the Energy to Lead

Minnesota Natural Gas Customer R&D Needs

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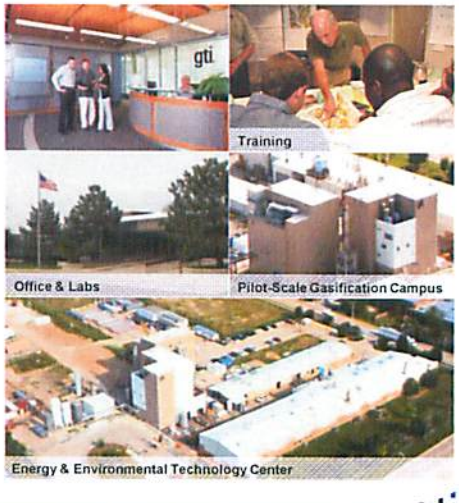
Company Overview

ESTABLISHED 1941

- Independent, not-for-profit company established by natural gas industry
- Providing natural gas research, development and technology deployment services to industry and government clients
- Performing contract research, program management, consulting, and training
- Facilities
  - 18 acre campus near Chicago
  - 200,000 ft^2 with 28 labs
- Staff of 250
- Wellhead to the burner tip including energy conversion technologies



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Addressing Key Issues Across the Energy Value Chain

Expanding the supply of affordable energy

Ensuring a safe and reliable energy delivery infrastructure

Promoting the efficient use of energy resources

Reducing carbon emissions to the environment

Supporting sustainable economic growth

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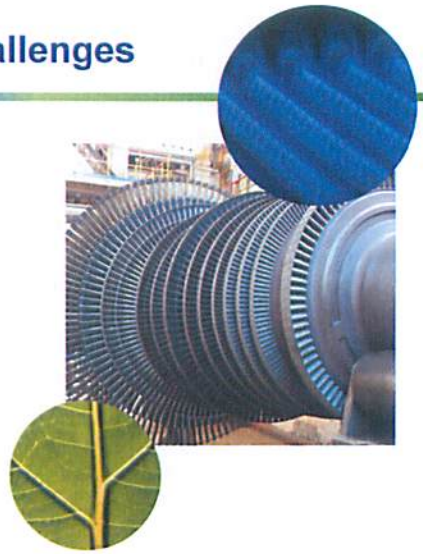
Natural Gas End Use Challenges

> Affordability of Energy Use
  - Energy costs, efficiency
  - Venting safety
  - First costs
> Environmental Impacts
> Increased Use of Gas for Power Generation



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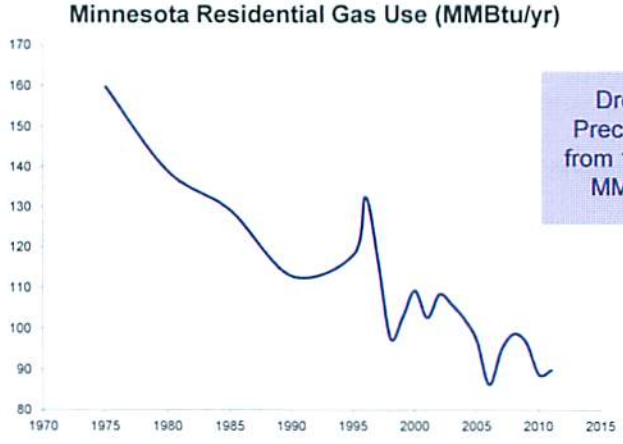
Minnesota Residential Gas Use



Dropped Precipitously from 160 to 90 MMBtu/yr

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

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Why has Minnesota Gas Use Dropped?

- High efficiency furnace (90%+) developed by GRI /GTI, introduced in the 1980s
- Tighter homes, better insulation and windows
- Warmer weather (?)

Conclusion: Technology has made a major difference in Minnesota residential gas use

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Minnesota Consumer Benefits

REAL-WORLD EXAMPLE

High-Efficiency Furnaces (Six years of Sales through 2002)*

> High-efficiency furnaces sold in Minnesota:	190,786
> Consumer benefits (NPV):	$1,035 per furnace
> Total consumer benefits:	$197 million
> Benefit/cost ratio compared to entire cost of GRI FERC R&D program:	6.93/1

* No GAMA High-efficiency furnace sales data after 2002

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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

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Energy Efficiency R&D

Tankless Water Heater*

Water/Space Heater Combo

Gas Heat Pump

Ultramizer® Super Boiler*

FlexCHP

Equinox Solar-Assisted Heating System*

*Commercialized

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Energy Efficiency R&D

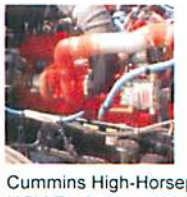
NovelAire Dehumidification*

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

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Next-Step Function Opportunities in Energy Efficiency

> Gas heat pump water heater (EF = 1.3)

> Gas heat pump COP(h) = 1.3 COP(c)= 1.2

EF = Energy Factor
COP = Coefficient of Performance

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Natural Gas Industry Collaboration

ETP
Emerging Technology Program

Emerging Technology Program (ETP)

> GTI-led, utility supported, North American collaborative targeting residential, commercial, and industrial solutions

> ETP's principle goal is to accelerate the market acceptance of emerging gas technologies

2013 Members:

AGL Resources · Alagasco · ATMOS energy · etic · Intermountain Gas Company · National Fuel · CenterPoint Energy · CNG · DTE Energy · Enbridge · NYSEG · Pacific Gas and Electric Company · Questar Gas · Union Gas · Yankee Gas

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Potential ETP 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

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Potential ETP Projects for Residential/Commercial Customers

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

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Operations R&D Challenges

> Aging infrastructure

> Pipeline and distribution safety and integrity

- Identification of high-risk sections of pipe
- Prevention of third party damage

> Gas/electric interoperability/smart energy grid/resilience

> Cybersecurity

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Minnesota's Natural Gas Mains

	Miles
Bare, Unprotected Steel	520
Coated, Protected Steel	6,887
Steel, Other	200
Plastic	22,151
Cast Iron	65
Totals	**29,822**

Ref. A.G.A. Gas Facts, with 2013 Data

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Minnesota's Natural Gas Services

	Number
Bare, Unprotected Steel	7,514
Coated, Protected Steel	132,577
Steel, Other	6,576
Plastic	1,282,966
Cast Iron	0
Copper	17,975
Totals*	**1,451,075**

* Includes 3,467 "other"

Ref. A.G.A. Gas Facts, with 2013 Data

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New Operations Technologies

- > 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

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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

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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)

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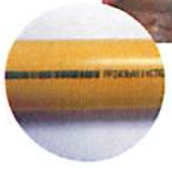
Asset Lifecycle Tracking

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



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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

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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)

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Project: Understanding Threat Interactions

> Background
- Many pipeline incidents are the result of multiple, interacting causes, not a single threat.
- Individual threats can each be at "acceptable" levels but when overlaid result in a significant threat to the pipeline or even a failure.

> Approach
- Identify threat combinations to address and control,
- Develop a method to calculate threat interaction levels and severity, and
- Provide a method to continuously monitor threat interactions and flag concerns at trigger points.

> Benefits
- Operators will be able to adequately identify combinations of threats and their associated risk.
- Reduction of an operator's risk and enhancement of compliance with Subpart O regulations.

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GTI DIMP Consequence Model

> Developing a model that quantifies the consequence of failure for distribution systems and DIMP based on various factors, such as:

- Population density, proximity of critical infrastructure and business districts, failure mode based on material properties, gas migration patterns, soil and surface conditions, pressure and potential energy

> Model will assist in prioritizing replacements and the deployment of other mitigation techniques based on risk (not just probability of failure)

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Key Challenges to Achieving the Smart Energy Grid Challenge

Key Challenges by Sector:

Supply	• Rapid Response Supply • Better Supply and Demand Forecasting • Integrated Communications
Delivery	• Enhanced Infrastructure Flexibility • Optimized Investment • Integration of New Supply Sources and End Uses
End Use	• Full Fuel Cycle Analysis • Comparable Energy Information • Energy Management Tools

Overarching Emphasis On Safety

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Cyber-Security

Active participation in the Smart Grid Interoperability Panel (SGIP) Gas Technology Domain Expert Working Group (GT-DEWG)

> Deliverables:

- Reports of standards activity within the SGIP via quarterly newsletters
- Maintenance of the on-line reference system
- White paper (final report) on the automation of natural gas distribution and smart energy grid interoperability issues (will be made publicly available)

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Delta Map

> **Approved States = 28**

Company and Regulatory Approval (# of companies)

Pending filings

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28 States Have Approved Voluntary Recovery

- **Maryland:** Washington Gas (2011); Columbia Gas of MD (2014)
- **South Carolina:** Piedmont Gas (2011)
- **Texas:** Atmos Energy (2011)
- **Tennessee:** AGL (2010)
- **Nevada**: Southwest Gas (2010)
- **Louisiana:** CenterPoint; Entergy; Atmos Energy (2009)
- **California:** Sempra; PG&E(2007; 2013)
- **Arizona:** Southwest Gas (2006)
- **Oklahoma:** ONG (ONEOK) (2005)
- **New Mexico:** PNM (2005)
- **Minnesota:** CenterPoint Minnegasco (07/05)
- **Pennsylvania:** National Fuel (2005), NiSource, PECO (2011)
- **Virginia:** Atmos Energy (2005)
- **Delaware**: Conectiv (2003)
- **Oregon:** NW Natural; Avista (2003)
- **Florida:** TECO Peoples Gas (2003)
- **New Hampshire:** NiSource (2002)
- **Kentucky:** Delta Natural Gas (2004); NiSource (2002); Atmos Energy
- **Utah/Wyoming:** Questar Gas Co.
- **Alabama:** Alabama Gas Corp.
- **Idaho:** Avista; Intermountain Gas
- **Washington:** NW Natural; Avista
- **Illinois:** Atmos Energy, Nicor (2005), Peoples Gas (2010)
- **Mississippi:** Atmos Energy
- **North Carolina:** NCNG, Piedmont (2005)
- **New York:** Con Ed, KeySpan Energy, NYSE&G, National Fuel, National Grid, Central Hudson E&G, Rochester G&E
- **New Jersey:** PSE&G

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Why Collaborative R&D Programs?

- Highly **cost effective, highly leveraged dollars**
- Funders **drive research agenda** 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**

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Conclusions

> End-use efficiency R&D 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

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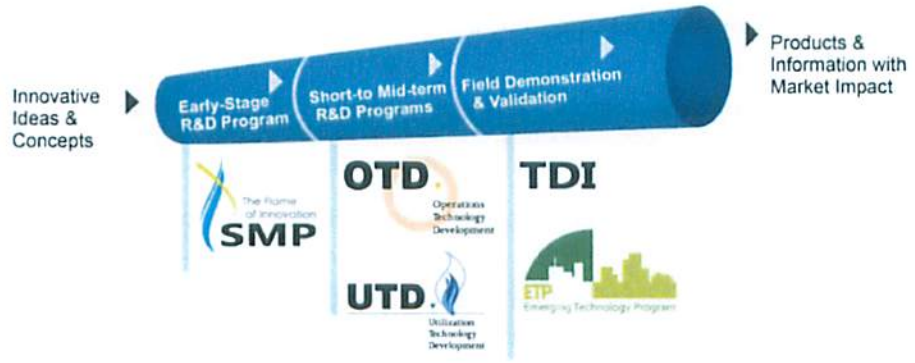
RD&D Pipeline



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Questions

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