the Energy to Lead

ADVANCED ENERGY
RESEARCH AND TECHNOLOGY CENTER

Fuel Cells and Natural Gas: An Emerging Partnership

Advanced Energy and Technology Research Center
2011 Advanced Energy Conference
October 12 & 13 2011

Ted Conway
Gas Technology Institute

gti®

Today's Talk

- Who is GTI
- Why Hydrogen and Fuel Cells
- What is a Fuel Cell
  - Stationary Fuel Cells
  - Transportation Fuel Cells
- Fuel Infrastructure
- Markets & Implications for Gas Utilities
- Hydrogen Safety

GTI at a Glance…

- Not-for-profit research, with 65+ year history
- Facilities
  - 18 acre campus near Chicago
  - 200,000 ft², 28 specialized labs
- $60 + million in revenue
- Staff of 250
- A growing business
- Commercial partners take our technologies to market

Offices & Labs

Flex-Fuel Test Facility

Energy & Environmental Technology Center

Addressing Key Energy Industry Issues Across the Value Chain

Supply

Expanding the supply of affordable energy

Delivery

Ensuring a safe and reliable energy delivery infrastructure

End Use

Promoting the efficient use of energy resources

Reducing carbon emissions to the environment

gti

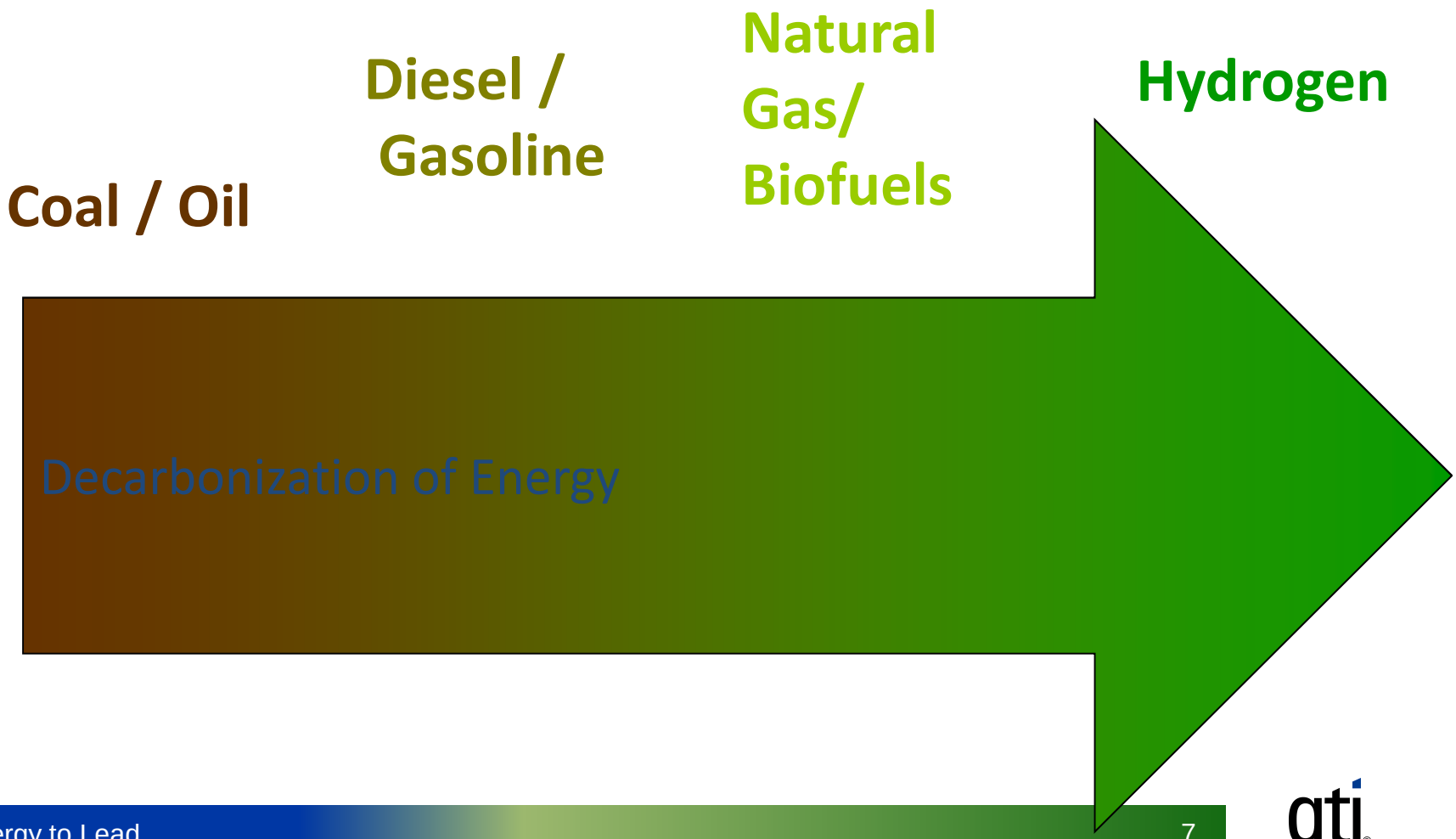
Why Hydrogen and Fuel Cells

- Recognition that the cost of fuel includes social costs
- There are clear private sector benefits to adopting hydrogen and fuel cell technology
- International Auto and Energy Companies are investing heavily in this area
- Volatile oil prices
- CHP technologies are gaining popularity

Hydrogen Facts Continued

- 95% of hydrogen produced worldwide comes from Natural Gas.
- There a 8.7 million NGV's on the road worldwide (only 250K in the U.S.) so compressed gas vehicles are common in most of the developed world.
- Growth of hydrogen as a fuel yields positive benefits for the natural gas industry.

Evolution of the Fuels Industry

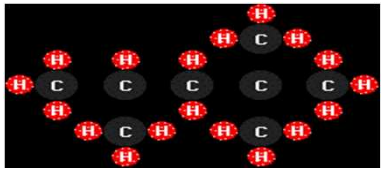


Carbon Content of Transportation Fuels

Today's Fuels

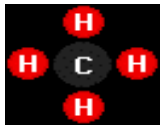
Diesel C16H34

Gasoline C8H18

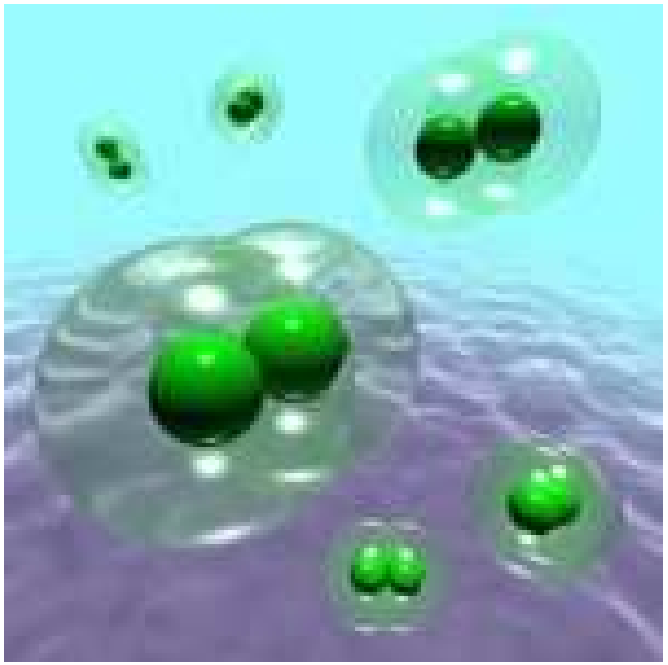


Propane C3H8

Natural Gas CH4



Hydrogen



Fuel Cell Types

Fuel Cell Type	Time to Market	Temp (°C)	Applications
Alkaline	Present	70-90	Space Shuttle
Phosphoric Acid	Present	150-210	Power, 250kW+
Proton Exchange	Present	70-90	Mobile
Solid Oxide	Emerging	800-1000	Power, 1 kW – 1 MW
Molten Carbonate	Present	550--650	Power, 250 kW+

Stationary Fuel Cells

- **Standby or Emergency Power**: Used for customers that cannot tolerate an interruption of electrical service for either public health and safety reasons, or where power outage costs are unacceptably high.
- **Portable Power**: Consumer electronics, defense applications, specialty commercial/industrial applications.
- **Combined Heat & Power**: Combines power and thermally activated technologies at customer facilities.

Stationary Fuel Cell Players

	PEMFC Proton Exchange Membrane	PAFC Phosphoric Acid	MCFC Molten Carbonate	SOFC Solid Oxide
North American Companies*	Ballard Hydrogenics Idatech Nuvera Plug Power	UTC	FuelCell Energy	Accumetrics Bloom Energy Rolls-Royce UTC/Delphi Versa Power Systems
Observations	Mainly for standby, emergency, specialty power. Limited success in CHP due to durability limitations.	PureCell® Model 400 Fuel Cell System is a market leader stationary fuel cell power and CHP. Greatest level of market experience and lowest $/kW.	DFC300 system is a 300 kW building block, with sizes 3 MW. Second in terms of market experience (to UTC). Main challenge is reducing capital cost.	Substantial R&D efforts underway. Mostly pre-commercial products at this time. Generally limited ability to start/stop often over time. Most desired use is baseload/CHP use.

* North American. Not a comprehensive list.

Vehicle Fuel Cells

- **Passenger Vehicles**: All major carmakers have or are developing fuel cell vehicles for demonstrations or test markets (most are in southern California).
- **Buses**: US DOT has invested considerable funds in promoting fuel cell buses. Several deployed in Europe and parts of Asia
- **Material Handling Equipment and Ground Service Equipment**: Represents first “real” commercial opportunity for fuel cell vehicles. Hundreds currently deployed in North America

Why Fuel Cell Vehicles?

Performance Feature	Conventional Vehicle	Fuel Cell Vehicle
Emissions		✓
Performance and Efficiency		✓
Versatility		✓
Range and Convenience	✓	
Cost	✓	

gti

Industrial Truck Market is a Near-term Commercial Application

Value Drivers:

- Lower cost than electric batteries
- Increased productivity
- Better performance
- Frees up warehouse space

Observations:

- Focus is on battery replacement (not outdoor forklifts)
- Infrastructure not as much of an issue
- Government is big supporter
- Three projects in Texas

Hydrogen Infrastructure

- One of the biggest obstacles for fuel cell vehicles is lack of a national supply infrastructure
- Fewer than 100 stations in North America
- Most stations are on the coasts (CA, NY, SC, FL, WA, BC)

Hydrogen Supply

Reformer
- Low variable cost
- high capital cost
- high efficiency
- low emissions

Hydrogen Tube Trailer
- readily available
- High variable cost
- low efficiency
- high emissions

Electrolyzer
- High capital cost
- Med variable cost
- Med efficiency
- Med emissions

Fuel Cell Markets

Fuel Cells are Finding Early Markets

Market Sectors

- Commercial
- Industrial
- Individual
- Government
- Educational

Products

- CHP (Heat+Power)
- Remote/off grid
- Backup power
- Industrial vehicles
- Battery chargers
- Military/Specialty
- Educational

Fuel Cell Markets

Success Stories in Power Generation/CHP

- University Campuses in CA, through PG&E and SCE
- Price Chopper/Whole Foods/Walmart
- Google/eBay/Staples/Coca-Cola/FedEx
- Sierra Nevada/Fosters/Sapporo/Kirin/Gills Onions
- Waste water treatment plants in CA, NY, WA
- Sheraton/Hilton/Hyatt/Westin Hotels
- Mixed use buildings in the Northeast
- Hospitals in the Northeast and CA
- Naval Submarine Base in CT
- USPS in San Francisco Distribution Center

Fuel Cells and the Gas Utility

- **The most efficient way to delivery hydrogen is via the natural gas network (80%+ of the cost of delivered hydrogen is transportation and storage).**
- **Emerging SOFC's can take methane directly from utilities without stand-alone reformers.**
- **Fuel Cells provide a clean, energy-efficient application to leverage an existing supply network.**
- **Commercial products are beginning to emerge – but more slowly than hoped for.**
- **Fuel Cells are looking better as realism begins to kick in regarding 100% "zero-emissions" renewables.**

Solving **important** ***problems*** **facing the energy industry and its consumers …**

“*making a difference* in the marketplace”

Contact Information

Thank you for your attention!

Ted Conway
781-449-5649
ted.conway@gastechnology.org