Testimony of
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Before the U.S. Senate
Committee on Energy & Natural Resources

Hearing to examine the impacts of climate change on the reliability, security, economics and design of critical energy infrastructure in coastal regions

May 13, 2008

Introduction

Good morning Chairman Bingaman, Ranking Member Domenici, and distinguished members of the Committee. It is an honor to appear before you today to discuss the national energy infrastructure and its vulnerability to extreme weather events and climate change. I will also discuss some of the tools in development at the Department of Energy's national laboratories to guide policymakers on these issues.

I am Terry Wallace, the Principal Associate Director for Science, Technology and Engineering at Los Alamos National Laboratory. Los Alamos' mission is to develop and apply science and technology to ensure the safety, security and reliability of the U.S. nuclear deterrent; reduce global threats; and solve other emerging national security challenges. No emerging challenge is greater than that of energy.

Energy is the cornerstone of our nation's prosperity and the global demand is extraordinary. If the rest of the world's population enjoyed the U.S. standard of living today, it would require an immediate six-fold increase in energy production. Within a generation, energy demand will more than double.[1] The speed of this growth, and its global scale, are unlike anything we have experienced. While energy use in the US will grow more modestly over this period, we are interconnected to global demand through our infrastructure. Our national security vulnerabilities are intimately tied to this infrastructure. In this testimony, I will focus on how we are using today's best science to create tools to understand and mitigate vulnerabilities to our energy infrastructure from increased energy demand and climate change.

The Nation's Energy Infrastructure

The United States' energy infrastructure starts with the generation and delivery systems for our primary energy sources: electricity (dominated by coal and nuclear), liquid fuels (dominated by petroleum), and natural gas. There are 160,000 miles of electrical transmission lines connecting over 600 coal-fired plants and 65 nuclear plants, over 600 major sources of hydropower, and many smaller plants using renewable resources. The electrical backbone delivers power to consumers through 35,000 substations that ultimately reach 140,000,000 individual, commercial and industrial users. For petroleum, there are 180,000 miles of pipelines for oil and 300,000 miles for natural gas, supplying end users through a network of 150 refineries of liquid fuel, and through 1,900,000 miles of natural gas lines to consumers.[2]

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[1] Projections from the Energy Information Agency indicate a growth of 57% worldwide by 2030, or doubling in approximately 40 years. Scenario planning from LBL takes this as a lower limit, with an upper limit of 2.8% per year, or tripling in 40 years.

[2] http://www.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/ngpipeline/index.html
http://www.referenceforbusiness.com/industries/Transportation-Communications-Utilities/Petroleum-Pipelines-Refined.html
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http://www.eia.doe.gov/basics/quickelectric.html
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http://www.whitehouse.gov/energy/National-Energy-Policy.pdf
http://www.gasfoundation.org/ResearchStudies/SafetyReport.pdf
http://www.eia.doe.gov/neic/quickfacts/quickoil.html

However, the infrastructure is much more complex than just this backbone, and I will explore some of the ways that different elements are linked together and interdependent. Beyond the backbone, the energy infrastructure links directly to telecommunications, the banking system, public health, transportation, food, and manufacturing. Understanding the links helps us make better policy choices.

For example, electric power and water are linked. A 500 MWe coal-fired generating plant typically consumes 1.8 billion gallons of water per year. The use of this water impacts regional choices for farming, industrial, and residential use. The CO_2 emissions from such a plant will accelerate climate change, with both regional and global impacts on temperature. The availability of water will increasingly constrain economic growth. Changes in climate will affect where human populations grow or migrate. The changes in population create shifting demands, in turn, for energy and water, and these demands should guide the investments we are making today in our infrastructure. It is particularly urgent that we develop science-based tools now to inform these investments. While the timescale for climate change is long, today's energy choices will also be felt long into the future, because the lifetime of our capital investments in the energy backbone is more than 50 years.

Global climate change models have been developed with support by the DOE Office of Science, and several national laboratories play a strong role in this science, including Los Alamos. Climate change can lead to specific threats to our energy infrastructure, for example through flooding in coastal areas, and water shortages triggered by temperature rise and regional drought. These effects will be felt most acutely on our coasts, both because most of our population lives near the coast, and because many climate change impacts are concentrated at the coasts. This is illustrated in Fig. 1, which shows the proximity of electrical lines and substations to flood-prone areas in Baltimore, and the network of electrical generation and transmission facilities near California, which rely directly on water (hydropower and coal).

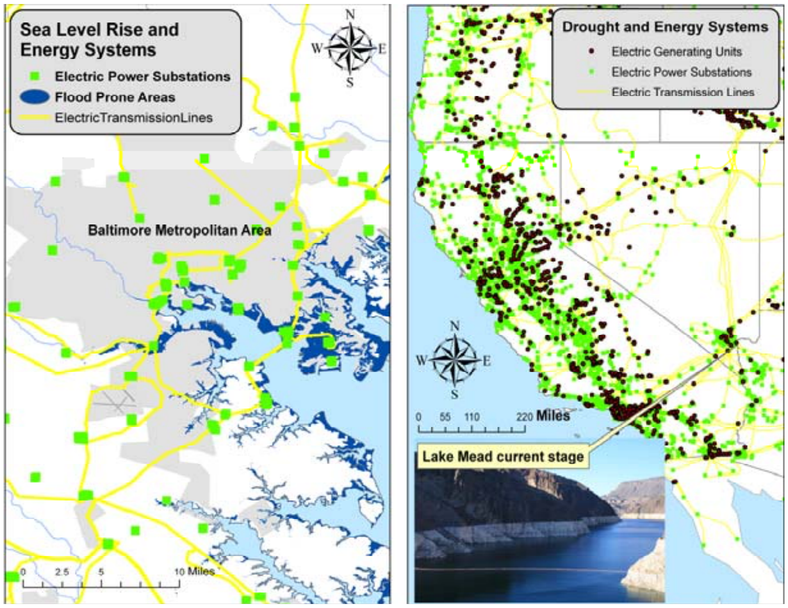

Figure 1: Coastal energy systems are vulnerable to climate change through flooding (left, Baltimore) and drought (right, southwest US).

Fragility and Storm Vulnerability

The national laboratories have developed infrastructure models to assess vulnerabilities in domestic infrastructures (to sudden events such as terrorist attacks or natural disasters). These models include best-in-class infrastructure data on US critical infrastructure sectors. They are already in wide-use by the federal government (such as the Department of Homeland Security's National Infrastructure Simulation and Analysis Center [NISAC],[3]) to improve our ability to prepare for and respond to natural disasters. The models allow predictions of where resources should be targeted to make the backbone more robust. They allow us to run scenarios that help train our emergency responders, and they help the government position disaster response resources at the locations where they can make the biggest difference.

For example, less than a month after Hurricane Katrina, infrastructure modeling was used to position emergency responders, telecommunications and power repair crews, and supplies in Florida prior to Hurricane Rita. This intensive modeling effort by NISAC from several national labs (including Los Alamos and Sandia), incorporated lessons learned from Katrina, and helped the nation bring back the critical energy and communications infrastructure in Florida within two weeks, with a dramatic benefit to the regional population and economy. Similarly, these scientific models today inform a wide range of national security simulations to help us prepare both homeland security professionals and our soldiers. This powerful set of tools for decision makers has been validated using detailed data for our infrastructure today, in all its complexity, and shown to have strong predictive value for natural disasters. The nation can benefit by extending these tools to more broadly inform our national energy policymakers.

Energy Demand and Climate Change

Los Alamos researchers recently applied similar models in California and the 14-state western region to highlight the connections between power, water, and infrastructure planning. Using the best global climate science to bracket predictions of temperature rise in coastal California, we evaluated the cascading effects on the electric grid and water availability. The results were dramatic, and illustrated the need for state politicians to begin making changes in their near-term capital investment planning as a response.

The midpoint prediction for rising temperature in California in the year 2030 is between 2 degrees F (winter) and 4 degrees F using today's best climate models.[4] Although this may seem like a small number, looking at its impact on electricity demand, several key predictors of system failure for the electrical grid change dramatically in these scenarios. First, the length of the season for heat-wave days grows from roughly 110 days to 140 days. Heat-wave days generate the largest short-term demand for air conditioning. Second, the need for rolling blackouts is triggered when average demand across a region crosses a threshold near the peak delivering capacity of the existing grid. The infrastructure models predict that by the year 2020, there will be 100 hours of rolling blackouts across more than 20 days, triggered primarily by overtaxed capacity in the Bay area, but with effects across the state (Fig. 2). The effects of climate change will trigger a need for approximately 11 GW of new power capacity, in addition to the 57 GW that will be needed from projected growth to the state economy based on current trends. Beyond the increased power needs, the connection to water will be acutely felt in the southwest through both reservoirs in the Sierras and through the Colorado river system. The climate impacts will result in decreases in Sierra snowpack of about 35%, and decreases of total reservoir inflow of

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[3] http://www.dhs.gov/xabout/structure/gc_1197658542121.shtm

[4] Hayhoe et al, *Proc. Natl. Acad. Sci* **101**, 12422-27 (2004).

about 10%. On the demand side, meeting the increased power need from coal sources would require an additional 280 billion gallons of water per year.

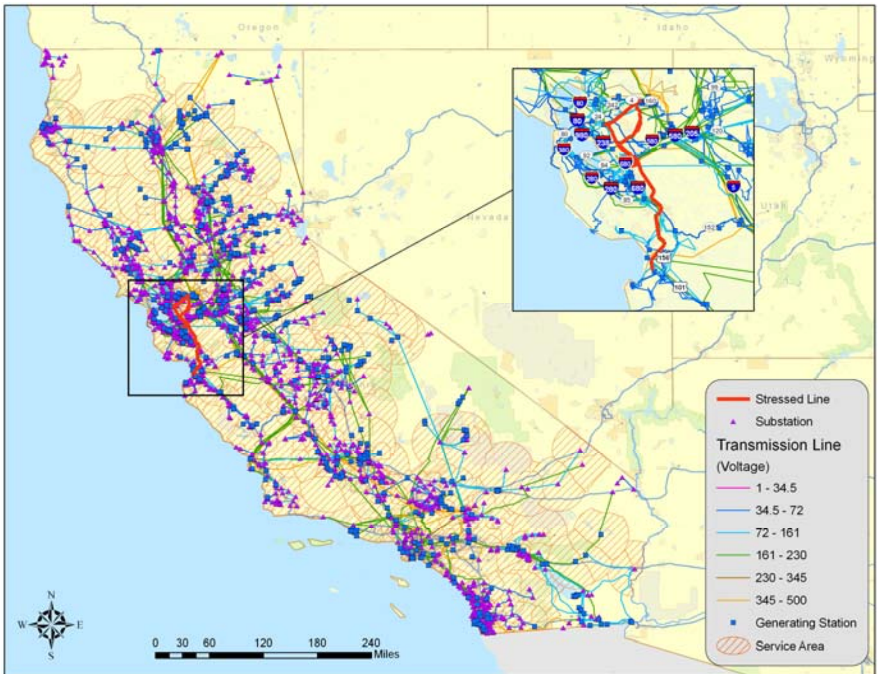

Figure 2: Electrical grid in California, showing regions of rolling blackouts (hatched circles) caused by overstressed lines in the Bay area, due to rising temperatures of 2-4 degrees F.

In other words, even modest climate change (2-4 degrees F) is expected to trigger a 20% change in the projected need for new electrical energy capacity, and a dramatic effect on water resources. Together, these effects point to a potential cost to the cumulative California gross state product (the value of all goods and services) of more than $200 billion by 2030. Because these effects will be felt within two decades, the planning for this increased capacity has already started. Luckily, the modeling identifies key failure points (such as those transmission lines in the San Jose- East Bay corridor), and also allows us to test different mitigation strategies, compared to the cost of taking no action. Most importantly, these tools allow policymakers to compare the inter-related impacts of simultaneous adoption of policies across the spectrum of conservation, new infrastructure construction by region and by technology, and the interplay of resources such as water and power. This provides a science-based framework for informing tradeoffs that must happen between different interests in policy discussions at state, regional, and national levels.

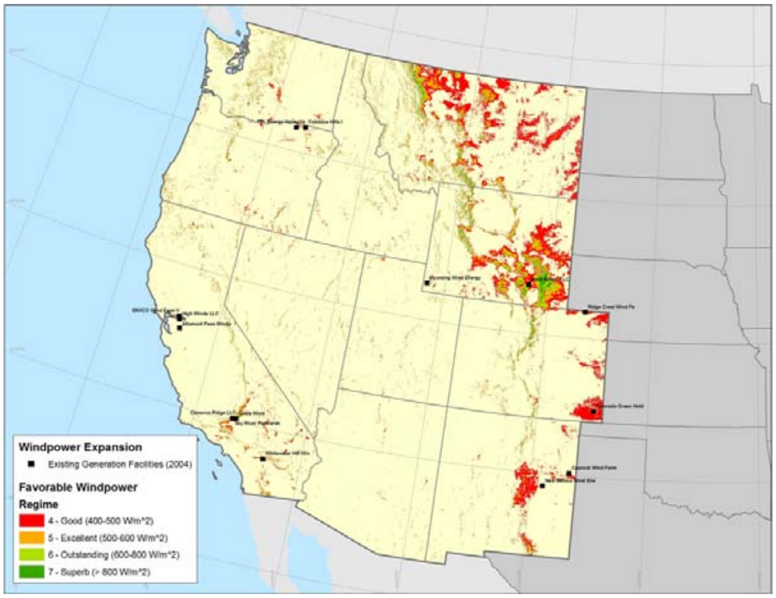

Figure 3: Regions of west most favorable for wind power generation.

Impacts of a Push for Wind

One of the strongest policy responses being adopted to address this need for new energy sources because of growth and climate change is to require the rapid scale-up of renewable resources such as wind energy. Actions are being taken at the state, regional, and national level to provide both financial incentives and regulatory requirements for utilities to increase wind energy. Wind provides a clean (but intermittent) source of energy, and in the West the water savings for implementing wind energy provide a substantial additional benefit. As one mitigation strategy, this infrastructure modeling approach was used to model the growth of wind energy to 25% of the western regional total. Because the wind generation capacity must be installed in geographic areas where there are sustained wind resources, this has substantial implications for today's electrical grid. Figure 3 shows the intensity of wind in the western region, which is concentrated across four Rocky Mountain states, plus California. Getting to the goal of 25% wind power requires wind generation across about 20,000 square miles (unlike solar panels, the land around wind farms can continue to be used for farming, ranching and resource exploration).

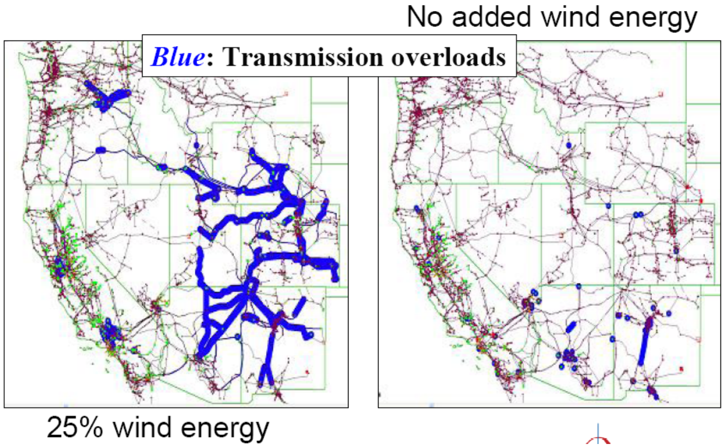

Figure 4: Predicted transmission line overloads on western grid with addition of wind energy to meet 25% of total (left) and with no added wind energy (right)

However, this generation capacity occurs far from the existing grid, and the resulting load in getting this power to where it is needed by the growing population centers across the West will result in transmission line overloads across a major portion of the western network (Fig. 4). Interestingly, if conventional power plants continue to be built near existing load requirements, there is much less impact on transmission lines.

Of course, where people live, especially in concentrated population centers such as Phoenix, has a profound influence on regional energy and water use. There is a large body of evidence documenting the effects of urban heat islands (such as Phoenix) in raising the average temperature, especially the nighttime low temperatures, over the entire geographical area of the city. In the case of Phoenix, the average daily low temperature is more than 10 degrees F higher, over an 800 square mile area, than the surrounding undeveloped areas. This has accelerated the use of energy for air conditioning, as well as water. According to a recent estimate, a rise of 5 degrees in the low nighttime temperature led to a 9% increase in residential water usage. This equates to more than 500 million gallons per month just from the effects of the urban heat island in Phoenix.[5] Similar effects are now occurring for Las Vegas and many other cities across the southern U.S. In this way, population growth not only concentrates the use of energy and water, it accelerates the pace of regional climate change in a way that provides positive feedback, or more rapid growth of consumption.

As these scenarios illustrate, there are tradeoffs involved in the different choices we might make to meet a growing energy need. Climate change provides a set of future constraints with quantitative economic impacts that can be bracketed with high confidence, even though there is

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[5] Guhathakurta & Gober, J. Am. Planning Assoc. 73, 317-29 (2007).

substantial uncertainty in the range of outcomes. If we choose primarily coal-based power, we can quantify the impacts on water resources; if we choose renewable resources such as wind, we can quantify requirements for improvements in the transmission network. Growth of population centers couples strongly to both intensity of water and energy use, and the need for future infrastructure. Using today's predictive science modeling tools, we can give a balanced view of these tradeoffs to policymakers at a state, national, and global scale. Tomorrow's tools can be targeted to ask the right questions to strengthen our future infrastructure.

Conclusion

In summary, I have given just a small number of examples of how our national laboratories are working to apply science to understanding important vulnerabilities in our national infrastructure, and the interdependencies that impact public policy choices. These science-based modeling tools could, and should be much more widely applied in energy security, as we move rapidly into a future where our national security, economy, and lifestyle depend on how we prioritize investments to meet global climate and energy challenges.

Thank you for this opportunity to testify. I would be pleased to answer any questions you may have.