Alternative Natural Gas Applications Workshop: Creating a Prosperous Demand Market

Workshop Summary Report

The Savannah River National Laboratory and the National Energy Technology Laboratory teamed up with engineering societies lead by the American Institute of Chemical Engineering's Center for Energy Initiatives to conduct a workshop entitled Alternative Natural Gas Applications Workshop: Creating a Prosperous Demand Market. The workshop was conducted on October 8 and 9, 2014. The objective of the workshop was to identify high impact applications for increased utilization of natural gas and to identify related technology gaps. Participants included 71 key representatives of industry, academia, national labs, DOE and professional engineering societies including AIChE, IEEE, ASME and ASCE. Invited speakers and panelists included Shell, Dow, Honeywell-UOP, Air Products, Gas Turbine Association, FuelCell Energy, Sasol, Chrysler, Toyota, Ford, Bayer, Braskem, Ashland Inc., University of South Carolina, Exxon, Global CCS Institute, Trillium CNG, and DOE. The workshop focused on three market sectors - Transportation, Chemical Synthesis, and Stationary Energy Generation. This report provides a summary of the workshop results for each of the 3 market sectors.

Transportation

Potential Areas for Expansion

Even though Natural Gas (NG) accounts for 26% of the total U.S. energy consumption, only about 3% of the NG consumed annually in the U.S. is in transportation. The fastest growing NG transportation market is direct fueling for Heavy Duty (HD) and Medium Duty (MD) trucks, buses, and commercial fleets. This is the fastest growing sector for NG use and is expected to grow from 30 bcf on gas consumed in 2012 to 850 bcf by 2040. Other areas of expansion are in Marine, Rail and Mining Operations.

Technical and Regulatory Barriers (Regulatory and Externalities)

The major difficulties affecting the use of NG in transportation include a combination of regulatory and technical issues. Some of the regulatory issues involve inconsistent taxes and credits for NG use at the local, state, and national levels, as well as inconsistent regional refueling and infrastructure standards. The availability of NG refueling stations continues to be an obstacle with only about 750 CNG and 65 LNG stations currently in the U.S., compared to over 150,000 gasoline stations. The cost discrepancy between LNG and CNG is another issue. LNG not only has higher associated processing and delivery costs but also is often taxed at higher rate based on being a liquid fuel. In addition, NG's lower combustion efficiency and the much lower volumetric energy density (compared to gasoline) are major issues for LD vehicles.

Technical Gaps

Some of the goals and challenges related to the technical gaps involve the following:

- NG Storage
  - Develop lower cost composite tanks and tank materials
  - Pursue conformable tanks, with absorbent/low-pressure technology
- Engine Technology
  - Develop higher temperature materials/lubricants
  - Examine new ignition technologies (lean burn technologies, methane oxidation catalyst, RCCI, adaptive controls, dual and tri-fuel engines)
- Infrastructure
  - Pursue lower cost higher efficiency compressors
  - Examine faster fill options, including heat of compression dissipation designs
  - Evaluate home refueling options

Role of Government

The major role by the government in transportation include: 1) developing consistent federal and state policies for NG as a transportation fuel, 2) using the National Labs (NLs) to help provide data to support good market driven decisions and 3) using the NLs, Universities, and Industry to help address and overcome the technical gaps, both for the short- and long-term.

Metrics

The National Energy Goals and Climate Action Plan call for a 50% reduction in oil imports and 17% reduction in GHG emissions by 2020. Natural gas as a transitional fuel can play a major role in helping to achieving these targets either by direct use or by transformation to hydrogen, electricity or a higher energy liquid fuel.

Chemical Synthesis

The focus of the Chemical Synthesis and Utilization workshop session was to identify opportunities to better utilize natural gas feedstock to decrease the dependence on conventional petrochemical routes towards the development of a variety of beneficial end use products.

Current Uses

With current domestic natural gas (NG) prices low, U.S. producers have turned towards “wet” gas reserves in an effort to capitalize on an emerging energy and feedstock source and maximize profit. Between 2008 and 2013, production volumes of natural gas liquids (NGLs) grew at an average of seven percent annually (Michael Kopalek, 2014). Over this time, crude oil refining has been relatively flat while natural gas processing plants have accounted for an increase in nearly 75% NGL production from 2008 to 2014. The trends in NG production have resulted in a surplus of ethane, while petrochemical refining trends have resulted in shortages of propylene, butadiene, aromatics and pentanes.

The current pathways for NG use in chemical synthesis and utilization include:

- Continued dominance of ethane cracking
- Maturation of technologies focused on the production of propylene, butadiene and aromatics through affordable NG

What will Success look like three years from now?

- Successfully scaled pilots of 1 to 3 economically viable processes
- Develop a prioritized research agenda for Federal resources on where research efforts could have the greatest impact. Also developing a timeline and identify steps to accomplish the plan
- Concrete DOE policies for supporting R&D to enable further/broader utilization of NG in chemical industry

Potential Areas of Expansion

The fastest growing NG chemical synthesis and utilization market is the downstream derivatives sector. Global demand is expected to increase at five percent per year for ethylene and propylene. Market segments for "on purpose" manufacturing of C3+ hydrocarbons are projected to fill the gaps developed from steam cracking of ethane. Areas of consideration for technological expansion that would further the chemical synthesis and utilization sector are as follows:

- New chemical routes/processes focused on direct conversion to desire products (*i.e.* direct conversion of methane to methanol)
- New separation technologies circumventing conventional, energy intensive distillation processes (*i.e.* membranes).

What is the value proposition in capitalizing on NG?

- Profound economic development with renewed U.S. manufacturing of durable goods packaging, pipes, nanowoven fibers, etc. based on polymers from NGLs
- Energy security for the U.S. with geopolitical benefits. Economic security for our children and us
- A return to a manufacturing-based economy that provides good-paying jobs and a strong service sector that provides services to manufacturers

Technical and Regulatory Barriers (Regulatory and Externalities)

The major obstacles affecting the use of NG as a source for chemical feedstocks include a combination of regulatory and technical concerns.

The regulatory barriers include

- Streamlining the regulatory process
- Development of a rationalized regulatory framework including a comprehensive energy policy

What are the largest technical roadblocks were identified with associated time frames:

- 5 Years
  - Selective C-H bond deviation
  - Capital cost reduction for syngas production
  - Selective building of C-C bonds
  - Membrane-based separations
- 20 Years
  - (Direct) Catalytic conversion of C1-C2 (non-syngas routes)
  - Selective methane activation (C-H bond)
  - Develop cost effective high temp materials (>1300^{o}C) enabling CH4 pyrolysis.

The near-term impact of the technical gaps is improving since the United States is currently one of the lowest cost producers of NG. In addition, several new NG processing plants (feedstock and product driven) are scheduled to come online over the next five years, which will increase overall capacity in the United States. Longer term goals may be to build larger plants such as polystyrene, polypropylene, and polyethylene, and to expand our reach into the international space by exporting more products abroad. Significant R&D is required to develop new technologies to improve overall plant operating efficiencies. A deeper investigation of infrastructure and plant operation improvements may also be warranted. The industry goal is to help drive down costs to build new plants and stabilize the demand for end products. The mail end goals are for consumers to pay less for products over time and for the United States to become more energy independent.

Role of Government

The suggested role of government is

- The development of a roadmap and vision
- Be steward of a sustained long-term effort. Enable Industry, academia and national lab partnerships
- Basic R&D funding, workforce development, rationalize regulatory framework

Metrics

NG, as a source for chemical feedstock, can play a major role in returning advanced manufacturing to the United States. Meaningful metrics to measure the progress toward achieving this goal include:

- Identify the national and international costs related to NGL's and subsequent polymer manufacturing/commercialization
- Consider talent and human capital involvement (schooling and subsequent jobs for chemical engineers and NG skilled technicians)
- Measure sustainability and environmental effects (carbon balance)
- Establish milestones that will demonstrate progress, even without success

In order to properly measure such metrics, an analysis of the current petrochemical industry should be established (baseline the industry). A view of the U.S.'s current demand for manufactured goods and its existing manufacturing capabilities relative to the manufacturing of imported goods will help identify meaningful data years after this roadmapping effort's conclusions are published.

Stationary Energy Generation

Potential Areas for Expansion

Areas for expansion in stationary power include gas turbines and fuel cells along with cross cutting areas.

It was recognized that the increased supply of domestic natural gas has supported a great advance in US industry manufacturing gas turbines. However, in order for the U.S. to build on or maintain these gains, a substantial investment in associated R&D for is required. The major variable is U.S. government support of increased R&D funding. If it does not happen, the share of the NGCC market filled by U.S.-based manufacturers is projected to drop to 42% from 84% today by 2037 and 36,000 fewer US jobs by 2035. One area of recommended research is improved efficiency for combined cycles.

For fuel cells, reliable and resilient distributed power generation is an emerging market where NG has the demonstrated advantage for use as clean fuel. Technologies such as SOFC can efficiently utilize NG in CHP and electricity generation in scales ranging from small commercial to large distributed generation (hundreds of kWe to MWe).

Cross-cutting areas of expansion were also identified including CHP (combined heat and power) and polygen (where products in addition to electric power are produced). Polygen includes production of oxygen plus power, production of CO_2 for enhanced oil recovery plus power, and production of hydrogen plus power and CO_2.

Regulatory and Policy Barriers

GHG (Greenhouse Gas) Mitigation is an uncertain factor. Current proposed regulations exempt NG generation, but if GHG mitigation goals are to be reached, eventually regulations will require mitigation from NG-fired sources. The interim period where NG is not subject to GHG regulations provides an ideal time for R&D targeted at reducing costs for carbon capture utilization and storage, so that when regulations are put into place, industry will be ready to comply. The problem will only cost more if we wait to address it; the problem will not just go away.

Current utility pricing policies create difficulty in connecting CHP to the utility grid. There are high charges for back-up power but low prices for produced power.

Technical Barriers

For NG turbines, major technical areas are combustion, heat transfer, and materials, or thermal barrier coatings. It is very much the overall efficiency goal that includes the 3 barriers.

For fuel cells, technical gaps include: (1) deployment of clean and efficient energy conversion system such as SOFC, (2) development and deployment of OTM, and (3) reclamation of water used during NG extraction. Technology development areas include functional ceramics and membranes, catalysts, robust filtration processes.

For carbon capture and sequestration (CCS), DOE is actively funding coal focused CCS R&D but should consider funding gas focused CCS R&D to overcome the differences in flue gas content. Demonstration would alleviate some of the risks associated with the technology.

Needed Science or Engineering Research and Development

The workshop also identified programs that should be expanded to address the technical gaps.

For NG turbines, the Gas Turbine Association pointed out that the Tonko Bill would provide sufficient funding to enable U.S.-based NGCCs of 64% to go online by 2022 and 67% by 2027. The bill was introduced in November 2013 in the House and will be reintroduced with next congress requesting $50M/year for 7 years ($350M total). This would support major component testing.

For fuel cells, viable solutions are needed to extend the lifetime of fuel cells and reduce the materials and manufacturing costs.

Cross-cutting R&D should focus on integrated basic science programs to understand thermal barrier coatings and high temperature materials. These technologies are complimentary in nature so an integrated research is required.

For CCS, an R&D program is needed to develop capture technologies specific to natural gas fired systems. This program should focus on accelerating the development of technologies tailored to the

unique characteristics of natural gas derived flue gases such as lower CO_2 concentrations as well as lower contaminant concentrations.

Suggested Role of Government

For NG turbines, the National Energy Technology Laboratory (NETL) would be the major government player in the proposed Tonko Bill which would address this issue for gas turbines. Presumably NETL would manage the program, as they did for the successful Advanced Gas Turbine Systems Research (AGTSR) Program, which ran from about 1992 to 2000, to demonstrate major components.

For fuel cells, the government should support developing programs to attack the key technical problems associated with implementing the fuel cell technology in next generation systems. These programs should fund the R&D that is beyond near term vision (*i.e.*, 5 years horizon) along with demonstration projects (*e.g.* de-carbonized fuel demonstration projects) and efficient and cost effective NG utilization for stationary applications (*e.g.* in polygen, to gain market confidence and acceptance).

Public–private partnership under the guidance of federal/state government, university research and industrial participation at the R&D and demonstration level should be examined. National labs will play a key role in developing big science and engineered systems for accelerating the deployment.

Metrics

Stationary power programs for natural gas should develop and demonstrate cost effective GHG reduction strategies related to NG stationary power gen (all technologies – gas turbines, fuel cells and CCS) with parallel targets for reduction over time. A goal could be to demonstrate a 20% improvement CAPEX and OPEX over current state of the art which will enable further investment.

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