

Think Corner Research Note

Outlooks on Industrial Sector Demand for Natural Gas

An Evaluation Using the CEE Industrial Projects Database

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The industrial sector has been reclaiming market share in the U.S. natural gas market, which is important to understand to base future outlooks on natural gas prices and production. This effort is part of CEE's sectoral look at the U.S. demand for natural gas, which includes modeling of environmental regulations in the power sector, and investigation of global natural gas markets (demand growth in key countries, LNG sector and competitiveness of U.S. exports).

CEE developed a comprehensive inventory of projects in gas-intensive industries in early 2014 in order to understand the potential for incremental gas demand in the industrial sector and its timing. We reported some estimates from the database in June 2014 as a research snapshot and an updated snapshot in February 2015. This research note provides some of the details on individual projects (cost, capacity, locations) and our evaluation of project status and gas consumption calculations.

Since the collapse of the oil prices in late 2014, market dynamics have changed, impacting the investment decisions for some of these projects. The attractiveness of the projects depend on not only natural gas prices but also the prices of ethane, propane, butane, condensate and final products. Mostly, these prices are linked to the price of oil but there can be regional or product-specific diversions from historical price relations owing to infrastructure bottlenecks and/or individual product's own market dynamics. The competition is international since the U.S. has to export most of its LPG, ethylene, and other petrochemical products and even some of its ethane. The U.S. upstream will likely be able to provide globally competitive feedstock for the rest of the 2010s but beyond, there are uncertainties regarding the ability of the upstream to supply the right feedstock mix at attractive prices that can sustain global competitiveness of new industrial facilities.

We will continue to update the database, and study implications up and down the individual value chains for oil, natural gas and petrochemical products as these markets will certainly continue to face several uncertainties in the future.



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Introduction

Following a period of rising prices in the early 2000s with occasional price spikes, many U.S. chemical plants and other industrial facilities closed down; much industrial demand for natural gas was destroyed. Between 1997 and 2009, U.S. lower-48 industrial gas consumption declined by 30 percent (Figure 1). Although power sector use of gas increased, total demand remained fairly constant and there was no persistent shortage. Increasing natural gas prices in the mid-2000s and low interest rates encouraged investment in the upstream sector, especially in new domestic shale plays, resulting in a surge of supply. The surplus pushed the natural gas price to historically low levels after 2009, especially in 2012. Lower prices also re-ignited interest in natural gas in the industrial sector, which recovered from 6.2 TCF in 2009 to almost 7.7 TCF in 2014.

Since the shale production surge beginning in the late 2000s, U.S. dry natural gas production grew significantly from 18.1 TCF in 2005 to 25.7 TCF in 2014, according to the Energy Information Administration (EIA), despite the decline in production from conventional plays. Low oil prices since late 2014, combined with persistently low natural gas prices, have led to a significant decline in drilling activity (as measured by the rig count and completions). Operators have been able to sustain production owing to already-committed drilling in best locations, but if low oil and gas prices persist through early 2016, production might start to decline. In the meantime, a growing perception of long-term reliable supply of natural gas at predictable and affordable prices has been attracting new demand into the market. Gas fired power generation, liquefied natural gas (LNG) exports, pipeline exports to Mexico and Eastern Canada, and new industrial demand are all expected to contribute to demand growth at least through 2018.





Four segments represent the bulk of U.S. demand for natural gas, each facing a complex set of uncertainties that are interrelated: electric power, industrial, residential, and commercial. In 2014, these segments accounted for 30%, 29%, 19% and 13% of total consumption, respectively. There is potential for increased use of natural gas in the transportation sector, especially in fleet vehicles and long-



distance trucks. There are initiatives around the country to switch vehicles from diesel to either compressed natural gas (CNG) or LNG; but the volumes are negligible at this time (about 33 BCF in 2014). Lease and plant fuel use of natural gas increases proportionally with natural gas production but has a relatively small share of total demand (1.6 TCF in 2014, or less than 6% of total consumption). These two segments are not depicted in Figure 1.

Although an uptick can be observed in the last couple of years, natural gas consumption in residential and commercial remained fairly constant over the last 17 years (Figure 1). Increasing end-use efficiency and conservation in response to higher prices in the 2000s appears to have kept demand growth in check. The use of natural gas in the industrial sector had been declining due to higher levels and volatility of the price of natural gas before 2009 but started to recover since then owing to lower prices. In 2007, power generation surpassed the industrial sector as the largest user of natural gas.¹ Going forward, the power sector is expected to use more gas as coal plants retire due to new environmental regulations and unattractive economics compared to gas-fired units as well as retirements of nuclear plants with expiring licenses.²

The industrial sector uses natural gas as fuel and/or feedstock to meet a variety of energy requirements. The EIA's Manufacturing Energy Consumption Survey in 2010 (MECS 2010)³ provides a detailed breakdown of natural gas consumption by manufacturers, which account for about 80 percent of total industrial gas demand. The remaining 20 percent is consumed primarily in the agriculture, construction, and mining sectors. Just two industries, chemicals, and petroleum and coal products, account for 55 percent of total U.S. manufacturing gas demand of 5.6 TCF in 2010 (Figure 2). Including food and primary metals, each of which consume 10 percent of the total, the top four natural gas consuming industries account for three quarters of the total industrial natural gas consumption. Compared to data reported in MECS 2006,⁴ the share of the chemicals industry increased from 30% to 39%. The share of the petroleum and coal products industry also increased but only from 14% to 16%. The shares of food, primary metal, paper, nonmetallic mineral products, fabricated metal products, and transportation equipment shrank.

Since 2009, relatively low natural gas prices, maintained by growing shale gas production, have boosted natural gas-intensive industries: 7.7 TCF was consumed in the industrial sector in 2013 compared to 6.2 TCF in 2009 for an average annual growth rate of 4.8 percent, much faster than the growth of real gross domestic product, or real GDP, which shrank about 3 percent in 2009 and has only grown about 2 percent on average since then. There are many proposed projects and capacity expansions with an estimated investment amount of more than \$110 billion in total during 2014-2020. A surge in industrial demand can change the market dynamics, putting upward pressure on price, especially when combined with increased gas utilization in power generation and increased exports, but could also lead to increased employment and positive multiplier effects in the economy.

Is this "industrial renaissance" sustainable? Over the last several years, the United States has enjoyed a global advantage in both the supply and price of oil (given the divergence of WTI and Brent) and natural

¹ There are significant seasonal variations in gas use in both industrial and power sectors (annual data in Figure 1 smoothens this volatility). Demand for gas in power generation peaks in summer whereas demand for gas in the industrial sector peaks in winter, with the former being much larger.

² CEE conducts power sector modeling in order to evaluate the impacts of these developments in ERCOT and other power regions, using a power dispatch software (AURORAxmp). Please see <u>www.beg.utexas.edu/energyecon/</u> for links to research snapshots and articles published in *The Electricity Journal*.

 $^{^{\}rm 3}$ MECS 2010 was released in March, 2013. The next MECS will be fielded in 2015.

⁴ MECS 2006 was released in 2009.



gas. Industrial production and manufacturing has been converting to natural gas for cost savings. For most users, especially petrochemicals, it is essential for natural gas to be cost competitive with other fuels. The sustainability of this shift requires that U.S. natural gas supply will meet expected increases in demand at competitive prices. If sufficient confidence exists in the ability of producers to supply enough gas to meet plausible demand scenarios for a long time to come, reasonably low prices can be expected, which would allow industrial projects to remain competitive in the medium to long-term after they are built.





The recent collapse in global oil prices, if sustained for a year or more, can undermine the competitiveness of natural gas for some users, especially if the price of natural gas starts rising as producers shift their rigs to higher-cost locations in shale plays. Industrial users may use financial tools such as futures or forward contracts to hedge price risk. They can also sign long-term agreements. For example, Methanex and Chesapeake signed a 10-year agreement in 2013 to supply all of the natural gas required for Methanex's one million metric ton per year methanol plant in Geismar, Louisiana, at a price linked to the methanol price. Some big gas consumers are acquiring gas production assets as a physical hedge. Unlike financial hedges, physical hedges can provide long-term benefits without exposure to credit and collateral risk requirements. A recent example is Florida Power & Light Co., which is investing in natural gas supplies with a plan to develop up to 38 natural gas production wells in the Woodford Shale with PetroQuest Energy.



In this report, we present data on projects that have been in various stages of development and should go forward but the level of uncertainty has increased for some projects. We will discuss the increased risks where relevant.

Comparative Gas Industrial Demand Outlooks

We start by comparing several investment and gas demand outlooks in the industrial sector from various sources. Our discussion would focus on projections within the next 5 to 10 years when most of the LNG export projects and big petrochemical projects are supposed to come online.

In the EIA Annual Energy Outlook, NEMS Industrial Demand Module⁵ (IDM) is used to estimate energy consumption by energy source for 15 manufacturing and 6 non-manufacturing industries. The petroleum refining industry is not included in the IDM, but the projected consumption is reported under the industrial totals. The assumption of unit energy consumption⁶ is aligned with the MECS 2010 data.





In the AEO 2014 Reference case, natural gas consumption in the industrial sector increases from 7.4 TCF in 2013 to 8.4 TCF in 2025 and 8.7 TCF in 2040 (Figure 3). These forecasts are basically the same in the AEO 2015 Reference Case but higher than those in the AEO 2013 Reference case by 0.6 TCF in 2025 and 0.8 TCF in 2040, despite the fact that AEO 2014 predicts slower GDP growth and higher Henry Hub price than AEO 2013. The difference appears to be a result of faster expected growth of the manufacturing sector in AEO 2014; estimates for shipment and employment in the manufacturing sector are both higher than those of AEO 2013, especially those in chemicals, plastics and rubber products, primary metals and fabricated metal products.

⁵ Part of the EIA's in-house model National Energy Modeling System (NEMS).

⁶ The unit energy consumption is defined as the amount of energy to produce a unit of output; it measures the energy intensity of the process or end use.



The High Oil and Gas Resource case assumes larger oil and gas resources and higher technological development and productivity, which have significant impact on the natural gas price, industrial production and thereafter natural gas consumption. AEO 2014 and AEO 2015 are mostly consistent beyond 2020 but industrial demand increases faster in the early years in AEO 2015. In this case, the natural gas price in 2040 is 40 percent lower than that in the Reference case. Energy intensive sectors, especially the bulk chemicals sector, show greater sensitivity to these assumptions than any other manufacturing sector. Industrial natural gas consumption in the High Oil and Gas Resource case reaches 8.6 TCF in 2025 compared to 8.4 TCF in the Reference case and 9.2 TCF in 2040 compared to 8.7 TCF in the Reference case (Figure 3).

IHS Monthly Gas Briefing Outlook in November 2014 (MGBO) predicts higher industrial natural gas consumption through 2021 than in the AEO cases but IHS forecast peaks in 2023 at about 8.4 TCF and declines steadily and ends up with 7.7 TCF at 2040, the lowest among all outlooks (Figure 3). The post-2020 slow decline seems to be the result of energy efficiency gains and a lower long-term competitive outlook for certain industries because of a stronger U.S. dollar.⁷

A bottom-up industry report published by Raymond James & Associates (RJ) in June 2013 is rather more aggressive. It estimates industrial demand for natural gas to grow to about 10 TCF per year by 2020. Even if we deduct 0.7 TCF gas use by Shell's cancelled gas-to-liquids (GTL plant), at 9.3 TCF, this estimate would be much higher than the others discussed above. The outlook covers five industrial gas demand sub-segments and the largest driver for industrial demand is new ethylene production units, ammonia plants and GTL facilities. The outlook is based on the capacities of announced projects and the in-house assumption of unit natural gas consumption.





⁷ IHS CERA Private Report "U.S. Industrial Gas Demand", March 2014.



In AEO 2014, energy intensive industries, such as paper products, food products, bulk chemicals,⁸ iron and steel,⁹ and metal-based durables,¹⁰ are the primary beneficiaries of lower natural gas prices for energy and feedstock in coming years (Figure 4). However, due to growing foreign competition, shipments and gas use in some trade-exposed energy intensive industries, such as bulk chemicals and iron and steel, decline after they peak in the late 2020s. Gas use by the refining sector experiences an upward jump between 2014 and 2015, probably owing to two new refineries (Dakota Prairie and Kinder Morgan) that are scheduled to start up by the end of 2014. There is no more new petroleum refinery crude unit capacity built in the AEO 2014 Reference Case. The continued growth until 2025 reflects increased use of natural gas for heat and power and feedstock.





In order to better study future industrial gas demand, we developed and maintain a database of projects in the industrial sector, which is described in detail in the next section of this report. First, we want to compare industrial sector gas use outlooks from our database with other outlooks. We consider two cases, CEE Reference and CEE High, depending on our assessment of the likelihood of projects coming online as announced. Additionally, in each case, we have two levels of gas use, Low and High, based on the unit natural gas consumption of each industrial subsector (see next section for details). At the time of writing, we include 83 projects in the CEE Reference Case, representing \$65 billion of investment and natural gas consumption of 22.1 BCFD (8.1 TCF) by 2018. In the CEE High Case, there are 112 projects, representing capital investment of \$98 billion and natural gas consumption of 23.3 BCFD (8.5 TCF) by 2020. We include announced projects in ethylene, polyethylene, propylene, hydrogen, methanol,

⁸ An energy intensive subcategory of chemical manufacturing, including inorganic, organic, resin, synthetic fiber and fibers, and agricultural chemicals.

⁹ An energy intensive subcategory of primary metal.

¹⁰ Include fabricated metal, machinery, computer, transportation equipment and electrical equipment.



nitrogen fertilizers, chlor-alkali, and steel. Comparing the list of NAICS industries in natural gas consumption in Figure 2, we cover most of the growing capacity in chemical and primary metal sectors, which accounted for 50 percent of manufacturing natural gas demand in 2010. Since manufacturing accounts for about 80 percent of total industrial gas demand, the study probably covers about 40 percent of industrial gas demand.

Two CEE cases are compared to several AEO and IHS outlooks through 2020 in Figure 5. The CEE Reference Case yields the highest level of consumption in 2020 at 8.7 TCF. Although not shown in the chart, the RJ June 2013 estimated for 2020 was 10 TCF. The estimates in other cases fall between 8 TCF and 8.4 TCF. The differences can probably be explained by the use of different methodologies and assumptions. CEE and RJ outlooks are bottom-up approaches and only cover a subset of industries. Both EIA and IHS use in-house top-down macro models to capture the demand growth. CEE and RJ outlooks may use a different way to decide the likelihood of projects getting built not to mention that the CEE analysis is of a later vintage. The assumption of unit natural gas consumption in each industry may be different as well. Still, although we only include a portion of the industrial sector, our outlooks are either higher than or comparable to those by EIA and IHS, which cover the whole industrial sector.

CEE Industrial Projects Database

For the purposes of this report, we offer a snapshot in time of the database, covering 112 projects in natural-gas-intensive sectors with startup date from 2013 to 2020. Plant types include ethylene, polyethylene, propylene, methanol, chlor-alkali, nitrogen fertilizer, iron and steel, and fuels from the gas-to-liquids (GTL) and methanol-to-gasoline (MTG) processes.¹¹

Under consideration	The project is still under internal discussion with preliminary announcement.
	May still look for partners.
Planning	The project is declared and a consultant may be hired to define the budget, risk, and schedule of the project.
FEED	The project owner retains an engineering firm to take the holistic approach of a
	stage-gate model for evaluating development of projects. Substantial capital
	outlay may occur.
Permits	The project has some permits and/or is filing/waiting for other permits.
In progress	The project is either under project procurement or construction.
Completed	The project is finished and achieves operations.

Table 1: Definition of Project Status

For each project, we record its capital investment, capacity, startup date, location, project type and project status based on publicly available information such as company announcements, regulatory documents, and industry news, often cross-checking multiple sources. Still, it is important to note that the market is dynamic and most companies have alternative projects, to which to allocate their capital as conditions and expectations change. We have seen new projects added to our database and many cancelled or suspended between our initial snapshot in June 2014 and this report.

¹¹ A report from American Chemistry Council (ACC) published in July 2014 records 191 projects, covering a wider range of facilities. The cumulative capital investments of these projects reach \$117 billion, which is only slightly larger than the \$98 billion estimated for our 112 projects. An update in April 2015 by ACC raises the number of projects to 225 (including those announced by March 2015) and total investment to \$138 billion. Note that the ACC reports include LNG and many plastics projects not included in our analysis as we are focusing on gas-intensive facilities. The ACC reports do not provide natural gas consumption estimates but we include the projects listed in the ACC report from July 2014 as long as they are large users of natural gas and still viable candidates for completion by 2020.



Projects were classified as new, expansion, relocation, and restart. Project status includes under consideration, planning, front end engineering and design (FEED), permits, in progress, and completed as defined in Table 1.

Capital Investment and Capacity

The CEE Reference Case includes 83 projects that are completed, in FEED, obtaining permits, or in progress. Total investment for these projects is about \$65 billion between 2013 and 2018 (Figure 6). Since all projects with startup year beyond 2018 are in the planning phase, they are not included in these calculations. In the CEE High Case, we consider all 112 listed projects, including ones that are still under consideration and planning. The total investment reaches \$98 billion in 2020 under this high case.



Figure 6: Total Investment in Major Natural-Gas-Intensive Industries (CEE Reference Case)

Potential investment streams across different industrial segments by project status are summarized in Table 2. At the time of writing, we do not have any projects in the "under consideration" phase with an announced startup date. Not included in the Reference Case are 29 projects with \$33 billion, about 28 percent of total investment, which are in the planning phase and need to be further confirmed. Seventeen projects with another \$20 billion are in FEED or Permits status and more likely to be completed. Forty projects (\$37 billion) are in progress and 26 projects (\$7.9 billion) have already been completed. Details of projects and increased capacity in major industrial subsectors are discussed in the following sections.



	Planning		FEED		Permits		In Progress		Completed		Total	
Project Type	Count	Investment	Count	Investment	Count	Investment	Count	Investment	Count	Investment	Count	Investment
Chlor-Alkali	1	\$500					1	\$132	4	\$1,956	6	\$2,588
Ethylene	6	\$14,599	1	\$7,000	1	\$972	9	\$17,226	7	\$1,505	24	\$41,303
GTL			2	\$265	1	\$200					3	\$465
Hydrogen	1	\$24					2	\$29	2	\$165	5	\$218
Methanol	4	\$6,100	1	\$1,000			4	\$2,805	2	\$730	11	\$10,635
MTG	3	\$3,200	1	\$195	1	\$200	1	\$1,400			6	\$4,995
Nitrogen fertilizers	7	\$6,393	1	\$3,000	5	\$5,352	12	\$10,490	4	\$438	29	\$25,673
Polyethylene	5	\$922	2	\$386			7	\$2,467	1	\$20	15	\$3,796
Propylene	2	\$1,380			1	\$1,200	4	\$2,499	2	\$357	9	\$5,436
Steel									4	\$2,755	4	\$2,755
Grand Total	29	\$33,119	8	\$11,846	9	\$7,924	40	\$37,048	26	\$7,927	112	\$97,865

Table 2: Counts of Projects and Total Investments in Major Gas-Using Industries (\$ million)



Ethylene

Ethylene can be produced from a variety of natural gas liquids (NGLs) including ethane, propane, butane, or petroleum products such as naphtha. In the United States, ethylene production has been switching to ethane as feedstock in recent years since ethane supplies have quickly increased owing to the growing production of wet gas from unconventional plays. The price of ethane has collapsed in the early 2012 due to inability of the pipeline and processing infrastructure to handle increasing volumes (Figure 7). The prices for heavier molecules also fell but stabilized at a much higher level until the oil price collapse in late 2014. The volume of ethane that is being "rejected" is estimated at about 250 to 300 thousand barrels per day and might triple if drilling activity in Marcellus, Eagle Ford and other liquids-rich locations continues at its recent pace. Even if drilling, and, in consequence, production slows down as a result of low oil prices, this excess supply situation is expected to last several years until ethylene production units and ethane export facilities are built.





However, the call for ethane from ethylene producers, especially from new plants, is now challenged because of significantly lower naphtha and gas oil prices. The ethylene economics is not straightforward; naphtha-based crackers generate significant value from byproducts such as propylene, butadiene, raffinates and aromatics, prices of which fluctuate over time as a function of their own demand-supply dynamics. Moreover, there are regional differences in terms of prices of feedstock and outputs across the U.S. Gulf Coast, Western Europe, Middle East and Far East Asia. It might be difficult for a brand-new ethylene plant that needs to recover its capital investment to compete with an existing cracker that mostly uses naphtha or gas oil, in the Middle East or Asia —especially if these facilities are subsidized.

In addition, global ethylene capacity has been increasing, especially in the Middle East and Asia-Pacific. Between 2008 and 2014, capacity has doubled in the Middle East and Africa region as reported by the Oil & Gas Journal while the capacity growth in the Asia-Pacific region was 38% over the same time period. The latter region surpassed North America in 2010. New capacity in the U.S. Gulf Coast will not be sufficient to close the gap. The demand growth has been mostly in line with capacity growth but,



given signs of a slowing global economy, continued growth cannot be assured. In any case, the global market for ethylene and byproducts deserves further analysis beyond the scope of this report.¹²



Figure 8: Global Ethylene Capacity (tons per year)

For now, following ethylene projects listed in Table 2 above, remain worth tracking. More details are provided on some projects in the Geographic Distribution section below.

- Ethylene production units represent a total of \$41.3 billion worth of investment across 24 facilities. The total incremental capacity of these projects is 16 million metric tons per year (MMTPA) of ethylene.
- > Out of the 24 projects, 13 are new builds, and 11 are plant expansions.
- Many of the expansions have been announced to come online by 2014 and new builds are expected online by 2017 (Figure 6). Seven new ethylene projects are expected to be online in 2017 with 8.2 MMTPA of additional capacity.
- At the time of writing, seven expansion projects have been completed; nine projects are in the phases of equipment procurement and construction; two projects are in FEED or permit stages. Remaining six projects with announced total capacity of 5.3 MMTPA of ethylene are in planning and hence excluded from our Reference Case calculations.
- Overall, we expect 11 MMTPA of incremental ethylene capacity to come online by 2020 in the CEE Reference Case.

Ammonia and its derivatives

Low natural gas prices have boosted the profitability of domestic ammonia production, and a large number of ammonia, urea, and fertilizer plants are expected to be online by 2019.

Nearly \$26 billion across 29 projects is currently being planned for investment. Many of the larger plants will be multipurpose, producing product mixes of ammonia, urea, and UAN. Ammonia capacity is expected to increase by 14 MMTPA, urea by 13 MMTPA, and UAN by 5.7 MMTPA. The future output of these products is somewhat ambiguous given that final production amounts may change with product mixes and price differentials.

¹² We are currently developing models for cracker economics, collecting historical data on byproduct prices by region to investigate ethylene markets further. This is part of a larger effort to understand NGL value chains better.



- Four projects are already completed by 2014. Two are expansions, including a debottlenecking project by Rentech Nitrogen, and one is a restart.
- 12 projects are in progress, with a total investment of more than \$10 billion and more than 7 MMTPA of capacity. These are all expected online by 2017, with 10 of them by 2016.
- Six projects are in FEED or in the process of collecting permits, with a total investment of more than \$8 billion and about 3.6 MMTPA of capacity.
- The remaining seven projects are currently in planning phase and excluded from our Reference Case.

Methanol

Between 1999 and 2006, with natural gas prices on the rise, U.S. methanol capacity had shrunk by 85 percent. Now, with lower prices supported by sustained shale gas production, U.S. methanol industry is making a big comeback.

- Eleven methanol-specific plants (as opposed to multipurpose facilities that also yield methanol) are expected to be built for a total investment of \$10.6 billion and a production increase of 15 MMPTA by 2020. Seven of these projects are built or very likely to be built, representing \$4.5 billion of investment and eight MMTPA of capacity.
 - Two projects are completed in 2013 (restart of a 780,000-MTPA plant) and 2014 (relocation of a one-MMPTA plant from Chile).
 - One project is now in FEED; and four projects are in progress. All five facilities are expected to be online by 2016.
- > Four plants are in the planning phase (not included in the Reference Case).
 - The one with the most aggressive schedule is a 1.6-MMTPA plant near New Orleans by Valero, targeting early 2016.
 - Northwest Innovation Works, a joint venture by the CECC (Shanghai Bi Ke Clean Energy Technology Co. Ltd.),¹³ Dalian Xizhong Island Petrochemical Park, and H&Q Asia Pacific, announced three similar methanol plants with total capacity of 5.5 MMTPA in WA and OR and target startup in 2018 and 2019.
- In addition, Celanese Corp. announced its intent to construct a 1.3 MMTPA methanol plant at Bishop, Texas in March 2014; but since no startup date was provided, we excluded this facility from the database for the purposed of this report.

Polyethylene

Polyethylene production is the largest ethylene derivative market and accounts for over 60% of global ethylene consumption in 2014. Polyethylene is produced in three main forms: low density (LDPE), linear low density (LLDPE) and high density (HDPE). Markets include film, packaging, containers and articles for home and light industrial use.

- There are 15 polyethylene plants at different stages of development with a total investment of \$3.8 billion and total capacity of 8.2 MMTPA. Most of these projects are expected to come online in the 2016-2017 timeframe, and are currently in progress.
- Announced along with the large-scale GTL project, the two 450,000 metric tons per year projects at Lake Charles by Sasol are in FEED phase. But, the faith of these projects is uncertain after the suspension of the GTL project.
- LyondellBasell is planning a 400,000-MTPA plant but the location has not been chosen. A joint venture by Braskem and Odebrecht is planning to launch three new plants at Wood County, WV

¹³ A Joint Venture between Chinese Academy of Science Holdings Co. Ltd. (CAS HOLDINGS) and BP.



in 2020, representing over \$400 million investment and about one MMTPA capacity. These projects are not included in our Reference Case.

Propylene

Propylene is widely used in downstream petrochemical processes to make films, packaging and synthetic fibers and is a byproduct of oil refining and petrochemical steam cracking. Both of these processes have been producing less propylene. Refineries do not upgrade as much heavier feedstock as before given the availability of competitively priced light feedstock. Similarly, lighter feedstock such as ethane is replacing heavier feedstock such as naphtha in chemical plants.

- We consider nine propane dehydrogenation (PDH) plants that are targeted to produce propylene on purpose, representing about \$5.4 billion in investments for about 4.7 MMTPA of capacity up to 2018.
- Two of the projects, expansions by Enterprise Products and Mitsui Chemicals, have already been completed in 2013, representing 255,000 metric tons of propylene production per year.
- Mitsui has another small 35,000 metric tons expansion to be finished in 2014.
- Dow is currently constructing two 750,000-MTPA plants; one is expected to come online in 2015, the other identical unit in 2018.
- Another project in progress is a 750,000-MTPA plant by Enterprise Products expected online in 2015.
- > A one-MMPTA project by C3 petrochemicals is now pursuing permits.
- Two more plants are currently in the planning phase, with an estimated \$1.4 billion in investment and roughly 1.2 MMPTA of capacity. These projects are not included in our Reference Case.

Chlor-Alkali

The production of chlor-alkali family of products is highly electricity intensive. Most of the manufacturers generate power and steam using their own gas-fired generation and will benefit from the low natural gas prices. There are six projects in our database, representing an investment of \$2.6 billion.

- ▶ Four of them, costing roughly \$2 billion, were completed in 2013 and 2014.
- A large project by HF Chlor-Alkali is in progress and will add capacity of 100,000 dry short tons of caustic soda and 250,000 short tons of muriatic acid per year in 2015.
- The other project by Shintech is still in planning and is expected to produce 300,000 metric tons per year of PVC, 300,000 metric tons per year of VCM, and 200,000 metric tons per year of caustic soda.

GTL and MTG

In order to convert natural gas to liquid fuels, one commonly used technology is Fischer-Tropsch (FT) synthesis.¹⁴ Of all gas-conversion processes, FT synthesis is where the most capital investment was proposed, primarily owing to one large facility. The \$14-billion GTL plant at Lake Charles, Louisiana by SASOL was recently suspended, presumably in response to low oil prices. Shell has abandoned plans to build a multibillion-dollar GTL plant in Louisiana, even before the fall in oil prices, "amid skyrocketing costs for the project and doubts about where U.S. oil and gas prices are headed."¹⁵

¹⁴ Primus Green Energy has developed a new patented GTL technology known as STG+, which is claimed to be more efficient, less expensive to build, and more scalable than competing GTL technologies. The company is planning to build an approximately 2,500-bpd plant in the U.S. but the exact location is yet to be determined.

¹⁵ The Wall Street Journal "Shell Backs Out of Lousiana Gas-to-Liquids Project" December 5th, 2013.



On the other hand, smaller-scale GTL solutions might be economically viable with a lower up front capital cost. None of these projects started construction at the time of writing but are moving forward.

- Calumet Specialty Products Partners is currently in the FEED stage for its 1,000-bpd plan in Pennsylvania. This plant will cost roughly \$130 million to complete and appears to be headed toward construction.
- Pinto Energy (acquired by Velocys plc in June 2014) is pursuing permits for a 2,800-bpd plant near the Port of Ashtabula, OH. Both projects will have access to abundant low cost natural gas from the Marcellus shale play.
- > Another 1,100-bpd GTL plant in FEED is at Westlake, Louisiana, owned by Juniper GTL LLC.

An alternative technology is to convert natural gas to gasoline via methanol (MTG). Six projects are reported in this category and one of them is in progress.

- G2X has started construction for a \$1.4 billion MTG facility with a capacity of 12,500 bpd at Lake Charles in Southwest Louisiana.
- A 15,000-bpd project by Sundrop is currently in FEED status. Both G2X and Sundrop have licensed ExxonMobil's MTG process technology for their projects.
- > A 2,000-bpd project in Pennsylvania reported by Marcellus GTL is acquiring permits.
- Two 14,000+ bpd plants by EmberClear are still in the planning phase and not included in the CEE Reference Case.

If all of the GTL and MTG plants (including those in the planning stage) were to be built it would entail about \$5.5 billion in capex.

Steel

Gas consumption in the U.S. steel sector fell from 1.3 BCFD in 1998 to 0.9 BCFD in 2010 due to stagnating steel production and a shift away from gas-intensive technologies. Electric arc furnace (EF) process has replaced gas-intensive blast furnace due to its cost advantage, which requires approximately 60% less direct use of natural gas. However, in recent years, direct-reduced iron (DRI), a briquette-forming process relying on natural gas and iron pellets, starts replacing scraps as raw inputs for EF steel makers. Using DRI is more cost effective and allows producers to improve output.

Four steel projects were completed in 2013 or 2014, including two new world-scale DRI plants by Essar Steel and Nucor Steel, with capacity 1.5 MMTPA and 2.5 MMTPA separately. Nucor Steel also completed a couple of expansions with total more than 1.1 MMTPA capacity added at different sites. We will deepen our investigation of new plants and, more importantly, switching to natural gas in the steel sector for the next round of database update.

Hydrogen

Hydrogen is produced by steam reforming of light hydrocarbons supplied from refinery off-gas feeds and natural gas in a steam methane reformer (SMR), then passed through pressure swing adsorption (PSA) systems for hydrogen purification. Hydrogen is used to convert heavy petroleum sources into lighter fractions suitable for use as fuels, and to produce ammonia fertilizer. In our database, we list five hydrogen projects, two of which were completed in 2013. They are operated by Praxair and each adds 135 MMSCFD hydrogen capacity. One is at Valero's St. Charles refinery in Norco, Louisiana, the other one is at Valero refinery in Port Arthur, Texas, as a result of a long-term supply contract. Two projects are now in progress and relatively small with 40 MMSCFD capacity each. Another project of similar size is in the planning phase. We are considering exploring the hydrogen projects further for the next round of database update.



Natural Gas Demand Estimation

In addition to capacities of new projects/expansions discussed above, we need two more parameters to estimate incremental natural gas demand from these facilities: unit natural gas consumption of each industrial output and average capacity utilization of plants.

Unit natural gas consumption

The unit natural gas consumption varies by different petrochemical facilities. Unit gas consumption ranges for seven major gas-intensive chemical and metal industrial sectors are provided in Table 3. The calculation of data is based on three reference sources.

- 1. An energy usage and intensity study in U.S. chemical industry by Lawrence Berkeley National Laboratory in April 2000, which summarizes the energy consumption and estimated energy intensity of ethylene, methanol, polyethylene, polypropylene and ammonia production in United States in 1994. Then we assume 10 percent efficiency improvement between 1994 and 2013 to calculate current energy intensity numbers. Shares of electricity and natural gas in manufacturing energy use can be found in EIA MECS 2010. Assuming all electricity is generated by natural gas and the efficiency rate is 60 percent, we could then calculate unit natural gas consumption in each chemical sector. This methodology is used to calculate unit natural gas usage of polyethylene production.
- 2. We obtained a range of natural gas usage in ethylene, propylene, methanol and ammonia production from the American Chemistry Council (ACC).¹⁶ A generic ethylene production unit uses about 14,000 BTUs per pound of ethylene. A propylene plant uses 3,000–6,000 BTUs per pound of propylene output. Natural gas feedstock use for methanol production consumes 96,000–98,000 BTUs per gallon of methanol output and ammonia plant uses 12,000–14,000 per pound of ammonia produced. We converted above numbers into MMBTU/metric ton. These ranges are used in calculations of unit natural gas usage of ethylene production in High Case, propylene and methanol in both Low case and High Case, and ammonia in Low case.
- 3. Statements of basis for emission permits by environmental regulatory agencies. A statement of basis usually contains the facility location, project description, added capacity, applicable emission units and BACT analysis. BACT discussion lists every applicable emission unit, such as furnaces and boilers, their annual operating hours, and their annual average firing rate. For example, in the statement of basis for Chevron Phillips Cedar Bayou ethylene plant on October 2012 (Permit Number: PSD-Texas-748-GHG), we found the statement below: "This (compliance) cap is based on the firing of seven furnaces 8,760 hours per year at the annual average firing rate of 412 MMBTU/hr, with one furnace being on standby and available for decoking." Hence the natural gas used in steam cracking furnaces would be 412 MMBTU/hr times 8760 hours, given the combustion source is natural gas. Then we added up natural gas usage of each applicable unit and divided it by capacity to estimate natural gas usage of the whole plant. This methodology is used to calculate unit natural gas usage in ethylene production in Low case, ammonia in High Case and steel in both cases.

The unit natural gas consumption numbers of GTL plants and hydrogen plants are not included in the table due to different units. For GTL plants, we use information from existing GTL plants. Pearl GTL, the largest GTL plant in the world, which is owned half by Shell and Qatar Petroleum, consumes about 1.6 BCFD of feed gas to produce 140,000 BPD and 80 MMCFD of ethane, condensate and syngas. After unit conversion, 10 MCF gas can produce 0.875 BPD liquid fuel. Nerd Gas Company has

¹⁶ Personal communication.



reported on their website that 10 MCF gas can be converted to 1 BPD of clean diesel and naphtha. Naturalgas.info also reported a similar number (10.1 MCF to 1 bpd). Hence we use Pearl GTL number in the CEE High Case, and the Naturalgas.info number in the CEE Low case.

			CEE	
NAICS	Product	CEE Low	Reference	CEE High
325110	ethylene	13.23	19.30	30.87
325191	methanol	19.70	31.97	32.63
325211	polyethylene	4.80	4.80	4.80
325211	polypropylene	5.40	6.62	13.23
325311	ammonia	26.46	30.87	36.58
331111	Steel	7.30	11.55	13.00

Table 3: Unit natural gas consumption range	es of various industries	(MMBTU/metric ton)
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An article "Time for a new hydrogen plant?" from Hydrogen Engineering February 2004 compares natural gas usage (feedstock and fuel) per 1,000 SCF hydrogen between old style plant and new style plant. The new style plant at that time is said to consume 0.443 MMBTU to produce 1,000 SCF hydrogen, which we use in the CEE Low case. An article by Air Products and Chemicals Inc. published in 2004 mentions that net efficiency for a conventional hydrogen plant is 480 BTU/SCF, which we use in the CEE High Case.

Capacity Utilization

Capacity utilization is presented as an average percentage ratio of actual output to the potential output by industry and economy-wide. The G17 form released by Federal Reserve Bank (FRB) reports industrial production and capacity utilization indexes monthly. The long term average capacity utilization rate is 76 percent for the chemical sector, 79 percent for the primary metal sector, and 80 percent for the iron and steel sector. We use these rates in our natural gas usage calculation.

Estimated natural gas demand

Based upon our review of industrial projects in various stages of development, it appears that roughly 22.1 BCFD (8.1 TCF per year) of total natural gas demand could be achieved by 2018 in the CEE Reference case, in which all projects in planning and under consideration phases are excluded and lower range of unit natural gas consumption is used (Figure 9). This level of demand is slightly higher than the AEO 2014 Reference case projection (22 BCFD) although we have not attempted to calculate potential gas utilization for some sectors (other chemicals, plastics and manufacturing). Comparing to the industrial gas use from Raymond James, our estimate is 5.2 BCFD lower in total. In the GTL and MTG sector, our number is about 2.5 BCFD lower mainly due to the cancellation of Shell and SASOL GTL plants, which accounts for about 2 BCFD gas use.

Comparing to 19.8 BCFD natural gas demand in 2012, 2.3 BCFD will be added by 2020. Fertilizer plants are expected to contribute 0.7 BCFD followed by methanol plants with more than 0.5 BCFD and ethylene plants with more than 0.4 BCFD. These three segments constitute 32 percent, 22 percent and 19 percent of our estimated industrial gas demand additions, respectively.





Figure 9: CEE Reference Case of U.S. industrial gas demand through 2020

Geographic Distribution

While some petrochemical build-out is scheduled for other parts of the United States, such as fertilizers in the farm belt, the bulk of industrial investment and gas demand will remain in the Gulf Coast region. Of the total amount of \$65 billion investment in the CEE Reference case, 26 percent will be in Louisiana, 41 percent in Texas, and 33 percent in rest of the U.S.



Figure 10: Total Investment by Industry by Region, CEE Reference Case



There are five world-scale new cracker projects (more than one MMTPA capacity) under way in the U.S. – by ExxonMobil Chemical, Dow, ChevronPhillips Chemical, Sasol, and Formosa Plastics. All five crackers are planned to be built on the U.S. Gulf Coast: one in Louisiana and the rest in Texas. There are four more world-scale projects in planning or under consideration by Axiall/Lotte, Indorama Ventures, Braskem/Odebrecht and Shell Chemical. Axiall/Lotte is planning to build a 1 MMTPA plant in Louisiana, and Indorama Ventures wants to build a 1.3 MMTPA plant, either in Texas or Louisiana. Another two are planned for West Virginia and Pennsylvania in order to be close to the long term gas supply from the Marcellus shale play and capture domestic demand in the Northeast.

Seven methanol facilities included in the CEE Reference Case are all targeting the Gulf Coast region. Methanex has completed relocation of one train from Chile to Geismar, Louisiana in December 2014 and the second is on the way. Again in Geismar, South Louisiana Methanol (A partnership of ZEEP and Todd Corp) is expected to start construction on a large facility (1.8 MMPTA) by the end of 2016. Lyondell Basell has restarted their Channelview, Texas methanol facility (0.7 MMPTA); and Celanese-Mitsui is under construction of their 1.4 MMTPA facility in Clear lake, Texas. Natgasoline LLC's 1.75 MMTPA facility at Beaumont, Texas is now in FEED status. G2X is building a small 65000 MTPA plant at Pampa, Texas. Orascom (OCI) is restarting their 750,000 tons per year multi-purpose facility in Beaumont, Texas.

Over seventy percent of investment on nitrogen fertilizer plants is outside the Gulf Coast region, while only five projects out of 22 are going to be built in either Texas or Louisiana. For domestic demand, ideal location for fertilizer plants would be the "farm belt" in the Midwest, which is targeted by 10 out of 17 facilities. Orascom (OCI) is building a 1.5 MMPTA multipurpose facility in Iowa, the largest project on deck. Cronus Chemical will build a 1 MMPTA ammonia facility in Illinois. CHS Inc. chose North Dakota for its new 0.9 MMPTA fertilizer plant. Ohio Valley Resources and PotashCorp are moving forward with their multipurpose facilities in Indiana and Ohio, respectively, adding 0.8 MMPTA capacity each. These facilities are expected to benefit from production in the Bakken in North Dakota, Utica in Ohio, and Marcellus and are close to markets for their products. Seven other projects are in Idaho, Arkansas, Oklahoma, Tennessee and Florida, either surrounding the "farm belt" area or possibly taking advantage of having access to farming communities in these states.

We also identified \$12-14 billion of investment in other chemicals, plastics, manufacturing, and metals, roughly 60% of which are expected outside Texas and Louisiana. We do not have good data on gas use for most of these facilities but most of them are not gas-intensive. Still, this upside potential for gas use is worth noting.