# Adaptation, Resilience, and Sustainability as Objectives for Energy Systems

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**Roundtable on Science and Technology for Sustainability**

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# Hurricane Sandy Was a Vivid Reminder that the Continuity of Energy System Services Cannot Be Assumed in the Face of Environmental and Other Threats:

- **One more of in long succession of reminders since the environmental impact issues of the 1960s and the oil shock of the 1970s**
- **From the perspectives of science & technology knowledge, responses to these threats are related to three key concepts that are "in the air," plus a fourth that is emerging rapidly**
    - **The three: adaptation, resilience, and sustainability**
    - **The fourth: transformation**

# Sorting Out the Meanings and Implications of the Three Key Concepts:

- **An increasingly frequent question in reviews of US National Climate Assessment draft chapters, IPCC Working Group 2 AR5 draft chapters, and global change/climate change consequences discourses more broadly is whether adaptation, resilience, and sustainability mean the same thing or, if not, how they are different**
- **All are concerned with sustaining (energy) services in the midst of a host of possibly destabilizing forces and events: i.e., with effective *change management***
- **Why does this matter?**
  - **We are all impatient with glossaries, but our terminology shapes how we think, how we communicate, and how we develop strategies for action**
  - **Lack of clarity suggests to audiences and users that our thinking and our perspectives are fuzzy and confused – and they are often right…**

# Regarding Energy Sector Adaptation:

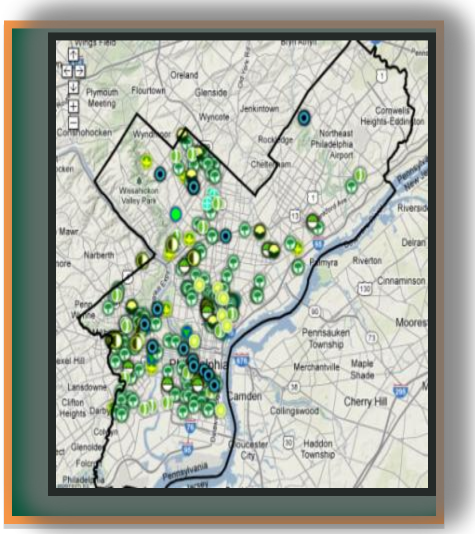
- **Adaptation is an adjustment in a human, human-managed, or natural system to a new or changing environment that moderates negative effects and/or exploits beneficial opportunities (NRC, 2010).**
- **Sources include:**
  - **General: NAS/NRC America's Climate Choices panel on Adapting to Impacts of Climate Change (2010); IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (2012); four chapters of IPCC Working Group II Fifth Assessment Report (forthcoming 2014)**
  - **Energy sector specific: CCSP SAP 4.5 (2008); GCRP Climate Change Impacts in the US (2009); Climate Change and Energy Supply and Demand, in support of NCA (2012)**
- **Recent activities include:**
  - **DOE/Atlantic Council workshop on Climate Change and Extreme Weather: Vulnerability Assessment of the US Energy Sector, DC, July 2012**
  - **IPIECA Workshop on Addressing Adaptation in the Oil and Gas Industry, London, October 2012**

# Regarding Energy Sector Resilience:

- **Adaptation for what? Resilience is the ability of a system and its component parts to anticipate, reduce, accommodate, or recover from the effects of a threat in a timely and efficient manner (IPCC SREX, 2012)**
- **Sources include: Technical reports by the Community and Regional Resilience Institute, 2008 - 2010); NAS/NRC Committee on Disaster Resilience: A National Imperative, 2012; forthcoming IPCC WG II AR5 chapter on "Climate-resilient Pathways: Adaptation, Resilience, and Sustainable Development"**
- **Especially an issue for *built infrastructures*, which so often appear both aging and rigid in a time when large-scale public sector funding is likely to be scarce:**
  - **NATO conference, 2012, and book on "Sustainable Cities and Military Installations," 2013**
  - **Infrastructure Subcommittee, Homeland and National Security Committee, OSTP**
  - **Particular attention to water system management, from warnings to innovations:**
    - **ASCE**
    - **Philadelphia**

# For example, Regarding Issues for the Resilience of Water Management Systems in the US:

- **In urban areas, in response to growing concerns about stormwater and wastewater handling; e.g., Philadelphia's "Green City, Clean Waters" program:**
  - **A 25-year commitment to convert more than 1/3 of the city's impervious land cover to green facilities, along with stream corridor restoration and preservation**
  - **Being implemented through leveraged funding from the development community as a part of every new development project**
  - **Has catalyzed a Model Neighborhood program to encourage community participation in greening the city**



**Big Green Map**

- **More generally, a focus of the American Society of Civil Engineers (ASCE) "water infrastructure" report card, 2011: by 2020 US will have fallen $84 billion short of needed investments in critical water systems, meaning $416 billion in lost GDP and 700,000 lost jobs and increased vulnerability to both flooding and droughts**

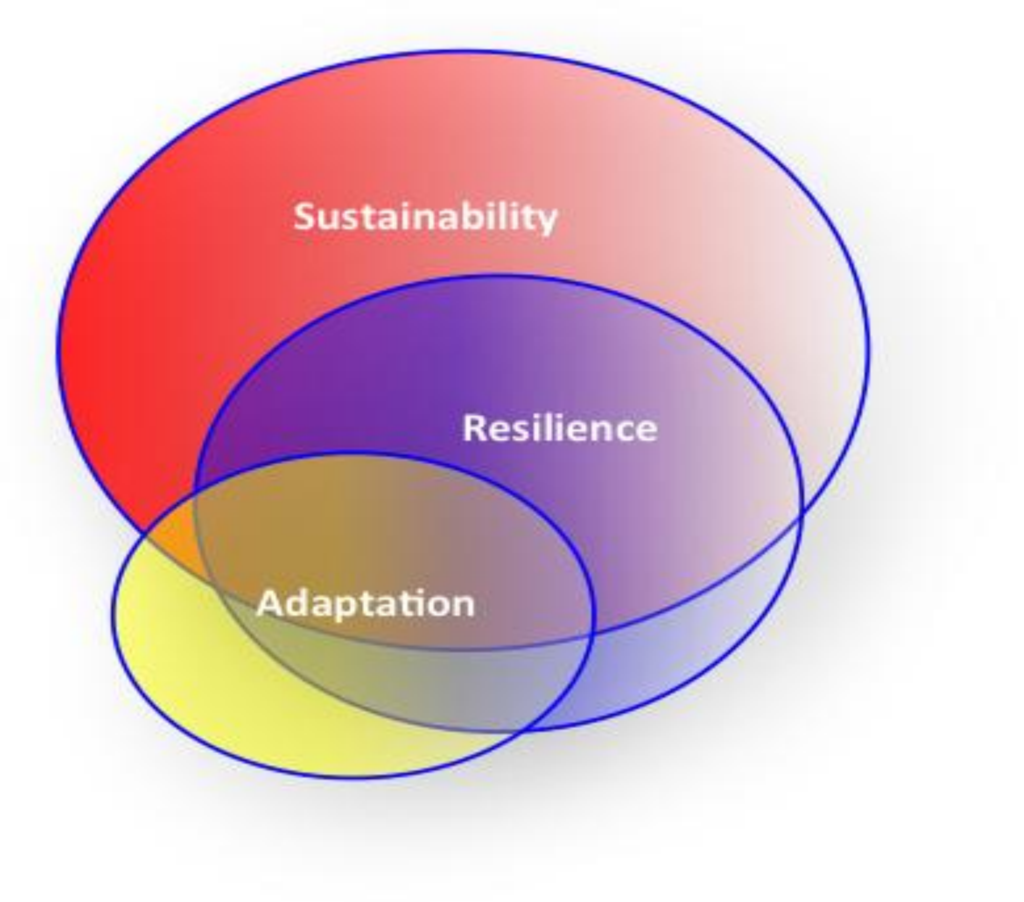
# Regarding Energy Sector Sustainability:

- Resilience for what?  Sustainability is a development pathway that – in a participative manner that values equity – achieves continuing economic and social progress and assures a balanced relationship with a physical environment that is already under stress
- For sources, see (among a host of resources):
  - NAS, *Our Common Journey*, 1999
  - Graedel and van der Voet, eds., *Linkages of Sustainability*, 2008
  - Kates, ed., *Readings in Sustainability Science and Technology*, 2010
- The focus of this Roundtable and its activities over the past ten years, such as the Sackler Colloquium on Linking Knowledge with Action for Sustainable Development, National Academies of Science, April 2008
- The topic of the Roundtable meeting on 27 June 2012 on "Sustainable Energy and Materials:  Assessing the Landscape"

# A Few Thoughts about How the Three Concepts Relate to Each Other:

- Nested in time frames:  adaptation focused on the relatively near-term, resilience on the mid-term, sustainability on the long-term?
- Actions vs. outcomes:  adaptation focused on actions, resilience and sustainability on outcomes
- Linkages:  adaptation focused on local contexts, resilience also relatively local but related to integrating bottom-up and top-down driving forces, sustainability fundamentally rooted in linkages
  - Sustainability of a local context depends on sustainability of critical linkages:  inputs, outputs, and threats – interruptions of linkages mean disruptions
  - Sustainability of any one location/system cannot be assured when other locations/systems are not sustainable – resulting instabilities are very likely to spill over, sooner or later, directly or indirectly

# Thoughts about How the Three Concepts Relate to Each Other in Time:



# Thoughts about How the Three Concepts Relate to Each Other:

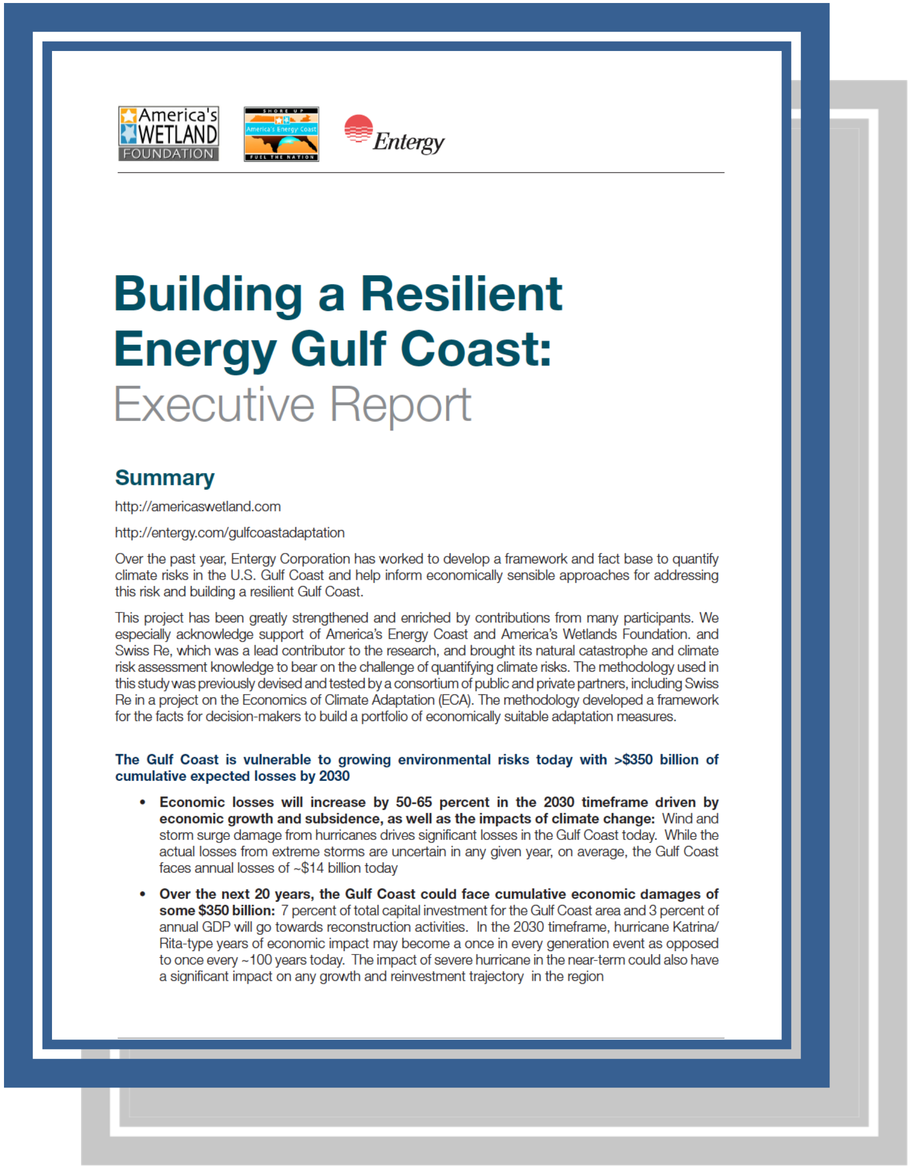
- **Nested in time frames: adaptation focused on the relatively near-term, resilience on the mid-term, sustainability on the long-term?**
- **Actions vs. outcomes: adaptation focused on actions, resilience bridging the two, and sustainability on outcomes**
- **Linkages: adaptation focused on local contexts, resilience also relatively local but related to integrating bottom-up and top-down driving forces, sustainability fundamentally rooted in a host of linkages**
    - **Sustainability of a local context depends on sustainability of critical linkages: inputs, outputs, and threats to them – interruptions mean disruptions**
    - **Sustainability of any one location/system cannot be assured when other locations/systems are not sustainable – resulting instabilities very likely to spill over, sooner or later, directly or indirectly**
- **What is clear is that strategies and actions for one goal should also be supportive for the others – some dangers from tunnel vision, especially regarding adaptations that reflect localized agendas**

# Consider, for Example, Possible Responses of Energy Facilities to the Kinds of Coastal Vulnerabilities Exposed by Hurricane Sandy:

- **Assuring sustainability requires increased resilience to coastal storm surges, flooding, winds, and sea-level rise, which requires near-term adaptations – some (many?) transformational: fundamental changes in the attributes, composition, structure, or scale of a system and/or of its location**
- **Transformational adaptations to achieve increased resilience are:**
  - **Protection: e.g., seawalls or dikes**
  - **Hardening: e.g., strengthening or raising structures**
  - **Relocation to less vulnerable areas**
- **Responses to coastal vulnerabilities differ for oil/gas facilities vs. electricity generation facilities:**
  - **Oil/gas: national markets, short-term protection, longer-term relocation**
  - **Electricity generation: regional markets preclude relocation**

# An Example of Energy Sector Leadership in Addressing Threats to Resilience and Sustainability Head-on:

- Entergy, a major Gulf Coast electric utility, is concerned about the sustainability of its regional customer base in the face of threats from climate change plus land subsidence
- They have conducted a study of how to assure the resilience of their region to such threats, and therefore its demographic and economic sustainability
- Including analyzing costs and benefits of a range of adaptation options, in order to enhance resilience



# 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

## Key areas examined within 70 miles of the coast

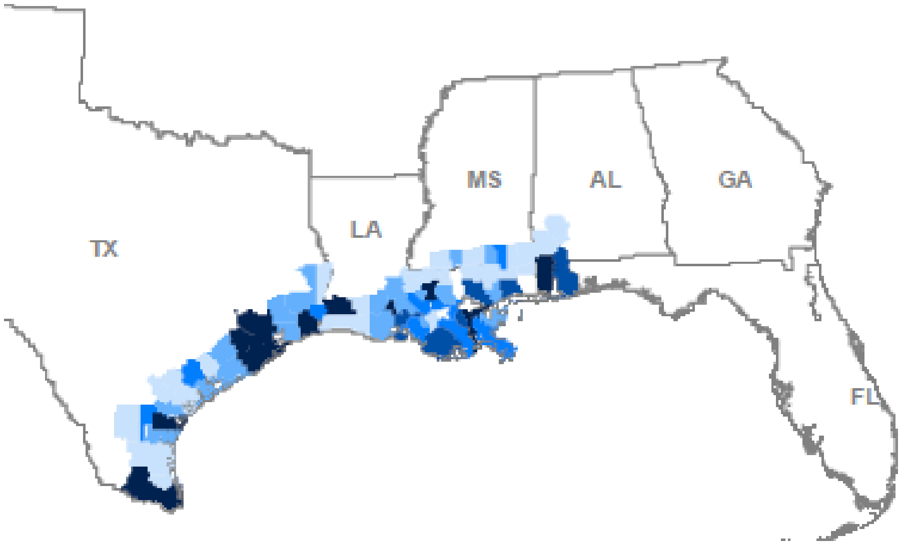
### US Gulf Coast region and counties in scope[1]

**2010 GDP ($M)**

- ▢ ≤1,000
- ▢ 1,000-2,500
- ▢ 2,500-5,000
- ▢ 5,000-10,000
- ■ >10,000

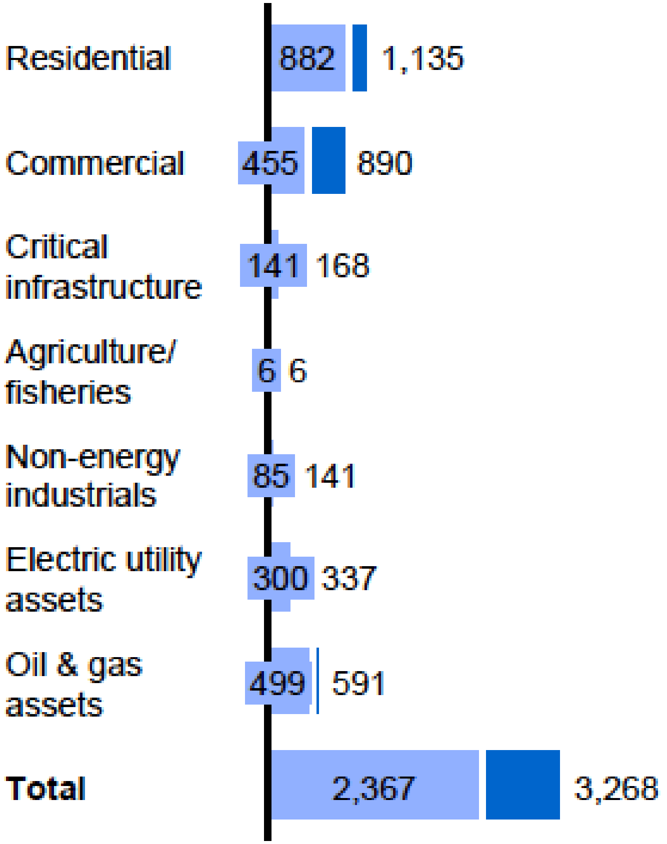
**Basic metrics**

| | |
|---|---|
| *Counties* | 77 |
| *Area* | 61,685 sq. mi |
| *GDP* | $634 B |
| *Population* | 11.7 million |



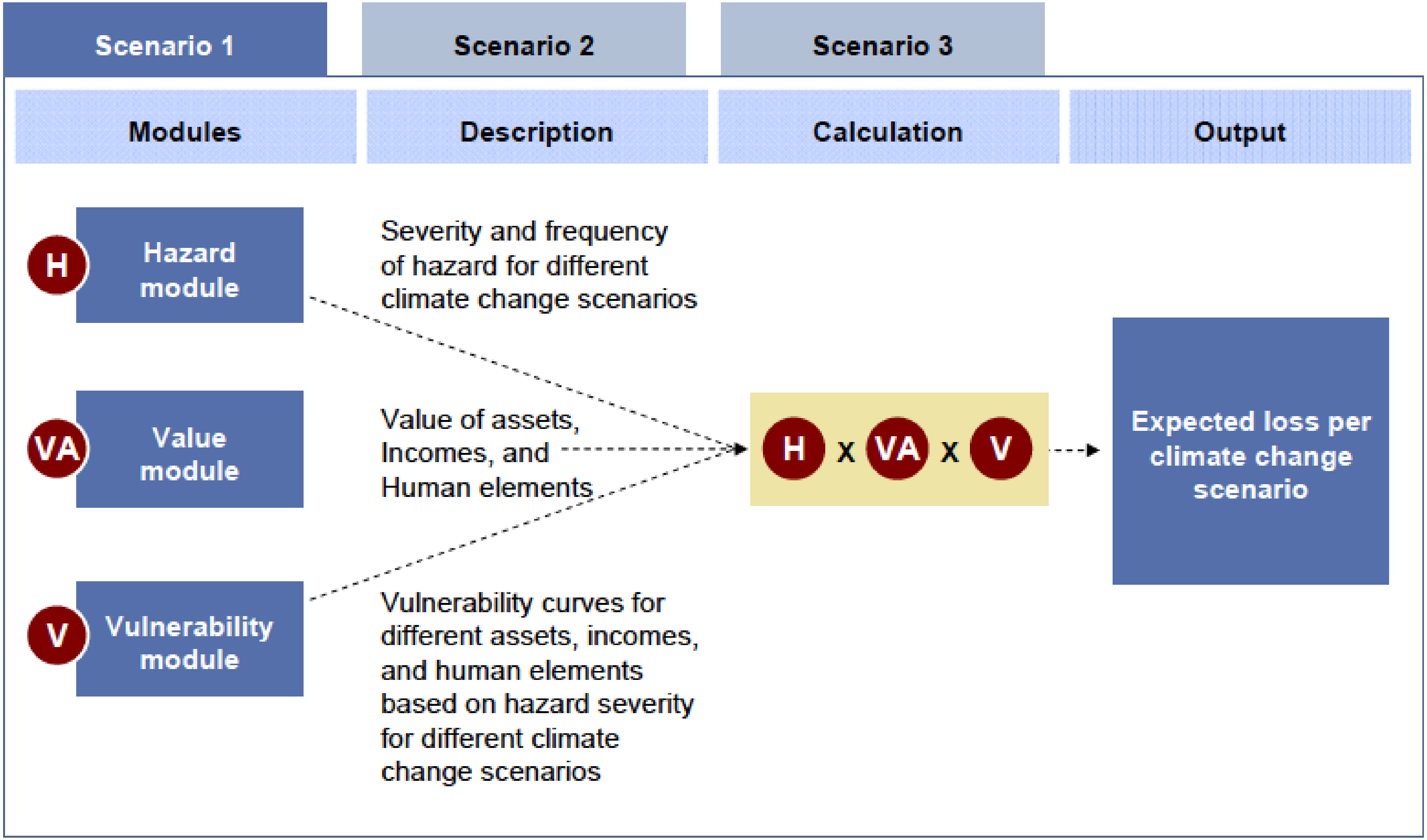
## Asset values by class

**Replacement value by class**
$ Billions, 2010 dollars



1 Includes 30 Louisiana parishes

Source: ESRI; Energy Velocity

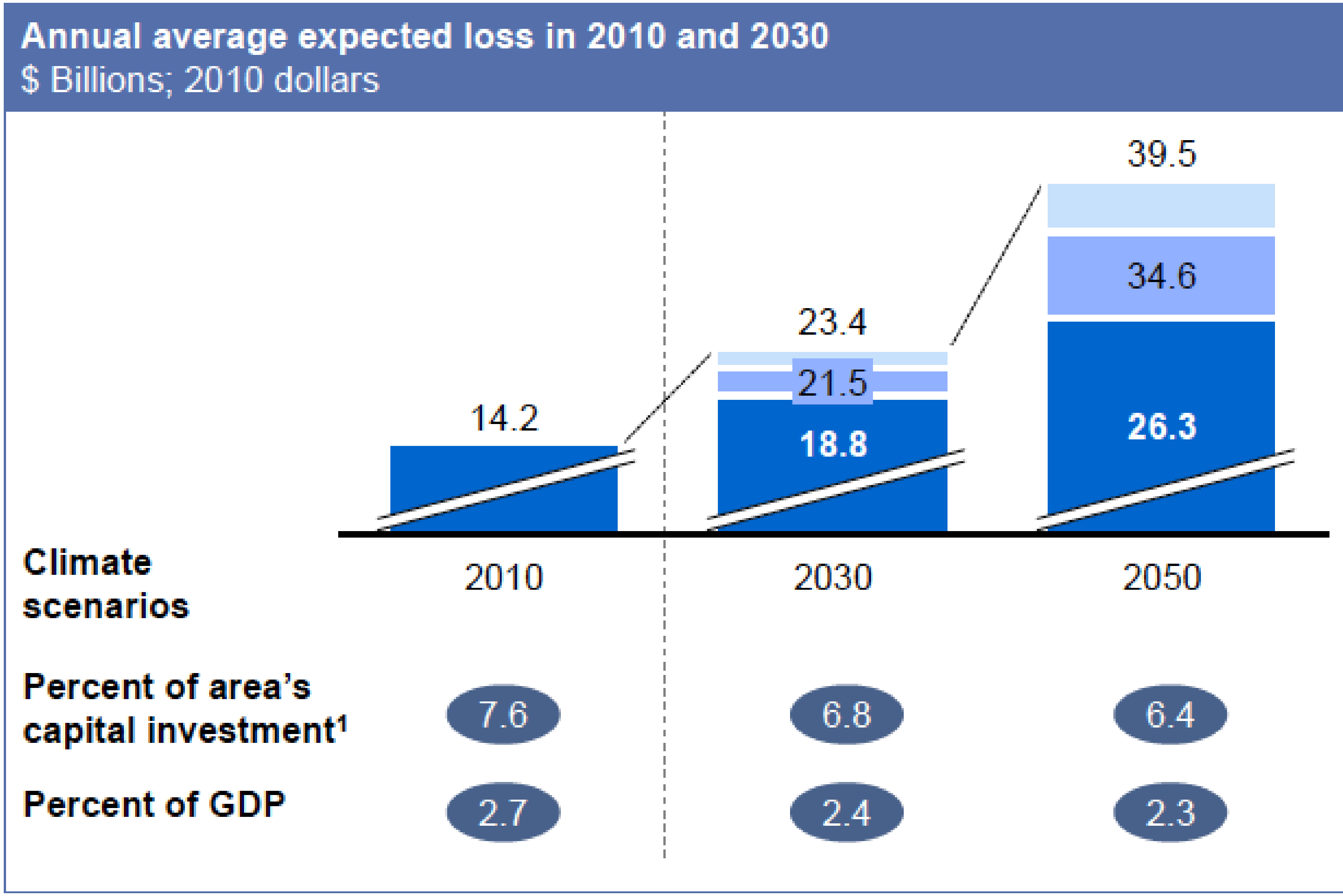


Severity and frequency of hazard for different climate change scenarios

Value of assets, Incomes, and Human elements

Vulnerability curves for different assets, incomes, and human elements based on hazard severity for different climate change scenarios

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



**Annual average expected loss in 2010 and 2030**
$ Billions; 2010 dollars

**Average annual losses can increase significantly by 2100 (to $131-211 M)**

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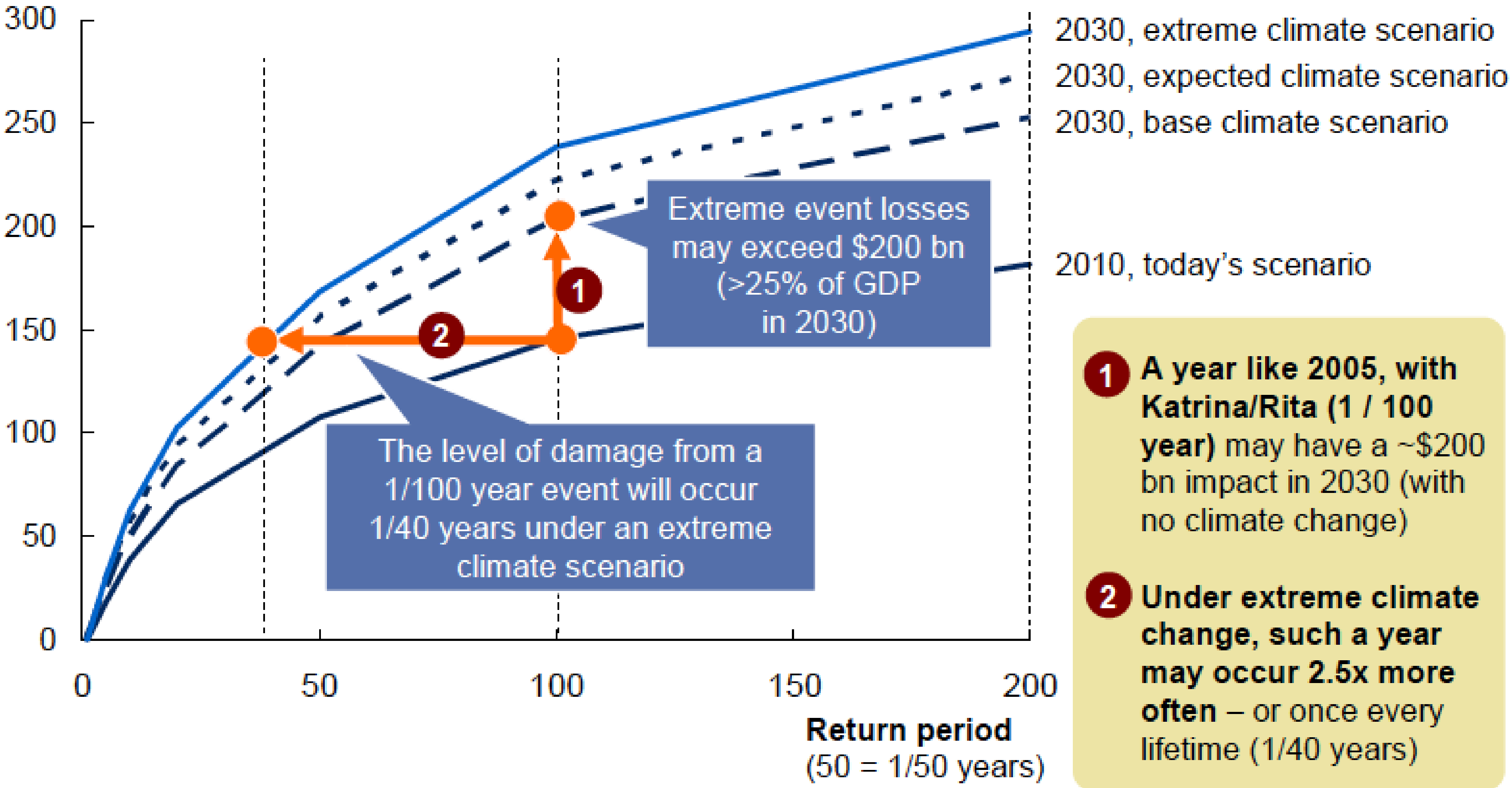
1 No climate change; includes impact of subsidence
2 Based on BEA historical average of capital investment (private and total government expenditures) as a percentage of GDP

Source: Swiss Re

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

**Loss frequency curve for annual loss**
$ Billions; 2010 dollars



Extreme event losses may exceed $200 bn (>25% of GDP in 2030)

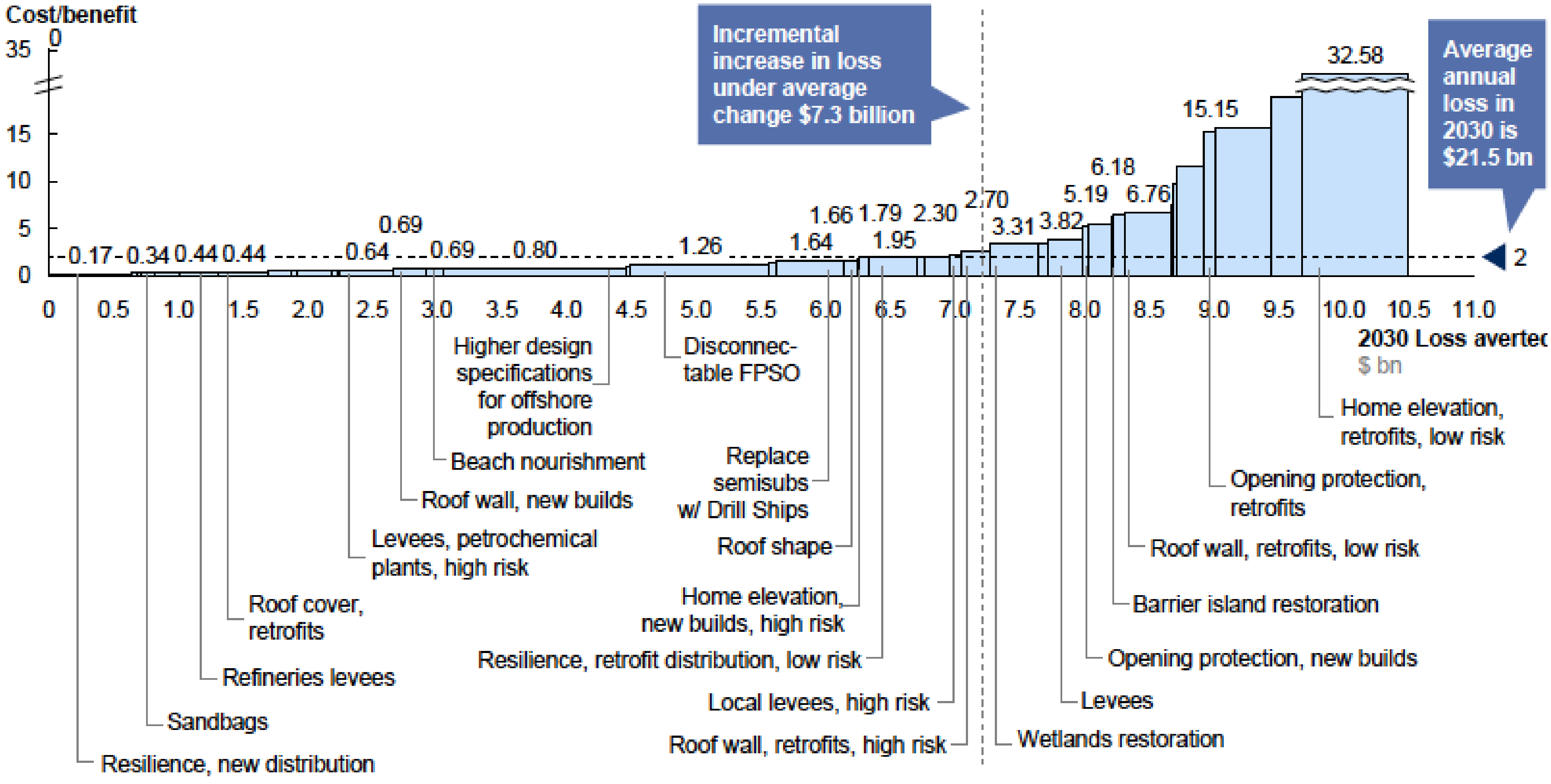
The level of damage from a 1/100 year event will occur 1/40 years under an extreme climate scenario

1. **A year like 2005, with Katrina/Rita (1 / 100 year)** may have a ~$200 bn impact in 2030 (with no climate change)

2. **Under extreme climate change, such a year may occur 2.5x more often** – or once every lifetime (1/40 years)

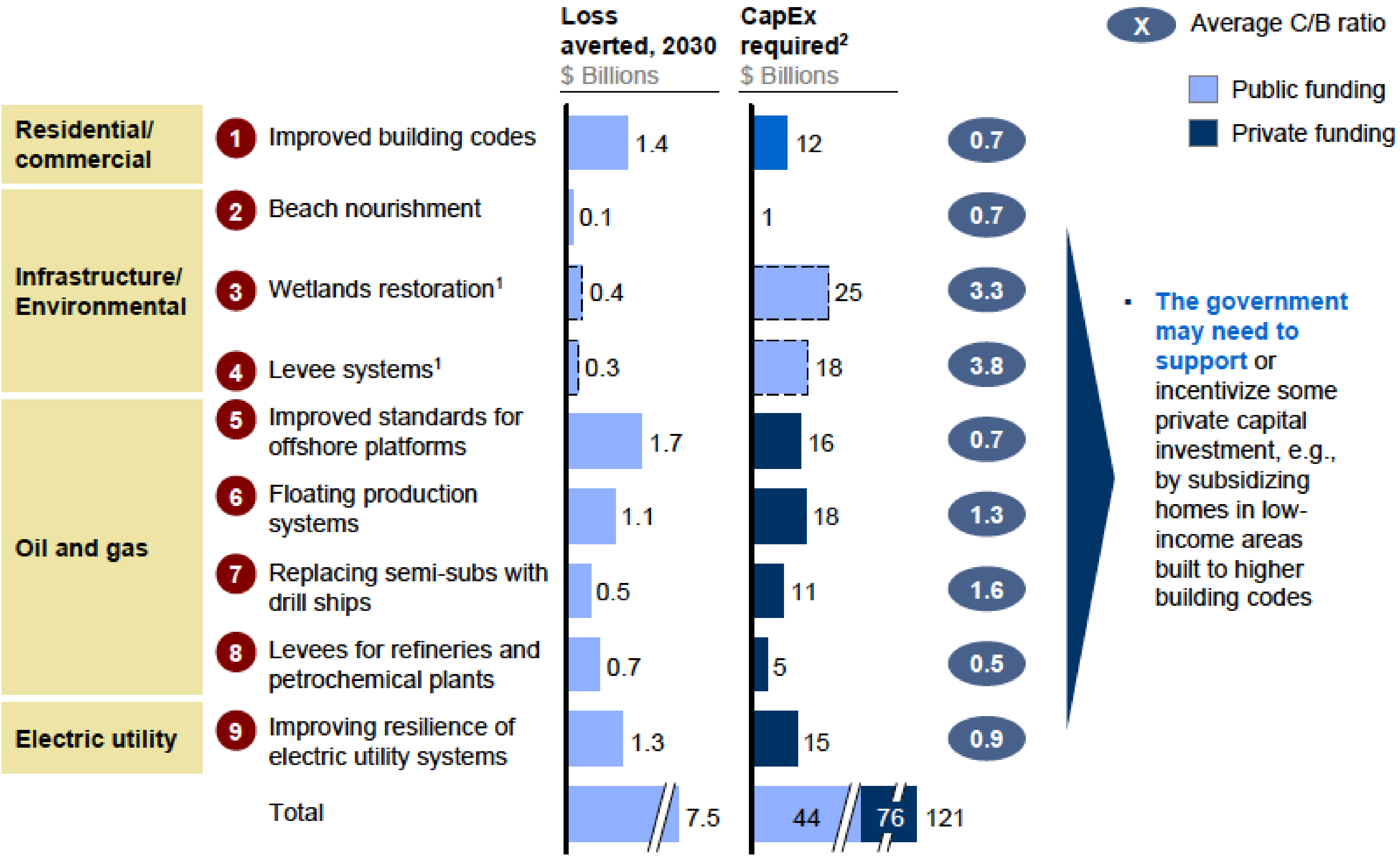
Source: Swiss Re; Press searches

# 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



# 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



| | | | Loss averted, 2030<br>$ Billions | CapEx required[2]<br>$ Billions | Average C/B ratio |
|---|---|---|---|---|---|
| **Residential/ commercial** | 1 | Improved building codes | 1.4 | 12 | 0.7 |
| **Infrastructure/ Environmental** | 2 | Beach nourishment | 0.1 | 1 | 0.7 |
| | 3 | Wetlands restoration[1] | 0.4 | 25 | 3.3 |
| | 4 | Levee systems[1] | 0.3 | 18 | 3.8 |
| **Oil and gas** | 5 | Improved standards for offshore platforms | 1.7 | 16 | 0.7 |
| | 6 | Floating production systems | 1.1 | 18 | 1.3 |
| | 7 | Replacing semi-subs with drill ships | 0.5 | 11 | 1.6 |
| | 8 | Levees for refineries and petrochemical plants | 0.7 | 5 | 0.5 |
| **Electric utility** | 9 | Improving resilience of electric utility systems | 1.3 | 15 | 0.9 |
| | | Total | 7.5 | 44 / 76 / 121 | |

- **The government may need to support** or incentivize some private capital investment, e.g., by subsidizing homes in low-income areas built to higher building codes

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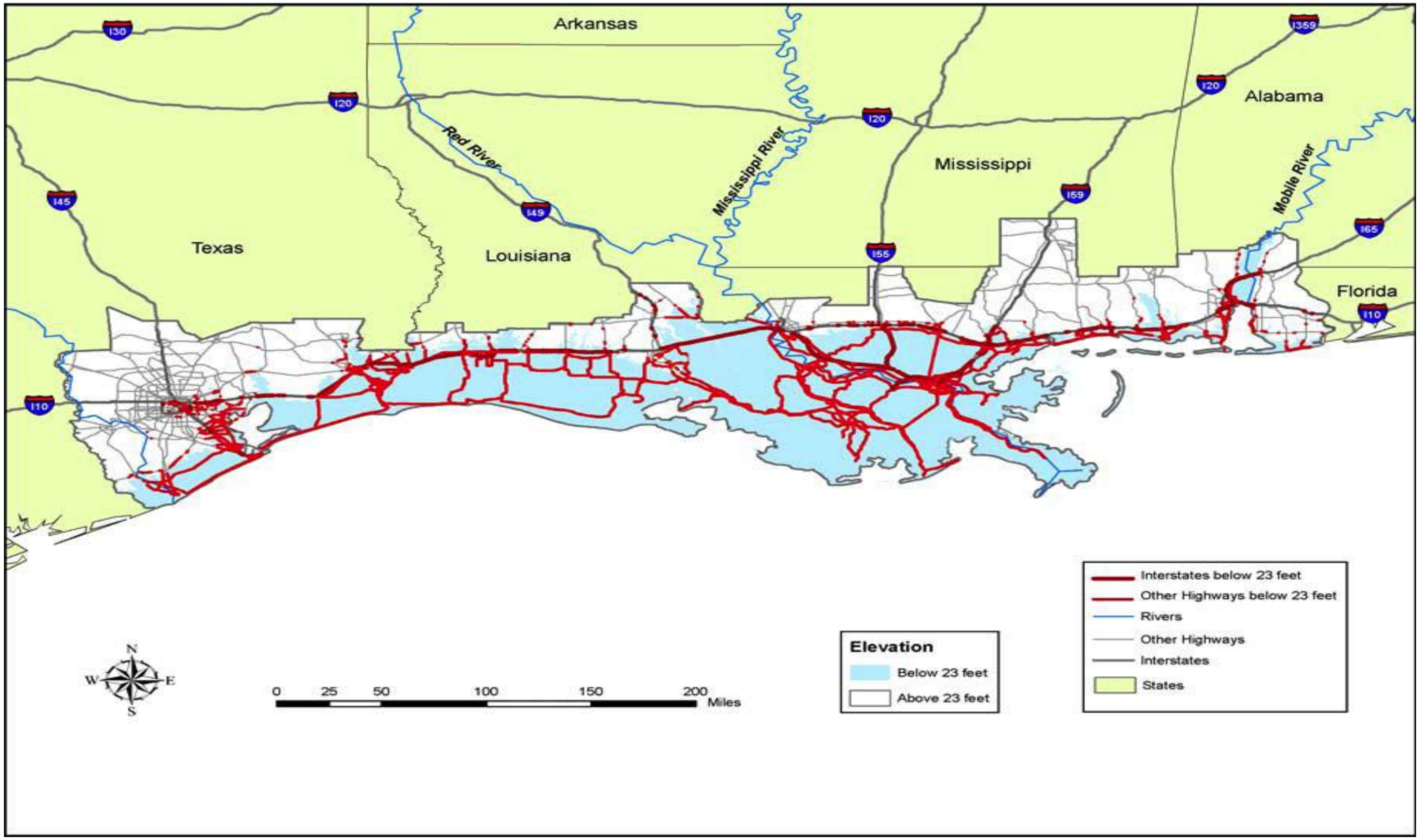
1 Included despite high C/B ratios due to strong co-benefits, risk aversion

2 Total capital investment, non-discounted, across 20 years

# Among the Major Current Issues Regarding the Three Concepts Are:

- **How to *measure* adaptive capacity, resilience, and sustainability:**
  - **More vs. less**
  - **Getting better or not**
  - **Better than system X or not**
  - **Meets a standard/certification requirement or not**
- **Prospects that in some (many?) cases, change management may require *transformational* actions, not just incremental, because some threats are growing (Kates, Travis, and Wilbanks, PNAS, 2012):**
  - **A familiar response *after* a disaster**
  - **But sustainability may call for *anticipatory* transformations**
    - **How can such anticipatory responses be encouraged and sustained?**
    - **What are the ways to get such a process started?**

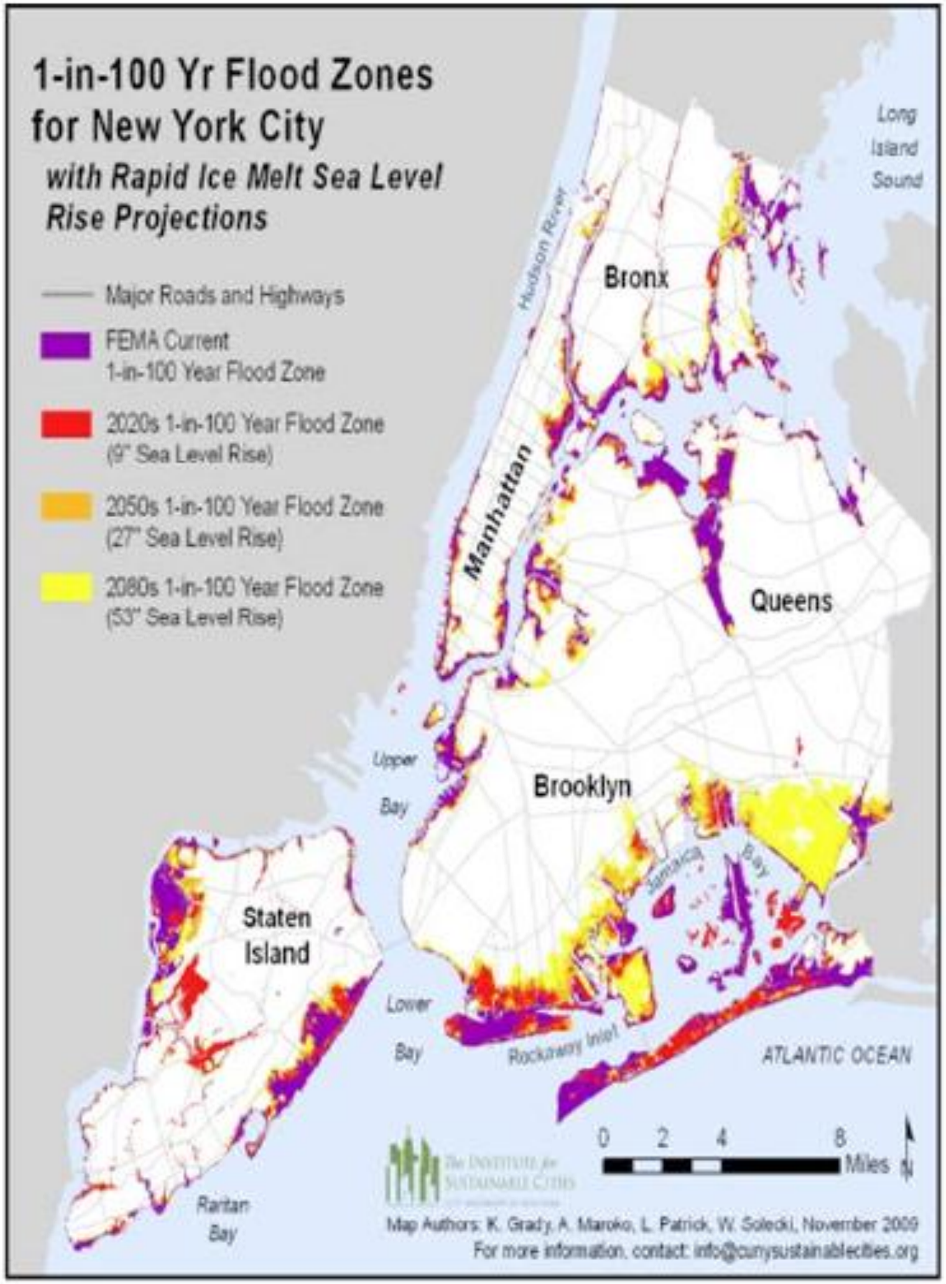
# AS ONE EXAMPLE: GULF COAST HIGHWAYS CURRENTLY AT RISK FROM STORM SURGE AT ELEVATIONS CURRENTLY BELOW 7.0 M (23 FT.) – CCSP SAP 4.7, 2009



## Atlantic City: Today's 100-Year Flood Could Become a Two-Year Flood by 2100

The top image shows the location of Atlantic City, NJ, on Absecon Island. The light blue area in the bottom image depicts today's FEMA 100-year flood zone (which extends beyond the area shown). Currently, this area has a 1 percent chance of being flooded in a given year. By 2100, this approximate area is projected to flood, on average, once every year or two under either emissions scenario, inundating high-tourist-value hotels and casinos. Under the higher-emissions scenario, the new 100-year flood height would be roughly four feet greater in 2100 than today, flooding a far greater area than the current FEMA flood zone.

# In the Most Severe of the Climate Change Scenarios, Current Land Uses in Some Coastal Parts of the NYC Metropolitan Area May Be Difficult to Sustain



1-in-100 Yr Flood Zones for New York City

*with Rapid Ice Melt Sea Level Rise Projections*

Map Authors: K. Grady, A. Maroko, L. Patrick, W. Solecki, November 2009

For more information, contact: info@cunysustainablecities.org

# Locations in New York City Power Plants Relative to 10-foot Elevation Contour

# Possible Needs for Transformational Changes for Energy Systems in Order to Assure Resilience and Sustainability Include Both Location and Linkages (I):

- **A source of serious private sector concern regarding business continuity, facing the certainty of climate change impacts combined with other risk factors**
- **Prospects for changes in the energy facility map over time, reflecting reductions in exposures to risks in especially vulnerable areas**
- **Related to risks associated with linkages, e.g. experience with:**
  - **Linkages between locations: offshore and onshore oil and gas operations**
  - **Linkages between energy systems: electricity outages affecting oil refinery and natural gas compression/pumping activities (Northeast blackout of 2003, Hurricane Katrina, 2005)**
  - **Linkages between energy systems and socioeconomic contexts: electricity outages caused by disruption/displacement of consuming populations rather than by flooding or wind (Hurricane Katrina)**
  - **Linkages between energy systems and other infrastructures: vulnerabilities of “smart grids” to interruptions in communication infrastructures**

# Possible Needs for Transformational Changes for Energy Systems in Order to Assure Resilience and Sustainability include Both Location and Linkages (II):

- **Private sector moving toward vulnerability assessments, vulnerability reduction strategies, and stronger emergency response capacities**
- **Combined with improved monitoring of emerging evidence to inform iterative risk management**
- **Plus gap-filling technology development targeted on key vulnerabilities (e.g., from above-ground transmission lines or effects of ocean acidification on offshore facilities) – potentials for innovative public-private sector partnerships**
- **In many cases, headed toward near-term adaptation, together with consideration of transformational actions as current infrastructures are replaced or revitalized over the next 30 years or so**

# THANK YOU !

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