Stormy Seas, Rising Risks

What Investors Should Know About Climate Change Impacts at Oil Refineries
www.ucsusa.org/risingrisks

Appendix A: Extended Methodology

Center for Science and Democracy at the Union of Concerned Scientists

This appendix describes the methods used in the Union of Concerned Scientists' report entitled, *Stormy Seas, Rising Risks: What Investors Should Know about Climate Impacts at Refineries*. The full report and bibliography can be found at *ucsusa.org/risingrisks*.

This report focused on the top five U.S. energy companies with respect to their total crude-refining capacity: Valero, Phillips 66, Exxon Mobil, Marathon Petroleum, and Chevron (Brelsford, True, and Koottungal 2013). One coastal refining facility for each of the five companies was chosen for analysis based on perceived risk, which was determined by vulnerability of location and historical storm damage. (See Table A1 and Figure A1.)

Methods used in this report draw from the best practices established by the NOAA Coastal Services Center and laid out in the "Mapping Coastal Inundation Primer" (NOAA 2012).

1. Data Sources

The capacity information and location for each petroleum refinery was reported using U.S. Energy Information Administration (EIA) data as of January 1, 2014 (EIA 2014d). Capacity was listed in barrels per calendar day (b/cd), a measure of the amount of input that a distillation unit can process in a 24-hour period under usual operating conditions; this measure takes into account both planned and unplanned maintenance (EIA 2014e).

Refinery property lines were determined using county-level parcel-ownership data, when available. Union County, New Jersey; Harrison County, Texas; and Galveston County, Texas parcel-ownership data was taken from data made available online by each respective county. Mississippi parcel-ownership data was taken from data made available by the state of Mississippi. Publicly available parcel-ownership data could not be found online for St. Bernard Parish, Louisiana. An approximate boundary was drawn for the Meraux, Louisiana facility using Google Earth imagery around the approximate border. Building and road GIS shapefiles were taken from the publicly available OpenStreetMap source. Waterways were identified with the National Hydrography Dataset and the US Census Tiger/Line Shapefiles (2013). Digital Elevation Model (DEM) data were obtained from the U.S. Geological Survey National Map. For all sites except New Jersey, data resolution used was 1/9 arc second. In New Jersey, data resolution used was 1/3 arc second. (See Table A 2).

The extent of future sea level rise was mapped for the years 2030, 2050, and 2100 using recently published, localized sea level rise projections obtained from *Kopp et. al.* (Kopp et al. 2014). (See Table A3.) The projection used for each site analysis was from the geographically closest tide gauge evaluated by *Kopp et. al.* Maps featured in this report show the median (50^{th} percentile) projection for the Representative Concentration Pathway (RCP) 4.5 scenario from the Intergovernmental Panel on Climate Change Fifth Assessment report (IPCC 2013b). The RCP 4.5 can be viewed as a moderate mitigation policy scenario that has emissions peaking around 2040 and then declining (Kopp et al. 2014; IPCC 2013b).

TABLE A1. **Facility Statistics and Company Disclosure for Refineries Analyzed**

U.S. refining rank of company by crude capacity	Global refining rank of company by crude capacity	Company	Site location	Crude capacity at facility analyzed(barrels per calendar day)	Company disclosure of physical climate risk
1	6	Valero	Meraux, Louisiana	125,000 b/cd	None
2	10	Phillips 66	Linden, New Jersey	238,000 b/cd	Poor
3	1	Exxon Mobil	Baytown, Texas	560,500 b/cd	None
4	13	Marathon Petroleum	Texas City, Texas	84,000 b/cd	None
5	9	Chevron	Pascagoula, Mississippi	330,000 b/cd	None

GLOBAL RANKINGS AND CRUDE CAPACITIES WERE BASED ON 2013 SEC FILINGS (BRELSFORD, TRUE, AND KOOTTUNGAL 2013) AND COMPANY DISCLOSURE ASSESSMENTS WERE CHARACTERIZED USING TOOLS DEVELOPED BY CERES (2012).

FIGURE A1. **Map of U.S. Coastal Refineries of the Five Companies Analyzed**

The five companies analyzed have refineries along the Gulf, East, and West Coasts, as well as in Hawaii. Some of these facilities face risks, now and in the future, from sea level rise and storm surge. The oil and gas infrastructure in the Gulf of Mexico is especially vulnerable because of rising seas, sinking land, and frequent tropical storm systems.

TABLE A2. **Data Sources**

Component	Source	URL
SLR numbers	Kopp et al. 2014	*http://onlinelibrary.wiley.com/doi/10.1002/2014EF000239/abstract*
Elevation data	USGS National Elevation Dataset	*http://ned.usgs.gov/*
New Jersey Parcels	Union County, NJ	*http://ucnj.org/community/maps/*
Texas (Harrison County) Parcels	Harrison County, TX	*http://pdata.hcad.org/GIS/index.html*
Texas (Galveston County Parcels)	Galveston County, TX	*http://www.galvestoncad.org/PA/Shapeidx/shapes.htm*
Mississippi Parcels	State of MS	*http://www.gis.ms.gov/Portal/download.aspx?dom=&x=1600&y=1200&browser=Netscape*
LA Parcels	Boundary drawn using Google Earth around facility	*N/A*
Buildings	OpenStreetMap	*https://www.openstreetmap.org/*
Roads	OpenStreetMap	*https://www.openstreetmap.org/*
Waterways	National Hydrography Dataset	*http://nhd.usgs.gov/*
Waterways	US Census Tiger/Line Shapefiles (2013)	*https://www.census.gov/geo/maps-data/data/tiger-line.html*

TABLE A3. **Sea Level Rise Projections Used**

Site(s)	Nearest SLR projection from Kopp et al. 2014	SLR (ft) 2030-RCP 4.5	SLR (ft) 2050-RCP 4.5	SLR (ft) 2100-RCP 4.5
Linden, NJ	Bergen Point, NJ	0.7	1.2	2.5
Galveston area, TX	Galveston, TX	1.0	1.6	3.4
Meraux, LA	Grand Isle, LA	1.2	2.1	4.3
Pascagoula, MS	Dauphin Island, AL	0.6	1.1	2.4

LOCALIZED SEA LEVEL RISE PROJECTIONS OBTAINED FROM *KOPP ET. AL.* (KOPP ET AL. 2014).

2. Sea level rise and storm surge models

Inundation from storm surge was calculated using the National Weather Service Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model's maximum of maximums (MOMs) at Gulf and East Coast sites. MOM data for each relevant SLOSH basin used was relative to the vertical datum NAVD88.

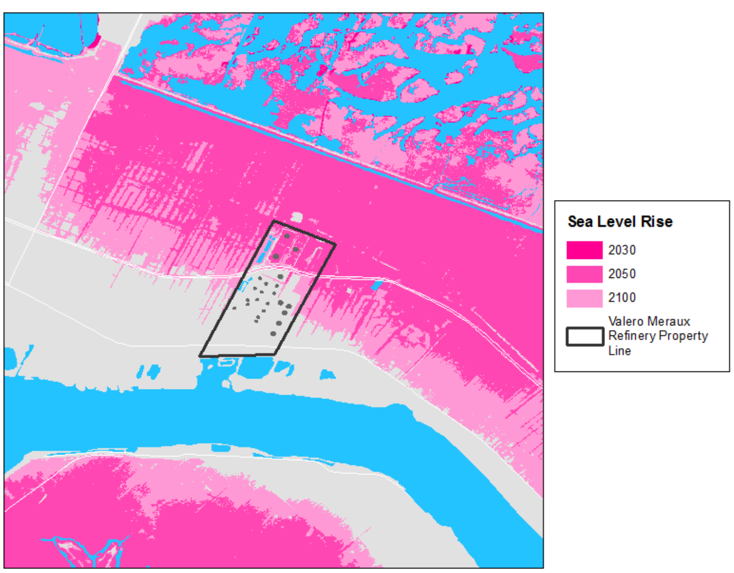
Using ArcGIS, polygon centroids were created for all cells within each SLOSH basin. Interpolation between centroids was done with a resolution that matched that of the DEM used in each basin. The DEM was subtracted from the modeled storm surge height for all locations where the surge height exceeded the elevation of the site. The hydrologic connectivity of the flooded area was assessed to determine actual flooded area. Flooded areas were converted to polygons for vector graphics.

In the report body, maps are shown for each facility of a) an aerial image of; b) extent of storm surge flooding at present day from Category 1–5 hurricanes; c) storm surge at present day and with sea level rise by 2030, 2050, and 2100 at RCP 4.5 for a hurricane category that already affects each facility; and d) present day storm surge flooding depth from a Category 3 hurricane.

Areal images of each refinery were produced using screen shots of Google Earth Pro with the publicly available refinery boundaries displayed as kml files. Extent of storm surge flooding was projected for Category 1-5 hurricanes or up to the maximum category that completely inundated the facility and depth of flooding from a Category 3 hurricane at present day levels were produced with SLOSH MOM models. Only hurricane Categories 1-4 were modeled in New Jersey as Category 5 storms are very rare in that part of the coast and the SLOSH model does not include Category 5 storms for that basin. For projections of the effect of sea level rise on storm surge extent of a hurricane at each site, projected sea level rise values were added to the flood layers created by the SLOSH model at each site for the relevant hurricane category. Except in Louisiana, hurricane categories were selected for each site based on present day surge modeling shown to already affect each facility. In Louisiana, the site appeared to be unaffected by a Category 2 hurricane at present-day sea levels and completely inundated by a Category 3 hurricane at present-day sea levels; therefore, a Category 2 hurricane was selected to examine how sea level rise is estimated to flood the facility.

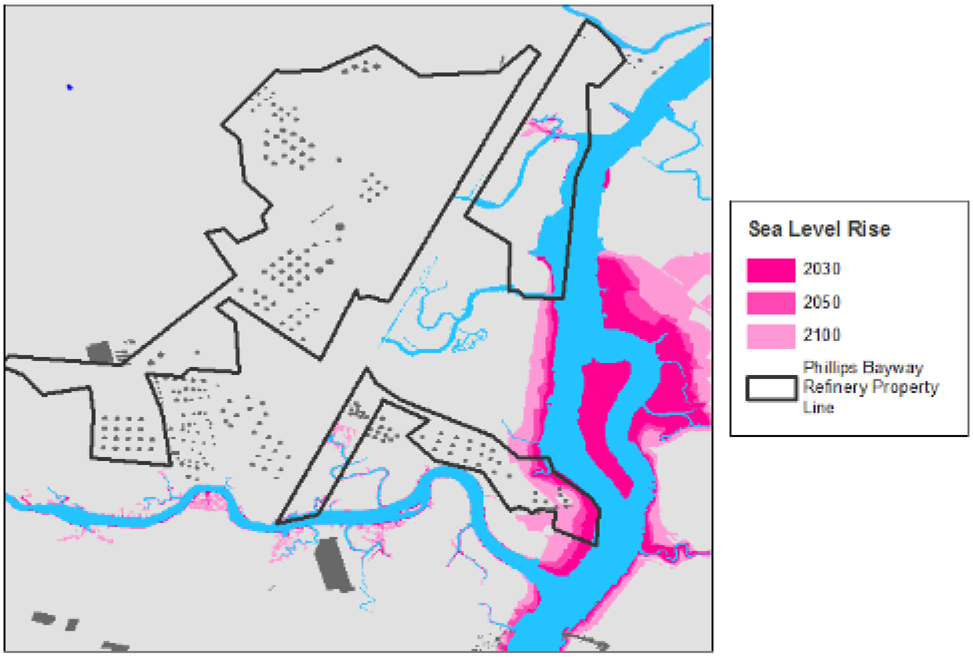
Maps of sea level rise projections alone in 2030, 2050, and 2100 at RCP4.5 were also produced, but not included in the body of the report. (See Figures A2-A6).

FIGURE A2. **Valero's Meraux, LA Refinery**



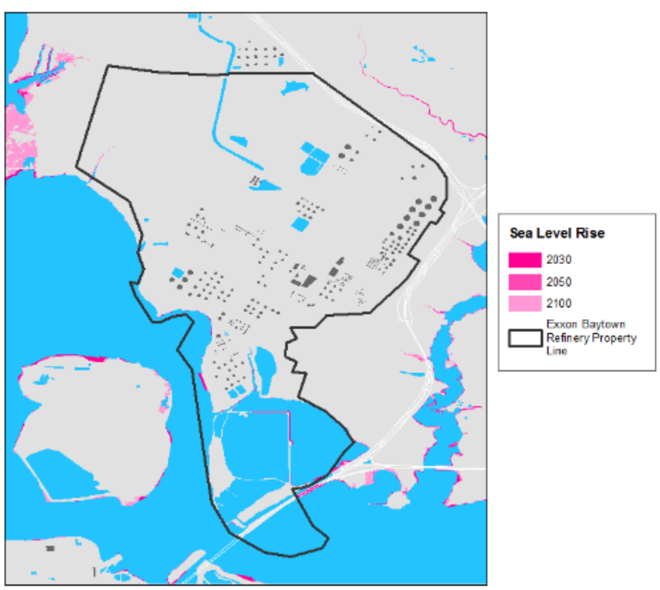
Projections for sea level rise above today's levels for 2030, 2050, and 2100.

FIGURE A3. **Phillips 66's Linden, NJ Bayway Refinery**



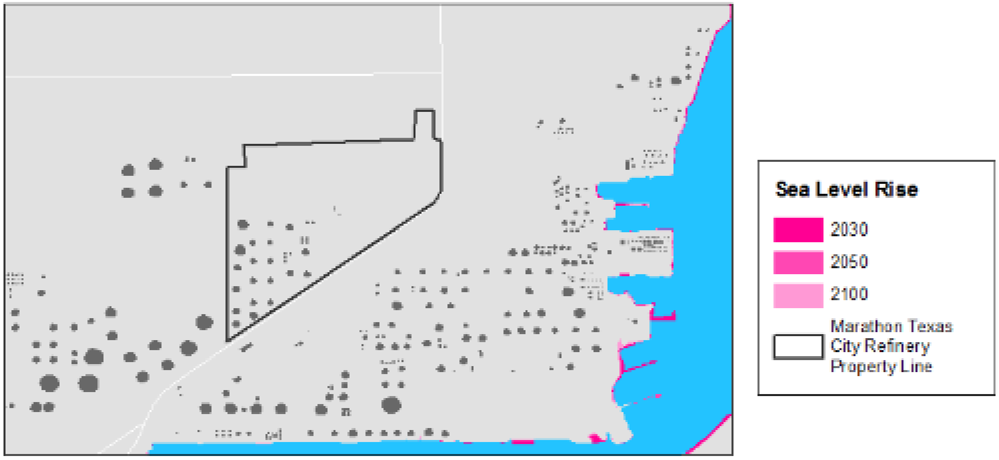
Projections for sea level rise above today's levels for 2030, 2050, and 2100.

FIGURE A4: **ExxonMobil's Baytown, TX Refinery**



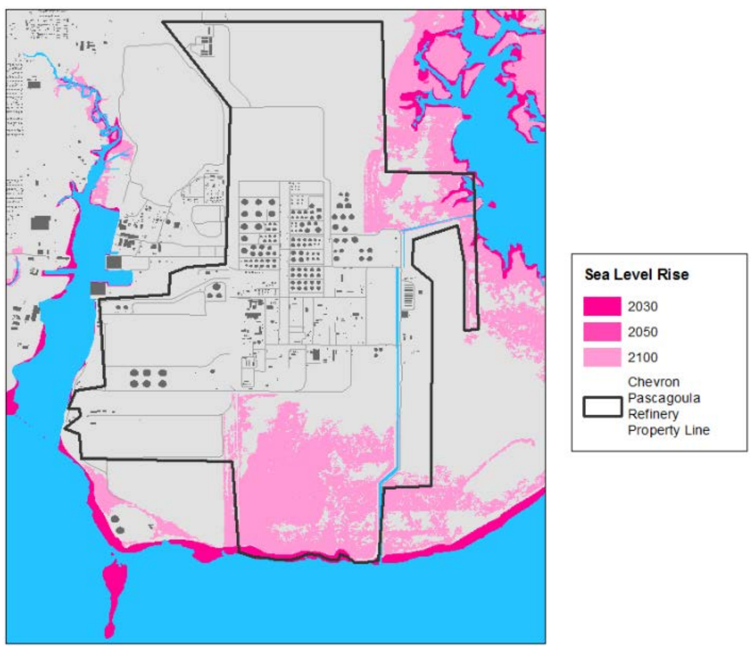
Projections for sea level rise above today's levels for 2030, 2050, and 2100.

FIGURE A5: **Marathon Petroleum's TX City, Texas Refinery**



Projections for sea level rise above today's levels for 2030, 2050, and 2100.

FIGURE A6: **Chevron's Pascagoula, MS Refinery**



Projections for sea level rise above today's levels for 2030, 2050, and 2100.

3. Disclosure information

The extent to which each company disclosed—i.e., how thoroughly it considered the physical impacts of climate change itself—was assessed using (a) the SEC's EDGAR database; (b) targeted keyword searches in the Ceres/CookESG SEC Climate Disclosure Search Tool; and (c) 2013 SEC Form 10-K filings, which note all of the companies' disclosed material risks (for the most recent year for which data were available) (Ceres 2014; SEC 2014). Specifically, each company was assigned a disclosure score for its reporting on physical risk to the SEC (in its 2013 Form 10-K filings), based on methodology established in the Ceres 2012 report referenced below. Ceres defines good disclosure of physical risks from climate change this way:

> *"Provides a detailed analysis of the physical climate risks the company faces (including in its supply chain), the operational segments and/or specific company facilities that might be impacted, the magnitude and timeframes of the anticipated impacts (quantified, when feasible), and how the company plans to respond. Includes an assessment of whether these physical risks 'will have, or are reasonably likely to have, a material impact on the company's liquidity, capital resources, or results of operations' (SEC 2003) and the basis for the company's conclusions. Discusses past physical impacts, if material"* (Ceres 2012).

Note that the 2012 Ceres report and this report focus on disclosure, rather than assessing how well companies are actually managing and preparing for these risks.

4. Limitations

Storm surge maps produced from SLOSH MOMs show worst-case-scenario flooding given all possible storm paths for a hurricane of a particular strength. It is unlikely that any singular storm could produce all of the flooding shown in these storm surge inundation maps for a particular category; rather, the maps demonstrate maximum risk for damage from storm surge at refineries, now and in the future, from Category 1–5 hurricanes.

Additionally, modeling done in this study was localized to the area immediately surrounding each refinery. Full basin level analysis that accounts for additional geographical or benthic features in the broader region that might affect results was not conducted.

Only publicly available data was used in this study. Property boundaries and structural outlines should therefore be viewed as approximate locations. There is a possibility that additional structures or other protections at facilities not publicly reported or available in public data could affect the outcome of the flood extent and depth modeled. In addition, storm surge mitigation features at or around refinery properties, such as constructed wetlands and levees, were not specifically included in modeling. Though levees were not specifically modeled, levee height and placement is captured to some extent in the DEMs. Clearly defined levees, such as those in the vicinity of the Meraux refinery in Louisiana, were taken into account as best as possible when assessing hydrologic connectivity. Such features may, however, attenuate the storm surge extent and depth modeled in this analysis, and local experts may have additional insights into the ability of coastal defenses to limit storm surge flooding.

Due to the lack of publicly available information on refineries' level of preparedness for storm impacts, it is unknown the degree to which storm surge like that modeled in this analysis would cause material damage to facilities; however, given historical examples of physical damage to refineries from tropical systems and the extent of storm surge modeled here, it can be estimated that current and future storm surge, potentially enhanced by sea level rise, at the five locations modeled may pose significant risks to refining operations.