GPEC GAS POWER
ENGINEERING & CONSTRUCTION
JUNE 18-19, 2018 | PITSBURGH

U.S. Natural Gas Power Engineering and Construction Trends and Outlook 2018

The U.S. Natural Gas Power Engineering and Construction Trends and Outlook 2018 report provides a distinctive analysis of why natural gas is quickly becoming a prime fuel choice for new power generation and taking a majority for best source of electricity generation in the United States. An overview on what factors are driving investment, the capex and maintenance investment outlook for this segment and details on the new builds is provided. Interviews with industry experts provide insight into the future of construction and engineering trends for natural gas power plants in North America.

Featuring Insight from:

Karl E. Humberson
Director Generation Projects
Generation Construction
Dominion

Bruce Turczynski
Management Consultant
BT All Gen Engineering
Former VP
Development and Project Management
Constellation

Dan Fahrer
Director, Major
Enterprise Projects,
DTE Energy

Dale Linaweaver
Energy Industry
Management Consultant

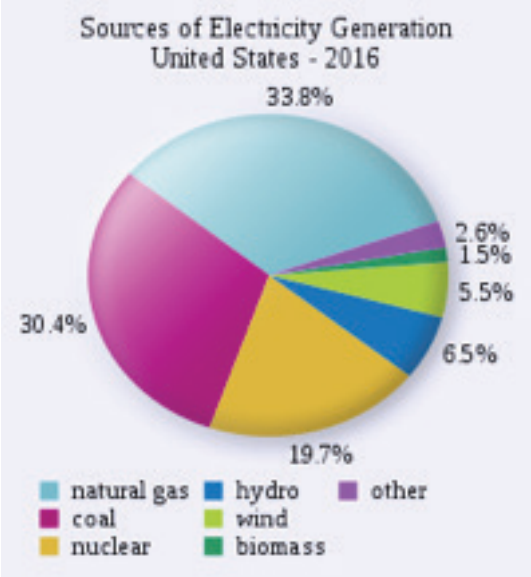
Table of Contents

INTRODUCTION

Change is the key theme for North American power markets. Change in how electricity is generated and change in how plants are designed, developed and constructed; change in grid management and change in legislation, taxes, environmental regulation and demand are all fueling the future decisions and investment of the power market. Ingenious solutions are being researched and implemented daily as the US power industry strives to supply reliable and affordable electricity to a growing population, while also reducing carbon emissions.

As nuclear-fired plants retire, and coal fired units are shuttered, gas and renewables are making up an increasingly larger piece of the pie. Gas and renewables continue to comprise most incremental new capacity in the U.S. and North America. The U.S. Energy Information Administration (EIA) projects that by 2025 renewables will comprise 24% of net generation in the power sector, with gas comprising 26%.

In 2016, about 4.08 trillion kilowatt hours (kWh) of electricity were generated at utility-scale facilities in the United States, according to data from the EIA. About 65% of this electricity generation was from fossil fuels (coal, natural gas, petroleum, and other gases), 20% from nuclear energy, and 15% from renewable energy sources. The EIA estimates that an additional 19 billion kWh (or about 0.02 trillion kWh) of electricity generation was from small-scale solar photovoltaic systems in 2016.



The discovery of shale gas and fracking the gas out of the basins has altered the previous $8-12/MMBtu price of long-term natural gas fuel supply contracts on the U.S. down to the $3/MMBtu range making the fuel a cost effective resource for power. Natural gas is becoming a prime fuel choice for new power generation and now ahead of coal for highest percentage of U.S. capacity.

With new capex and maintenance investments in the billion dollar range, schedules spanning years and an ever changing supply/demand outlook, owners and contractors must be prepared for the enormous challenges that come with project management of these mega projects. Read on to discover key trends shaping the industry, an update on projects and investment, and gain insight and real examples from engineering and construction leaders who have recently completed mega capital projects.

1. US POWER MARKET OVERVIEW AND OUTLOOK

Growth in natural gas fueled power facilities is largely driven by an aging fossil infrastructure, customer needs for greater power flexibility and efficiency, increased legislation, costs and the amount of time it takes to build a facility.

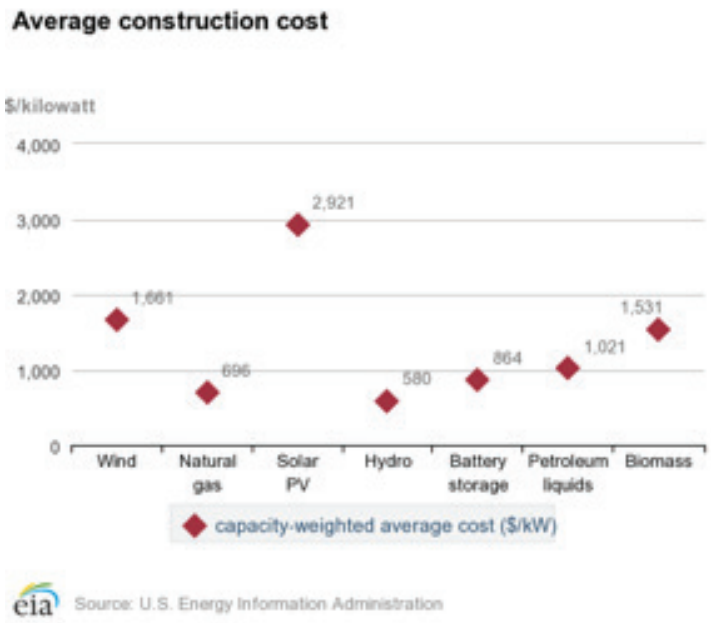
"It is time to invest and grow in the big scheme of things. It is prudent to move forward. There is growing need for improved emissions controls and efficiency and an overall move to renewables," said Dan Fahrer, Director of Major Enterprise Platforms (MEP) at DTE Energy. "Gas power is considered more reliable over renewables. The industry needs reliable gas-based generation to support renewables which have outputs predicated by the weather."

In areas such as Texas, California, and the Northeast where states have renewable energy requirements, a sudden storm or windless, overcast day can shutter renewable power.

"If a storm comes through and it is cloudy and not much sun to boost solar power or if there is not enough wind for wind power, peakers are needed to come on quickly for grid stability. In most cases wind and solar do not have the same grid support capabilities as a peaking plant (for example, voltage and frequency support)," said Bruce Turczynski, Management Consultant for BT All Gen Engineering. "With states increasing their renewable requirements, the flexibility that gas power offers is essential."

Construction costs for natural gas fueled power plants at around $696 ($kW) capacity weighted average cost are one of the lowest just behind hydro power to build, according to data from the EIA. This compares to solar at $2,921 (kW), wind at $1,661 ($kW) and biomass at $1,531 ($kW).

"Nuclear plants are cost prohibitive and have longer build cycles. The natural gas plants take two to three years to build. With low natural gas prices, we can keep power rates lower for customers," said Karl E. Humberson, Director Generation Projects Generation Construction at Dominion.



The entire power industry is facing increased environmental pressure pushing power companies' decisions on which type of fuel source to use.

"Considering the Clean Power Plan and the current administration, I believe there will be even more regulations on greenhouse gas emissions and C02 emissions to come," Humberson said. "When you look at the base energy supply plans, natural gas is the best for environmental needs."

To continue growth, infrastructure hurdles must improve. Natural gas pipelines must be built, especially in the Northeast where the Marcellus and Utica Shales are producing significant amounts of natural gas. Project managers lament that the FERC approval process to get pipelines started is long and challenged by multiple groups and must be considered as a key hurdle in project planning.

Legislation to keep nuclear and coal plants alive and running and to push renewables is ever increasing adding pressure to natural gas power.

“Measures to subsidize nuclear plants to keep their capacity and the potential for similar measures to keep coal plant capacity along with easing of environmental requirements will put additional pressure on the viability of gas plants,” Turczynski said. “ We are anticipating that with the previous mild winter and relatively mild summer there will be several or more merchant bankruptcies in 2018. “

“Gas plants, especially peakers do have a niche market in support of grid stability where there is significant renewable market penetration,” he added.

Gas power plants replace closed plants, while simultaneously forcing closures of older plants

A rush to build power plants fueled by cheap natural gas from the Marcellus and Utica Shales in the northeast will swell power supply in the region coordinated by PJM Interconnection, operator of the largest power grid in North America, driving down prices and forcing the closure of many coal-fired plants over the next four years, according to analysis by Moody’s Investors Service.

The report predicts that power supply within the 243,417 square mile area covered by PJM will surge by 25% by 2021, causing on-peak electricity prices to drop by 15% and leading to widespread closures or conversion to gas at coal-fired plants. Power grid operator PJM manages the movement of electricity to 65 million people living in Pennsylvania, New Jersey, Delaware, Maryland, Virginia, Washington, D.C., West Virginia, Ohio, and parts of Illinois, Michigan, Indiana, Kentucky and North Carolina.

The Moody’s report said that inefficient gas-fired plants will also find it hard to compete, while nuclear plants will depend on whether fossil fuel interests succeed in their legal challenges to state subsidies. If they do, a reduction in supply from uneconomic nuclear plants could help coal-fired plants survive.

The additional supply will come from plants using combined gas cycle technology, a process that produces competitively priced electricity, and is more efficient than open cycle gas turbine or steam turbine technology used by other gas-fired generators, the report said.

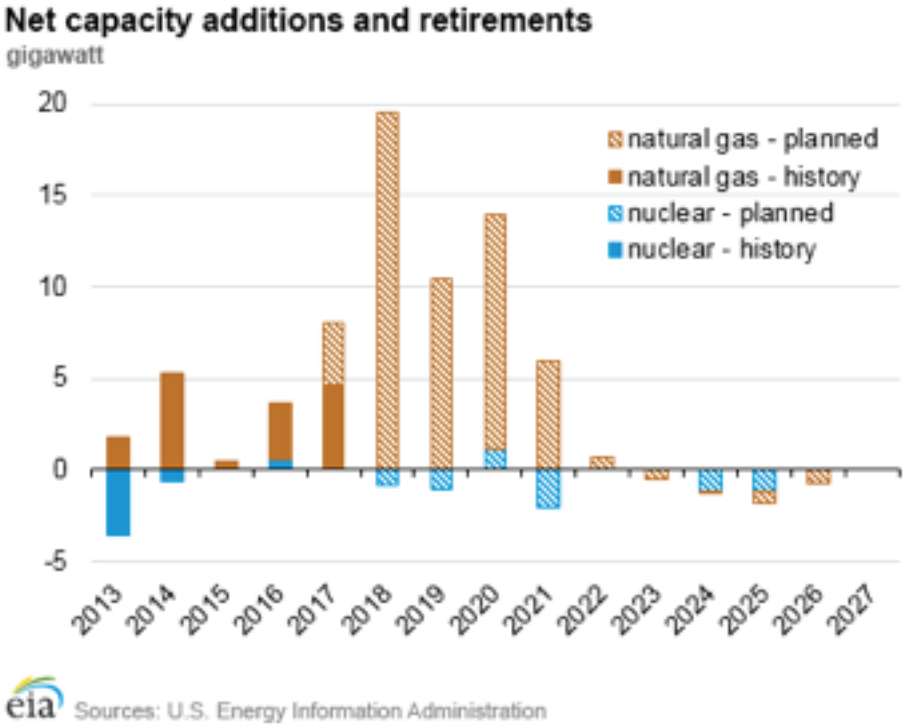
As the new efficient gas plants begin operation, there are likely to be “widespread” retirements of coal-fired plants, including some of the largest units on the market.

Coal plants that don’t have easy access to gas are likely to shut down. “We believe that a large share of coal plants not near a gas pipeline will probably be closed,” the report said.

Surging supply will coincide with little or no increase in demand. The report projects that peak demand, when adjusted for weather, will grow by only 0.2% a year for the next 10 years. The flattening of demand is due, in part, to greater energy efficiency.

Nuclear Power

As nuclear power plants shut down, natural gas-fired generation capacity is growing.



In the past seven years, six nuclear power plants announced their intentions to retire early. The most recent announcement came in May 2017 from Exelon's Three Mile Island power plant in Pennsylvania. These six plants have a current operational capacity of about 7.2 gigawatts (GW) with an average capacity factor of 95%.

In addition to these plants, construction of South Carolina Electric and Gas Company's 2.2 GW (capacity factor of 100%) VC Summer power plant was halted in July 2017. While nuclear capacity is expected to decrease in the next eight years by 7.2 GW, announced builds at natural gas-fired power plants will offset some of the lost capacity.

Generation from nuclear energy accounts for almost 20% of total generation in each year from 2016 through 2018.

As of July 2017, natural gas-fired generation capacity was slightly more than 40% of total U.S. operating capacity, with the net summer capacity for natural gas-fired generation at about 453 GW (average capacity factor of 88%). About 54% of the natural-gas fired capacity comes from natural gas combined-cycle (NGCC) plants.

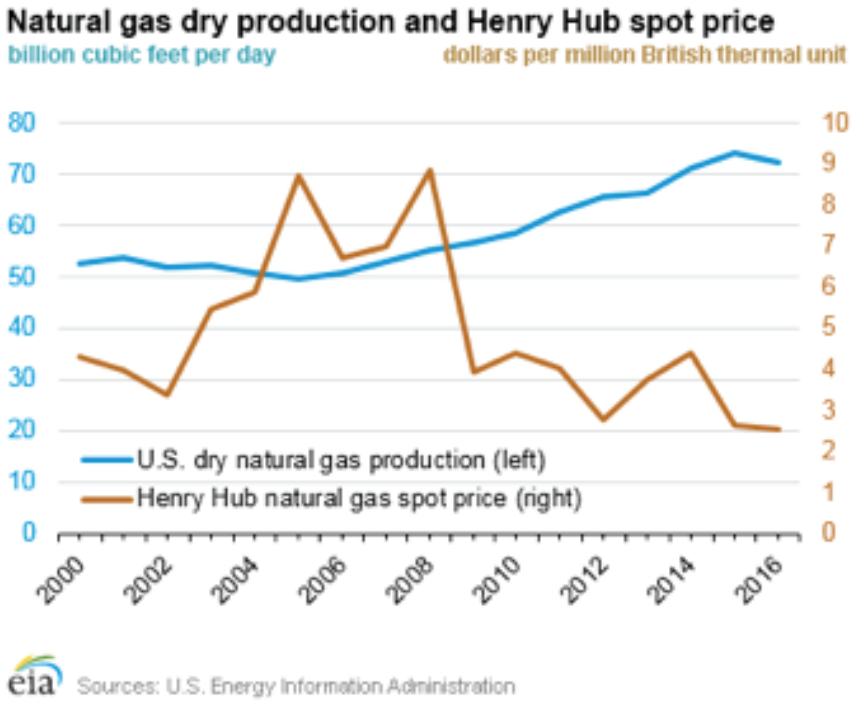
Between 2013 and 2017, 25 GW (average capacity factor of 91%) of natural gas-fired generation capacity retired; many of these generators were steam turbines (about 72% of the capacity retired) and most were older generators with an initial operation year between 1950 and 1980 (87% of the capacity retired).

In comparison, as of July 2017, nuclear generation net summer capacity totaled 99 GW (average capacity factor of 95%). Although no nuclear plant retirements occurred between 2002 and 2012, from 2013 to 2017, five plants, with a combined capacity of 4.7 GW (average capacity factor of 99%), were retired. From 2013 to 2016, average net generation for electric power from nuclear energy remained nearly flat, and the generation from natural gas has grown by about 6% per year.

Through 2027, planned natural gas generation capacity additions total 62 GW for 130 projects. More than three-quarters of the planned capacity are from NGCC plant builds. The two NGCC projects with the largest planned capacity are Citrus County Combined Cycle Plant (1.6 GW) and Okeechobee Clean Energy Center (1.7 GW), both located in Florida. The capital

cost estimate for a nuclear power plant is more than six times greater than that of a NGCC plant on a per kilowatt basis. One nuclear plant has planned construction in the next few years, the Vogtle project in Georgia, with a total capacity of 2.2 GW.

Dry natural gas production has increased steadily over the past decade, averaging 72 billion cubic feet per day (Bcf/d) over 2014–2016. During that same time period, the Henry Hub spot price for natural gas averaged $3.17 per million British thermal units (MMBtu) and reached its lowest annual price in seventeen years in 2016 at $2.52/MMBtu.



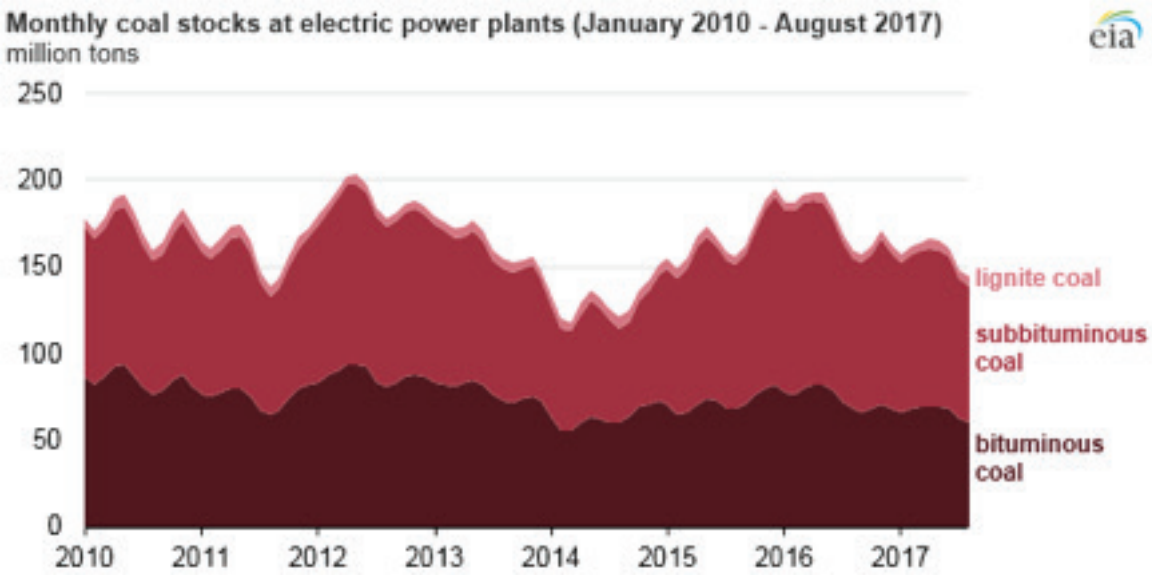
Lower natural gas prices combined with increased electricity generation from natural gas-fired plants contributed to a decrease in electricity prices. In 2016, the national average wholesale price for electricity was about $30 per megawatt hour (MWh), about 17% lower than in the previous year.

Renewables and Coal

The EIA expects the share of U.S. total utility-scale electricity generation from natural gas will end up falling from an average of 34% in 2016 to about 31% in 2017 as a result of higher natural gas prices and increased generation from renewables and coal.

Coal's forecast generation share rises from 30% in 2016 to 31% in 2017. The projected annual generation shares for natural gas and coal in 2018 are 32% and 31%, respectively. Coal production for the first 10 months of 2017 is estimated to have been 656 million short tons (MMst), 59 MMst (10%) higher than production for the same period in 2016. Annual production is expected to be about 790 MMst in both 2017 and 2018.

In August 2017, coal stockpiles at electric power plants were 144 million tonnes, the lowest monthly level since late 2014, according to the U.S. EIA's Electric Power Monthly. Coal stockpiles at U.S. coal-fired power plants typically follow a seasonal pattern of increasing during the spring and fall, when electricity demand is relatively low, and decreasing during the summer and winter, when electricity demand is relatively high. Coal stockpiles typically reach their lowest point in August.



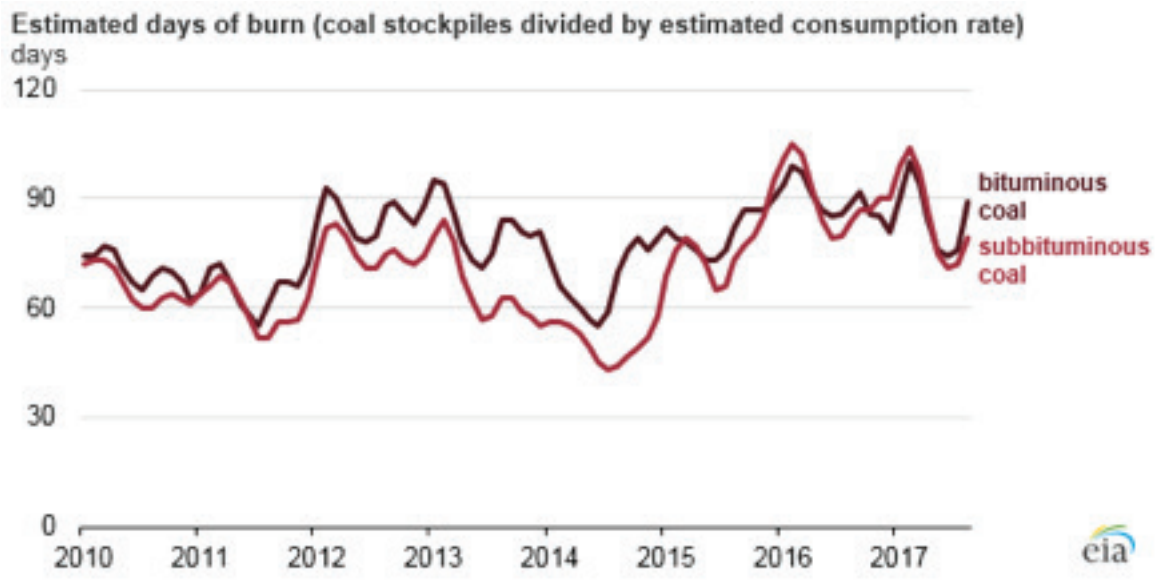
Coal plants generally stockpile much more coal than they consume in a month. Coal consumed by power plants follows the seasonal pattern in overall electricity generation, meaning coal consumption is typically highest in summer and winter months and lowest in spring and fall months. Coal receipts at power plants fluctuate less than consumption, but they have averaged 53,000 tons in each month of 2017, slightly lower than the average monthly consumption rate of 56,000 tons, based on data through August.

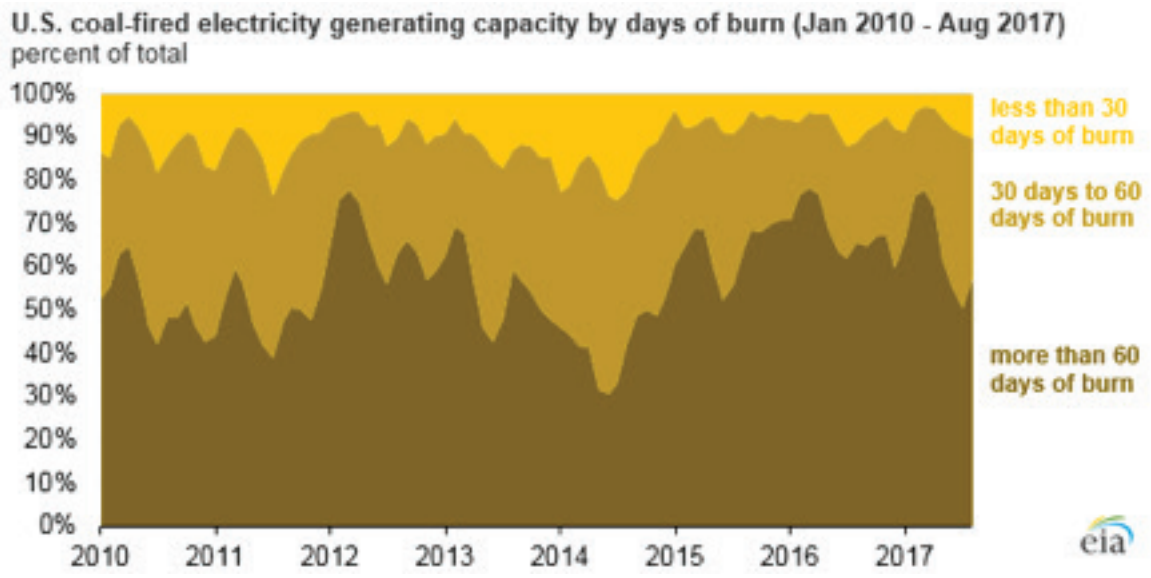
Coal receipts are less variable than consumption because the producing mines and coal transporters (mainly railroads) generally require power plants to receive coal at a roughly constant rate during the year.

In addition to surveying coal stockpile levels, EIA also calculates how long these stockpiles would last assuming no additional coal was received. This value, known as days of burn, considers each plant's current stockpile level and its estimated consumption rate in coming months. EIA estimates the historical burn rate by averaging the most recent three years of historical data and applying that to the upcoming months.

As of August 2017, about 55% of total coal stocks were subbituminous coal, most of which is produced in Wyoming. On average, coal plants using subbituminous coal can operate about 80 days at August 2017 stockpile levels. Another 42% of coal stocks are bituminous coal from states such as West Virginia, Kentucky, and Pennsylvania. Plants using bituminous coal can operate about 90 days at August 2017 stockpile levels. Individual plants may be capable of operating on much shorter or longer timelines, depending on their own stockpile levels and consumption rates.

In the Electricity Monthly Update, individual plant-level stockpile estimates are aggregated into three categories: those with more than 60 days of burn, those with 30 days to 60 days of burn, and those with less than 30 days of burn. As of August 2017, 57% of U.S. coal-fired electricity generating capacity had more than 60 days of burn. About 33% of capacity had between 30 days to 60 days of burn, and the remaining 10% had fewer than 30 days of burn.





Renewables

Generation from renewable energy sources other than hydropower is expected to grow from 8% in 2016 to a forecast share of about 9% in 2017 and 10% in 2018, according to the EIA.

Wind electricity generating capacity at the end of 2016 was 82 GW. The U.S. EIA expects wind capacity additions in the forecast to bring total wind capacity to 88 GW by the end of 2017 and to 96 GW by the end of 2018.

Total utility-scale solar electricity generating capacity at the end of 2016 was 22 GW. The U.S. EIA expects solar capacity additions in the forecast will bring total utility-scale solar capacity to 27 GW by the end of 2017 and to 31 GW by the end of 2018.

After declining by 1.6% in 2016, energy-related carbon dioxide (CO2) emissions are projected to decrease by 0.8% in 2017 and then to increase by 2.1% in 2018. Energy-related CO2 emissions are sensitive to changes in weather, economic growth, and energy prices.

Lithium Batteries

Lithium batteries may compete with gas power in the years to come, an analyst told FCBI. 2 megawatt lithium ion batteries are now being used in substations in places such as California for times when solar power is ramping up or down.

"Lithium batteries are beginning to go mainstream due to decreasing costs and improved operating characteristics," said Dale Linaweaver, Energy Industry Management Consultant.

"Batteries are contributing to reduced market LMP volatility. In specific areas such as California, they are being selected over gas turbine peakers," he added.

Already, utility companies store energy in neighborhood battery junction boxes during off-peak hours for later use during peak demand hours. In this way, utilities avoid purchasing expensive peak demand electricity. Multiple states are now looking at high-density Li-ion energy storage solutions used to power homes and make the energy grid more efficient.

In Arizona, the largest home energy storage project in the country is being undertaken by Mandalay Homes, which plans to build 4,000 ultra-energy-efficient homes equipped with eight kilowatt-hour Li-ion battery cells.

Green Mountain Power in the state of Vermont has offered homeowners a Tesla Powerwall for $15 a month. The batteries, which hold about 13.5 kilowatt-hour, engage when the electrical grid is strained to max capacity. This can preserve the grid, saving the utility company significant coin.

National Grid plans to install a 48 MWh battery energy storage system on Nantucket, Massachusetts, to help address some of the island's unique energy challenges.

Nantucket has been experiencing significant growth and demand for electricity, both of which are expected to continue for the foreseeable future. The island's electricity is supplied via two submarine cables that connect with the mainland transmission system on Cape Cod. In the event of a failure on one of the cables, two six-megawatt diesel generators are available to provide partial back-up power. The diesel generators are reaching the end of their useful life and need to be replaced. Additionally, given the growth forecast, the island's emergency electricity back-up system needs to be expanded, and a third submarine cable likely will be needed in about 12 years.

National Grid explored several options to address these infrastructure needs and the ever-increasing on-island demand for electricity, and came up with a unique solution: the BESS and a new diesel generator that together can supply the island in the event of a cable failure. National Grid expects that with the BESS, the need for a third cable can be delayed for 15 to 20 years beyond the current 12-year forecast. The BESS will be six megawatts with an eight-hour duration, which is also described as a 48 megawatt-hour system, and is being provided by Tesla.

"The BESS provides a very efficient and effective solution to two major energy challenges facing the island," said Rudy Wynter, president and COO of National Grid's FERC-regulated Businesses. "Our customers, communities, and policymakers look to us to deliver innovative solutions like this to help advance our clean energy future."

The BESS is the latest of several National Grid battery systems that are up and running or being planned. The company also has roughly 30 energy innovation pilots underway across the three states it serves, including microgrids, smart grids, community solar projects, geothermal heating and cooling, and distributed energy installations that unlock value for National Grid's customers and communities, accelerating progress toward a sustainable future.

2. PROJECT UPDATES AND OVERVIEW

2-I Investment and Construction Outlook

Construction of new natural gas fired generation has remained active due to the low price and wide availability of the fuel. Natural gas is expected to remain the go to fuel to replace coal fired generation retired in recent years or scheduled for closure, according to Britt Burt, Vice President of Research for the Power Industry at Industrial Information Resources (IIR).

Natural gas is expected to account for just over 42% of all new generation from 2018-2022, according to IIR estimates. The geographic regions with the greatest amount of natural gas fired generation under development are the Northeast, Great Lakes, Southwest and Southeastern United States.

From 2012-2016, the U.S. saw over 44 GW of natural gas fired generation start commercial operation.
"From current accounts, it appears we will see nearly 13 GW start up in 2017, over 18 GW in 2018 and a slight downwards trend in 2019 at just over 11 GW," Burt said.

From a construction kick off stand point, more than 58 GW started construction from 2012-2016.
In 2017-2019, projects representing over 47 GW have the potential to kick off between the end of 2017 through 2019.
Yet the industry is looking at an unbalanced supply/demand scenario if things don't change, some market participants believe.

Surging supply will coincide with little or no increase in demand, according to Moody's Investor Services.
Moody's issued a report on the natural gas power industry projecting that peak demand, when adjusted for weather, will grow by only 0.2% a year for the next 10 years. The flattening of demand is due, in part, to greater energy efficiency.
"With demand growth expected to remain lethargic, we anticipate many of these projects to be cancelled or delayed to future years for construction," Burt said.

2-II Projects

Northeast Natural Gas Power Projects

U.S. natural gas production continues to rise especially in the northeast quad state Appalachia area of Pennsylvania, Ohio, Kentucky and West Virginia, a result of access to Marcellus and Utica shales, according to the EIA.

The EIA projects that the U.S. will become a net exporter of natural gas on average in 2017, with net exports expected to average 0.4 BcF/day. As LNG exports increase, 2018 net exports are forecast to be 1.3 BcF/d.

"Increased natural gas production in the region could yield an additional 1.1 to 1.3 billion barrels/day of NGL by 2022, said Martha Moore, Senior Director of Economics and Policy Analysis at the American Chemistry Council (AC).

Natural gas power is expected to be a prime fuel choice in the northeast in the next few years in light of recent and planned retirement of existing coal-fueled generating assets located in the PJM Interconnection area, which is the largest grid operator in the US serving more than 65 million people.

PJM Interconnection, as mentioned in earlier sections of this paper, is a regional transmission organization (RTO) that coordinates the movement of wholesale electricity in all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia and the District of Columbia. More than 30,000 MW of coal-fueled generating assets in PJM have retired since 2003 and almost 7,000 MW are pending retirement by the end of 2020, including several plants in Ohio, according to the Guernsey Power Station.

More than half of the coal-fueled generating assets have retired in the last five years. Over 16.3 GW of coal-fired generating assets have retired in the PJM system since 2013. Within Ohio alone, a total of 59 individual coal boilers have been decommissioned, which represents 10,003 MW of lost electrical generation.

Notable coal plants that have closed located in the American Transmission System transmission zone, the same transmission zone as the project, include Toledo - ACME (288 MW), J.R. Whiting (328 MW) and Bay Shore Units 1 through 4 (631 MW). Other economically challenged regional plants include Avon Lake coal (778 MW) and Davis Besse nuclear (890 MW), according to Clean Energy Future Oregon LLC.

The gas-fired power business in Ohio, in particular, is in line for major expansion in the next few years, with four projects representing about 4600 MW of new capacity making preparations for possible construction in 2018.

Pending: Harrison Power

Harrison Power filed an application in May 2017 to construct a natural gas-fired combined cycle power plant with a generating capacity of up to 1,100 megawatts in the Harrison County Industrial Park in Cadiz, Ohio.

The project will consist of two gas-fired, high-efficiency combustion gas turbines with two heat recovery steam generators and two steam turbines. Natural gas will be sourced using one or multiple existing nearby pipelines. The project will provide power into the PJM Interconnection market.

Harrison Power told the board it anticipates that all necessary permits and the PJM interconnection process could be completed in the third quarter of 2018 and construction might proceed by fourth quarter 2018. Construction will take about 30 months, and commercial operations are anticipated for second quarter of 2021.

Pending: Oregon Energy Center

Clean Energy Future Oregon LLC filed an application in April 2017 to construct a natural gas-fired combined cycle power plant with a generating capacity of 955 megawatts in Oregon, Ohio. Natural gas would be delivered to the plant via one or more nearby pipelines. The plant will be interconnected to nearby 138 and 345 kilovolt transmission lines. Clean Energy Future Oregon said it would like to start construction in early 2018 and commence commercial operation in 2020.

“The project will help meet electricity demand in the region, particularly in light of the recent and planned retirements of existing coal-fired generating assets located in Ohio and throughout the PJM Interconnection system,” the company stated in its application.

With the exception of limited use emergency equipment the Oregon Energy Center project is designed to operate solely on natural gas and will not be designed to operate on fuel oil. The company said that based on a firm gas transportation plan and the abundant, low-cost natural gas in proximity to the project, including Utica shale gas, a back-up fuel such as fuel oil is not required.

Approved: Clean Energy Future-Trumbull

The case for Clean Energy Future Lordstown to add 140 MW of capacity to the 800 MW electric generation facility in Lordstown, Ohio has been approved. This project is identified in its PJM application as a maximum net 940-MW capacity and energy facility, and will use advanced H-class gas turbine/steam turbine combined-cycle technology to generate electricity. The project site is located in an industrial area of the Village of Lordstown, within and adjacent to the Lordstown Industrial Park, a designated Enterprise Zone with Foreign Trade Zone status. The company expects the project to be operational by June 2020.

Approved: Guernsey Power Station

This 1,100 megawatt natural gas fired combined cycle power station located in in Valley Township, Guernsey County and will consist of three units in a single shaft configuration, each using both a gas and steam turbine. The plant will be served by natural gas from one or multiple pipelines and will interconnect to a 765 kilovolt transmission line on the project site. Guernsey Power Station, LLC (GPS) is proposing to develop, build and operate Guernsey Power Station, a new 1650-MW natural gas-fired combined-cycle facility located in Guernsey County, Ohio. GPS will use state-of-the-art combined-cycle technology and a dry air cooling system to reduce air emissions and minimize water use.

GPS is being jointly developed by Apex Power Group, LLC and Caithness Energy, LLC. Apex completed two major power generation projects: the Pio Pico Energy Center, a 300-MW peaking and load-following plant in San Diego County, California; and the Panoche Energy Center, a 400-MW peaking plant in Fresno County, California. Apex is also developing Neches Station, a quick-start, gas-fired combined-cycle facility capable of producing between 450 MW and 900 MW, located in Cherokee County, Texas.

Over the last 40 years, Caithness has developed, operated, and owned interests in more than 42 power projects across the United States. Caithness recently partnered with Moxie Energy LLC to develop the Caithness Moxie Freedom Generating Station in Luzerne County, Pennsylvania, a 1029-MW natural gas-fired generating facility that is currently under construction and targeted to be on line in mid-2018. It also developed and constructed the Shepherds Flat Wind Farm, an 845-MW wind energy facility located in eastern Oregon, and the Caithness Long Island Energy Center, a 350-MW gas-fired facility in Long Island, New York.

2-III Talent availability and workforce development

Capital projects and hurricane rebuilding efforts are now competing for labor, which is driving up labor costs and further squeezing an already tight labor market.

The U.S. Gulf needed some 37,000 travelers to meet labor demand, and now hurricanes have exacerbated the situation.

Industrial investment in the U.S. Gulf Coast is expected to hit $51.9 billion in 2018, and will require all kinds of labor including pipefitters, ironworkers and other craftsman, according to Industrial Information Resources (IIR).

Investment in the U.S. Gulf Coast has been booming for more than five years as the industry takes advantage of low cost natural gas. Since 2013, the total man hours required to meet labor demand in the metropolitan areas of the U.S. Gulf Coast has grown by some 40%, according to IIR.

“The impact of Hurricane Harvey on the timing of active capital projects along the U.S. Gulf Coast will be felt for months and perhaps even years to come,” according to Tony Salemme, vice president of IIR’s Craft Labor Group.

“Labor will remain tight and wages should increase,” Salemme said. “Shortages in mechanical and electrical crafts will be the worst. Operators will be in extreme shortages and soft crafts such as painters will now experience shortages where there were none prior.”

Hurricane Impact on Labor

Harvey was a Category 4 hurricane when it made landfall in Corpus Christi, Texas on August 25. It then went on to dump record quantities of rain along the Texas Coast and into Louisiana before dissipating nine days later. 25 trillion gallons of water total spilled over the U.S. Gulf Coast region, causing an estimated $200 billion in damage.

The storm is responsible for the worst flooding in U.S. history, and is the costliest natural disaster in U.S. history, according to the Federal Emergency Management Administration (FEMA).

The U.S. Coast Guard flew over The Port of Beaumont, ExxonMobil and the Jefferson Rail Port along the Neches River on September 1. Photo: U.S. Coast Guard Charly Hengen.

Repair work is estimated to take more than one to two years for the damage to be resolved.
More than 50,000 homes and commercial buildings were seriously damaged in Texas and Louisiana. This situation will have a domino effect of delaying ongoing construction activities and will aggravate the current challenging labor shortage that was in place prior to Hurricane Harvey.

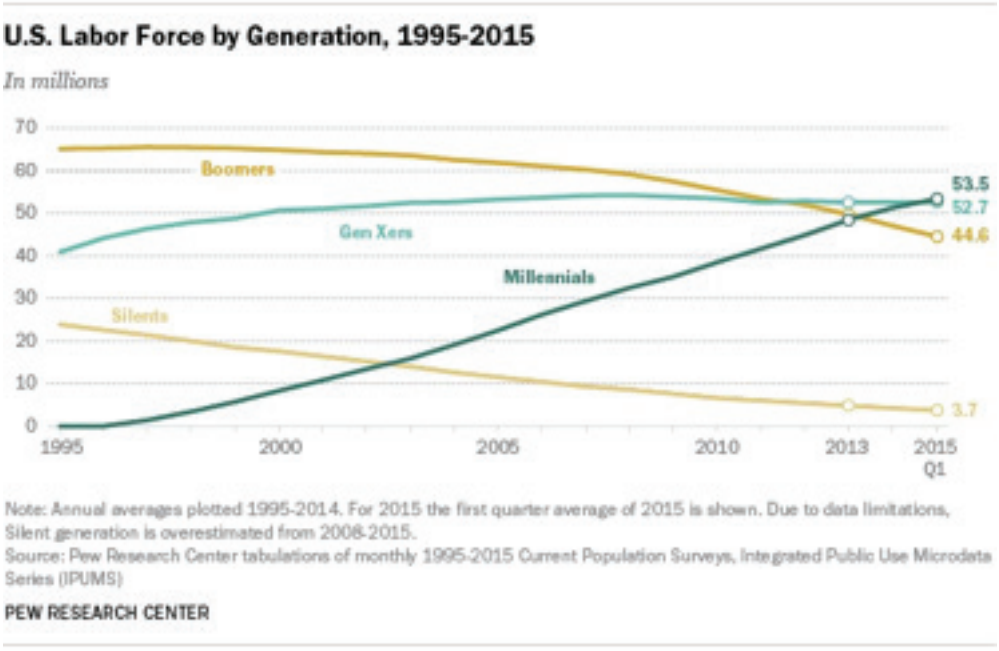
The current lack of skilled labor resources after hurricanes Harvey, Irma and Maria, just made a bad situation worse in the US Gulf Coast. Damage caused by Hurricanes Harvey, Irma and Maria in Texas, Florida and Puerto Rico in August and September combined with the high level of current activity in the U.S. Gulf Coast already will push hourly base rates to increase significantly by 3.5% to 6.5% in the fourth quarter of 2017 and first quarter of 2018.

CAPEX costs are expected to move upwards by at least 2.5% to possibly 5% as the increased costs of field labor, bulk materials and extended field in-directs are incorporated into current CAPEX budgets.

Changing labor demographics: Millennials surpass Boomers

"Gulf Coast productivity is not what it used to be," said Joe Thompson, General Manager of Bechtel's Downstream and Chemicals Business, while speaking at a Petrochemical Update Conference. "Millennials outnumber Boomers now. They need experience and training. We have to invest in them."

Millennials surpassed both the Baby Boomer generation and Generation X in 2015 as the largest generation in the workforce, according to the U.S. Bureau of Labor Statistics.



The Baby Boomer workforce peaked in size at nearly 66 million in 1997. About 45 million Baby Boomers were in the labor force at the start of 2015, at the time the Census report was done.

The youngest Boomer is now in their early 50s, while the oldest have recently turned 70. With more Boomers retiring every year, the size of this generation's workforce will continue to shrink.

"U.S. Gulf Coast craft labor used to be the benchmark around the world, it was known as the most productive, safest, most knowledgeable in the world, but I don't think we are seeing that now," Ed Lehotsky, senior vice president of LNG Engineering and Construction at Cheniere Energy, said while speaking at a Petrochemical Update Conference.

"One of the metrics that I watch as far as productivity is weld rejects rates, the quality of the welds the first time," Lehotsky said. "I am used to seeing 1-2 %, but we are seeing 6% and as much as 12% now in rejects.

Lehotsky said he believes the reason for the decline is because the welders are not as experienced as before.

"Our team has over 1,700 years of combined experience in oil and gas and 900 of that is in liquefied natural gas (LNG) and contractors respect us for our knowledge, but the industry is seeing retirement in both leadership and the crafts," Lehotsky said. "We really have to work on this if we want to build these specialty projects on time and on budget."

Training Solutions

Both owners and contractors are looking at options to train the new workers.

Cheniere is funding welding programs in Louisiana for both high school, technical colleges and returning serviceman. To date, Cheniere has trained at least 90 workers in high quality welding such as stainless steel welding.

Fluor is focusing on building the pipeline of skilled craft professionals by offering training to encourage individuals to choose craft careers, said Mark Fields, President of Energy and Chemicals Americas at Fluor.

"Through our pre-employment training, after-hours training at jobsites and supervisory training, we provide comprehensive training at every stage of a worker's career at no cost," he added.

Fluor opened the U.S. Gulf Coast Craft Training Center in Texas, which offers pre-employment, tuition-free, industry-recognized training in the welding, pipefitting, instrumentation, millwright and electrical disciplines.

"Students are under no obligation to work for Fluor after graduation, and we have had more than 300 students graduate from the program since it opened last year," Fields said.

Fluor has initiated holistic training to focus not just on the craft, but also on leadership skills to help craft laborers plan and prepare for advancement.

"We are conducting leadership training courses at sites to improve our foremen and general foremen's skills in effective communication, work planning and safety leadership," Fields said. "We also offer after-hours craft training, at no cost, at our jobsites, to encourage our employees to enhance their skills and career growth."

2-IV U.S Gulf Coast Labor Productivity Analysis

Rising construction costs and competition for high-quality labor have shifted how owners and contractors attract and retain craft labor. Owners and contractors are now looking for novel ways to accommodate the rising construction costs and to lock in quality labor.

Construction costs continue to rise each year. On an annual basis, labor costs are increasing by 1.9% to 2.9% while bulk materials are increasing by 4.7% to 5.7% annually, according to Compass International.

Construction labor in the U.S. Gulf Coast will continue to be in short supply and base wages rates for all trades and per diems for travellers will increase in the fourth quarter of 2017 and into the first quarter of 2018, according to Compass.

Travellers are individuals / craftsman (typically the Pipefitters, Welders, Electricians and Instrumentation Installers) that live more than 50 miles from the construction site and are paid a per diem to offset their daily living expenses. This per Diem rate is between $80 and $140 ($10 to $17.50 per hour worked) for each day worked. Typically between 25% and 50% of the skilled craftsmen i.e. Pipefitters, Welders, Electricians and Instrumentation Installers can be considered travellers and are paid this per diem.

Pipefitters, welders, electricians and instrumentation installers are in the highest demand and shortest supply right now. Insulators, carpenters, roofers, masons and painters will also be in demand for the next six to twelve months to meet the construction repair effort from hurricane damage. Base rates are expected to increase over the next couple of quarters.

The cost of bulk materials such as ready mixed concrete, plywood, lumber, rebar and imported stone is also expected to rise in the next three to six months by at 5% to 10%.

Construction Equipment / Plant Hire Hourly Rates for 3rd Q 2017

#	Construction Equipment Description	$ Hourly Rate
1	Backhoe 1 CY	136.40
2	Crane, crawler, 50 Ton, 100' Boom	66.94
3	Crusher (stone / rock) plant 100 Ton / hour	101.98
4	D-8R crawler / tractor / dozer / ripper	141.87
5	Dump Truck - off highway (775F) 70 Ton	160.52
6	Fork lift, 7,500 pound, with 20' lift, propane	22.48
7	Gradall swivel excavator, 1 CY bucket	71.20
8	Grout pump 54 CF / hour with 150' hoses	21.86
9	Hoist 80' high 4,500 pound capacity electric	117.40
10	Log chipper, 12" diameter, gasoline	11.81
11	Lowboy trailer / hitch, 25 ton, 2 axle	9.15
12	Mortar / grout mixer 3.5 CF, gasoline	20.01
13	Paving / tarmac arrow breaker	44.52
14	Pile hammer rig 10,000 pounds	90.94

Notes:
Excludes Driver / Operator
Excludes Fuel, Repairs and Engine Oil

With the recent major damage caused by Hurricanes Harvey Irma and Maria in Texas, Florida and Puerto Rico in September and the high level of construction activity in the US Gulf Coast the need for the above construction equipment is high, look for the above hourly rates for the Construction Equipment / Plant Hire described above to increase by 5% to 10% in the 4th Q 2017 and 1st Q 2018.

Average Open Shop Wage Rates US Gulf Coast): 3rd Q 2017:
Abbreviations
FB/H = Fringe Benefits - Holidays
WCI = Workers Compensation Insurance Average
F&S / FICA = Federal & State Unemployment / FICA
ST&C = Small Tools & Consumables
SS = Safety Supplies
ST = Sub Total
HO & S & P = Home Office Support & Profit
THR (W/O per Diem)* = Total Hourly Rate without per diem per Diem)

Northeast Craft Labor Productivity Data

Labor increases in the northeast will not experience the significant increase the U.S. Gulf Coast will see, but will be impacted by the pull on resources.

#	Trade Skill	Base Hourly Rate	FB/HWP Average 3.25%	WCI Average 16.50%	F&S / FICA Average 15%	ST&C $3.85	SS 2.5%	ST	HOS & P 15%	THR (W/O) * per diem)
1	Carpenter (Journeyman)	28.82	0.94	4.76	4.32	3.85	0.72	43.41	6.51	49.92
2	Mason / Bricklayer (Journeyman)	28.66	0.93	4.73	4.30	3.85	0.72	43.19	6.48	49.66
3	Concrete Finisher	21.90	0.71	3.61	3.29	3.85	0.55	33.91	5.09	38.99
4	Equipment Operator (Heavy Crawlers / Cranes)	29.19	0.95	4.82	4.38	3.85	0.73	43.91	6.59	50.50
5	Electrician (Journeyman))	32.12	1.04	5.30	4.82	3.85	0.80	47.93	7.19	55.12
6	Instrumentation Installer (Journeyman)	32.12	1.04	5.30	4.82		0.80	44.08	6.61	50.70
7	Insulator (Journeyman)	27.39	0.89	4.52	4.11	3.85	0.68	41.44	6.22	47.66
8	Ironworker (Journeyman)	29.14	0.95	4.81	4.37	3.85	0.73	43.84	6.58	50.42
9	Laborer	19.57	0.64	3.23	2.94	3.85	0.49	30.71	4.61	35.32
10	Millwright (Journeyman)	31.33	1.02	5.17	4.70	3.85	0.78	46.85	7.03	53.88
11	Oiler / Mechanic (Journeyman)	29.40	0.96	4.85	4.41	3.85	0.74	44.20	6.63	50.83
12	Pipefitter (Journeyman)	31.37	1.02	5.18	4.71	3.85	0.78	46.91	7.04	53.94
13	Painter	24.37	0.79	4.02	3.66	3.85	0.61	37.30	5.59	42.89
14	Refractory (Journeyman)	28.90	0.94	4.77	4.34	3.85	0.72	43.52	6.53	50.04
15	Rebar Installer	28.53	0.93	4.71	4.28	3.85	0.71	43.01	6.45	49.46
16	Scaffolder	24.03	0.78	3.96	3.60	3.85	0.60	36.83	5.52	42.36
17	Truck Driver / JLG Lift	21.83	0.71	3.60	3.27	3.85	0.55	33.81	5.07	38.88
18	Welder (Journeyman)	31.42	1.02	5.18	4.71	3.85	0.79	46.97	7.05	54.02

Compass is forecasting increases of 1.5% to 2.5% in the fourth quarter of 2017 and into 2018.

The cost of northeast bulk materials such as ready mixed concrete, plywood, lumber, rebar, imported stone is also expected to rise by at least 2.5% to 5% in the next six months because of all the construction purchasing activity related to hurricanes Harvey, Irma and Maria.

Average Union Wage Rates (Pennsylvania): 3rd Q 2017:
Abbreviations
FB/H = Fringe Benefits - Holidays
WCI = Workers Compensation Insurance Average
F&S / FICA = Federal & State Unemployment / FICA
ST&C = Small Tools & Consumables
SS = Safety Supplies
ST = Sub Total
HO & S & P = Home Office Support & Profit
**THR (W/O per Diem) = Total Hourly Rate without per diem per Diem)

Productivity

While the U.S. is preparing for a major construction boom at the same time an experienced generation of workers retires, quality and productivity are becoming an even bigger challenge than the labor shortage.

#	Trade Skill	Base Hourly Rate	FB/HWP Average 4.25%	WCI Average 16.50%	F&S / FICA Average 15%	ST&C $4.35	SS 2.5%	ST	HOS & P 15%	THR (W/O) ** per diem)
1	Carpenter (Journeyman)	35.30	1.50	5.83	5.30	4.35	0.88	53.16	7.97	61.13
2	Mason / Bricklayer (Journeyman)	35.15	1.49	5.80	5.27	4.35	0.88	52.94	7.94	60.88
3	Concrete Finisher	26.83	1.14	4.43	4.02	4.35	0.67	41.44	6.22	47.65
4	Equipment Operator (Heavy Crawlers / Cranes)	35.76	1.52	5.90	5.36	4.35	0.89	53.79	8.07	61.85
5	Electrician (Journeyman))	39.35	1.67	6.49	5.90	4.35	0.98	58.75	8.81	67.56
6	Instrumentation Installer (Journeyman)	39.35	1.67	6.49	5.90	4.35	0.98	58.75	8.81	67.56
7	Insulator (Journeyman)	33.45	1.42	5.52	5.02	4.35	0.84	50.60	7.59	58.19
8	Ironworker (Journeyman)	35.80	1.52	5.91	5.37	4.35	0.89	53.84	8.08	61.91
9	Laborer	23.99	1.02	3.96	3.60	4.35	0.60	37.52	5.63	43.15
10	Millwright (Journeyman)	38.44	1.63	6.34	5.77	4.35	0.96	57.49	8.62	66.12
11	Oiler / Mechanic (Journeyman)	36.06	1.53	5.95	5.41	4.35	0.90	54.20	8.13	62.33
12	Pipefitter (Journeyman)	38.43	1.63	6.34	5.76	4.35	0.96	57.48	8.62	66.10
13	Painter	29.85	1.27	4.93	4.48	4.35	0.75	45.62	6.84	52.47
14	Refractory (Journeyman)	35.40	1.50	5.84	5.31	4.35	0.89	53.29	7.99	61.29
15	Rebar Installer	34.95	1.49	5.77	5.24	4.35	0.87	52.67	7.90	60.57
16	Scaffolder	29.48	1.25	4.86	4.42	4.35	0.74	45.10	6.77	51.87
17	Truck Driver / JLG Lift	26.94	1.15	4.45	4.04	4.35	0.67	41.60	6.24	47.84
18	Welder (Journeyman)	38.47	1.63	6.35	5.77	4.35	0.96	57.53	8.63	66.16

Many factors decrease labor productivity, including but not limited to:

- weather: extreme temperatures hot or cold; continuous rain or snow conditions; major hurricanes or storms;
- crew size too small or too large;
- inadequate worker skill or lack of experience;
- union vs. non-union tensions on the same site;
- unsuitable, inappropriate, or incorrectly sized construction equipment; lack of trained equipment operators;
- “hot work” in operating facilities requiring work permits for shut downs, demolition, hot taps, welding, etc.;
- inadequate crew supervision;
- limited access to work areas caused by congested work areas, stairs, numerous floor levels and inadequate access roads;
- frequent work stoppages and re-starts as the result of contractual disputes between the contracting parties;
- negative worker attitude caused by unsatisfactory temporary site infrastructure (inadequate temporary toilets, change rooms, lunch tents, drinking water); poor communications and tolerance of poor housekeeping;
- site logistics: inadequate or poor material handling of owner or contractor furnished material or equipment hinder ing start or continuity of work at the work face;
- extended work week more than 40-50 hours; overtime; shift work and
- limitations on utilizing construction equipment in confined / tight work areas.

How can Construction Productivity be improved

Measures that bolster productivity include, but are not limited to the following:

#	Description	Remarks
1	Materials, labor and construction equipment availability	Ensure adequate resources are available at the time they are required at the site.
2		
3	Improve Field Labor Work Conditions:	Optimize the projects work environment, provide clean change rooms, lunch areas, toilets and worker parking areas, offer competitive wage rates, per diems if necessary, safety requirements, training opportunities and site temporary facilities to attract and draw motivated skilled and unskilled workers to the project. Make sure there are enough temporary facilities located around the jobsite, ensure they are cleaned every day, this will minimize down time, provide adequate water coolers for the workers and consider allowing food lunch trucks on the jobsite.
4		
5		
6		
7		
	Modularization / Pipe Fabrication:	Endeavour to move as much of this projects scope that is practical, to specialist fabrication vendors, allow the fabrication vendors to purchase the piping material. Use modularization as a key ongoing construction approach / practice. The primary goal of modularization is that it moves skilled construction and supporting field in-directs away from the construction site into dedicated fabrication shops, quality, safety and production can be significantly improved with this approach.
	Communications and Team Spirit:	Increased communications and dialog with all participants on the construction project(s) will many times improve productivity at the construction site. Apprising the construction field force of the current status of the project, number of days to project completion etc., is useful. Failure to communicate the projects current status and any important construction issues can impact field production and overall worker motivation.
	Constructability Reviews:	Key members of the construction management team should be part of the FEED study or in the early stages of the construction effort, to advise on optimized construction methods, contracting strategy and construction sequencing.
	Construction Staff / Worker Feedback:	Seek ideas / suggestions from the construction field force on how construction related work could be improved.
	Trouble Shooting / Performance Monitoring	Improve progress monitoring and project control procedures that can pin point and rectify specific delays and problems.

Modularization moves a percentage of the project work offsite to fabrication yards, and helps ensures that our onsite resource needs match craft availability. Advanced work packaging involves construction early in FEED and ensures adequate materials, labor and construction equipment are at the work face.

The seven key areas that would boost productivity by as much as 60% according to McKinsey Global institute are:

- reshaping regulation
- rewiring the contractual framework to reshape industry dynamics
- rethinking design and engineering processes
- improving procurement and supply-chain management
- improving onsite execution
- infusing digital technology, new materials, and advanced automation
- reskilling the workforce.

McKinsey Global Institute in its publication "Reinventing Construction: A Route to Higher Productivity" (February 2017)

U.S Gulf Productivity Data

The term "US Gulf Coast Productivity" (USGC) is specific to construction work and how it impacts the Estimating / Budgeting effort. It is used when determining if effective labor production goals are being realized at construction site(s).

US Gulf Coast Productivity: is an industry term related to the efficiency and output of construction field labor performance or production. A productivity measure is typically expressed as the ratio of output to inputs used in a production process, i.e. output per unit of labor production. Labor productivity is defined here as the amount of man-hours that a construction worker strives to complete a unit of work in a specific time period.

The U.S. Gulf Coast (USGC) construction workhour norms that are widely used in "Process / Refinery / Manufacturing" construction sectors in the USA, are based on 1,000's of completed facilities, completed over the last 25+ years.

Numerous final labor man-hour completion reports related to these construction projects have been compiled over the years that for the most part form the historical basis of "US Gulf Coast Productivity". These construction (USGC) work-hour averages or norms are used by Owner and EPC companies executing work in the in Texas, Louisiana, Alabama and Mississippi states, i.e. the US Gulf Coast.

Labor construction productivity values are used in:

- Cost Estimating, Resource Planning and Benchmarking / Project Control activity.
- Comparing labor production with similar construction related projects.

In the USA the "Process / Refinery / Manufacturing" construction sector relies on the Gulf Coast Factor described below.

USA City & State Construction Productivity Factors

The Gulf Coast is an arc from Corpus Christi Texas in the south to Mobile Alabama in the north, it includes Gulfport, Baton Rouge, New Iberia, Lake Charles, Houston, Beaumont, Port Arthur, Baytown, Texas City and Victoria

The normal approach of evaluating "process / refinery / manufacturing" construction productivity is to compare various locations around the USA, or the USGC, to a known basis or benchmark of 1.00 or 100 for US Gulf Coast. Given that there is so much historical labor and cost data that has been accumulated over the last 20 – 30 years, the term Gulf Coast productivity is understood in the (EPC) Engineering / Procurement / Construction industry. Open Shop / Non-Union Labor is for the most part carried out in the US South East and other rural areas of the USA and outside major cities. Union Work is performed primarily in the major US cities such as New York, Chicago, Philadelphia, Los Angeles and Pittsburgh etc. Union labour is typically 20% to 30% more expensive than Open Shop / Non-Union Labor. Union labor typically requires addition labor support, such as helpers and is more rigid with site procedures.

State City	Open Shop / Non-Union Workers	Union Workers
Alaska	1.00	1.10 - 1.15
Arizona (Phoenix / Tucson)	1.10 – 1.15	1.25 – 1.35
Arizona	1.00	1.10 - 1.15
Arkansas	1.00	1.10
California (LA / Long Beach / SF / SD / SJ)	0.95 - 1.00	1.15
California	1.10	1.20 – 1.30
Colorado (Denver)	1.05	1.10 - 1.20
Colorado	1.00 - 1.10	1.10 - 1.15
Connecticut	1.00	1.05 - 1.10
Delaware	1.15	1.20 - 1.30
Florida (Jacksonville / Miami / Orlando / St P)	1.10	1.20
Florida	1.00 – 1.10	1.15 - 1.20
Georgia (Atlanta)	1.00	1.10
Georgia	1.00 - 1.10	1.10 - 1.20
Hawaii	1.00	1.10
Idaho	1.10 - 1.15	1.30
Illinois (Chicago)	1.05	1.25
Illinois	1.00 - 1.15	1.20 – 1.30
Indiana	1.05	1.10 - 1.15
Iowa	1.05	1.10 - 1.15
Kansas	1.05	1.10 - 1.15
Kentucky	1.05	1.10 - 1.15
Louisiana	1.05	1.10 – 1.15
Maine	1.00	1.10 – 1.15
Maryland (Baltimore)	1.05 - 1.15	1.10 - 1.25
Maryland	1.05 – 1.10	1.10 - 1.25
Massachusetts (Boston)	1.00 – 1.05	1.10 – 1.15
Massachusetts	1.10 - 1.15	1.20 – 1.30
Michigan (Detroit)	1.00 – 1.10	1.10 – 1.15
Michigan	1.05 - 1.10	1.20 - 1.30
Minnesota (Minneapolis – St Paul)	1.05	1.10 - 1.20
Minnesota	1.05 - 1.10	1.10 - 1.20
Mississippi	1.05	1.10 - 1.15
Missouri (St Louis)	0.95 - 1.00	1.10 - 1.15
Missouri	1.05 – 1.10	1.10 – 1.20
Montana	1.00 – 1.05	1.05 – 1.15

State City	Open Shop / Non-Union Workers	Union Workers
Nebraska	1.05	1.10 - 1.15
Nevada (LV / Reno)	1.05	1.15
Nevada	1.00 – 1.05	1.05 – 1.10
New Hampshire	1.05 - 1.10	1.10 - 1.20
New Jersey (Newark / Northern)	1.15	1.20 - 1.30
New Jersey	1.10	1.10 - 1.20
New Mexico	1.05	1.15
New York City	1.10 - 1.15	1.30 – 1.40
New York	1.05 - 1.10	1.10 - 1.20
North Carolina	1.05	1.15
North Dakota	1.05	1.15
Ohio (Cleveland)	1.05 – 1.10	1.15 – 1.20
Ohio	1.05	1.10 - 1.15
Oklahoma	1.05	1.15
Oregon	1.05	1.15
Pennsylvania (Philadelphia / Pittsburgh)	1.10 - 1.15	1.20 – 1.30
Pennsylvania	1.05 - 1.10	1.10 - 1.20
Puerto Rico	1.60 – 1.90	1.50 – 2.00
Rhode Island	1.05	1.15
South Carolina	0.95 - 1.00	1.05 - 1.10
South Dakota	1.05	1.15
Tennessee	1.00 - 1.05	1.10 - 1.15
Texas (Dallas / Houston)	1.05 - 1.10	1.10 - 1.20
Texas (Gulf Coast) - Base Case this includes Gulfport, Baton Rouge, New Iberia, Lake Charles, Beaumont, Port Arthur, Baytown, Texas City and Victoria: (Note: in certain cases i.e. large projects with a lot of repeat / similar work activities: productivity could be 0.90 – 1.00 say an average of 0.95)	**1.00**	**1.10 – 1.15 (typically all work is completed on open shop basis)**
Utah	1.05	1.10 - 1.15
Vermont	1.05	1.15
Virginia (Washington D.C.)	1.10 - 1.15	1.20 - 1.30
Virginia	1.05	1.15
Washington	1.05	1.15
West Virginia	1.00 - 1.05	1.00 - 1.15
Wisconsin	1.05	1.15
Wyoming	1.05	1.15

An example of this is a task or work effort (for example erecting structural steel) on the USA Gulf Coast took 1,000 man-hours to complete (1.00), the same task or work effort in say Pittsburgh, PA utilizing Union labor will take 1,250 man-hours (1.25) which is the average of 1.20 -1 .30 indicated above.

3. OWNER / OPERATOR CASE STUDY

3-I Dominion Energy –Greenville

Dominion Energy Virginia began construction June 17, 2016. When completed in late 2018, the station will be one of the largest, most efficient and environmentally friendly generating stations of its kind in the world. According to the Virginia Department of Environmental Quality, the stations air permit is the most stringent in the nation in terms of carbon dioxide emissions.

Greensville/Brunswick County, VA
Powers 400,000 homes

Facts

- Net generating capacity is 1,588-megawatts.
- Fueled by natural gas, it will use the latest generation of highly efficient combined-cycle technology to produce the electricity.
- Cost - $1.3 billion.
- The station will have low-carbon intensity by using clean-burning natural gas and the best available control technolo gy to reduce emissions.
- In its first year of operation, it is expected to provide up to $8 million in property taxes for Greensville County.
- Post-construction economic benefits are projected to amount to about $36 million annually.
- Over its expected 36-year life, the station will save customers about $2 billion.
- At the peak of construction, the site will have more than 1,000 workers.
- Once completed, the station will have a staff of 45 employees.

When planning a gas power plant construction project, Dominion's main priorities are safety, fuel infrastructure, size and technology, cost (capex) transmission upgrades, and heat rate and output.

"If we can do a safe project, we can build a successful project. If you look at a plant with safety issues, these are the plants with high turnover of craft, high costs and delays," Humberson said. "We will review the EPCs for several key aspects. We are looking for a long track record of good safety experience and performance to determine if they will build a safe environment."

Building communication

Humberson said Dominion puts tremendous focus on the relationship with the EPC and owner as well as teambuilding.

"The relationship between EPC and owner drives us. When things go awry, you can work it though," Humberson said.

From the very beginning, Dominion sends a few members of its engineer team to the EPC office to show up front how important communication is to them. At the start of the meeting, a goals and drivers meeting is held.

To set up the goals and drivers meeting, Dominion will separate both sides, owner and contractor, in separate rooms before the project begins to brainstorm each goal and the reason behind it. Once the teams meet individually, they reconvene together to discuss and explain.

"When we explain the goals and reasons behind our goals to the EPC, most of the time they are very different than the EPC has. When we can explain our drivers and reasons and establish why we need things the way we need them, they understand better and can deliver better," Humberson said.

"EPCs may assume we want things to get them in trouble or catch them doing something wrong, but when they realize why we need something, they are more capable of doing it for us," he added.

Dominion will keep the flow of communication throughout the project with monthly executive meetings between owner and EPC contractor to discuss the project's progress report. Dominion also makes sure it include some of its own employees working in the field for greater visibility.

"So many people rely on spreadsheets and metrics which may show you one view of the project, but if you get out in the field you may see a more accurate picture and realize where the project really stands. The owner needs to be actively involved for a project to be successful," Humberson said.

Team building

Dominion is pushing team building to make sure communication and trust is built.

"When there is a problem, teams can work through issues more effectively and quickly once trust is established. It is a difficult issue to tackle but establishing trust is important," Humberson said.

Dominion has taken employees on safety driving courses and sets up team building activities throughout the project.

"There are several things one can do to make sure people understand each other and understand themselves. If you do it right and build relationships up front, you can deal with the biggest commercial issue, then turn around and go out to dinner together and keep on going working through problems all the way to the end of the project."

Productivity, recruitment and retaining talent

To overcome industry-wide issues with attracting and retaining talent and improving productivity, Dominion used a novel approach by engaging and encouraging families to become vested in the project with a Family Fun Day at its site.

"When looking at ways we can improve productivity, we think of the craft and how to get craft engaged to perform. There are only so many ways to influence craft to get them to stay on your project to the end," Humberson said.

"We brainstormed on what would retain the craft. The first thing everyone considers is money, but you can get into wage wars if you go that route. The other thing that really effects the craft is their family," Humberson said.

The site was at 30-40% completion and with the help and support of our EPC Fluor, Dominion invited the craft and their families: kids, spouses, parents, everyone to see the project. They had snow cones and gave away promotional materials like Frisbees, but the biggest part of the show was taking families on a fascinating behind the scenes tour of the project in order to show families just how meaningful and important their family member's job was.

"We invited the families to come and tour the project. We talked to them and explained why the work was important, why it mattered for the community, what the plant would mean for power rates and how that would impact so many people. We showed them the details and intricacies and importance of the job their family member is doing and made it meaningful and exciting to them," Humberson said.

By getting families vested, kids, spouses and moms would then constantly ask the craft about the project and then no one wanted to leave. They did not want to let their families down.

"We had low to zero first aid/injury reports, high safety, high productivity. This is one of the construction sites where everyone is smiling," Humberson said.

Also by getting the kids in the plant and showing them these jobs, Dominion is investing in the future and making the industry appealing and exciting to the next generation.

"TV does not make our industry appealing, but when kids get in and see these jobs and what is involved, they are more interested in pursuing a similar career path. We showed the families just how valuable the craft is and these kids want to be part of something just as important," Humberson said.

Alternative methods

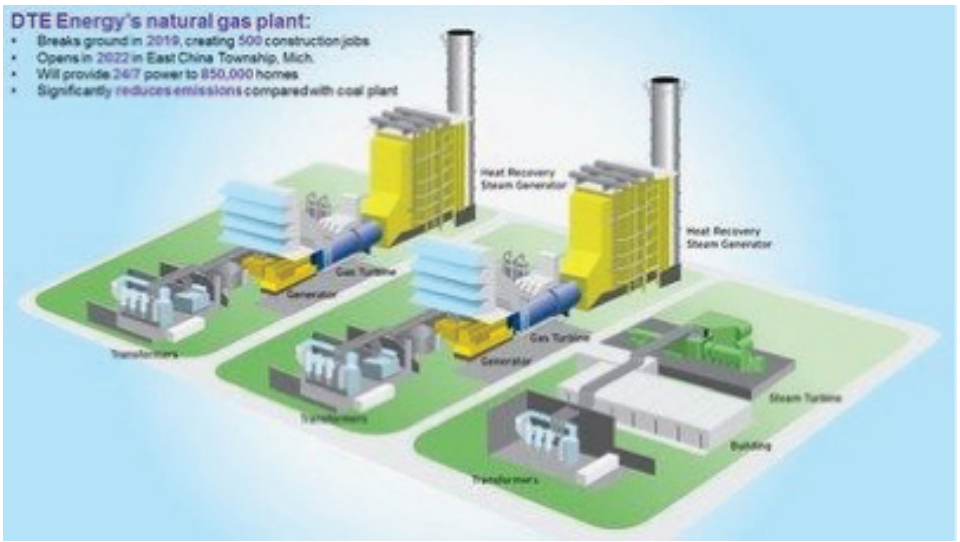
Another novel technique Dominion uses is to involve foreman and superintendents in the early design for constructability. By doing this, team members look for alternatives to the traditional way of doing things and come up with solutions to age old problems.

For example, Flour decided to build the HRSG stair towers prior to setting any of the HRSG modules on the project.

"This reduced the scaffolding needed, took away man hours to build the scaffolding which improved productivity and was safer," Humberson said. "By rethinking the process, we found a cleaner, safer, more effective way of constructing."

By constantly thinking of its employees, safety and rethinking processes, Dominion's push for innovation has increased productivity at its sites and helped the group to stay on schedule and on budget.

3-II DT Energy



3-II DTE Energy

DTE Energy has filed a Certificate of Necessity with the Michigan Public Service Commission (MPSC) seeking to build a state-of-the-art natural gas-fired power plant of about 1,100 megawatts (MW) on existing company property in East China Township, Michigan that will provide affordable and reliable power for 850,000 homes beginning in 2022.

The almost $1 billion project will be built at a cost of approximately $860 per kilowatt and is scheduled to break ground in 2019, creating hundreds of Michigan jobs during construction.

It is one of many steps DTE is taking to achieve its goal of reducing carbon emissions by 30% by the early 2020s and more than 80% by 2050. DTE will achieve these reductions by adding 4,000 MW of renewable energy from wind and solar farms, transitioning its 24/7 power sources from coal to natural gas, continuing to operate its zero-emission Fermi 2 power plant, and providing additional opportunities for customers to save energy and reduce bills.

"A fundamental transformation in the way we produce power in Michigan has already begun. Last year, we announced three DTE coal-fired power plants will be retired by 2023 and replaced with cleaner, more efficient, reliable and affordable energy, including natural gas and renewables," said Trevor F. Lauer, DTE Electric president and COO.

"This filing with the MPSC includes nearly a year of research and a competitive bidding process that determined building a natural gas-fired plant is the best solution for our customers due to many factors, including the environment, reliability and affordability."

Upon receiving the filing, the MPSC has 270 days to review DTE's request and respond. If approved, the new gas-fired plant would be the most efficient power plant in Michigan.

"Natural gas-fired plants will be a critical part of our power generation capacity in the decades ahead," Lauer said. "Natural gas significantly reduces carbon, sulfur dioxide and nitrous oxide emissions, offers an affordable and abundant domestic supply, is easy to transport and provides a reliable 24/7 power source for our 2.2 million customers."

Long term, DTE plans to produce over three-quarters of its power from renewable energy and highly efficient natural gas-fired power plants. DTE also will continue to reduce its energy waste annually by 1.5 percent.

DTE selected the East China Township site for its new natural gas plant because it already has in place electric, natural gas and other infrastructure, experienced employees and a supportive community. DTE has operated the St. Clair and Belle River coal-fired power plants there for many decades.

If approved, DTE expects plant construction to create about 500 jobs.

"Representing the construction trades, I'm excited to see DTE investing in and bringing jobs into our state," said Shorty Gleason, Legislative Director, Michigan Building and Construction Trades Council. "This gas plant build represents real, sustainable economic growth and it will be exciting to be a part of the industry's transformation."

The new plant is scheduled to begin operation in 2022, offsetting some of the capacity retired when three of the company's Michigan coal-fired power plants – River Rouge, St. Clair and Trenton Channel – are removed from service in the 2020-2023 timeframe.

Project planning priorities

When planning a major natural gas power project, DTE will first consider its integrated resource plan and if it indeed does require a base load generation. If the answer at that time is yes, then planners will look at the requirement of base load generations and look at all alternatives in determining the best technology to meet its needs.

“As we look at what is the best technology to meet our needs, we must acknowledge what we are going to build is a 30 to 40 year asset. The decision making is about making sure we build an asset that meets the needs of our system and brings value to customers with respect to affordability,” Fahrer said.

"We have to balance the need for system integrity coupled with customer affordability and best technology for the long run," Fahrer added.

Project communication

DTE pushes adherence to scheduling, transparency and visibility with weekly and monthly reviews throughout a project cycle.

Weekly meetings look at statistics in the moment, including checking off what was done the prior week and examining what was intended to be done but did not get completed.

Monthly meetings look at formal financial systems matching monthly updates cost against budget and are an owner and EPC collaborative review.

Managing productivity with pre project planning

To manage effective productivity, DTE's approach is threefold. First, the owner makes sure it has gone through appropriate engineering reviews well in advance before construction begins in order to optimize engineering time for construction. Second, DTE will optimize the modularization opportunity by moving as much together in bigger pieces for site delivery. Third, the company engages in best practices of the Construction Management Institute (CMI) associated with Advanced Work Packaging (AWP) to make sure the work package itself is ready to go to field.

"The reason for using AWP is simple. What we see in productivity loss is Indecision and that leads to questions, which leads to issues resolving the process, which means someone is sitting waiting for an answer and not working and that is time wasted," Fahrer said. "AWP planning outlined in CMI is an important best practice we follow on our projects."

When it comes to making the most of engineer time and estimating its overall readiness, DTE utilizes the Construction Industry Institute (CII) tool, Project Definition Readiness Index (PDRI). The PDRI is a project scope definition tool that is a powerful and easy-to-use tool offering a method to measure project scope definition for completeness.

Research has shown that PDRI allows a project team to evaluate the completeness of scope definition prior to detailed design or construction and helps a project team to quickly analyze the scope definition package and predict factors that may impact project risk, according to the Project Management Institute (PMI).

Extraordinary risks are many times the result of unresolved scope issues or unforeseen conditions. At a point of time right before detailed design, poorly-defined scope definition elements are identified during the PDRI evaluation process within the owner's organization. These poorly defined scope definition elements should be treated as potential risk factors that might cause negative impact to project outcomes. By identifying potential risk factors early in a project, the project team may quickly respond to the risks and thus reduce the possible negative impact resulting from the risks.

(Project Management Institute: Using PDRI for project risk management)

"This way we can identify early on any gaps in development," Fahrer said. "We want productivity beyond field hours. We want productivity in engineering as well because engineering hours are more expensive than field hours so we want to drive productivity as an issue resolution early in the process and we want to make sure productivity is over the entire project."

When it comes to finding a balance between labor productivity and quality of work, Fahrer says that both win. Neither safety nor quality should be compromised.

"If you focus on safety and quality, productivity will follow and follow in a positive nature. Do it right the first time and it helps productivity. Do it right focusing on safety and it avoids issues and productivity loss. A well thought out plan that identifies the execution of the tasks will give you good productivity and quality," Fahrer said.

DTE continues to advance modularization as a productivity and safety measure as well.

"These are things good EPC firms do because they want to take hours from field and put them in the shop because that improves overall safety quality and productivity," Fahrer said.

A challenge for some facilities is the infrastructure to get equipment to the site. Sometimes a job site can be constrained by trucking or rail shipments only. These are not issues for DTE as they are located on the water and can bring in large components by barge.

Fahrer says that good siting characteristic reviews make sure the owner has picked the best site most suitable for building, considering interconnectivity to gas and electric as well as site logistics with respect to modularization and shipping,

Recruiting and training –Force for change, force for good

With the project expected to require 500 jobs, DTE has begun early working with big players in Detroit to prepare for the state's entire labor needs at a time when the city is in a construction boom.

DTE Energy is working closely with city leadership and schools to reestablish trade schools within the City of Detroit's public education system to attract and train youth and adults to pursue careers in trades, versus going on to two-year and four-year universities The idea is about reintroducing Michigan students to trades job, and developing a pipeline that goes directly into apprenticeship programs to fulfill those needs.

DTE is taking a lead role in trying to reestablish technical and vocational schools that had gone into disrepair or no longer existed within the City of Detroit. DTE's Chairman and CEO Gerard Anderson is active with a cross section of business and civic leaders. Leaders are establishing relationships and in doing so, donations are coming in to refurbish the schools from other places other than taxes.

A recent example is a long-neglected vocational school on Detroit's west side that will get new life this school year after city officials and the Detroit Public Schools Community District unveiled the newly improved Randolph Career Technical Education Center. DTE Energy led the transformation by offering its skilled volunteers to install new lighting, renovate classrooms and provide $765,000 in new equipment and supplies. The center, which opened in October 2017, offers skilled trades training to 300 youth during the day and 300 adults in the evenings for in-demands jobs in the construction industry.

The building's revitalization was made possible through $10 million in funding and in-kind contributions. Among the top supporters: $3.5 million from the Gordie Howe Bridge Workforce Training program, $1.75 million from the City of Detroit Workforce Training Fund, $1.5 million from the Wilson Foundation and $1.1 million from DTE Energy.

4. MAJOR PROJECT CHALLENGES FOR GAS POWER PLANTS

Scope

Inadequate or poor scope definition, which negatively correlates to the project performance, is recognized as one of the most serious problems on a construction project. Two of the most frequent contributing factors to cost overrun are: poor scope definition at the estimate (budget) stage and loss of control of project scope.

The result of a poor scope definition is that final project costs can be expected to be higher because of the inevitable changes which interrupt project rhythm, cause rework, increase project time, and lower the productivity as well as the morale of the workforce. Success during the detailed design, construction, and start-up phases of a project highly depends on the level of effort expended during the scope definition phase, as well as the integrity of project definition package.

A project definition package is one of the first steps in defining scope according to market participants. A scope definition package that encompasses the results of the pre-project planning efforts is developed for each project. During this process, information such as general project requirements, necessary equipment and materials, and construction methods or procedures are identified and compiled.

This document consists of a detailed formulation of continuous and systematic strategies to be used during the execution phase of the project to accomplish the project objectives. It also includes sufficient supplemental information to permit effective and efficient detailed engineering to proceed.

"Defining scope is first and foremost," Fahrer said. "Know what you are going to build and understand the timeframe tasked with building it. Make sure early surveillances with respect to early studies and knowing where you are going to build it are done."

The Project Definition Rating Index (PDRI) as mentioned in the DTE case study is a project scope definition tool developed under the guidance of Construction Industry Institute (CII),that is a powerful and easy-to-use tool offering a method to measure project scope definition for completeness.

"Make sure you have done siting characteristics to pick the best site most suitable for building which means you are looking at interconnectivity to gas and electric and site logistics with respect to modularization and shipping," Fahrer said. "Understand the pulse on labor in the area and what else is going on in that site's jurisdiction associated with labor."

Extraordinary risks are many times the result of unresolved scope issues or unforeseen conditions. At a point of time right before detailed design, poorly defined scope definition elements are identified during the PDRI evaluation process within the owner's organization. These poorly defined scope definition elements should be treated as potential risk factors that might cause negative impact to project outcomes. By identifying potential risk factors early in a project, the project team may quickly respond to the risks and thus reduce the possible negative impact resulting from the risks.

Leadership selection and development

Once scope is figured out, then it is about selecting a good project management leadership team.

"There is a level that their competencies are high both in project management space as well as technology understanding space. A good leadership team will fully understand project management controls and construction management techniques. Safety first and quality are their priorities. Neither one is compromised," Fahrer said.

DTE has a Talent Planning Process to select potential leaders and prepare them for these big roles. The process gives senior management the ability to see who is ready for the next big thing and how to get future leaders ready. The selection committee is just that, a group of people. Choosing project management leaders is not a one-person job.

The company has a robust training program within its Major Enterprise Projects (MEP) group in which a structured planning review takes place. The planning review considers Project Manager Professional (PMP) certifications, but also advanced problem-solving skills and certifications in the areas of yellow belt, green belt black belt as well as other leadership exposure opportunities.

"These people in leadership roles have high competencies and the attributes of a good project manager. They adhere to Project Management Institute principles. They progress through different roles in small projects to large projects," Fahrer said.

DTE uses PMI principles for process oversighting the company, pushes self-evaluation and brings in an external evaluator to verify where the company is with respect to maturity within the Project Management Institute.

A chief complaint seasoned managers have about incoming managers is their need to learn to balance the end goal priorities against the current firestorm of the day. New managers get caught up in the problems versus the solutions and are too over confident to ask for help. New managers should prioritize with the end goals in mind and never hesitate to bring things up and ask for help.

"In my wisdom I would not put as much stress and effort into some of these day to day storms, but in his youth and aspiration he has a hard time deciding what is important and not important and is reluctant to ask," Fahrer says.

The other place where new project managers face challenges is in ensuring sustainability to the project. Good project managers are visionaries and can look at a project 40 months down the road rather than be blinded by the day to day details.

"Project managers need a good system for how to start the project with the project team, knowing that these standards are measured in years not months," Fahrer said. We need to see continuity to ensure that when we get to finish line, we

are capable of going from construction complete to initial commission activities start up, and there is a well-trained workforce to make it happen successfully."

Estimating

Estimating the effort, time, and resources needed to complete project activities is one of the most challenging tasks that project managers must face. This is because of the inherent uncertainty associated with many activities, and sometimes inexperience of new managers.

Estimating is the biggest driver for an EPC to execute successfully. Knowing the expectations and bidding appropriately is key. Owners must be clear about what is expected, and EPC have to estimate the actual plant that is expected. If the money isn't there and the EPC losses profit the whole project will be hurt.

The EPC must be honest. Competitive bidding forces the EPC to bid low. Owners should not simply go with the lowest bidder.

"We've gotten bids where the commodity bid couldn't actually build the project so the bid was rejected and we did not go with the lowest bidder," Humberson said Owners need to give true evaluation criteria.

Dominion has put a lot of effort into solving this problem with the creation of a 500-page spec sheet showing exactly how they want their plants built. The spec guide is so detailed it includes a $ amount for KW and BTU costs and provides detailed specs on temperature megawatts.

"When people go with lowest bidder and estimation is not detailed out from the beginning, the EPC can't meet the owner's demands. There needs to be ownership on both sides. EPC needs to be honest and state what the back end costs are. Owner should go with the EPC that will provide these costs. It all comes down to building honest, open relationships from the beginning," Humberson said.

5. CONSTRUCTION INNOVATION

More than 80% of the cost for construction projects is tied to materials and labor management in the field. The average project in our industry last three to five years and has capital expenditures of $2.4 billion. A 10% cost reduction for mega projects results in millions of dollars in savings impacting the projects bottom line.

If there is one predominant theme in the downstream construction industry, it is imperative that Owners and EPC contractors together address the "mission critical "issue of declining field productivity over the past four decades.

Digital transformation tools are increasingly used to sort through huge volumes of data to address issues related to complexity, size, risk, operations and maintenance of major capital projects.

"Bold, tightly integrated digital strategies will be the biggest differentiator between companies that win and companies that don't, and the biggest payouts will go to those that initiate digital disruptions," according to global management consulting firm McKinsey & Company.

Virtually every other industry sector has embraced data-driven, collaborative information management platforms and integrated applications, with media/entertainment, retail, high tech, health care, travel/transport and telecom at the forefront.

The industry must address the expectations and harness the appetite for innovation found in the millennial generation that is already emerging as the primary resource pool for capital projects and asset performance management.

"Millennials simply want what everybody wants: A working environment that is intuitive, collaborative and flexible. Young engineers want to learn. They want to be valued, to contribute, and to feel a sense of satisfaction after a job well done. The catch: They want all this from day one. Millennials want workplace technology that allows them to connect and contribute," Olfa Hamdi, chief executive of Concord Product Technologies said.

Owner and EPCs companies are recognizing that the legacy core element of project delivery supported by document-centric, functional, independent data silos must be reinvented. Companies that embrace digitization and accelerate the speed of adoption, especially in the face of record high years of capital investment and record low years of skilled craft labor availability are the winners.

5-I Advanced Work Packaging

The Advanced Work Packaging (AWP) process has grown in popularity as a way for owners and contractors to handle the construction boom environment in which schedules, budgets and labor are increasingly tighter. The processes and tools of AWP were first outlined in the early work of the Construction Owners Association of Alberta (COAA) in 2005 and later endorsed by the Construction Industry Institute (CII) in 2013 in CII Publication 272.

AWP is a work process framework based on thinking with the end in mind. It is designed to allow engineering planning to be driven by construction sequencing.

The driver behind AWP is the bold statistic that 37% of craft labor is time on tools; 15% of craft labor is waiting on material. The goal of AWP is to eliminate rework and to improve predictability in forecasting readiness to start work and state of completion while work is in progress. The principle applied in AWP is the sequence of construction activities that results in construction crew readiness at every work front in the field.

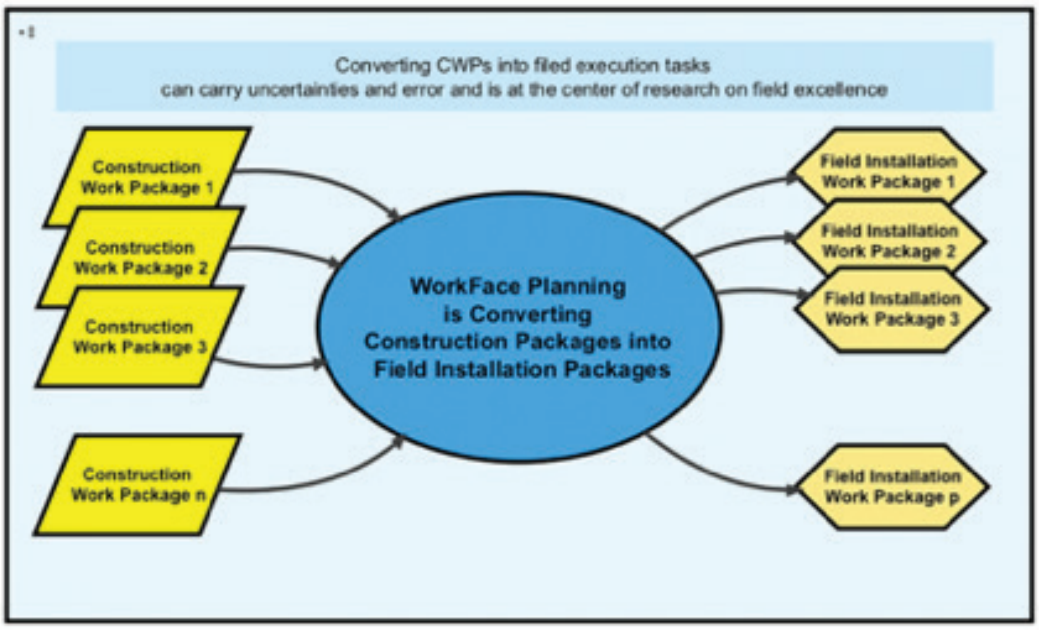


Image source: The Advanced Work Packaging Institute

Olfa Hamdi of The Advanced Work Packaging Institute has been documenting through case studies and expert interviews AWP benefits as part of her academic research work and thesis published at University of Texas Austin entitled "Advanced Work Packaging (AWP): from project definition through site execution."

"The most notable benefit from AWP implementation is field execution acceleration and accuracy which translates in schedule savings," Hamdi said. "Cost savings have been observed but they do depend on the level of maturity of AWP implementation. There is an initial front end cost to it, but savings achieved down the road are way worth it."

Indirect benefits observed and documented by the AWP Institute are improved front end alignment and more predictability to the overall project value.

The Institute has documented up to 25% savings of total installed costs and up to 15% field productivity increase.

ExxonMobil, Shell, SABIC and DTE Energy are just some of the owners using AWP for mega projects.

Owners are recognizing they must lead the change and that AWP starts early in FEED.

"I think there are some key things with Advanced Work Packaging, that people need to consider," said William Lewis, Senior Manager and Projects Coordinator at SABIC said while speaking at a Petrochemical Update Conference.. "You must start early in the process, you need to get back to the FEED."

When building AWP, it is important to think with the end in mind and build from there, Lewis said.
"In the end, you will be going to turnover conditioning activities, so you need to work that back to your construction packages, and back to your design packages, so it all must flow," he said.

"I have seen a lot of cases where they try to use a form of Advanced Work Packaging, and don't bring all the factors to the table, and that is just a recipe for failure," Lewis added.

The best way to implement a successful AWP program is to start at the owner level, Lewis said.
Owner involvement is more important to change than many realize, Lewis said.

"If you think back a couple decades, when we went into the safety venture, it took the owner driving safety to actually make a difference," he said. "If you want to improve productivity, the owner has to play a major role in it. The owner will have to mandate it and encourage it to make that change."

The most common thing owners fail to do early in the project cycle is sufficiently define the project to support a successful FEED.

"Productivity is a piece of capital efficiency and takes a number of steps. I don't think there is any one thing that is the answer, but there are a couple of important things that can be done," said Jim Collins, President of Business Development for Global Refining, Chemical, Petrochemical and Midstream at AMEC Foster Wheeler.

"One of the things for the owners to look at is contractor involvement very early in the planning of how the project will be, and construction and put that in the feed and build up from it," Collins said. "In the field, there are many activities really complemented by AWP, but that's only good as scope allows."

Key elements of AWP are as follows:

1. *A "path of construction" defined in early FEL in the Construction Execution Strategy defines Construction Work Areas (CWAs). This requires iterative, interactive, collaborative planning by Operations, Construction, Engineering and Procurement to align work sequences that support the construction, commissioning and start-up schedules.*

2. *Later in FEL Construction Work Packages (CWPs) are defined in the Construction Execution Plan as a specific division of bulk construction within a CWA, defined by area and by discipline. The physical boundary of each CWP allows for a scope of work to be performed by a single construction contractor. As such, CWPs can be used as contractual boundaries of work in bid packages.*

3. *The Work Breakdown Structure and Cost Breakdown Structure are consistent with the CWP definition and the CWPs form the basis of the Level 3 schedule and Level 3 estimate.*

4. *In FEL an Engineering Work Package (EWP) and a Procurement Work Package (PWP) are defined to execute the work of each CWP. EWPs and PWPs are integrated and linked to CWPs in the Project Level 3 schedule,*

5. *In the field, planners divide each Construction Work Packages into Installation Work Packages (IWPs) that represent work that can be completed by one foreman and one crew in a single reporting period, typically 1-2 weeks. IWPs are not released to the field until each is constraint-free (all drawings, materials, construction equipment, permits, etc. are available at the work front).*

Prerequisites to implementation of a Workface Planning Process (WFP) include effective materials management, supporting document control, and project control systems. These systems provide information in the requisite level of detail and coordinate with work packaging procedures.

For a WFP strategy to be effective, the contract language and terms and conditions include provisions to establish, measure, and report key metrics surrounding both the development and implementation of the spectrum of CWP, EWP, PWP and IWP activities.

Traditional contracting, staffing and compensation strategies are not well suited to support a lifecycle integrated delivery of projects using AWP. Additionally, technology infrastructure to manage work packages is needed to avoid the chaos of manual administration.

5-II4D/5D Construction Models

4D/ 5D model technologies enable the development and visualization of work packages by providing the dimension of time (4D) and cost (5D). The visualization of work progress and cost data enable effective, timely decisions and prioritization of work in the field.

Owners, EPC's and software vendors are recognizing the need to attribute the 3D model with metadata that can flow seamlessly into the 4D model. Metadata provides information about other data, and helps applications find and share information more efficiently by describing the content and context ("attributes") of an object.

Deployment of 4D models (3D model + time) provides the flexibility for the users of the 3D CAD model to easily test planning scenarios and progress status of completion. The display can be structured by area, module, unit, pipe, or system. A 4D model has the powerful ability to visualize the planning of the completions /commissioning phase. It saves significant time in generating both IWPs and test packages. It also eliminates scheduling and spatial conflicts in construction sequencing. Operations and maintenance can engage at the work face through 4D models that bring time and scope together.

Deployment of 5D models adds cost as a function. 5D models provide linkage of real time material data to IWPs, placing material control in the hands of the construction and field workface planner teams. It also facilitates 30, 60, and 90 days look ahead planning with the capability to visualize when materials are expected to be delivered to site. Allowing earlier risk identification, the 5D platform allows owners and contractors to analyze the impact of changes on project costs and scheduling and make better decisions.

Indeed, for construction and project delivery, a big part of the digital journey is moving from document-centric to data-center work flows, where a single source of data "truth" exists at all time; where the same information can be access from the corporate, home office engineering, job trailer and the field; where human errors that propagated error, rework and manual entries are eliminated; where real-time data transparency between all parties promotes collaboration and technical accuracy.

5-III Digital Transformation

The energy industry is lagging other sectors on the race to adopt digital technology, but increases in capital investment are pushing digital transformation now more than ever.

Tools for digital transformation include data powered analytics, cloud computing, automation, asset visualization, Internet of Things, social media and more.

IFS, a global enterprise applications company, recently conducted a Digital Change Survey that polled 750 decision makers in 16 countries to assess maturity of digital transformation in sectors such as manufacturing, oil and gas, aviation, construction and contracting, and service.

The oil and gas industry was at the bottom of the list.

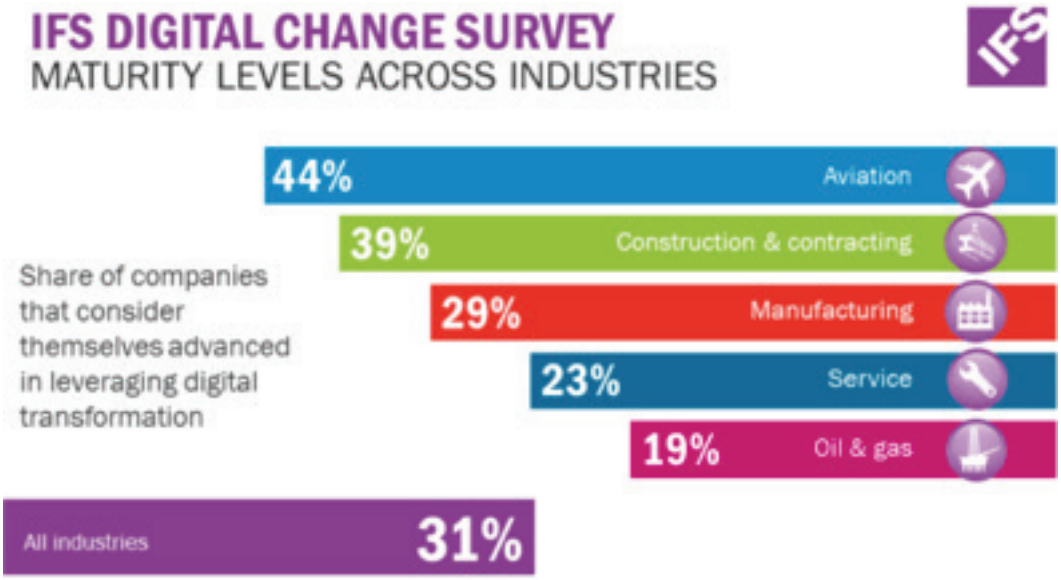


Image Source: IFS

"It is apparent that companies today understand the urgency of focusing on digital transformation." IFS Vice President of global industry solutions Antony Bourne said. "Technologies such as big data and analytics, enterprise resource planning and internet of things are paramount to transforming a business.

Given the industry's substantial increases in capital investment, optimizing production efficiency using digitization is essential, according to McKinsey & Company.

The costs savings to optimizing production through digital transformation are so substantial that McKinsey & Company estimate that improving production efficiency by 10 percentage points can yield up to $220 million to $260 million bottom-line impact on a single asset.

"Executives need to have an intimate knowledge about the digitization and how it will transform their business, rather they want it or not," said Trond Ellefsen, Special Advisor Digital Transformation and Strategy at Statoil. Ellefsen was speaking on an Upstream Intelligence webinar.

"This is where we are headed. This is not just a technology journey. This is foremost a cultural change toward something completely different than what it is today. The world will look completely different to the oil and gas industry in five to seven years," Ellefsen said.

Big players leading the technology shift including Uber, Twitter, Amazon, AirBnB, LinkedIn, Facebook, Snapchat, Google and more have found success by understanding and pushing digital disruption technology including the use of data powered analytics, cloud computing, automation, asset visualization, mobility, and social media.

"If you look at Uber, Facebook, LinkedIn, AirBnB, etc, these are technology platforms where the customer creates, consumes and shares the information and the ability to connect from any device anywhere is the actual technology shift going on," said Terry Price, Industry and Technology Thought Leader at IBM.

The energy industry is different in that the information is created and maintained by the operator and most often kept in silos, often unused. Therefore, in the case of oil, gas and petrochemicals, the customer is not interacting with the information or working with the supply chain in the same way disruptive technology does.

"What we are finding is that the executive is driving digital transformation and in many cases, this is based on improvements in disruptive technology," Price said. "Then this directive is pushed down to the business where people are trying to align the new ways of thinking to traditional programs and thinking."

Leading EPC firm Bechtel has created a data analytics team, hiring data scientists to mine the company's growing datasets. Data analytics, along with the deployment of the latest handheld devices and 4D and 5D modelling, has improved decision-making in areas such as piping productivity and staff logistics, Joe Thompson, Senior Vice President, General Manager – Downstream & Chemicals, Bechtel Oil, Gas & Chemicals said.

Microsoft and Halliburton are entering into a strategic alliance to drive digital transformation across the oil and gas industry. The relationship will combine Microsoft's expertise in cloud and digital transformation with Halliburton's exploration and production (E&P) science, software and services.

"The next generation of really successful companies will be those that manifest their intellectual property in digital form and take advantage of the transformation opportunities that exist for them," said David Holmes, CTO Energy for DellEMC.

The dynamic space in which the construction industry finds itself is a state where hardware and software are fast becoming a commodity; where every person on the project regardless of company designation has fast, easy access to trusted data in the cloud; and where the elimination of data silos drives collaboration.

Downstream industry drivers include the complexity and size of projects (many more than $5 billion); reduced facility footprint to minimize bulk materials and thus capital spend; modularization to limited craft labor at the site; and compression of project execution duration to reach first product, especially from mega-projects that are in the field for years.

When software is a service solution in the cloud, projects are no longer tethered to physical location, as all participants have access to same data in any geography and time zone.

5-IV Data Analytics

Big data is a broad term for data sets so large or complex that traditional data processing applications are inadequate. Challenges include analysis, capture, data curation, search, sharing, storage, transfer, visualization, and information privacy.

Construction-sector companies and vendors are embracing data science - the growing need to analyze and interpret vast amounts of data collected on projects for planning; decision-making; project transparency; risk mitigation; and resource planning.

Leading EPC firm Bechtel has created a data analytics team, hiring data scientists to mine the company's growing datasets. Data analytics, along with the deployment of the latest handheld devices and 4D and 5D modelling, has improved decision-making in areas such as piping productivity and staff logistics, according to Joe Thompson, Senior Vice President, General Manager – Downstream & Chemicals, Bechtel Oil, Gas & Chemicals. "It's really paying big dividends for us...we see data analytics to be a big differentiator in the future," he said.

Having disjointed data repositories with little or no understanding of available data or how it relates to the projects historically, currently and predictively, is a recipe for continued mediocrity. Technology that enables organizations to mine into vast amounts of historical and current project documentation and lessons learned exists today. By having the intelligent search engine capable of understanding a project query, an organization becomes capable of putting its project history to work for its future and increases productivity of team members across the board to perform their jobs more effectively when powered by what was previously "dead data."

5-V Convergence to the Digital Ecosystem

According to the World Economic Forum, by 2020 there will be 50 billion networked devices worldwide. That means that hyper connectivity is exponentially increasing the digital interconnection of people and things, anytime, anywhere.

Digital information exchange is set to accelerate as design, construction, and asset data is increasingly standardized and integrated. For capital projects, digital transformation includes data powered analytics, cloud computing, automation, asset visualization, Internet of Things, social media and more.

Cloud- based solutions reduce client investment in IT hardware and support. The cloud is a network of distributed servers hosted on the Internet; managed in a highly automated way; and is shared by many applications at the same time with speed, realizability and security.

For too long the downstream industry has lacked an integrated platform that spans project planning, design, construction, operations and maintenance. In addition, Owners and EPCs often use different platforms that do not sync with one another.

In a recent survey by Dodge Data Analysts the highest risk for both Owners and EPCs was deemed to be poor collaboration and lack of information integration.

As the capital effectiveness moves from document centric to a data-centric foundation, technology solution providers are racing to meet the needs of Owners and EPCs with productivity improvement and project delivery software platforms that are increasingly cloud-based and agile. Many of these address aspects of project delivery, i.e., project estimating, scheduling, cost management, contract managements, design, construction, and interface management.

Solution providers that offer a common data environment that supports interoperability between products from multiple vendors can provide a less disruptive improvement process and reduce the need to replace all existing software.

Thus, some software technology providers create Application Programmable Interfaces (APIs) that allow multiple, best of breed platforms to tie together in an ecosystem. They serve as "translators" between software applications, providing Owners and EPCs the flexibility to retain in-house applications. API's also enable custom configuration to a client's project delivery work processes and templates.

Providers offering APIs and those that comply to industry information exchange standards are clearly advantaged. Whether choosing to partner with a well-established global company or an entrepreneur startup, Owners and EPCs find themselves on an innovation, learning journey as new products are piloted on new capital investments. Often this requires new job roles, skill set and componentizes.

"For the first time, Owner and EPC companies have the power to build the tools they need to leverage historical project data and facilitate multi-stakeholder collaboration throughout the capital project lifecycle," Hamdi said.

Hamdi shares her perspective: "Owner and EPC project organizations function in essence as an ecosystem. A game-changing platform mirrors that specific ecosystem, to serve its various collaboration channels, support continuous improvement and, most importantly, not interfere with the chosen governance and assurance systems. The Team-Concord Platform does just that."

The Team Concord platform (T-CON™ / patent pending) is one of the first cloud-based scalable platform purpose-built for capital project teams. Based on a deep understanding of capital projects and Advanced Work Packaging (AWP) protocols, T-CON™ uses artificial intelligence, big data and a progressive knowledge architecture to support capital projects from beginning to end through a "Projects Performance Acceleration Platform.™"

Data-centric software solutions serve as powerful collaboration and productivity tools for all stakeholders at all stages of the project lifecycle. Benefits include, but are not limited to:

- ***increased speed and quality of decision making;***
- ***early identification and mitigation of risks;***
- ***seamless, single-source-of-truth data among the Owner, multiple contractors, subcontractors, vendors and suppliers;***
- ***intelligent analysis of information using purpose-built algorithms, at last enabling a functional, searchable, experience-based, structured knowledge library;***
- ***project data captured and shared in real time;***
- ***workflow-focused, automatic dissemination of data to reviewers and approvers; and***
- ***reliable data for benchmarking performance and passive non-intrusive data collection to continuously evaluate project practices.***

In the MIT Sloan Management Review Research Report, Achieving Digital Maturity, 2017, digital maturity is described as how organizations systematically prepare to adapt consistently to ongoing digital change. Beyond simply implementing new technology, maturity requires an alignment of company strategy, workforce, culture, technology, and structure.

5-VI Technologies Reshaping the Future of Construction Productivity

Project sites generate vast amounts of data, but little of this is captured, let alone measured and processed. The Internet of Things - sensors and wireless technologies that enable equipment and assets to become "intelligent" by connecting them with one another - is changing that.

The following is a sampling of technologies that are revolutionizing how work gets done in the field. The list is by no means comprehensive.

- 3D laser scanning; Light detection and ranging (Lidar) technology
- Geographic information systems - allow maps, images, distance measurements and GPS positions to be overlaid on 3D images
- Survey layout and verification – leverages 3D model coordinates for equipment assembly or control of movement; automated machine guidance (AMG); photogrammetry
- Field mobility tools – paperless data, available 24/7 on site, with tablets, handheld devices and smartphones; usher ing in a new generation of cloud-based crew-mobility apps
- Radio-frequency identification (RFID) tagging – to track and trace materials; well-established in retail, logistics and manufacturing, cost of equipment are falling, expanding application to include information on specifications, dates, defects, vendors and original-equipment manufacturers, maintenance records, etc.
- Site control and validation – GPS for quick layout and QC checks; stockpiles, acreage, excavation
- Robotics for repetitive construction tasks
- Robotic Total Station – precision layout; concrete; imbeds and anchor bolts
- UAV data capture and site monitoring; drones and unmanned aerial vehicles for scanning, monitoring, and mapping
- Augmented Reality: Microsoft HoloLens – the first wearable, self-contained holographic computer; multiple sensors; advanced optic and custom processing units allowing user iteration with design data intuitively; seamless, immersive integration of physical and digital; no tethering; interaction and collaboration with other users irrespective of geography. In this "mixed reality" environment, users can pin holograms to physical objects and interact with data using gesture, gaze, and voice commands.
- Virtual Reality: HTC Vive and Oculus Rift - head mounted display for immerse interaction with 3D models; limited physical movement; isolation of user; tethered; prototype
- Productivity and safety monitoring system – tracks worker availability and productivity in real-time for actionable data, benchmarking and planning in future projects

As industry grapples with cost overruns, a trio of national construction associations is launching an online benchmarking tool, Construction Labor Market Analyzer (CLMA), this year to track labor productivity and address declining performance levels. The tool will allow companies to input projects into the CLMA in the planning stages and track productivity over the entire life cycle, providing a forward-looking view and a simplified productivity score over chosen periods.

Alliance Safety Council in Baton Rouge is promoting a tool called eTracker, which allows users to dynamically discover and collaborate tackle issues and concerns related to both productivity and safety.

5-VII Reinventing Culture – People are first, always

Culture is the beliefs that influence engrained individual behaviors and established ways of doing things, such as follow- ing procedures, questioning things out of the ordinary, backing colleagues up, and acting stop work in an unsafe environ- ment. The construction industry over a long period has made great strides in changing culture to promote an Incident and Injury Free environment.

Building on that experience, it is easy to recognize digital transformation as a journey that starts with leadership and permeates to the front-line workers to commit to change ways of working and behaviors. People are the engine that delivers sustained, systemic change.

Project delivery organizations are inherently process-centric, non-collaborative across interfaces, and risk adverse. When new technology platforms do not mirror work processes, the capture of productivity gains is delayed and diminished. Success depends both on communicating, preparing and enabling the user community to adapt to new behaviors and ways of working and often requires re-tooling work processes, procedures and practices to take full advantage of a data-centric solution.

Preparing software end users to see and accept how changes impact their daily work is essential to realizing a quicker return on investment. Areas that are challenged by the alignment of people, processes and tools are resulting from deployment of a new technology platform: transparency in the flow of design and materials data; willingness to share data and to collaborate; standardization of work processes, systems, and organizations across companies; specific changes in work flows; and changes to individual roles and responsibilities.

Software and technology must be recognized as an enabler, not a panacea. Technology providers vary from "installers" to "implementers and service providers" who are vested to various degrees on the outcomes by leading joint design and implementation teams with their clients for customized solutions based on a client's digital maturity.

Transformational, systemic changes in project delivery organization culture, strategy, leadership, work processes and tools will require the collaboration of Owners, EPC contractors, and software and service providers to identify issues and seek improvement.

Today, the industry is like an ice field with fissures and discreet, slow movement of ice blocks by early adopters willing to invest in digitation. To accelerate the change of landscape requires movement from all players. Owners, and to a large extent EPC's, are generally risk averse and struggle to navigate an unfamiliar market. Also, Owner and EPC contractors vary in their internal capability to tackle large scale enterprise change.

Digital transformation will be embraced when a sufficiently broad range of software solution providers penetrate the market with more proven standardized products.

CONCLUSION & FORWARD LOOKING ASSESSMENT

Low prices for natural gas and wide availability of the fuel have ushered a construction boom for natural gas fired power generation since 2012. The largest areas for growth in the U.S. are the northeast, Great Lakes, southwest and southeastern United States.

Natural gas is expected to remain the go to fuel to replace coal fired generation retired in recent years or scheduled for closure. Construction costs for natural gas fueled power plants at around $696 ($kW) capacity weighted average cost are one of the lowest just behind hydro power to build, according to data from the EIA.
From a construction kick off stand point, more than 58 GW have started construction since 2012. Additional projects representing 47 GW are expected to kick off from 2017 to 2019.

There is a possibility that the rush to build power plants fueled by cheap natural gas could swell supply with little or no increase in demand.

At the same time, an aging infrastructure of nuclear and coal plants are shutting down at a rapid pace. If enough shut down, it is possible that supply and demand could be balanced.

Meanwhile, government initiatives are on the table to protect coal-fired and nuclear power plants that are struggling to compete with cheaper energy sources, but it remains to be seen if these initiatives pass.
Construction projects in the energy industry are always highlighted by uncertainty with supply, demand and market conditions ever changing, and the natural gas power sector is no different. It is more important than ever that owners and EPCs focus on productivity as well as recruiting, training and retaining skilled employees in order to keep these projects on time and on budget.

REFERENCE SOURCES

U.S. Energy Information Administration | Moody's Investor Service | Ohio Power Siting Board | U.S. Bureau of Labor Statistics | Industrial Information Resources | Petrochemical Update | Federal Emergency Management Association (FEMA) | Compass International | McKinsey & Company | Virginia Department of Environmental Quality
Project Management Institute | Construction Industry Institute | MIT Sloan Management | Dodge Data Analysts