PCA
America's Cement Manufacturers™

MARKET INTELLIGENCE

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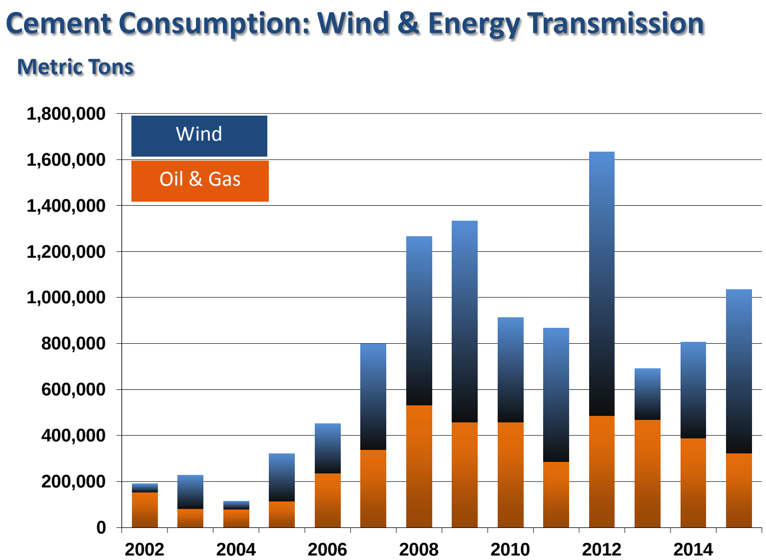
Energy-Related Cement Consumption Outlook

Overview

PCA Market Intelligence Group is engaged in a comprehensive research project that estimates long-term opportunities for cement consumption. The comprehensive study provides a 25 year outlook and evaluates both vertical (buildings) and horizontal (non-buildings) markets. The study not only estimates growth in building activity based on economic, demographic, and structural issues, such a technology changes that are likely to impact demand, but also measures material market share trends when available and identifies areas of risk as well as opportunity.

This report focuses on the United States' energy market. Market dynamics, technological advancements, and political policies have dramatically changed how the U.S. sources and consumes energy. Domestic oil production has grown 81% over the last decade while natural gas production has grown 50%. Technological advances have unlocked oil fields that have long been uneconomical to develop. In doing so, natural gas reserves have expanded substantially and become a competitive fuel source toward coal in electrical generation. Furthermore, concerns regarding climate change and carbon emissions have accelerated coal's decline in power generation. This report will assess expected cement opportunities associated with the U.S. energy market.

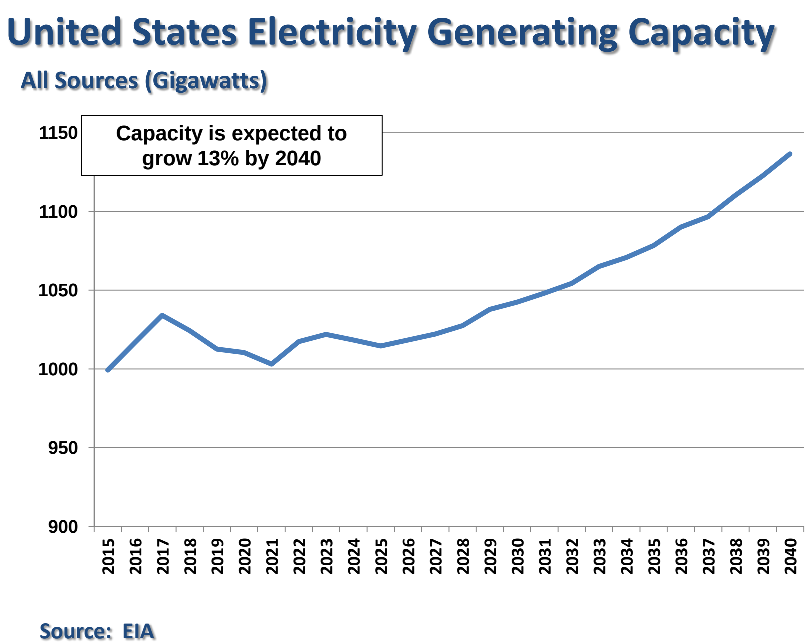


Source: PCA

The energy sector is vast and diverse. To properly identify opportunities for the cement industry, PCA focused on two segments that can provide a long-term opportunity. The emphasis for this report focuses on wind energy and pipelines. Annual cement consumption of these two segments has grown from roughly 200,000 metric tons in 2002 to over one million metric tons in 2016. In terms of the energy segment's importance, wind and pipeline construction now accounts for 1% of total cement tonnage nationally and account for substantially higher exposure in regional markets, particularly in the interior U.S.

U.S. Electricity Energy Generation

The amount of electricity produced annually in the United States has grown substantially in past decades, but the rate of growth is expected to slow in future decades. Since 1980, net electric generation has grown 78%; however, EIA projections expect net generation to expand only 13% through 2040. Slower population growth, energy efficiencies and structural economic shifts away from energy intensive industries all account for this slower pace of growth. Despite the expected subdued rate of expansion for total generation, the industry remains very dynamic in terms of how electricity is sourced. While net capacity growth is expected to slow, investment and construction into alternative types of energy sources is expected to remain robust as U.S. electrical generation adapts to a changing economic landscape and adopts new technologies.



Traditional sources such as coal and petroleum have decreased in share of electrical power generation in recent years. Coal, once the primary source of electrical generation, has declined from a peak share of 57% of total electrical generation capacity in 1988 to a historic low of 31% in 2016. Looking ahead, natural gas prices are expected to continue to further pressure coal in the near-term while in the longer run, policies such as the Clean Power Plan (CPP) and/or California's SB32 (bill requires reduction of greenhouse gas emissions to 40% below 1990 levels by 2030) will likely continue to pose as impediments to coal use. With that said, policy uncertainty is ever-present and projections assume continuation of the guidelines established under the CPP for the long run in a similar form even in the event of a CPP repeal.

Electrical Generation by Source (Million Kilowatt-hours)

	Coal	Petroleum	N. Gas	Nuclear	Hydro	Wood	Waste	Geothermal	Solar	Wind
1950	154,520	33,734	44,559	0	100,885	390	0	0	0	0
1970	704,394	184,183	372,890	21,804	250,957	136	220	525	0	0
1990	1,594,011	126,460	372,765	576,862	292,866	32,522	13,260	15,434	367	2,789
2010	1,847,290	37,061	987,697	806,968	260,203	37,172	18,917	15,219	1,212	94,652
2016	1,240,108	23,906	1,380,295	805,327	265,829	40,504	22,068	17,417	36,754	226,872

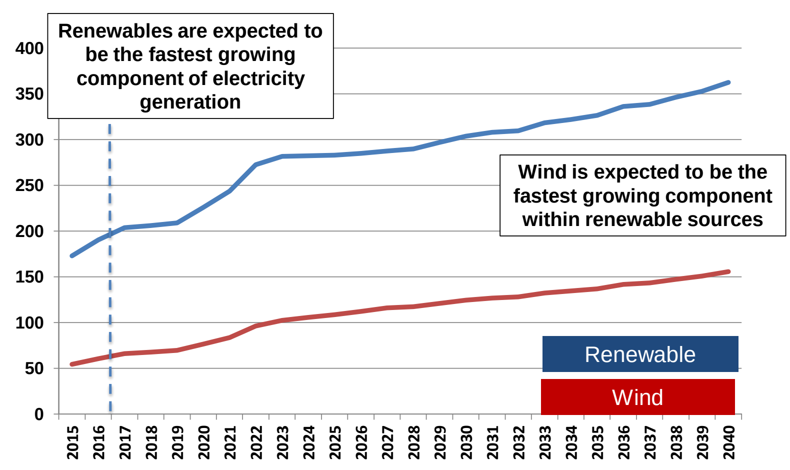
Share of Total Electrical Generation

	Coal	Petroleum	N. Gas	Nuclear	Hydro	Wood	Waste	Geothermal	Solar	Wind
1950	46%	10%	13%	0%	30%	0%	0%	0%	0%	0%
1970	46%	12%	24%	1%	16%	0%	0%	0%	0%	0%
1990	53%	4%	12%	19%	10%	1%	0%	1%	0%	0%
2010	45%	1%	24%	20%	6%	1%	0%	0%	0%	2%
2016	31%	1%	34%	20%	7%	1%	1%	0%	1%	6%

Source: EIA

In the context of the decline in electricity derived from coal, renewable energy sources have steadily increased from 8% of capacity in 1988 to 14% in 2016. Looking ahead, the EIA anticipates renewable energy sources to expand to 19% of electrical generation by 2020 and 27% in 2040.

United States Electricity Generating Capacity
(Gigawatts)



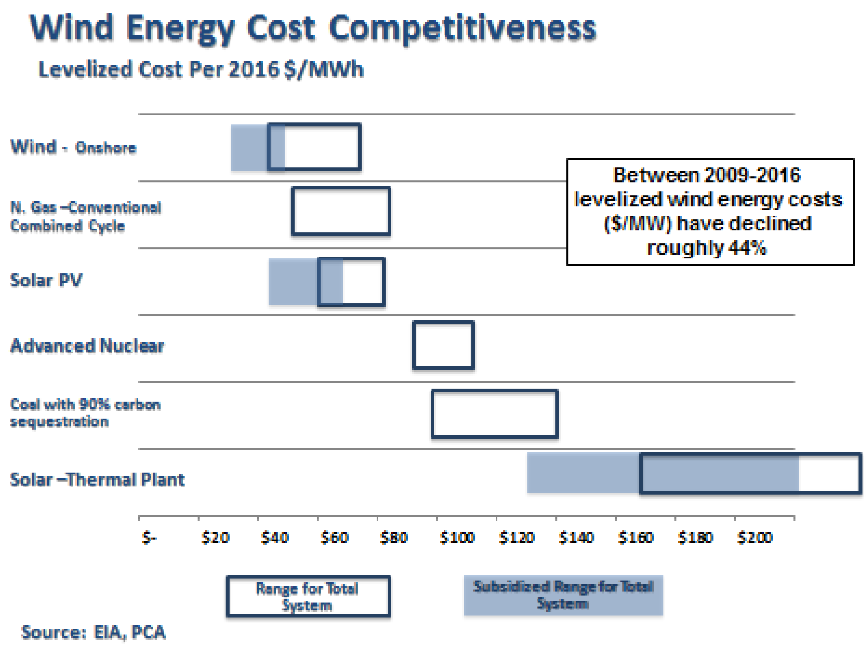
Source: EIA, PCA

Driving much of this growth in renewable energy sources is the expected acceleration of wind turbine capacity. Over the course of the next ten years it is estimated wind energy will represent 75% of renewable energy growth. Toward the backend of the outlook, as wind energy growth eases, solar is expected to lead growth in renewable energy.

Cost of Electricity by Source

As with many construction decisions, cost is a key factor in determining which technology is utilized in electricity generation. The number of available technologies varies dramatically and each has its own unique set of capital, fuel, and maintenance costs. As a means to allow for cross-analysis, PCA examined the levelized cost of electricity (LCOE) which is a measure of overall competitiveness based on a per-kilowatt-hour cost breakdown. This methodology assumes a set financial life of the competing technologies in conjunction with assumed utilization rates and discounts the costs to inflation adjusted real dollars. Like any measure, it does have its limitations such as an inability to capture regional fuel cost differences, state & local programs, or power purchase agreements. With that said, LCOE still serves as a valuable high-level tool to put competing technologies in relative perspective.

On an initial cost basis, wind energy remains among the most expensive electrical energy sources with an average installation price of $1,661 per kilowatt compared to $696 per kilowatt for natural gas[1]. However, given lack of fuel needed to produce electricity, wind has become the lowest-cost type of energy on a levelized basis. This cost advantage now exists on both a subsidized and unsubsidized basis and continues to improve as costs decrease. Presently, project costs of wind energy construction have fallen 27% from past peak levels set in 2009. Improving industry production scale, technological

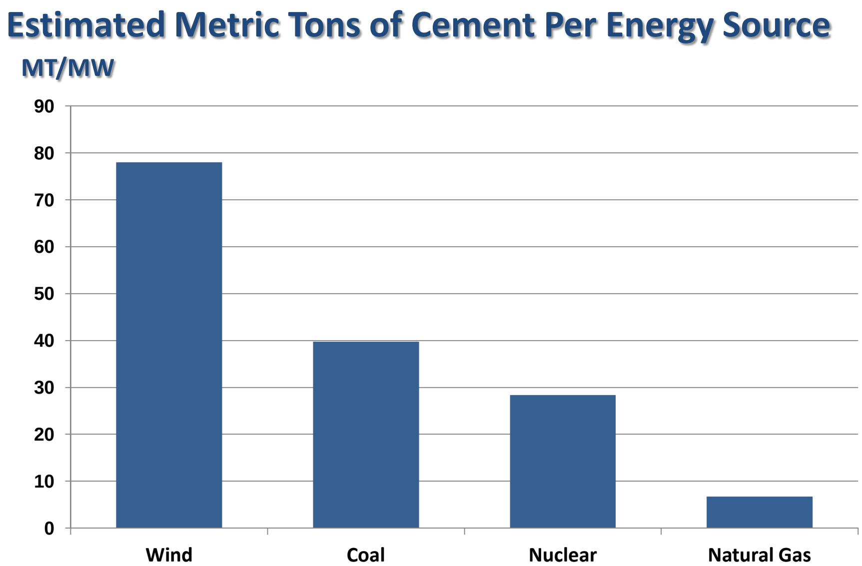


advances, as well as improving siting techniques have all contributed to the cost reduction. This improving cost dynamic supports the outlook that wind energy will remain among the fastest growing components in renewable energy sources.

[1] U.S. Energy Information Administration (EIA), *Construction costs for most power plant types have fallen in recent years, 2017.*

Wind Energy Cement Opportunity

Electrical generation construction can be a very cement intensive application. As the technologies vary, so can the amount of cement used by type. To normalize this information, PCA estimated cement consumption by electrical energy source on a per megawatt (MW) basis. Based on this metric, wind energy is the most cement intensive application. Nuclear generation, despite popular conceptions, has a much lower cement intensity on a per MW and initial cost basis. Furthermore, the outlook for domestic nuclear energy construction is bleak. Recent U.S. projects have faced substantial cost overruns and project delays/halts. Coupled with lack of political will and poor economic competiveness in the context of cheaper alternative energy sources, PCA expects minimal nuclear plant construction activity throughout the forecast horizon.



Source: PCA

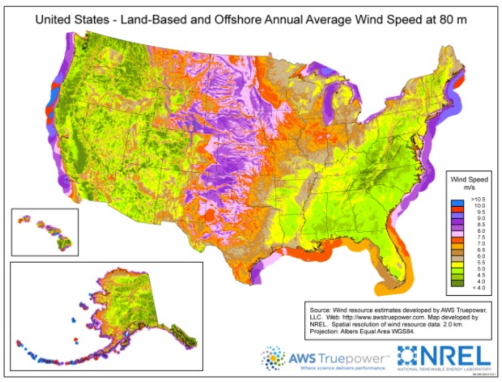
Wind energy poses a unique opportunity for cement. Standard wind turbine height is 50 meters but wind turbines are increasingly approaching and exceeding 100 meters in order to access faster, sustained wind speeds. Wind turbines undergo complex dynamic load conditions and therefore require secure foundations. Types of foundations vary vastly and are determined by numerous factors such as tower height, cost, subsurface geology and water table levels. Foundations can be divided into two groups: spread foundations and piled foundations. The most common base is a spread foundation, typically the octagonal gravity base which consumes an estimated 40 to 140 metric tons of cement depending on size. Given the remote nature of wind fields, soil cement opportunities also exist in stabilizing access roads for construction and maintenance traffic. Based on the scope of this report, soil cement opportunities are not included in the analysis.

Concrete Towers

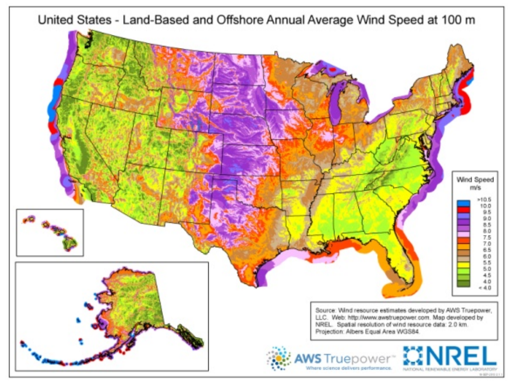
The demand to reach taller heights is ever present in wind energy. As height increases, winds become stronger and more sustained. Turbine blade length can increase with height and allow for higher MW turbines. Additionally, many state governments have implemented and/or expanded renewable portfolio standards which grant credits to renewable sourced energy. Higher towers could expand geographic footprints and allow additional areas around the country to add wind to their renewable energy portfolio.

Tubular steel towers have dominated U.S. wind turbine construction but these towers face a practical limit of roughly 80 meters due to road transport logistics constraints and weight scalability with height. Weight scalability is a concern as additional steel is needed at increasing rates with height to add stiffness in order to combat the greater forces exerted at and above 100 meters. Therefore, costs can grow exponentially in steel towers with height.

Alternative tower designs such as concrete towers and hybrid steel/concrete towers have been growing in presence. The components can consist of precast or cast-in-place concrete but tend to favor precast given the cost savings of scale with larger wind farms. On an initial cost basis, concrete towers become more competitive when towers reach 100 meters and above. On a life cycle basis the cost advantage improves substantially as concrete towers exceed the typical 20 year tower life of steel – by a margin up to 20 years. Concrete towers also offer a structural advantage as the material offers greater stiffness and damping to counteract the complex dynamic load conditions exerted on tall towers.



Sustained wind at 80M (brown through blue scale is wind turbine viable).



Sustained wind at 100M (brown through blue scale is wind turbine viable).

Given the rigid nature and weight of concrete towers, this construction type will require fewer materials for concrete foundation construction. PCA estimates foundation concrete consumption would decline between 20%-60% to that of foundations for traditional tubular steel towers. However, overall cement consumption is expected to grow roughly 45% on net for each concrete tower compared to traditional 80 meter tubular steel tower. PCA estimates concrete tower and hybrid tower currently have a market share of 3%. In terms of promotion opportunity, 1% gain in concrete tower market share would yield roughly 24,000 additional metric tons per year on average.

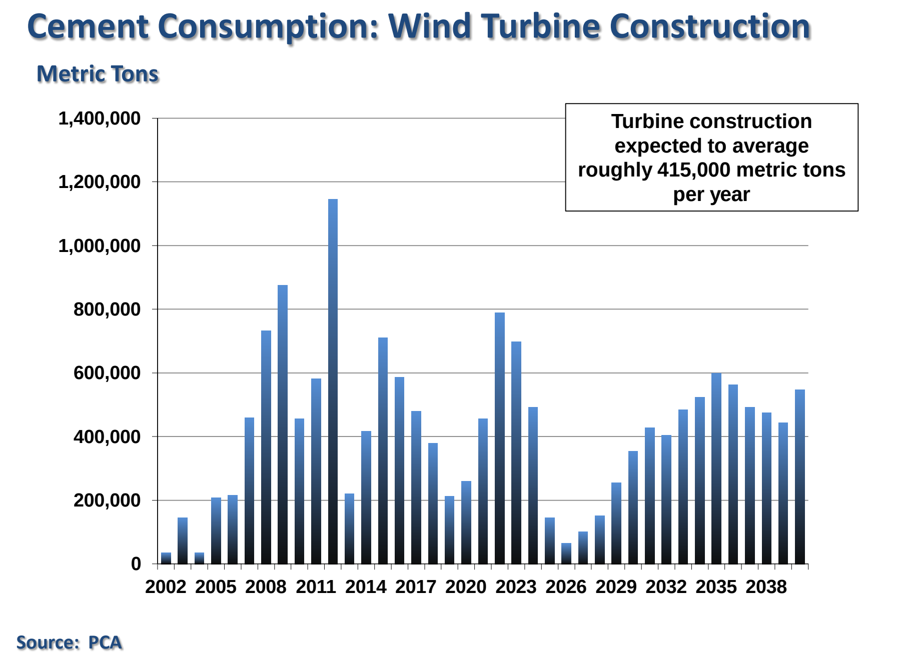
Wind Energy Cement Outlook

Given the improvement in relative cost and policies moving towards carbon neutral energy sources, wind energy construction is expected to expand. To quantify this, PCA utilizes EIA energy electrical energy source projections[2]. Based on these capacity projections, PCA estimates the current weighted average strength of wind turbines in place based on a per MW basis. Assuming 1.6 MW per turbine on average, PCA can therefore extrapolate the number of placed turbines. Throughout the forecast horizon the 1.6 MW average increases to an assumed 2.6 MW to capture larger, taller turbines as grid efficiency demands increase. From these estimated turbine counts, cement intensities are applied ranging from 40

[2] U.S. Energy Information Administration, *Annual Energy Outlook 2017,* January 2017.

to 160 metric tons per turbine based on high-low scenarios. PCA has also taken into account replacement rates of existing wind turbines which are phased into the outlook as existing fields approach the end of their functional life.

From this analysis, PCA estimates wind turbines will on average contribute roughly 415,000 metric tons per year through 2040. This compares to a historical average volume of 183,000 between 2002 and 2007. In the short run, wind is expected to remain volatile as subsidies and polices continue to exert strong influence on the market. Current subsidies such as the Production Tax Credit and Investment Tax Credit are currently being phased out and set to expire in 2019. As the subsidies are retired and markets readjust, near-term demand is expected to soften. Longer term, as levelized costs further improve the market is expected to stabilize. Furthermore, increased adoption of precast towers has the potential to add additional volumes not incorporated in this baseline outlook.



U.S. Pipeline Infrastructure

The United States has a vast network of energy pipelines. Oil is often thought of in the context of energy pipelines, but despite a few high profile and politically controversial projects, the vast majority of pipelines in the U.S. carry natural gas. The U.S. currently has 210 natural gas pipeline systems covering 305,000 miles of interstate and intrastate transmission lines. Combined with distribution, pipeline stock represents 2.6 million miles. The U.S. is currently undergoing a boom in pipeline construction. As natural gas production geogrpahies shift in the U.S., additional pipeline construction has been necessary to carry energy from new production fields to market. Furthmore, technological advances in drilling have unlocked additioanal reserves in existing fields. This, combined with increasing global demand, is moving the U.S. into becoming the top global exporter of natural gas. According to the Federal Energy Regulatory Commission, nineteen major interstate pipeline projects have been approved in 2017 consisting of 1,091 miles with another fifteen projects pending. This compares to 219 miles approved in in the balance of 2012.

Pipeline Cement Opportunity

When pipelines are discussed, often times images of the Trans-Alsaka Pipeline System (TAPS) come to mind with the iconic raised pipeline. This pipeline is likely the most photographed pipeline as it is above ground and, therefore, lends itself to photography. However, the TAPS is much more the exception to the rule as nearly all pipelines are underground and are only raised to surface for valves and pumping stations. Depth of cover requirements for hazardous liquid pipelines range between three and four feet and vary based on regulating agency and topography[3]. Given the buried nature of pipeline construction, this application is not cement intensive.

Cement consumption in pipeline construction typically occurs at pumping/compression stations, concrete casings, concrete encasements, and thrust blocks. Concrete casings and encasements are used to protect the pipeline in dynamic load areas such as road and railway crossings, as well as to lend support to the crossings themselves. An additional use of casings can be in wetlands and serve a dual purpose of protecting the pipeline from corrosion in ecologically sensitive areas as well as for buyoancy control. Requirements for pipeline casings are not broad-based and are largely implemented by railways as a part of right-of-way specifications granted to pipelines.

Use of concrete casing in wetland during construction.

Despite not being overly cement intensive, demand for cement consumption in pipeline construction has grown dramatically in recent years. The sheer volume of energy transmission construction brought about by geographically shifting domestic sources of energy has led to substantial volumes of cement consumption. Over the last five years, PCA estimates oil and gas transmission lines have represented roughly 450,000 metric tons of cement consumption annually. This growth is up from an average of 100,000 metric tons per year prior to 2006.

Pipeline Outlook

To generate an outlook for energy pipelines, PCA utilized EIA projections[4] to measure the expected amount of natural gas consumption in the United States. These values were compared against historical pipeline capacity to gauge future expansion needs. Historical net changes in capacity were also analyzed in the context of PCA apparent use of cement and the category containing Electric/Gas/Communication Transmissions. Gas transmission cement figures were isolated using historical records of interstate gas projects as well as Dodge Contract Awards. From this historical intensity, PCA applied the figures to the energy outlook to estimate future demand of cement in energy transmission construction.

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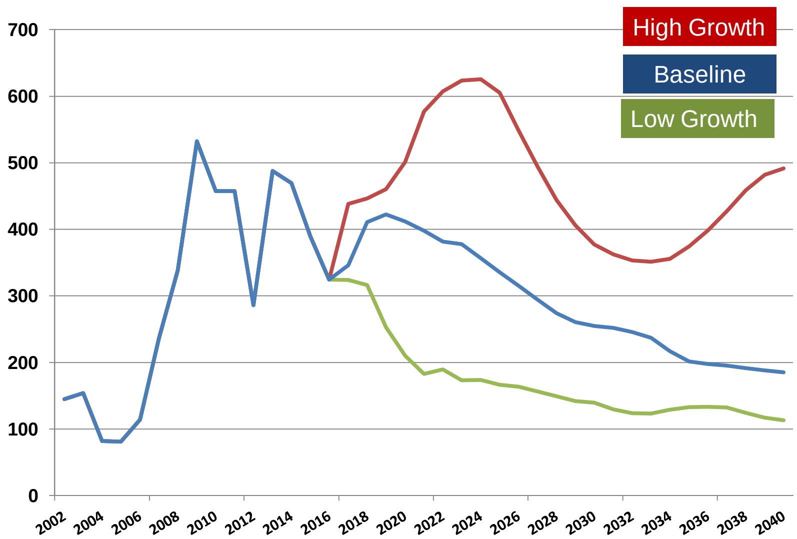
[3] American Petroleum Institute, Association of Oil Pipelines, *Damage Prevention Toolbox: Pipeline Depth of Cover*

[4] U.S. Energy Information Administration, *Annual Energy Outlook 2017,* January 2017.

Cement Consumption: Energy Pipelines

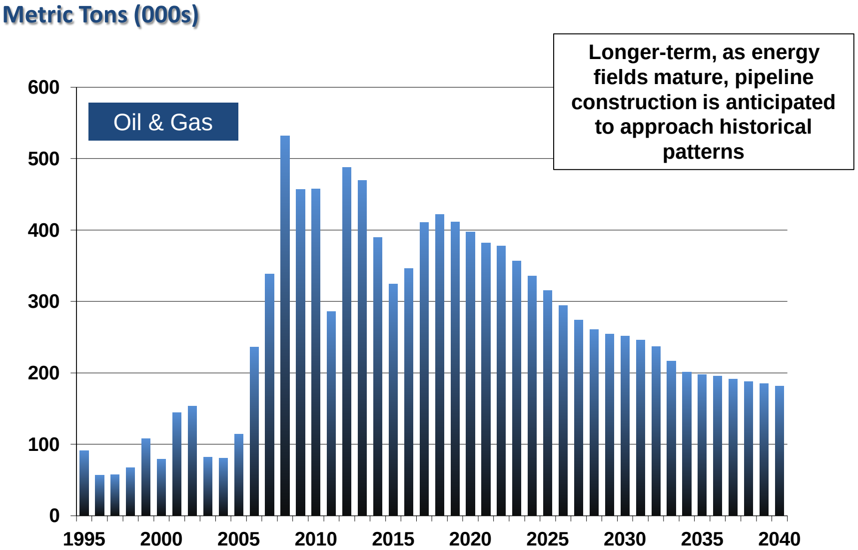
Metric Tons (000s)



This outlook utilizes the EIA's reference base case outlook as well as high/low scenarios. The alternate scenarios lead to substantial variance from the baseline. This is unsurprising given the volatile nature of energy prices coupled with changing technologies that can unlock additional reserves. The high scenario assumes higher recovery of existing U.S. reverses as well as a 50% increase in undiscovered resources estimated in the baseline. The low scenario assumes lower recovery of existing U.S. reserves as well as a 50% decrease in undiscovered resources from the baseline.

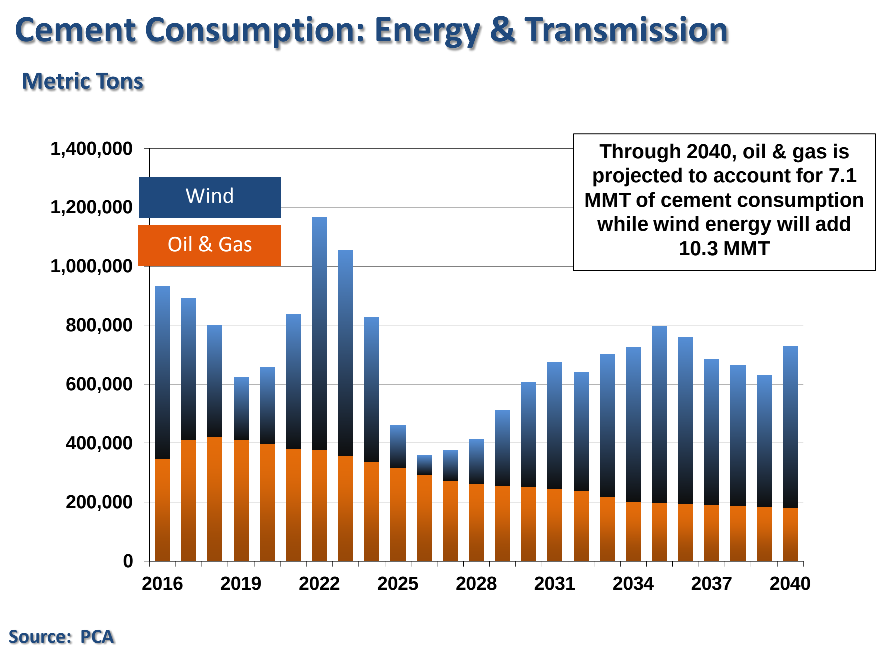
Cement Consumption: Energy Transmission

Metric Tons (000s)



Source: PCA

The outlook expects demand to oil and gas pipeline related cement to remain elevated through 2025, averaging roughly 375,000 metric tons per year. Further out, energy transmission cement is expected to decline as domestic energy production matures and regional balances between supply and demand stabilize. Between 2025 and 2040, average energy transmission cement volumes are expected to decline to 200,000 metric tons per year with volumes decreasing throughout the balance of the forecast.



Under PCA's high scenario, cement consumption in energy pipelines could peak above 600,000 metric tons as additional pipelines and LNG export facility construction accelerates. PCA's low scenario estimates a rapid decline in pipeline construction as lower than expected supply leads to excess pipeline capacity and brings cement volumes back into historical norms.

Overall Cement Consumption Projections

According to the baseline scenario, 811,000 metric tons are expected to be consumed in wind and pipeline construction by 2040. This amount compares to an average annual volume of 128,000 metric tons between 2002 and 2006. Energy pipelines are expected to decline in share of roughly 40% of energy volumes in 2020 to 23% with substantial variation in intermediary years given the inherent volatility of energy.

Energy Cement Consumption Outlook
(000 Metric Tons)

		2020	2025	2030	2035	2040
Wind Turbine Placement	Baseline	623	43	450	578	626
	Low	422	26	267	299	292
	High	803	141	505	1,070	669
Energy Pipeline Construction	Baseline	412	335	255	201	185
	Low	210	167	139	133	113
	High	501	605	377	374	491
Total Energy	Baseline	1,035	379	705	780	811
	Low	632	192	406	431	405
	High	1,304	746	882	1,444	1,160