Modular Chemical Processing

A revolution in process technology to capture America's natural gas opportunity

A window of opportunity has opened. Enticed by low-cost natural gas feedstocks, chemical companies from around the world have pledged over $70 billion in new chemical production capacity investments in the United States.[1] Will these investments be into century-old process technology or will the U.S. sieze this opportunity to advance its global leadership in chemical production technology?

Overview

The development of standard container-sized, processing units with innovations in process-intensified reaction and separation technology that leverage advanced manufacturing innovations (e.g. additive, smart manufacturing) and commercial off-the-shelf, balance-of-plant equipment into integrated, commercially viable, field deployable chemical process plants have the potential to overcome the classic "scale-up" challenge by reducing first unit costs and accerlerating "experience learning" cost reductions through the manufacturing of many small modular units. In many parts of the country associated natural gas is flared because it cannot be delivered to the market economically with conventional technology; presenting a unique opportunity to develop novel, field deployable chemical process modules capable of upgrading natural gas to higher value, economically transportable products.

Size versus Number

Commercial chemical process plants today are scaled-up to huge sizes in order to achieve well-known "economies of unit scale" that reduce overall chemical production costs. For example, a 2 barrel per day (bpd) pilot-scale gas-to-liquids plant may cost $10 million ($5M/bpd), but a 10,000 bpd commercial-scale unit will cost about $1 billion ($0.1M/bpd), see Figure 1. But, who can finance a billion dollar plant? Very few, and herein lies the challenge with today's approach to increasing chemical production capacity. Traditional economies of scale have stifled innovation, as the high cost of adopting new technology blocks all but the most incremental improvements.

By contrast, "economies of mass production" offer a fundamentally new way to achieve low-cost chemical production without high risk capital investments. Henry Ford did not invent the automobile or mass manufacturing; but marrying them he produced the first affordable automobile (Figure 2). The development of process intensified, modular processing promises to do the same for the chemical processing industry, leveraging the multitude of advantages offered by small-scale, modular chemical plants over traditionally scaled-up process plants, including:

- Less upfront capital, no down time, less risk
- Faster market response, adaptable output
- Deployable assets (no sunk capital)
- Access to remote resources/assets
- Better integration, less waste

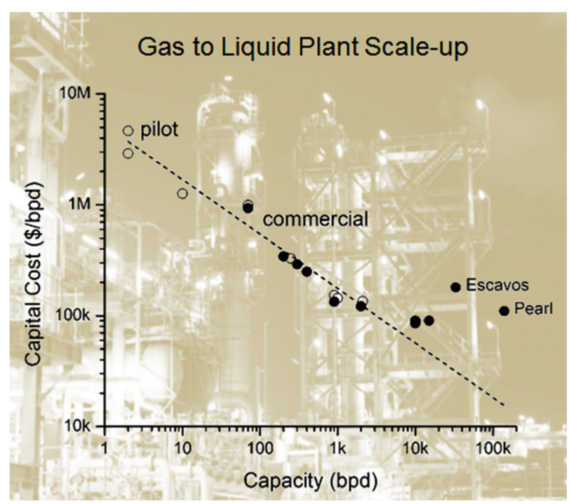

Figure 1. Economies of scale for gas-to-liquid plant scale-up.

[1] Economics & Statistics Department, American Chemistry Council. *Shale Gas, Competitiveness, and New US Chemical Industry Investment: An Analysis Based on Announced Projects*. May 2013.

- New capital and consumer markets
- Faster innovation (uses latest technology)

Innovation

Simply reducing the size of existing chemical processes alone will not be sufficient to realize the benefits economies of mass production—innovations are required. Fundamentally, there a two key challenges to operating processes at small-scale: (1) isothermal operation and (2) gravity-based separations. These challenges and overall process efficiency will require innovations in process intensification that dramatically reduces the volume, capital, and/or environmental footprint of a process per rate of product output and include:

- Combining reactions and separations into one unit operation
- Designing reactors and separators that dramatically reduce mass and heat transfer limitations
- Converting batch processes into continuous processes
- Developing enhanced catalysis

Opportunity

While the modular approach has broad applicability across the process industry, upgrading stranded or discounted natural gas presents a unique opportunity. The U.S. flares over 260 million cubic feet (MMcf) of natural gas per year and most flaring comes from relatively small wells of 0.1—250 thousand cubic feet per day (Mcfd),[2] providing an optimal size range for field-deployable processing modules (Figure 3). Processes that convert natural gas to methanol, ammonia, or olefins are particularly promising because of their widespread use as feed stocks across the chemical industry.

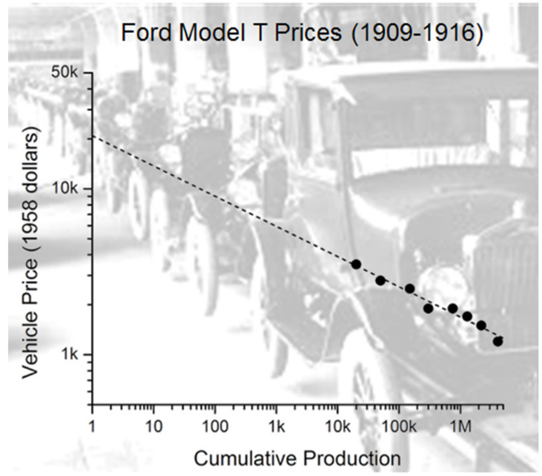

Figure 2. Economies of mass production and experience learning curve for the Ford Model T.

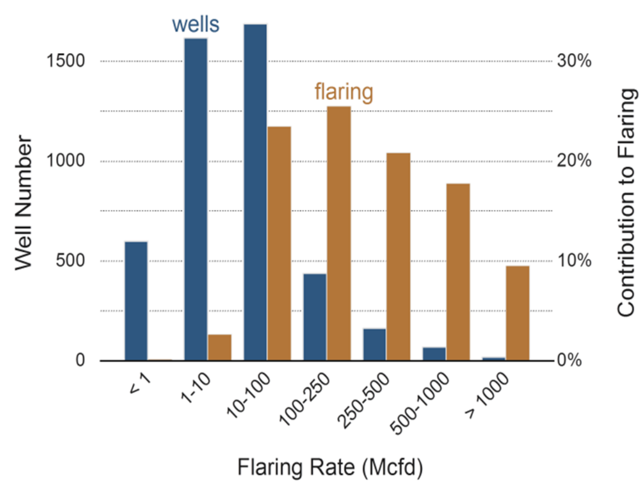

Figure 3. Rate of natural gas flaring in North Dakota, August 2013.[2]

Contact

Dane Boysen, PhD
Executive Director of Research Operations
Gas Technology Institute
1700 S Mount Prospect Road
Des Plaines, IL 60018
(626) 676-0410
dane.boysen@gastechnology.org

[2] Kringstad, J.J. *North Dakota natural gas. A detailed look at natural gas gathering.* North Dakota Pipeline Authority, 2013.