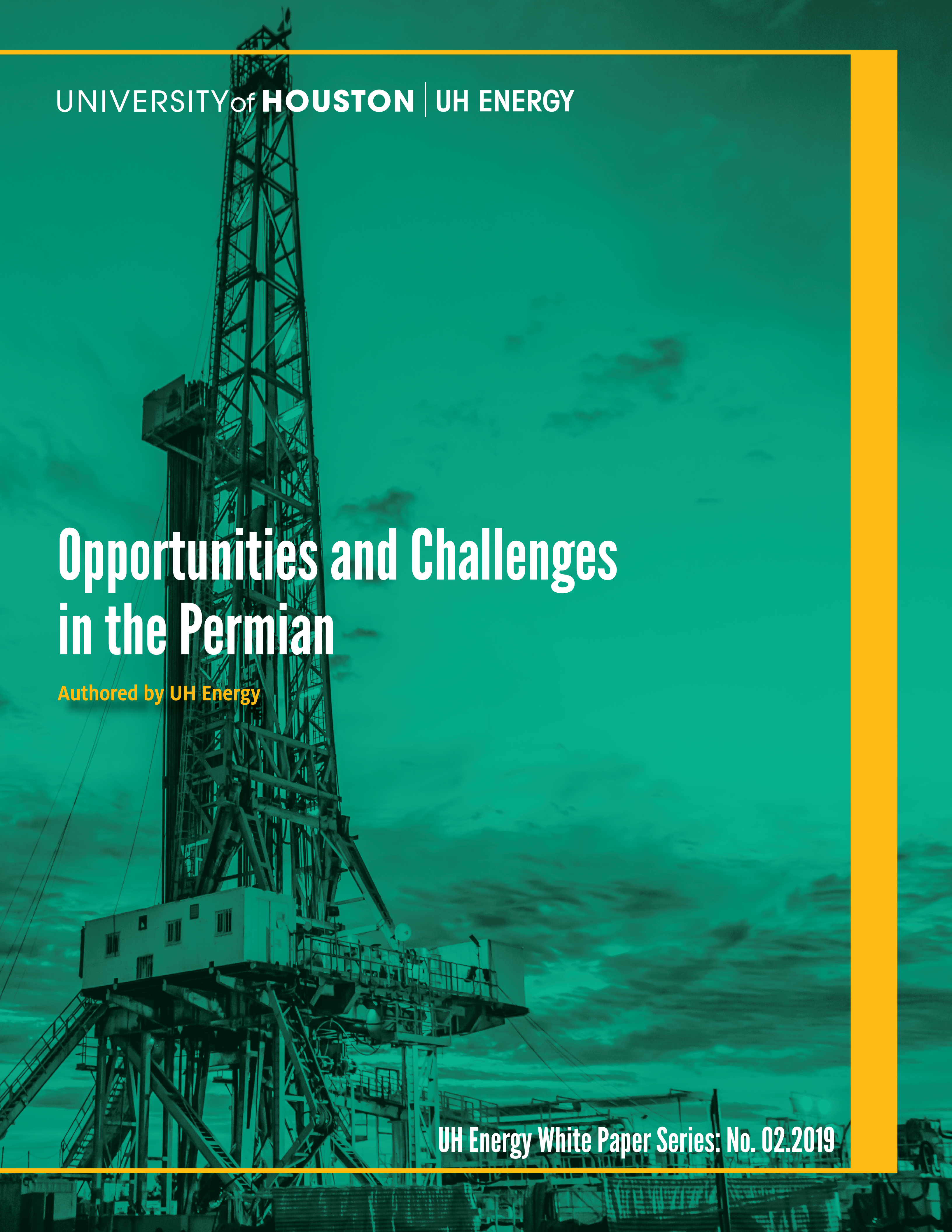


UNIVERSITY of HOUSTON | UH ENERGY

Opportunities and Challenges in the Permian

Authored by UH Energy

UH Energy White Paper Series: No. 02.2019

White Paper Contributors

About the Authors

Radha Radhakrishnan

Dr. Suryanarayanan Radhakrishnan is a Professor of Practice in the Decision and Information Sciences at the University of Houston's Bauer College of Business. He is also the Managing Director of UH Energy. Prior to joining the University of Houston, he had worked for 36 years at Shell holding various responsible jobs mostly in Planning, Strategy, Marketing and Business Management. Since retiring from Shell in 2010, Dr. Radhakrishnan has been teaching Undergraduate, MBA and Executive MBA courses at the Bauer College of Business. At UH Energy, he has been involved in the development of UH Energy's strategy working closely with the Energy Advisory Board and coordinating special projects. Dr. Radhakrishnan holds a bachelor's degree in Mechanical Engineering; a master's degree in Industrial Engineering and a doctoral degree in Business Administration.

Ramanan Krishnamoorti

Dr. Ramanan Krishnamoorti is the chief energy officer at the University of Houston. Prior to his current position, Krishnamoorti served as interim vice president for research and technology transfer for UH and the UHSystem. During his tenure at the university, he has served as chair of the UH Cullen College of Engineering's chemical and biomolecular engineering department, associate dean of research for engineering, professor of chemical and biomolecular engineering with affiliated appointments as professor of petroleum engineering and professor of chemistry.

Aparajita Datta

Aparajita Datta is a graduate student at the Hobby School of Public Affairs. Her research at UH Energy is focused on carbon management and climate change mitigation. Datta holds a masters degree in energy management from the University of Houston.

Contributing Experts

Gino Lim
Professor and Chair, Hari and Anjali Agrawal Faculty Fellow, Industrial Engineering

Jiming Peng
Associate Professor, Industrial Engineering

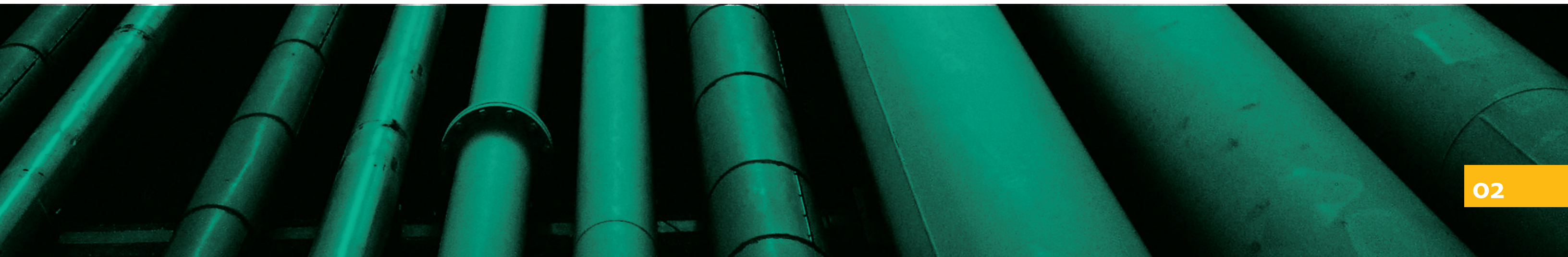
Mohammad Najarian
Ph.D. Candidate, University of Houston

Contributors

CONTRIBUTING EDITOR
Jeannie Kever

PROGRAM COORDINATOR
Lauren Kibler

WEB DEVELOPER
Kyle Kinder



EXECUTIVE SUMMARY

As a result of the shale revolution, U.S. crude production has been growing significantly. The increased output from the Permian Basin has been the biggest contributor to this growth. UH Energy and the University of Houston's Department of Industrial Engineering undertook a study to assess the ultimate outcome of this increased production. The key findings of the study were validated through conversations with industry, government and infrastructure leaders, and are summarized as:

a. There is no domestic U.S. customer for the incremental crude projected to come out of the Permian Basin. The Permian Basin produced 3.2 million barrels per day in 2018. That number is expected to grow by 1 million barrels per day each year for the next four years to ~ 7 million barrels per day in 2022. U.S. refineries have all the light crude they need from current domestic suppliers and Gulf Coast refineries have not imported significant quantities of light crude since 2015. As a result, most of the 4 million barrels per day of incremental crude coming out of the Permian Basin will have to be exported.

b. Pipeline takeaway capacity in the Permian has caused a major bottleneck until recently and will move back into balance with demand by the middle of 2020, if not before. Recognizing the need for additional pipeline capacity to evacuate the increasing production from the Permian, there have been a series of announcements about plans to build pipelines from the Permian to the Gulf Coast – several to the Ports at Corpus Christi, Houston, and Beaumont. These are planned to come on stream at different times between now and 2022. The announced pipeline capacity and timing will be more than adequate for the evacuation of additional crude oil to be produced in the Permian. However, new bottlenecks will emerge further downstream as the export terminals in Corpus Christi, in particular, are unlikely to be ready to handle the volume, even though it is designed for the operation of very large crude carriers.

c. The Permian and the supply chain for domestic refined products are increasingly being consolidated by major operators (including ExxonMobil, Chevron, BP, and Shell) and this would require Independent producers to export their crude.

d. The independent producers are relatively inexperienced with exporting and likely to face challenges in the absence of appropriate intermediaries stepping in to the market. If the issue of building export capabilities is not addressed by the independent producers, they could become targets for acquisition. Independents face additional pressures because of the flight of capital from the Permian a result of the relatively weak return on investment. This will lead to the gradual erosion and ultimate destruction of enterprise value among many oilfield services companies due to the lack of pricing power.

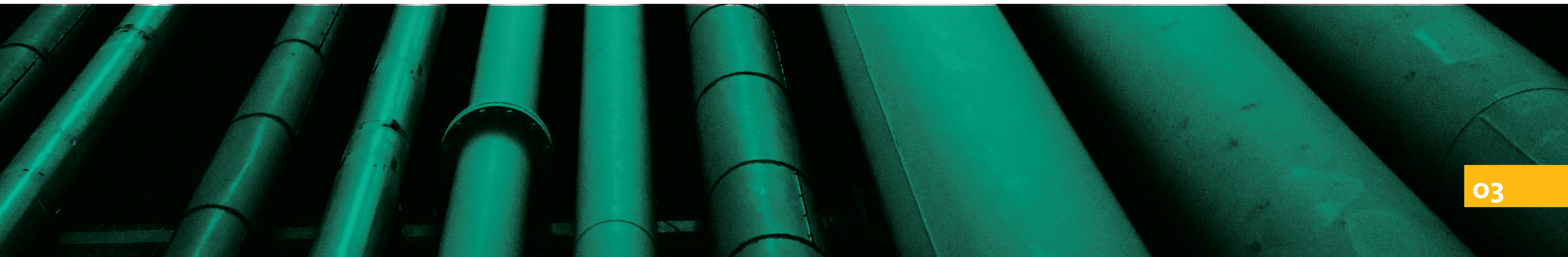
e. There is significant uncertainty regarding the dislocations in timing of completions of the pipeline and export ports, especially the planned expansion of the Port of Corpus Christi and the ancillary facilities that must co-develop.

f. Two notable challenges must be resolved in the short term to ensure the appropriate valorization of the Permian resources:

1. The poor consistency of crude quality exported to Asia, and
2. The continued environmental footprint especially from the flaring of associated natural gas that is produced in conjunction with oil.

Acknowledgements

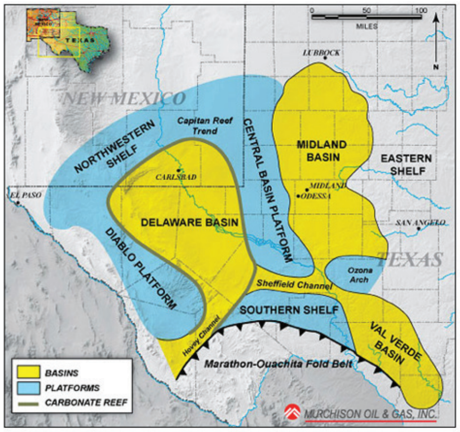
The authors and UH Energy thank Hastings Equity Partners for sponsoring part of the research on which this white paper is based. We especially thank Tanner Moran and Ted Patton for their valuable insights and encouragement to develop this white paper. We also thank the numerous inputs from our colleagues in the industry, government and non-profit agencies.



POTENTIAL OF THE PERMIAN

In April 2019, the Permian Basin became the highest producing field in the world, producing about 4.2 million barrels per day. Located in western Texas and southeastern New Mexico, the Permian Basin covers an area of ~86,000 square miles.[1] Various smaller component basins such as the Midland Basin, the Delaware Basin and the Marfa Basin[2] make up the greater Permian Basin. The latter is the smallest component basin of the Permian while the other two are the largest and second-largest respectively.

Figure 1: Permian Basin



Source: Murchison Oil & Gas Inc.

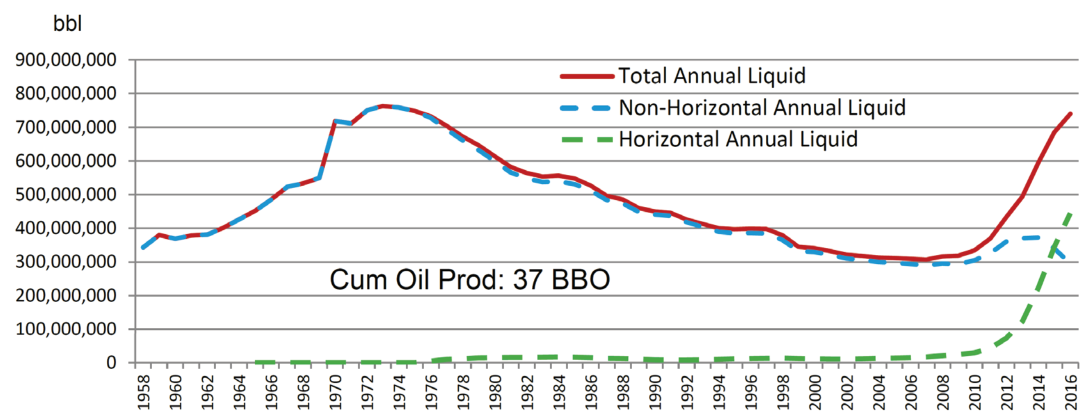
Among these, the Midland Basin and the deeper Delaware Basin have significant potential for hydrocarbon recovery. Stratigraphically, they can be characterized by stacked plays, also known as a "multilayer" cake with different geologic zones.[3] Formations in the Permian average a thickness of about 1,300-1,800 feet.[4] In contrast, the Bakken Shale averages 10-120 feet in thickness, while Eagle Ford Shale formations are 150-300 feet thick. The sheer number of layers and their unrivaled thickness has allowed production from the Permian to grow 72% in the last two years.[5]

The U.S. Energy Information Administration (EIA) reports that as of September 2018 the Permian has generated more than 33.4 billion barrels of oil, and ~118 trillion cubic feet (tcf) of natural gas.[6] Analysts expect sustained growth to double over the next 4 years, producing about 7 million barrels per day.[7] However, production analyses of these plays indicate that vertical production has been steadily declining since 1973, after having gone through primary through tertiary recovery.[8] This production drop has been countered by hydraulic fracturing, horizontal drilling, and completion technology in the past decade, resulting in the unprecedented and sharp growth in production. Targeting resources in the non-continuous type reservoirs located in bypassed, and tight intervals has led to the Permian producing about a third of total U.S. oil production.

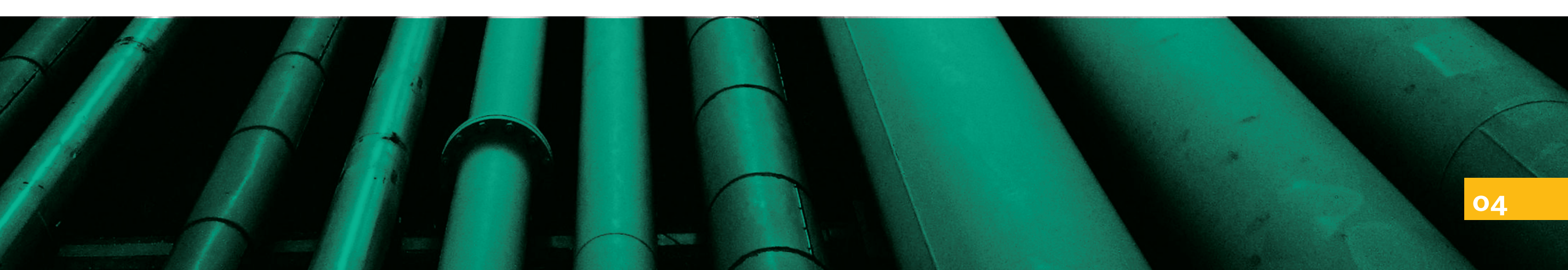
The Wolfcamp Shale is a tight oil and shale gas-rich formation which extends across the subsurface of the Permian. The U.S. Geological Survey (USGS), in its 2018 study of the Wolfcamp for continuous oil and undiscovered and technically recoverable resources, reported that the Permian contains an estimated 46 billion barrels of oil, 280 tcf of gas, and 20 billion barrels of natural gas liquids.[9,10] If these resources can be extracted economically, proved oil reserves in the U.S. would increase by

> "The U.S. Energy Information Administration (EIA) reports that as of September 2018 the Permian has generated more than 33.4 billion barrels of oil, and ~118 trillion cubic feet (tcf) of natural gas."

Figure 2: The Permian Basin is Headed for a Second Peak



Source: IHS Markit, 2017



more than 100%, with current estimates totaling 40 billion barrels. Natural gas proved reserves would see a 60% increase, with current estimates at ~465 tcf.[11]

TECHNOLOGY DRIVES THE CHANGE

In its Annual Energy Outlook for 2019, the EIA has provided long-term energy projections which emphasize that the U.S. will become a net energy exporter by 2020 for the first time after 1953. This will be supported by continued growth in oil and gas production, wherein oil production will continue to increase through 2027, reaching more than 15 million barrels of oil per day (bopd), and will remain above 14 million bopd through 2040. Dry natural gas production is expected to remain fairly constant through 2050, and natural gas liquids are expected to grow to 6 million bopd by 2029.[12]

Given its current status as the nation's leading oil and gas producer, Texas is expected to support the bulk of this growth. From 2016 to 2017, Texas saw the largest volumetric increase of crude oil and condensate production.[13] The current and anticipated increase in Texas production is largely due to additional drilling and exploration in previously discovered reservoirs, lateral length extensions, precision targeting, high-density stimulations, and cost reductions. According to the EIA, the average lateral length of completed wells in the play increased from approximately 5,200 feet in 2016 to approximately 6,100 feet in 2017.[14]

Figure 3: Wells Drilled

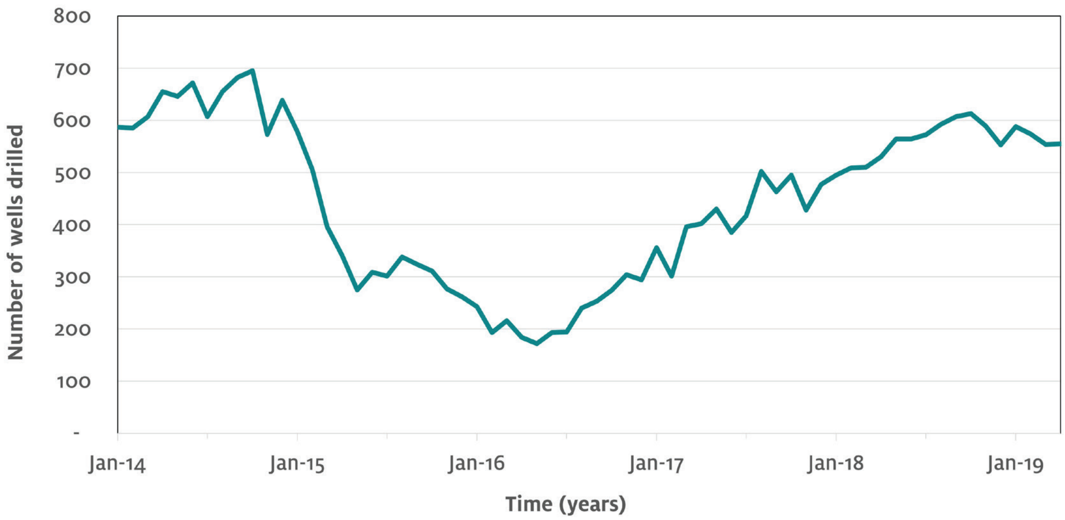
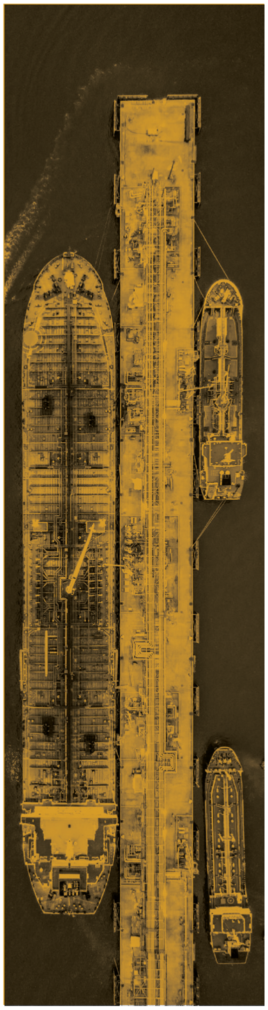


Figure 4: Wells Completed



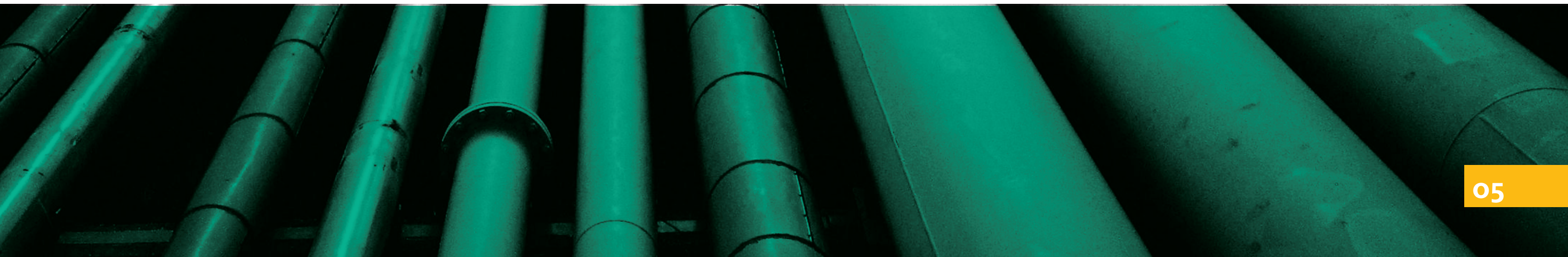


Figure 5: Total Oil Production

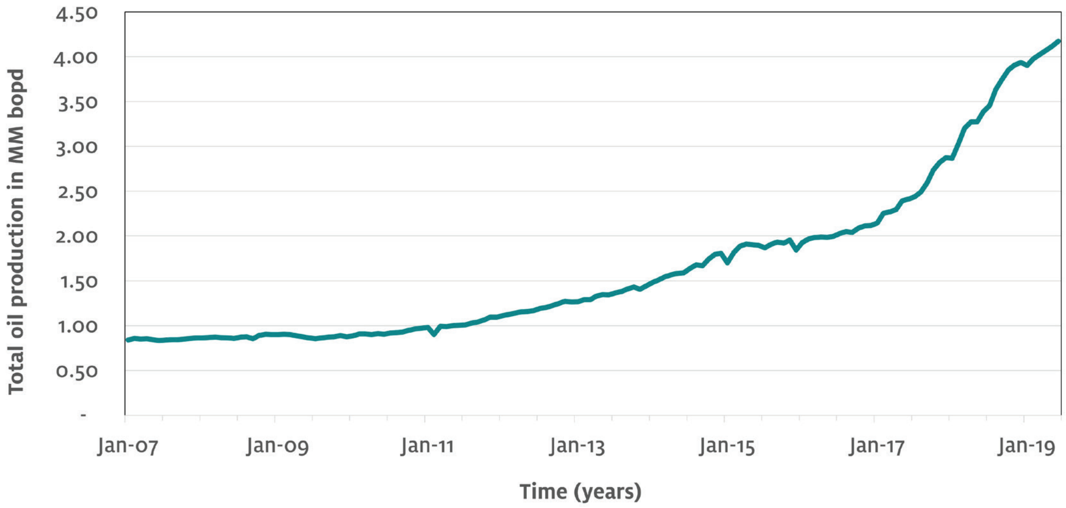
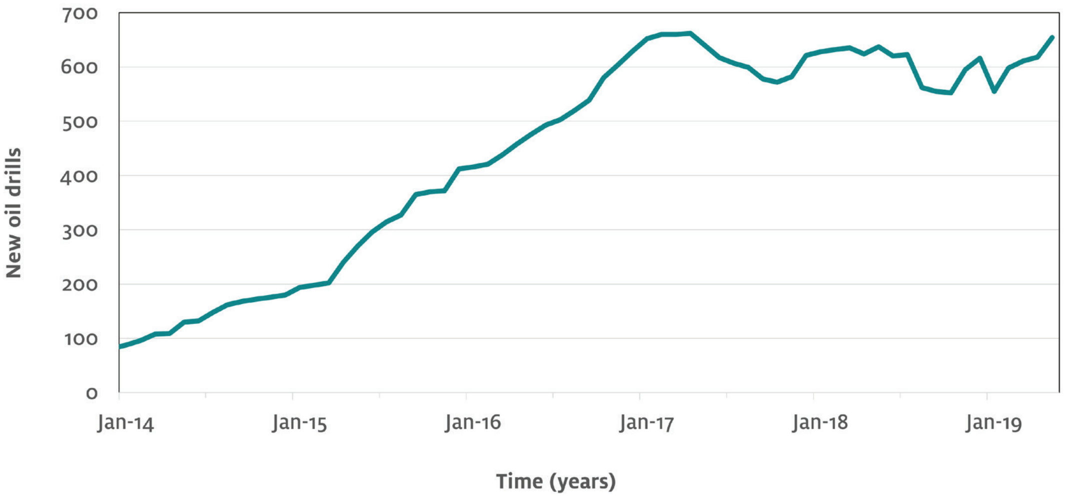
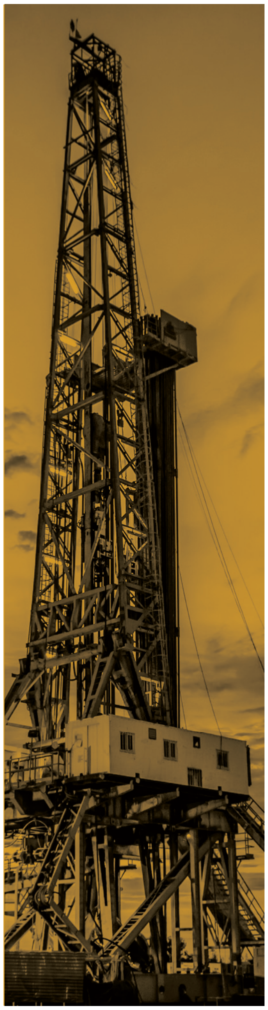
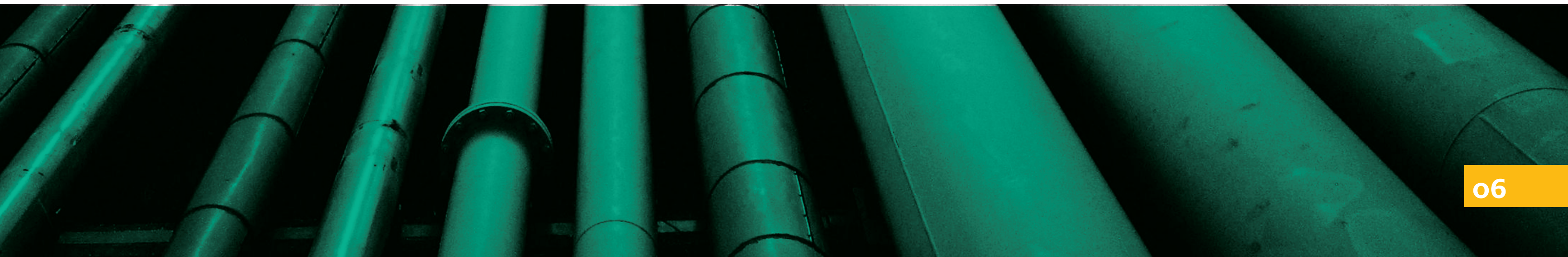


Figure 6: New Oil Drills





- *Precision targeting* from advances in *logging while drilling* (LWD) technology (both sensors and software) has resulted in improved real-time geosteering during horizontal drilling. This has allowed operators to identify the best rock (i.e., sweet-spot identification) and achieve precise wellbore placement within it.
- *High-density stimulations* (hydraulic fracturing) lead to an increase in the number of perforation clusters per fracturing stage and consequently, an increase in the proppant load per lateral foot.
- Multi-pad drilling has proven to save time and money for oil and gas producers because the drilling rig has to be moved less than 10 yards before another well can be drilled into the same reservoir.[15] By reducing the need for new infrastructure, significant savings of time and money are achieved.
- The leading producers in the Permian have recently seen increased drilling efficiencies and decreasing costs, primarily through the deployment of new technologies. New technologies, such as diverting agents, microfracturing, coil-tipping racks and digitalization, in combination with improvements in drilling and completions have resulted in an increased production in the Permian.[16]



Greater savings have been achieved for a variety of reasons:

- Greater number of rigs with an experienced workforce.
- Average time taken to drill a well has dropped from 35 days to 14 days in the last two years. Simultaneously, costs have dropped from $4.5 million to $2.6 million per well.
- The drop in commodity costs have been offset by a 42% decrease in average drill cost per foot, from $245 to $143.[17]

Figure 7:

Year	Actual or Projected Permian Production (MM bopd)
2018	2.8
2019	3.8
2020	4.8
2021	5.8
2022	6.8

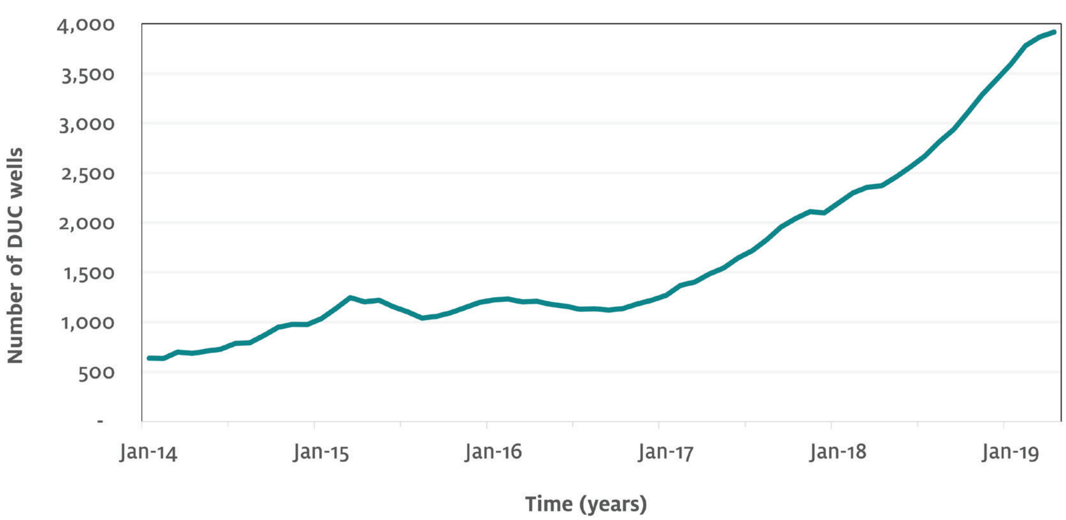
Cost-saving advances in shale drilling have allowed for the continued growth of the unconventional oil and gas industry in the U.S. despite the lower oil prices since 2014, which experts predicted would make such enterprises unprofitable. Along with cost saving measures for greenfield exploration and drilling, refracturing older wells has resulted in savings of 75% over drilling a new well.[18] The process of cost-effectively refracturing is aided by advanced software, new seismic information, precision completions, and re-engineered workovers.

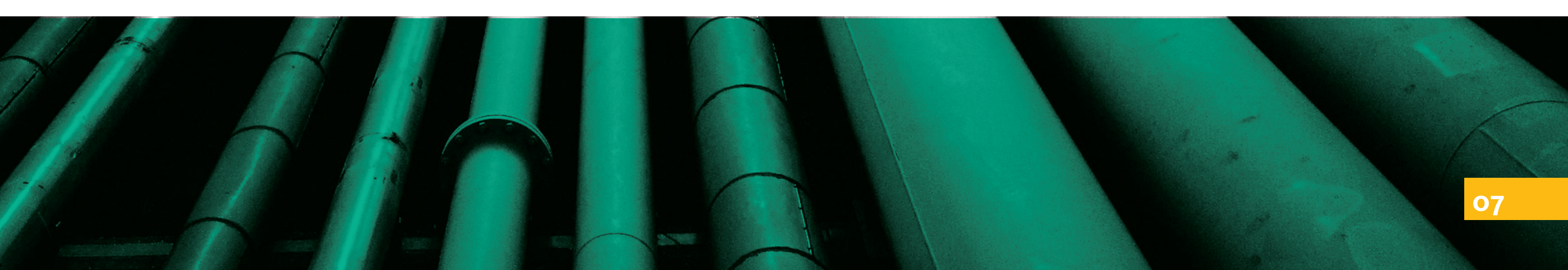
Hydraulic fracturing has significantly increased production in the Permian. By the end of 2018, production had reached 3.8 million bopd, positioning the Permian as second only to the Ghawar oil field in Saudi Arabia. With an expected annual production growth rate of ~1MM bopd, the Permian overtook Ghawar in April this year. At this rate, production is expected to reach 6.8 MM bopd by beginning of 2022.

Oil and gas majors are vying to efficiently extract the Permian's vast quantities of hydrocarbon while ensuring increased profitability. Industry estimates reveal that the cost to develop and operate wells in the Permian is below $15 per barrel.[19] Given these economics, one of the biggest producers in the Permian is ExxonMobil, with a position of 1.8 million Permian acres. ExxonMobil plans to produce more than 1 million bopd by 2024 from the Permian.[20]

> "Average time taken to drill a well has dropped from 35 days to 14 days in the last two years. Simultaneously, costs have dropped from $4.5 million to $2.6 million per well."

Figure 8: Wells DUC





REFINERY INTAKES OF PERMIAN CRUDE

The logical choices for handling this increasing production from the Permian is to domestically utilize as much of the light crude as possible, reduce current imports, and export the remaining crude overseas.

An emerging problem for Permian producers is a quality mismatch between the produced feedstock and refinery capabilities. The Gulf Coast is home to most of the nation's petroleum refineries which run a diverse mix of crude oils. Most investments for equipment since 1985 were directed towards heavy crude as it was cheaper feedstock. Resultantly, crude oil inputs to refineries in the Gulf Coast ranged from an API gravity of 34.1 degrees in 1985 to 29.5 degrees in 2008.[21]

Simultaneously, imported crude oil processed in these Gulf Coast refineries increased from 1.4 MM bopd to its highest level of 5.8 MM bopd between 1985 and 2004. However, between 2008 and 2017, the API gravity of crude oil inputs to these refineries increased to 32.0 degrees while imported crude oil processing decreased to 3.1 MM bopd, as refineries switched to processing domestic light crude from shale operations instead.[22]

In February 2019, Exxon broke ground on a major expansion of its refinery in Beaumont, Texas. The project is expected to add an additional 250,000 bopd of processing capability, making it the largest refinery in the country. To process the light, sweet crude produced in the Permian and across North American shale plays, a new refining train will be installed at Beaumont. This would also cap the current growing volume of light crude that must be exported to be refined, given the absence of adequate refining capabilities within the country.[23]

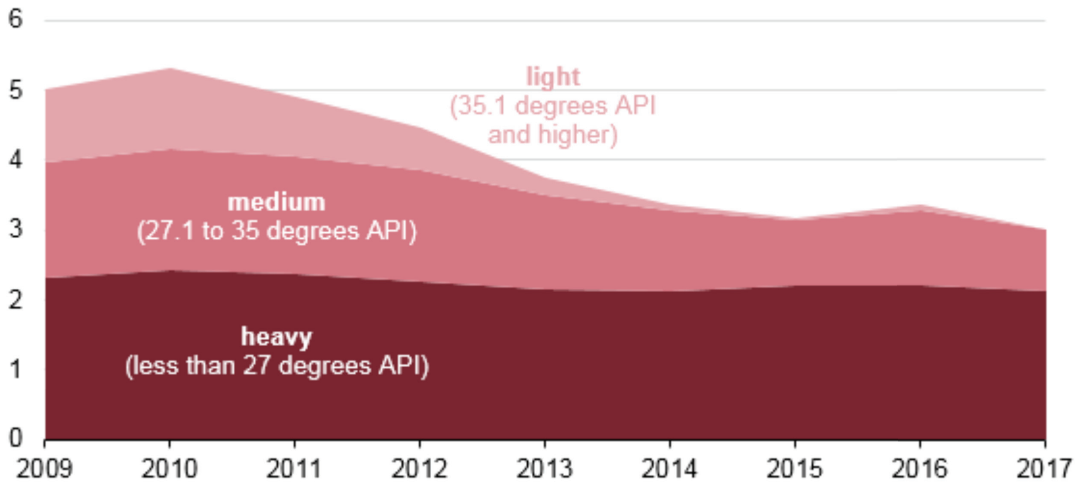
In May 2019, Chevron completed the purchase of Pasadena Refining System in Texas. The facility was previously owned by the Brazilian oil company, Petrobras. This purchase added 110,000 bopd to Chevron's light sweet crude refining capacity. These moves by the two integrated major oil and gas companies clearly indicates their intent to leverage their integrated operations. A repetition or adaptation of these strategies by others may be limited at best.[24]

Most refiners have made all the adjustments to their refinery operations they find economical to take more of the light crude produced domestically, including from the Permian. It is now evident that continued domestic intake of all the net new production, especially from the Permian, is not possible, and exports are the primary outlet for this increased oil production.

This conclusion is supported by the EIA. The agency had previously anticipated that the U.S. would become a net energy exporter by 2022; however, as discussed previously, this threshold will now be crossed in 2020.[25] Large increases in crude oil, natural gas, and natural gas plant liquids

"The Gulf Coast is home to most of the nation's petroleum refineries which run a diverse mix of crude oils. Most investments for equipment since 1985 were directed towards heavy crude as it was cheaper feedstock."

Figure 9: Imports of Crude Oil to the Gulf Coast by API Gravity, million barrels per day



Source: US Energy Information Administration.

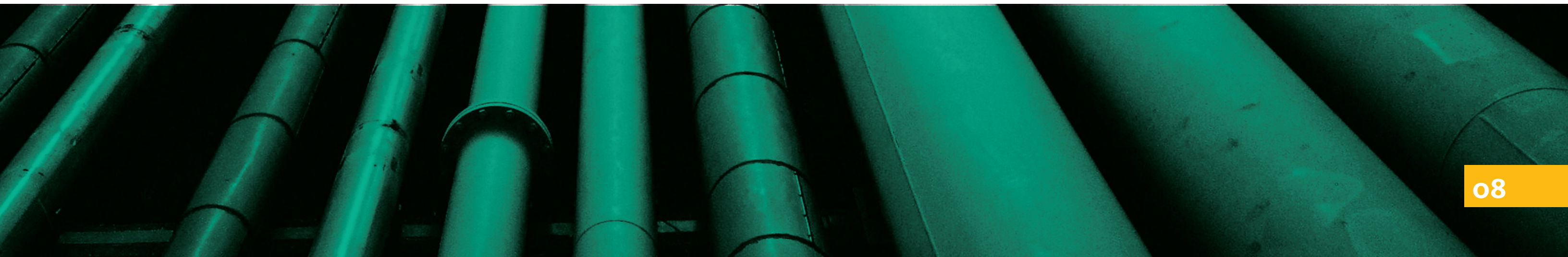
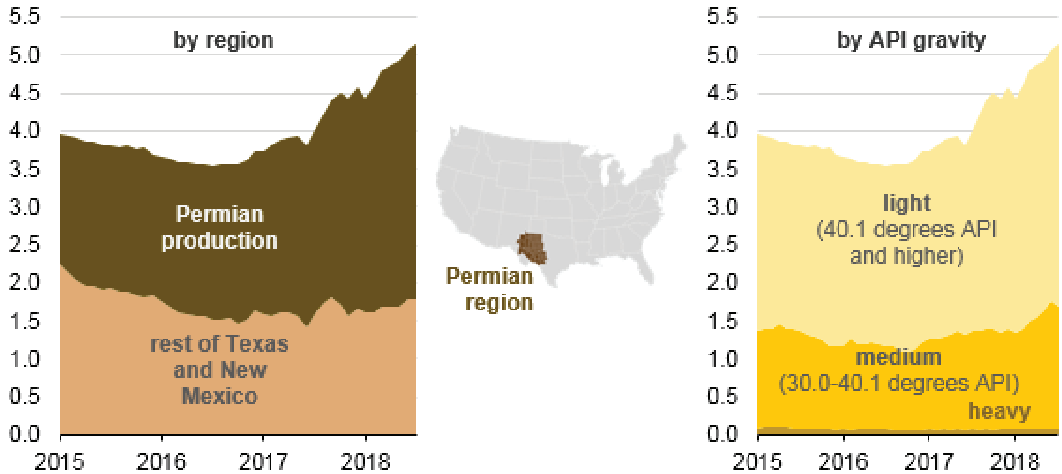
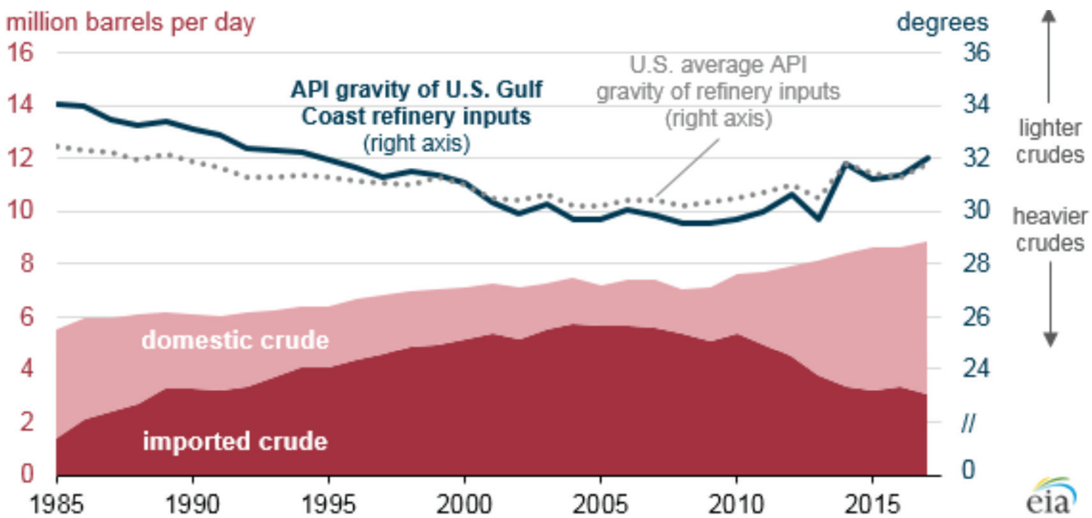


Figure 10: Texas and New Mexico Crude Oil Production (Jan 2015-Jul 2018)
million barrels per day



Source: US Energy Information Administration.

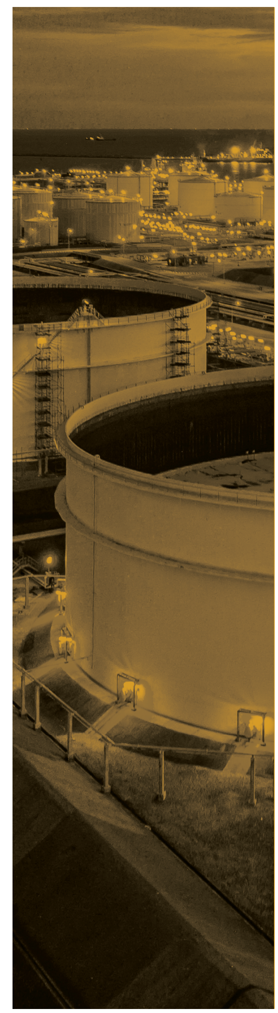
Figure 11: Gulf Coast Refinery Inputs and Crude Oil API Gravity

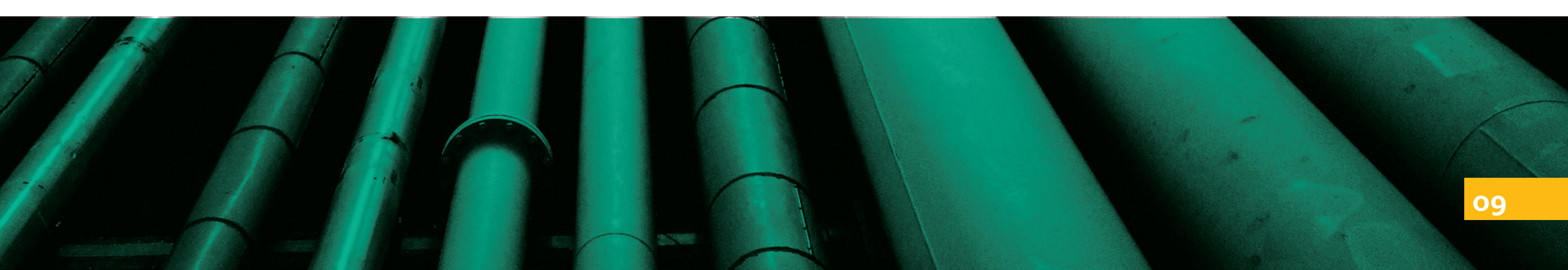


Source: US Energy Information Administration.

(NGPL) production coupled with slow growth in U.S. energy consumption are the foremost drivers for this change.[26]

This consolidation and intensification of oil extraction from the Permian by the oil majors, along with their domination of the entire supply chain of the domestic processing of the crude, is adding to the pressures of the independents operating in the Permian. The continued depressed crude oil prices with the exaggerated discount prices caused by the pipeline bottleneck have resulted in poor return on investment and a progression of capital flight out of the Permian Basin. This continued pressure on the independents and the consolidation by the majors is likely to lead to the gradual erosion of the profitability of the service industry and ultimately to the projected growth of the Permian.





CRUDE OIL EXPORTS FROM THE GULF COAST

After a 40 year ban was lifted at the end of 2015, the U.S. exported ~ 0.6 MM bopd of crude oil in 2016. Exports averaged 1.1 MM bopd in 2017 and reached over 3.6 MM bopd in Feb 2019. Amongst these, crude exports out of the Gulf Coast averaged more than 2.4 MM bopd in the first four months of 2019.[27]

Large volumes of U.S. crude are traveling long distances via marine routes to reach worldwide destinations. Crude exports to Asia are transported through Very Large Crude Carriers (VLCCs), which are designed to carry 2MM barrels of crude and are the largest and most economic vessels used for crude oil transportation. On the other hand, shipments to Europe are transported via smaller Suezmax (1.3 MM bbl) and Aframax (500 – 650 MM bbl) vessels.[28]

Crude export growth in the U.S. has been primarily achieved through these smaller and less cost-effective ships, since ports along the Gulf Coast cannot fully load VLCCs. The EIA states that VLCCs require ports with waterways of sufficient width and depth for safe navigation. Onshore U.S. ports on the Gulf Coast from which petroleum is actively traded are located in inland harbors and are connected to the open ocean through shipping channels or navigable rivers which are 45-55 ft deep. Even though these waterways are dredged on a regular basis to ensure depth and safe navigation for vessels, they are not wide enough and deep enough for deep-draft vessels such as fully loaded VLCCs with a draft of 75 ft . Resultantly, VLCCs which transport crude from U.S. ports along the Gulf Coast are only partially loaded. They also employ ship-to-ship transfers in designated zones between vessels of different sizes. This process is known as lightering.

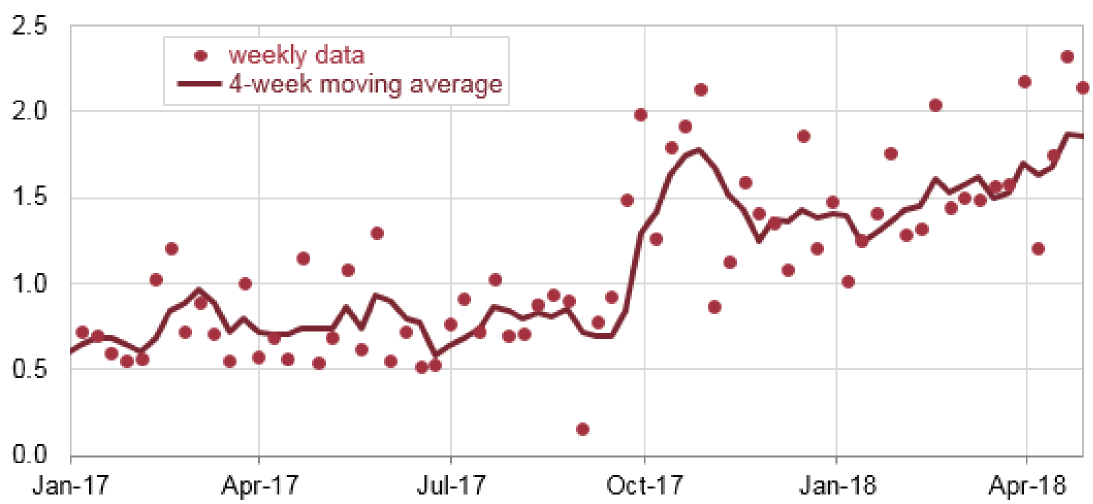
The Louisiana Offshore Oil Port (LOOP), off the coast of southern Louisiana in the Gulf of Mexico, is currently the only U.S. facility which can harbor fully loaded VLCCs. LOOP was previously used exclusively for imports, and was only recently modified to accommodate exports.[30]

The partial loading of VLCCs is a cost center for crude transport. Using several smaller ships for lightering further adds to these costs. While the costs are relatively negligible for short distances, they compound to significantly higher expenses over longer distances, such as for crude transport to Asia. Offsetting these additional costs and lower economies of scale necessitates a wider spread between U.S. crude oil prices and international crude oil prices. With growing demand from Asia, this spread is expected to be a crucial determinant for future exports.

Since the U.S. began exporting crude over the last four years, the landscape for crude exports has changed remarkably and has overcome various bottlenecks. Nonetheless, logistics, scheduling, and planning remain crucial for the industry. With increased exports and demand for U.S. crude, ports are dealing with congestion and scheduling

"Since the U.S. began exporting crude over the last four years, the landscape for crude exports has changed remarkably and has overcome various bottlenecks."

Figure 12: Weekly US Crude Oil Export (Jan 2017-May 2018), million barrels per day



Source: US Energy Information Administration.

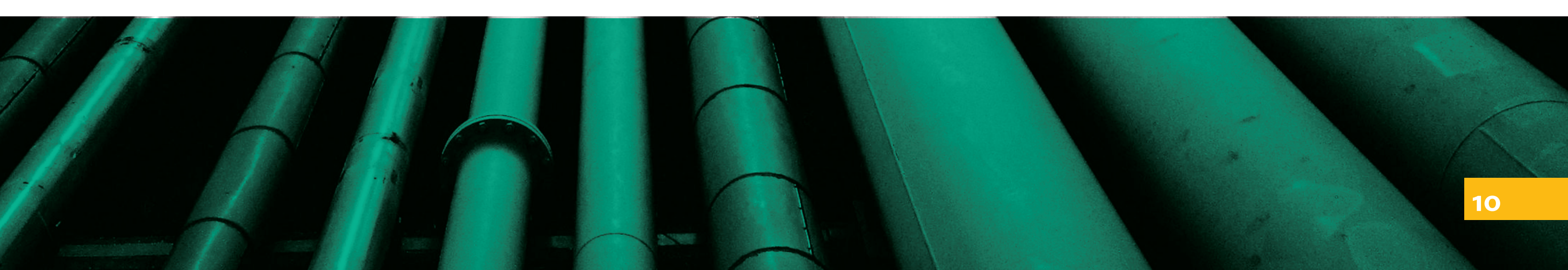
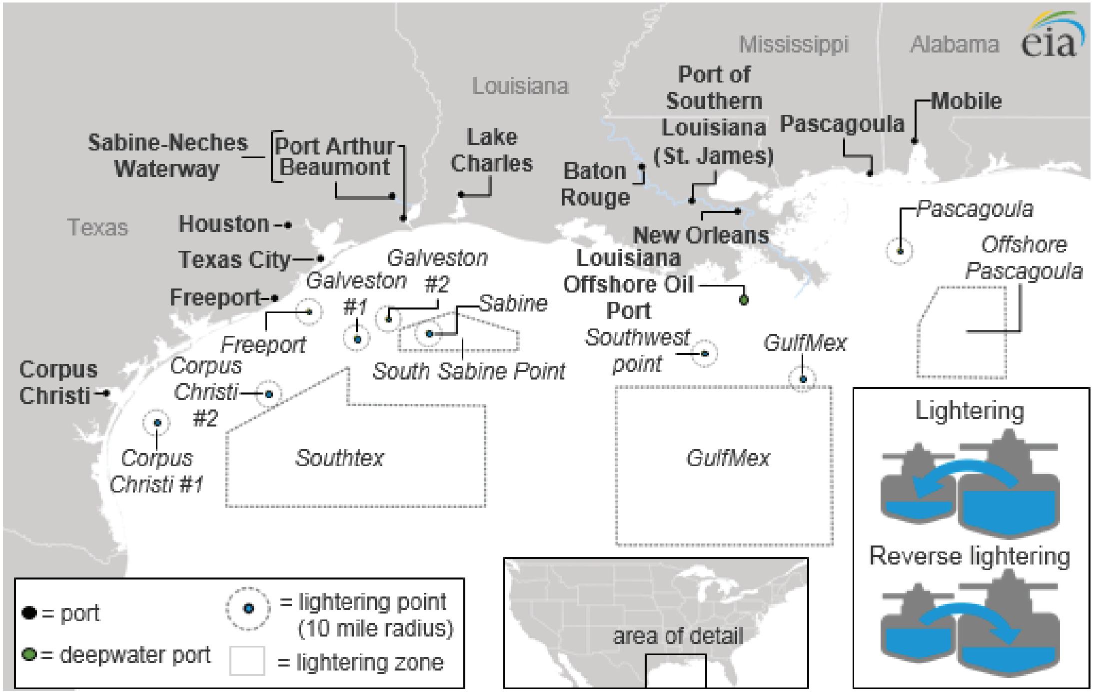
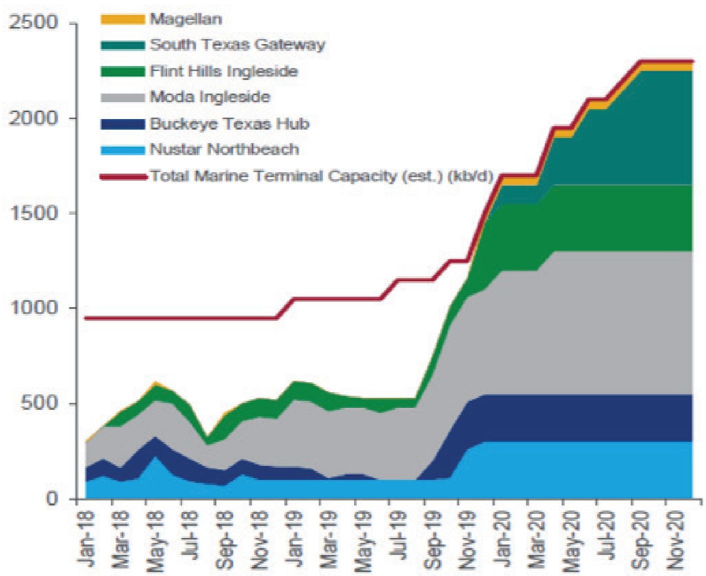


Figure 13: US Gulf Coast Petroleum Ports and Lightering Areas



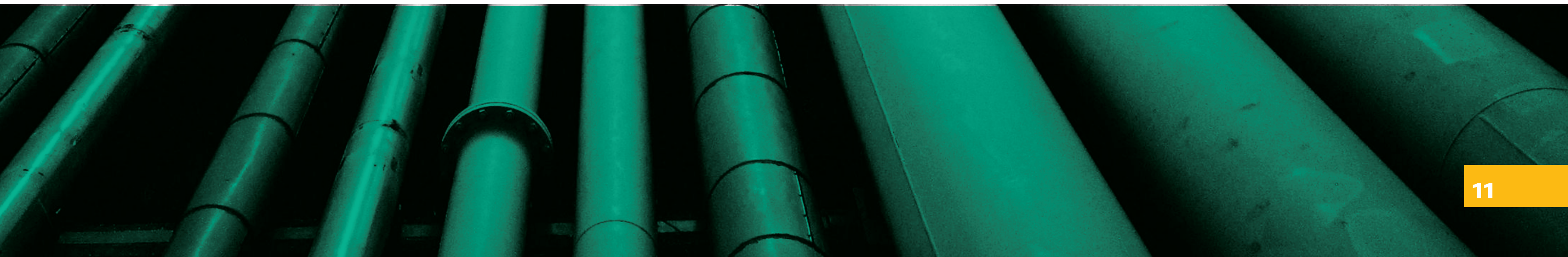
Source: US Energy Information Administration.

Figure 14: Export Capacity and Terminal Volumes



Source: US Energy Information Administration.

conflicts. To ease this congestion, new projects to build deepwater Gulf of Mexico terminals off the coast of Freeport, Texas City, Corpus Christi, Brownsville (all in Texas) and Louisiana have been proposed. Recommendations have also been made to expand the Corpus Christi harbor channel. These projects would be able to accommodate fully loaded VLCCs. On the other hand, plans to widen the Houston Ship Channel to accommodate VLCCs could prove limiting as the Ship Channel is only 54 ft deep. Additionally, meeting air quality standards for the City of Houston is expected to



delay expansion projects at the Ship Channel.

Figure 15:

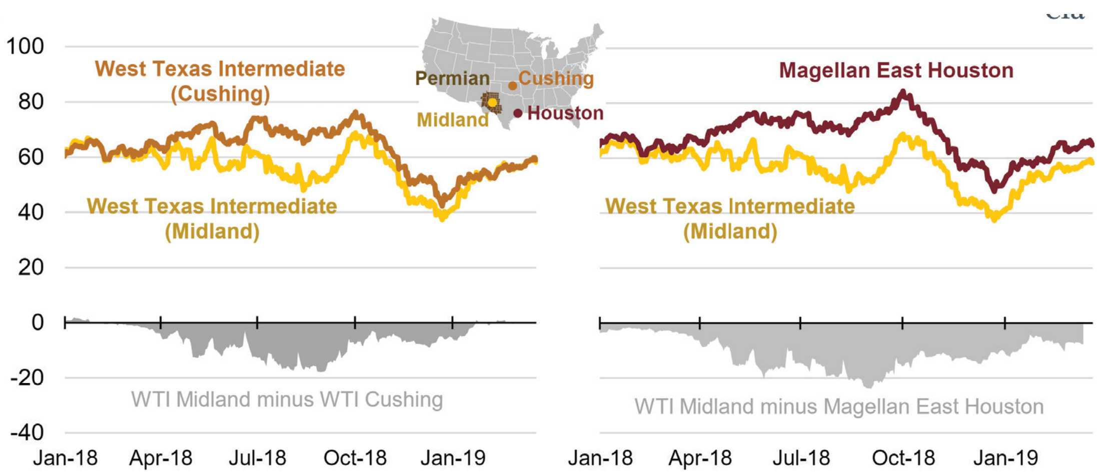
Magellan	45 MM bopd
South Texas Gateway	615 MM bopd
Flint Hills Ingleside	350 MM bopd
Moda Ingleside	760 MM bopd
Buckeye Texas Hub	240 MM bopd
Nustar Northbeach	305 MM bopd
Total	**2315 MM bopd**

Among these, the expansions and new projects to accommodate VLCCS at Corpus Christi will most likely commence soon. However, funding, permitting and execution permissions for these projects are onerous procedures that can take up to several years.[31] If all of these planned expansions are launched on schedule, then the terminal and port capacity would be synchronized to handle the net new Permian crude coming to Corpus Christi. Currently, all indications are that the dredging and widening of the channel from Gulf to Harbor Island will not be ready till end 2021. Similarly, if any of the proposed new deepwater terminals are built on schedule, the lightering requirements and costs can be reduced considerably, and VLCCs can then be fully loaded. However, if for any reason these deeper terminals don't get built or see delays in completion, the industry should expect to see increased congestion at ports along the Gulf Coast.

PIPELINES FROM THE PERMIAN

A major concern for Permian producers is the mismatch between the oil production in the basin and the capacity of pipelines to get it to market, which impacts the price of the crude in Midland versus in Cushing, Oklahoma. This mismatch resulted in takeaway constraints in 2018, which were eased by three pipeline capacity additions in 2019, following which crude oil prices in the Permian region have increased. These expansions included the expansion of Midland-to-Sealy pipeline, extensions to the Sunrise Pipeline, and repurposing of the Seminole-Red pipeline. The 416-mile long Midland-to-Sealy pipeline from the Permian to Houston area is owned by Enterprise Products Partners L.P. Its capacity was expanded from 540,000 bopd to 575,000 bopd in May 2018.[32] As reported by Plains All American Pipeline LP, an extension to the Sunrise Pipeline added ~120,000 bopd of takeaway capacity from the Permian basin to Cushing, alleviating crude transportation constraints along the route. Lastly, the Seminole-Red pipeline, also owned by Enterprise Products Partners L.P., was repurposed to deliver crude oil. It previously delivered natural gas liquids (NGLs) from the Permian to the Houston area. This project is expected to add an estimated 200,000 bopd of takeaway capacity for the Permian.[33] These recent capacity additions can successfully prevent a price mismatch. However, given the sustained growth of production in the Permian basin, these measures are expected to only act as temporary fixes.[34]

Figure 16: Daily Permian Region Crude Oil Prices and Spreads (Jan 2018-Mar 2019)
dollars per barrel



Source: US Energy Information Administration, based on Bloomberg LP.

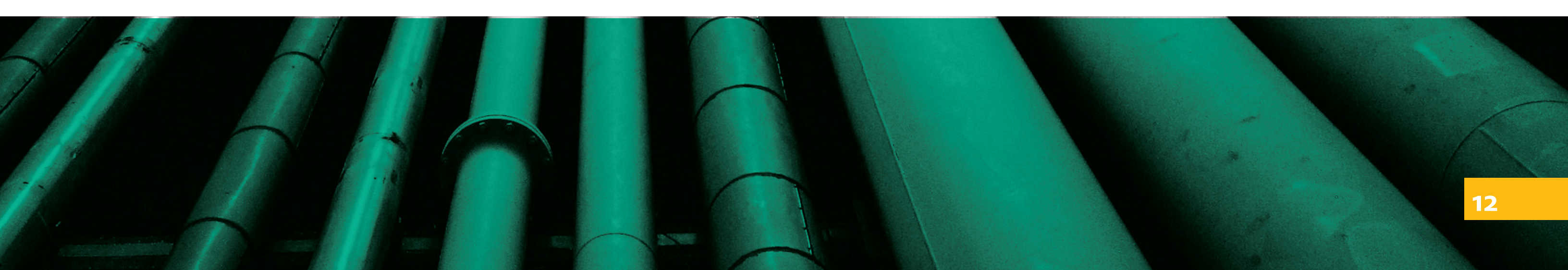
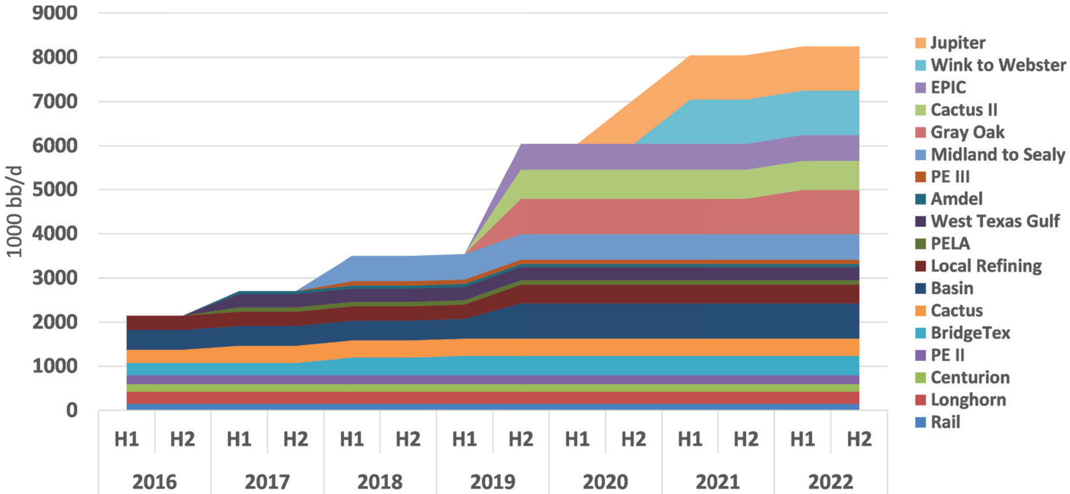


Figure 17: Permian Takeaways



Source: US Energy Information Administration.

Figure 18:

“

Recent capacity additions can successfully prevent a price mismatch. However, given the sustained growth of production in the Permian basin, these measures are expected to only act as temporary fixes.

”

The following are additional pipelines at various stages of completion, and are expected to alleviate the remaining takeaway constraints in the Permian region at least for the next three years (EIA). Of these the Wink to Webster pipeline (1 MM bopd), a partnership between ExxonMobil, Plains All American Pipeline and Lotus Midstream is the only one bringing the Permian crude to the ExxonMobil refineries in the Houston area.[35] The remaining pipelines – Gray Oak, Cactus II, EPIC and Jupiter, will bring the Permian crude to the Port of Corpus Christi and Brownsville.

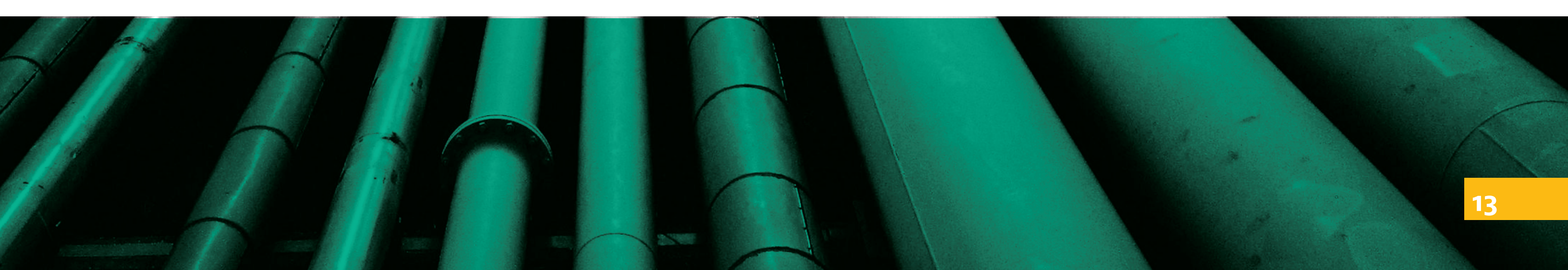


Figure 19:

	2016		2017		2018		2019		2020		2021		2022	
	H1	H2	H1	H2	H1	H2	H1	H2	H1	H2	H1	H2	H1	H2
Cactus	300	300	390	390	390	390	390	390	390	390	390	390	390	390
Gray Oak								800	800	800	800	800	1000	1000
Cactus II								670	670	670	670	670	670	670
EPIC								585	585	585	585	585	585	585
Jupiter										1000	1000	1000	1000	1000
	300		390		390		390	2445	2445	3445	3445	3445	3645	3645

Gray Oak pipeline is an 850-mile long pipeline from the West Texas Permian Basin to Corpus Christi. It's owned by Gray Oak Pipeline LLC, a joint venture owned 75% by Phillips 66 Partners and 25% by Andeavor. The pipeline will be built and operated by Phillips 66 and is expected to be in service by the end of 2019. Along with bringing Permian crude to the Houston area, Gray Oak is also expected to connect to other major markets in Texas such as Sweeny and Freeport.[36]

Cactus II extends from the Permian Basin to the Corpus Christi/ Ingleside area. It's owned by Plains All American Pipeline and has an initial capacity of 585,000 bopd, which can be expanded to 670,000 bopd by adding incremental pumping capacity.[37,38]

The 730-mile long EPIC Crude Oil Pipeline is owned by EPIC Midstream Holdings, Ares Management, Apache Corp., and Noble Energy. It will extend from Orla, Texas to the Port of Corpus Christi and will service the Delaware, Midland, and Eagle Ford Basins. The pipeline is expected to begin interim service in the third quarter of 2019 with an initial capacity of 590,000 bopd. Permanent service is expected to begin in January 2020.[39,40]

The proposed 650-mile Jupiter Pipeline, owned by Jupiter Energy Group, would have a 36 inch diameter with a capacity to carry 1 MM bopd crude oil. The pipeline is expected to have origin points near Crane and Gardendale/Three Rivers and an offtake point in Brownsville. It will potentially provide access to all three deep water ports in Texas, namely Houston, Corpus Christi, and Brownsville. It would also have direct access to a loading facility proposed to be off the coast at Brownsville which would have the ability to fully load VLCCs. Additionally, the Brownsville terminus would have a storage capacity of 10 million barrels and three docks in the Port of Brownsville.[41]

CHALLENGES AND OPPORTUNITIES

Current expectations are that all the pipelines to Corpus Christi will be completed by the end of 2019. However based on the evidence on the ground it appears that this may happen by mid-2020. Moreover, it is not clear, based on current data, whether the Jupiter pipeline will be undertaken and completed.

Further, as noted previously the Permian acreage and production is increasingly being dominated by the oil majors. Industry analysts consider this to be typical for any field where in the first movers are usually investors willing to take risks, followed by small E&P companies, and lastly, the oil and gas majors.[42]

Several changes in the Permian players have occurred over the last few years. The small to medium independents face a capital crunch as the investment community has soured on the poor rate of return from their investment in the Permian following the extended price decline that started in 2014 and exaggerated somewhat due to the pipeline bottleneck until recently. The major operators (including ExxonMobil, Chevron, Occidental and BP) have sensed an opportunity to secure the entire supply chain and have acquired acreage and consolidated significantly in the Permian.

Figure 20: Permian Basin Top 10 Operators 2016

OIL		
Rank	Operator Name	Crude Oil (BBL)
1	PIONEER NATURAL RES. USA, INC.	59,359,738
2	OCCIDENTAL PERMIAN LTD.	42,697,587
3	APACHE CORPORATION	30,098,087
4	XTO ENERGY INC.	25,279,187
5	COG OPERATING LLC	20,336,309
6	OXY USA WTP LP	19,121,487
7	KINDER MORGAN PRODUCTION CO LLC	18,647,309
8	ENERGEN RESOURCES CORPORATION	16,483,466
9	CHEVRON U. S. A. INC.	16,283,952
10	ENCANA OIL & GAS(USA) INC.	14,047,502

> “Gray Oak Pipeline LLC, is a joint venture owned 75% by Phillips 66 Partners and 25% by Andeavor. The pipeline will be built and operated by Phillips 66 and is expected to be in service by the end of 2019.”

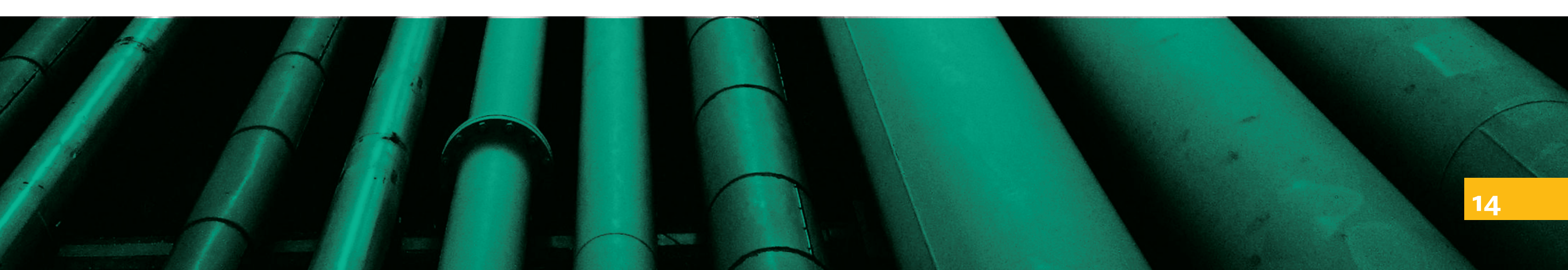


Figure 21:

January '18	**Exxon Mobil**	**275000 acres**	**Bass Family**	**$6.6 B**
March '18	**Concho Resources**	**640000 acres**	**RSP Permian**	**$8 B**
July '18	**BP**	**83000acres+**	**BHP Billiton**	**$10.5**
August '18	**Diamondback Energy**	**390000 acres**	**Energen**	**$8.4 B**
November '18	**Encana Corp**		**New Field Exploration**	**$5.5 B**
April '19	**OXY**	**600000 acres**	**Anadarko**	**$33 B**

Resultantly, in March 2019, both Chevron and Exxon announced plans to increase production in the Permian.[43] ExxonMobil has indicated that it hoped to reach 1 million bopd in five years, and Chevron said it expects to more than double its output, taking production to 900,000 bopd by the end of 2023.[44] Occidental Petroleum and BP are also active players in the region. Shell has also expressed an interest to expand its position in Permian. It has been suggested that major Gulf Coast refiners such as Total and Motiva might look for upstream partners (such as Pioneer, Concho, Diamondback, Endeavor) to vertically integrate their operations in the Permian.[45]

For the Permian basin, the shale game is now a scale game.[46] Small and mid-cap companies are drilling fewer wells and exercising capital discipline as they are more sensitive to costs and price fluctuations. On the contrary, with big majors announcing plans to expand their presence and operations in the region, the production landscape in the Permian basin is transforming rapidly. Several additional challenges are possible limiters for the continued growth of the Permian production.

Recently there have been several reports of crude exports from Texas shale operations being rejected by refiners in South Korea because of inconsistencies with the quality of crude.[47] Some of this emerges from the mixing of different density of API values of crude because of common transportation pipelines. The crude inconsistencies have resulted in significant discounting of the product after it had reached Asian shores.

The crude oil produced in the Permian is increasingly of a 40 - 50 API gravity (labeled as WTL), and is lighter than the typical 38 - 42 API of WTI Midland. With increases in Permian production, the lighter WTL crude oils with higher API gravity are blended with relatively heavier crudes to get a blend that is similar to WTI.[48]

Currently, the supply of the lighter crudes (WTL) is significantly higher than the amount that can be blended with the heavier crudes (WTI). Production forecasts from the two basins are that the production of WTL crudes will continue to increase. There is a clear need for segregating the different crude oils before shipping overseas. Some pipeline operators such as Enterprise Products and Plains are starting to address this issue. But the industry needs to ensure there is adequate tankage to do this for the growing production out of the Permian.

Perhaps more important are challenges emerging from the continued flaring of associated natural gas produced during the production of crude in the Permian.[49] The associated gas cannot be appropriately valorized because of the absence of gathering and transportation pipelines and the reluctance of operators to invest significantly in gas infrastructure when the resource plays have rapid decline rates such as those seen in the Permian.[50] Additionally, the technology to reinject the gas into the formation has not been fully developed to make it a viable option to handle the associated gas. The flaring and direct release of natural gas have resulted in negative reaction towards the growth of the production from the Permian. Additionally, the issues of water use

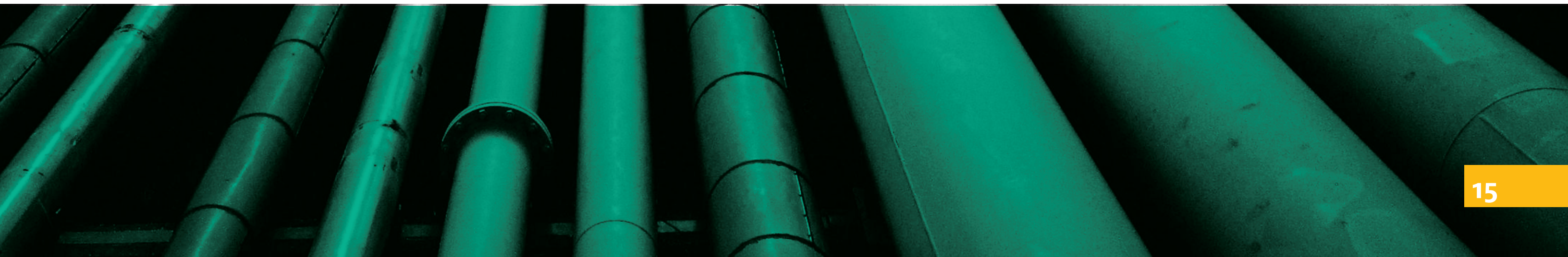
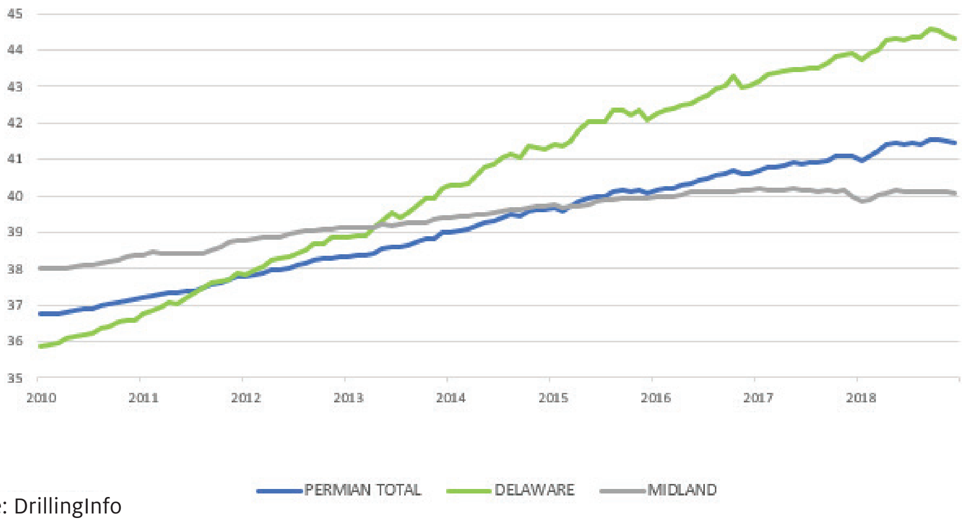
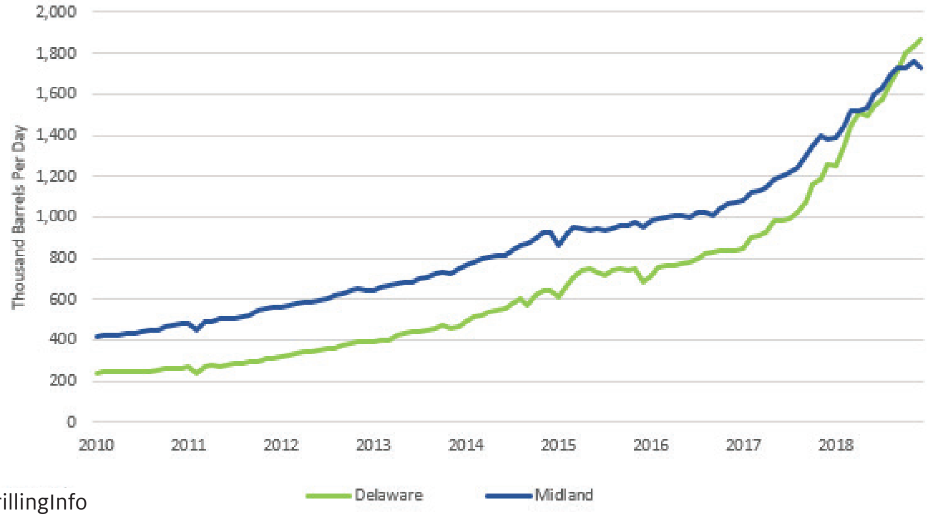


Figure 22: Production Weighted Average of Tested Wells



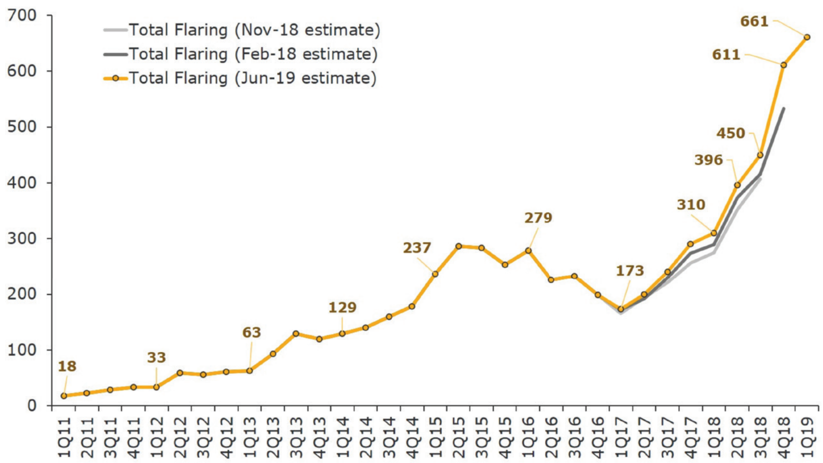
Source: DrillingInfo

Figure 23: Permian Oil Production by Sub-Basin

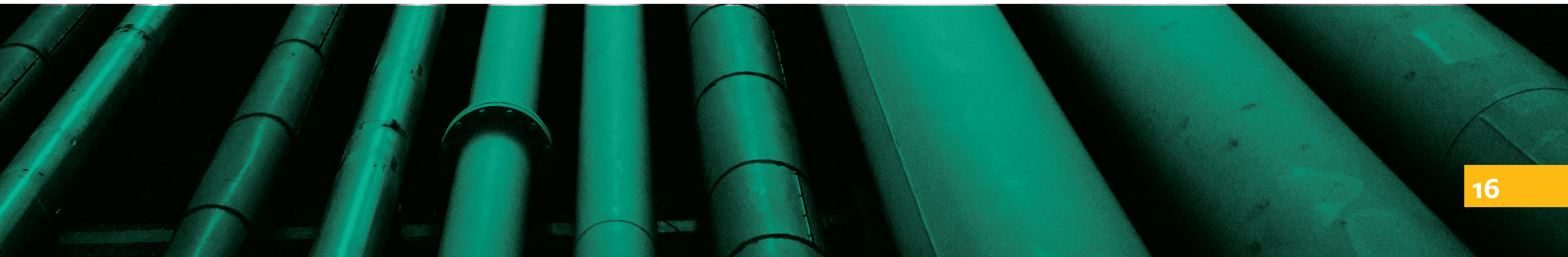


Source: DrillingInfo

Figure 24: Natural Gas Flaring and Venting in the Permian Basin by Quarter
million cubic feet per day



Source: Rystad Energy research and analysis, Rystad Energy ShaleWellCube.



for fracturing and produced water continue to grow and the business solutions still are lacking causing considerable consternation amongst local communities in these areas.[51]

The study here suggested that the pipeline infrastructure to evacuate the oil out of the Permian will be built out on schedule with increased Permian production. However, recently environmental concerns have caused some doubts on the actual development and deployment of these pipelines. Pipeline projects traversing through the Texas Hill Country have encountered stiff local challenges for the deployment of the pipeline.[52] Moreover, the development of processing and storage units near Corpus Christi have also encountered similar local challenges with regards to siting of the infrastructure.

CONCLUSIONS

Historically, the Permian has been a robust contributor to the U.S. supply of oil for over 75 years, although in the early 2000s it showed a significant decline in production. The shale revolution has changed this narrative. The Permian basin is currently the single largest producer of oil in the world. This change has been made possible by several factors:

- Application of innovations in hydraulic fracturing and horizontal drilling technologies
- The entrepreneurial spirit of independent oil producers taking risks in the early development of the fields
- The long term view and continued investments by the Major operators to make the Permian one of the lowest cost producing areas through improvements in drilling technology, production techniques, scale of operation and optimization of the supply chain.

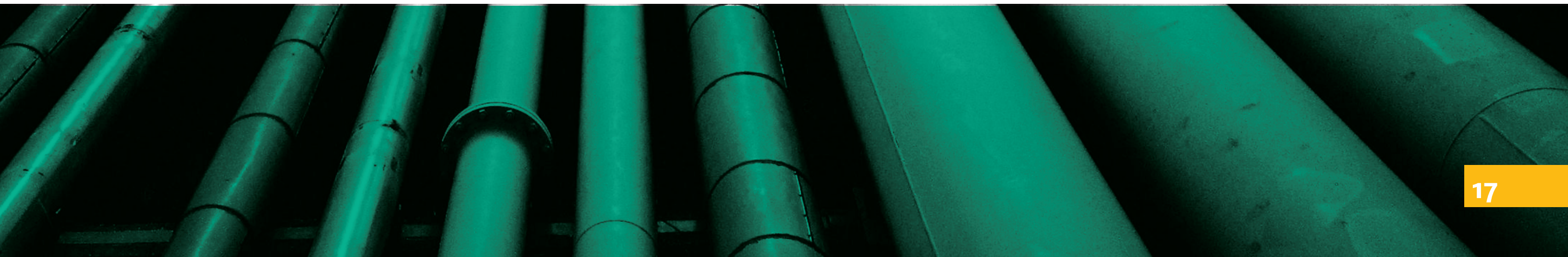
All indications suggest that the production from the Permian will continue to increase over the next five years. The rate of growth in the next three years will, however, critically depend on the availability of pipelines to evacuate the increased production in a timely manner, and the ability of the Gulf Coast ports to have the capacity to export. Notable amongst these is the Port of Corpus Christi that is anticipated to go from handling 0.5 MM bopd to over 4 MM bopd in the next five years.

The following are a few other key developments in the near term that could have an impact on the rate of growth of production from the Permian and are important to monitor:

- Dislocations in timing of completions of pipelines and capabilities to export,
- Timely resolution of quality issues of crude exports to Asian markets,
- Natural gas flaring issues impact on crude production.

In the longer term, the developments in following areas would shape the rate of growth of the Permian:

- The consolidation of production in the Permian by Major operators and their control of the supply chain out of the Permian,
- Impact on independent producers' profitability with drop in crude prices and their need to tap into an export market that they are ill-positioned to handle,
- The continued addressing of sustainability issues including natural gas flaring and management of water,
- The ability of Gulf coast ports to handle VLCCs and as such the ability to move crude in large quantities at a competitive cost.



FOOTNOTES

1 – Ball, M. 1995, Permian Basin Province (044), in Gautier, D.L., 1995, National Assessment of the United States oil and gas Resources – Results, Methodology and Supporting Data: U.S. Geological Survey Digital Data Series DDS-30, USGS.

2 – Railroad Commission of Texas. Permian Basin Information. Retrieved from https://www.rrc.state.tx.us/oil-gas/major-oil-and-gas-formations/permian-basin-information/

3 – Permian Basin Geology: The Midland Basin vs. the Delaware Basin Part 2. (2019, April 15). Retrieved from https://info.drillinginfo.com/blog/permian-basin-geology-midland-vs-delaware-basins/

4 – Natural Gas Intelligence. Information on the Permian Basin. Retrieved from https://www.naturalgasintel.com/permianinfo

5 – Crowley, K., & Adams-Heard, R. (2019, July 12). The Shale Boom in the Permian Is Slowing Down. Retrieved from https://www.bloomberg.com/news/articles/2019-07-12/cracks-show-in-the-permian-s-promise-as-shale-producers-retrench

6 – U.S. Energy Information Administration. (2018, October). Permian Basin Wolfcamp Shale Play Geology review. Retrieved from https://www.eia.gov/maps/pdf/PermianBasin_Wolfcamp_EIAReport_Oct2018.pdf

7 – Domm, P. (2019, March 08). This Texas area is expected to double oil output to 8 million barrels in just four years, boosting U.S. exports. Retrieved from https://www.cnbc.com/2019/03/08/permian-oil-output-doubling-to-8-million-barrels-boosting-exports.html

8 – U.S. Department of Energy Office of Fossil Energy – Office of Oil and Natural Gas. Basin Oriented Strategies for CO2 Enhanced Oil Recovery: Permian Basin. Retrieved from https://www.adv-res.com/pdf/Basin%20Oriented%20Strategies%20-%20Permian_Basin.pdf

9 – Gaswirth, S.B., French, K.L., Pitman, J.K., Marra, K.R., Mercier, T.J., Leathers-Miller, H.M., Schenk, C.J., Tennyson, M.E., Woodall, C.A., Brownfield, M.E., Finn, T.M., and Le, P.A., 2018, Assessment of undiscovered continuous oil and gas resources in the Wolfcamp Shale and Bone Spring Formation of the Delaware Basin, Permian Basin Province, New Mexico and Texas, 2018: U.S. Geological Survey Fact Sheet 2018–3073, 4 p., https://doi.org/10.3133/fs20183073. Retrieved from https://pubs.er.usgs.gov/publication/fs20183073

10 – United States Geological Survey. (2018, November 28). USGS Estimates 20 Billion Barrels of Oil in Texas' Wolfcamp Shale Formation. Retrieved from https://www.usgs.gov/news/usgs-announces-largest-continuous-oil-assessment-texas-and-new-mexico?utm_source=news&utm_medium=email&utm_campaign=de-basin-2018

11 – U.S. Energy Information Administration - EIA - Independent Statistics and Analysis. (2018, November 29). U.S. Crude Oil and Natural Gas Proved Reserves, Year-end 2017. Retrieved from https://www.eia.gov/naturalgas/crudeoilreserves/

12 – U.S. Energy Information Administration - EIA - Independent Statistics and Analysis. (2019, January 24). Annual Energy Outlook 2019. Retrieved from https://www.eia.gov/outlooks/aeo/

13 – U.S. Energy Information Administration - EIA - Independent Statistics and Analysis, U.S. Crude Oil and Natural Gas Proved Reserves, Year-end 2017.

14 – Ibid.

15 – Rose and Associates. (2016, April 7). The Current Costs for Drilling a Shale Well. Retrieved from https://www.roseassoc.com/the-current-costs-for-drilling-a-shale-well/

16 – Walzel, B. (2018, June 1). Permian Basin Continues To Lead US Production Gains. Retrieved from https://www.hartenergy.com/exclusives/permian-basin-continues-lead-us-production-gains-177027

17 – Rose and Associates, The Current Costs for Drilling a Shale Well.

18 – Ibid.

19 – Crowley, K. Exxon(2019, March 14). Aims for $15-a-Barrel Costs in Giant Permian Operation. Retrieved from https://www.bloomberg.com/news/articles/2019-03-14/exxon-aims-for-15-a-barrel-costs-in-giant-permian-operation

20 – Exxon Mobil. (2019, May 17). ExxonMobil Permian development to provide $64 billion in benefits to New Mexico: Study. Retrieved from https://corporate.exxonmobil.com/en/news/newsroom/news-releases/2019/0517_exxonmobil-permian-development-to-provide-64b-in-benefits-to-nm-study

21 – U.S. Energy Information Administration - EIA - Independent Statistics and Analysis. (2018, October 2). Crude oil entering Gulf Coast refineries has become lighter as imports have declined. Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=36933

22 – Ibid.

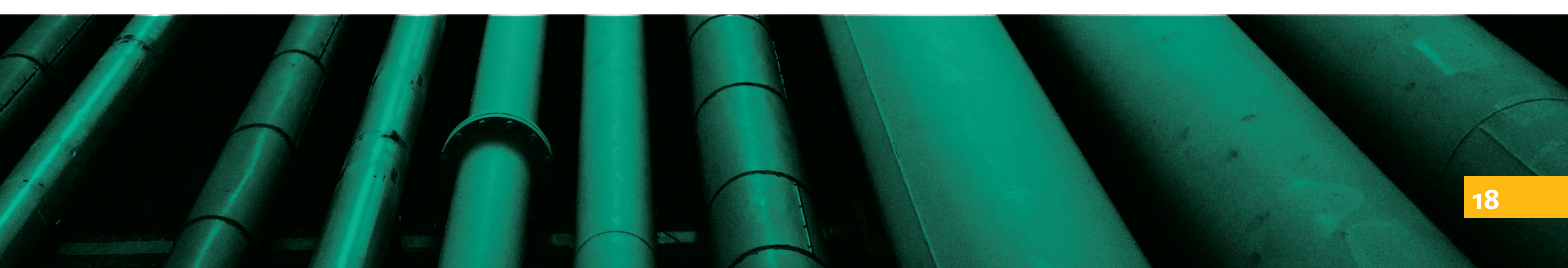
23 – Douglas, E. (2019, January 30). ExxonMobil to begin construction on Beaumont refinery expansion. Retrieved from https://www.chron.com/business/energy/article/ExxonMobil-to-begin-construction-on-Beaumont-13570871.php

24 – Blackmon, D. (2019, February 04). The Permian Basin Continues To Drive Record U.S. Energy Growth. Retrieved from https://www.forbes.com/sites/davidblackmon/2019/02/04/the-permian-basin-continues-to-drive-record-u-s-energy-growth/#5abca0a05869

25 – Jacobs, N. (2019, January 24). U.S. to Achieve Net Energy Exporter Status Two Years Earlier Than Expected: EIA. Retrieved from https://www.energyindepth.org/u-s-to-achieve-net-energy-exporter-status-two-years-earlier-than-expected-eia/

26 – DiChristopher, T. (2017, January 05). United States may become net energy exporter by 2026, EIA reports. Retrieved from https://www.cnbc.com/2017/01/05/united-states-may-become-net-energy-exporter-by-2026-eia-reports.html

27 – U.S. Energy Information Administration - EIA - Independent Statistics and Analysis. (2019, July 9). Short-Term Energy Outlook



2019. Retrieved from https://www.eia.gov/outlooks/steo/

28 – Carr, H. (2018, March 7). RBN Energy. Retrieved from https://rbnenergy.com/rock-the-boat-the-growing-role-of-vlccs-in-the-us-crude-oil-exports

29 – U.S. Energy Information Administration - EIA - Independent Statistics and Analysis. (2018, May 16). U.S. Gulf Coast port limitations impose additional costs on rising U.S. crude oil exports. Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=36232

30 – U.S. Government Publishing Office. (2010, July 1). 33 CFR 156.300 - Designated lightering zones. Retrieved from https://www.govinfo.gov/app/details/CFR-2010-title33-vol2/CFR-2010-title33-vol2-sec156-300

31 – Fielden, S. (2019, May 13). Gulf Coast Crude Exporters Navigate Port Limitations. Retrieved from https://go.morningstar.com/gulf-coast-crude-exporters-navigate-port-limits?cid=CON_CNE0003

32 – Enterprise Begins Full Service on Midland-to-Sealy Pipeline. (2018, April 16). Retrieved from https://ih.advfn.com/stock-market/NYSE/enterprise-products-EPD/stock-news/77183050/enterprise-begins-full-service-on-midland-to-sealy

33 – Luck, M. (2019, July 03). Pipeline additions boost Permian Basin prices. Retrieved from https://www.chron.com/business/energy/article/Pipeline-additions-boost-Permian-Basin-prices-13720215.php

34 – U.S. Energy Information Administration - EIA - Independent Statistics and Analysis. (2019, March 26). Permian region crude oil prices have increased with additional pipeline takeaway capacity. Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=38832

35 – ExxonMobil, Plains All American and Lotus Midstream Proceeding with Wink to Webster Pipeline. (2019, January 30). Retrieved from https://www.businesswire.com/news/home/20190130005219/en/ExxonMobil-Plains-American-Lotus-Midstream-Proceeding-Wink

36 – Phillips 66 proceeds with Gray Oak Pipeline. (2018, June). Retrieved from https://pipeline-news.com/phillips-66-proceeds-with-gray-oak-pipeline/

37 – Kumar, D. K. (2019, June 27). Exclusive: Plains' Cactus II oil pipeline to begin line fill in a... Retrieved from https://www.reuters.com/article/us-plains-all-amer-cactusii-exclusive-idUSKCN1TS2XJ

38 – Gray Oak Pipeline. Retrieved from https://grayoakpipeline.com/

39 – Kumar, D. K. (2019, April 12). U.S. FERC approves EPIC oil pipeline rates, interim service to... Retrieved from https://www.reuters.com/article/us-epic-crude-pipeline/us-ferc-approves-epic-oil-pipeline-rates-interim-service-to-begin-mid-2019-idUSKCN1RO28F

40 – Crude Pipeline. Retrieved from https://epicpipelinelp.com/projects/crude-pipeline/

41 – Jupiter Announces Extension of Open Season for Crude Oil Pipeline from the Permian Basin to the Port of Brownsville. (2019, February 28). Retrieved from https://www.businesswire.com/news/home/20190228005853/en/Jupiter-Announces-Extension-Open-Season-Crude-Oil

42 – Tomlinson, C. (2019, March 08). Big Oil is settling into the Permian, so where will the wildcatters go next? Retrieved from https://www.houstonchronicle.com/business/columnists/tomlinson/article/Big-Oil-is-settling-into-the-Permian-so-where-13670505.php

43 – T., DiChristopher. (2019, March 05). Exxon and Chevron just announced big plans to surge oil and gas output from top U.S. field. Retrieved from https://www.cnbc.com/2019/03/05/exxon-chevron-announce-plans-to-surge-output-from-permian-basin.html

44 –Ibid.

45 – Tomlinson, Big Oil is settling into the Permian.

46 – DiChristopher, Exxon and Chevron just announced big plans.

47 – Chung, J. (2019, March 29). S.Korean refiners reject U.S. oil cargoes, but will keep trade going. Retrieved from https://www.reuters.com/article/southkorea-crude-usa/s-korean-refiners-reject-u-s-oil-cargoes-but-will-keep-trade-going-idUSL3N21F27V

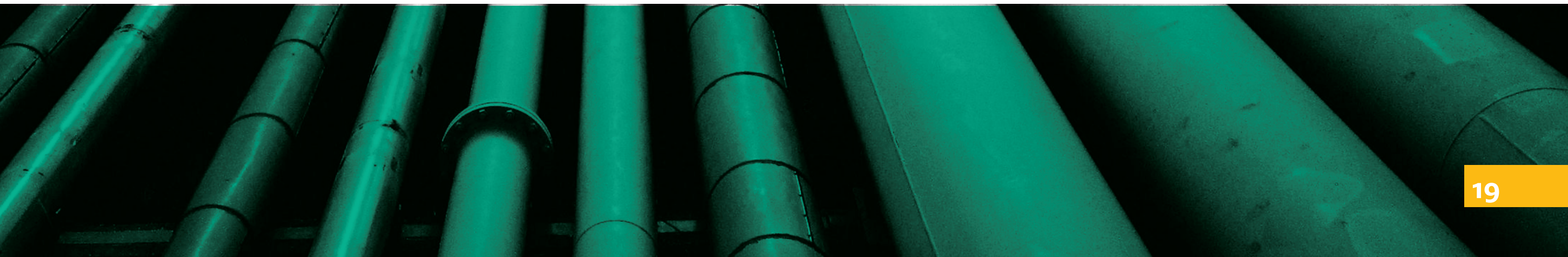
48 – Drillinginfo. (2019, April 26). West Texas Light – Analyzing the Growth of the Permian's Latest Crude Grade. Retrieved from https://info.drillinginfo.com/blog/west-texas-light-analyzing-the-growth-of-the-permians-latest-crude-grade/

49 – Hiller, J. (2019, June 04). Natural gas flaring hits record high in Q1 in U.S. Permian Basin. Retrieved from https://www.cnbc.com/2019/06/04/reuters-america-natural-gas-flaring-hits-record-high-in-q1-in-u-s-permian-basin.html

50 – Rystad Energy. (2019, June 4). Permian natural gas flaring and venting reaching all-time high. Retrieved from https://www.rystadenergy.com/newsevents/news/press-releases/Permian-natural-gas-flaring-and-venting-reaching-all-time-high/

51 – McEwen, M. (2019, February 25). Projected Permian production growth raises water management challenges. Retrieved from https://www.mrt.com/business/oil/article/Projected-Permian-production-growth-raises-water-13637240.php

52 – Shelor, J. (2018, November 02). Regulatory Challenges Mounting for Greenfield Natural Gas Pipelines, Executives Say. Retrieved from https://www.naturalgasintel.com/articles/116298-regulatory-challenges-mounting-for-greenfield-natural-gas-pipelines-executives-say



About UH Energy

UH ENERGY

UH Energy is an umbrella for efforts across the University of Houston to position the university as a strategic partner to the energy industry by producing trained workforce, strategic and technical leadership, research and development for needed innovations and new technologies.

That's why UH is the Energy University.

White Paper Editorial Board