The Vulnerability of Energy Infrastructure to Sea-Level Rise and Climate Variability and Change

Testimony to the Senate Energy and Natural Resources Committee

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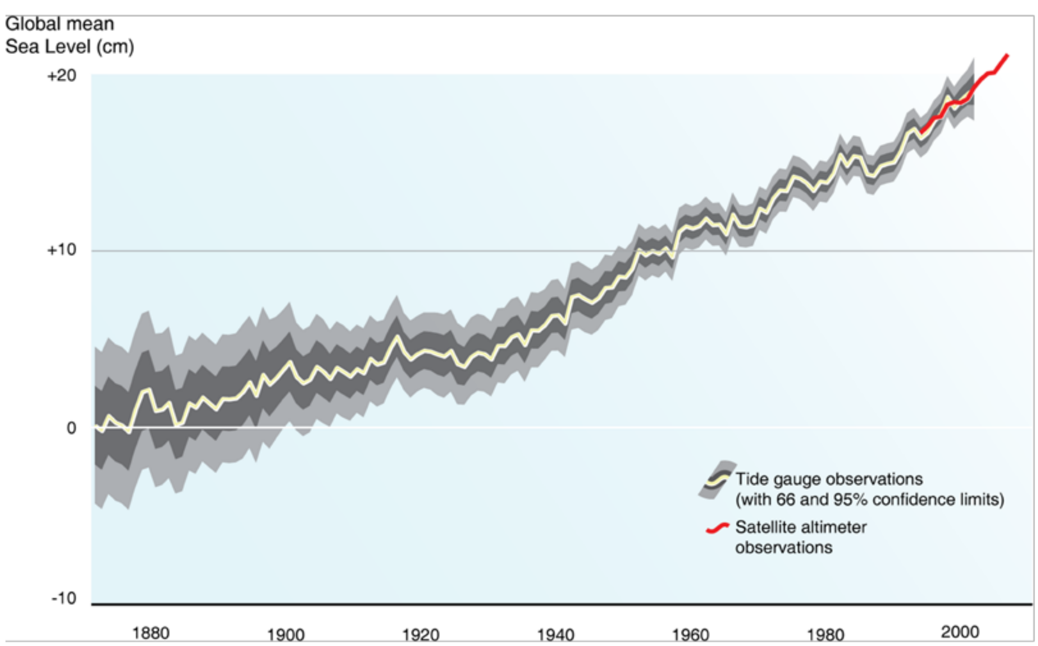
Good morning, Mr. Chairman and members of the Committee. Thank you for inviting me to testify this morning. I am very pleased to be able to speak briefly on the topic of the vulnerability of the energy infrastructure to sea-level rise, and more broadly to climate variability and change.

A Concise Summary of Current Knowledge

Other witnesses on this panel will speak to the scientific issues behind rising sea-levels. The figure below, drawn from the last scientific assessment of the Intergovernmental Panel on Climate Change, shows mean global sea-level changes over the past century (figure provided by V. Burkett).

Global Mean Sea Level Rise, 1870-2006

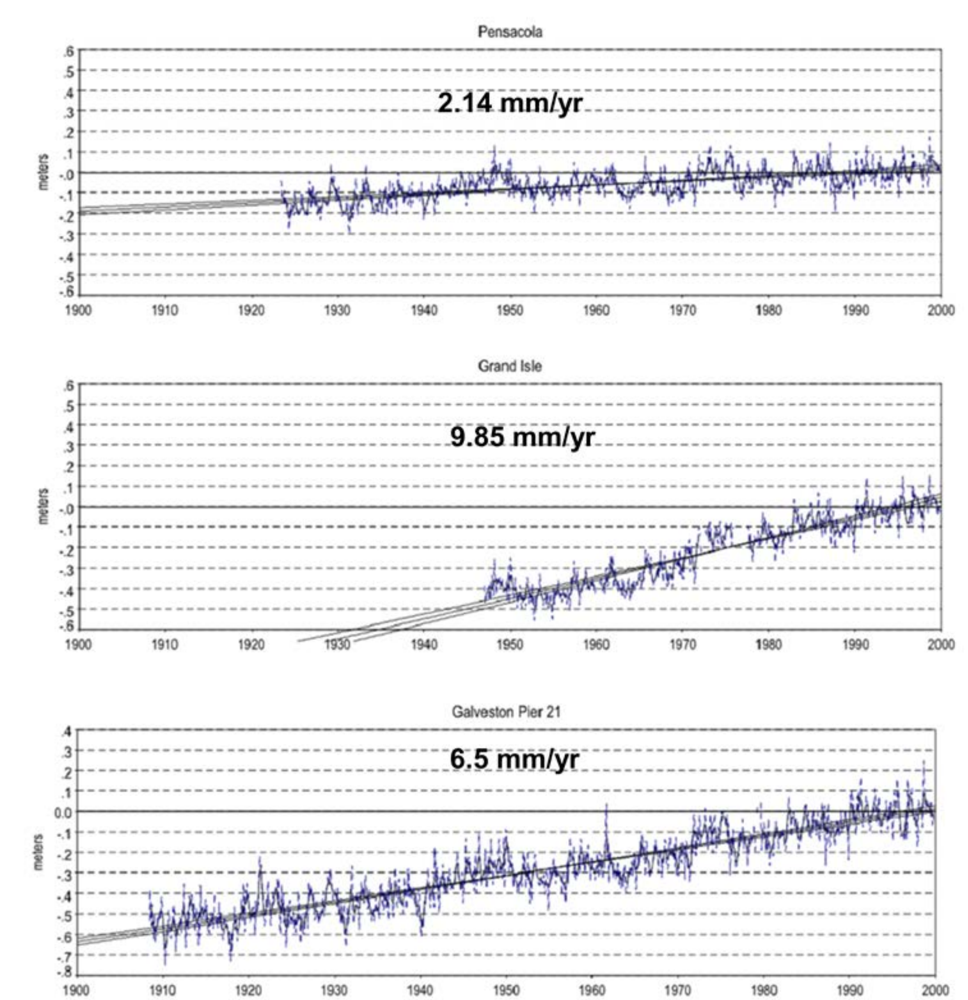


Church, J.A. and White, N.J. (2006)

http://maps.grida.no/go/graphic/trends-in-sea-level-1870-2006

By the year 2100, global sea-level could rise somewhere between an additional 20 cm and 60 cm, depending on what emissions trajectory the world ends up on, and how sensitive the interacting processes of thermal expansion and glacier ice dynamics are to rising temperatures, both globally and regionally. The science in this area is quite dynamic, and some of the physical uncertainties are large, making detailed predictions difficult.

In any particular coastal region, sea-level rise is governed not only by the dynamics of the global ocean, but by the particular physical forces at work in that region itself. So, for example, local bathymetry is important on the ocean side, and so are the dynamics of the land itself – whether it is subsiding, as in much of the Gulf Coast, for example, or rising, as in parts of the Pacific Northwest. Examples from several locations in the Gulf are shown below (figure provided by V. Burkett).



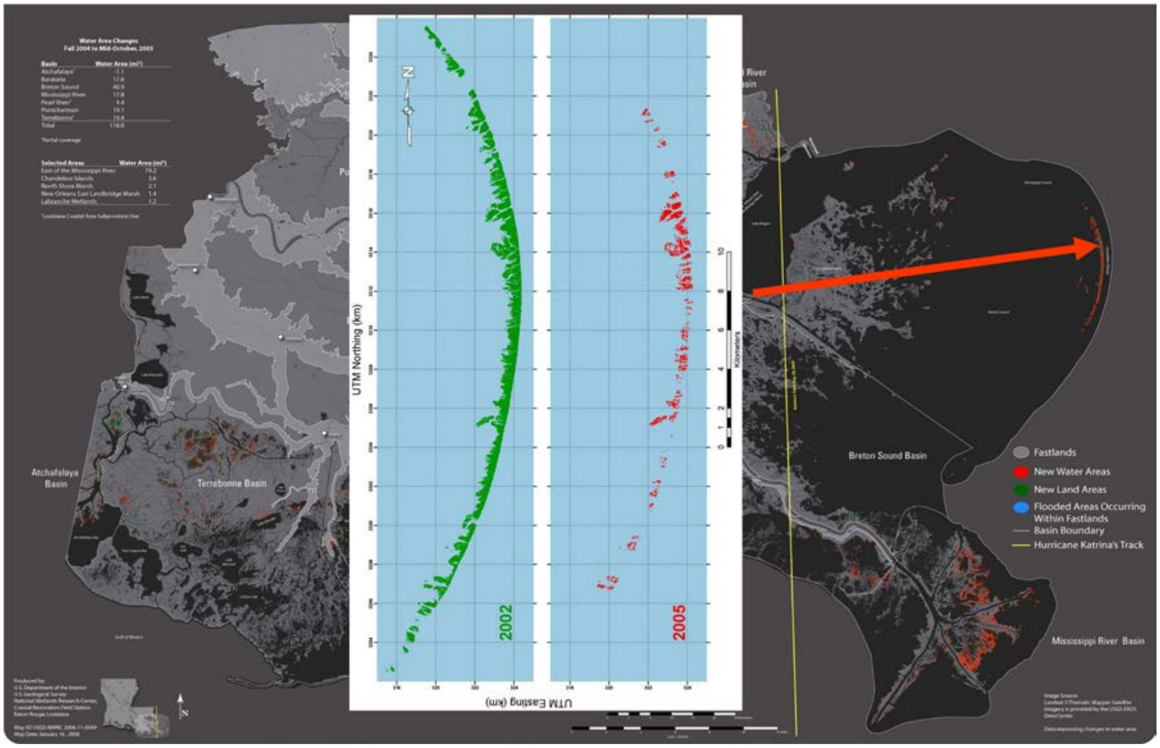
NOAA Historical Tide Gauge Data (1900-2000)

But regardless of the particular rates of sea-level rise in any one place, it is clear that there is always some degree of concern about potential impacts of infrastructure to rising sea-level, for many reasons. This concern can be divided into two parts. The first aspect is the degree to which infrastructure is exposed to current or increased physical impacts of rising seas.

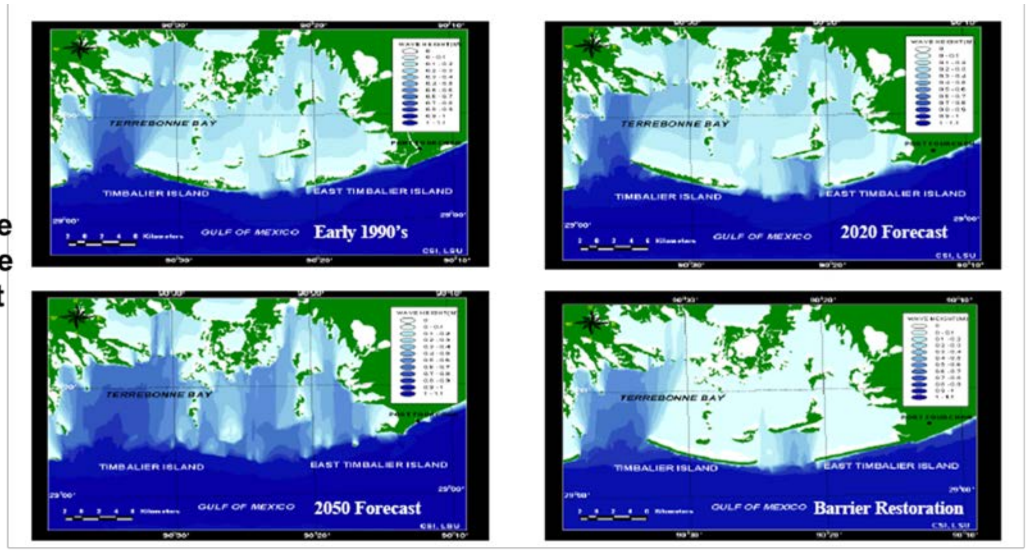
One of the biggest concerns in this respect is storm surge, the risk of which increases as sea-level rises for the simple reason that there is more water to be transported by winds, tides, and waves. So even without changes in frequency or intensity of storms, rising sea-levels will lead to greater storm surge, and therefore greater risk to existing infrastructure. An example of why storm surge is of such importance is shown by Hurricane Katrina, whose initial surge was more than 25 feet at the time of landfall. Katrina's effects included a reduction in oil production of roughly 19% for the year through disruption of energy infrastructure, and linked transportation infrastructure (summarized in Wilbanks et al 2012a).

The presence or absence of barrier islands can make a very large difference in the amount of physical energy that near-shore or on-shore infrastructure is exposed to. Barrier islands can absorb a large amount of wave energy by acting in effect as natural seawalls, and thereby reduce (but not eliminate) the exposure of infrastructure to the effects of waves and storm surge (figures below from V. Burkett).

Increased storm intensity amplifies the effects of sea-level rise



Change in Wave Height

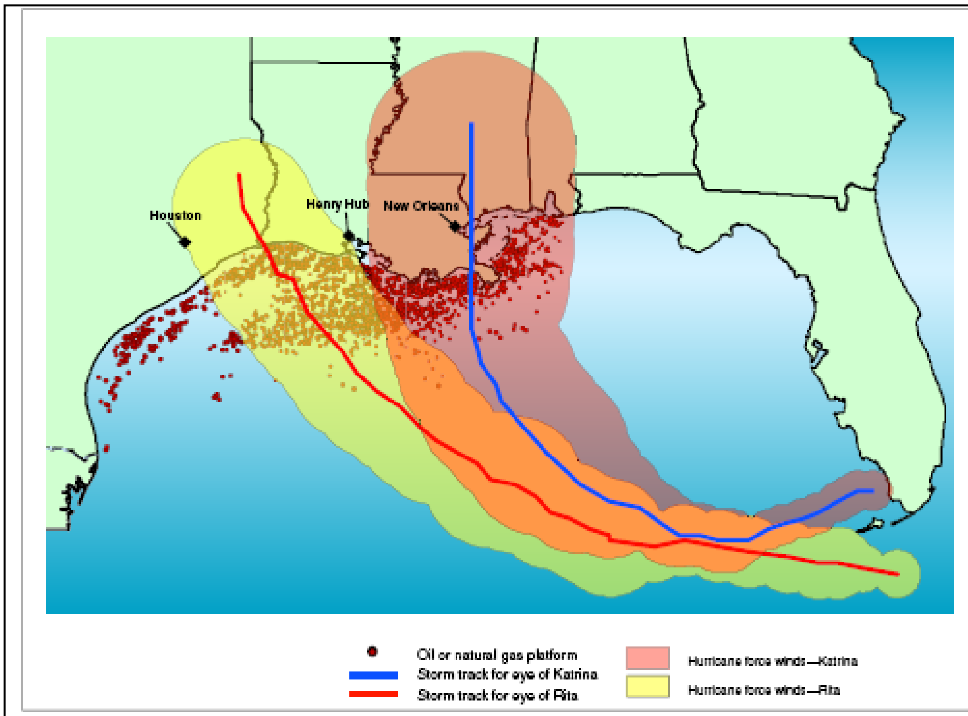


8'-10' Change in Storm Surge, 1950-1990

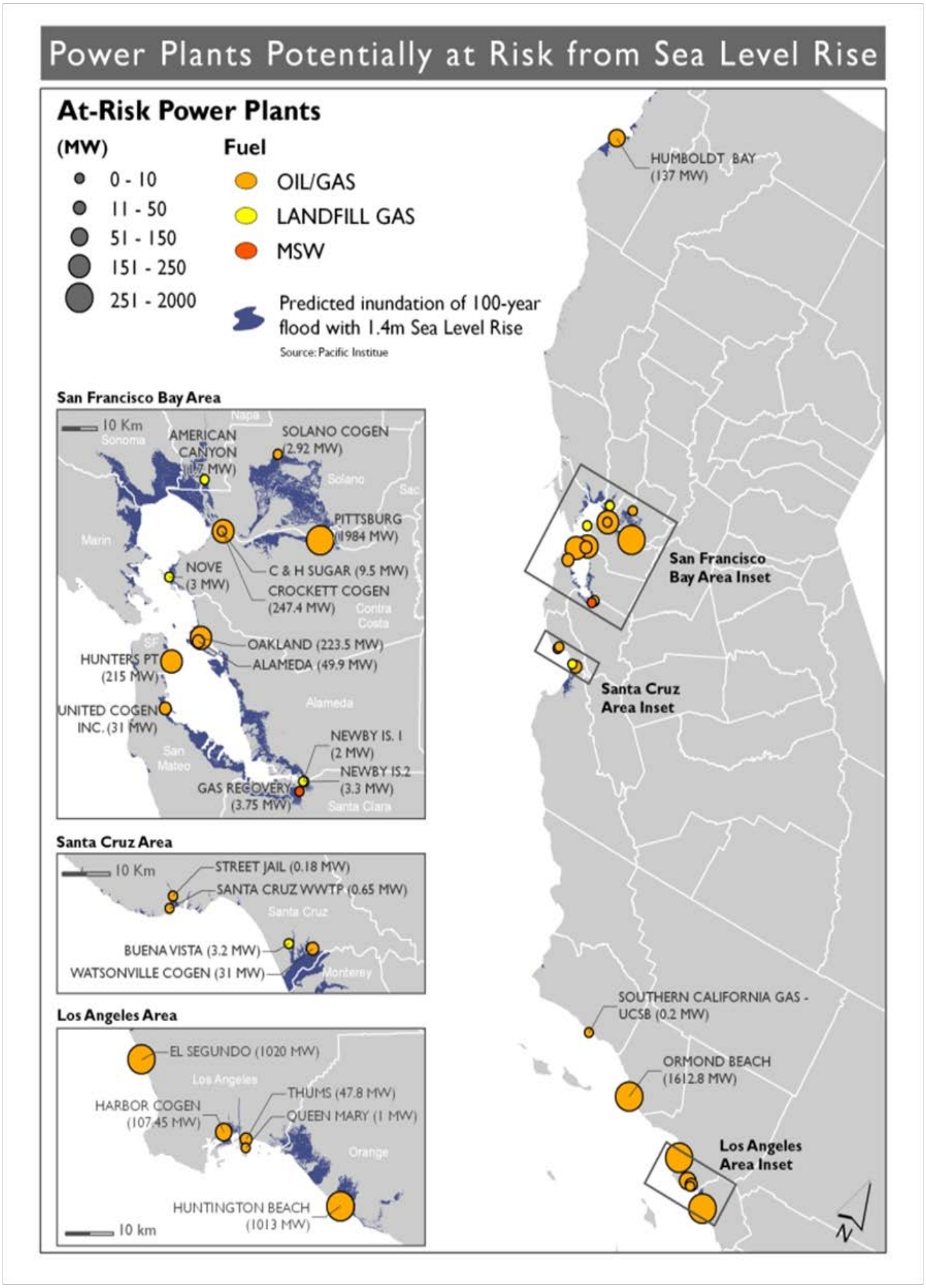
(Stone *et al.* 2003)

If storm frequency or intensity were to change as a consequence of longer-term changes in the physical climate system, that would also have an effect on exposure to physical impacts. The science is mixed on these points, with recent scientific assessments from the US Global Change Research Program (2010) suggesting that increases in tropical storm frequency is not well-supported by the science, but that tropical storm intensity is likely to increase over the coming decades.

The second major component of the potential impacts of sea-level rise and climate variability and change on energy infrastructure is the intrinsic vulnerability of the existing infrastructure. Infrastructure that is already situated in coastal waters, or energy generation, transportation, or grid infrastructure that is on the coasts is variously vulnerable to storms, erosion, temperature extremes, and other aspects of the physical climate system. Some of this vulnerability comes simply from location. Several scientific assessments and papers identify the locations of major collections of energy and other infrastructure in the Gulf region, for example (Burkett, Wilbanks, CCSP study). These clearly are vulnerable to the effects of tropical storms and the rising sea-level of the Gulf. But the Gulf is not the only region with infrastructure that is potentially vulnerable. The Hampton Roads/Newport News region of Virginia, for example, has been recognized both by NOAA and USGS as being potentially quite vulnerable to sea-level rise impacts, and there are power plants in coastal regions of California that have been identified as potentially vulnerable (figures below from Wilbanks et al 2012a and 2012b).



Source: GAO analysis of data provided by the National Weather Service and the Minerals Management Service.



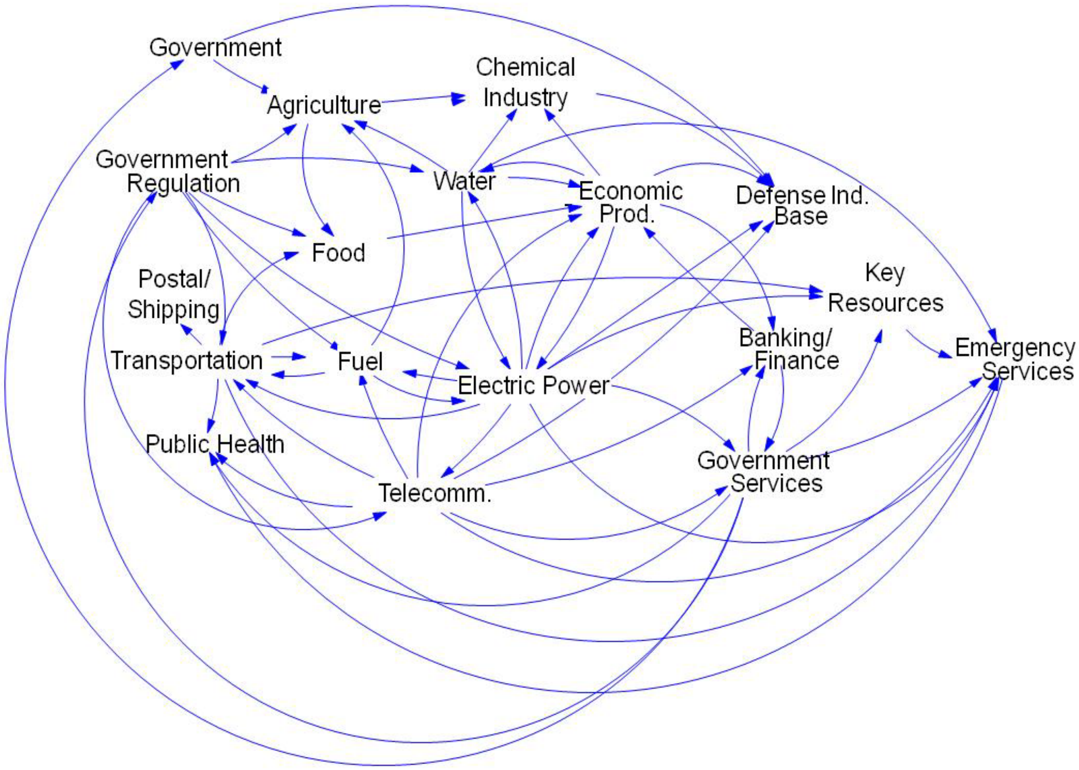
Operators of equipment in the Gulf already recognize, and have operational policies in place to deal with the existing stresses caused by the physical environment in the Gulf. But it is not clear yet what additional procedures might need to be put in place to adapt to changing conditions, in large part because of the difficulty in projecting climate variability and sea-level rise on regional scales.

Burkett (2011) identifies six primary drivers of vulnerability of coastal (both on-shore and off-shore) energy infrastructure:

- Increased ocean and atmospheric temperature
- Changes in precipitation pattern and runoff
- Sea-level rise
- More intense storms
- Changes in wave regimes
- Increased dissolved CO_2 and ocean acidity

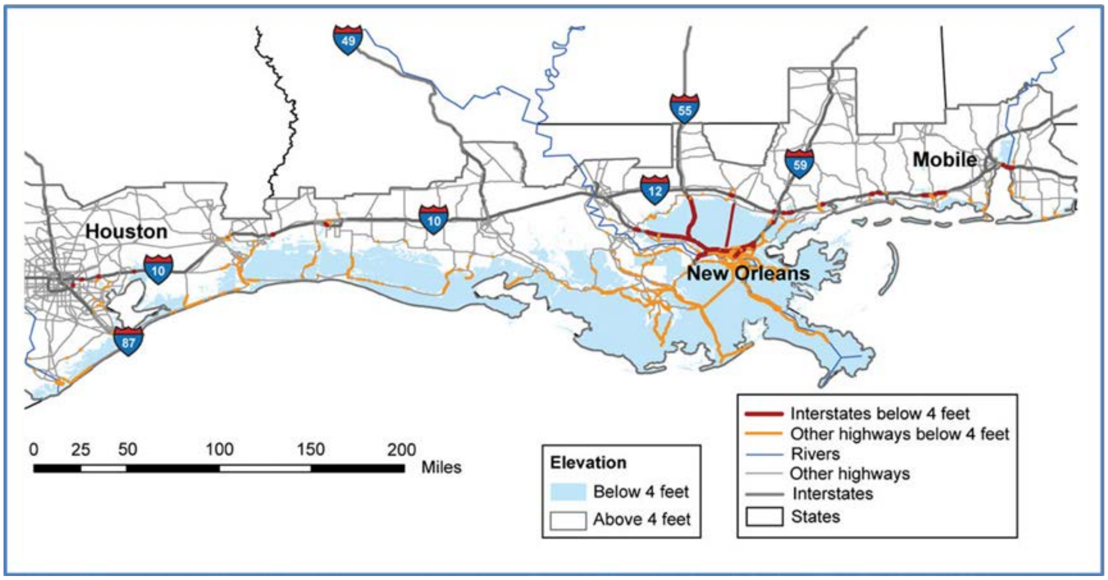
This list of physical drivers of vulnerability recognizes that both changes in the ocean environment and the near-shore terrestrial environment (e.g. runoff) as well as the climate system itself have potentially important implications for energy and other infrastructure.

Wilbanks and colleagues (2012a,b) point out that the vulnerability of the energy sector's physical infrastructure is also linked to the vulnerability of other societal infrastructure – in particular, the condition and vulnerability of the transportation sector to similar physical stresses. Likewise, the vulnerability of the grid itself to changes in the physical climate system is important. There are both well-documented case studies from particular events (with an emphasis on the impacts of severe storms), and concerns about the potential for both average conditions and extremes to change over time. A major contribution of these assessments is the recognition that the delivery of energy services is a multi-sectoral phenomenon, and thus considerations of the linked vulnerabilities of major infrastructures should be part of an analysis of potential adaptation options. The figure below (Wilbanks 2012a) illustrates the complexity of sectoral interactions that affect the response of energy infrastructure to climate variability.



A particular example of known vulnerabilities of closely related sectors to energy comes from a major scientific assessment of the vulnerability of the transportation sector in the Gulf Region, jointly conducted by the US Department of Transportation and the US Geological Survey (CCSP 2008). One illustration of their results, the distribution of road and rail networks vulnerable to long-term inundation, is shown below.

Gulf Coast Area Roads at Risk from Sea-Level Rise

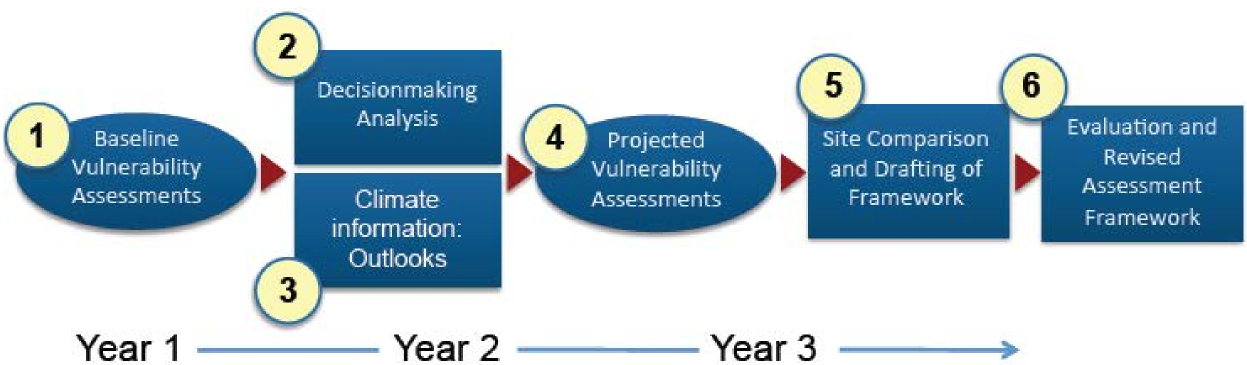


What Can Additional Research Contribute?

While the scientific community and both the public and private sectors are assessing what is known about current risks and vulnerabilities, there are many knowledge gaps that make assessing future risks and vulnerabilities difficult. These gaps provide an opportunity for additional contributions from both fundamental and applied research.

In order to help identify some of the knowledge gaps, we provide an overall framework based on a research project in our own laboratory, supported by SERDP, that will do a vulnerability analysis of military installations (Moss, personal communication).

Overview of research approach for vulnerability assessment of DoD installations



When adapted to the needs of the energy sector, and particularly to issues associated with understanding the vulnerability of that sector to sea-level rise and other changes in the physical climate system, this framework provides a guide to several potentially important interdisciplinary research topics.

- We clearly need to improve our understanding of the interactions of energy demand and supply with other sectors, including land-use and water, but also transportation. Along with this integrated understanding should come the ability to model integrated systems on regional scales.

- At the same time, determine the sensitivity of the energy sector to other stresses and forcing agents, e.g. changes in population, in demand for energy services, in cooling technologies, in the productivity of terrestrial and coastal ecosystems, in the availability of alternative renewable sources of energy such as hydropower and biofuels.

- Understanding and quantifying regional climate change, and other regional changes in the physical environment, such as sea-level rise and storm surge, is also a very high priority. The relationships between global changes in these physical systems and regional changes are complicated, but the scaling questions must be resolved so that decision-makers can analyze different possible scenarios of the future at scales that matter to their decisions.

- It is critically important to understand the potential magnitude of changes in the climate system, including the oceans, for several decades. But just as important will be fundamental research on other modes of variability in the climate system, including seasonal-to-interannual variability and any potential changes in storm frequency and intensity or other extreme events.

- And as important as it is to understand the changes in the physical environment, their forcing agents, and the processes that control how they affect important features of climate, or important aspects of sensitivity of natural systems, it is just as important to understand the human dimensions of change. A much better understanding, and the ability to model adaptation decisions must be sought in order to understand how different potential futures might be addressed in reasonable and thoughtful ways.

Thank you very much for your attention.

References

Burkett, Virginia. 2011. Global climate change implications for coastal and off-shore oil and gas development. Energy Policy 39:7719-7725.

Burkett, Virginia. Personal communication (figures).

CCSP. 2008. Impacts of climate change and variability on transportation systems and infrastructure: Gulf Coast study.

Moss, Richard. Personal communication (figure).

USGCRP. 2010. Global Climate Change Impacts on the United States. US Global Change Research Program. Washington, DC.

Wilbanks, Tom et al. 2012a. Climate change and infrastructure, urban systems and vulnerabilities. Technical Input Report to the US Dept. of Energy in support of the National Climate Assessment. Oak Ridge National Laboratory. 119 pp.

Wilbanks, T.W. et al. 2012b. Climate change and energy supply and use. Technical Input Report to the US Dept. of Energy in support of the National Climate Assessment. Oak Ridge National Laboratory. 90 pp.