



Building a Resilient Energy Gulf Coast:

Executive Report

Summary

<http://americaswetland.com>

<http://entergy.com/gulfcoastadaptation>

Over the past year, Entergy Corporation has worked to develop a framework and fact base to quantify climate risks in the U.S. Gulf Coast and help inform economically sensible approaches for addressing this risk and building a resilient Gulf Coast.

This project has been greatly strengthened and enriched by contributions from many participants. We especially acknowledge support of America's Energy Coast and America's Wetlands Foundation, and Swiss Re, which was a lead contributor to the research, and brought its natural catastrophe and climate risk assessment knowledge to bear on the challenge of quantifying climate risks. The methodology used in this study was previously devised and tested by a consortium of public and private partners, including Swiss Re in a project on the Economics of Climate Adaptation (ECA). The methodology developed a framework for the facts for decision-makers to build a portfolio of economically suitable adaptation measures.

The Gulf Coast is vulnerable to growing environmental risks today with >\$350 billion of cumulative expected losses by 2030

- **Economic losses will increase by 50-65 percent in the 2030 timeframe driven by economic growth and subsidence, as well as the impacts of climate change:** Wind and storm surge damage from hurricanes drives significant losses in the Gulf Coast today. While the actual losses from extreme storms are uncertain in any given year, on average, the Gulf Coast faces annual losses of ~\$14 billion today
 - **Over the next 20 years, the Gulf Coast could face cumulative economic damages of some \$350 billion:** 7 percent of total capital investment for the Gulf Coast area and 3 percent of annual GDP will go towards reconstruction activities. In the 2030 timeframe, hurricane Katrina/Rita-type years of economic impact may become a once in every generation event as opposed to once every ~100 years today. The impact of severe hurricane in the near-term could also have a significant impact on any growth and reinvestment trajectory in the region
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There are key uncertainties involved in addressing this vulnerability including: (1) the impact of climate change; (2) cost and effectiveness of measures to adapt; and (3) the ability to gain alignment and overcome obstacles

- **There is a long-standing debate around the extent to which climate change will occur, how large the impacts will be and how soon they will be realized.** However, this analysis indicates that irrespective of any impacts from climate change, the Gulf Coast will face increasing loss from subsidence and asset growth. Uncertainties in climate science are addressed by considering a range of scenarios, informed by the best available science. Depending on the scenario annual losses in 2030 will increase by 30-60 per cent over current figures.
- **There are several adaptation measures that can reduce risk (e.g., improved construction codes, restoration of wetlands); however, there is uncertainty related to their economic benefits.** While the costs related to actions are more certain, the benefits (averted losses) are difficult to quantify – and are related to the occurrence and intensity of hurricanes and other extreme weather events.
- **Actions involve a broad set of stakeholders that have conflicting interests, differing timeframes, and varying levels of effectiveness.** Benefits from measures are therefore difficult to capture. For example, measures related to improved construction codes may require new policies to be put in place by local regulators, actions by individual home owners (who may face barriers related to capital needs), and appropriate enforcement.

Driving a “practical” solution that takes Gulf Coast “resilience” to the next level represents an optimal solution to balance cost requirements with risks that impact of the Gulf Coast

- **There are several key “no regrets” options for adaptation** that have low investment needs, high reduction potential of expected losses (regardless of impact of climate change) and additional strong benefits (e.g., wetlands restoration). These investments will avoid “mortgaging our future” with a heavy burden of ineffective actions, which is of utmost importance for the Gulf Coast. In particular, investing approximately \$50 bn over the next 20 years in measures with cost-to-benefit ratio less 1 will lead to approximately \$135 bn in averted loss over the lifetime of measures. Pursuing all potentially attractive actions may involve an investment of approximately \$120 bn over the next 20 years, and may lead to \$200 bn in averted loss over the lifetime of measures
- **There needs to be a focus on adaptation to address near-term risks, and mitigation to address longer-term risks.** In the near-term, significant impacts from climate change may be “locked in”, and will require strong action today (actions should begin with low-cost, “no-regrets measures”).
- **Policy makers can and must take a leadership role in driving a coordinated response across individuals and sectors.** Policy makers can support and enforce a range of actions to reduce the risks that individuals bear (e.g., through building codes, development decisions). They can also unlock barriers to increasing the resilience of industry (e.g., electric utility and oil and gas sectors).

Building a Resilient Energy Gulf Coast: Executive Report

Study supported and sponsored by America's Energy Coast, America's Wetlands Foundation, Entergy Corporation

The analysis scope includes the overall Gulf Energy Coast:

The objective of this work is to develop a consistent fact base that quantifies climate risks in the U.S. Gulf Coast and helps inform economically sensible approaches for addressing this risk. It represents the first comprehensive analysis of climate risks and adaptation economics along the U.S. Gulf Coast.

The scope of this analysis includes Coastal counties and parishes considering a strip of land up to 70 miles inland across the shoreline, ranging from southern Texas, to Coastal Mississippi and Alabama. Since this work is primarily focused on areas of the Gulf Coast where the energy is key to the economy (the Energy Gulf Coast), Florida is excluded from the analysis. The area of study includes 800 zip codes across 77 counties and parishes, and covers a population of ~12 million people, and an annual GDP of ~\$630 MM (Exhibit 1).

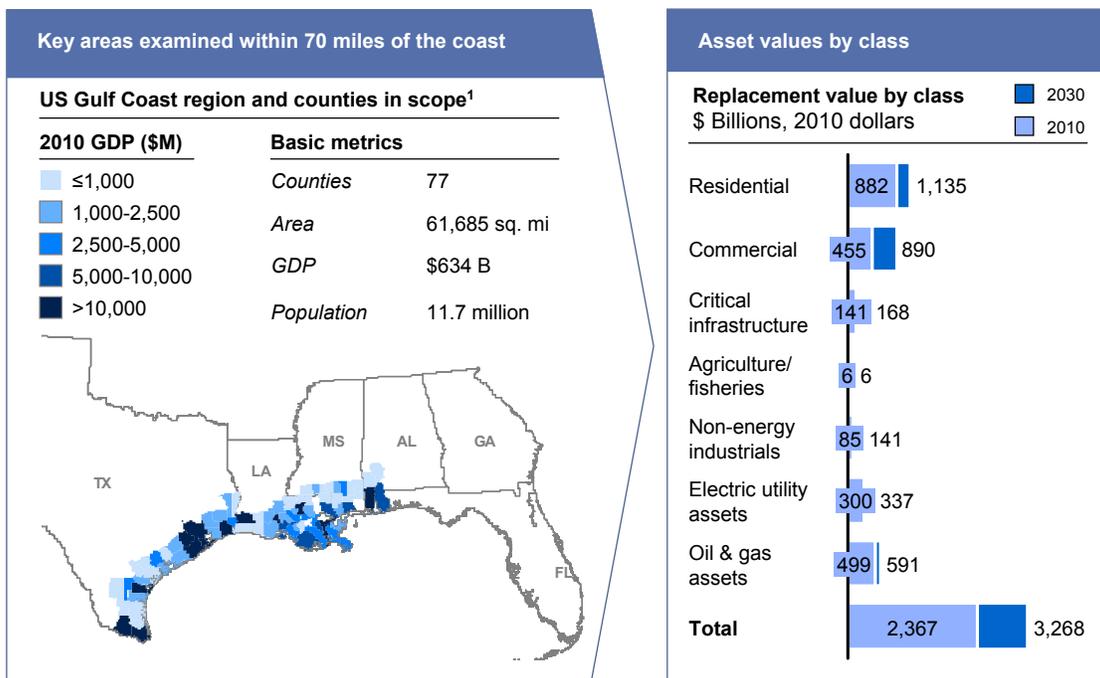
The Gulf Coast faces significant risk from climate hazards:

The Gulf Coast faces significant risks from hurricanes that extensively damage assets and impact the economy. Hurricanes drive damage through extreme winds and storm surge or flooding. Over the last century, hurricanes have caused significant asset damage (~\$2,700 billion, 2010 dollars) across Texas, Louisiana, Mississippi and Alabama¹. In addition to the risk to the Gulf Coast from hurricanes (wind and storm surge damage), impacts due to relative sea level rise are also assessed. Relative sea level rise can be driven by land subsidence and by climate change (rising sea levels) and can magnify storm surge impacts.

The magnitude of loss in the areas most at risk is calculated in three steps (Exhibit 2). The magnitude of the hazard, the value of assets at risk from the hazard, and the vulnerability of those assets to the hazard are assessed in order to calculate the expected loss over time. To size risk, the methodology follows the insurance industry's natural catastrophe model approach, which is directly applicable to future climate-sensitive risks.

1. **Hazard assessment:** Three key hazards are considered – hurricanes, subsidence and sea level rise. Future scenarios for hazards are developed in consultation with expert scientists in the field. For hurricanes, while there is uncertainty regarding their future, there is broader agreement that warmer sea surface temperatures in the future may lead to more severe hurricanes. Recent science helped inform

1 Analysis scope includes 77 counties along the Gulf Coast, involving an asset value of over \$2 trillion



¹ Includes 30 Louisiana parishes

Source: ESRI; Energy Velocity

relationships of increase in wind speed per degree increase in Sea Surface Temperature (SST)². And the Intergovernmental Panel on Climate Change (IPCC) General circulation models (GCMs) provided information on increase in SST³.

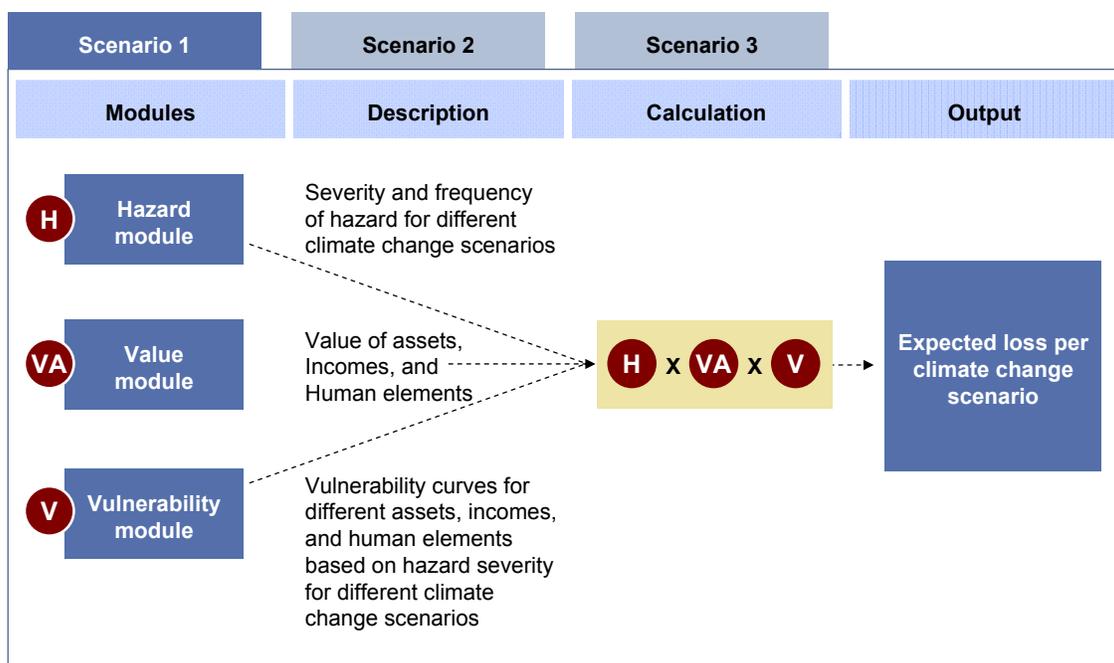
For sea level rise (SLR), recent science indicates that the IPCC fourth assessment estimates are too conservative. SLR estimates used here are based on Rahmstorf⁴. For subsidence, estimates are based on subsidence maps for the Louisiana Gulf Coast developed by NASA/JPL*.

To address uncertainty in climate change, three scenarios are developed in the 2030 and 2050 timeframes representing low, average and extreme climate change. In 2030 and 2050, low change refers to climate as it is today (i.e., frequency and severity of hurricanes are unchanged). While there are significant uncertainties in 2100, analyses of risk in this timeframe are also performed. In 2100, scenarios used were aligned with IPCC emission pathways - with the low scenario aligning with B1 (green world); average scenario with A1 B; and high scenario with A2.

Modeling natural hazards requires a consideration of the probabilistic nature of events (i.e., considering event frequencies and severities). Natural hazard modeling is done in collaboration with Swiss Re and leverages their probabilistic event set. This event set “simulates” hurricane activity over a period of

* National Aeronautics and Space Administration, Jet Propulsion Laboratory

2 We use 3 assessments to quantify expected losses for different climate scenarios



10,000 years on the basis of statistical data and the dynamic development of tropical cyclones that have occurred in the North Atlantic over the past hundred years. This simulation produces cyclone tracks that may have never occurred in reality but may occur in the future.

A comparison of simulated and historical climate data (for example, frequency of various wind speeds) can test the validity of the artificially generated event set. When producing an annual occurrence set, it must be ensured that the distribution of probabilistic cyclones into Saffir-Simpson Intensity Scale categories and the cyclones' landfall characteristics correspond to historical records and/or the laws of physics. The validated event set – based on the latest scientific research – gives a reliable picture of exposure to cyclones in the Gulf Coast.

- Economic value assessment:** This step requires estimating the size and location of current and future “assets” of economic value. Because the impact of the hazard changes spatially, it is important to also distribute the value of assets. Note - we use “assets” here to mean the replacement value of physical assets or the economic value of business interruption. However, a holistic assessment of the value at risk from climate change can additionally include second-order macro-economic impacts, human lives, socioeconomic factors such as health, and ecosystem degradation – in addition to physical asset valuation. 23 asset classes are valued spatially across the Gulf Coast (on a zip-code basis) for both property and economic value. A current baseline for assets/economic value is developed, and then grown to 2030 based on a range of industry and government sources⁵.

The Gulf Coast has over \$2 trillion dollars in asset value today (Exhibit 1). Asset values are expected to grow to over \$3 trillion in the 2030 timeframe. Residential and commercial assets are key sources of value. Among industrial assets, oil and gas, and electric utility assets are key sources of value. The analysis includes a detailed and granular assessment of oil and gas and electric utility assets. Over 50,000 oil and gas structures (including pipelines, offshore structures and wells), and over 500,000 miles of electric transmission / distribution assets and ~300 generation facilities are modeled across the Gulf Coast.

3. **Vulnerability assessment:** Vulnerability curves relating value at risk to events of different severities are created in this assessment step. A vulnerability curve shows the correlation between hurricane severity and asset loss, where asset loss is presented as a proportion of total asset value. Event severities are specified by different metrics (for example, height of storm surge, wind speed) and assessed in hazard assessment. The result of this step is a set of vulnerability curves that plot the percentage of value damaged by hazards of different severity.

Categories of assets typically have different vulnerability curves (for example, residential property may look quite different from utility assets in its vulnerability to extreme winds). Similarly, within a single asset category, curves are highly sensitive to parameters such as construction codes or materials used. Given the availability of robust insurance data in the Gulf Coast, these curves are tuned for the different asset categories.

The Gulf Coast currently faces an annual expected loss of \$ 14 billion; losses are expected to increase going forward:

Based on an analysis of hazards, assets and vulnerabilities, the Gulf Coast faces significant losses today. On an average annual basis, current losses amount to \$14 billion today. These losses are expected to increase going forward to ~\$18 billion (no climate change) to \$23 billion per year (with extreme climate change) in the 2030 timeframe, based on the scenario. Losses may also increase further in the 2050 timeframe, ranging from ~\$26 billion to \$40 billion per year, based on the climate change scenario (Exhibit 3).

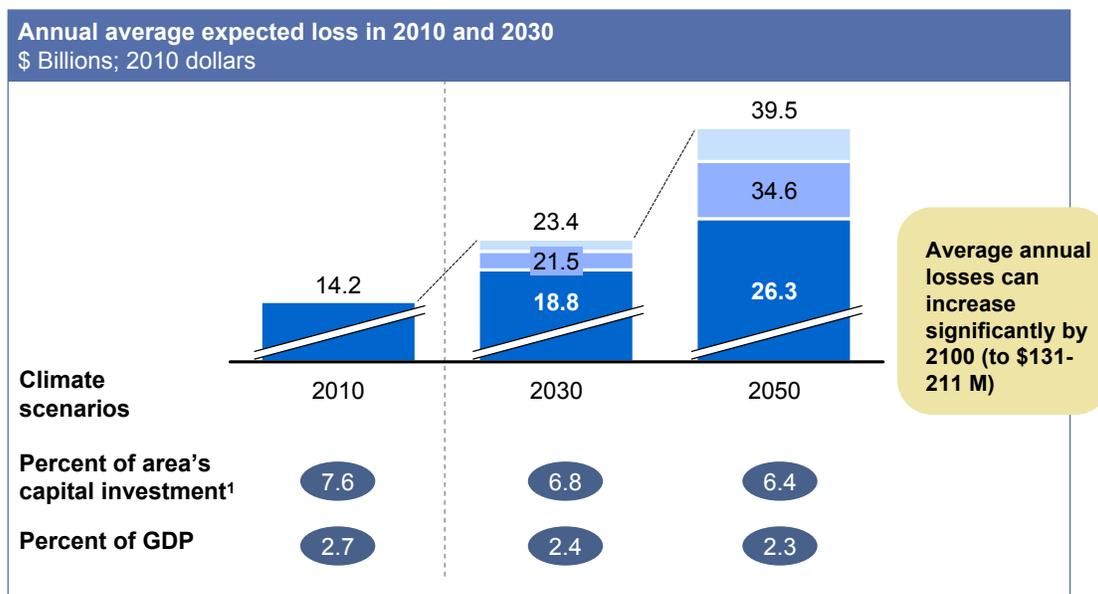
These losses also represent a significant annual impact of ~2-3 percent on the region's GDP. Also, losses amount to ~7 percent of the region's capital investment – implying that the region spends about ~7% of its invested capital each year on rebuilding infrastructure – rather than on capital investments that could be driving future economic growth. The impact of a severe hurricane in the near-term could also have a significant impact on the growth and re-investment trajectory in the region.

However, a key point is that regardless of climate change, the Gulf Coast faces an increase in risks from natural hazards going forward. Approximately half the increase in loss faced by the Gulf Coast is driven entirely by economic growth (baseline growth in risky areas) and subsidence (not related to climate change).

The risk profile of the region (the severity and frequency of economic loss) is also expected to shift going forward (Exhibit 4). Examining the frequency distribution of loss highlights two key shifts in the 2030 timeframe. First, extreme loss years may increase in magnitude. That is, damages from a 100-year loss year (e.g., 2005 with hurricanes Katrina and Rita) may increase by ~70 percent in the 2030 timeframe. Second, more extreme loss years may occur more frequently going forward. For example, extreme loss years (like the Katrina/Rita year) may be 2.5 times as likely to occur in the 2030 timeframe – that is, such loss years may occur at least once each lifetime (1 in 40 years) rather than once every 100 years.

3 Extreme storms drive significant economic damage with losses increasing going forward

■ Extreme climate scenario
■ Average climate scenario
■ No climate change



1 No climate change; includes impact of subsidence

2 Based on BEA historical average of capital investment (private and total government expenditures) as a percentage of GDP

Source: Swiss Re

Among economic sectors, the oil and gas industry and commercial/residential interests are particularly vulnerable - together these sectors contribute a significant share of annual expected loss (88 percent of loss in the 2030 timeframe). Among oil and gas assets, offshore assets are particularly vulnerable to damage.

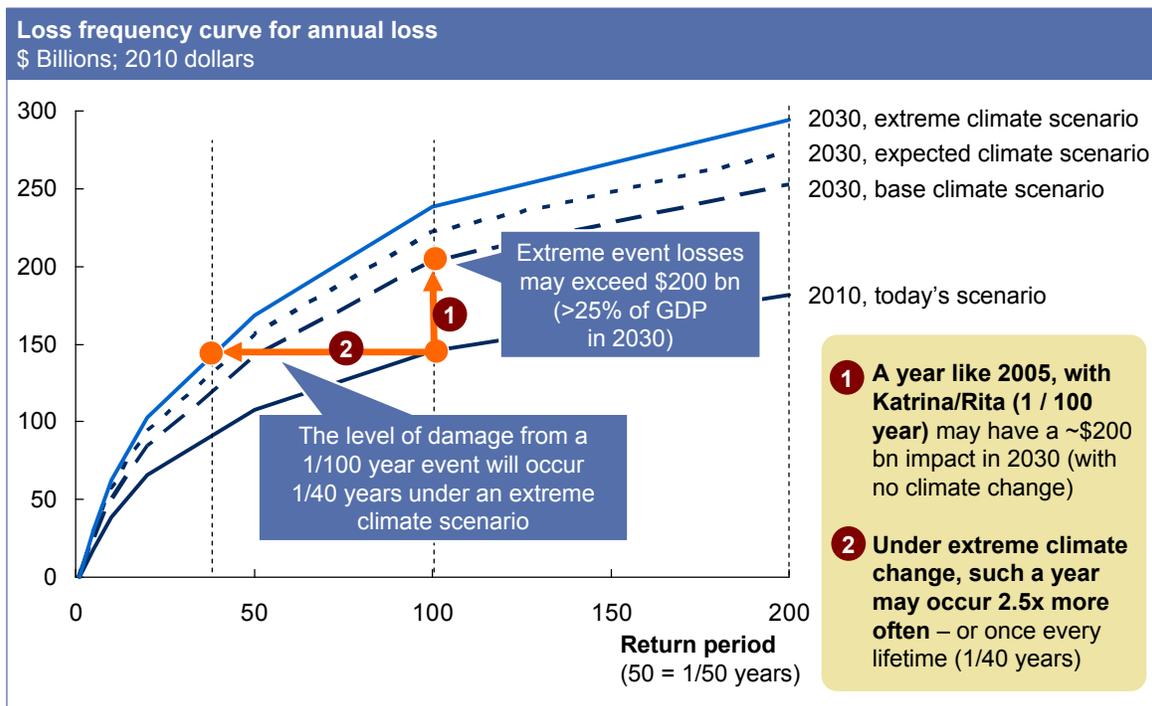
Over the next 20 years, losses along the Gulf Coast add up to a significant amount ~\$ 350 billion. To place this in context, this amount could be used to re-build the entire asset base in New Orleans approximately six times over.

There are a number of potentially attractive measures that can prevent loss:

To address loss, a range of potential adaptation measures are identified that can reduce the impact of hurricanes. Identifying a full range of measures provides a broad set of options to mitigate and prevent risk. Key actions considered ranged from infrastructure- or asset-based, technology-based and systemic or behavior – all risk mitigation or prevention measures.

In addition to risk mitigation measures, there are also financial measures – including insurance instruments that can be used to transfer risk. These measures are particularly relevant to protect against low frequency, but significantly high-impact events.

4 | The risk profile of the region will also shift going forward



Source: Swiss Re; Press searches

The primary focus is on assessing measures that are known and executable today, so future innovations in technology are not assessed. This choice has the benefit of making the measures much more tangible to decision-makers, but the results of the analysis must be considered from the point-of-view that future developments (e.g., new building materials/methods that may be more hurricane resilient) can be incorporated. Correspondingly, the analyses should be repeated periodically (recommend every five years), to incorporate new innovations in adaptation.

The analysis then considers both the costs and benefits of the measures in order to help prioritize actions. Costs of a measure capture life cycle costs over time, including capital expenditures, operating expenditures, and operating expenditure savings. Costs are discounted over time to capture a “present value” cost.

Benefits of measures are estimated in terms of averted loss. Similar to the cost calculations, benefits of each measure are estimated over time, and the discounted “present value” of benefits is used to estimate cost to benefit ratios of measures.

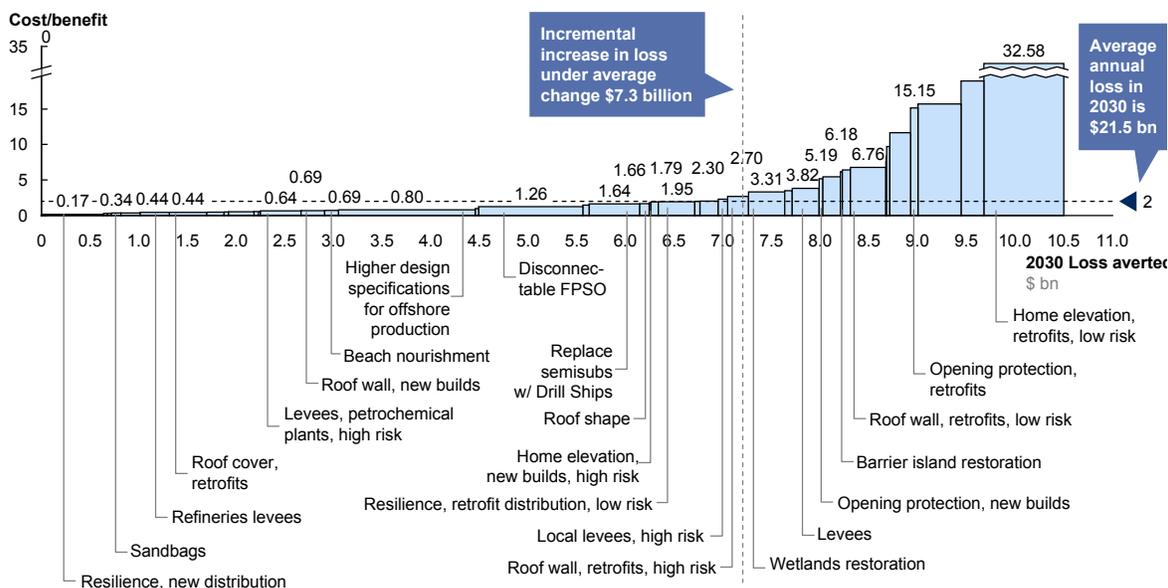
In the near-term, potentially attractive measures can address almost all the increase in loss, and keep the risk profile of the region constant.

Expected loss is likely to increase going forward, from \$14 billion today, to \$19 billion to \$24 billion in 2030 – leading to an increase in loss of ~\$5 billion to \$10 billion (based on the climate change scenario).

This work has identified a set of potentially attractive measures that can address almost all of this increase in loss going forward. There are measures that can address ~\$7 billion per year in annual expected loss in the 2030 timeframe.

These measures include those with a cost to benefit (C/B) ratio of less than 2 (Exhibit 5). The reason we have chosen a C/B ratio of less than 2 (rather than 1) in order to identify a potentially attractive set – is that several measures (e.g., wetlands protection or levees) have strong co-benefits that are not captured in the analysis (which focuses primarily on averted loss). These co-benefits include aspects such as biodiversity protection, ecosystem services or second order economic effects (e.g., risk aversion that encourages economic growth).

5 A range of attractive measures can address the increase in annual loss between today and 2030 and keep the risk profile of the region constant



Assessing the potential loss aversion is particularly uncertain, even for measures for which extensive research exists – for example, for building codes to fix roofs against hurricane winds. On the cost side, we have minimized uncertainties in the test cases by evaluating only measures already developed and tested. However, while we verified costs locally using bottom-up estimates, the cost figures for the test cases are just that – estimates – and incorporates a set of assumptions. Finally, these estimated costs are societal costs/benefits. They do not consider taxes or other private actor costs, so the analysis developed here cannot be used to determine individual economics.

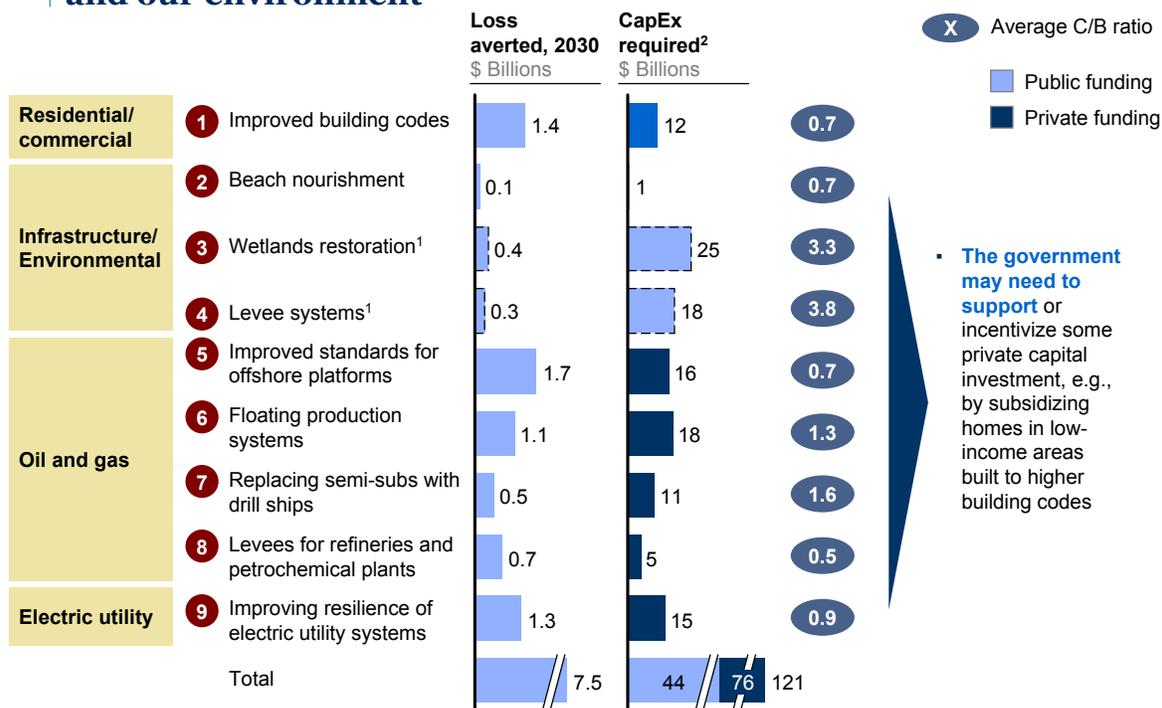
Measures are compared on an overall cost curve (Exhibit 5). The width of each bar in a cost curve represents the total potential of that measure to reduce expected loss up to 2030 for a given scenario. The height of each bar represents the ratio between costs and benefits for that measure.

The assembled cost curve shows – from left to right – the range of measures from least to most cost-efficient. The results of the cost curve can be used to start discussions on the different measures and the opportunity to avert expected losses.

There are a set of particularly low cost measures on the left hand side of the curve, that typically include low cost measures, such as new building codes for industries (e.g., resilience measures for new distribution lines) or buildings (e.g., roof cover measures).

These measures translate to nine broad efforts to reduce risk across all sectors: residential/commercial, infrastructure/environmental, oil and gas and electric utility (Exhibit 6). On the whole, approximately \$ 44 billion of public funding will be required over the next 20 years to fund key infrastructure projects (including wetlands and levees). Some \$76 billion in private funding will be required. However policy makers may need to support and incent some private capital investment e.g., by subsidizing homes in low-income areas built to higher building codes

6 Measures can translate into broad near-term actions to protect our region – that are cost effective and will help our economy and our environment



¹ Included despite high C/B ratios due to strong co-benefits, risk aversion
² Total capital investment, non-discounted, across 20 years

After these 9 efforts are put in place, there is still ~\$14 billion in annual expected loss remaining in residual risk. For tail-risk (extreme events), insurance or risk transfer measures are more cost-efficient than physical measures in providing coverage. Existing insurance penetration in the Gulf Coast can help cover approximately half of the \$14 bn in residual loss.

There are four key risk transfer actions that can help address residual loss that include: increasing penetration of existing insurance (through more affordable premiums that are linked to physical measures); decreasing the prevalence of underinsurance (through incentives that encourage updating of insured value of property); encouraging additional self insurance; and transferring top-layer risk (e.g., through catastrophe bonds).

Implementing key measures will require broad engagement across the region:

Actions are dispersed and will involve a broad set of structures, activities and stakeholders. For example, some 230 miles of beach nourishment activities, 1,000 square miles of wetlands restoration, ~ 540,000 miles of new, rebuilt or retrofitted distribution lines will be required.

Actions will need to be taken by policy makers (federal, state and local), electric utilities, the oil and gas industry and infrastructure developers. There will be a strong need for leadership and coordination across stakeholders.

However, while significant and broad engagement will be required across the Gulf Coast, these actions are also essential – in order to place the region on a resilient path going forward. The alternative will be to give in to a spiral of increasing loss and greater economic and human impact.

Endnotes

- 1 Pielke et. al, Normalized Hurricane Damage in the United States: 1900-2005
- 2 An average relationship of wind speed to sea surface temperature across work by Emanuel, Knutson and Bengtson helped develop average wind speed to sea surface temperature relationships (Emanuel (2005) “Increasing destructiveness of tropical cyclones over the past 30 years.” Nature 436; Knutson and Tuleya (2004) “Impact of CO₂-induced warming on simulated hurricane intensity and precipitation: Sensitivity to the choice of climate model and convective parameterization”. J. Climate 17; Bengtsson et al (2007) “How may tropical cyclones change in a warmer climate?”, Tellus 59)
- 3 Results for GCM SSTs sourced from Prof. Reto Knutti, ETH Zurich based on IPCC B1, A1B and A2 scenarios;
- 4 Vermeera and Rahmstorf. “Global sea level linked to global temperature.” 2009.
- 5 Key sources include Federal Emergency Management Agency (FEMA), Bureau of Economic Analysis (BEA), Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE), Energy Velocity, Handy-Whitman, Energy Information Administration