Natural Gas Extraction, Utilization, and Conversion

Compact, Inexpensive Micro-Reformers for Distributed Gas-to-Liquids

RTI's small scale engine reformer technology can enable an economically competitive, efficient use of distributed and stranded natural gas, as well as, biogas.

- Increases the utility of geographically isolated natural gas reserves, further reducing U.S. dependence on foreign oil
- Significantly reduces greenhouse gas emissions related to flaring
- Small unit size allows for centralized or distributed right-in-time deployment
- Low CAPEX and fast replacement times result in reduced business risk
- Syngas can be converted into various other value added products such as methanol, ammonia, DME, or FT liquids

The rapid increase in unconventional gas extraction from shale gas formations via hydraulic fracturing and the drive to utilize stranded gas from oil and gas extraction have created new challenges seeking technological solutions, particularly in the areas of flowback and produced water treatment, small-footprint conversion technologies, and natural gas as direct fuel for vehicles. RTI has utilized its broad existing strengths and capabilities in the areas of gas separation and conversion, sorbent development, and industrial wastewater treatment to rapidly establish itself at the forefront of research efforts to address these new challenges.

New Shale Gas Challenges

The U.S. EIA estimates that total U.S. natural gas resources exceed 2,200 trillion cubic feet, a hundred years of supply. Domestic supplies of natural gas, spurred on primarily by advances in shale gas discovery and extraction, are now expected to exceed domestic consumption by 2020. Prices of natural gas are as low as they have been in over a decade. The rapid increase in unconventional gas extraction from shale gas formations has created great opportunities for increased domestic energy supply and security, but has also created new challenges seeking technological solutions.

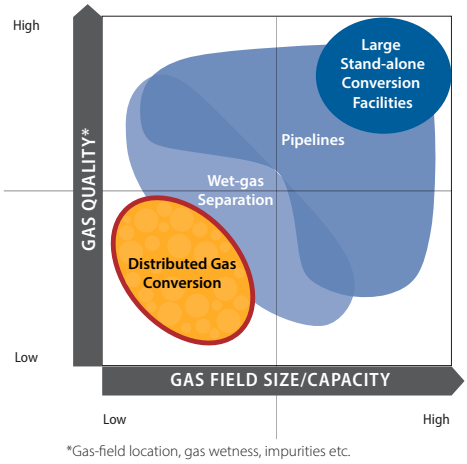
New Stranded Gas Challenges

The Global Gas Flaring Reduction Partnership of the World Bank estimates that more than 100 billion cubic meters of stranded gas are vented or flared each year globally in association with oil and gas extraction, enough gas to satisfy one-quarter of the U.S. demand, while emitting several hundred million tons of carbon dioxide equivalents to the atmosphere. This creates additional challenges for the utilization of such stranded natural gas resources, but solutions may be similar to those that enable small-footprint conversion technologies for shale gas.

RTI Leadership to Address These Challenges

RTI has utilized its broad existing strengths and capabilities to rapidly establish itself at the forefront of research efforts to address these new challenges. RTI has led shale gas workshops for the U.S. Department of Energy's National Energy Technology Laboratory (NETL) and Advanced Research Projects Agency – Energy (ARPA-E), and RTI Press has published a book entitled Shale Gas: The Promise and the Peril, authored by Vikram Rao, which has been favorably received by those in the field as bringing an objective and informed perspective. RTI's Energy Technology Division has

Prototype of a 6-liter adsorbed natural gas (ANG) fuel tank that relies on innovative advanced porous materials



*Gas-field location, gas wetness, impurities etc.

initiated a number of research projects addressing the challenges associated with natural gas extraction, utilization, and conversion, as further described below.

Improved Shale Gas Extraction

RTI has developed hybrid membrane technology approaches for the treatment and reuse of flowback and produced wastewaters resulting from the oil and gas extraction process, in cooperation with leading universities and a leading water treatment company. RTI is also developing technologies in the areas of advanced proppants and analytical sensors and advanced hydraulic fracturing techniques that may improve the yield and reduce the environmental footprint of gas extraction.

Natural Gas Use as Transportation Fuel

RTI has partnered with Texas A&M University, General Motors, Lawrence Berkeley National Laboratory, and the U.S. Department of Energy to develop innovative adsorbent materials that will improve the performance, safety, and storage capabilities of adsorbed natural gas fuel tanks for vehicles. The materials will improve storage in the fuel tank by achieving high gas capacity, high energy density and resistance to impurities typically present in natural gas fuel lines. RTI is working to develop cost-effective scale-up procedures and improve the packing density of the materials and will also lead efforts to identify suitable cost-reduction pathways and define technology-to-market strategies.

Small-Footprint Conversion Technologies

RTI has a number of current research and development efforts underway in the area of natural gas reforming and conversion to higher value chemicals. In one particular effort, funded by DOE/ARPA-E, RTI has partnered with Massachusetts Institute of Technology and Columbia University to develop a small-scale process for natural gas conversion into useable liquid products, by utilizing an internal combustion engine as compact reformer. Such small-footprint direct conversion technologies, consistent of mass produced process components, can allow for elimination or reduction of a significant portion of the capital and operating costs associated with conventional gas processing and dedicated pipelines, can be easier to finance than world-scale crackers or GTL plants, may not require long-term supply agreements for large blocks of ethane or natural gas, and can create significant jobs in the local region of the natural gas extraction.

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