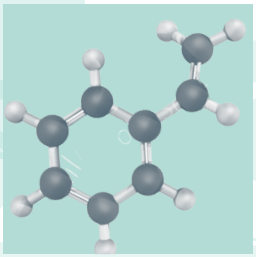
RESINS BRIEFING PAPER

November 2020

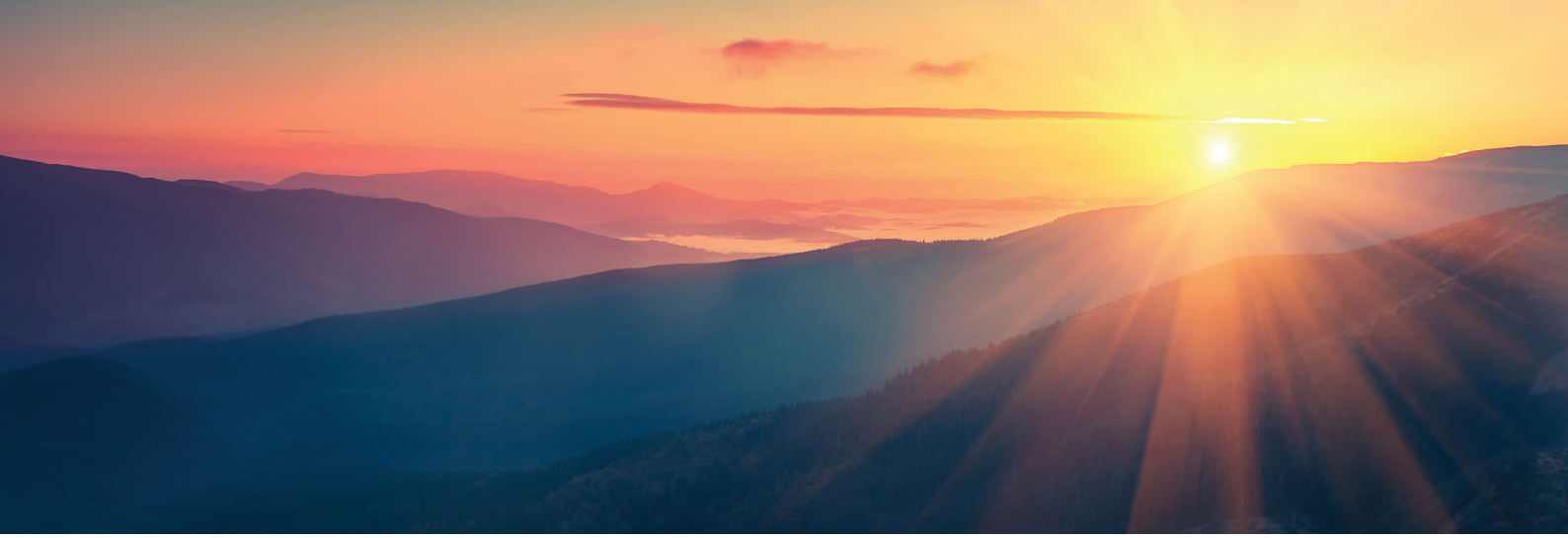
STORMY OUTLOOK

FOR US PLASTICS REFINERS

Risk of stranded assets in the Gulf of Mexico



Planet Tracker



ABOUT PLANET TRACKER

Planet Tracker is a non-profit financial think tank aligning capital markets with planetary limits. It was created to investigate the risk of market failure related to environmental limits. This investigation is primarily for the investor community where environmental limits, other than climate change, are often not aligned with investor capital. Planet Tracker generates breakthrough analytics to redefine how financial and environmental data interact with the aim of changing the practices of financial decision makers to help avoid both environmental collapse and financial failure.

PLASTICS TRACKER

The goal of Plastics Tracker is to stem the flow of environmentally damaging plastics and related-products that are creating global waste and health issues by transparently mapping capital flows and influence in the sector starting from resins production through to product-use. By illuminating risks related to natural capital degradation and depletion, investors, lenders and corporate interests across the economy will be enabled to create more sustainable plastics products.

ACKNOWLEDGEMENTS

Authors: Gabriel Thoumi CFA FRM, John Willis
Editor: Dominic Lyle

Planet Tracker would like to acknowledge the input of those who reviewed draft papers, including Dominic Charles, Chris Gee, Courtney Lowrence, Dawn Rittenhouse and Ame Trandem.

WITH THANKS TO OUR FUNDERS

MINDEROO FOUNDATION

Flotilla FOUNDATION

PLASTIC SOLUTIONS FUND

Key Takeaways

- 89% of U.S. PP, LDPE, HDPE and LLDPE capacity is in the 'Plastics Production Corridor', an area which runs along the U.S. Gulf Coast in Texas and Louisiana, where 34 facilities are below, at, or slightly over 30 feet (9 metres) above sea level.
- Facilities are at risk of incurring substantial damage from storms which are increasing in frequency and intensity.
- Forecasts of continuing sea-level rises are supported by measuring station data along the Texas and Louisiana coast in the Gulf of Mexico.
- The risk increases as the frequency of storm surges rises.
- As external risk factors increase, the industry faces the growing possibility of stranded assets of USD 56 billion by 2025, USD 40 billion in the Plastics Production Corridor alone.
- Capacity at risk in the U.S. Plastics Production Corridor represents 12% of overall global capacity.
- Companies are currently decreasing capital expenditure and delaying the construction of facilities, but the U.S. polyolefins sector is still forecasting an investment of USD 40 billion by 2025 in the Plastics Production Corridor.
- Forecast demand relies on securing new export markets which are already increasing their own plastics production.
- Overcapacity of olefins and polyolefins production is resulting in long-term price weakness, despite pockets of recent demand from Covid-19. We expect industry margins to continue their decline through to 2035.
- Has the time come for investors and financiers to encourage plastic producers to cancel plans for the expansion of production facilities and swing their focus to solutions to plastics pollution instead?

[1] PP = polypropylene, LDPE = low density polyethylene, HDPE = high density polyethylene, and LLDPE = linear low density polyethylene, PET bottle grade is excluded from the analysis in this paper as there are no existing major PET bottle grade facilities within the Plastics Production Corridor according to NexantECA accessed via Bloomberg L.P.
[2] Capacity means "maximum level of possible output and production means "actual level of output".
[3] The majority of U.S. plastics resins production for the monomers ethylene and propylene and the polymers HDPE, LDPE, LLDPE and PP lies in a thin 600 mile-long corridor along the Gulf of Mexico through Texas and Louisiana. Planet Tracker calls this thin strip of land the Plastics Production Corridor.
[4] Stranded assets are assets that have suffered from unanticipated or premature write-downs, devaluations or conversion to liabilities.

Climate Change Risks Impact U.S. Plastics Production Corridor

89% of U.S. plastics capacity is situated in what Planet Tracker terms 'the Plastics Production Corridor'.

The Plastics Production Corridor is along the Gulf of Mexico (see Figure 1), a low-lying region next to the ocean below, at, or slightly over 30 feet above sea level and near the estimated maximum height of recent hurricane storm surges - see Table 1.

Table 1: U.S. Capacity Plastics Production Corridor % of Global Capacity at Risk, 2019[i]

	Sum of HDPE, LDPE, LLDPE and PP Capacity (kiloton)
Total Capacity in the Plastics Production Corridor	24,819
Total U.S. Capacity	27,895
Global Capacity	200,431
U.S. % Capacity in the Plastics Production Corridor	89%
Global Capacity in the Plastics Production Corridor	12%

15 publicly traded companies and, indirectly, their institutional investors, primarily own the 34 plastics production facilities in the Plastics Production Corridor. Altogether, this highlights the U.S. plastics resins industry's long-term vulnerabilities to climate change. Furthermore, the industry is facing overcapacity as supply is forecast to outpace demand between 2020 and 2035.

As air and ocean temperatures continue to increase due to climate change, tropical storms including hurricanes are forecast to cause greater precipitation, increasing their devastation on coastal areas.[ii, iii] At the same time, warmer waters also cause higher wind speeds, increasing storm strength, with models predicting more devastating category 4 and 5 hurricanes.[iv]

As precipitation and more dangerous storms increase, storm surges are more frequently impacting facilities, as the shallow seafloor along the Plastics Production Corridor amplifies the risks to the plastics production facilities situated there.[v]

Since 1990, there have been 56 storms, ranging from tropical depressions to hurricanes, that have made landfall within the Plastics Production Corridor.[vi] Their paths are shown by the lines in Figure 1, with each line representing the path of one of the 56 storms since 1990.

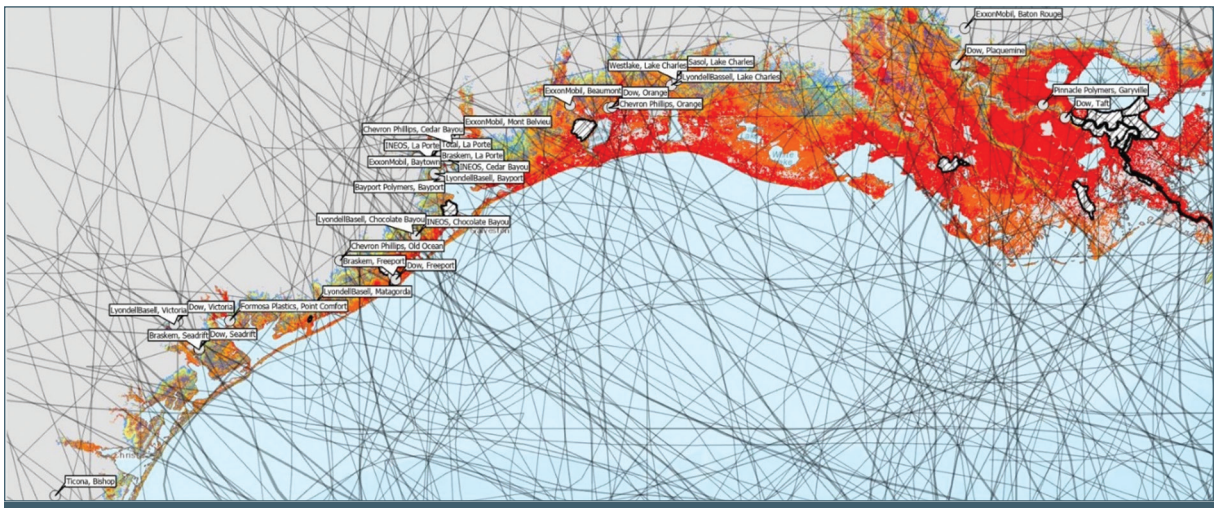


Figure 1: Modelled Category 2 Hurricane Storm Surge [5] Risk in Plastics Production Corridor Overlaid with Lines (black) from Hurricanes, Tropical Storms and Depressions 1990 to 2020, U.S. National Oceanographic and Atmospheric Administration (NOAA). This employs the SLOSH model.[vii] As of 30 September 2020.[viii] Planet Tracker chose to model Category 2 hurricane storm surge risk [ix] as Category 2 is when winds are 96 miles per hour or greater which can result in extensive damage.[x]

To read Figure 1, apply the following criteria. The Sea, Lake and Overland Surges from Hurricanes (SLOSH) model developed by the National Weather Service (NWS) estimates storm surge heights resulting from historical, hypothetical, or predicted hurricanes. It takes into account atmospheric pressure, size, forward speed, and track data. These parameters are used to create a model of the wind field which drives the storm surge.

The SLOSH model consists of a set of physics equations which are applied to a specific locale's shoreline, incorporating the unique bay and river configurations, water depths, bridges, roads, levees and other physical features.

The NHC SLOSH Model (Storm Surge) layer with the red fading to blue, the regions are as follows:

- The metric shown is inundation height (ft):
- BLUE colouring = up to 3 feet above ground
- YELLOW colouring = greater than 3 feet above ground
- ORANGE colouring = greater than 6 feet above ground
- RED colouring = greater than 9 feet above ground
- BLACK hatched = leveed area so consult local officials for flood risk

[5] Storm surge is the abnormal increase in the height of water above mean sea level dependent on a storm's track, intensity, size and speed, along with the geological and hydrological characteristics of the coastline the storm is modelled to pass over.

Recent storms highlight U.S. Plastics Production Corridor's long-term risks

Between August and October 2020, five named storms - Hurricanes Delta, Laura, Marco, Sally and Tropical Storm Beta - made landfall along the Texas and Louisiana coast in the Gulf of Mexico causing storm surges and high winds which damaged plastics refineries and impacted U.S. plastics resins capacity and production. With capacity offline due to damage from the storms, the resulting decrease in resins production highlights the U.S. industry's long-term vulnerabilities to climate change, resulting in an increased risk of stranded assets.

These storms, along with some unrelated planned maintenance issues, decreased capacity in the Gulf of Mexico for the key plastics resins in the olefins/polyolefins value chain by 7% to 28% with some recovery since August – see Table 2.

Table 2: Texas and Louisiana Olefins and Polyolefins Capacity Decrease August to September 2020.[xi] Forecasts differ depending on databases assessed [xii]

Product	U.S. % Capacity Offline	Capacity Offline (kiloton)	U.S. Capacity 2019 (kiloton)
Ethylene	22%	7,560	35,047
Propylene	7%	1,166	15,736
PP	28%	2,208	7,856
LDPE	15%	565	3,648
HDPE	14%	1,213	8,744
LLDPE	13%	990	7,647

While some of this decrease in capacity was for previously scheduled maintenance,[xiii] much of it was the result of the impacts from the five named storms.

A single storm – Hurricane Laura – shut down industry, demonstrating overcapacity and risk

Just one storm alone - Hurricane Laura - shut down six ethylene crackers in Lake Charles, Louisiana, with some crackers now forecast to be offline for up to 14 weeks.[xiv]

When ethylene capacity losses from Hurricane Laura are added to forecast North American capacity losses, it places 2020 capacity losses ahead of both 2019 and 2018[xi] – see Table 3. Generally speaking, we should note that not all ethylene supply goes exclusively to plastics resins production.

Table 3: North American Ethylene Capacity Offline by Year, 2018 to 2020 forecast [xvi]

Year	U.S. Ethylene % Capacity Offline
2020 forecast	6.5%
2019	4.8%
2018	3.5%

By using the 1.7% of capacity loss between 2020 and 2019 (see Table 3) and the Nexant 2019 ethylene annual price of USD 591 per tonne along with 2019 U.S. ethylene capacity of 35 million metric tonnes, this loss amounts to around USD 350 million.[xvii]

Even within a 2°C target for global warming under the 2015 Paris Agreement, models predict more devastating category 4 and 5 hurricanes as waters warm up.[xviii]

Category 4 Hurricane Laura, which made landfall near Lake Charles, Louisiana, on August 27, 2020, produced storm surges 17 feet (5m) above dry ground and 20 feet (6m) above sea level about 12 miles (19 km) east of the Calcasieu River.[xix]

Together with Hurricane Marco's landfall on August 24, 2020 also near Lake Charles, the two hurricanes damaged plastics production facilities, decreasing U.S. ethylene, propylene, polyethylene and PP capacity by 12%, 1%, 5% and 7% respectively[xx] – see Table 4.

Table 4: Examples of Shutdowns and Force Majeure at Lake Charles, Louisiana, August 27, 2020 [xxi, xxii]

Company	Capacity Offline (kiloton)	% U.S. Capacity	Product
Indorama Ventures	440	1.1%	Ethylene
Lotte Chemical and Westlake Chemical	1,000	2.5%	Ethylene
Sasol*	2,004	5.0%	Ethylene
Westlake Chemical	1,420	3.4%	Ethylene
Total Ethylene	**4,864**	**12%**	
Sasol	90	<1.0%	Propylene
Total Propylene	**90**	**1%**	
Sasol	540	2.4%	Polyethylene
Westlake Chemical	665	3.0%	Polyethylene
Total Polyethylene	**1,205**	**5%**	
LyondellBasell**	638	7.3%	PP
Total Polypropylene	**638**	**7%**	

** Announced sale to LyondellBasell October 2, 2020. ** Full restart occurred October 1, 2020.*

As a result, the industry reacted by declaring force majeure for much of the polyethylene capacity near Lake Charles. Force majeure is a clause in contracts that frees both parties from liability or obligation when an extraordinary event or circumstance beyond the control of the parties, such as a war, strike, riot, crime, epidemic or an event described by the legal term "Act of God", prevents one or both parties from fulfilling their obligations under the contract.

In practice, most force majeure clauses do not excuse a party's non-performance entirely, but only suspend it for the duration of the force majeure.

By August 31, 2020, the following forces majeures were declared, reducing both U.S. capacity and production:

- Westlake Chemical declared force majeure shutting down 58% of its U.S. capacity. This included 385,000 and 285,000 metric tonnes per year facilities for LDPE and LLDPE respectively.[xxiv, xxv]
- Sasol declared force majeure on its LLDPE and HDPE facilities. The company shut down its Lake Charles, Louisiana facility, which is responsible for 470,000 metric tonnes per year of LLDPE – est. 4% of U.S. total capacity.[xxvi, xxvii] On October 2, 2020, Sasol agreed to sell a USD 2 billion stake in its Lake Charles ethylene and polyethylene business to LyondellBasell to raise USD 2 billion so that Sasol could decrease its debt from USD 10 billion to USD 8 billion. The Lake Charles expansion approved in 2014 was estimated to cost USD 8.1 billion but is now 60% over budget at more than USD 13 billion.[xxviii]
- Chevron Phillips Chemical declared force majeure impacting 1.63 million metric tonnes per year of HDPE capacity (est. 15% of U.S. capacity), 1.32 million metric tonnes per year LLDPE capacity (est. 12% of U.S. capacity) and 280,000 metric tonnes LDPE (est. 7% of U.S. capacity).[xxix, xxx]

U.S. Plastics Production Corridor risks impact the global market

In 2019, the Plastics Production Corridor was responsible for 12% of global capacity of HDPE, LDPE, LLDPE and PP, the most important resins used in both fast-moving plastics and single-use plastics which many claim have resulted in a global plastics pollution crisis. But these resins are also a necessary ingredient used in products across the economy, including healthcare and other key economic sectors.

Digging deeper, much of the U.S. capacity for HDPE, LDPE, LLDPE and PP is at risk, ranging from 78% to 97% depending on the resin, which in turn impacts global capacity, ranging from 8% to 18% depending on the resin – see Table 5.

Table 5: U.S. Capacity vs. Global Capacity, 2019 [xxxi]

	HDPE	LDPE	LLDPE	Polypropylene
Total Capacity in the Plastics Production Corridor	8,509	2,858	7,185	6,267
Total U.S. Capacity	8,744	3,648	7,675	7,856
Global Capacity	48,152	26,801	43,486	81,992
U.S. % Capacity	18%	14%	18%	10%
U.S. % Capacity in the Plastics Production Corridor	97%	78%	94%	80%
Global Capacity in the Plastics Production Corridor	18%	11%	17%	8%

Fast-moving plastics are almost exclusively derived from HDPE, LDPE, LLDPE and PP. These four resins form the key building blocks for fast-moving plastics. Fast-moving plastics are plastics with short lifespans of less than 6 months. Fast-moving plastics often become plastic waste shortly after production. Fast-moving plastics also include the single-use plastics category.[xxxii] Examples of fast-moving plastics are:

- Packaging such as beverage bottles, cling wrap, candy wrappers, fast-food, cleaning and personal care product containers
- Single-use plastic products such as cutlery, plates, and shopping bags
- Consumer goods with short lifespans such as throwaway apparel or shoes that go out of fashion or fall apart quickly through normal wear and tear
- Products that are intentionally or unintentionally discarded such as fishing gear that gets lost in open seas including: fishing nets, ropes, floats, baskets, crates, traps and other similar products.

Across the U.S., only 8 facilities are not in the Plastics Production Corridor - See Table 6.

Table 6: U.S Plastics Production Facilities, Capacity and Ownership, 2019 [xxxiii]

Location	Owner	In Plastics Production Corridor	HDPE	LDPE	LLDPE	PP
Freeport, Texas	Braskem	Yes				348
La Porte, Texas	Braskem	Yes	40			354
Marcus Hook, Pennsylvania	Braskem	No				414
Neal, West Virginia	Braskem	No				240
Seadrift, Texas	Braskem	Yes				225
Cedar Bayou, Texas	Chevron Corp. and Phillips 66	Yes	478	281	222	
Old Ocean, Texas	Chevron Corp. and Phillips 66	Yes	500		500	
Orange, Texas	Chevron Corp. and Phillips 66	Yes	440			
Pasadena, Texas	Chevron Corp. and Phillips 66	Yes	890		100	
Freeport, Texas	Dow	Yes		210	1,060	
Orange, Texas	Dow	Yes		270		
Plaquemine, Louisiana	Dow	Yes		570	544	
Seadrift, Texas	Dow	Yes	318	210	136	
Taft, Louisiana	Dow	Yes	404		404	
Victoria, Texas	Dow	Yes		125		
Baton Rouge, Louisiana	ExxonMobil	Yes	907	473		405
Baytown, Texas	ExxonMobil	Yes				818
Beaumont, Texas	ExxonMobil	Yes	227	231	790	
Mont Belvieu, Texas	ExxonMobil	Yes	220		2,207	
Longview, Texas	Flint Hills Resources	No				354
Point Comfort, Texas	Formosa Plastics Corp.	Yes	807		249	745
Carson, California	INEOS (majority owned by James Ratcliffe)	No				231

Location	Owner	In Plastics Production Corridor	HDPE	LDPE	LLDPE	PP
Cedar Bayou, Texas	INEOS (majority owned by James Ratcliffe)	Yes	208			
Chocolate Bayou, Texas	INEOS (majority owned by James Ratcliffe)	Yes				463
La Porte, Texas	INEOS (majority owned by James Ratcliffe)	Yes	726			148
Bayport, Texas	LyondellBasell Industries	Yes				737
Chocolate Bayou, Texas	LyondellBasell Industries	Yes	220			
Clinton, Iowa	LyondellBasell Industries	No	235	250		
La Porte, Texas	LyondellBasell Industries	Yes		102	268	
Lake Charles, Louisiana	LyondellBasell Industries	Yes				500
Matagorda, Texas	LyondellBasell Industries	Yes	915		100	
Morris, Illinois	LyondellBasell Industries	No		245	295	
Victoria, Texas	LyondellBasell Industries	Yes	261			
Linden, New Jersey	Phillips 66	No				350
Garyville, Louisiana	Pinnacle Polymers (97% owned by Beaulieu International Group)	Yes				454
Lake Charles, Louisiana	Sasol	Yes			415	
La Porte, Texas	Sasol and INEOS jointly owned	Yes	470			
Bishop, Texas	Ticona	Yes	38			
La Porte, Texas	Total SE	Yes				1,070
Bayport, Texas	Total SE and Borealis	Yes	440			
Longview, Texas	Westlake Chemical Corp.	No		295	195	
Lake Charles, Louisiana	Westlake Chemical Corp.	Yes		386	290	
Total U.S. Capacity by Resin			**8,744**	**3,648**	**7,675**	**7,856**
Total Capacity by Resin in the Plastics Production Corridor			**8,509**	**2,858**	**7,185**	**6,267**

Some of these facilities are still highly exposed to climate risks, such as Phillips 66 Bayway Refinery in Linden, New Jersey, which was damaged and shut down when Hurricane Sandy hit in 2012. The refinery is below 30 feet above sea-level which is why Calvert Investment Management (now owned by Morgan Stanley) filed a resolution requesting that Phillips 66 disclose and address climate risks at their facilities. Calvert filed the resolution due to the fact that according to the January 2010 U.S. Securities and Exchange Commission (SEC) disclosure guidance,[xxxiv] the SEC requested that companies describe the physical risks their assets face from climate change, including storm surges and sea-level rise.[xxxv] The resolution stated:

> *"Diminished refining utilization rates, potential downtime or closure of facilities due to direct damage to facilities, danger to employees, disruption in supply chains, and power supply [outages] due to storm surges or sea level rise could have a material impact on the company's production and related cash flows. This was made evident when the company's Bayway refinery lost power after Superstorm Sandy, was shut down for several weeks due to flood damage from the storm, and incurred significant maintenance and repair expenses".*[xxxvi]

A decade after the SEC ruling, key questions remain as to how publicly traded companies such as ExxonMobil, LyondellBasell, Chevron, Phillips 66, Braskem, Total, Formosa Plastics, Sasol and others, who own the 34 facilities in the Plastics Production Corridor, are disclosing and mitigating the physical risks their assets face from climate change, including storm surges and sea-level rise.

Recent storms highlight long-term risks to U.S. Plastics Production Corridor

It is evident that frequent storms are causing capacity to go offline as facilities are damaged and temporarily closed, resulting in decreased resins production and highlighting the U.S. industry's long-term vulnerabilities to climate change. The risk of stranded assets is increasing.

These storms, along with some unrelated maintenance issues, decreased capacity in the Gulf of Mexico for these key plastics resins in the olefins/polyolefins value chain by 7% to 28% with some recovery since August – see Table 7.

Table 7: Texas and Louisiana Olefins and Polyolefins Capacity Decreased between August and September 2020.[xxxvii] Forecasts differ depending on databases assessed.[xxxvii]

Product	U.S. % Capacity Offline	Capacity Offline (kiloton)	U.S. Capacity 2019 (kiloton)
Ethylene	22%	7,560	35,047
Propylene	7%	1,166	15,736
PP	28%	2,208	7,856
LDPE	15%	565	3,648
HDPE	14%	1,213	8,744
LLDPE	13%	990	7,647

While some of this decrease in capacity was caused by previously scheduled maintenance,[xxxix] much of it was the result of the impacts from the five named storms – Hurricanes Sally, Marco, Laura, Delta and Tropical Storm Beta.

The region's shallow sea-level topography and its sediment types make it susceptible to physical risks associated with climate change. The region is particularly at risk from rising sea-levels, subsidence and storm surges.

To complicate things further, subsidence has combined with rising sea-levels to put plastics infrastructure further at risk of becoming stranded assets.

Looking at the height above sea level and the same map, much of the region and the Plastics Production Corridor itself are at or under 30 feet (9m) above sea level – see Figure 2.

To date, Louisiana alone has lost an estimated 1,900 square miles (4,921 sq.km) – an average of 25 to 35 square miles annually (65 to 91 square kilometres) – due to a combination of subsidence and sea-level rise since the 1930s,[xli] while parts of Houston have subsided by seven feet in the past 100 years.

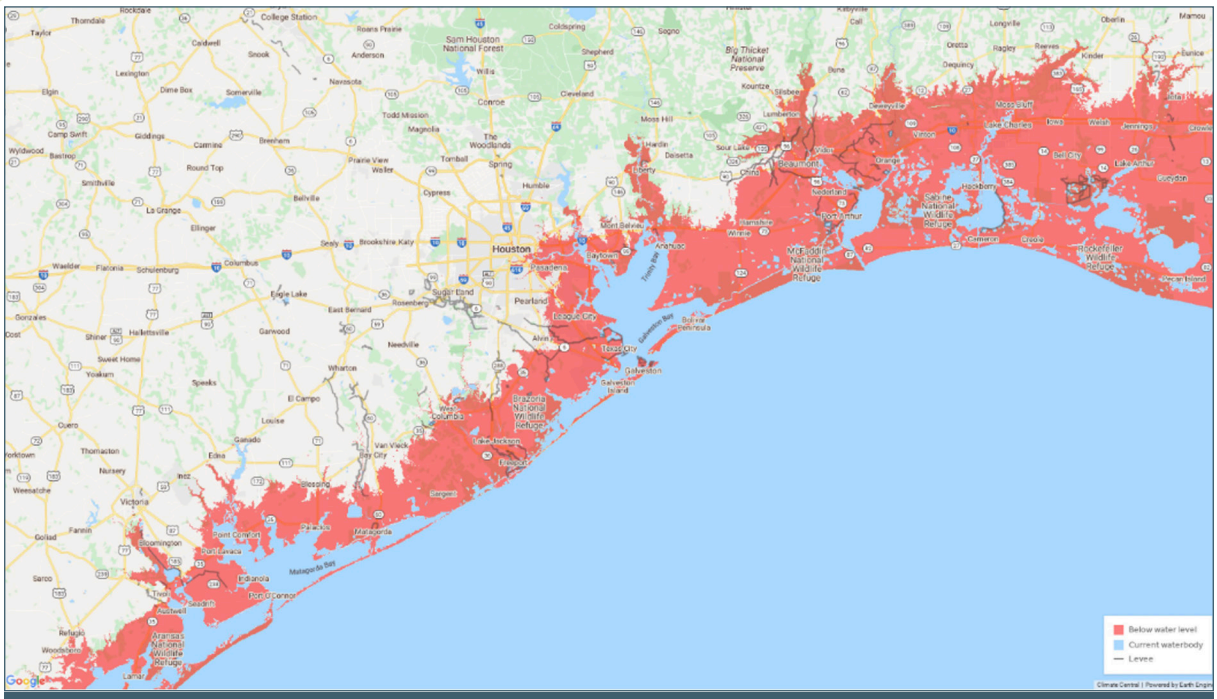


Figure 2: Land below 30 Feet (9 metres) above High Tide (red).[xl] Data used is CoastalDEM90®which is a high-accuracy Digital Elevation Model for coastal areas. It reduces median errors in NASA's SRTM DEM to near zero and reveals flood threats more than three times larger. Source: Climate Central.

Louisiana will continue to subside and lose land for many different reasons, including the steepening of the Mississippi River channel by a factor of two, shortening the Mississippi River by 150 miles (241 km) and then rechannelling much of the Mississippi's water flow out the Atchafalaya River to the Gulf of Mexico via the USD 2 billion Old River Control Project. As a result, the ability of the Mississippi River to act as the region's natural defences against storm surge and sea-level rise has been heavily degraded.[xlii]

Infrastructure failure risk...

If the Old River Control Structure experienced infrastructure failure, it would be a cataclysmic outcome that would damage much of the Plastics Production Corridor in Louisiana.[xliii] The Old River Control Structure is one of the largest waterflow engineering projects globally. It reached its second highest flood mark in March 2019.

Since 1988, flood heights have increased 7 feet (2m) for the same rate of water flow, putting further stress on the Old River Control Structure. Flow rates of the Mississippi River itself are forecast to rise by 60% by 2100.[xliv]

If the structure failed, as it did on 14 April 1973 when a single very small section of the structure collapsed, releasing a torrent of water six times the size of Niagara Falls, the Mississippi would finds its own path to the Gulf of Mexico, destroying and inundating everything in its way, including much of the Plastics Production Corridor.

At the same time, all 12 National Oceanographic and Atmospheric Administration measuring stations along the coast of Texas and Louisiana have recorded a significant sea level rise - see Figure 3.

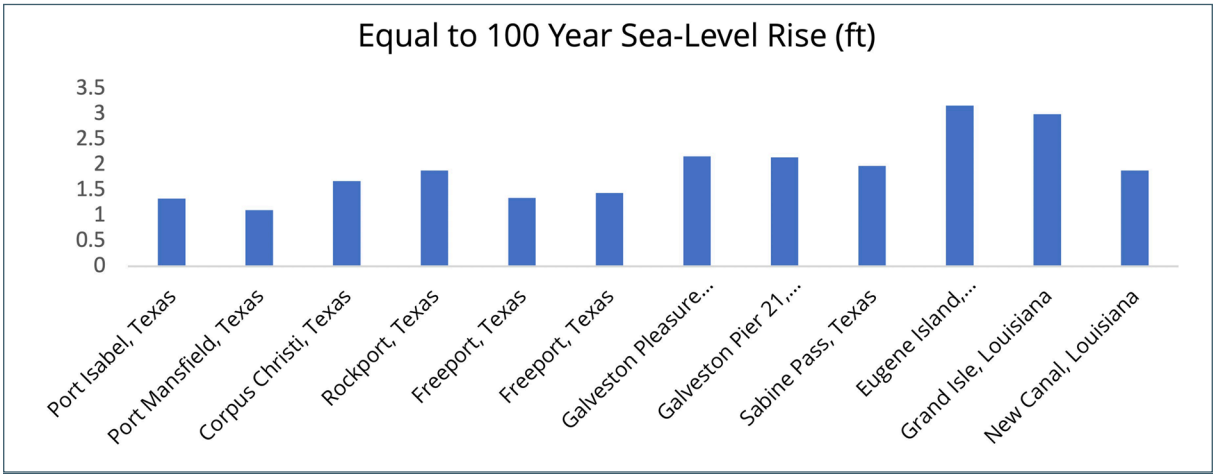


Figure 3: Texas and Louisiana Observed Sea Level Rise in Feet Over 100 Years, Based on Monthly Mean Sea Level Data for 12 Observation Stations at 95% Confidence Interval. [xlv]

The 12 measuring stations that have recorded sea-level rises estimated at 1.11 (0.3m) feet to 3.00 feet (0.9m) report a high confidence level in their observations - see Table 8.

Table 8: NOAA Measuring Stations Along the Coast of Texas and Louisiana, 1904 to 2019 [xlvi]

	Equal to 100 Year Sea-Level Rise (ft)	Sea Level Rise per Year (in)	95% Confidence Interval +/- per Year (in)	NOAA Site Number	Monthly Mean Sea Level Data
Port Isabel, Texas	1.34	0.16	0.013	8779770	1944 to 2019
Port Mansfield, Texas	1.11	0.13	0.028	8778490	1963 to 2019
Corpus Christi, Texas	1.68	0.20	0.042	8775870	1983 to 2019
Rockport, Texas	1.89	0.23	0.019	8774770	1937 to 2019
Freeport, Texas	1.35	0.16	0.028	8772447	1954 to 2019
Freeport, Texas	1.45	0.17	0.041	8772440	1954 to 2008
Galveston Pleasure Pier, Texas	2.17	0.26	0.027	8771510	1957 to 2011
Galveston Pier 21, Texas	2.15	0.26	0.001	8771450	1904 to 2019
Sabine Pass, Texas	1.98	0.24	0.029	8770570	1958 to 2019
Eugene Island, Louisiana	3.17	0.38	0.049	8764311	1939 to 1974
New Canal, Louisiana	1.89	0.23	0.045	8761927	1982 to 2019
Grand Isle, Louisiana	3.00	0.36	0.016	8761724	1947 to 2019

At the same time, Galveston, Texas, which is 50 miles (80 km) from Houston and within the Plastics Production Corridor, has seen sea-levels increase by over 2.15 feet (0.6m) over the past 100 years (95% confidence interval) with current sea-level now increasing at 1 inch (2.5cm) per year [xlvii] – see Figure 4.

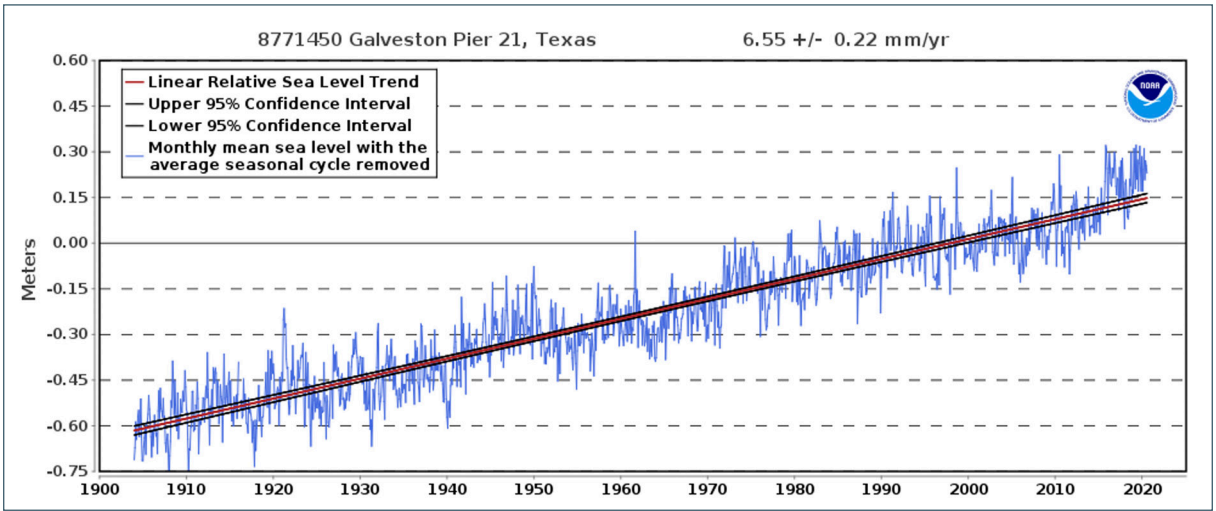


Figure 4: Next to Houston, Galveston Pier 21, Galveston, Texas Sea-Level Rise 1904 to 2019. The relative sea level trend is 6.55 millimeters/year with a 95% confidence interval of +/- 0.22 millimeter per year based on monthly mean sea level data from 1904 to 2019 which is equivalent to a change of 2.15 feet in 100 years. [xlviii]

Forecast sea-level rises for the Plastics Production Corridor put much of the region's capacity at risk of stranded assets. Even if sea-level rise remains within a 2°C target for global warming it will further increase risk to facilities in the Plastics Production Corridor – see Figure 5.

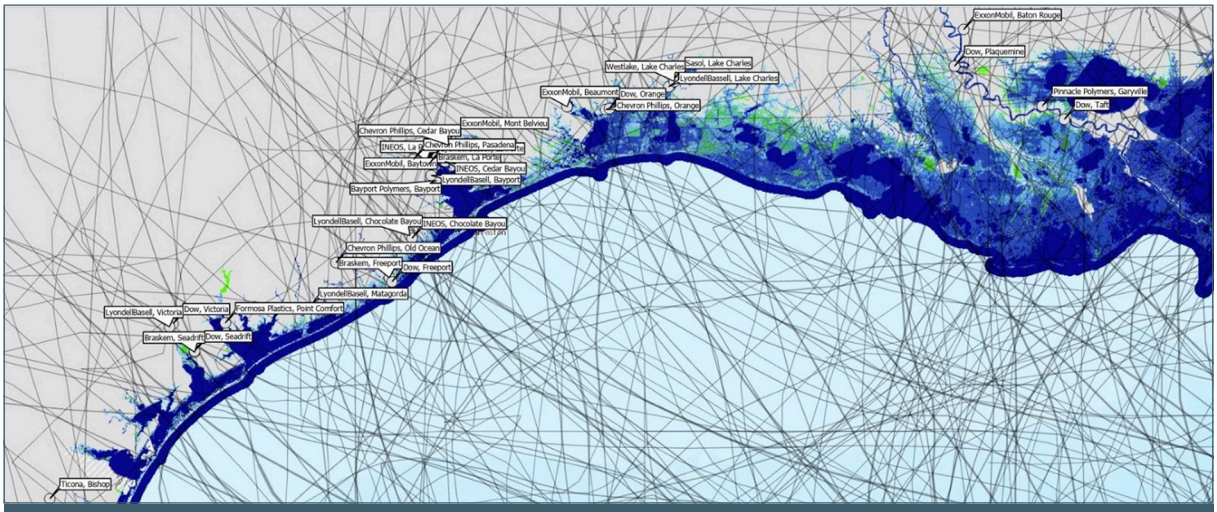


Figure 5: Sea-Level Rise 2050 Forecast for the Plastics Production Corridor Consistent with a 2°C Target for Global Warming under the 2015 Paris Agreement, Overlaid with Black Lines from Hurricanes, Tropical Storms and Depressions 1990 to 2020. [l,li]

To read Figure 5, apply the following criteria:
The SLR (sea level rise layer) with dark blue fading to light blue and to green, the regions are as follows:

- The blue graded metric shown is sea level rise depth (ft):
- NAVY BLUE colouring = high SLR depth
- ROYAL BLUE colouring = medium SLR depth
- LIGHT BLUE colouring = low SLR depth
- The Lime Green metric shown is the classification of SLR low lying area.

CASE STUDY Greater Houston metropolitan area

When looking at just a single economic region, risks are also high. The Greater Houston metropolitan area, a key economic region in the U.S., which generated USD 479 billion for the U.S. economy in 2017, is in the middle of the Plastics Production Corridor.

The metropolitan area is home to 15% and 25% of U.S. capacity of ethylene and propylene respectively and its petrochemical facilities are generally protected against storm surges of up to about 15 feet (5m) – see Figure 6.

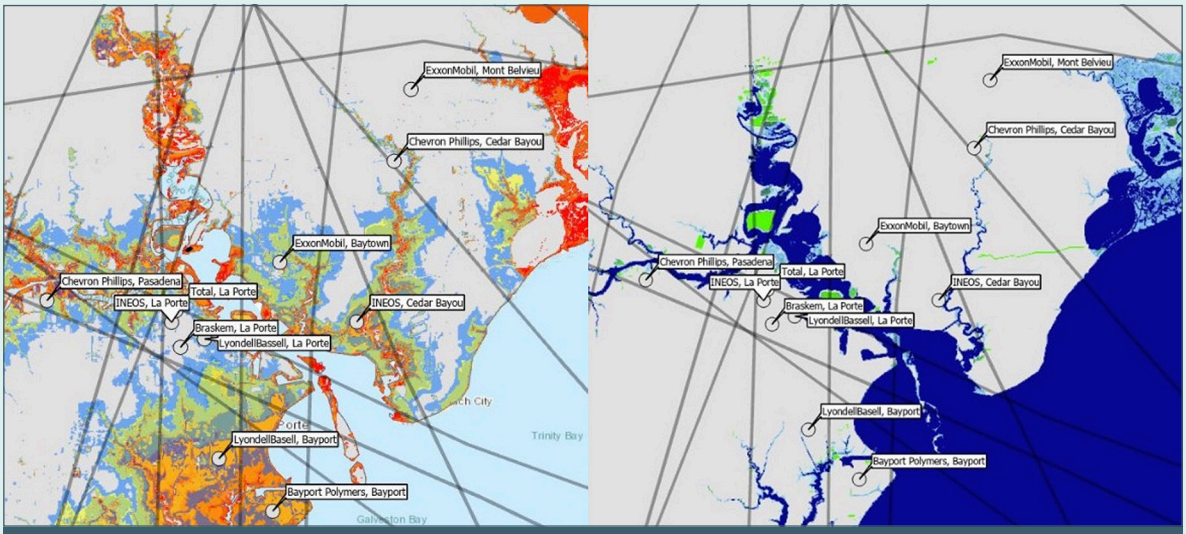


Figure 6: Greater Houston Metropolitan area: Modelled Category 2 Hurricane Storm Surge Risk (left)

Sea-Level Rise[lii] 2050 Forecast for the Plastics Production Corridor Consistent with a 2°C Target for Global Warming under the 2015 Paris Agreement (right) in Plastics Production Corridor Overlaid with Lines (black) from Hurricanes, Tropical Storms and Depressions 1990 to 2020, U.S. National Oceanographic and Atmospheric Administration (NOAA).

This employs the SLOSH model [liii] and the Sea-Level Rise [liv] 2050 Forecast Consistent with a 2°C Target for Global Warming under the 2015 Paris Agreement model.[lv, lvi]

In the Greater Houston metropolitan area in 2008, during Hurricane Ike, storm surges reached 30 miles (48km) inland, deep into the Plastics Production Corridor, despite many facilities having storm surge mitigation measures in place.[lvii]

Hurricane Harvey shut down 68 plastics facilities and related refineries around the Plastics Production Corridor

The Plastics Production Corridor also includes the plastics production industrial area that was damaged and temporarily shut down due to Hurricane Harvey in 2017.[lviii] Some shutdowns occur pre-emptively in order to protect facilities from physical risks.

Hurricane Harvey, which caused USD 125 billion in damages, in particular from flooding and in some cases from storm surges, is the second most costly natural disaster in U.S. history, after Hurricane Katrina in 2005 (which was estimated to have cost USD 250 billion).

Hurricane Harvey was a Category 4 hurricane that measured about 200 miles (322 km) across. It made landfall in the Plastics Production Corridor region of Texas on 25 August 2017 with 12-foot (4m) storm surges and then stalled over the region for five days resulting in 60 inches of rainfall in some areas.

After the storm, the U.S. government declared a disaster area of 41,500 square miles (108,000 sq. km). Hurricane Harvey caused 75% of U.S. polyethylene capacity to declare force majeure – see Figure 7.

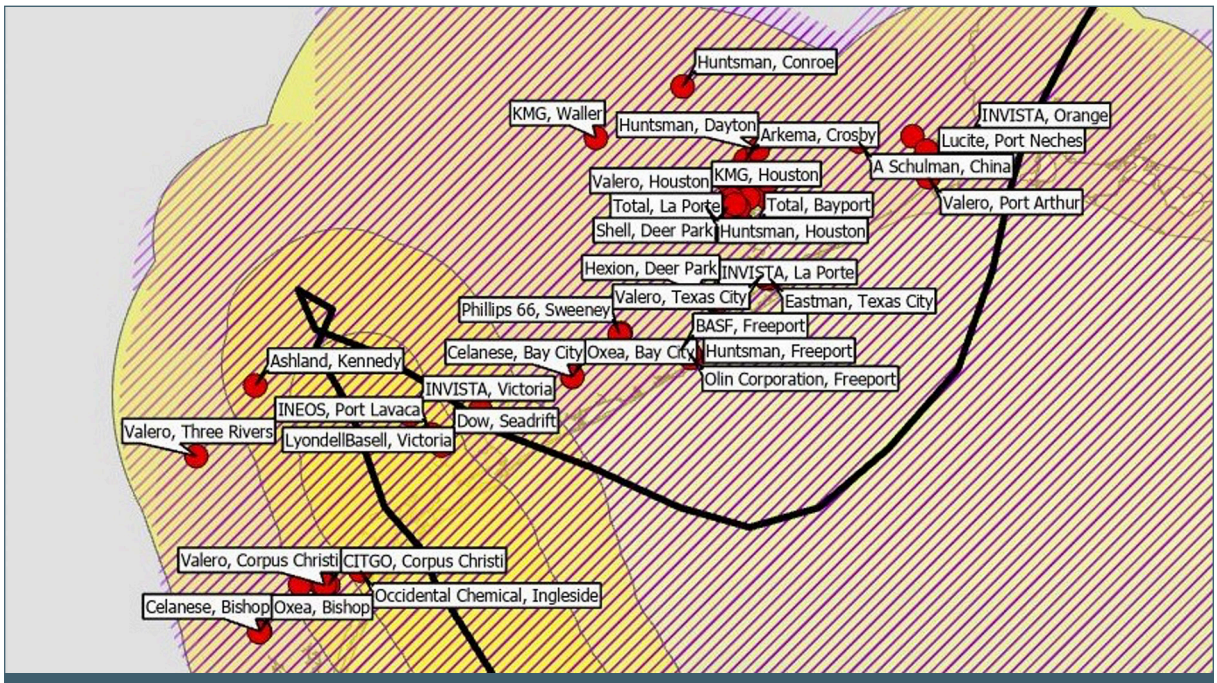


Figure 7: 68 Plastics Facilities and Related Refineries Damaged by Hurricane Harvey, 2017.[lx,lxi] Note: not all facilities shown in the image. A complete list by company, location and chemical process is available in Table 11 (Appendix). Purple crosshatch is storm radius; yellow is the wind swathe; black line is Hurricane Harvey's storm path.

In the greater Houston area alone, even with seawalls and physical protection in place, Hurricane Harvey caused 26 plastics facilities and related refineries to temporarily shut down or suffer damage.

Going forward, investors would benefit from mapping their investments in the Plastics Production Corridor against exposure to climate risks, for example using the SLOSH and SLR rise models, as plastics refineries and facilities face immediate risks from climate change.

U.S. Market Analysis

The risks to operations from more frequent storms should not distract investors from other longer-term financial risks playing out in the U.S. plastics resins industry:

- **U.S. Plastics Resins Prices and Margins Declining:** Long-term U.S. HDPE, LDPE, LLDPE and PP prices are in decline and U.S. margins[6] are forecast to continue to decline.
- **Global Expansion Faster than U.S. Expansion:** Global expansion, primarily in plastics resins capacity with higher margins, is increasing faster than U.S. supply as Asian markets expand their plastics' capacity and increase production.[lxii]
- **U.S. Exporting into Headwinds:** U.S. industry expansion forecasts are based increasingly on exporting, yet the U.S. faces growing export headwinds.
- **U.S. New Construction Facing Delays:** USD 56 billion of expansion faces delays primarily due to market forces as either partners have pulled out or permits have been declined, much of it in the Plastics Production Corridor. Investors may benefit if companies they invest in delay or cancel planned expansion in the Plastics Production Corridor in a strategy to prudently conserve investor capital instead of risk future stranded assets.
- **North American 2020 to 2035 Demand Dominated by Single-Use Plastic:** North American market demand between 2020 and 2035 is forecast to be dominated 38% by film, 21% by injection moulding and 15% by blow moulding.

U.S. prices fall below long-term averages

Even though, in Q3 2020, significant declines in polymer capacity due to frequent storms were followed by upticks in prices driven by pockets of domestic demand, monthly benchmark prices (sum of weekly averages) for HDPE (black), LDPE (blue), LLDPE (red) and PP (green) in Houston, within the Plastics Production Corridor, remain well below their long-term averages, generally in line with their respective natural gas and oil feedstocks' prices, between Q4 2013 and Q3 2020 – see Figure 8.

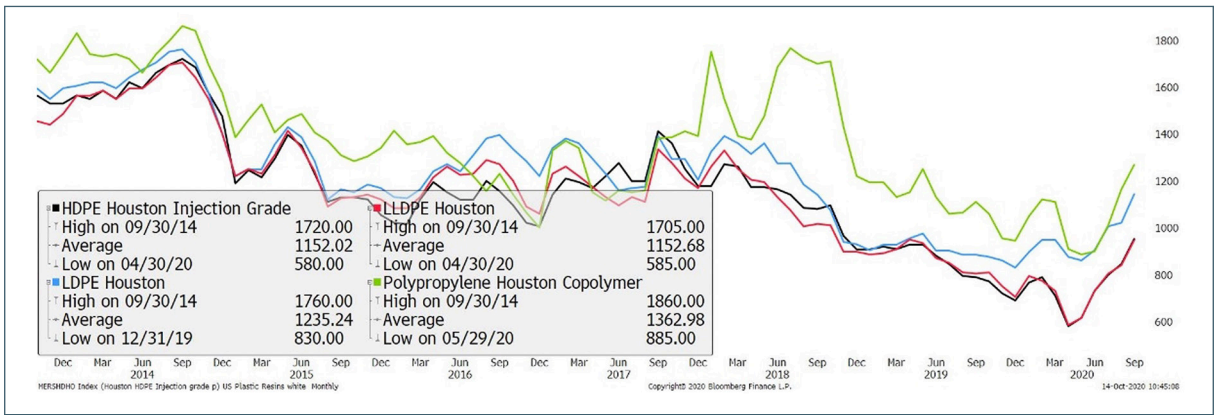


Figure 8: Month U.S. Spot, High, Low and Average HDPE, LDPE, LLDPE an PP Prices USD per Tonne, October 2013 to October 2020. X-axis months October 2013 to October 2020. Y-axis USD price per tonne. Source: Bloomberg L.P. and NexantECA. [lxiii]

[6] Margin calculations from Nexant Chemsystems include all plant cash costs (variable and fixed, depending on ticker). Tecnon OrbiChem margins are reference raw materials margins based on input costs.

U.S. prices fall below long-term averages

Furthermore, U.S. production is forecast to grow at a lower rate than global production between 2020 and 2035 - see Figure 9.

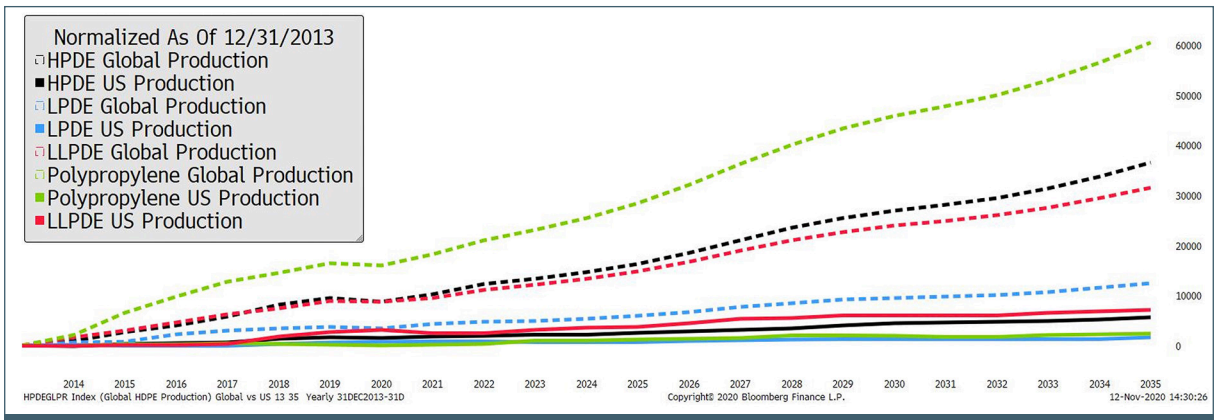


Figure 9: Global (dotted line) vs. U.S. (solid line) Rate of Increase of Global Capacity Additions for HDPE, LDPE, LLDPE and PP Production 2013 to 2019 and 2020 to 2035 Forecast. X-axis years 2013 to 2035. Y-axis tonnes increase per 2013 normalized baseline of zero. Source: Bloomberg L.P. and NexantECA. [lxiv]

This decline in the U.S. percentage share of global market production is occurring as the U.S. positions itself as a low-cost competitor, by using abundant shale gas and healthy ethane margins. However, this scenario is challenged by increasingly competitive and more efficient crude oil-to-chemical (COTC) facilities being built, particularly in China and the Middle East.

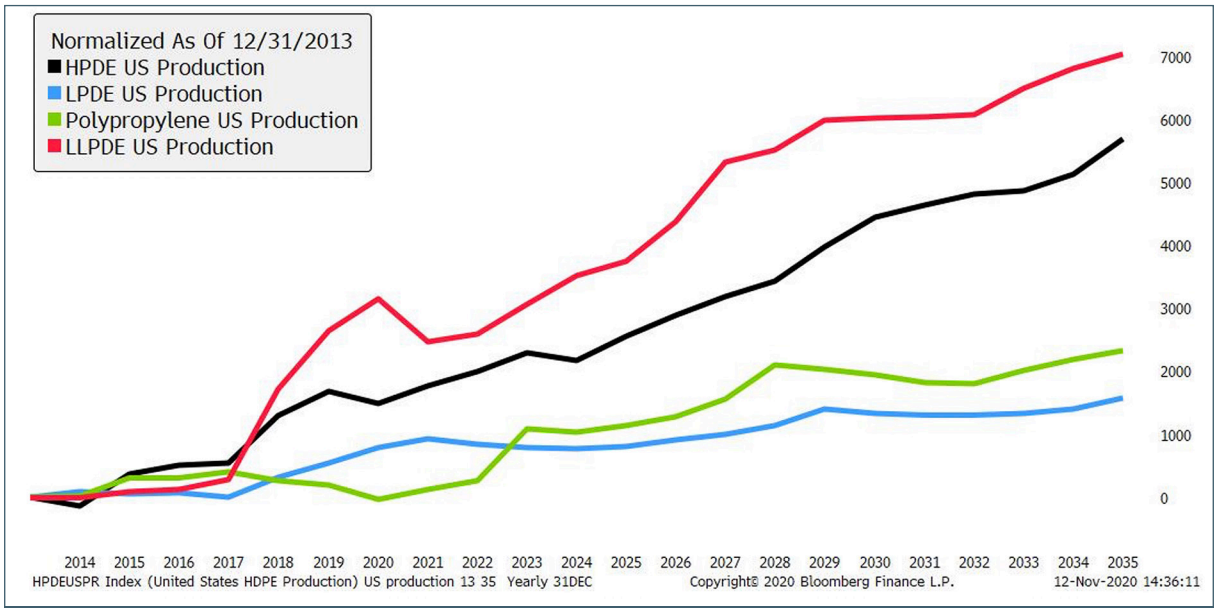


Figure 10: Forecast U.S. Expansion 2013 to 2035. X-axis years 2013 to 2035. Y-axis tonnes increase per 2013 normalized baseline of zero. Source: Bloomberg L.P. and NexantECA. [lxv]

The U.S. plastics industry is, in many cases, forecasting its future growth based on increasing demand for fast-moving plastics and single-use plastics - see Figure 10 - as is evident by Formosa Petrochemical Corp.'s USD 10 billion proposed facility in St. James, Louisiana on 2,400 acres being built to meet forecast single-use plastics demand.[lxvi] Note: this proposed facility had its licence suspended 4 November 2020 by the U.S. Army Corps of Engineers due to a court case filed by the Center for Biological Diversity.[lxvii]

Global expansion has high margins

The U.S. plastics industry is forecast to grow at a lower rate than the global industry partly due to declining feedstock advantages. The U.S. industry also expects to expand its exports between 2020 to 2035 while its intended markets are heading for plastics self-sufficiency.

For example, China may achieve PP self-sufficiency by 2022.[lxviii] This is despite the fact that China's PP demand has grown from 4.6 million tonnes in 2010 – or 10% of the global market – to 29.6 million tonnes in 2020 and is forecast to achieve 45.7 million tonnes by 2030, equal to 39% of the global market.[lxix]

It is also important to understand that plastics have a clear upstream oil footprint. Petrochemicals are now the fastest-growing percentage of a barrel of oil with the OECD and OPEC forecasting 3.2 million barrels of oil per day growth for plastic feedstock by 2030.[lxx]

At the same time, crude oil-to-chemicals (COTC) facilities, primarily based in China, Saudi Arabia and the Gulf, which are expected to have much higher production and profitability margins, have received about USD 163 billion [lxxi, lxxii, lxxiii, lxxiv] in investment over the past three years – see Table 9.

Table 9: Global COTC Examples, not exhaustive. [lxxv,, lxxvi, lxxvii, lxxviii]

Project	Investment (USD billions)	Start	Country
Hengli Petrochemical	12.0	2019	China
Hengyi Brunei	3.5	2019	Brunei
Zhejiang Petroleum and Chemical Phase 1	13.0	2020	China
Shenghong	11.0	2022	China
Zhejiang Petroleum and Chemical Phase 2	12.0	2023	China
Aramco/SABIC Joint Venture	20.0	2025	Saudi Arabia
Tangshan Xuyang (Risun) – under review			China
Aramco/Total SE	9.0	2023	Saudi Arabia
Shandong Yulong Island	18.2	-	China
Huajin Aramco Petrochemical (Aramco 35%, NORINCO 36%, Panjin Sincen 29%)	10.0	2024	China
ADNOC, Aramco, Indian Oil, Hindustan Petroleum, Bharat Petroleum	44.0	2025	India
Reliance Jamnagar	9.8	-	India
Total	**162.5**		

In an effort to substitute their oil income and improve their balance of payments, oil-producing countries are investing in facilities that move them further downstream into plastic resins production.

This is part of the reason why China's 14th five-year plan is mandating that the country move towards self-sufficiency in petrochemicals capacity and production with the goal of eventually expanding its plastics' exports.[lxxix] China is aiming to expand its facilities, thereby increasing its polyethylene and PP self-sufficiency ratios, currently at 52% and 85%.[lxxx]

Currently, China imports paraxylene primarily from South Korea and Saudi Arabia for its polyester producers. Under the expansion plan that is being promoted by government policies, China will import crude oil – two steps upstream from importing paraxylene – to use as feedstock for its growing COTC build out. China's four large COTC projects – Shenghong Petrochemical Group, Hengli Petrochemical Group, Hengyi Industries and Zhejiang Petrochemical & Chemical Co. – are all funded primarily via Chinese private and governmental institutions.[lxxxi]

In fact, China, Saudi Arabia and other Arabian Gulf states now see part of their oil future in growing plastics' exports. Saudi Arabia plans to triple its petrochemical capacity and production – from 12 million metric tonnes per annum (mmtpa) to 34 mmtpa – by 2030, while China's government has invested heavily in expanding COTC infrastructure.

Margins for COTC projects, such as return on investment (ROI), according to Bloomberg, are forecast to start at 7% in down markets increasing to 15% as markets recover.

Yields per barrel of oil through chemical conversion in COTC projects', at 40% to 60%, are 2 to 3 times higher than unintegrated facilities, whose yields are around 20%.

COTC yields "for Hengli and Zhejiang Petrochem are about 50%, the highest in the world among oil downstream plants".[lxxxii] Furthermore, the Hengli and Zhejiang Petrochemical plants, for instance, some of the largest in the world, could see their production costs decline by 20% per tonne vs. competitors.[lxxxiii]

U.S. industry continues to expand yet delays occur

Time will tell how many planned facilities will be completed and be financially viable as the economic profile for the U.S. plastics industry is rapidly changing. Facilities valued at "at least" USD 40 billion are currently either under construction or facing imminent Final Investment Decision (FID) within the Plastics Production Corridor and thus at risk of not being built or becoming stranded assets – see Table 10.

Table 10: Examples of U.S. Facilities under Construction 2020 and 2025. Highlighted in yellow are facilities in the Plastics Production Corridor along the Gulf of Mexico Coast. Green are new facilities being built along the Ohio River Plastics Hub. Forecast completion date highlighted in red means delayed [lxxxiv]

Companry	Location	Product	Capacity	Year
Total/Borealis	Port Arthur, Texas	Ethylene	1,000	2020
Shell	Monaca, Pennsylvania	Ethylene	1,500	2021-22
ExxonMobil/SABIC	San Patricio, Texas	Ethylene	1,800	2022
PTT	Belmont, Ohio	Ethylene	1,500	2024
Chevron Phillips/Qatar Petroleum	Texas	Ethylene	2,000	2024
Formosa Petrochemical Corp.*	St. James Parish, Louisiana	Ethylene	1,200	2024
Total Ethylene			**9,000**	
Enterprise Products	Mt. Belvieu, Texas	Propylene	750	2023
Formosa Plastics	Point Comfort, Texas	Propylene	600	2024
Total Propylene			**1,350**	

Companry	Location	Product	Capacity	Year
Braskem	La Porte, Texas	PP	450	2020
Formosa Plastics	Point Comfort, Texas	PP	250	2022
ExxonMobil	Baton Rouge, Texas	PP	450	2022
INEOS	Alvin, Texas	PP	45	2022
Total PP			**1,195**	
Total/Borealis	Bayport, Texas	HDPE	625	2021
Shell	Monaca, Pennsylvania	LLDPE	1,100	2021-22
PTT	Belmont, Ohio	HDPE	700	2022-23
Chevron Phillips/Qatar Petroleum	Texas	HDPE	2,000	2024
Formosa Petrochemical Corp.*	St. James Parish, Louisiana	HDPE	400	2024
Formosa Petrochemical Corp.*	St. James Parish, Louisiana	HDPE	400	2025
Total HDPE			**5,225**	
Shell	Monaca, Pennsylvania	LLDPE	500	2021-22
PTT	Belmont, Ohio	LLDPE	900	2022-23
Formosa Petrochemical Corp.*	St. James Parish, Louisiana	LLDPE	400	202
Formosa Petrochemical Corp.*	St. James Parish, Louisiana	LLDPE	400	2025
Total LLDPE			**2,200**	

With polymer prices declining since 2013, U.S. industry is still pursuing capacity expansion by 2025 costing over USD 56 billion with USD 40 billion in the Plastics Production Corridor.

U.S.-based expansion is founded upon inexpensive shale gas as an ethane-based feedstock. Many projects are also facing significant delays due to environmental risks, changing markets and project partners declining to continue partnerships.

This expansion scheduled for 2020 to 2025 is dominated by the following projects in the Plastics Production Corridor.

- USD 10 billion: Gulf Coast Growth Ventures, a joint venture between ExxonMobil and Saudi Arabian Basic Industries Corporation (SABIC).[lxxxv]
- USD 10 billion: Formosa Petrochemical Corp.'s St. James Parish, Louisiana facility.[lxxxvi] The Sunshine Project had its permitting suspended 4 November 2020. USD 8 billion: Chevron Phillips and Qatar Petroleum ethylene cracker and HDPE units.[lxxxvii]
- USD 5 billion: Formosa Plastics, Point Comfort, Texas expansion.[lxxxviii,lxxxix]
- USD 3 billion to USD 5 billion: Total/Borealis facility with estimate based on comparables.
- USD 1 billion: Enterprise Products with estimate based on comparables.
- USD 750 million: Braskem's La Porte, Texas facility.[xc]

U.S. margins forecast to decline by 2035

While companies in Q4 2020 are addressing declining U.S. prices by employing various strategies – from decreasing utilisation rates and shutting facilities to selling assets – what is most important is that when applying NexantECA's moderate oil growth scenario from 2020 to 2035, U.S. production for HDPE, LDPE, LLDPE and PP is forecast to continue to grow, albeit less than global growth forecasts over the same period – see Figure 11.

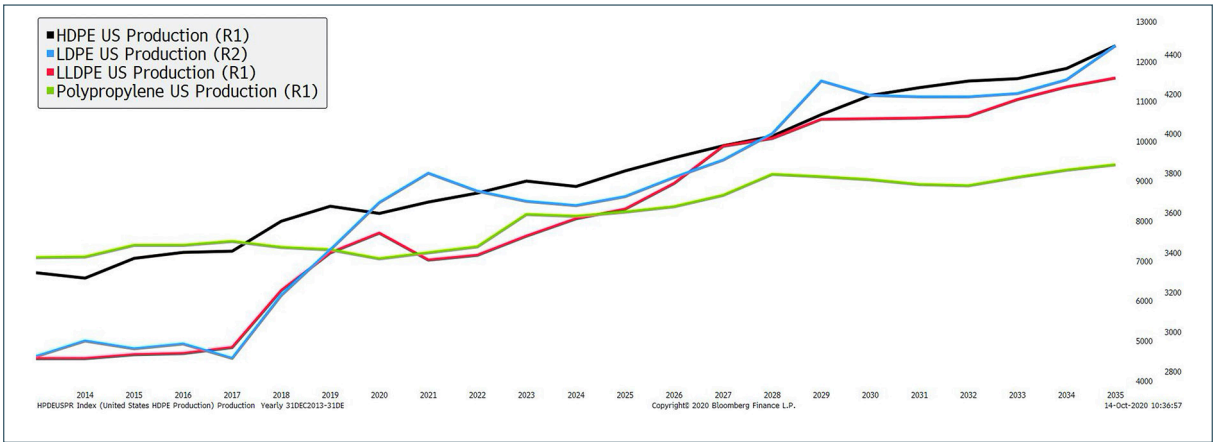


Figure 11: Annual U.S. HDPE, LDPE, LLDPE and PP Production 2013 to 2019 and Forecast 2020 to 2035. X-axis years 2013 to 2035. Y-axis tonnes increase tonnes per 2013. HDPE, LLDPE and PP on first y-axis and LDPE on second y-axis. Source: Bloomberg L.P. and NexantECA.[xci]

Over the same period, despite increasing prices, margins in U.S. HDPE, LDPE, LLDPE and PP production are forecast to decline to 2035, as U.S. competitive advantages from inexpensive ethane feedstocks are offset by the growth in global capacity and more efficient COTC facilities coming online, primarily in China, which is the largest market globally for plastics - see Figure 12.

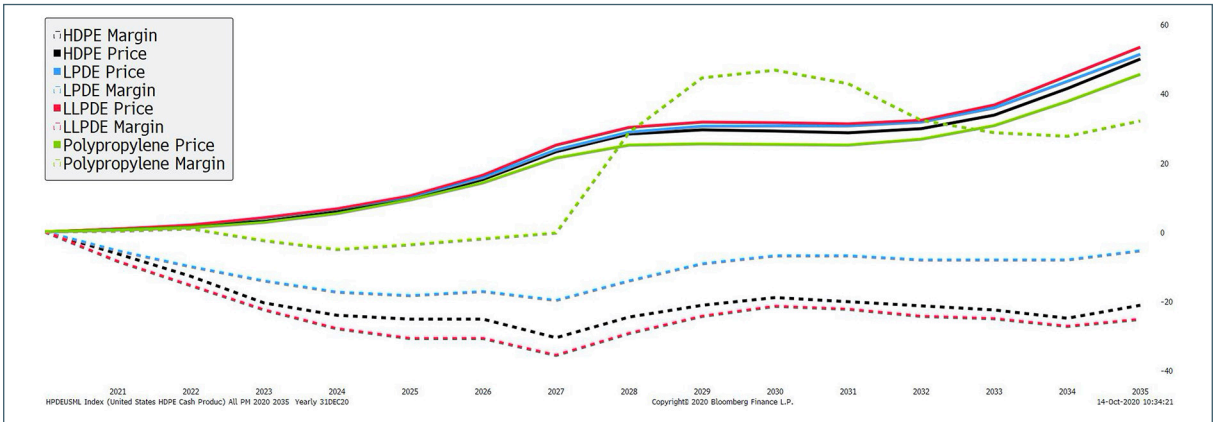


Figure 12: Annual U.S. HDPE, LDPE, LLDPE and PP Forecast Margins Decline while Prices Increase 2020 to 2035. X-axis years 2020 to 2035. Y-axis tonnes increase or decrease % normalized baseline of zero in 2020. Source: Bloomberg L.P. and NexantECA. [xcii]

The dilemma for the plastic businesses is that despite the decline, these product margins remain superior to other feedstock options.

U.S. firms rely on growth in exports

Despite competitive markets globally expanding into more efficient and higher yielding COTC facilities, U.S. industry is still counting on exporting into these headwinds in their attempt to maintain their market share. Even when including U.S. forecast market share growth via increasing exports, U.S. overall market share is forecast to decline to 2035 - see Figure 13.

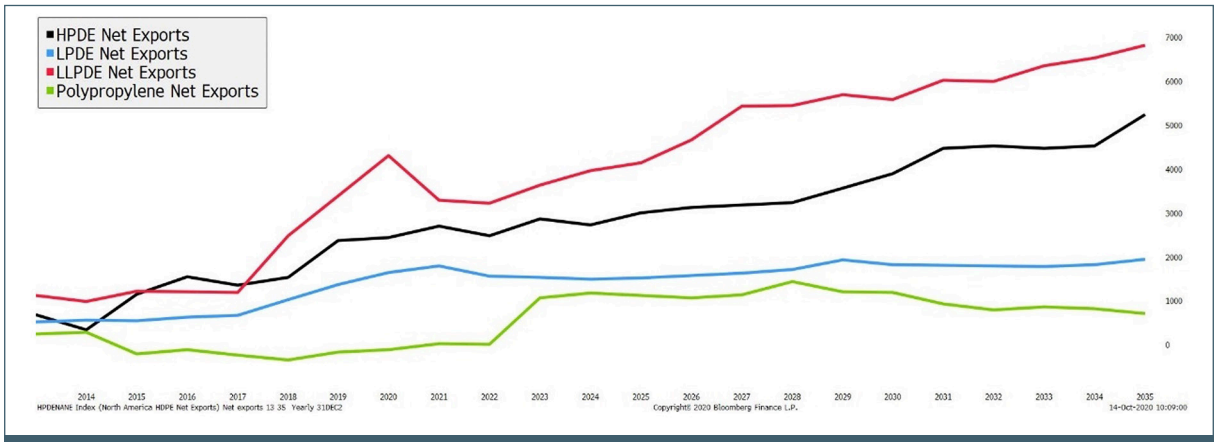


Figure 13: U.S. HDPE, LPDE, LLPDE and PP Exports 2013 to 2019 and Forecast 2020 to 2035. X-axis years 2013 to 2035. Y-axis tonnes increase tonnes exported per 2013. Source: Bloomberg L.P. and NexantECA. [xciii]

North American LDPE, LLDPE, HDPE and PP growth forecast is based on single-use plastic

North American market segment forecasts in the graphs below are colour-coded for film (orange), injection moulding (red), other (green), fibre (blue), blow moulding (yellow) and extrusion coating (light blue). Production is black (solid) and consumption is black (dotted). The difference between production and consumption equals forecast exports.

According to Nexant, the North American market demand from 2020 to 2035 is forecast to be dominated by:

- Film: 38%
- injection moulding: 21%
- Blow moulding: 15%
- Fibre: 6%
- Other categories: 9%

[7] (Given that segment forecasting is only available at the North American market level, Planet Tracker employed North American segment forecasts for this section of the analysis.)

Analysing forecast demand in detail, LLPDE demand to 2035 includes increasing U.S. exports from 2.4 million tonnes in 2019 to 5.3 million tonnes in 2035, while North American consumption is dominated by the expansion of single-use film. To 2035, LLDPE production is forecast to increasingly outpace LLDPE consumption with significant consumption growth forecast in the film segment, which is one of the primary sources of fast-moving plastics and single-use plastics – see Figure 14.

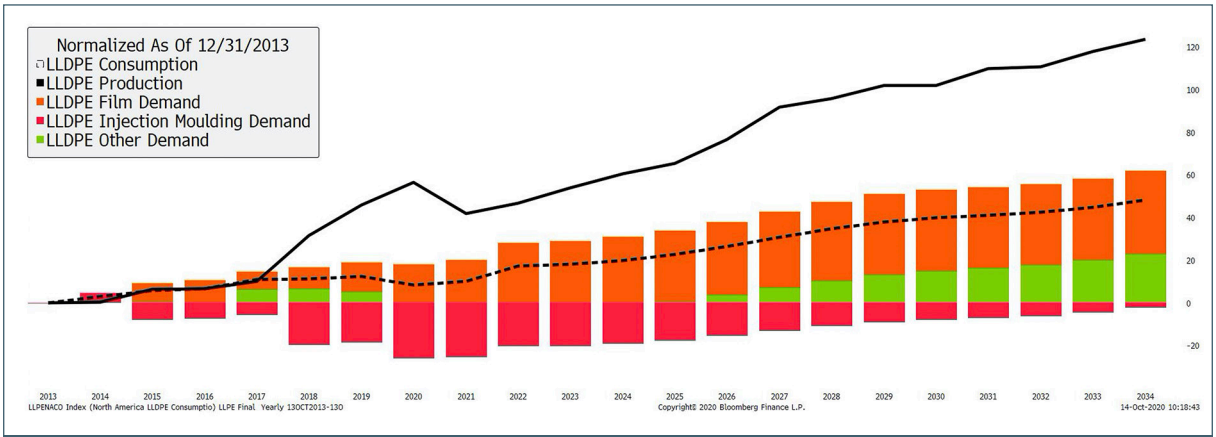


Figure 14: North America Forecast LLPDE Demand 2020 to 2035. X-axis years 2013 to 2035. Y-axis tonnes percent per baseline 2013 of zero. Source: Bloomberg L.P. and NexantECA. [xcv]

Similarly, in the North American PP market forecast 2020 to 2035, the region in aggregate is forecast to increase exports by 150% while increasing North American consumption in fibres, film, injection moulding and other categories - see Figure 15.

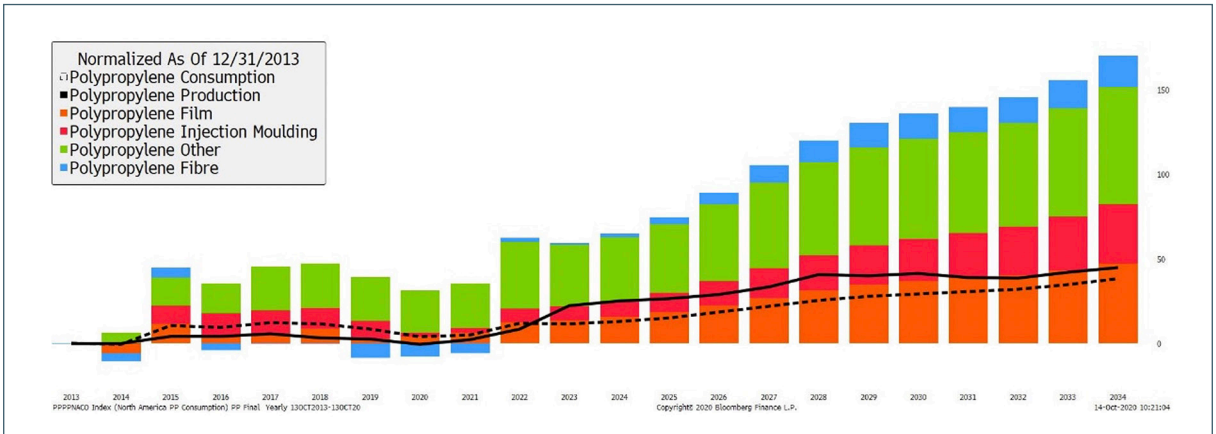


Figure 15: North America Forecast PP Demand 2020 to 2035. X-axis years 2013 to 2035. Y-axis tonnes percent per baseline 2013 of zero. Source: Bloomberg L.P. and NexantECA. [xcvi]

While production and consumption – supply and demand – are forecast to grow generally at the same pace until 2035, consumption growth forecast is dominated by the film, fibre and injection moulding segments, which are all one of the primary sources of fast-moving plastics and single-use plastics.

In North America, the HDPE market is forecast to increase exports from about 2 million tonnes in 2019 to 4.2 million tonnes in 2035 while expanding North American consumption in film, blow moulding, injection moulding and other categories - see Figure 16.

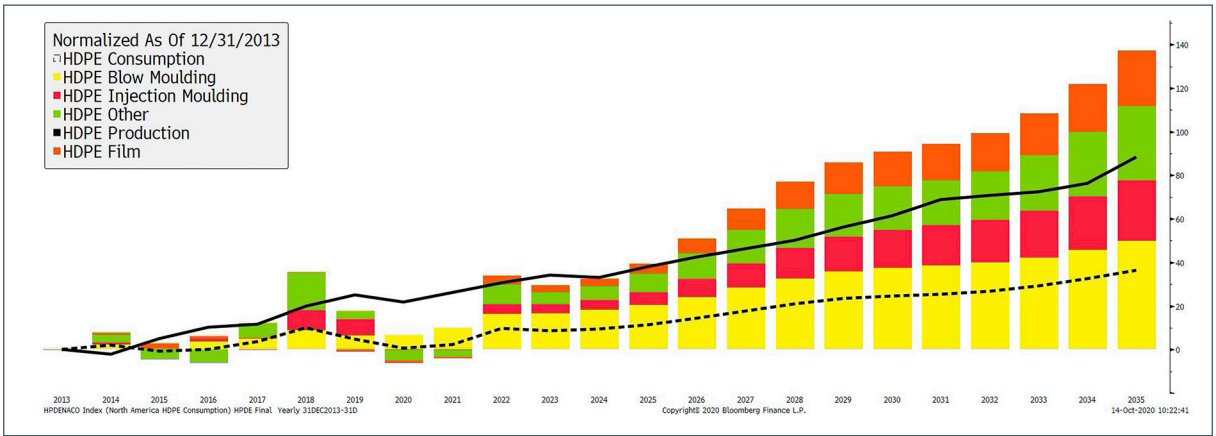


Figure 16: North America Forecast HDPE Demand 2020 to 2035. X-axis years 2013 to 2035. Y-axis tonnes percent per baseline 2013 of zero. Source: Bloomberg L.P. and NexantECA. [xcvii]

As with the PP industry, the HDPE market forecast to 2035 generally has production and consumption growing at similar rates.

Yet again, consumption growth forecast is dominated by the film, blow moulding and injection moulding segments, which are all one of the primary sources of fast-moving plastics and single-use plastics.

Finally, the U.S. is forecast to increase its LDPE exports 50% to 2.1 million metric tonnes by 2035 while North American demand is dominated by expansion in extrusion coating markets. Forecast to 2035, LDPE production may significantly outpace demand as markets migrate from LDPE to LLDPE resins given generally superior physical characteristics.

At the same time, consumption growth forecast is dominated primarily by extrusion coating, another primary source of fast-moving plastics and single-use plastics – see Figure 17.

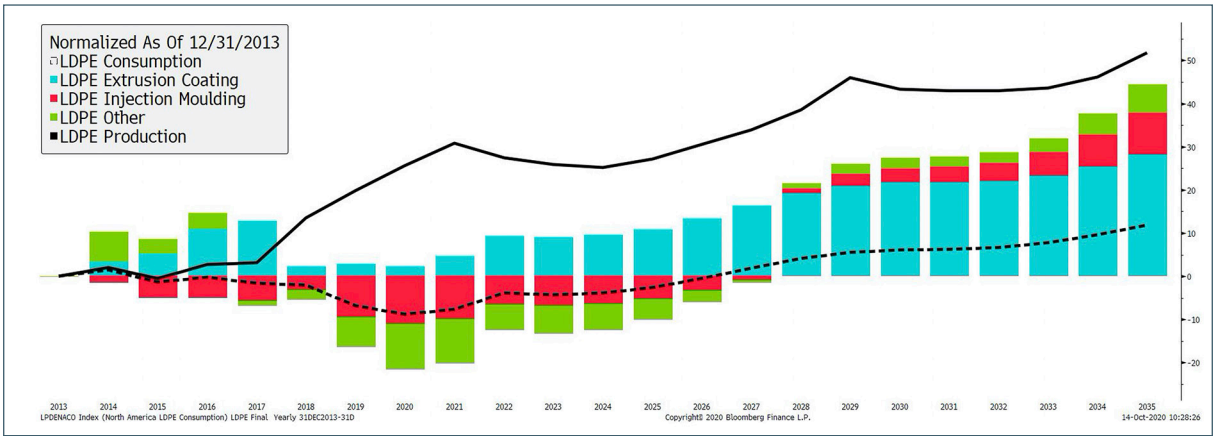


Figure 17: North America Forecast LDPE Demand 2020 to 2035. X-axis years 2013 to 2035. Y-axis tonnes percent per baseline 2013 of zero. Source: Bloomberg L.P. and NexantECA. [xcviii]

Given these trends, companies react

Decreasing demand in 2020 is driven by declining demand in the automotive sales, household appliances and some packaging products sectors, yet demand is forecast to stabilize for HDPE, LDPE and LLDPE moving into 2021.

Despite some potential demand stabilisation forecast in the short-term as polyethylene and its derivatives are exposed to consumer non-durable including packaging concerns given Covid-19, industry is actively showing some signs that it is starting to address overcapacity.

Three-quarters of U.S. chemicals companies cut capital expenditures in 2020. Emerging stranded assets can be observed in decreasing capital expenditures, delayed completion of construction of polyolefins projects and selling assets to pay off debt.

Decreasing capital expenditures

According to a survey of U.S. chemicals companies conducted by the American Chemistry Council between April 22 and May 2, 2020, published in September 2020, as reported by ICIS:

> *"On average, 74% of chemicals companies have cut capex and 60% have delayed or cancelled investments"* [cii]
>
> *"46% of producers partially or fully shut down some or all of their plants"* [ciii]

The survey included 50 chemical and plastics companies representing USD 463 billion in annual chemical sales.

According to this survey, the top two risks highlighted by 84% and 70% of the respondents respectively were "weaker US economy and sales for our products to US customers" and "weaker global growth and export sales". This represented an estimated increase of 100% and 50% in these risks versus 2019's survey response.[civ]

Delaying construction

As shown in Table 10, most U.S. facilities scheduled to come online between 2020 and 2025 are facing major delays.

For example, before its licence was suspended, Formosa Petrochemical Corp. had suspended some of the preconstruction work on its USD 10 billion Sunshine Project in St. James, Louisiana within the Plastics Production Corridor until 1 February 2021 pending further review of environmental and land permitting by the U.S. Army Corps of Engineers and the Louisiana Department of Environmental Quality due to climate and other risks.[cv] Formosa Petrochemical owns 100% of the subsidiary – FG LA LLC – who is the developing the project. FG LA LLC also announced 19 October they are deferring "major construction until the pandemic has subsided and/or an effective vaccine is widely available" [cvi]

This Sunshine Project, with its ten chemical plants and multiple facilities, would be one of the largest plastics facilities in the world. Alone, this Formosa Petrochemical Corp.'s project is responsible 13%, 15% and 36% of forecasted estimated U.S. capacity growth between 2020 and 2025, for ethylene, high density polyethylene and linear low-density polyethylene, respectively.

Whether looking at LLDPE and HDPE specifically, or at all the plastics highlighted in this report, forecasts for North American demand between 2020 and 2035 are dominated by single-use plastics and fast-moving plastics, with much of the forecast supply also earmarked for export into markets with growing overcapacity.

Selling assets to pay off debt

On October 2, 2020, Sasol agreed to sell a USD 2 billion stake in its Lake Charles, Louisiana, ethylene and polyethylene business to LyondellBasell to raise USD 2 billion so that Sasol could decrease its debt from USD 10 billion to USD 8 billion. The Lake Charles project was approved in 2014 at an estimated cost of USD 8.1 billion but finished 60% over budget at more than USD 13 billion.[cvii]

The key is that Sasol sold its assets to Lyondell "meaningfully below replacement costs".[cviii]

In response, Moody's and S&P downgraded Lyondell's credit rating to Baa2 and BBB- respectively due to lower margins and its net leveraging increasing from 2x to 2.9x as Lyondell issued USD 3.9 billion in debt to fund its USD 2 billion purchase and to refinance debt near maturity. If markets do not recover, Lyondell faces another potential downgrade in 2021.[cix]

Moody's wrote that ***"prices are likely to fall around year end as temporary capacity shutdowns, largely due to Hurricane Laura, and should be fully back on line for November and December" forecasting that Lyondell's "adjusted net financial leverage will rise to over 3 times and retained cash flow/net debt will fall toward 15% by year end"*** due to weak market fundamentals.[cx]

The USD 2 billion purchase for Sasol's Lake Charles Chemical Project includes:

- An ethane cracker with a capacity of 1,540 kilotons annually used to produce ethylene.
- A LDPE facility used to produce 420 kilotons annually.
- A LLDPE facility used to produce 471 kilotons annually.[cxi]

In summary, even with LyondellBassell purchasing these assets from Sasol at "65% of replacement value" [cxii] implying a 50% discount on the cost of new-build facilities,[cxiii] Lyondell's credit rating was downgraded.

These are the LLDPE and HDPE facilities for which Sasol declared force majeure after Hurricanes Marco and Laura in late August. Its Lake Charles facility, which is responsible for 470,000 metric tonnes per year of LLDPE (est. 4% of total U.S. capacity) was shut down.[cxiv]

Summary

Overcapacity and climate risk are both increasing stranded asset risk in the U.S. Plastics Production Corridor as both capacity and production are forecast to grow to 2035, despite increasing climate risks from storms, sea-level rise and storm surges. Within this risk cocktail sit myriad regulatory and infrastructure pressures that immediately endanger investor capital.

Corporations for their part need to publicly disclose their supply and demand forecasts for their facilities. They also need to disclose analyses of all climate-related risks which might impact their facilities.

As external risk factors increase, the industry faces the growing possibility of stranded assets of USD 56 billion by 2025, of which USD 40 billion in the Plastics Production Corridor alone.

It is imperative for investors to actively manage their investments, which are facing short-term and mid-term climate and oversupply pressure along the Plastic Production Corridor before these risks negatively impact their investments' performance.

It may be prudent for investors to seek further delays and/or project cancellation as a hedge given these investment risks highlighted here.

Appendix

Table 11: 68 Company Facilities Shutdown or Damaged by Hurricane Harvey, 2017. [cxv]

Company	Location	Product
A Schulman	China, Texas	Specialty powder
A Schulman	Houston, Texas	Engineered plastics
A Schulman	La Porte, Texas	Masterbatch
American Acryl	Bayport, Texas	Acrylic acid
Arkema	Crosby, Texas	Liquid organic peroxide
Ascend	Chocolate Bayou, Texas	Acrylonitrile, hydrogen cyanide, disodium iminodiacetate
Ashland	Texas City, Texas	Polyvinyl pyrrolidine, linear and crosslinked homopolymers, polyvinyl pyrrolidine/vinyl acetate, copolymers, N-methyl-2-pyrrolidine
Ashland	Kennedy, Texas	Guar derivatives
BASF	Freeport, Texas	Acrylic monomers, oxo-alcohols
Celanese	Bay City, Texas	Methanol, vinyl acetate monomer
Celanese	Bishop, Texas	Polyethylene
Chevron Phillips	Cedar Bayou, Texas	Ethylene, propylene, polyethylene, normal alpha olefins, polyalphaolefin
Chevron Phillips	Sweeney, Texas	Ethylene, propylene, polyethylene
CITGO	Corpus Christi, Texas	Refinery
Covestro	Baytown, Texas	Methyl di-p phenylene, isocyanate, toluene di-isocyanate, polycarbonate, aniline, chlorine
Covestro	Channelview, Texas	Methyl di-p phenylene, isocyanate, toluene di-isocyanate, polycarbonate, aniline, chlorine
Dow	Seadrift, Texas	Butyl acetate, ethanolamines, ethylene glycols, ethylene oxide, glycol ethers, polyethylene, surfactants
Eastman	Texas City, Texas	Dioctyl terephthalate
Enterprise Products	Corpus Christi, Texas	NGLs
Enterprise Products	Mont Belvieu, Texas	Propylene, NGLs
ExxonMobil	Baytown, Texas	Refinery, ethylene, propylene, aromatics, PP, etc.
ExxonMobil	Beaumont, Texas	Refinery, ethylene, propylene, polyethylene, etc.
Flint Hills Resources	Corpus Christi, Texas	Refinery
Formosa Plastics	Point Comfort, Texas	Ethylene, propylene, polyethylene, PP, chlorine, caustic soda, polyvinyl chloride
Hexion	Deer Park, Texas	Epoxy resins, bisphenol A
Huntsman	Chocolate Bayou, Texas	Surfactant intermediates, solvents, lubricating oils, head transfer fluids
Huntsman	Freeport, Texas	Lubricant-oil and gasoline additives, asphalt additives, bleach activators, epoxy hardeners, fabric softeners, fungicides, surfactants, chelants, wet strength resins, oilfield chemicals, etc.
Huntsman	Conroe, Texas	Intermediate chemicals for cosmetics, epoxies, etc.
Huntsman	Dayton, Texas	Products packaging and printing, fuel, lubrication, surfactants, oilfield products
Huntsman	Houston, Texas	(not clear)
Huntsman	Port Neches, Texas	Ethylene, propylene, ethylene glycol, ethylene oxide, propylene glycol, propylene oxide, methyl tertiary butyl ether, surfactants, etc.

Company	Location	Product
Indorama	Clear Lake, Texas	Ethylene oxide
INEOS	Chocolate Bayou, Texas	Ethylene, propylene, PP
INEOS	Pasadena, Texas	Cumene
INEOS	Port Lavaca, Texas	Acrylonitrile
INVISTA	La Porte, Texas	Butanediol
INVISTA	Orange, Texas	Adiponitrile, hydrogen cyanide, nylon intermediaries
INVISTA	Victoria, Texas	Adipic acid, adiponitrile, hexamethylene diamine
KMG	Houston, Texas	Lubricants
KMG	Waller, Texas	(not clear)
Lucite	Port Neches, Texas	Methyl methacrylate, methacrylic acid
LyondellBasell	Bayport, Texas	Ethylene oxide, ethylene glycol, polypropylene, propylene oxide, propylene glycol
LyondellBasell	Channelview, Texas	Ethylene, propylene, butadiene, styrene, methanol, isopropanol
LyondellBasell	Chocolate Bayou, Texas	Toluene, polyethylene
LyondellBasell	Corpus Christi, Texas	Ethylene, propylene, benzene, toluene
LyondellBasell	Houston, Texas	Refiner
LyondellBasell	Victoria, Texas	Polyethylene
LyondellBasell	La Porte, Texas	Ethylene, propylene, polyethylene, ethylene vinyl acetate, copolymers, acetic acid, vinyl acetate
Marathon	Texas City, Texas	Refinery
MarkWest Javelina	Corpus Christi, Texas	Ethylene, propylene
Monument Chemical	Bayport, Texas	Propylene glycol, dipropylene glycol
Monument Chemical	Baytown, Texas	Methyl tertiary butyl ether, aromatic solvents, isopropyl alcohol
Monument Chemical	Houston, Texas	(not clear)
Occidental Chemical	Ingleside, Texas	Ethylene, chlorine, caustic soda, vinyl chloride
Occidental Chemical	Pasadena, Texas	Polyvinyl chloride
Olin Corporation	Freeport, Texas	Caustic soda, chlorine, epichlorohydrin, bleach, feedstocks for polyvinyl chloride, ethylene dichloride, vinyl chloride monomer
Oxea	Bay City, Texas	Butyl acetate, butyraldehyde, isobutanol, n-butanol
Oxea	Bishop, Texas	Refinery
Petrobras	Pasadena, Texas	Petrobras
Phillips 66	Sweeney, Texas	Refinery
Shell	Deer Park, Texas	Refinery, ethylene, propylene, aromatics
Total	Bayport, Texas	Polyethylene
Total	La Porte, Texas	PP
Valero	Corpus Christi, Texas	Refinery
Valero	Houston, Texas	Refinery
Valero	Port Arthur, Texas	Refinery
Valero	Texas City, Texas	Refinery
Valero	Three Rivers, Texas	Refinery

Note: Two facilities were excluded from this list of facilities impacted by Hurricane Harvey as both facilities were not impacted by physical risks from climate change. Rather, both facilities were shut down due to decline in supply sourced from impacted facilities

DISCLAIMER

As an initiative of Investor Watch, Planet Tracker's reports are impersonal and do not provide individualised advice or recommendations for any specific reader or portfolio. Investor Watch is not an investment adviser and makes no recommendations regarding the advisability of investing in any particular company, investment fund or other vehicle. The information contained in this research report does not constitute an offer to sell securities or the solicitation of an offer to buy, or recommendation for investment in, any securities within any jurisdiction. The information is not intended as financial advice.

The information used to compile this report has been collected from a number of sources in the public domain and from Investor Watch licensors. While Investor Watch and its partners have obtained information believed to be reliable, none of them shall be liable for any claims or losses of any nature in connection with information contained in this document, including but not limited to, lost profits or punitive or consequential damages. This research report provides general information only. The information and opinions constitute a judgment as at the date indicated and are subject to change without notice. The information may therefore not be accurate or current. The information and opinions contained in this report have been compiled or arrived at from sources believed to be reliable and in good faith, but no representation or warranty, express or implied, is made by Investor Watch as to their accuracy, completeness or correctness and Investor Watch does also not warrant that the information is up-to-date.

References

i NexantECA's forecasts accessed 12 October 2020 via Bloomberg L.P. (2020)

ii Webster et al., Science 309, 1844-46 (2005). Changes in Tropical Cyclone Number, Duration, and Intensity in a Warming Environment.

iii UCAR Center for Science Education. Accessed 7 October 2020.

iv UCAR Center for Science Education. Accessed 7 October 2020.

v UCAR Center for Science Education. Accessed 7 October 2020.

vi National Oceanographic and Atmospheric Administration. Historical Hurricane Tracks. Accessed 25 September 2020. Including Hurricane Laura, Hurricane Marco, Hurricane Sally and Tropical Storm Beta not yet described in the Historical Hurricane Tracks data tool. Categories of storms included range from Tropical Depressions to Tropical Storms to Hurricanes. Total are 55 recorded storms 1991 to 2020.

vii The SLOSH (Sea, Lake, and Overland Surges from Hurricanes) model is a numerical model used by NWS to compute storm surge. Storm surge is defined as the abnormal rise of water generated by a storm, over and above the predicted astronomical tides. Flooding from storm surge depends on many factors, such as the track, intensity, size, and forward speed of the hurricane and the characteristics of the coastline where it comes ashore or passes nearby. For planning purposes, the NHC uses a representative sample of hypothetical storms to estimate the near worst–case scenario of flooding for each hurricane category.

SLOSH employs curvilinear polar, elliptical, and hyperbolic telescoping mesh grids to simulate the storm surge hazard. The spatial coverage for each SLOSH grid ranges from an area the size of a few counties to a few states. The resolution of individual grid cells within each basin ranges from tens to hundreds of meters to a kilometre or more. Sub-grid scale water features and topographic obstructions such as channels, rivers, and cuts and levees, barriers, and roads, respectively, are parameterized to improve the modelled water levels.

The NHC provides two products based on hypothetical hurricanes: MEOWs and MOMs. MEOWs are created by computing the maximum storm surge resulting from up to 100,000 hypothetical storms simulated through each SLOSH grid of varying forward speed, radius of maximum wind, intensity (Categories 1-5), landfall location, tide level, and storm direction. A MEOW product is created for each combination of category, forward speed, storm direction, and tide level. SLOSH products exclude Category 5 storms north of the NC/VA border. For each storm combination, parallel storms make landfall in 5 to 10 mile increments along the coast within the SLOSH grid, and the maximum storm surge footprint from each simulation is composited, retaining the maximum height of storm surge in a given basin grid cell. These are called MEOWs and no single hurricane will produce the regional flooding depicted in the MEOWs. SLOSH model MOMs are an ensemble product of maximum storm surge heights. SLOSH MOMs are created for each storm category by retaining the maximum storm surge value in each grid cell for all the MEOWs, regardless of the forward speed, storm trajectory, or landfall location. SLOSH MOMs are available for mean tide and high tide scenarios and represent the near worst–case scenario of flooding under ideal storm conditions. A high tide initial water level was used for the storm surge hazard maps.

This product uses the expertise of the NHC Storm Surge Unit to merge the operational SLOSH grids to build a seamless map of storm surge hazard scenarios using the MOM product. Each individual SLOSH grid for the Category 1-5 MOMs are merged into a single, seamless grid. The seamless grid is then resampled, interpolated, and processed with a DEM (Digital Elevation Model, i.e. topography) to compute the storm surge hazard above ground for each hurricane category. The SLOSH MOM storm surge hazard data used to create these maps are constrained by the extent of the SLOSH grids and users should be aware that risk due to storm surge flooding could extend beyond the areas depicted in these maps.

Users of this hazard map should be aware that potential storm surge flooding is not depicted within certain levee areas, such as the Hurricane & Storm Damage Risk Reduction System in Louisiana. These areas are highly complex and water levels resulting from overtopping are difficult to predict. Users are urged to consult local officials for flood risk inside these leveed areas. If applicable to the region displayed by the map, these leveed areas will be depicted with a black and white diagonal hatch pattern. Not all levee areas are included in this analysis – in particular, local features such as construction walls, levees, berms, pumping systems, or other mitigation systems found at the local level may not be included in this analysis. Additionally, some marshy or low-lying areas are not mapped in this analysis.

viii Planet Tracker and U.S. National Oceanographic and Atmospheric Administration (NOAA). Accessed 30 September 2020.

ix Meteorologists use the Saffir Simpson Hurricane Wind Scale to measure a hurricane's strength. The system divides storms into five categories:
- Category 1: Winds 74 to 95 mph (Minor damage)
- Category 2: Winds 96 to 110 mph (Extensive damage — Can uproot trees and break windows)
- Category 3: Winds 111 to 129 mph (Devastating — Can break windows and doors)
- Category 4: Winds 130 to 156 mph (Catastrophic damage — Can tear off roofs)
- Category 5: Winds 157 mph or higher (The absolute worst and can level houses and destroy buildings) (Source: CNN).

x Map modelled using ArcGIS by ESRI, Google Maps, Google Earth Pro, Bloomberg, L.P., ICIS, NexantECA, Inc. data accessed via Bloomberg, L.P., and NOAA SLOSH layers and scenarios. Support from Joe Hagerty.

xi ICIS (21 September 2020). Supply and Demand Database. NexantECA, Inc. via Bloomberg, L.P. (2020) accessed 25 September 2020.

xii Begleiter, Griffin and Huang, Deutsche Bank (13 September 2020). Railcar & Petrochemical Update: US Chemical Shipments down 5%. Ethane up 2 c/gal to 21 c/gal. Forecasts differ depending on databases assessed with IHS Markit forecast 18% ethylene offline.

xiii Begleiter, Griffin and Huang, Deutsche Bank (13 September 2020). Railcar & Petrochemical Update: US Chemical Shipments down 5%. Ethane up 2 c/gal to 21 c/gal.

Current non storm related outages include:
• Formosa Plastics' Point Comfort, Texas cracker equal to 1.7% (1,564 kilotonnes per year)* North American ethylene capacity offline since April 2020.
• INEOS' Chocolate Bayou, Texas cracker equal to 2.5% (1,887 kilotonnes per year)* North American ethylene capacity offline since April 2020.
• BASF/Total Port Arthur, Texas cracker equal to 2.6% North American ethylene capacity offline since June.
• Indorama's Lake Charles, Louisiana cracker equal to 1.1% North American ethylene capacity offline since August.
• Dow's Orange, Texas cracker equal to 1.3% North American ethylene capacity

NexantECA, Inc. via Bloomberg, L.P. (2020) accessed 25 September 2020.

xiv Begleiter, Griffin and Huang, Deutsche Bank (13 September 2020). Railcar & Petrochemical Update: US Chemical Shipments down 5%. Ethane up 2 c/gal to 21 c/gal.

xv Begleiter, Griffin and Huang, Deutsche Bank (8 September 2020). Trends for Chems: Hurricane Laura Underpins August and September Polyethylene Price Increases.

xvi Begleiter, Griffin and Huang, Deutsche Bank (8 September 2020). Trends for Chems: Hurricane Laura Underpins August and September Polyethylene Price Increases.

xvii Bloomberg, L.P. (2020). Accessed 7 October 2020.

xviii UCAR Center for Science Education. Accessed 7 October 2020.

xix Cappucci, The Washington Post (25 September 2020). Hurricane Laura produced a 17-foot surge, Weather Service finds, validating its dire predictions: The observed surge ranks among the 10 highest on record along the Gulf Coast.

xx Begleiter, Griffin and Huang, Deutsche Bank (8 September 2020). Trends for Chems: Hurricane Laura Underpins August and September Polyethylene Price Increases.

xxi Begleiter, Griffin and Huang, Deutsche Bank (8 September 2020). Trends for Chems: Hurricane Laura Underpins August and September Polyethylene Price Increases.

xxii Chang, ICIS (27 August 2020). INSIGHT: Hurricane Laura to tighten US petrochemicals, polymers.

xxiii Moore, ICIS (1 October 2020). Plant status: LyondellBasell restarts US Lake Charles PP plant.

xxiv Sheehan and Osterland, CFA, Truist Securities (2 September 2020). Chemicals: Hurricane Laura Continues to Impact Chemical Markets.

xxv NexantECA, Inc. via Bloomberg, L.P. (2020). Accessed 25 September 2020.

xxvi Sheehan and Osterland, CFA, Truist Securities (2 September 2020). Chemicals: Hurricane Laura Continues to Impact Chemical Markets.

xxvii NexantECA, Inc. via Bloomberg, L.P. (2020). Accessed 25 September 2020.

xxviii Burkhardt, Bloomberg (2 October 2020). Sasol to Sell $2 Billion Chemicals Stake to LyondellBasell: Disposal of part of Lake Charles project will pay down debt and Sasol will form chemicals joint venture with LyondellBasell.

xxix Sheehan and Osterland, CFA, Truist Securities (2 September 2020). Chemicals: Hurricane Laura Continues to Impact Chemical Markets.

xxx NexantECA, Inc. via Bloomberg, L.P. (2020). Accessed 25 September 2020.

xxxi NexantECA's forecasts accessed 12 October 2020 via Bloomberg L.P. (2020)

xxxii United Nations Industrial Development Organisation (April 2019). Addressing the challenge of Marine Plastic Litter using Circular Economy methods: Relevant considerations.

xxxiii Ownership data from Bloomberg, L.P. and BvD Orbis. Capacity data from NexantECA, Inc. via Bloomberg, L.P. (2020). Accessed 25 September 2020.

xxxiv Securities and Exchange Commission (2010). 17 CFR PARTS 211, 231 and 241 [Release Nos. 33-9106; 34-61469; FR-82] Commission Guidance Regarding Disclosure Related to Climate Change.

xxxv Goldman, Ph.D., Dahl, Ph.D., and Carlson, Center for Science and Democracy at the Union of Concerned Scientists (2015). Stormy Seas, Rising Risks: What Investors Should Know About Climate Change Impacts at Oil Refineries.

xxxvi Goldman, PhD., Dahl, PhD., and Carlson, Center for Science and Democracy at the Union of Concerned Scientists (2015). Stormy Seas, Rising Risks: What Investors Should Know About Climate Change Impacts at Oil Refineries.

xxxvii ICIS (21 September 2020). Supply and Demand Database. NexantECA, Inc. via Bloomberg, L.P. (2020) accessed 25 September 2020.

xxxviii Begleiter, Griffin and Huang, Deutsche Bank (13 September 2020). Railcar & Petrochemical Update: US Chemical Shipments down 5%. Ethane up 2 c/gal to 21 c/gal. Forecasts differ depending on databases assessed with IHS Markit forecast 18% ethylene offline.

xxxix Begleiter, Griffin and Huang, Deutsche Bank (13 September 2020). Railcar & Petrochemical Update: US Chemical Shipments down 5%. Ethane up 2 c/gal to 21 c/gal.

Current non storm related outages include:
- Formosa Plastics' Point Comfort, Texas cracker equal to 1.7% (1,564 kilotonnes per year)* North American ethylene capacity offline since April 2020.
- INEOS' Chocolate Bayou, Texas cracker equal to 2.5% (1,887 kilotonnes per year)* North American ethylene capacity offline since April 2020.
- BASF/Total Port Arthur, Texas cracker equal to 2.6% North American ethylene capacity offline since June.
- Indorama's Lake Charles, Louisiana cracker equal to 1.1% North American ethylene capacity offline since August.
- Dow's Orange, Texas cracker equal to 1.3% North American ethylene capacity

NexantECA, Inc. via Bloomberg, L.P. (2020) accessed 25 September 2020.

xl Kulp and Strauss. Remote Sensing of Environment, 206, 231–239 (2018). CoastalDEM: A global coastal digital elevation model improved from SRTM using a neural network. Planet Tracker and Climate Central (2020). Accessed 2 October 2020.

Description: CoastalDEM90™ is a 3 arcsecond (~90 meter) horizontal resolution digital elevation model based on SRTM 3.0, a near-global dataset derived from satellite radar during a NASA mission in 2000. SRTM is known to contain significant error caused by factors such as topology, vegetation, buildings, and random noise. We have used machine learning techniques to estimate SRTM elevation error in coastal areas between (and including) 1-20m in nominal SRTM elevation. Each pixel in a CoastalDEM raster within the relevant elevation and spatial domains represents the corrected elevation at that point - the result of subtracting estimated error from SRTM 3.0. Pixels outside the elevation domain are set to their original SRTM value. Pixels outside the spatial domain (e.g., the specified country or continent) are set to the "no data" value (-9999).

Purpose: CoastalDEM was built to improve analysis related to coastal flood exposure due to sea level rise and storm surge.

Vertical Accuracy: Error rates in corrected areas of the United States and Australia, computed with high-accuracy lidar data, are listed in the table below. Similar improvements outside of these countries are generally expected, but not guaranteed. When compared to global elevations presented in NASA's ICESat product, median global bias in corrected areas drops from 1.93m to -0.24m, though these numbers are sensitive to noise, outliers, and gaps in coverage in ICESat, and so comparisons to lidar-derived elevations are much more reliable.

xli Kennedy, National Oceanographic and Atmospheric Administration (5 April 2013). Underwater: Land loss in coastal Louisiana since 1932.

xlii Masters, Ph.D., Weather Underground (10 May 2019). America's Achilles' Heel: the Mississippi River's Old River Control Structure.

xliii Masters, Ph.D., Weather Underground (10 May 2019). America's Achilles' Heel: the Mississippi River's Old River Control Structure.

xliv Masters, Ph.D., Weather Underground (13 May 2019). Escalating Floods Putting Mississippi River's Old River Control Structure at Risk.

xlv Tides and Currents, National Oceanographic and Atmospheric Administration (2020).

The Center for Operational Oceanographic Products and Services has been measuring sea level for over 150 years, with tide stations of the National Water Level Observation Network operating on all U.S. coasts. Changes in RSL, either a rise or fall, have been computed at 142 long-term water level stations using a minimum span of 30 years of observations at each location. These measurements have been averaged by month which removes the effect of higher frequency phenomena in order to compute an accurate linear sea level trend. The trend analysis has also been extended to 240 global tide stations using data from the Permanent Service for Mean Sea Level (PSMSL). This work is funded in partnership with the NOAA OAR Climate Observation Division.

The sea level trends measured by tide gauges that are presented here are local relative sea level (RSL) trends as opposed to the global sea level trend. Tide gauge measurements are made with respect to a local fixed reference on land. RSL is a combination of the sea level rise and the local vertical land motion. The global sea level trend has been recorded by satellite altimeters since 1992 and the latest global trend can be obtained from NOAA's Laboratory for Satellite Altimetry, with maps of the regional variation in the trend. The University of Colorado's Sea Level Research Group compares global sea level rates calculated by different research organizations and discusses some of the issues involved.

xlvi Tides and Currents, National Oceanographic and Atmospheric Administration (2020).

xlvii Tides and Currents, National Oceanographic and Atmospheric Administration (2020).

xlviii Tides and Currents, National Oceanographic and Atmospheric Administration (2020). Galveston Pier 21 2904 to 20219.

xlix This dataset was created as part of the National Oceanic and Atmospheric Administration Office for Coastal Management's efforts to create an online mapping viewer depicting potential sea level rise and its associated impacts on the nation's coastal areas. The purpose of the mapping viewer is to provide coastal managers and scientists with a preliminary look at sea level rise and coastal flooding impacts. The viewer is a screening-level tool that uses nationally consistent data sets and analyses. Data and maps provided can be used at several scales to help gauge trends and prioritize actions for different scenarios. The purpose of this dataset is to show potential sea level rise inundation of 5 ft above current Mean Higher High Water (MHHW) for the area.

For more information visit the Sea Level Rise Impacts Viewer (https://coast.noaa.gov/slr).

For metadata and source map service, see https://coast.noaa.gov/arcgis/rest/services/dc_slr/slr_5ft/MapServer.

For additional information or questions, contact the NOAA Office for Coastal Management (coastal.info@noaa.gov).

l Planet Tracker and Climate Central (30 September 2020).

Models inputs employed are:
- Elevation Data Used: CoastalDEM® v1.1
- Projection Type: sea level rise + moderate flood
- Year: 2050
- Pollution Scenario: Moderate cuts which are Annual global climate pollution peaks near 2040 and then declines to half of current levels. Consistent with about 2 ° Celsius (about 3.5 ° Fahrenheit) of warming, the main target from the Paris Agreement. Implies 1,266 gigatons of total carbon pollution by 2100. Technical term: RCP 4.5.
- Luck: Good luck means that heat-trapping pollution and global warming turn out to have weaker effects on sea levels than scientists generally expect. Bad luck is the opposite.
- Areas to show as threatened: Excluded potentially protected areas.
- Sea-level-projection source: Pessimistic model under Kopp et al. 2017.

li Map modelled using ArcGIS by ESRI, Google Maps, Google Earth Pro, Bloomberg, L.P., ICIS, NexantECA, Inc. data accessed via Bloomberg, L.P., and NOAA SLOSH layers and scenarios. Support from Joe Hagerty.

lii This dataset was created as part of the National Oceanic and Atmospheric Administration Office for Coastal Management's efforts to create an online mapping viewer depicting potential sea level rise and its associated impacts on the nation's coastal areas.

liii The SLOSH (Sea, Lake, and Overland Surges from Hurricanes) model is a numerical model used by NWS to compute storm surge.

liv This dataset was created as part of the National Oceanic and Atmospheric Administration Office for Coastal Management's efforts to create an online mapping viewer depicting potential sea level rise and its associated impacts on the nation's coastal areas.

lv Planet Tracker and Climate Central (30 September 2020).

Models inputs employed are:
- Elevation Data Used: CoastalDEM® v1.1
- Projection Type: sea level rise + moderate flood
- Year: 2050
- Pollution Scenario: Moderate cuts which are Annual global climate pollution peaks near 2040 and then declines to half of current levels. Consistent with about 2 ° Celsius (about 3.5 ° Fahrenheit) of warming, the main target from the Paris Agreement. Implies 1,266 gigatons of total carbon pollution by 2100. Technical term: RCP 4.5.
- Luck: Good luck means that heat-trapping pollution and global warming turn out to have weaker effects on sea levels than scientists generally expect. Bad luck is the opposite.
- Areas to show as threatened: Excluded potentially protected areas.
- Sea-level-projection source: Pessimistic model under Kopp et al. 2017.

lvi Map modelled using ArcGIS by ESRI, Google Maps, Google Earth Pro, Bloomberg, L.P., ICIS, NexantECA, Inc. data accessed via Bloomberg, L.P., and NOAA SLOSH layers and scenarios. Support from Joe Hagerty.

lvii National Hurricane Center. Introduction to storm surge.

lviii Masters, Weather Underground (16 November 2018). Hurricane Michael Brought Water Levels Over 20' High to the Coast.

lix PRWeb (14 October 2017). Hurricane Harvey Wreaks Havoc On Plastic Production Throughout The South.

lx Greenwood, ICIS (27 August 2018). INTERACTIVE: US Gulf petchem boom made Harvey the first global hurricane.

lxi Boghici, National Hurricane Center, National Oceanographic and Atmospheric Administration. NOAA NHC - Harvey 2017 Storm Track.

lxii Sundria and Chakraborty, Bloomberg (26 August 2020). Global Oil Refining Faces Shake-Up From Asian Plastics Boom.

lxiii Polymer Update and Bloomberg, L.P. (2020). Accessed 10 October 2020. Prices based real-time on assessment of 15 to 20 prominent industry players. Spots are quotes for immediate deliveries (usually within a month from the date of publication). Spot quotes are usually for single shipments.

Spot prices are usually a reflectionof current discussions of bids and offers. Prices calculated weekly as USD per metric tonne. Prices are Houston HDPE Injection grade polyethylene Polymers FAS Price USD/MT Weekly, Houston LDPE Polymers FAS Price USD/MT Weekly, Houston LLDPE Polymers FAS Price USD/MT Weekly and Houston PP

lxiv Polymer Update and Bloomberg, L.P. (2020). Accessed 10 October 2020.

lxv Polymer Update and Bloomberg, L.P. (2020). Accessed 10 October 2020..

lxvi Mosendz, Bloomberg (22 June 2020). Formosa Plastics Group's $10 Billion Bet on a Single-Use Future: A world leader in virgin resins comes to Louisiana's Cancer Alley with an unlimited vision for its products.

lxvii Younes, ProPublica (5 November 2020). Polluter's Paradise: Permit for Controversial $9 Billion Plastics Plant in "Chemical Alley" to Be Put on Hold - Proposed emissions from the plant would triple the levels of cancer-causing chemicals in one of the most toxic areas of the U.S., but the Army Corps of Engineers intends to suspend the permit.

lxviii Richardson, ICIS (29 June 2020). China could be in complete polypropylene self-sufficiency by 2022.

lxix Richardson, ICIS (29 June 2020). China could be in complete polypropylene self-sufficiency by 2022.

lxx Mathonniere, ICIS (1 March 2019). Corrected: INSIGHT: Crude oil to chemicals (COTC), a refiner's new mantra.

lxxi Bloomberg, L.P. (2020).

lxxii Chan, Bloomberg (20 August 2020). Crude Oil-to-Chemicals Primer: Ultimate Integration.

There are multiple routes where COTC technology enable efficiencies depending on various feedstocks to yield cost reductions in plastics production. Because of the scale of these investments, currently these projects governmental investment support and leadership. These are:

- Crude oil to refinery to naphtha to steam cracker to petrochemicals
- Light crude to steam cracker to petrochemicals
- Light crude to COTC to petrochemicals
- Different crudes to COPX complex to paraxylene to petrochemicals.

lxxiii Davis, ICIS (2 December 2019). INSIGHT: India's Reliance places high hopes on Jamnagar's crude-to-chemicals projects.

lxxiv Mostyn, Hydrocarbon Engineering (29 March 2019). Big oil to boost petrochemicals footprint.

lxxv ICIS (May 2019). Crude Oil-to-Chemicals (COTC): A look inside our technology & economic analyses from the 2019 – 2014 Process and Economics Program.

lxxvi Chan, Bloomberg (20 August 2020). Crude Oil-to-Chemicals Primer: Ultimate Integration.

lxxvii Davis, ICIS (2 December 2019). INSIGHT: India's Reliance places high hopes on Jamnagar's crude-to-chemicals projects.

lxxviii Mostyn, Hydrocarbon Engineering (29 March 2019). Big oil to boost petrochemicals footprint.

lxxix Chan, Bloomberg (22 September 2020). Plan's Policy Changes Have Big Implications.

lxxx Chan, Bloomberg (22 September 2020). Reduced Import Reliance Hurts Overseas Manufacturers. Policy published by the China National Petroleum & Chemical Planning Institute (NPCIC).

lxxxi Orbis (2020). Data accessed 26 October 2020.

lxxxii Chan, CFA, Bloomberg Intelligence (Insert). Insert.

lxxxiii Chan, CFA, Bloomberg Intelligence (9 March 2020). Crude Oil-to-Chemicals a Revolution of Petrochemicals.

lxxxiv Begleiter, Griffin and Huang, Deutsche Bank (8 September 2020). Trends for Chems: Hurricane Laura Underpins August and September Polyethylene Price Increases. ICIS. IHS Markit. Corporate presentations. Nicholson, Argus (14 November 2019). Global Cracker Additions – Impact of new capacities and changing feedstocks.

lxxxv Luck, Houston Chronicle (16 August 2019). Exxon-SABIC select long-term ethane, ethylene transportation provider.

lxxxvi Mosendz, Bloomberg (22 June 2020). Formosa Plastics Group's $10 Billion Bet on a Single-Use Future: A world leader in virgin resins comes to Louisiana's Cancer Alley with an unlimited vision for its products.

lxxxvii Wack, WSJ (July 9 2019). DJ Chevron Phillips Chem, Qatar Petroleum to Develop Petrochemical plant on U.S. Gulf Coast.

lxxxviii Formosa Energy. Formosa Plastics Expansion in Texas, USA.

lxxxix Moore, ICIS (20 December 2019). Formosa Plastics delays start up of US cracker, LDPE unit.

xc S&P Global Platts (24 September 2020). Braskem aims to hit nameplate capacity at new US polypropylene plant by end-2020: CEO.

xci NexantECA's forecasts accessed 12 October 2020 via Bloomberg L.P. (2020)

xcii NexantECA's forecasts accessed 12 October 2020 via Bloomberg L.P. (2020)

xciii NexantECA's forecasts accessed 12 October 2020 via Bloomberg L.P. (2020)

xciv NexantECA's forecasts accessed 12 October 2020 via Bloomberg L.P. (2020)

xcv NexantECA's forecasts accessed 12 October 2020 via Bloomberg L.P. (2020)

xcvi NexantECA's forecasts accessed 12 October 2020 via Bloomberg L.P. (2020)

xcvii NexantECA's forecasts accessed 12 October 2020 via Bloomberg L.P. (2020)

xcviii NexantECA's forecasts accessed 12 October 2020 via Bloomberg L.P. (2020)

xcix Pooler, Financial Times (7 June 2020). Plastic demand to tumble despite its importance in Covid-19 battle: LyondellBasell Industries predicts 15% fall amid weak car and home appliance sales.

c Sims, ICIS (30 September 2020). Balance of strong demand and sufficient supply expected in US ethylene market.

ci Chang, ICIS (3 September 2020). Three-quarters of US chemicals companies slash capex amid pandemic – ACC survey.

cii Chang, ICIS (3 September 2020). Three-quarters of US chemicals companies slash capex amid pandemic – ACC survey.

ciii Chang, ICIS (3 September 2020). Three-quarters of US chemicals companies slash capex amid pandemic – ACC survey.

civ Chang, ICIS (3 September 2020). Three-quarters of US chemicals companies slash capex amid pandemic – ACC survey.

cv Yetter, Bloomberg Law (24 July 2020). Formosa Plastics Halts Some Work on $9.4 Billion Louisiana Plant: Some preconstruction projects will continue and construction zone site of graves of enslaved people.

cvi Chang, ICIS (19 October 2020). Formosa defers major construction on US Sunshine petrochemicals project.

cvii Burkhardt, Bloomberg (2 October 2020). Sasol to Sell $2 Billion Chemicals Stake to LyondellBasell: Disposal of part of Lake Charles project will pay down debt and Sasol will form chemicals joint venture with LyondellBasell.

cviii Moody's (5 October 2020). Moody's downgrades LyondellBasell's ratings to Baa2, outlook stable, after Sasol joint venture announcement.

cix Bourke, Bloomberg Intelligence (9 October 2020). Lyondell Amends Covenant, Points to Leverage Peaking in 1Q21.

cx Moody's (14 October 2020). Moody's assigns Baa2 ratings to LyondellBasell's new notes.

cxi Sasol (2 October 2020). Sasol Limited: Divestment of a 50% Interest in Sasol's LCCP Base Chemicals Business and the Creation of a JV with LyondellBasell.

cxii Chang, ICIS (5 October 2020). INSIGHT: LyondellBasell set to reap immediate gains from Sasol JV in 'buy vs build' strategy.

cxiii Chang, ICIS (5 October 2020). INSIGHT: LyondellBasell set to reap immediate gains from Sasol JV in 'buy vs build' strategy.

cxiv NexantECA, Inc. via Bloomberg, L.P. (2020). Accessed 25 September 2020.

cxv Greenwood, ICIS (27 August 2018). INTERACTIVE: US Gulf petchem boom made Harvey the first global hurricane.

FUNDERS


MINDEROO
FOUNDATION


Flotilla
FOUNDATION


PLASTIC
SOLUTIONS
FUND