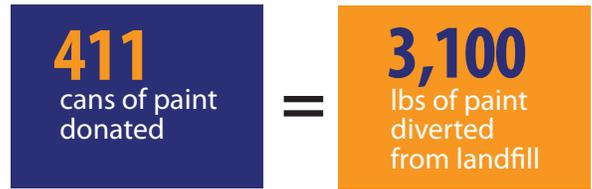
Veterans Day gives us the opportunity to acknowledge the bravery and sacrifice of all of America's veterans. Throughout the year, GTI employees collect personal-sized items such as shampoos and soap. In October, GTI hosts a service project to assemble the toiletries into basic supply kits that are delivered to needy veterans at the Jesse Brown VA Center in Chicago on Veteran's Day. Each kit is accompanied with a special note of appreciation for their service to our country.

Through an annual payroll deduction campaign, we provide financial support for the United Way each year to help create a brighter future for our community. GTI also collects for the annual U.S. Marine Corps "Toys for Tots" campaign.



# ENVIRONMENTAL SUSTAINABILITY

As a leading energy research institution, GTI believes everyone has a key role in protecting the integrity of our planet for future generations. From the projects we choose to the way we run our operations, we are committed to reducing our own environmental footprint. GTI's Environmental Sustainability Committee outlined our intention and goals in a Three-Year Sustainability Management Plan.



3,100 lbs = Approximate weight of a mid-size car

**All outdoor lights were replaced with LED lighting that is up to 80% more efficient than traditional lighting**

We are focused on reducing our own non-project related energy use, and an Energy Use Analysis is being developed to establish a baseline to determine the impact of our facility updates. We are replacing lights and were able to decommission many of our laboratory hoods to save energy.

During renovations, low-flow automatic flush toilets were installed to conserve natural resources. They save three gallons per flush and reduce overall water use by over 200,000 gallons of water/year.

We are always looking for new ways to responsibly manage material re-use, recycling, and disposal. All printers were set to print double sided to reduce paper use and excess colored paper was donated to a program at an alternative high school in Chicago that uses art as a teaching tool for underserved students.

Reusable plastic containers—made in the U.S. out of 50% recycled materials—replaced paper to-go boxes in our café to reduce waste, and we are keeping plastic bottles out of the landfill by giving each employee a re-usable water bottle.

Many recycling events hosted at our workplace to raise awareness on the importance of a sustainable lifestyle have received tremendous response. GTI employees brought in over 12 pallets worth of electronics to be recycled, minimizing what goes into the landfill and reducing our environmental impact. We also hosted our first paint recycling event last fall where over 3,000 lbs. of paint was diverted from landfills to be recycled and sold to local businesses.

In support of green spaces, the Environmental Sustainability Committee coordinated efforts to transform our outdoor courtyards into ideal settings for productive individual work, group meetings, and lunchtime breaks. In addition to patio tables, shade canopies, and flowers to add natural beauty, a butterfly garden was planted in the main lobby courtyard. This creates an inviting environment for enjoying the weather and catching a breath of fresh air, which help to reduce stress and stimulate creative thinking.



**GTI employees brought in over 12 pallets worth of electronics to be recycled**



**Gas Technology Institute**

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