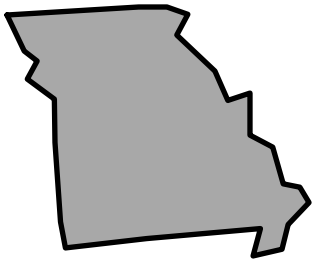
the Energy to Lead



Missouri Natural Gas Customer R&D Needs

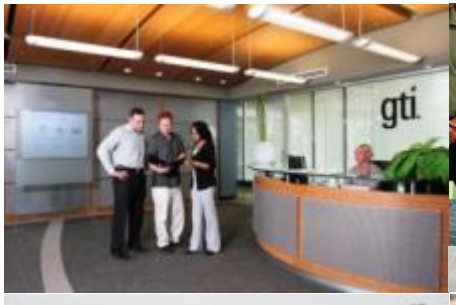
Ron Edelstein
Gas Technology Institute

Missouri Public Service Commission
January 2017
Jefferson City, MO

GTI Overview

ESTABLISHED 1941 (Gas Research Institute est. 1977)

- Independent, *not-for-profit* company established by natural gas industry
- Providing natural gas research, development and technology deployment services to industry, consumers, and government clients
- Performing contract research, program management, consulting, and training
- Wellhead to the burner tip including energy conversion technologies



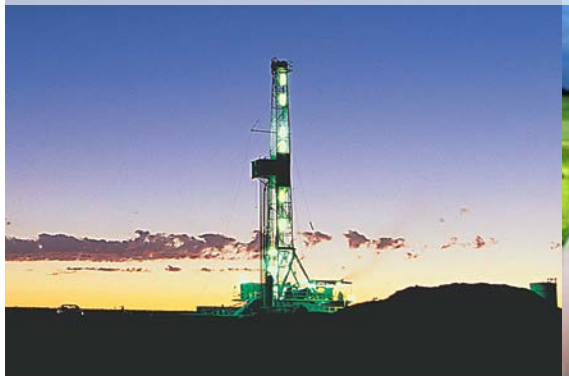
Training

Office & Labs

Pilot-Scale Gasification Campus

Energy & Environmental Technology Center

Addressing Key Issues Across the Energy Value Chain

SUPPLY	DELIVERY	END USE
		
Expanding the supply of affordable energy	Ensuring a safe and reliable energy delivery infrastructure	Developing technology for the efficient use of energy resources

Reducing carbon emissions to the environment

Supporting sustainable economic growth

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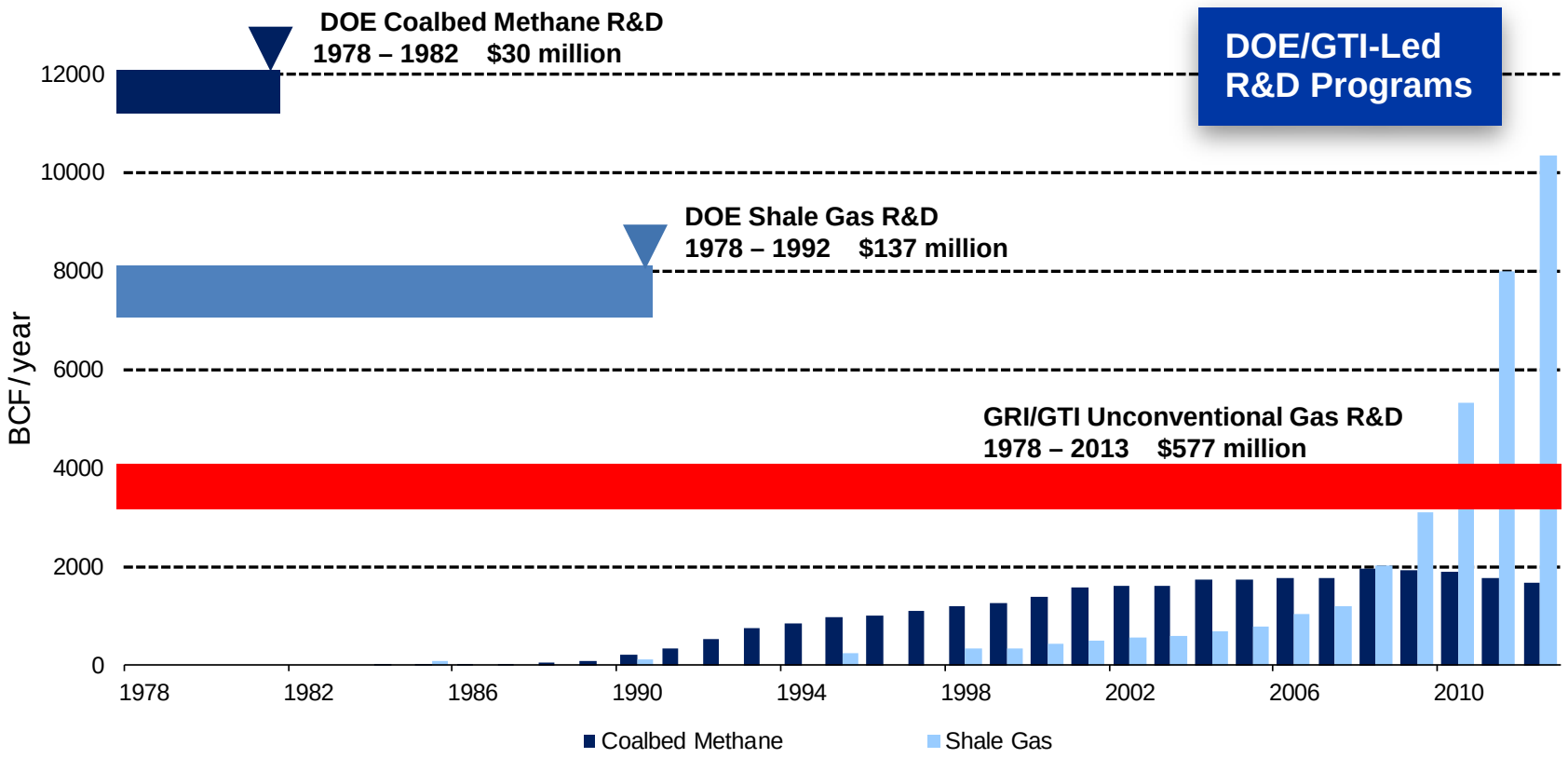
GTI/DOE Research Investments Sowed the Seeds of Unconventional (e.g., Shale Gas) Natural Gas Production



Shale expected to exceed 50% of U.S. gas production by 2035

Sources: GTI, EIA, DOE Department of Fossil Energy

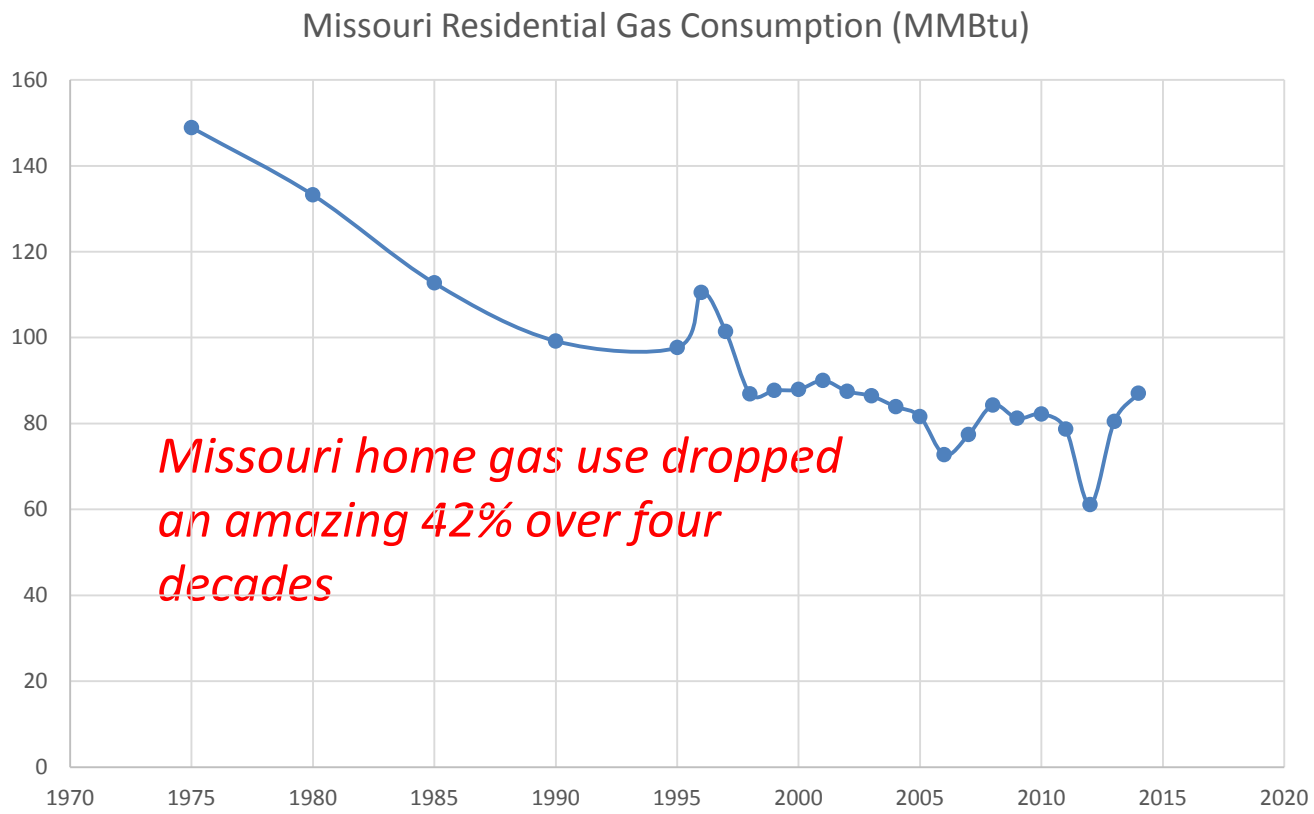
Huge Benefits to Missouri Consumers of E&P R&D

- Based on 2006 prices and 2015 prices,
  - Savings to ***Missouri*** (R, C, I) consumers of ***$765 million per year***
  - ***Residential customer savings of about $200 per year per customer***
- National savings for R, C, I customers of $*58 billion per year*, compared to 30-year R&D costs of $744 million total

Technology Solutions for Natural Gas End Use

- Affordability of Energy Use
  - Lower energy bills
  - Increase appliance efficiency
  - Reduce equipment first cost
  - Reduce environmental impact
  - New high-efficiency, low-emission options for Missouri commercial and industrial customers to aid economic development

Missouri Residential Gas Use



Ref: A.G.A. Gas Facts, uncorrected for degree days

Why has Missouri Residential Gas Use Dropped?

- High efficiency furnace (90%+) first developed by GRI /GTI, introduced in the 1980s
- Gas company energy efficiency programs
- Tighter homes, better insulation and windows
- Warmer weather: Not necessarily!
- ***Savings per residential customer at 2014 prices: $670/customer/year***

Conclusion: R&D and Technology Deployment has made a major difference in Missouri residential gas use and gas bills

Energy Efficiency R&D

Tankless Water Heater*

Water/Space Heater Combo

Gas Heat Pump

Ultramizer® Super Boiler*

FlexCHP

Equinox Solar-Assisted Heating System*

*Commercialized

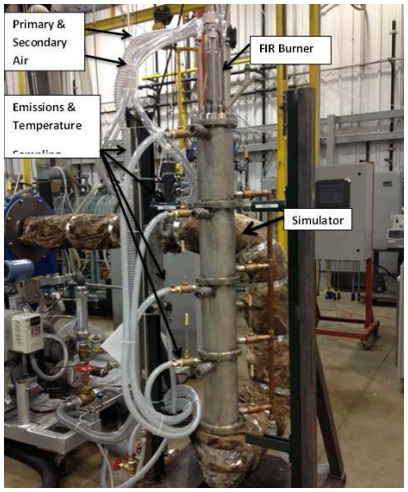
Next Step-Function Opportunities in Energy Efficiency

- Gas heat pump water heater (EF = 1.38)
- Gas heat pump
  COP(h) = 1.6
  COP(c)= 1.2

EF = Energy Factor
COP = Coefficient of Performance

Lower-Cost High-Efficiency Equipment for Low-Income Customers

Water/Space Heater Combo System (90% + efficiency)



Low-cost condensing water heater (90%+ efficiency)

Low-Capacity ”Right Sized” Condensing Furnace (15k-30k Btu/hr, 90% + efficiency)

Commercial/ Industrial Opportunities

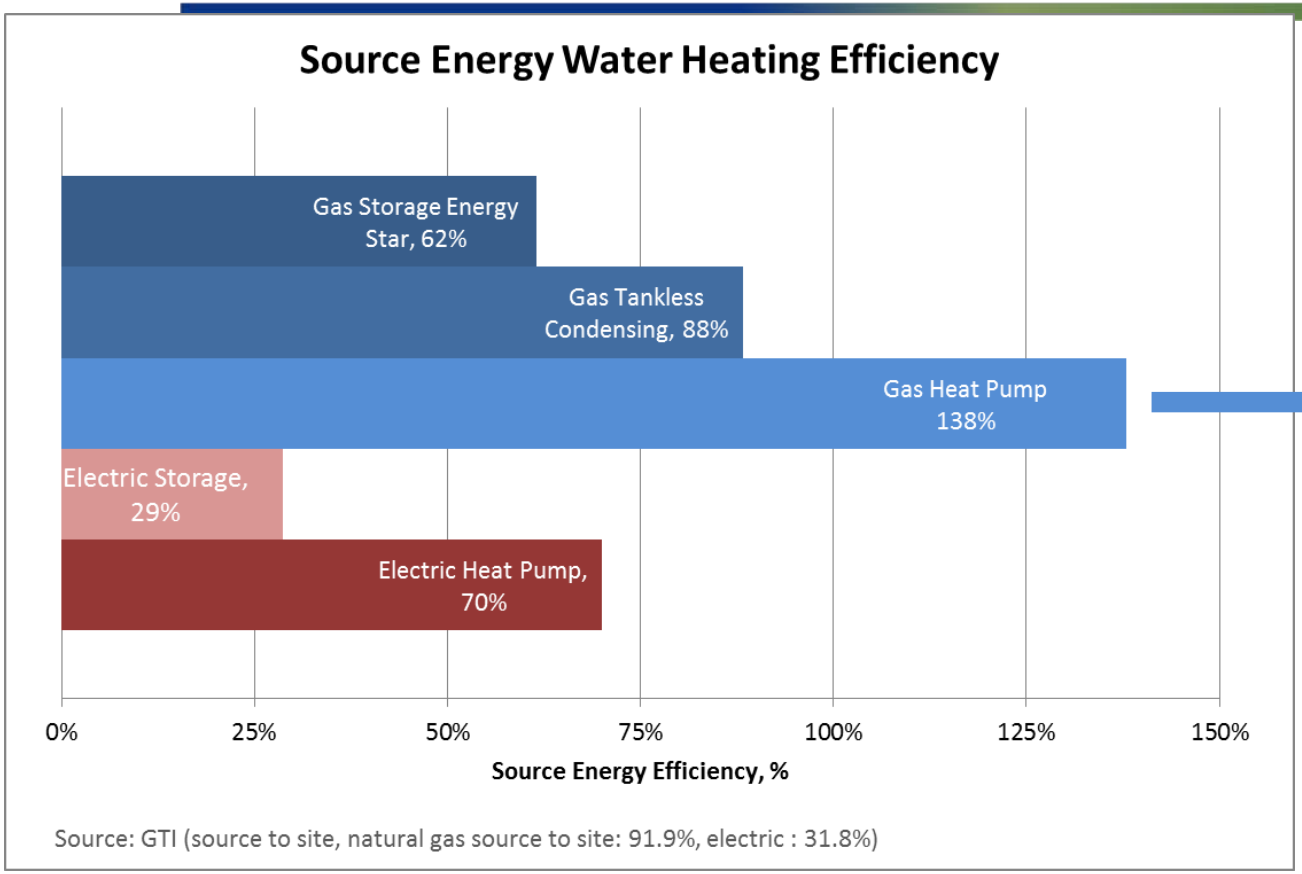
Ultramizer
condensing boiler
(90% + efficiency*

FlexCHP

Low-NOx industrial furnace

* Commercially available

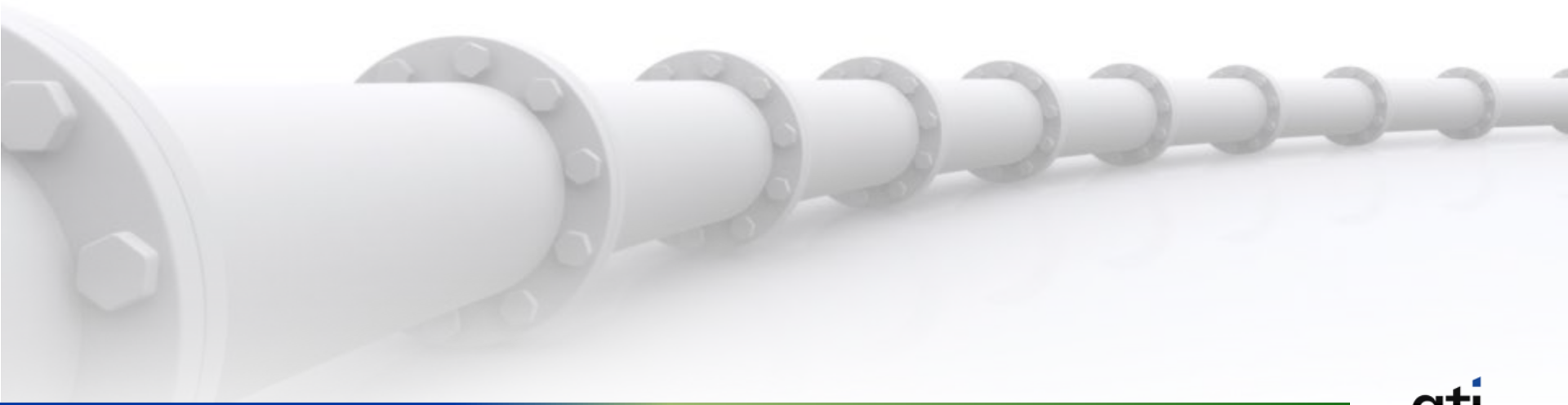
Environmental and Energy Savings Benefits Water Heating Efficiency Improvements With Natural Gas Heat Pumps



Natural gas heat pump water heater provides highest-rated source energy efficiency – over 50% advantage over electric heat pump water heaters.

Operations R&D Challenges

- Aging infrastructure
- Pipeline and distribution safety and integrity
  - Identification of high-risk sections of pipe
  - Prevention of third party damage
- Cybersecurity/physical security/resiliency



Missouri's Natural Gas Mains

	Miles
Bare, Unprotected Steel	0
Coated, Protected Steel	11,631
Steel, Other	1,169
Plastic	13,486
Cast Iron	1,028
Totals	**27,315**

Ref: A.G.A. Gas Facts, with 2014 Data
Note: 1 mile of copper in total

New Operations Technologies

- Crossbore prevention best practices
- Handheld Acoustic PE Pipe Locator*
- Radio Frequency ID tags for Gas Distribution
- Obstacle Detection for Horizontal Boring Tools
- Metallic Joint Locator*
- Portable Methane Detector*

*Commercialized

GTI Cross Bore Program

- **Cross Bore Best Practices Guide -** single source of information for natural gas operators to investigate and remediate existing cross bores as well as prevent future cross bores
- **Outreach and Education Program -** information to effect positive changes in attitude, practices and operations.
- **Cross Bore Database -** A national database of damages and incidents to assist in identifying trends.
- **New Developments** – Acoustic Pipe Locator, Cross Bore Detection, Obstacle Detection

New Operations Technologies

GPS, GEOSPATIAL

- GPS-enabled leak surveying
- GPS cameras for joint Inspection
- GPS for new installations
- Geospatial mapping for emergency response
- GPS for third party damage prevention
- Asset Lifecycle Tracking

Alternative Pigging Techniques

Smaller diameter electromagnetic acoustic transducer (EMAT) sensor development to find cracks and planar defects

- Background
  - Need to find cracks in pipe body and welds with tools that don't require a liquid couplant
  - Must work with inspection tools for unpiggable (difficult-to-inspect) pipe with variable diameter, dead legs, reduced diameter fittings, and low flow conditions
  - More inspection tools for small diameter pipe; as small as 6-inch
  - Able to fit onto existing unpiggable pipe inspection platforms
- Objective
  - To transfer EMAT sensors for integrity management inspections to the LDC industry with a specific focus on unpiggable pipe
  - Working with Quest Integrated
- End Result
  - Small diameter EMAT sensor integrated with an unpiggable platform that is bidirectional and collapsible (commercially available by Quest)

Breakaway Fittings for MSA's (OTD)

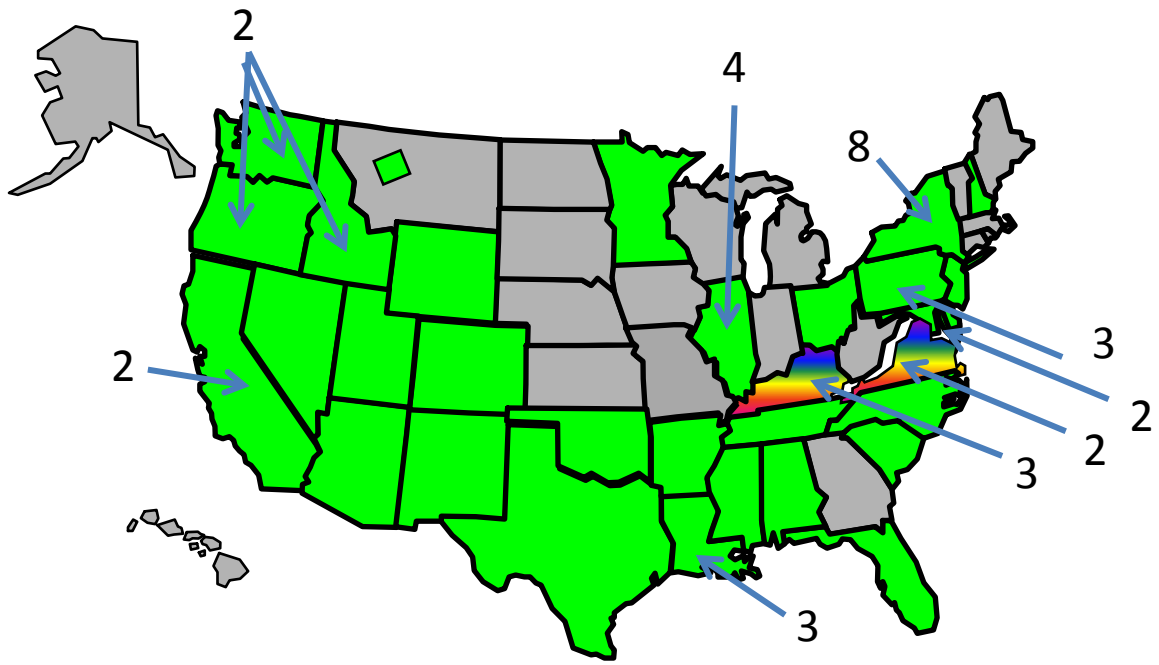
Objective:

> To develop a working breakaway disconnect / shutoff fitting for meter set assemblies (MSA) and other aboveground gas systems.

Focus

> Reduce the risk from vehicle collision or ice/snow falling from a building roof.

Delta R&D Program Map – Approved States 30



Company and Regulatory Approval (# of companies)

Pending filings (DC also)

Why Collaborative R&D Programs?

- Highly **cost-effective, highly leveraged dollars**
- Only funders **drive research agenda, select projects,** and influence product/process
- **Major benefits to company customers**: reduced energy usage and energy bills, reduced emissions; lower company O&M costs, increased safety, increased integrity, increased deliverability
- Leverages collective intelligence and experience of funders to develop the **best possible solutions**
- Provides **opportunity for field tests** within company service territory, enabling acceptance by utility personnel, customers and regulators
- While hardware is available to all**, technical reports are available only to the funders**

Conclusions

- End-use efficiency R&D *and* deployment will increase end-use equipment efficiency, lower first costs, enhance consumer safety
- Operations R&D will contain O&M costs, and increase system safety, integrity, and deliverability
- R&D costs: $1.00 per customer per year for end-use *and* Operations R&D, less than 9 cents per customer per month
- Funding R&D in Missouri will help to ensure that R&D projects get chosen that will benefit Missouri consumers, field tests will be conducted in Missouri, and that the results of the R&D will be used in and benefit Missouri gas consumers and industry

Questions

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ron.edelstein@gastechnology.org
202-661-8644

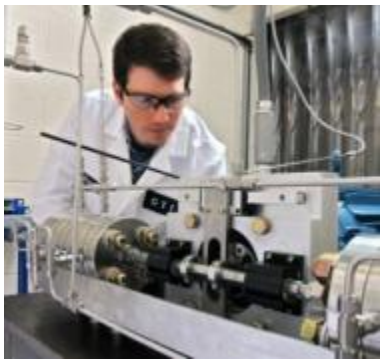
GTI: www.gastechnology.org

Appendix

- End Use R&D
- GTI Emerging Technology Program
- Energy Delivery R&D

End-Use R&D Areas of Technology Focus

- Residential/Commercial Water Heating
- Venting Safety
- Residential/Commercial Space Conditioning
- Commercial Food Service
- Industrial Processes
- Distributed Power/CHP and Steam Generation
- Transportation
- Renewable Energy (biogas, solar thermal)
- Carbon Management



Energy Efficiency R&D

NovelAire Dehumidification*

BRC FuelMaker's Phill*

Stellar Countertop Steamer*

Energy Source Analysis Tool*

Packaged Air Conditioner Furnace Condensate Freeze-up Prevention

Cummins High-Horsepower NGV Engine*

*Commercialized

Residential 'Low-Load' Heating: One Size Does Not Fit All

Combined Space and Water Systems

- Improves utility/customer value proposition for water heating by piggy-backing on larger space heating load.
- Equipment, system specification, operation, and load profiles all have significant impact on energy savings potential.
- Market development and training critical, new construction likely first significant market entry point

Through wall packaged heating, cooling systems

- Systems represent growing portion of multi-family market
- Manufacturers are beginning to roll out condensing options
- Barriers exist related to codes and standards, as well as practical matters such as condensate management and compliance with voluntary programs (e.g. ENERGY STAR)

Low capacity 'right-sized' furnace

- Low capacity high AFUE furnaces with full modulation, very small footprint, quiet operation, variable speed blowers, and high efficiency cooling
- 15,000-30,000 Btu/hr modulating down to 6,000 Btu/hr
- Ideal for multi-family with 2.5 inch supply ducts

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Role for Natural Gas in Emergency Power Systems

- Working to position natural gas as a viable option for standby and emergency power generation use
  - Natural gas as answer for critical infrastructure and resiliency
- Address existing restrictive code language for onsite fuel storage in life safety applications (NEC 70/NEC and NFPA 110)
- Potential for complementary role in electric demand response programs

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gti 75 YEARS ENERGY EXCELLENCE

Reliability Assessment of Diesel vs. Natural Gas for Standby Generation

INDUSTRY NEED

In the past, gaseous fuels were avoided in emergency power or standby power supply (EPSS) applications greater than 150kW based upon cost effectiveness, power density, and perceptions of durability and fuel reliability. Recently, cost-effective natural gas engines that are environmentally friendly and can sustain long run times have been developed and are now common in the market. These advancements in the design and controls of natural gas generators for EPSS offer several advantages for the end user. However, diesel gen-sets are currently the established technology due to regulations requiring on-site fuel storage and perceptions regarding the reliability of utility gas distribution.

EPSS generators are installed nationwide by a wide variety of residential, commercial, and industrial customers to avoid power disruptions. There are in excess of 250 gigawatts of standby generator power in the U.S. with over 15 gigawatts of new capacity added each year. Even more market potential exists as voluntary versus code-driven standby power increases. Today, in markets where volume is driven by code requirements, the natural gas share is 20% to 30%. Interestingly, for systems less than 150kW, more typical of voluntary non-code-driven installations, the natural gas share is close to 70%.

In tens of thousands of code-driven EPSS installations each year, local authorities having jurisdiction (AHJ's) are the determining factor in the selections of the systems and fuels that can be used. How those AHJs perceive and regulate fuel choices is a primary reason for the low percentage of installed natural gas EPSS generators.

The National Electric Code (NFPA 70/NEC) and National Fire Protection Association NFPA 110 are the most frequently referenced standards for specifying EPSS generators. NFPA70 NEC 700.12(B)(2) states, "*Where internal combustion engines are used as the prime mover, an on-site fuel supply shall be provided with an on premise fuel supply sufficient for not less than 2 hours' full-demand operation of the system*". However, article 700.12(B)(3) states an exception, "*Where acceptable to the authority having jurisdiction, the use of other than on-site fuels shall be permitted, where there is a low probability of a simultaneous failure of both the off-site fuel delivery system and power from the outside electrical utility company*".

GENERAC | INDUSTRIAL POWER

Reliability Whitepaper

"*Reliability of fuel supply tends to be of great concern for authorities having jurisdiction (AHJs). On-site fuel (most often diesel) is typically required for life-safety applications, and many mission-critical applications like 911 call centers specify it because it is perceived to be more reliable. Nonetheless, maintenance issues and delivery concerns of diesel fuel in an emergency, combined with the reliability and cost-effectiveness of natural gas, must be considered in a standby power system. NFPA and NEC offer provisions for the use of natural gas in standby power applications that had previously been the clear domain of diesel-fueled systems. There are also many ways to work with the AHJ to clear the way for the use of gaseous fuel in a standby power system.*"

https://www.generac.com/GeneracCorporate/media/Library/pdfs/whitepapers/0200930SBY-nat-gas-whitepaper.pdf

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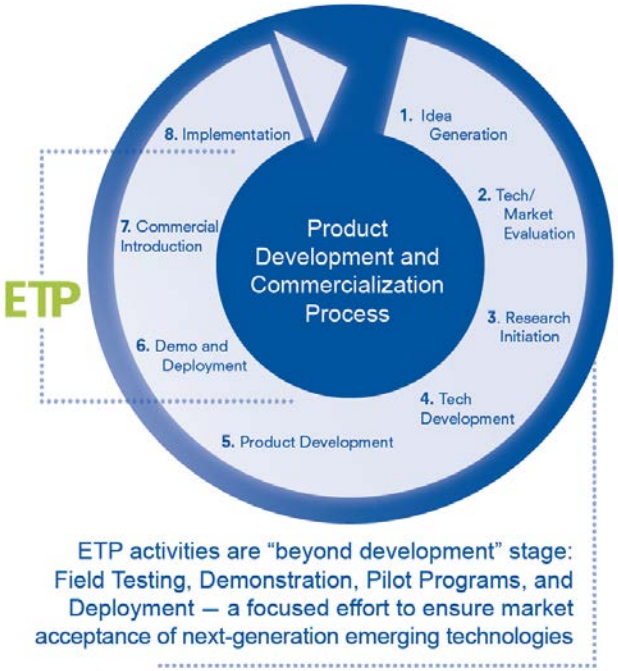
Energy Efficiency Program Collaboration

Emerging Technology Program

- Gas Technology Institute led, utility supported, **North American collaborative** targeting **residential, commercial,** and **industrial** solutions
- ETP's principle goal is to **accelerate** the **market acceptance** of emerging energy efficient technologies

Alagasco
Ameren Focused Energy. For Life.
Research Foundation
CenterPoint Energy
CNG
DTE Energy
ENBRIDGE
Laclede Gas The Original Green Energy™
neea
National Fuel
New Jersey Natural Gas
Intermountain Gas Company
Nicor Gas An AGL Resources Company
Energy Efficiency Program
NW Natural We grew up here.
NYSEG
PG&E Pacific Gas and Electric Company
QUESTAR Gas
SDGE connected
A Sempra Energy utility
Southern Connecticut Gas Service First!
A UIL HOLDINGS COMPANY
Southern California Gas Company
A Sempra Energy utility
uniongas A Spectra Energy Company
SOUTHWEST GAS
TECO PEOPLES GAS



ETP activities are "beyond development" stage: Field Testing, Demonstration, Pilot Programs, and Deployment – a focused effort to ensure market acceptance of next-generation emerging technologies

2016 ETP Members Listed Above

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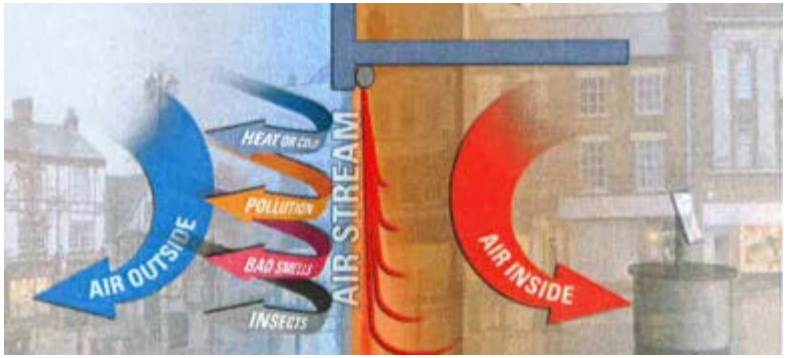
Potential Deployment Projects for Residential/Commercial Customers

- High-efficiency PAC Rooftop Units (RTU)
- Combination space/water heating systems
- GHPs

Potential Deployment Projects for Industrial Customers

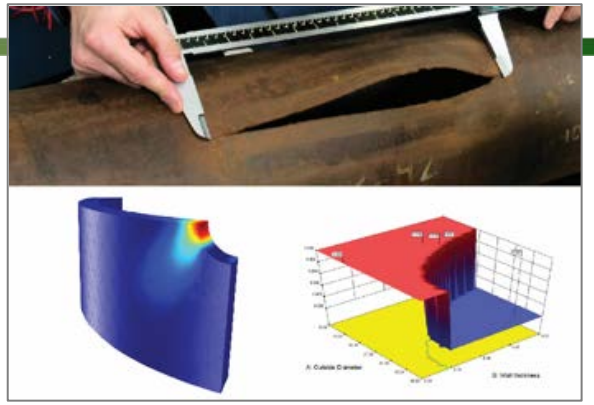
- Ultramizer® super boiler and heat recovery system
- Air curtains
- SRU flue gas condenser for waste heat recovery
- Automated steam trap monitoring
- CHP systems for industrial customers



GTI Energy Delivery Programs

Inspection and Verification

Intelligent Utilities



Risk and Decision Analysis

Construction Techniques

Methane Emissions and Detection

Grid Resilience

Internal Inspection – Optimization Program

Threats	Parameters of Interest	Sensor Technology	Platforms	Overarching Influencers / Other Considerations
• External Corrosion • Internal Corrosion • Stress Corrosion Cracking (surface and subsurface) • 3rd Party Damage • Fabrication / Weld Quality • Wrinkle Bends / Miter Bend • Residual Stresses • Soil and Other Superimposed Stresses	• Wall Thickness and Loss • Cracking • Residual Stress Levels • Hardness and Ultimate Strength • Yield Strength • Toughness • Physical Dimensions (ID) • Internal Defects (Porosity, Laminations, etc.) • Physical Contact to Other Structures	• Ultrasonic/microwave • Eddy Current/RFEC • Guided Wave UT • X-Rays • Magnetic Flux Leakage • Magnetic Field Strength • Electromagnetic • Optical/IR/UV • Video/Stills • Caliper • Hardness • Modulus • Stress-Strain Probe • EMAT	• Tethered (e.g., mechanical cable or coiled tube pulled) • Push Rod (e.g., coiled tube pushed) • Robotic Tethered (e.g., self-driven brush drive but with trailing power cord) • Robotic Autonomous (no tether for power, etc.) • Flowable Sensors (e.g., Fluidized Sensors, Smart Balls, etc.)	• Existing and Impending Regulations (i.e., Post San Bruno) • Market Size (diameters, distances, obstructions) • Cost (development and per inspection unit) • Time to market • Sponsors • Repeatability of Inspections • Commercializers

High Accuracy GPS

GTI partnered with NavCom to provide high accuracy GPS for smart phones and tablets

- Sub-foot quality data in real-time
- No need for post processing or a base station
- Field data directly inserted into the GIS (with controls)

Characterization and Fitness for Service of Corroded Cast Iron Pipe (U.S. DOT)

> Objective

- Provide a Fitness-For-Service (FFS) model and method for operators to characterize and grade graphitic corrosion defects on cast iron natural gas pipes. This will help operators make monitoring, repair, and replacement decisions, as well as prioritize accelerated replacement decisions related to cast iron mains and services.
- Summarize and categorize the required input parameters to the FFS model related to cast iron material, graphitic corrosion geometry and characteristics, and operational environment.
- Validate the FFS model by comparing its output to a statistically analyzed set of historical cast iron failure data.
- Provide a physical testing program to fully validate the FFS model.

> Focus

- FFS model and method for Cast Iron Pipe

Slow Crack Growth Evaluation of Vintage Polyethylene Pipes (U.S. DOT)

- **Objective**
  - Develop a novel endoscopic structured light scanning tool for internal inspection of small diameter plastic pipe – especially for slow crack growth issues.
  - Provide a probabilistic estimate of the remaining effective lifetime of individual segments of vintage plastic pipe and a yes/no determination of whether a short-term pressure test is capable of validating the maximum defect size in the system.
- **Focus**
  - GTI – Development of fitness for service calculations, Bayesian network and decision support tool, and guidelines for short-term pressure testing of vintage plastic pipelines.
  - University of Colorado, Denver – Development of endoscopic multi-spectral structured light scanning tools.
  - Arizona State University – Development of feature recognition and data reduction algorithms.

Approaches for Preventing Catastrophic Events (U.S. DOT)

- **Objective**
  - Review of approaches for preventing catastrophic “Black Swan” events, both within and outside the natural gas industry.
  - Empower the selection of the most appropriate approach(es) and model(s), develop them further, and ultimately issue guidelines for effective implementation in risk models and integrity management programs.
- **Focus**
  - A structured review of the existing methodologies.
  - Identify gaps.
  - Prepare the ground for the adoption and/or development of a suitable approach for the gas sector.

Asset Lifecycle Tracking

A GTI technology solution to implement ASTM F2897-11a

- > Barcode scanner
- > High accuracy GPS receiver
- > Tablet device with GIS-based data collection software
- > Application to convert barcode into asset attributes to auto populate the GIS

Pipe Defense with Combined Vibration, Ground Movement, and Current Sensing (U.S. DOT / CEC / OTD)

- **Objective**
  - Demonstrate the feasibility of a wireless pipeline right-of-way (ROW) defense system based on stationary sensors mounted on, or adjacent to, the pipeline.
  - Analytics will correlate the data to alert operators to events of interest occurring in the ROW with minimal latency.
- **Focus**
  - State-of-the-art review and gap analysis of pipeline ROW monitoring techniques.
  - Design and build a ROW monitor hardware based on testing results.
  - Develop a database structure and analytics to capturing pipeline data and discriminate significant events and display with a user interface to allow visualization of data.
  - Deploy and field test ROW monitor system.

GPS Excavation Encroachment Notification System (GPS EENS)

> Objective

- Develop and deploy the GPS EENS technology to increase situational awareness of operating excavators and significantly reduce the risk of third party damage on utility infrastructure.

> Focus

- Provide high-accuracy GPS location, which overlays the utility's GIS map services, 811 ticket boundaries, and custom geo-fences (defined by Utility)
- Provide real-time indications of the "state" of the geospatially located excavator device.
- Provide instant alerts (graphical, text, etc.) to relevant parties, including alerts to utility operators/inspectors when an excavator enters an 811 boundary or ROW, or to the excavator operator if unauthorized digging is occurring over utility infrastructure.