

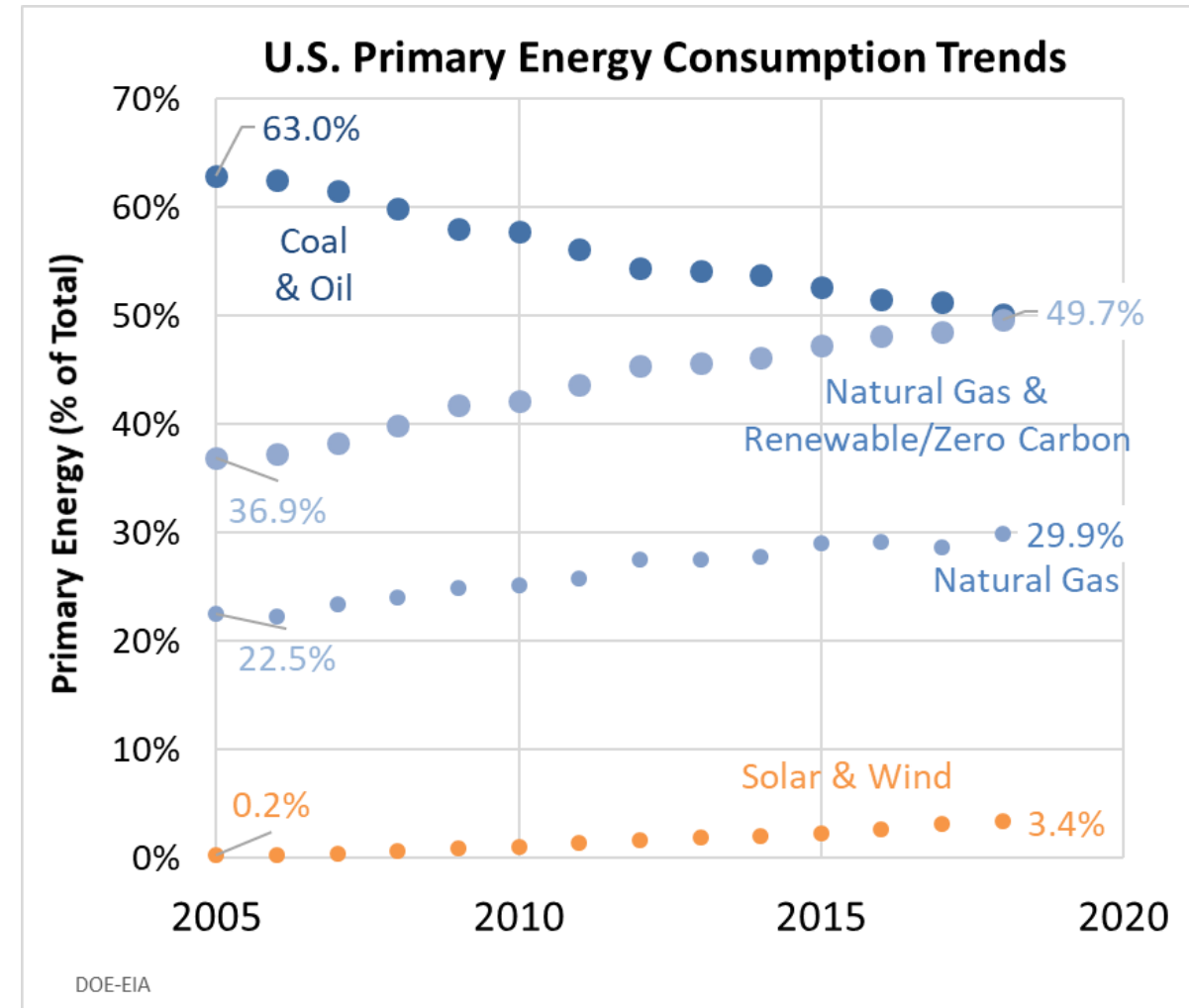
Innovations in U.S. Energy Sector

David C. Carroll
President and CEO, GTI
Immediate Past President, IGU

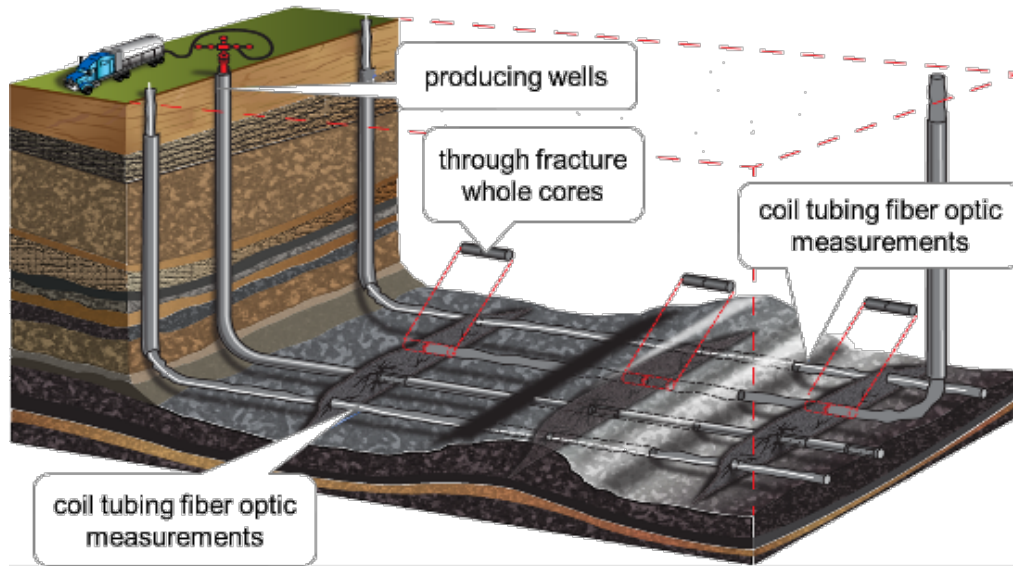
6th IEF IGU Ministerial Gas Forum
21-22 November 2018

Innovation and Policy Drive U.S. Energy Transformation

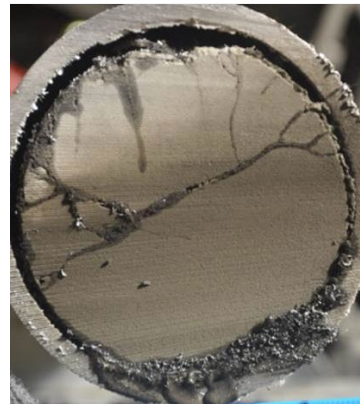
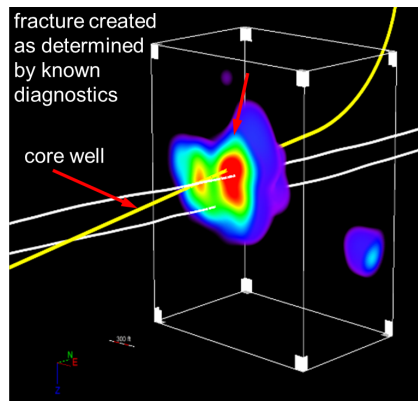
- > Technology and innovation improving cost and performance
 - Led by shale gas revolution; supplemented by growing wind and solar generation
 - World-leading CO₂ reductions – major reduction in coal use
 - Substantial improvement in electricity carbon intensity (28% lower than 2005)
- > Policies enabled shale gas to thrive and supported wind and solar growth via tax measures and other incentives
- > Energy efficiency across all sectors



Leveraging Public and Private Resources for Effective, Responsible Gas and Oil Production



coil tubing fiber optic measurements



- > One-of-a-kind core well to assess ground truth for shale fissure performance, identify pathways to maximize recovery, achieve optimal well spacing
- > Assess/minimize air and water impacts
- > Over \$100 million of data collected

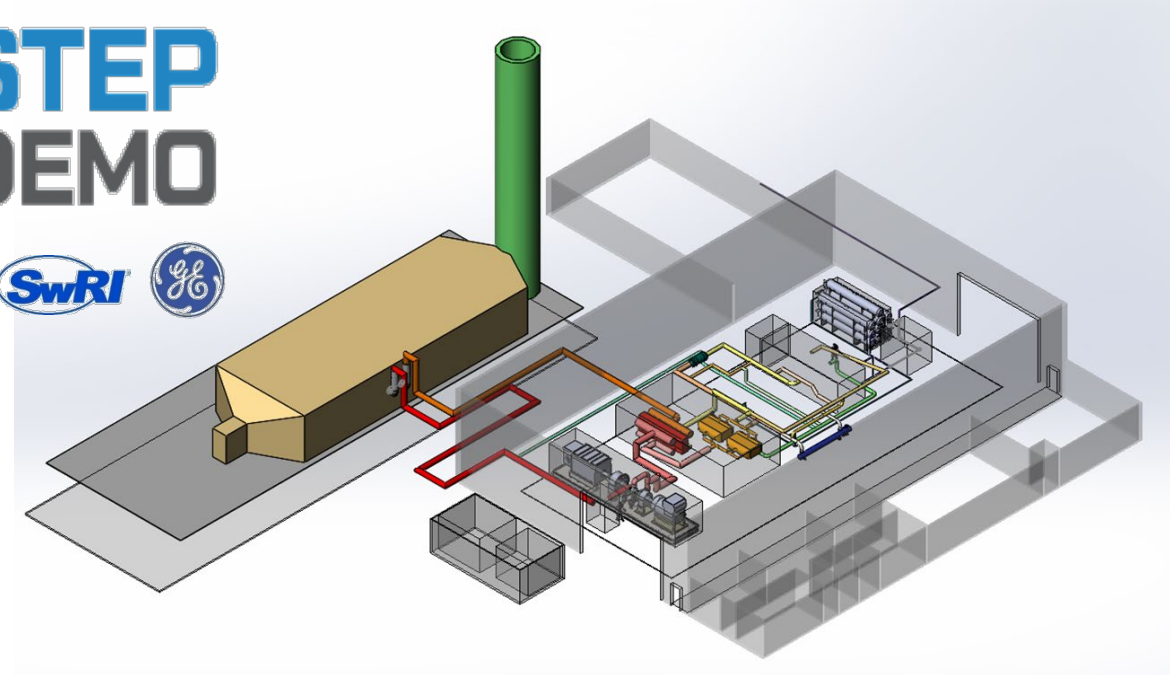
Public/Private Partnership



Powering The Future With Next-Generation Power Cycles

Supercritical Transformational Electric Power (STEP)

- > Next-generation power cycle
- > Supercritical CO₂ working fluid benefits
 - Application/heat source flexibility
 - Higher cycle efficiencies, lower carbon intensity, minimal water use
 - Compact turbo-machinery with scalability
- **\$119MM public/private partnership to design, construct, commission, and operate 10 MW_e test facility**



Concentrating Solar



Traditional Fuels



Geothermal



Waste Heat Recovery



Nuclear



Ship-board Propulsion

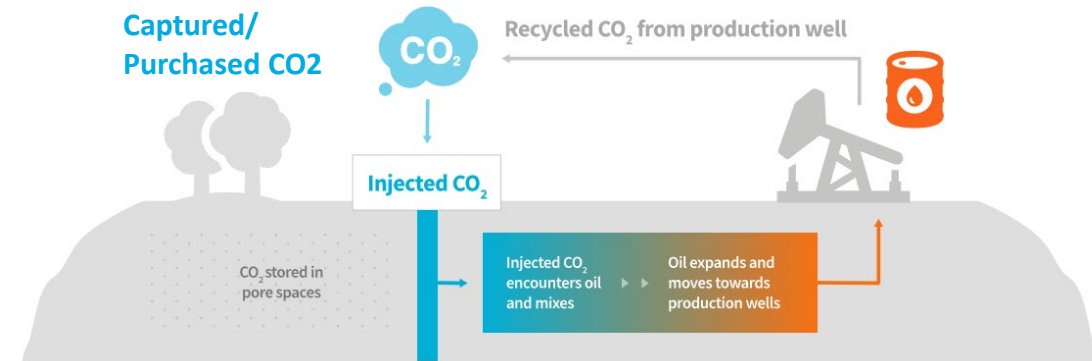
U.S. Carbon Capture Landscape

2018 FUTURE Act Extends and Enhances Tax Incentive Program

> Revised legislation extends tax benefits

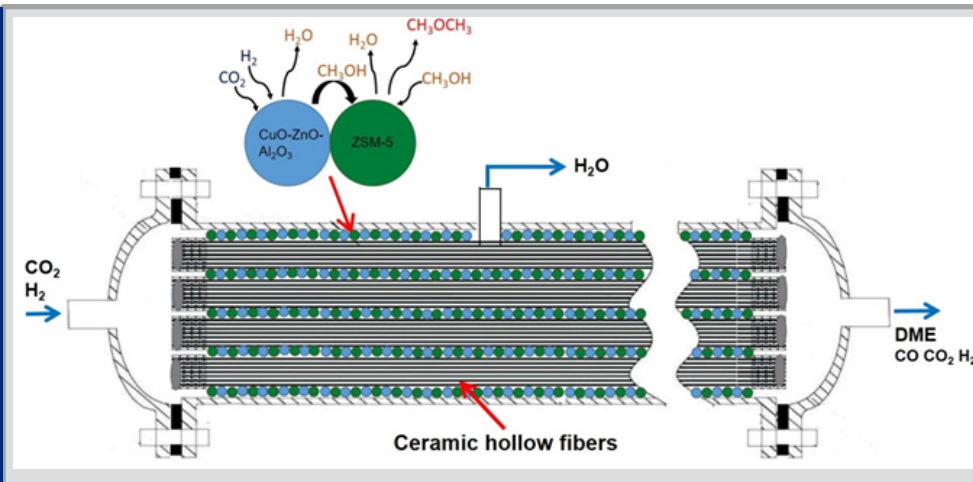
- \$50/ton CO₂ for sequestration
- \$35/ton CO₂ for EOR (12 years). About 70 MTPY now – mostly EOR

> GTI has active RD&D on CO₂ Storage & Use



Source: Carbon Capture Coalition

Example GTI
Process
Converting
CO₂ Into
Usable
Products

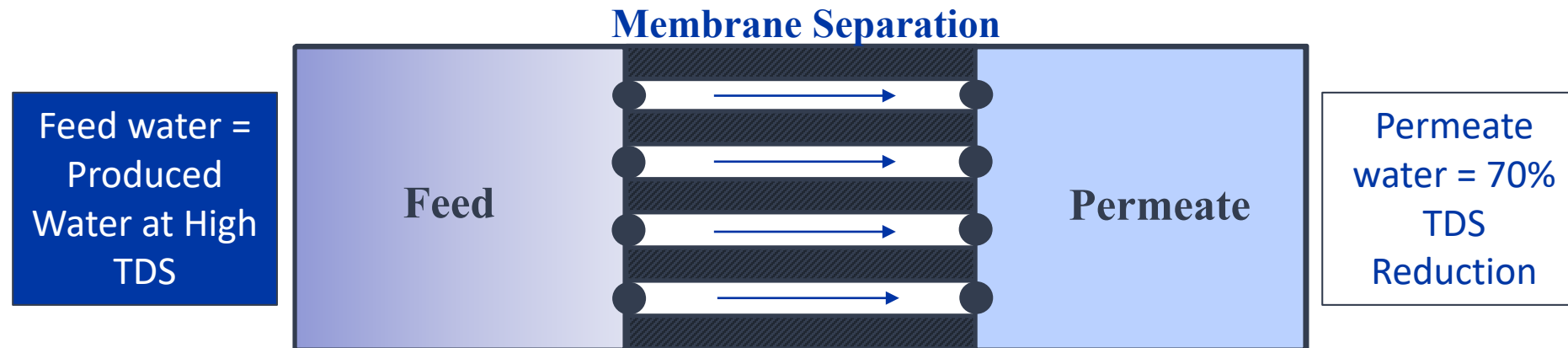


GTI CarboLock™ technology at
National Carbon Capture Center



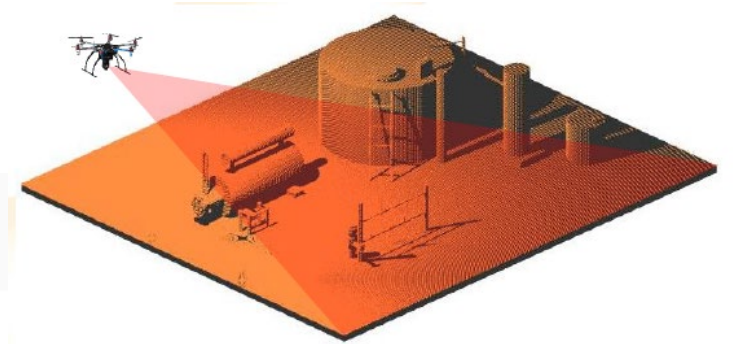
DOE/GTI/University of Pittsburgh Membrane Project

- Field test new water processing membranes at Permian basin HFTS 1-Midland Site
- Membrane advantages:
 - Operates at low temperature ($<100^{\circ}\text{C}$), potentially using onsite waste thermal energy from compressors and other onsite sources
 - Produces high-quality water
- If successful, could result in 90% reduction in O&M costs



Advancing Methane Science

- > Industry-led research consortium formed in 2018 to promote understanding of global methane emissions and develop solutions
- > Pursuing scientific studies addressing methane emissions from all sectors of the natural gas value chain
- > GTI is program administrator



Member Companies

CHENIERE



equinor

ExxonMobil

PIONEER
NATURAL RESOURCES

Low Carbon Pathways For Homes and Businesses

Near-Term
(25-50+%)

Expanded use of high-efficiency gas equipment



Hybrid natural gas furnace and electric heat pump systems



Building envelope improvements



Next-Gen
(40-60+%)

Thermal heat pumps for space & water heating



Micro CHP systems

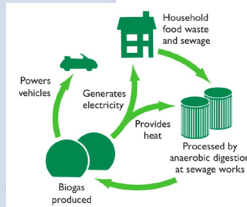


Deep building retrofits



Renewables
(Added 10-30%)

Renewable natural gas blends (biomethane)



Solar thermal - natural gas space and water heating systems

