Testimony of
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Committee on Energy and Commerce
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Hearing on
The American Clean Energy Security Act of 2009

Panel on Low Carbon Electricity, Carbon Capture and Storage, Renewables and Grid Modernization

April 23, 2009

My testimony is based on research described in an article in the Fall 2008 issue of *Issues in Science and Technology*, attached to this testimony, and in a longer working paper, and in several papers published in the research literature. Lester B. Lave and Sompop Pattanariyankool are colleagues in this research.

Chairman Markey, Ranking Member Upton, and members of this subcommittee including my Representative, Mr. Doyle, thank you for giving me the opportunity to testify.

At Carnegie Mellon University, I am a faculty member in the Engineering College and the Tepper School of Business. I am also executive director of the Carnegie Mellon Electricity Industry Center. The opinions here are mine and do not necessarily reflect the views of my coauthors, Carnegie Mellon University, or any other institution.

I commend you for searching for ways to reach the goals of reducing greenhouse gas emissions and pollution, enhancing energy security, maintaining electric supply reliability, and controlling costs. Renewable energy sources are a key part of the nation's future, but I caution that a singular emphasis on renewable energy sources is not the best way to achieve these goals. One goal is paramount as the greatest challenge of the century: reducing air emissions and the atmospheric concentration of carbon dioxide.

I have two recommendations that I hope you will consider:

1. Focus on reducing carbon dioxide rather than singling out renewables as the answer. There are significant savings from letting all technologies compete in satisfying the goals of lowering greenhouse gas emissions, increasing energy security, and improving sustainability, ensuring that energy prices are not so high that they derail the economy.
2. Ensure that efficiency gains, in generating electricity, as well as transmitting and distributing it, and in using it, can count in any low-carbon legislative mandate, such as Sec. 231 of the discussion draft.

If estimates of the amount of recoverable fossil fuels are correct, without carbon dioxide controls we will run out of atmosphere long before we run out of fossil fuels. Burning any appreciable fraction of the estimated coal, oil, and natural gas resources will send atmospheric carbon dioxide concentrations to far greater levels than humans have experienced and lead to major global climate change.

All fossil fuel sectors contribute emissions and need to be addressed, but my testimony focuses only on the electricity sector. The United States is increasing its reliance on electric power and will have to generate 40% more electricity by 2030 if demand keeps growing as it has the past 35 years. We face the additional challenge of quickly reducing carbon dioxide. At the same time, the price of power has risen 25% nationally in four years, and has risen much faster in cities such as Baltimore. We spend about 3% of GDP annually on electricity.

Removing 80% of the CO_2 we emit today from electric power generation with the most cost-effective technologies we know about will cost us about 2/3 of one percent of GDP annually. That's about what we spent on the Clean Air Act. That amount is affordable. But if we try to specify which technologies – like renewables – are the only ones that need apply and don't allow the least expensive clean technologies to compete, these costs can grow to unaffordable levels.

It is important to develop competing low carbon technologies to keep costs low, rather than trying to select technologies based on attributes that have little to do with controlling CO_2.

A national RPS is an expensive way to reduce greenhouse gas emissions because "renewable" and "low greenhouse gas" are not synonyms; there are several other practical and often less expensive ways to generate electricity with low carbon dioxide emissions. In addition, renewable energy is concentrated in only certain states. A national RPS would force other states to transfer wealth to windy or sunny states, instead of using it to develop low carbon technologies that are appropriate to their locales.

Mandating technologies can be much more expensive than mandating performance, by capping emissions at a level that declines over time or by requiring that no more than a given amount of CO_2 be emitted for every kilowatt-hour produced. Renewables portfolio standards unnecessarily increase costs (and often leave out efficiency and demand-side response) in an attempt to eliminate the use of uranium, coal, natural gas, and large hydroelectric power. What is needed instead is a direct performance standard that lowers the limits on emissions of CO_2 in a predictable fashion over the next few decades to very low levels.

For renewables, the maps I have provided of wind and solar resources show vast differences among states. For example, the Southeast has neither good wind nor solar resources. It does have biomass, but that will be needed for producing liquid fuels. Legislation should give each region the greatest flexibility to achieve the goals at least cost, including renewables, efficiency, conservation, fossil fuels with carbon capture and sequestration (CCS), and nuclear.

Many people like wind turbines in the abstract but don’t want them as neighbors, for example, the proposed wind farm off Cape Cod. In my state of Pennsylvania, we now have 200 wind turbines. About 10,000 would be required to meet a 25% RPS and the resulting land use issues can't be ignored. A handful of states require wind farm operators to pay into a fund for decommissioning the turbines at their end of life. A quick YouTube search for "wind turbine failure" is all that is required to see why this is very good idea.

Achieving a large national RPS requires building large amounts of transmission from areas with good wind resources to population centers. More people oppose transmission lines than wind turbines. There are likely to be delays of ten years or more in siting transmission.

Even in good areas, the wind doesn't blow all the time. Looking at all the wind power plants in Texas in 2008, we find that in a quarter of the hours during the year Texas wind production was less than 10% of its rated capacity. That means that when a wind farm is built, some other power source of the same size must be built to provide power during those calm hours. Our research shows that natural gas turbines, that are often used to provide this fill-in power, produce more CO_2 and much more nitrous oxide (as they quickly spin up and then slow down to counter the variability of wind than) than they do when they are run steadily.

The point is that wind and solar can lower the amount of fossil fuels used for generation, but they don’t lessen the need for spending money on always-available generation capacity, nor do we get all the air emissions benefits we once expected. For new generators, the capital cost is the vast majority of new costs and so the savings by having free fuel from the wind or sun are small.

As you know, wind and solar generation differ from the traditional ways of generating electricity because they are generally not available when we need power. Wind turbines and solar arrays generate electricity when the wind blows and the sun shines. One of the best solar sites in the USA is in the Arizona Desert. A very large solar generator there had a duty cycle, what we call the capacity factor, of 19%, out of the possible 100%, if it had generated full power every hour of the two years we studied it. Wind turbines have higher potential in good wind sites but, for example, the average capacity factor for the wind turbines in Texas was only 29% in 2008.

The solar map shows that the good sites are in the desert Southwest. Sites in the Southeast have lower potential because of cloud cover. The rest of the continental USA has much lower potential for generating solar power, particularly the most heavily populated areas. The capacity factor is important because almost all the costs are in manufacturing and installing the array. Thus, a solar array with a capacity factor of 20% would produce electricity at half the cost of an array with a capacity factor of 10%. Forcing solar installations into Atlanta, Washington, or New York would consume a vast amount of resources per kilowatt-hour.

Nature is more generous in distributing good wind sites around the nation, but they are still distant from population centers. In particular, note that there are no good wind sites in the Southeast. As with solar, the cost of produced power is inversely related to the capacity factor since almost all the costs are building the wind farm. Thus a site with a capacity factor of 40% would have half the cost per kilowatt-hour as a site with a 20% capacity factor.

In general wind and solar power are not available when demand is highest. Wind tends to be strongest at night and lowest in the summer. Solar power is best in the summer, but the Arizona data show that the arrays have all but stopped producing electricity by 5 PM in the summer, just as demand is hitting its peak.

Another problem is that wind and solar generation are variable. Wind speed changes from moment to moment and clouds block the sun, even in the desert. This variable power challenges the grid to provide reliable, high quality power when wind and solar are contributing more than a few percent of total generation.

One solution to both these problems is to store large amounts of electricity when these sources are generating so that it can smooth power output and have that output available when demand is high. Pumped hydroelectric storage is the best way to store electricity, but few new sites are available. Compressed air storage looks promising, but is expensive and less efficient than pumped hydro. The discussion draft does not appear to contain significant incentives for large-scale electricity storage.

Wind farms can affect climate downwind, reducing precipitation. Massive reliance on wind energy would take energy out of the wind, changing the Earth's climate. All power generation options have feet of clay. There is no generation utopia. But just because there is no free lunch doesn't mean we can't eat: we just have to acknowledge the issues honestly so that we are not faced with a public backlash later on.

There are other renewable sources that are also low-carbon. Hydroelectric dams generate six times as much power today as the other renewables, but there is little prospect for getting significantly more power. Dams are being torn down, not being built. Run of the river hydro could provide small amounts of power. Geothermal provides power in California and more is planned for the Southwest. Where there are good geothermal resources, this resource can be attractive. However, the good areas are limited to the West. Biomass could provide significant amounts of power at competitive costs, but there is a limited amount of land and water, and the biomass may be better used for transportation fuels. Ocean currents and waves can provide power, but corrosion and withstanding storms make the power expensive, in addition to other problems.

Where they can compete for our low-carbon dollar, renewables should be applauded. In good sites, wind power is competitive with new fossil generation with carbon capture and sequestration. At good sites, solar thermal power is almost competitive with new fossil generation. However, even at the best sites, solar photovoltaic generation is several times the cost of other low-carbon power per kilowatt-hour. We should not pick technologies with legislation – rather we should pick the low carbon goal and allow the cost-effective winners to emerge.

Federal support of R&D in this industry is essential to achieving low carbon electricity at affordable cost. While solar photovoltaic power is too expensive for massive deployment, I urge funding solar photovoltaics research, since this technology will ultimately provide most of our energy. I also recommend R&D funding for bulk electricity storage, such as compressed air. America's largest fossil fuel resource is coal; we will rely on coal for much of our energy in the coming decades. In particular, coal will continue to provide most baseload electricity generation.

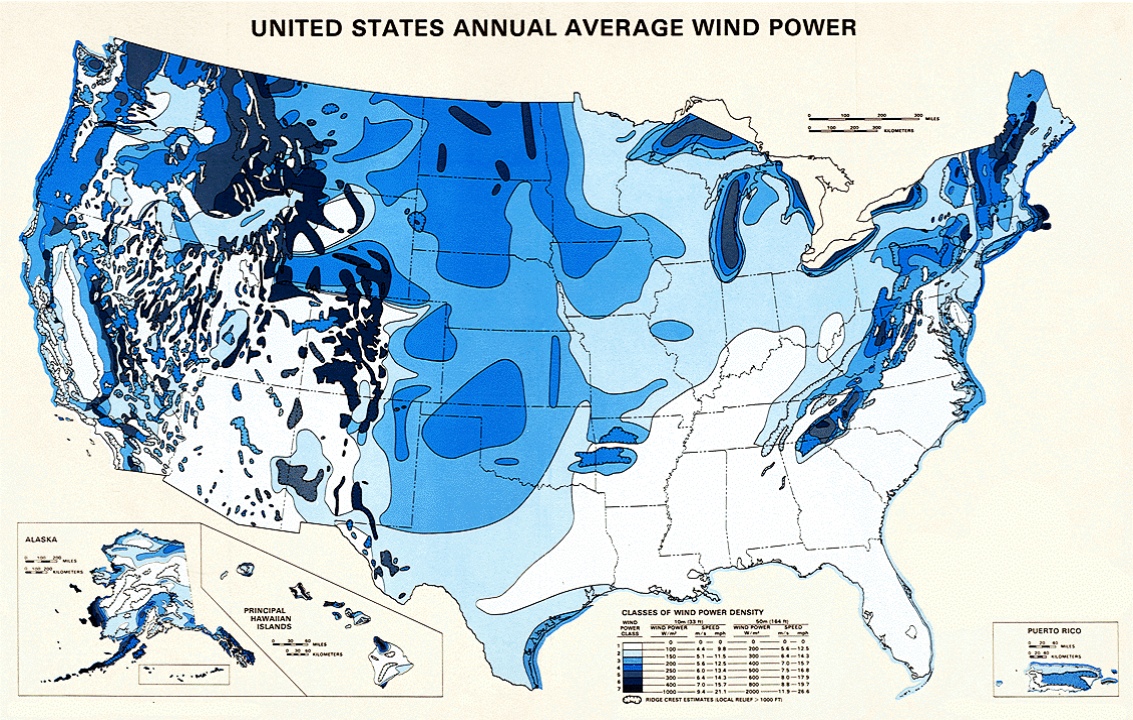
It is essential that demonstration coal plants with carbon capture be built to improve the technology and that we show that massive underground injection of carbon-dioxide in a range of geological strata can sequester the carbon dioxide without leakage. The Section 114 incentives are at the low end of what is required to demonstrate the commercial viability of sequestration.

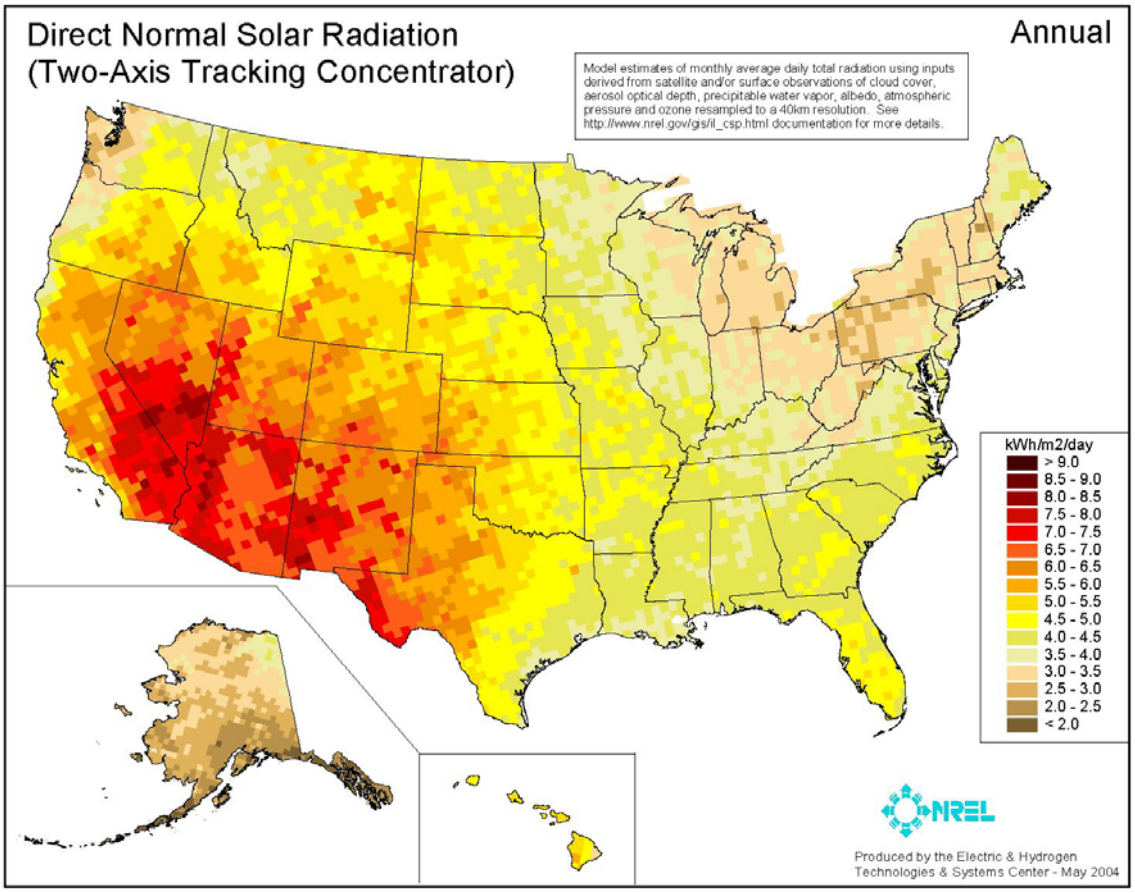
It is also essential that we build half a dozen nuclear plants using new technology to assess their costs and performance.

I commend the Committee and Congress for moving this most important topic forward. I hope that you will keep two principles in mind:

1. Focus on reducing carbon dioxide rather than singling out renewables as the answer. There are significant savings from letting all technologies compete in satisfying the goals of lowering greenhouse gas emissions, increasing energy security, and improving sustainability, ensuring that energy prices are not so high that they derail the economy.
2. Ensure that efficiency gains, in generating electricity, as well as transmitting and distributing it, and in using it, can count in any low-carbon legislative mandate, such as Sec. 231 of the discussion draft.

Thank you for the opportunity to testify on this important legislation. I would be happy to answer any questions.


UNITED STATES ANNUAL AVERAGE WIND POWER
ALASKA
PRINCIPAL HAWAIIAN ISLANDS
PUERTO RICO
CLASSES OF WIND POWER DENSITY
RIDGE CREST ESTIMATES (LOCAL RELIEF > 1000 FT)


Direct Normal Solar Radiation
(Two-Axis Tracking Concentrator)
Annual
Model estimates of monthly average daily total radiation using inputs derived from satellite and/or surface observations of cloud cover, aerosol optical depth, precipitable water vapor, albedo, atmospheric pressure and ozone resampled to a 40km resolution. See http://www.nrel.gov/gis/il_csp.html documentation for more details.
kWh/m2/day
> 9.0
8.5 - 9.0
8.0 - 8.5
7.5 - 8.0
7.0 - 7.5
6.5 - 7.0
6.0 - 6.5
5.5 - 6.0
5.0 - 5.5
4.5 - 5.0
4.0 - 4.5
3.5 - 4.0
3.0 - 3.5
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NREL
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He is Executive Director of the Carnegie Mellon Electricity Industry Center, the largest engineering-business center focused on the electricity industry. The Carnegie Mellon Electricity Industry Center is supported by grants from the Alfred P. Sloan Foundation and the Electric Power Research Institute, with contributions from a large number of government agencies, organizations, and companies.

He is the author of more than fifty peer reviewed scientific publications, and author of several books and book sections. He has received research support from a wide range of federal and state agencies, as well as foundations, nongovernmental organizations, and companies.

The publications of the Carnegie Mellon Electricity Industry Center are available at www.cmu.edu/electricity.

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