Climate Change and Energy Infrastructure Exposure to Storm Surge and Sea-Level Rise

James Bradbury†, Melissa Allen‡, and Rebecca Dell†

†Office of Energy Policy and Systems Analysis, U.S. Department of Energy

‡Oak Ridge National Laboratory

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Overview

This study provides an initial assessment of the effects of the interaction of sea-level rise (SLR) and storm surge on the exposure of energy infrastructure to coastal flooding. We find that climate change is likely to substantially increase the vulnerability of many energy facilities in the coming decades. As recent hurricane events have demonstrated, this study found that an extensive amount of U.S. energy infrastructure is currently exposed to damage from hurricane storm surge. Furthermore, between 1992 and 2060, the number of energy facilities exposed to storm surge from a weak (Category 1) hurricane could increase by 15 to 67 percent under a high sea-level rise scenario from the recent National Climate Assessment. The total number of facilities that are exposed to storm surge from Category 3 storms is much greater; however, the percent increase in facility exposure due to SLR under a Category 3 storm is lower than for a Category 1 storm. Any significant increase in the frequency of intense hurricanes in a warmer climate would further exacerbate exposure to storm surge and wind damage.

1.0 Introduction

Hurricanes Sandy, Irene and Katrina caused billions of dollars in economic losses and put a national spotlight on the vulnerabilities of coastal communities and infrastructure. Energy infrastructure like refineries, transport terminals, transmission hubs, pipelines, and storage facilities are all exposed to flooding from storm surges today, and sea-level rise (SLR) will exacerbate current vulnerabilities.

Over the past few decades the global oceans have been warming[i] and globally-averaged sea level has been rising – potentially at a rate faster than previously anticipated[ii] – more intense precipitation events and higher sea surface temperatures.[iii] Projections of future climate change anticipate a continuation of these trends, including an increase in coastal inundation and erosion[iv] and more frequent hurricanes on the high end of the Saffir-Simpson Hurricane Scale.[1] The Atlantic basin has seen a trend toward more intense and more frequent hurricanes in recent decades, with one study estimating that past Katrina-magnitude storm surge events have occurred twice as frequently during warm years than cold years.[v] Going forward, warmer temperatures are projected to continue to result in more intense storms in the North Atlantic Basin;[vi] the National Climate Assessment projects, with "medium confidence" that hurricane-associated storm intensity will increase in the future. Sea levels are projected to continue rising in the coming decades, which will result in more extensive flooding and inundation when tropical storms and hurricanes make landfall.[vii]

Between 1901 and 2010, the IPCC[viii] estimates that the global average sea levels rose at a rate of 6.7 inches per century; between 1993 and 2010, the estimated average rate accelerated to 12.6 inches per century. Scenarios developed for The U.S. National Climate Assessment (NCA) include a plausible range of future global SLR: from 8 inches to 6.6 feet by 2100.[ix] Rising global temperatures have contributed to observed SLR through two primary mechanisms: an expansion in ocean volume, and melting of glaciers and ice sheets. Going forward, the greatest uncertainty is related to the rate of future Antarctic and Greenland ice sheet melting (see Appendix for further discussion).

This technical report was conducted separately from a complementary recent DOE report, entitled: "*Effect of Sea Level Rise on Energy Infrastructure in Four Major Metropolitan Areas*".[x] That 2014 report was based on a pilot study that assessed energy infrastructure that would be exposed to different levels of SLR in four major Metropolitan Statistical Areas (MSAs): New York, Miami, Houston, and Los Angeles. That pilot study looked in some detail at what facilities would be inundated accounting for local sea-level effects like land subsidence by adjusting global SLR scenarios with historical local records of sea-level change. A key

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[1] The Saffir-Simpson Hurricane Wind Scale is a 1 to 5 rating based on a hurricane's sustained wind speed. For more information visit: http://www.nhc.noaa.gov/aboutsshws.php. Projections from U.S. Global Change Research Program, 2014. U.S. National Climate Assessment.

distinguishing factor between the 2014 pilot study and the analysis described in this technical report is that the pilot study did not take storm surge into account. That study also used the National Climate Assessment scenarios to address the temporal aspects of infrastructure exposure.

2.0 Methods and Scope

To better understand the compound hazards of SLR and storm surge, this study examines U.S. energy infrastructure exposure under three increments of global mean sea level rise and three hurricane storm strengths (Categories 1, 3, and 5 on the Saffir-Simpson Hurricane Scale, referred to as C-1, C-3, and C-5). The baseline sea levels for this analysis (i.e., zero SLR) correspond with average sea levels in 1992. The three increments of future sea-level rise – 10 inches of SLR in 2030, 23 inches in 2050 and 32 inches in 2060 – correspond with the high end of the recently published National Climate Assessment (NCA) SLR scenarios (Figure 1). The range of future scenarios were developed by an interagency team[2] and presented in a National Oceanographic and Atmospheric Administration (NOAA) report[xi], which explains, “Our Highest Scenario of global SLR by 2100 is derived from a combination of estimated ocean warming… and a calculation of the maximum possible glacier and ice sheet loss by the end of the century. The Highest Scenario should be considered in situations where there is little tolerance for risk (e.g. new infrastructure with a long anticipated life cycle such as a power plant).” The 2030, 2050 and 2060 time frames are valuable for assessing climate resilience of energy infrastructure investments (e.g., pipelines and power plants), many of which are expected to last for several decades.

To help inform policy considerations for the first installment of the Quadrennial Energy Review,[xii] the scope of this study is mostly limited to an assessment of exposure of energy transmission, storage and distribution infrastructure to storm surge. This technical report summarizes analytical results that focused on the potential for direct impacts to specific energy system assets, without taking into consideration the potential for indirect implications for interconnected energy systems or society more broadly.

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[2] Participants included NOAA, the Strategic Environmental Research and Development Program (a DoD program that is planned and executed in partnership with DOE and EPA), the U.S. Geological Survey and the U.S. Army Corps of Engineers.

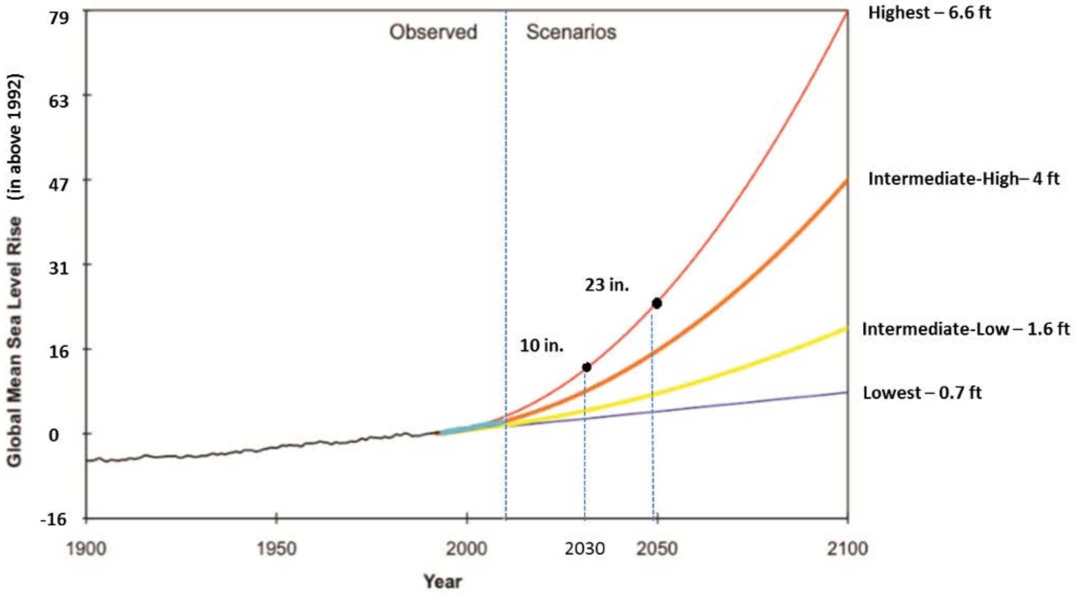

Figure 1: Global mean sea-level rise scenarios, 1900 through 2100. Note that SLR scenarios are relative to sea levels in 1992. Source: NOAA, 2012.[xiii]

The coastal inundation maps that were used for this analysis were developed for a peer-reviewed publication by Maloney and Preston (2014)[xiv]. Their study used several thousand hurricane simulations for 33 of 37 "SLOSH" model basins throughout the U.S. Eastern Seaboard and the Gulf of Mexico in order to identify coastal land areas potentially susceptible to storm surge inundation. The Sea, Lake and Overland Surges from Hurricanes (SLOSH) model, from the National Hurricane Center at NOAA, "estimates storm surge heights associated with hurricanes by simulating the effects of storm size, forward speed, track, wind speed and atmospheric pressure on water heights in the coastal zone. SLOSH basins consist of grid definition as well as various geographic features that route and impede the flow of water."

For each increment of future SLR, we used GIS mapping tool to compare the inundation maps with the locations of existing transmission, storage and distribution infrastructure facilities, from the most current HSIP Gold infrastructure database.[3] This gives a picture of exposed energy infrastructure:[4] those East Coast and Gulf Coast facilities that would be inundated by storm surge according to Maloney and Preston's application of SLOSH model simulations (e.g., Figure 2).

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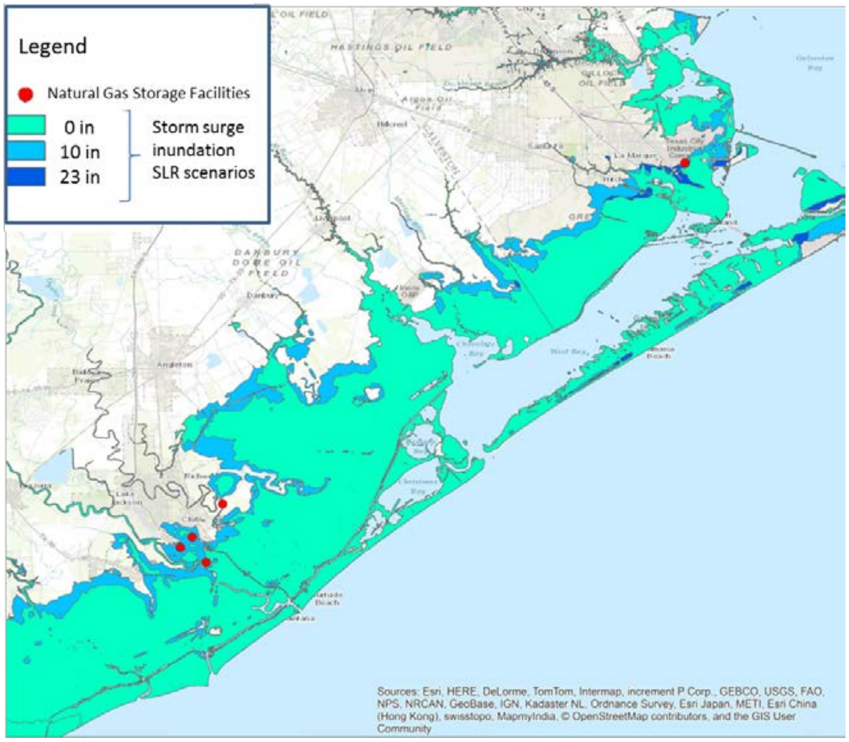
[3] As stated in the accompanying documentation of the Homeland Security Infrastructure Protection (HSIP) database, "The HSIP Gold 2013 Database is a unified homeland infrastructure geospatial data inventory assembled by the National Geospatial-Intelligence Agency (NGA) in partnership with the Department of Homeland Security (DHS). It is a compilation of geospatial data characterizing domestic infrastructure and boundaries assembled from a variety of Federal agencies, commercial vendors and State mission partners."

[4] Infrastructure data include point representation of asset locations identified by geographical coordinates. Elevation of the assets is coordinated with terrain elevation of respective locations.



Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 2: Illustrative map of five natural gas storage facilities exposed to inundation from Category 1 storm surge under two different increments of future SLR. Coastal area shown here is just south of Galveston Bay, Texas.

This is not a detailed risk assessment. The methods used for this study provide a useful first cut estimation of which currently existing facilities would be exposed to greater risk of storm surge in the future as a result of SLR. This method provides information about the relative exposure of existing energy infrastructure to hurricanes of varying storm intensities. Important factors not taken into account include: the probability of local hurricane strikes at any given location, the depth of inundation, and the degree of damage that would occur to each exposed facility (for example from flooding or storm-related wind damage). This analysis also does not account for many factors that either reduce or increase risks. Risks may be reduced by existing or future investments or operational changes by facility owners to harden individual facilities to storm surge impacts, like construction of dikes or berms or elevation of equipment; so, the amount of actual risk from SLR may vary significantly among the facilities identified as exposed. Additionally, this study does not address the possible relocation of facilities over the time period of the SLR. Relocation could reduce risk as a resilience-building measure, or could increase risk as part of a broader change in the geographical distribution of infrastructure over the coming decades. A key factor increasing risk from storm surge and SLR is land subsidence, which is happening even faster than the recently observed rates of global SLR[5] on the Mid-Atlantic and

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[5] Given that land subsidence is occurring throughout the Atlantic and Gulf coasts of the U.S., results from Maloney and Preston likely provide conservative estimates of future land area exposure to inundation from storm surge.

Gulf Coasts (see Appendix). Finally, this study does not examine the relative importance of individual exposed facilities, in terms of overall system resilience or reliability.

3.0 Key Findings

The most important findings of this analysis were:

- ***SLR will cause an increase in the exposure of energy infrastructure to storm surge; the greatest total exposure corresponds to the most powerful storms (Category 3 and Category 5), but the incremental increase in exposure due to SLR is largest in less-intense storms (Category 1).*** A significant amount of U.S. energy infrastructure is currently exposed to damage from hurricane storm surge. Total exposure increases with both higher SLR and more intense storms. For Category 1 (C-1) storms, SLR consistently causes a greater incremental increase in the exposure of energy facilities to storm surge, compared to Category 3 (C-3) and Category 5 (C-5) storms. This can be explained partly by the fact that each increment of SLR results in a larger incremental increase in the *area of coastal land* inundated by storm surge from C-1 storms compared to stronger storms.[xv]
- ***Any significant increase in the frequency of intense hurricanes would further exacerbate exposure to storm surge. .***Across every type of infrastructure we examined, the change in the number of exposed facilities and the capacity at risk was larger between the categories of hurricane than between the analyzed increments of sea-level rise. Often, the storm intensity effect was more than double the size of the sea-level effect. For example, the difference in infrastructure exposure between a C-1 hurricane today and a C-1 hurricane with 32 inches of sea-level rise is smaller than the difference in infrastructure exposure between a C-1 hurricane and a C-3 hurricane today.
- ***Petroleum facilities are more exposed to storm surge than electricity and natural gas, as a portion of each sector's total number of U.S. facilities and total operating capacities.*** Roughly 8 percent of U.S. oil refining capacity and 100% of strategic petroleum reserve storage capacity are exposed to storm surge caused by the largest hurricanes. Roughly 10 to 20% of petroleum pumping stations are exposed to hurricane storm surge, even with little to no SLR. Meanwhile, other energy facilities are relatively less vulnerable; on average, less than 5% of total NG and electric sector facilities are exposed to storm surge (Table A-2). This can be explained by the relative high concentration of petroleum infrastructure in the U.S. Gulf Coast region, and their co-location with shipping and port facilities with direct access, and therefore exposure, to the Gulf.

Detailed results of this analysis are provided in three tables in the appendix. Results include the total number of exposed facilities (Table A-1), the percentage of exposed facilities as a portion of total U.S. facilities (Table A-2) and the percentage of total U.S. capacity represented by exposed facilities (Table A-3). The results are specific to the 2030 to 2060 time frame and may not necessarily hold over longer time frames or for higher increments of future SLR.

In addition, Maloney and Preston (2014) found that for some facility types, changes in coastal development patterns could have a larger effect on energy infrastructure vulnerability than sea-level rise. Their analysis applied the inundation maps to different scenarios of coastal residential development in 2050, and found that the number of additional housing units exposed due to SLR was only *one quarter to one third* the number of units exposed because of new development in vulnerable areas. In other words, the future exposure of residential buildings to coastal flooding will likely be driven more by development patterns than SLR and other climate change impacts. Though this study does not include any projections of future energy infrastructure development, energy sector vulnerabilities could follow a similar path, particularly for energy distribution infrastructure (e.g., substations), some of which is by necessity co-located with population centers. Therefore, consideration for future climate risk may be an important element of strategic planning regarding infrastructure siting and development.

4.0 Sector Specific Results

This section highlights illustrative results from this analysis, focusing mostly on the exposure of transmission, storage and distribution infrastructure to storm surges from C-1 and C-3 hurricanes.[6]

4.1 Petroleum Sector

Up to 34 oil refineries, constituting 8% of US refining capacity, are currently exposed to storm surge inundation from C-3 hurricanes (Figure 3); SLR is expected to increase the portion of exposed refining capacity to 9%. However for a C-1 hurricane, 10 refineries are exposed with zero SLR, 12 will be with 10 inches of SLR, and 16 will be with 23 inches of SLR, a 60% increase in the number of facilities exposed to C-1 storms. With their close proximity to the Gulf of Mexico, Strategic Petroleum Reserve facilities are highly exposed to storm surge, with or without SLR: 80% of U.S. capacity is exposed to storm surge from C-3 storms, while 100% of capacity is exposed to C-5 storms[7]. Petroleum pipeline pumping stations and oil and gas pipeline facilities display similar patterns of exposure.

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[6] Note that Maloney and Preston (2014) did not generate inundation maps of storm surge from Category 5 hurricanes for the New England coastal region because there are no records of Category 5 hurricanes making landfall in New England. As a result, the nationwide total number of facilities exposed to storm surge from C-3 hurricanes can be higher than the number of facilities exposed due to C-5 storms. For this reason, Figures 3, 5 and 7 generally focus on C-1 and C-3 storm scenarios.

[7] Note: this does not mean that a single storm could affect all facilities, just that each of the SPR facilities could be affected by storm surge from a strong hurricane.

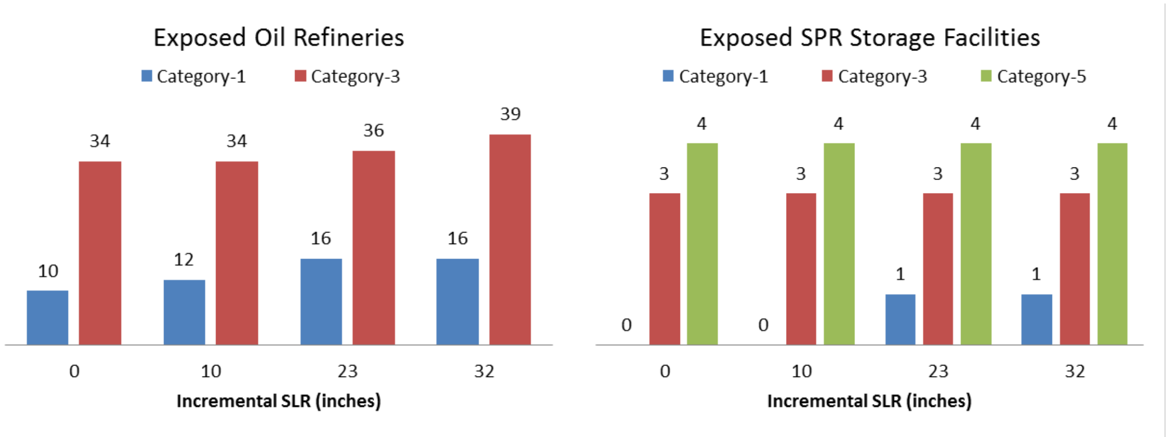
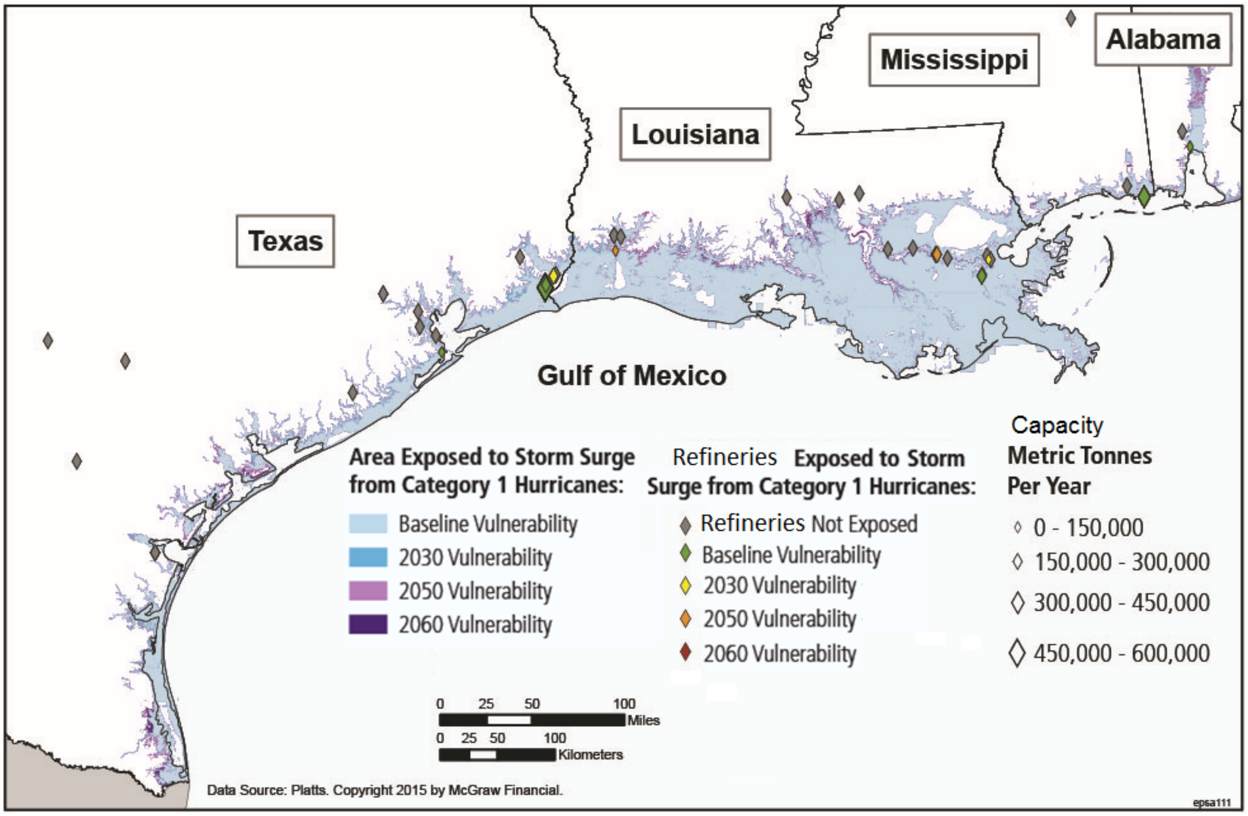


Figure 3: Total number of oil refineries (left) and Strategic Petroleum Reserve (SPR) facilities (right) exposed to storm surge under four SLR scenarios and different categories of hurricane.

Regionally, 10 of the 16 oil refineries that are exposed to storm surge from C-1 hurricanes are located in the Gulf Coast region (Figure 4). Most of the refineries that are not currently exposed to C-1 storm surge but would become exposed as a result of SLR are located in Louisiana and eastern Texas (Galveston Bay and Port Arthur).



Data Source: Platts. Copyright 2015 by McGraw Financial.

Figure 4: Oil Refineries on the Gulf Coast exposed to storm surge from Category 1 Hurricanes under four increments of future SLR.

4.2 Electricity Sector

Sea-level rise by 2050 could increase the number of electric power substations exposed to inundation caused by C-1 hurricanes by 35%, from 711 to 958 facilities (Figure 5). In a baseline scenario (i.e., without SLR), C-3 storms expose over twice as much coastal infrastructure to storm surge as C-1 storms. However, 23 inches of SLR in a C-3 storm only increases the number of exposed substations by 9% (from 1880 to 2049 facilities). Results for electric generation units (EGUs) are very similar.

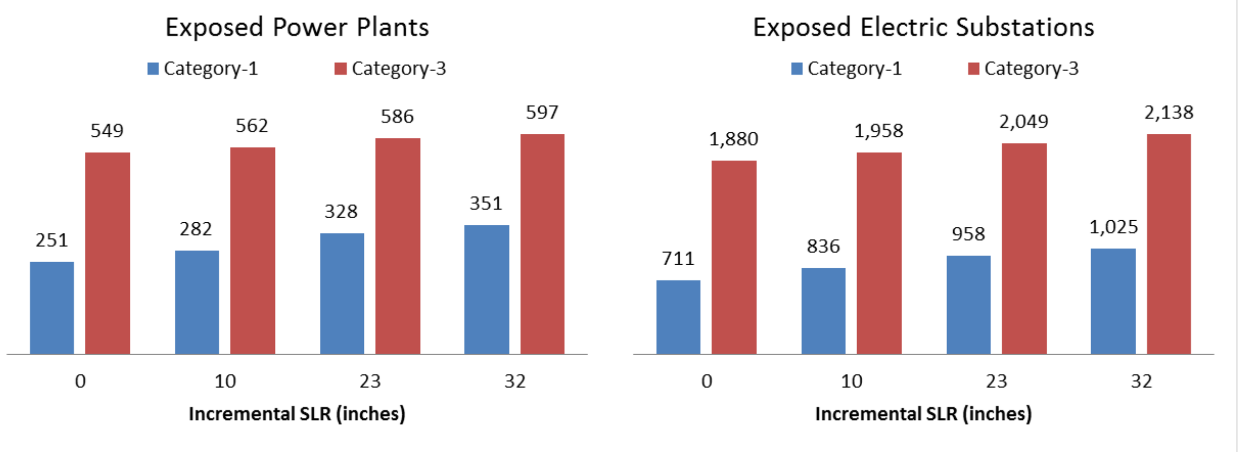


Figure 5: Total number of electric power plants (left) and substations (right) exposed to storm surge under four SLR scenarios and different categories of hurricane.

Regionally, substation facilities[8] exposed to storm surge from C-1 hurricanes are located throughout the Gulf Coast region (Figure 6). Since substation locations tend to be correlated with urban and industrial centers, the regions with the greatest exposure tend to be those with greater areas of inundated land and relatively dense development.

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[8] The Platts Electric Substation geospatial data layer contains point features representing electric transmission, sub-transmission, and some distribution substations in North America. These substations are fed by electric transmission and sub-transmission lines and are used to step-up and step-down the voltage of electricity being carried by the lines, or simply to connect together various lines and maintain reliability of supply. These substations can be located on the surface within fenced enclosures, within special purpose buildings, on rooftops (in urban environments), or underground. A substation feature is also used to represent a location where one transmission line "taps" into another.

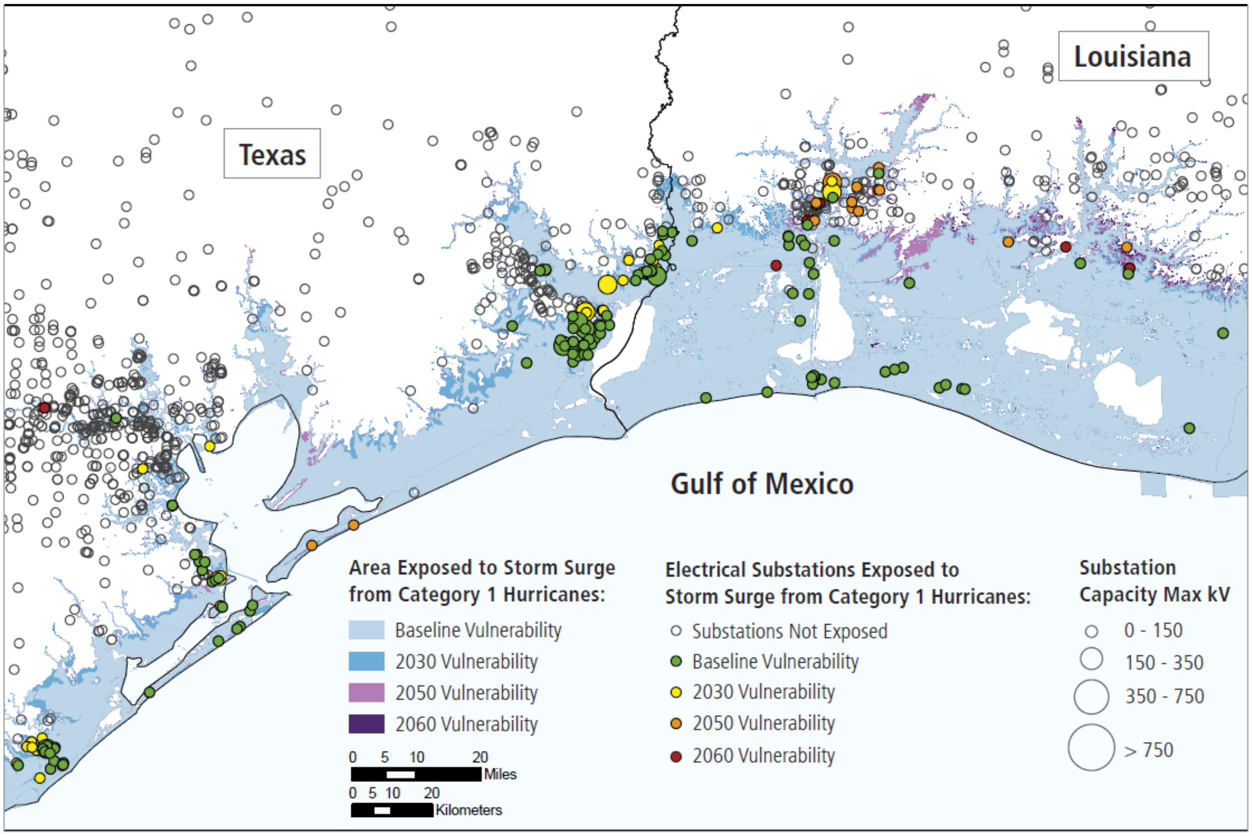

Figure 6: Electricity Substation facilities on the Gulf Coast exposed to storm surge from Category 1 Hurricanes under four increments of future SLR.

4.3 Natural Gas (NG) Sector

NG infrastructure displays similar patterns of change in exposure to storm surge as a result of SLR (Figure 7). However, a relatively small portion of total U.S. NG infrastructure is exposed to inundation. Just 10 inches of SLR increases from 9 to 14 the number of NG storage facilities exposed to storm surge from C-1 hurricanes. NG Compressor stations, LNG import terminals and oil and gas pipelines display similar patterns of exposure (see Tables A1 and A2).

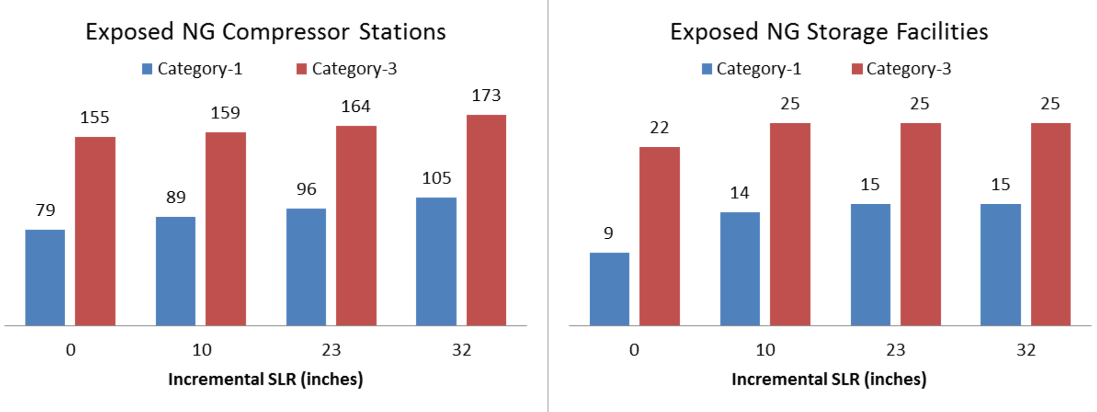

Figure 7: Total number of natural gas (NG) interstate pipeline compressor stations (left) and NG storage facilities (right) exposed to storm surge under four increments of future SLR and different categories of hurricane.

Regionally, 12 of the 15 NG storage facilities that are exposed to storm surge from C-1 hurricanes are located in the Gulf Coast region. Most of the NG storage facilities that are not currently exposed to C-1 storm surge but would become exposed as a result of 10 inches of SLR are located just south of Galveston Bay, Texas (Figure 2, above).

5.0 Conclusions and Implications

Sea-level rise will increase the exposure of coastal infrastructure to storm surge. Petroleum infrastructure appears to be relatively more exposed to inundation, due to the density of these facilities in the Gulf of Mexico and proximity to the shorelines. The actual impacts will depend on the specific characteristics of future storms (e.g. the location or track of any given storm and the type of infrastructure in question) and the infrastructure they impact, but on average SLR will increase these impacts.

More research is needed to understand the implications of these findings for energy system resilience and reliability. In particular, more information and analysis is needed to determine the extent to which exposed facilities would be damaged or debilitated and to project changes in energy infrastructure that could occur in the coming decades, including possible investments in infrastructure hardening and other resilience measures. Furthermore, energy system modeling is needed to understand the extent to which damaged facilities could disrupt energy services and for how long.

Finally, it is important to reiterate the fact that recent decades have seen an increase in the frequency and intensity of tropical storms and hurricanes observed in the Atlantic basin.[xvi] As discussed above, hurricane strength and precipitation is expected to become more intense in the future. While this remains an active area of research, with considerable associated uncertainty, a recent modeling study projected that a 1 °C rise in global temperatures would increase by two to seven times the frequency of Katrina-magnitude events in the North Atlantic basin.[xvii] While sea-level rise will increase exposure everywhere, the greatest sensitivity (and uncertainty) could be to a continued increase in storm intensity. This emphasizes the importance of limiting investments in new critical infrastructure in areas that are currently exposed to storm surge, even from the largest (and seemingly most unlikely) storm surge scenarios. It also emphasizes the importance of reducing greenhouse gas emissions, to avoid temperature increases that would increase the likelihood of dangerous levels of climate change.

6.0 Appendix

6.1 Additional Discussion of the Causes of Sea-Level Rise

Sea-level rise (SLR) has two main causes: thermal expansion of the oceans as they warm and input of new water into the oceans, primarily from melting ice sheets.[9] Since 1900, the global average sea level has been rising by 1.7 mm/yr, as measured by tide gauges, while satellites have measured 3.2 mm/yr of global sea-level rise over the last 20 years.[10, xviii] *SLR is expected to accelerate* in the 21st century, as contributions from both causes increase in a warming climate. The high SLR scenario developed for the NCA – and used as the basis for this analysis – assumes that the degradation of ice sheets will become more important with time.[xix]

Locally sea level change can be very different from the global average rate change. Vertical land motion (e.g., subsidence), changes in ocean circulation, and changes in the Earth's gravitational field as ice sheets melt will all affect local sea levels. Throughout much of the Gulf of Mexico and for the Mid-Atlantic States, the local relative sea level is rising substantially faster than the global average, largely because of *land subsidence*. It is estimated that this adds *5-10 mm/yr* to the SLR rate in these areas, nearly tripling the rate of SLR in the worst-affected areas. The highest rates estimated in the vicinity of the Mississippi River Delta,[xx] home to one of the largest concentrations of energy infrastructure in America and one of the highest storm surge hazards.

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[9] Historically, these two factors are typically estimated to have been equally important, though recent research has suggested melting ice-sheets is likely increasing in importance over time. National Research Council (2012). *Sea-Level Rise for the Coasts of California, Oregon, and Washington.*

[10] The difference in these two rates is thought to be from a combination of acceleration of SLR in recent years and differences arising from the different data sets. In the last 20 years, tide gauges show SLR of 2.8 mm/yr.

6.2 Results Tables

The below three tables present national-scale results of this analysis. To interpret these results, it is important to note that inundation data for Category 5 hurricanes are not available for the New England coastal region. This is because there are no records of Category 5 hurricanes making landfall in New England; this lack of data precluded Maloney and Preston (2014) from modeling impacts in this region in a manner consistent with the rest of the nation. As a result, for several infrastructure types the number of facilities affected by C-5 hurricanes is less than the number of facilities affected by C-3 hurricanes.

Table A-1: Total number of facilities exposed to storm surge under four increments of future SLR and three different categories of hurricane strength.

Number of Facilities Exposed									
				Petroleum					
	Petroleum Pumping			Oil Refineries			Strategic Reserves[11]		
SLR (in)	C-1	C-3	C-5	C-1	C-3	C-5	C-1	C-3	C-5
0	115	184	95	10	34	33	0	3	4
10	128	188	95	12	34	33	0	3	4
23	134	196	96	16	36	33	1	3	4
32	140	198	97	16	39	33	1	3	4
				Electric Power					
	Oil & NG Pipelines[12]			Power Plants			Substations		
SLR (in)	C-1	C-3	C-5	C-1	C-3	C-5	C-1	C-3	C-5
0	8,751	14,453	17,061	251	549	394	711	1,880	2,006
10	9,682	14,667	17,182	282	562	405	836	1,958	2,058
23	9,838	15,191	17,434	328	586	416	958	2,049	2,127
32	10,105	15,501	17,694	351	597	423	1,025	2,138	2,165
				Natural Gas					
	NG Compressors			NG Storage			LNG Import Terminals		
SLR (in)	C-1	C-3	C-5	C-1	C-3	C-5	C-1	C-3	C-5
0	79	155	142	9	22	27	13	24	22
10	89	159	143	14	25	27	13	24	22
23	96	164	144	15	25	29	15	25	23
32	105	173	148	15	25	29	15	25	23

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[11] Strategic Reserves includes only the following SPR storage sites: West Hackberry, Bryan Mound, Bayou Chocktaw, Big Hill.

[12] Oil and Natural Gas pipelines are counted as exposed if any segment of a facility in the database is located in a location that is inundated by modeled storm surge.

Table A-2: Percentage of facilities exposed to storm surge (as a portion of total U.S. facilities), under four increments of future SLR and three different categories of hurricane strength.

Percent of Facilities Affected									
				Petroleum					
	Petroleum Pumping			Oil Refineries			Strategic Reserves		
SLR (in)	C-1	C-3	C-5	C-1	C-3	C-5	C-1	C-3	C-5
0	11.3	18.1	9.3	1.4	4.9	4.7	0.0	75	100
10	12.6	18.4	9.3	1.7	4.9	4.7	0.0	75	100
23	13.2	19.2	9.4	2.3	5.2	4.7	25	75	100
32	13.7	19.4	9.5	2.3	5.6	4.7	25	75	100
						Electric Power			
	Oil & NG Pipelines			Power Plants			Substations		
SLR (in)	C-1	C-3	C-5	C-1	C-3	C-5	C-1	C-3	C-5
0	2.0	3.3	3.9	2.0	4.4	3.2	1.3	3.4	3.6
10	2.2	3.4	3.9	2.3	4.5	3.3	1.5	3.5	3.7
23	2.3	3.5	4.0	2.6	4.7	3.4	1.7	3.7	3.8
32	2.3	3.5	4.1	2.8	4.8	3.4	1.8	3.8	3.9
				Natural Gas					
	NG Compressors			NG Storage			LNG Import Terminals		
SLR (in)	C-1	C-3	C-5	C-1	C-3	C-5	C-1	C-3	C-5
0	2.2	4.3	3.9	1.4	3.4	4.2	4.7	8.6	7.9
10	2.5	4.4	4.0	2.2	3.9	4.2	4.7	8.6	7.9
23	2.7	4.5	4.0	2.3	3.9	4.5	5.4	9.0	8.2
32	2.9	4.8	4.1	2.3	3.9	4.5	5.4	9.0	8.2

Table A-3: The percentage of total U.S. capacity represented by facilities exposed to storm surge under four increments of future SLR and three different categories of hurricane strength.

Percent Capacities at Risk									
	Oil Refineries			Strategic Reserves			NG Storage		
SLR (in)	C-1	C-3	C-5	C-1	C-3	C-5	C-1	C-3	C-5
0	2.0	7.7	7.6	0.0	77.7	100	0.9	3.0	4.9
10	2.4	7.7	7.6	0.0	77.7	100	1.0	3.2	4.9
23	3.2	8.8	7.6	31.7	77.7	100	1.0	3.2	4.9
32	3.2	8.8	7.6	31.7	77.7	100	1.0	3.2	4.9

Endnotes

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