

SUPPLEMENTARY MATERIAL FOR ENERGY/GHG CONSENSUS QUESTION 2010

This material was prepared by the LWVDE Energy/Green House Gas Subcommittee during the period of late August 2010 to late February 2011. Its members were: John Austin, Chris Bason, Sumner Crosby, Mary Anne Edwards, Steve Hegedus, Peggy Schultz and Chad Tolman.

Detailed information is provided in 8 sections, including figures, tables and references. The figures and tables start with number 1 in each section; the references for all 8 sections are in a single set of Endnotes.

SECTION 1. LWVUS and LWVDE KEY STATEMENTS ON GHGS AND CLIMATE CHANGE

The national, as well as the Delaware leadership of the League of Women Voters, spoke out early and forcefully about the threat to the future vitality of the Earth if actions are not taken to aggressively protect our environment. At its 2008 national membership meeting the LWVUS agreed that global climate change is one of the most serious threats to the environment, health and economy of our nation. Noting that recent scientific studies show global warming is already causing environmental changes that will have significant global impacts, the LWVUS created the Climate Change Task Force (CCTF) from its membership to address this issue. One of the tangible products of this committee is the creation of the LWV Toolkit For Climate Action, an excellent resource for classroom teachers and the public, now on the League website (www.lwv.org) under **Toolkit for Climate Action**¹

The LWVUS called for prompt and aggressive action to cut U.S. greenhouse gas (GHG) emissions and cited detailed objectives to guide the development of comprehensive climate legislation. In a letter to the U.S. House of Representatives in January 2009, Mary G. Wilson LWVUS President, wrote the following:

“The League of Women Voters strongly urges you to take quick and strong action against global climate change. Based on the best available science, we urge you to support a cap on greenhouse gas emissions for the year 2020 that is at least 20 percent below 1990 levels, without loopholes that will undermine the cap. We also ask that you support a cap for the year 2050 that is 80-100 percent below 1990 emissions.”²

Delaware’s League of Women Voters exercised strong leadership on this subject. In a Letter to the Editor, December 11, 2009, published in both the Cape Gazette and Vol. 16, No. 4 of the LWV NCOs VOTER, Delaware League President Sandy Spence wrote:

“The League of Women Voters of Delaware believes that global climate change is one of the most serious threats to the environment, health, economy and security of our nation and the world. League members throughout the country call on the United States and world political leaders to cap emissions at 25% below 1990 levels by 2020. We also join many other civic and social organizations in urging providing critical adaptation and associated assistance to countries

most in need. Delaware itself is especially vulnerable to sea level rise, as it has the lowest average elevation of any state in the country....”³

In 2010, the national environmental debate is framed as a jobs issue. Reporting on the opening of UD’s Dec. 13 - 14 conference on “Creating the Clean Energy Economy”, The News Journal, bluntly states that it’s time to drop the ideological blinders when it comes to clean energy - the clean energy issue belongs to all of us and is primarily about jobs. Conference speakers said the Chinese and Europeans get this important point - it’s we American’s, or at least our politicians, who don’t. America will be playing catch up unless we stop ideological arguments, reduce our reliance on fossil fuels and focus on innovation in cleaner energy industries. Delaware is well positioned with its state leadership and its institutions of higher learning to do just this.

SECTION 2. THE BASIC SCIENCE OF CLIMATE CHANGE AND THE ROLE OF GHGS, ESPECIALLY CO₂

In the long span of about 4.5 billion years since the earth was first formed, it has undergone many changes, with temperatures ranging from superheated steam to freezing cold. Just in the past 800,000 years we have gone from warm interglacial periods to ice ages when Manhattan was buried beneath a mile of ice, and sea levels were low enough that people could walk from Siberia to Alaska.

For the past 8,000-10,000 years, during which time civilization developed, the global average temperature and the sea level have been remarkably stable. That started to change in about 1750 with the coming of the Industrial Revolution and the steam engine. The burning of fossil fuels – starting with coal, and later oil and natural gas – has added carbon dioxide (CO₂) to the atmosphere as the population grew and as more people wanted the comfort and convenience provided by machines getting their energy from fossil fuels. The concentration of CO₂ in the atmosphere has increased from about 280 parts per million (ppm) in 1750 to about 390 ppm today, and it’s increasing by more than 2 ppm per year as emissions continue to increase.⁴ The global average temperature has increased by about 0.8°C (1.5°F) since 1750, mostly in the last 30 years. The rate of warming is increasing and would continue to increase for several decades even if we were able to bring emissions of CO₂ and other greenhouse gases (GHGs) to a sudden stop. The slow response is called inertia in the climate system. Like the QE2, it takes time to respond and can’t be turned on a dime.

Carbon dioxide and a number of other gases in the atmosphere (water vapor, methane, nitrous oxide, ozone and fluorochemicals – but not oxygen or nitrogen) are called greenhouse gases because they act much like the glass on a greenhouse, allowing radiation from the sun (mostly visible light) to pass through the atmosphere, but impeding the longer wavelength infrared radiation from Earth from escaping back into space. Thus the glass on a greenhouse or these gases in the atmosphere make in warmer at the surface of the earth that it would be otherwise. (Your car, left in the sun with the windows rolled up, behaves similarly.) The average

temperature at earth's surface is now about 60°F; without GHGs the average temperature would be 0°F, and the oceans would be frozen. Global average temperatures remain stable only as long as the rate of energy absorption from the sun is balanced by an equal rate of energy loss into space.

Scientists have two ways to estimate what they call 'climate sensitivity,' the amount by which the average surface temperature rises for a doubling of CO₂ concentration. One is based on computer models of the atmosphere, land, ocean and ice system, and the other is by looking back to see the relationship between CO₂ concentration and temperature in the planet's past. The first gives sensitivities of about 1.5 to 4.5°C per doubling,⁵ while the second gives about 6°C,⁶ once enough time has passed to allow the oceans to warm up as much as they are going to and enough ice to melt and vegetation to move so that a new steady equilibrium condition is reached. Major sources of uncertainty are changes in clouds, the release of CO₂ and methane from natural sources as the earth warms, and how much time is required to reach equilibrium. Predicting the future is difficult both because of uncertainties in how the climate will respond to a particular concentration of GHGs and how rapidly humanity will reduce rates of emissions or take other actions to affect the balance of incoming and outgoing radiation.

One of the most important impacts of global warming for Delaware is flooding due to a combination of sea level rise (SLR) and increasing intensity of storms. Sea level in Delaware is rising as a result of expansion of water as it warms, the addition of water from the melting of ice on land, and the slow sinking of the land. During the past century these factors caused the sea level at Lewes to rise about a foot (0.3 meter) relative to the land. SLR by 2100 is projected to be in the range of 0.5 to 1.5 m (1.7 to 5 feet),⁷ but could be much more, depending on how rapidly GHGs are added to the atmosphere.⁸ The warming of water and the melting of ice takes heat, and the heat is being supplied by the imbalance between the incoming solar radiation being absorbed and the radiation going out into space. Warming increases the rate of water evaporation and makes it possible for the atmosphere to hold more water vapor. The result is increased droughts in some areas and floods in others. Low pressures during storms can add storm surges along the coast of 4 or 5 feet to the rising sea level, bringing salt water farther inland and endangering beaches, buildings, roads, bridges and farms. Delaware has already begun to plan ahead to minimize the damage from the climate change that cannot be avoided.⁴

SECTION 3. DELAWARE'S PER CAPITA ENERGY CONSUMPTION AND GHG EMISSIONS

The U.S. Dept. of Energy gives the rank ordering of states by per capita energy consumption. Some of the data for 2008 are shown in Table 1 ranked from highest to lowest per capita use.

Table 1. 2008 Per Capita Energy Use by State⁹

Rank	State	Million BTU
1	WY	1016
2	AK	946
3	LA	783
4	ND	687
25	DE	337
32	PA	310
34	NJ	304
40	MD	256
47	CA	229
48	MA	225
49	HI	220
50	RI	209
51	NY	205

Delaware is right in the middle of the rank ordering. (There are 51 because DC is included.) While Delaware's per capita energy use is only a half to a third of the worst states, it is higher than that in any of its neighbors and about 50% higher than the best states at the bottom of the list. Note that 38% of Delaware's electricity is generated out of state and imported via the PJM grid.¹⁰

Figure 1b¹¹ shows the carbon dioxide emissions (in 2008) on a per capita use basis. The ranking of states is similar to that shown in Table 1, but different. Now Delaware is 12th from the top while VT has the lowest per capita emissions. This is probably because much of Delaware's electricity comes from coal, while much of Vermont's comes from hydropower. Wyoming is so high in the table and the figure because it burns a lot of coal to produce electricity that is consumed in other states. The U.S. average is 20.6 metric tons (mt) per capita, with DE approximately 35% higher than that.

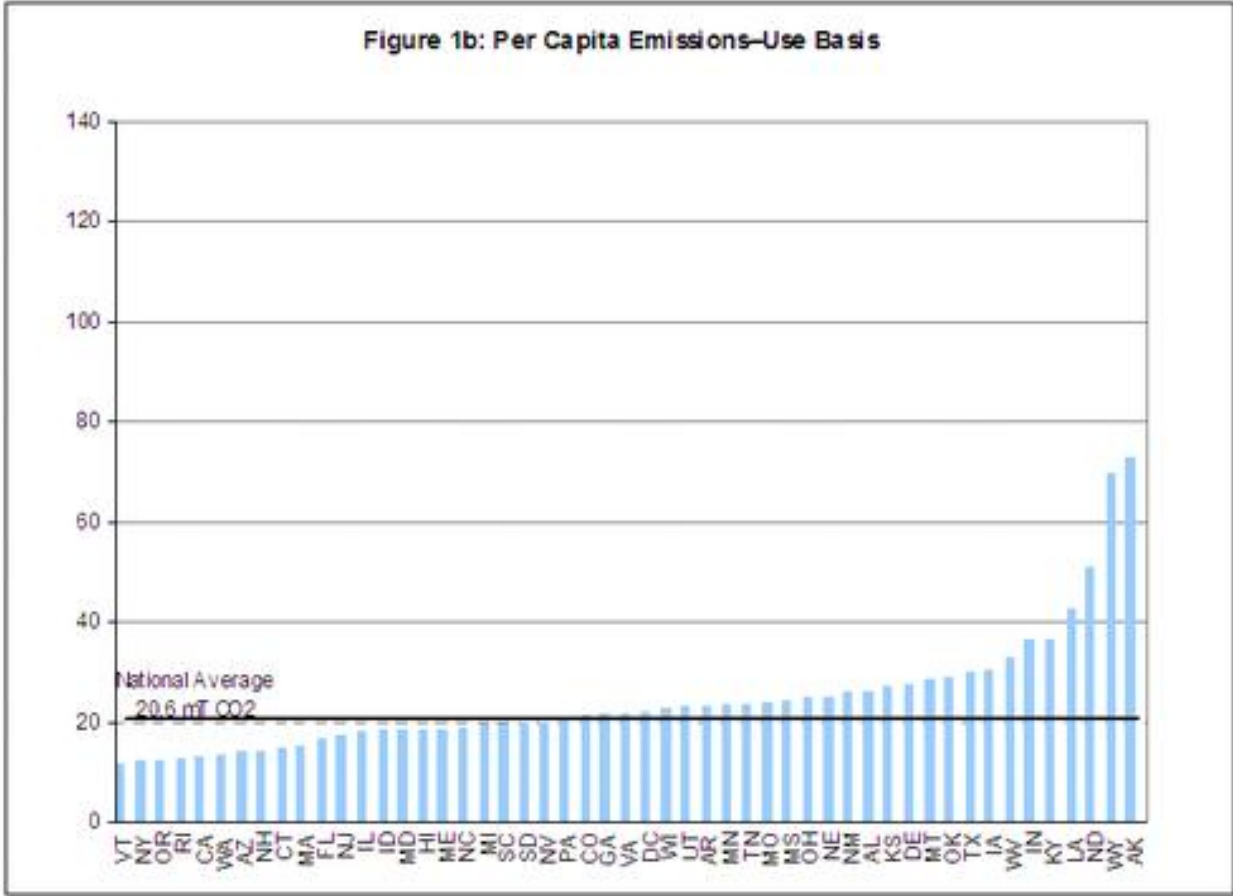


Table 2 below shows selected per capita CO₂ emissions by country, listed in decreasing order for 2006.

Table 2. List of Countries by Carbon Dioxide Emissions per capita (mt)¹²

Country	1990	2006
Qatar	25.2	56.2
U.S.	19	19
Canada	16.2	16.7
Denmark	9.8	9.9
UK	10	9.4
Germany	12.2 (1991)	9.7
China	2.1	4.6
India	0.8	1.3
Solomon Islands	0.5	0.4
Haiti	0.1	0.2

Qatar and some other oil-rich Middle Eastern countries have the highest per capita CO₂ emissions, but their populations are small. Though China has passed the U.S. in total emissions (note the large increase in per capita emissions from 1990 to 2006), on a per capita basis emissions are still only a quarter of those in the U.S. India is less than a tenth. Haiti, a very poor and densely populated Caribbean nation, is 1%. Note that the only country to experience a significant decrease in emissions was Germany, where CO₂ decreased by 20%. This is largely due to strong national policies to promote the installation of clean renewable energy and improved energy efficiency. These policies have resulted in a significant growth in clean energy industries and employment.

In Delaware significant reductions in energy use are possible with weatherization, improved building design, and more efficient transportation. Electric motors are inherently more energy efficient than internal combustion engines. A fleet of electric vehicles or plug-in hybrids with large batteries could use energy provided largely by wind or solar power. The batteries could also provide a means of storing energy during times of strong winds or bright sunshine when more renewable energy is generated than is needed by the grid. This concept is called V2G (Vehicle to Grid) and is being tested in a collaborative effort of the University of Delaware and Delmarva Power.¹³

SECTION 4. IMPACTS OF CLIMATE CHANGE ON DELAWARE

The 1990's were the warmest decade in a thousand years. And it's not going to get better. The Intergovernmental Panel on Climate Change says that average temperatures by 2100 will range from 3.2 to 7.2°F hotter than current temperatures, with winters warming more than summers.¹⁴ That doesn't sound too remarkable, but let's look at some of the implications of what may appear at first to be a modest temperature increase.

Scientists say that Delaware's growing season will last longer, and for a state whose major industry is agriculture, that could be good news. Unfortunately, weeds migrating from the south will also be more prolific. Crops and domestic animals will suffer from a higher survival rate of pathogens and parasites, including the corn flea beetle. Corn, as you know, is Delaware's major crop, yielding \$36 million annually.¹⁵ Furthermore, heat is shown to have a negative influence on the production of milk, Delaware's fifth most important agricultural product.¹⁶ Heat waves will be more common, and people who cannot afford air conditioning, especially the aged, will be at risk. Warmer air is also an encouragement to the formation of ozone. Northern Delaware is already a "moderate nonattainment" area for ozone¹⁷, which is known to aggravate respiratory illnesses as well as to reduce crop yields. Warmer seas will be more susceptible to algae blooms which can carry harmful bacteria, potentially harmful to both people and shellfish nursery habitats.¹⁸

With climate change will come greater storm intensity, with precipitation coming in short, intense bursts. The EPA says that precipitation, already increased up to 10% in some parts of the state, will increase 15-40% in all seasons.¹⁹ In 2009 a pea farmer in Kent County complained that flooding reduced his crop to about 1/4 of the usual yield. Several parts of State Highway #9 routinely close due to flooding following only moderate rainfalls. Though this weather event should not be equated with a climate change event, it is indicative of things to come. Increased precipitation in the winter comes with a serious price tag: last winter's "Snowmegeddon" cost Delaware taxpayers \$8.8 million for snow removal.²⁰

Sea level rise, another impact of global warming, will drive Delaware Bay's salt water further north, devastating baby oysters and intruding into aquifers normally used for drinking water. The oyster harvest was worth \$19.2 million in 2009 alone.²¹ Some landowners are already losing irrigation wells and ponds to saltwater intrusion.²² Given that 70-90% of the state's commercial fish and shellfish either live entirely in estuaries or use them as nurseries, a net loss of wetlands or increased salt in the water could seriously affect our fishermen's chances of earning a living.²³ Increased salinity in our waterways will also increase damage to infrastructure.

WILMAPCO, in the early stages of a report on climate change's effects on transportation, points out that New Castle County is more likely to suffer from sea level rise than either of the other two counties because of its vulnerable infrastructure, including roadways, dikes, railroads and sewage facilities. Salt-water intrusion and inundation will both be increasingly serious problems. Already the Wilmington water gates that discharge storm water are below river level for all but a few hours each day. With 4 1/2 feet of sea level rise, Wilmington's Southbridge neighborhood will be under water. Even now, several times a year when we have big rains, many places along Route 9 have to be closed due to flooding. Dikes and impoundments all along the Delaware River have already been breached multiple times, threatening both homes and wetlands. Delaware's land is also slowly sinking, which adds to the effects of sea level rise. One expert says that we can expect sinking of one foot by the next century.²⁴

Sea level rise, when combined with wind-driven waves, increases flood risk and flood damage that has already destroyed boardwalks and houses, and will ultimately even wash away hotels.²⁵ In 2006, tourism brought \$2.6 billion to the state.²⁶ That income is threatened as properties along both the ocean and Delaware River coasts are increasingly subject to storm damage. A rising water table near the inland bays poses a particular at risk because of the fly ash piles next to the Indian River Power Plant; harmful chemicals in the fly ash can easily leach into the drinking water.²⁷

By the end of the century a marked increase in extreme heat waves during the summers is expected to have serious health impacts on the elderly, the very young and the homeless.²⁸ Delaware's 381 miles of shoreline, its average elevation of 65 feet, its dependence on agriculture and tourism for economic well-being, all combine to make a compelling case for attention to climate change issues in the State.

SECTION 5. STEPS DELAWARE HAS TAKEN TO REDUCE GREENHOUSE GAS EMISSIONS AND ADAPT TO CLIMATE CHANGE

Efforts to reduce greenhouse gas emissions are taking place at all levels of government in the Mid-Atlantic Region, and especially here in Delaware. A wide variety of programs to reduce emissions, and promote energy efficiency and clean energy have been put in place, and state government is developing plans to reduce shoreline erosion and other effects sea level rise will have on Delaware's infrastructure and economy.

With 381 miles of shoreline, Delaware is particularly susceptible to increased coastal erosion and wetlands inundation from sea level rise along its many beaches and inland waterways. Changes in Delaware's average temperature, precipitation, and sea level have the potential to alter agricultural production and to affect local and regional hydrology - directly impacting not only the state's forests, wetlands, and estuarine environments, but also the habitation of coastal areas and even human health.

In 2008 Governor Minner signed Senate Bill 263 authorizing Delaware's participation in the Regional Greenhouse Gas Initiative (RGGI), the nation's first market-based, mandatory cap-and-trade program to reduce greenhouse gas (GHG) emissions.²⁹ It applies to power plants larger than 25 MW and aims to reduce GHG emissions from plants in the 10-state region by 10% by 2019. The bill set aside 10% of the money raised by the sale of the state's CO₂ emission allowances to fund GHG emission reduction projects in Delaware through a competitive grant program. A Greenhouse Gas Reduction Projects Advisory Body was established and met in May 2010, and has since evaluated 36 proposals in response to a Request for Proposals (RFP) from DNREC, with \$1.4 million available for grants in the first round of funding. Delaware's Sustainable Energy Utility (SEU) receives 65% of RGGI auction proceeds to promote energy efficiency and distributed renewable energy; 15% goes to weatherizing homes and providing affordable energy services for low-income families, and 10% to DNREC for program administration.

In 2010 Governor Markell signed Senate Substitute 1 for Senate Bill 119, strengthening Delaware's Renewable Energy Portfolio Standards (RPS).³⁰ The bill strengthened the earlier RPS and now requires that 5% of the total electricity sales come from renewable energy sources in 2010, increasing gradually each year to 25 percent in 2025; solar photovoltaics (PV) over the same period increase to 3.5% of the total. The benefits include improved regional and local air quality, improved public health, increased electric supply diversity, increased protection against price volatility and supply disruption, improved transmission and distribution performance, and new economic development opportunities.

Efforts are also underway to reduce GHG emissions directly by replacing coal-fired power plants by natural gas and by developing utility-scale renewable energy generation. Power companies are increasingly switching to natural gas to fuel their plants, driven by low prices and forecasts of vast supplies for years to come. As for whether coal is cheaper than natural gas or renewable energy, well, that's not just a matter of a comparison of the BTU cost or the cost per megawatt hour. In economics, there is a term known as externalities, costs not always figured into the

market place price of a product. The classic example of externalities is a business that pollutes, incurring environmental damages, medical costs and impairing public health. Such costs are not part of the market place price of the product, but are cost burdens the public and state government.

Calpine and Invista are two companies undergoing a fuel conversions from coal fired boilers to natural gas, and NRG's Indian River Power plant is in the process of closing its three oldest coal fired units. With the Calpine Corporation's purchase of Conectiv Energy's generation assets, the Edge Moor, DE and Deepwater, NJ plants began burning natural gas exclusively on July 1, 2010. As the result of a Consent Decree lodged in the U.S. District Court for the District of Delaware,³¹ corrective actions are expected to result in net reductions in emissions from three 10 MW boilers at the Invista Seaford plant of 1,029 tons per year of nitrogen oxides (NO_x); 4,211 tons per year of sulfur oxides (SO_x); and 269 tons per year of particulate matter (PM). Invista must control NO_x, SO_x, and PM by ceasing to use coal at the Seaford boilers and installing of a natural gas-fired boiler.

Pursuant to a September 25, 2007, consent order, between NRG Energy and the Delaware Department of Natural Resources and Environmental Control (DNREC), NRG agreed to operate the Indian River Power Plant in a manner that would limit the emissions of NO_x, SO_x and mercury. Further, NRG agreed to mothball IRPP 82 MW Unit 2 by May 1, 2010, and 82 MW Unit 1 by May 1, 2011. On February 3, 2010, the company and DNREC announced a proposed plan to retire the 155 MW Unit 3 by December 31, 2013. The closure of the three units will reduce GHG emissions generated in Delaware by 1.73 million tons CO₂ based on 2008 emissions.³² Only the 442 MW Unit 4 will continue operations - with advanced pollution controls. While the unit closures will reduce instate emissions by 4.16%, Delaware imports approximately 38% of its electrical power needs. Thus, these closures may be replaced by other coal generation within the PJM energy grid until more renewable generation projects come on line.

NRG will be replacing at least 220 MW of generating capacity with the construction of the offshore Bluewater Wind project. The project may be the first offshore wind farm in the United States, and is expected to start up in 2014. Though a power purchase agreement, Delmarva Power will buy 200 MW. The Delaware Municipal Electric Corporation has separately agreed to buy another 20 MW. The Bluewater Wind project will provide a supply of clean, stably-priced energy, and provide significant other economic and health benefits.

Delaware has the following state-level policies and incentives in place that support the development of renewable energy and energy efficiency technologies.

- **Building energy codes for energy efficiency**

In 2004 Governor Markell signed Senate Bill 59 to mandate continual adoption of the most recent building codes: the 2009 International Energy Conservation Code for residential construction and ASHRAE Standard 90.1-2007 for commercial construction.³³

- **Grants for energy efficiency**

Delaware has two grant programs for energy efficiency: the Delaware Energy An\$wers for Business Program and the Energy An\$wers for Home Appliances Program.

- **Grants for renewable energy**

Delaware has a program that provides grants to projects that demonstrate the market potential for renewable technologies and accelerate the commercialization of these technologies and a program that offers grants to projects that develop or improve renewable energy technology in the state.

- **Public benefits funds for energy efficiency**

Delaware has separate public benefit funds for investor-owned utilities (IOUs), cooperatives, and municipal utilities that each provide support for energy efficiency

- **Public benefits funds for renewable energy**

Delaware has separate public benefit funds for investor-owned utilities (IOUs), cooperatives, and municipal utilities that provide support for renewable energy.

- **Rebates for renewable energy**

Delaware's three public benefit funds each offer rebates for eligible renewable energy technologies

- **Renewable portfolio standard for renewable energy**

Delaware requires investor-owned utilities (IOUs) and participating cooperatives and municipal utilities to purchase 25% of the electricity sold in the state from renewable sources by 2025, of which 3.5% must come from solar photovoltaics. No municipal or cooperative utilities have opted to participate in the state RPS.

- **State standards for public buildings for energy efficiency**

State agencies must purchase ENERGY STAR® qualified products if they are available competitively.

How will Delaware adapt to the effects of sea level rise?

Sea level rise (SLR) affects more than just beaches and oceanfront land owners. It can increase the height of storm waves, making more areas vulnerable to storm damage. SLR can inundate low lying areas, causing losses to tidal wetlands, habitat, and agricultural areas. It can also cause higher water tables and salt water intrusion, interfering with septic systems, drinking water and irrigation water. Sea level has increased along the Delaware coast by more than one foot over the past century.³⁴ However, due to human development and alterations, the coastline can no longer adapt naturally as it has in the past. Marshes and other critical habitats are at risk if they are unable to migrate landward with rising sea levels. Coastal areas now see inundation from the sea on a regular basis - resulting in significant social and economic impacts.

Development in Delaware's coastal zone that does not account for SLR puts homes, businesses and infrastructure at risk, resulting in human hardship, economic loss, and significant costs to government for response and recovery.

On January 27, 2010, DNREC Secretary Collin O'Mara issued an Administrative Policy³⁵ ordering that all DNREC programs shall consider the potential effect of coastal inundation in project planning, engineering, design, and review, as well as land acquisition, management, and restoration. The policy also directs that DNREC programs shall conduct a vulnerability assessment of DNREC holdings and assets, and shall consider project alternatives that avoid siting buildings and infrastructure within areas that are vulnerable to inundation.

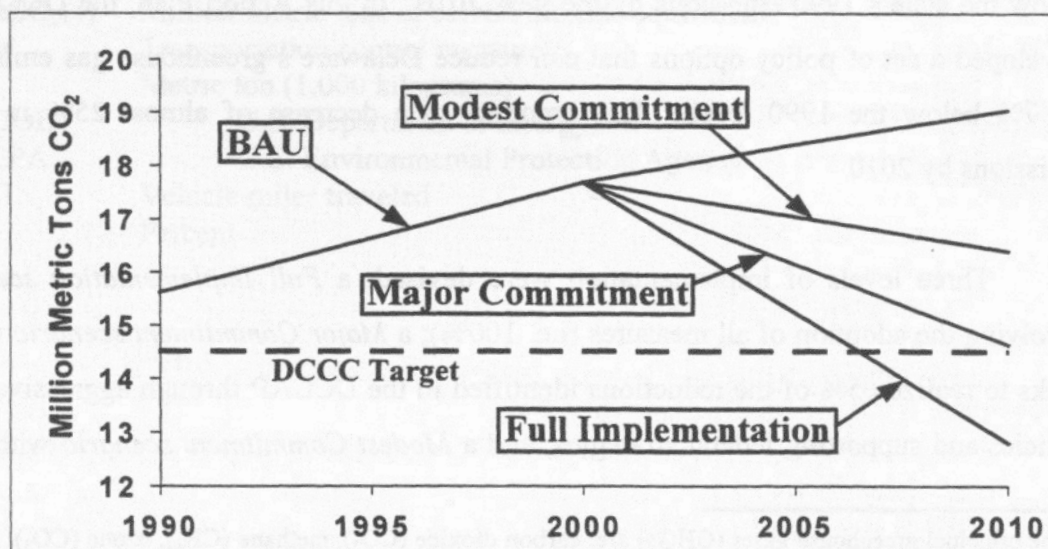
To further address these issues, a Sea Level Rise Advisory Committee has been formed by DNREC to recommend policy changes and practices that will ensure that Delaware makes informed policy and investment decisions today to prevent damage and losses to infrastructure, resources and homes tomorrow. The Advisory Committee includes stakeholders from a diverse network of interests including municipal governments, highway planners, landowners, emergency managers, wildlife managers, agricultural professionals, insurance agents, tourism officials, and environmentalists.³⁶ Chad Tolman represents the LWVDE. The Committee has a web site that includes information presented at its meetings.³⁷ There is also a DNREC web site for adaptation to sea level rise.³⁸

SECTION 6. BASED ON PAST DELAWARE ENERGY AND CLIMATE CHANGE STUDIES, WHAT NEAR- AND LONG-TERM ACTIONS DO WE RECOMMEND THE LEAGUE SUPPORT?

In the past decade there have been three major Delaware energy/climate change plans: **The Delaware Climate Change Action Plan** in 2000, **Bright Ideas for Delaware's Energy Future** in 2003, and the **Delaware Energy Plan 2009-2014**. Here we describe their origins and major recommendations.

The Delaware Climate Change Action Plan was prepared for the Delaware Climate Change Consortium (DCCC) by the UD Center for Energy and Environmental Policy (CEEP) and published in January 2000.³⁹ John Byrne of CEEP and Charlie Smisson (Delaware State Energy Office) acted as co-chairs. In addition to Byrne and Smisson, DCCC members included Andrea Kreiner (DNREC), state Senator Harris McDowell, Ralph Nigro (Applied Energy Group - now a contractor for the Sustainable Energy Utility (SEU)), Catherine Kallal (LWV DE) and Lorraine Fleming (DNS), along with 29 others from various business, labor and governmental organizations. The report described three levels of commitment for reducing CO2 emissions below what they would be with business as usual (BAU): Modest Commitment, Major Commitment, and Full Implementation. With Full Implementation, the state's projected CO2 emissions from all sources ((12.8 million metric tons (mmt)) in 2010 would be 18% less than what they were in 1990 (15.6 mmt), and 38% less than the BAU 18.8 mmt projected for 2010.⁴⁰ See Figure ES-1.

Figure ES-1
Policy Options for Reducing Delaware's
Future Greenhouse Gas Emissions



Data available from the EPA show Delaware's CO₂ emissions decreasing from 17.4 Mt (million tons) in 1990 to 16.6 in 2000 and 16.4 in 2008.⁴¹ While the numbers for 1990 and 2000 are different from those shown in the figure above, it is clear that little or no reduction in CO₂ emissions took place in Delaware between 2000 and 2008.

The Policy Priorities recommended by the Delaware Climate Change Action Plan were divided into 5 Programmatic Priorities and 3 Institutional Priorities. By each Programmatic Priority below is shown the estimated reduction of CO₂ emissions, rounded to the nearest 0.001 mmt (million metric tons). (In some cases the bulleted items are paraphrased.)

PROGRAMMATIC PRIORITIES

#1 Increase energy efficiency (5.461 mmt CO₂)

- Provide incentives for industrial efficiency upgrades.
- Promote cost-effective, energy efficient lighting.
- Raise energy efficiency standards for buildings and appliances.*
- Switch from electricity to natural gas for space and water heating, or to higher efficiency electrical appliances.
- Increase CAFE standards for vehicles.
- Provide incentives for the purchase of fuel-efficient vehicles.
- Reduce vehicle miles traveled.

#2 Switch to more environmentally friendly energy sources (0.729 mmt CO2)

- Promote wider use of natural gas for heating, ventilation and air conditioning.
- Encourage Alternative Fuel Vehicles.
- Switch electricity generation from high to low carbon fuels.*
- Investigate a regional environmental dispatch policy for power supplies.

#3 Increase natural carbon storage (0.139 mmt CO2)

- Strengthen afforestation/reforestation and urban tree planting programs.
- Develop growth management strategies that include afforestation/reforestation goals
- Strengthen forest management legislation to encourage conservation.

#4 Promote renewable energy (0.134 mmt CO2)

- Encourage building-integrated photovoltaics.*
- Develop and implement a renewable portfolio standard (RPS).*

#5 Promote recycling (0.068 mmt CO2-equivalents)⁴²

- Implement Pay-As-You-Throw or Volume-Based Fees Programs.
- Implement a mandatory curbside recycling program*
- Improve the bottle refund system.*

Line items marked with an asterisk (*) have been implemented in Delaware since the 2000 report. What is most interesting about the above is: 1) energy efficiency provides nearly 84% of the estimated total of 6.531 mmt CO2 emission reduction potential; 2) renewable energy provides only 2% of the total; and 3) solar PV is the only renewable energy source mentioned – no doubt because Willett Kempton and coworkers had not yet described the huge offshore wind resource off the Delaware coast.⁴³

INSTITUTIONAL PRIORITIES

#1 Public education and outreach

- Develop and publish a directory of sources of information on climate change, including an inventory of groups and agencies engaged in related activities.
- Develop and disseminate educational materials on climate change .. to promote the Delaware Climate Change Action Plan throughout the state.
- Create a website for the Delaware Climate Change Action Plan.
- Convene a series of educational and information exchange forums (seminars, discussions, workshops, etc.)
- Promote the diffusion of information on climate change in curricula of Delaware's schools.
- Develop activities specifically aimed at utilizing the mass media (TV, radio, and press) to help public education and outreach.

#2 Long term goals to limit sprawl, reduce greenhouse gas emissions and enhance sink capacity

- Develop policies aimed at changing land use patterns.
- Reform Delaware's land use planning.
- Expand Delaware's mass transit options and opportunities.
- Investigate a broader-based renewable energy policy initiative.

#3 Increase participation in voluntary programs.

- Promote auditing and benchmarking, especially for small- and medium-scale industries.
- Increase Delaware's participation in existing Federal programs for industrial, residential, and commercial energy efficiency.

Among the Institutional Priorities, the most striking is the emphasis on public education and outreach, even adding climate change to public school curricula. As the report notes in Chapter 8, "A well-conceived public education and outreach program will be critical to efforts to implement the Climate Change Action Plan." Public education and outreach received much less emphasis in subsequent state energy reports.

Bright Ideas for Delaware's Energy Future was prepared by a Delaware Energy Task Force that issued its Final Report to the Governor in September 2003.⁴⁴ The Task Force, chaired by Michael McCabe, was established by Governor Minner in 2002 and had 17 members in addition to McCabe, including: Senator McDowell, Andrea Kreiner (Office of the Governor), Arnetta McRae (PSC), Chris Coons (W.L Gore), John Hughes (DNREC) and Ralph DiNigro (Applied Energy Group), Dave Bacher (NRG), Joseph Rigby (Connective), Paul Bienvenue (DE Elec. Coop.), Phil Barefoot (Eastern Shore Natural Gas), and Gary Patterson (Delaware Petroleum Council). It's mission was to address Delaware's short- and long-term energy challenges.

The Task Force addressed the following goals:

- The expansion of the diversity of fuels used to meet Delaware's current and future energy needs.
- The development of conservation programs to reduce the need to build more electricity generation facilities.
- Ensuring that energy infrastructure will meet Delaware's future needs for efficiently transporting energy resources.
- Encouraging producers of clean energy technologies and producers of energy efficient products to locate their business operations in Delaware.

Reducing greenhouse gas emissions was not one of the goals.

The Task Force came up with nine strategies, each with a number of prioritized recommendations. (See the full report for details.)

Strategy 1: Reduce environmental and economic costs of energy consumption through improvements in end-use efficiency and conservation.

Strategy 2: Reduce the environmental impacts of electricity generation by encouraging clean and renewable energy generation.

Strategy 3: Reduce the economic impacts of transmission congestion.

Strategy 4: Promote clean distributed generation.

Strategy 5: Enhance availability of natural gas.

Strategy 6: Promote alternative transportation fuels.

Strategy 7: Promote economic development by encouraging advanced energy technology development.

Strategy 8: Implement energy efficiency, conservation and renewable energy in state government.

Strategy 9: Continue the planning effort to ensure that long-term goals are met.

Strategy 1 had a number of recommendations related to public education and outreach, including:

- Implement a comprehensive education program to inform residential consumers about how they can achieve the economic and environmental benefits of more efficient energy use.
- More completely disclose information about fuel sources, emissions, and costs to consumers to better inform their purchasing decisions.
- Develop an aggressive consumer education program to promote Energy Star appliances and equipment to builders and consumers in the Residential and Commercial sectors.

There was no mention of changing public school curricula or of involving the media.

The discussion of Strategy 2 included: “Renewable energy resources that can reduce dependence on fossil fuels for electric power generation, including solar, wind and biomass, are available in Delaware. While the initial costs of renewables are often higher than conventional energy supplies, the benefits of increased renewable use are significant. Renewable energy resource and technology development also have positive implications for economic growth.” The recommendations under Strategy 2 included:

- Re-assess photovoltaic system rebates from the state's Green Energy Fund with a goal of having 500 photovoltaic systems in Delaware by 2010.
- Establish a study group to determine the types and quantities of sustainable biomass

resources and their best use.

- Establish a renewable energy goal for electricity consumed in the state.

There was no mention of Delaware's offshore wind resource.

The third and most recent plan was the **Delaware Energy Plan 2009-2014**. It was prepared by the Governor's Energy Advisory Council (GEAC), chaired by David Hodas (Widener University School of Law), and published in March 2009.⁴⁵ In addition to Hodas, the GEAC had 18 members, including: Seth Ross (DNS), John Hughes (DNREC), Arnetta McRae (PSC), Gary Stockbridge (Delmarva Power), Stephen Thompson (Chesapeake Utilities), Bill Andrew (DE Electric Coop.), Patrick McCullar (DE Municipal Electric Coop.), and Alan Levin (DE Economic Development Office).

"The goal for the energy plan was to identify where Delaware's energy system should be headed over the next 20 – 30 years, and to identify what can and ought to be done over the next five years to move Delaware in that direction." The process of developing the plan was governed by the following Guiding Principles:

- Increasing energy end-use efficiency and conservation
- Reducing the environmental impacts (footprint) of energy used and generated in Delaware
- Reducing energy used for transportation
- Maximizing clean energy economic development opportunities
- Maintaining and improving the reliability and security of Delaware's energy systems
- Minimizing energy-related costs and impacts on Delaware citizens

There were five Work Groups dealing with various aspects of the plan:

1. Reducing Delaware's Energy Use
2. Reducing the Environmental Footprint of the Energy Delawarean's Use
3. Transmission & Distribution
4. Reducing Transportation Energy Use
5. Clean Energy Businesses

In the Council Chair's Introduction Hodas wrote, "This energy plan represents the emergence of a new generation of energy policy that will begin to move us from a fossil fuel dependent society to a sustainable energy future. Several energy storms are headed in our direction. First, global warming requires that we drastically reduce our greenhouse gas emissions from burning fossil fuels. Second, we need to worry about our dependence on foreign oil. The price of oil has dropped, due to a collapse of demand in response to the global recession, but as the world's economy picks up, demand will rapidly rise, and oil prices will soar again. We must face the fundamental fact that the global demand for petroleum in a healthy world economy will rapidly bump up against real limits on the total oil supply."

Each of the Work Groups made a number of recommendations. Climate change was addressed by the Footprint (FP) Work Group 2, which made seven recommendations:

FP-1: Establish a greenhouse gas reduction goal and a Climate Change Commission to develop a detailed Climate Action Plan for Delaware.

FP-2: Align the Green Energy Program to complement other state and federal programs to help achieve Delaware's renewable energy goals.

FP-3: Enact legislation to eliminate forfeiture provisions from the Net Metering Law.

FP-4: Enact legislation addressing deed restrictions and/or covenants that unduly prohibit the use of renewable energy sources.

FP-5: Examine and revise the Renewable Energy Portfolio Standards.

FP-6: Gather updated supply data and remove legislative restriction on environmentally beneficial Biomass Energy utilization.

FP-7: Reduce the carbon emissions from the State's existing coal facilities.

Energy education and outreach involved recommendations from a couple of groups:

EO-1: Develop and implement a comprehensive Energy Education and Outreach Program.

CE-2: Develop and implement a Comprehensive Energy Workforce Training Strategy.

CE-4: Facilitate public and private sector funding for Clean Energy Research at Delaware's universities.

Other important recommendations included:

G-1: Create a Governor's Executive Office for Energy Policy.

EE-1: Adopt an Energy Reduction Goal & Vision to achieve energy self-sufficiency and carbon neutrality in Delaware's built environment by 2030.

LU-2: Promote Transit-Oriented Development.

CE-3: Fund targeted Wind and Solar industry business development initiatives.

Carolyn Snyder has been hired by DNREC as their new Director of Clean Energy & Climate Policy. Ellis Morgan, who reports to Dr. Snyder, is tracking the recommendations in the **Delaware Energy Plan 2009-2014**.⁴⁶ The plan should be updated in 2015.

SECTION 7. WHAT OTHER STATES ARE DOING ABOUT GHG EMISSIONS

Many states have been proactive in looking for solutions to the mitigation challenges of climate change. The Pew Center on Global Climate Change has documented a plethora of climate change efforts.⁴⁷ The site points out the happy coincidence between the need for action and the concomitant perks of such action: as states reduce their greenhouse gas (GHG) emissions, they

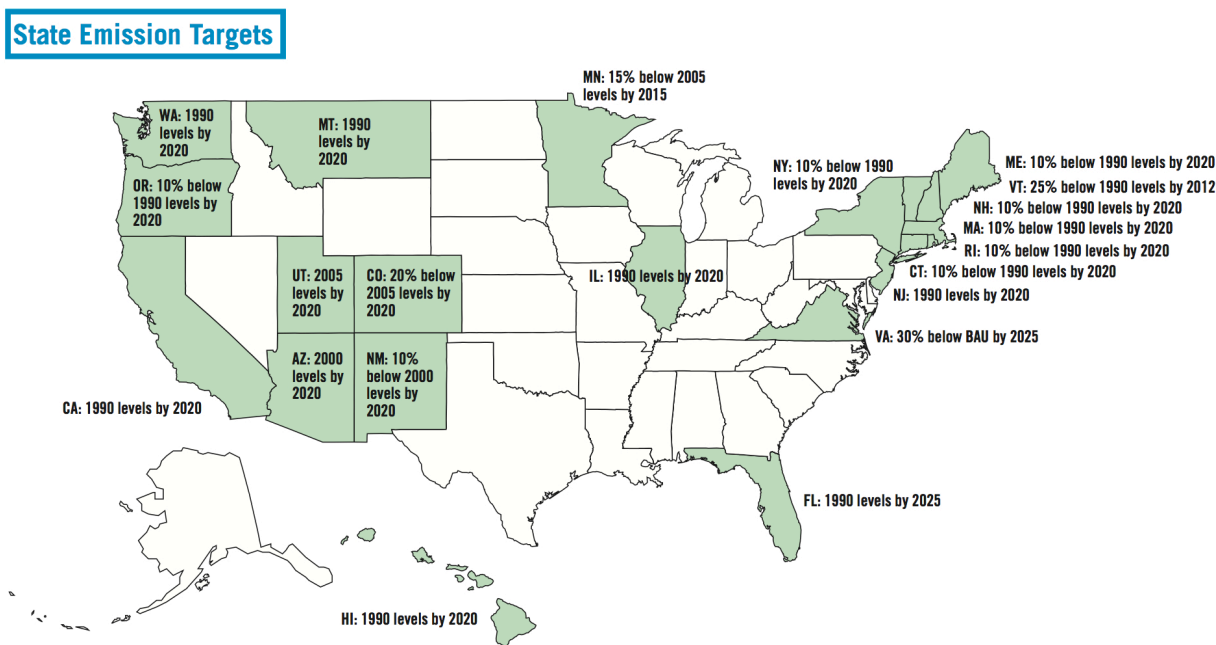


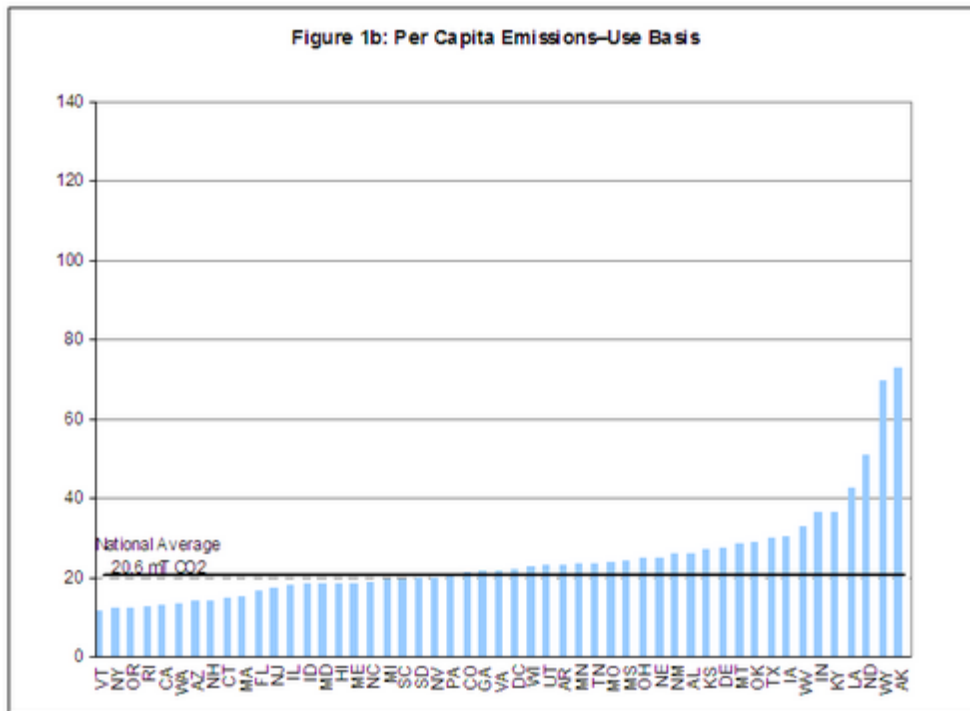
Figure 1. State emission targets. Source: from Figure 6 in Reference 1.

simultaneously reduce traffic congestion, develop domestic clean energy supplies, improve air quality, receive income from selling GHG emission reduction credits and attract high-tech business.

Selling GHG emission reduction credits is the well-known “cap and trade” action discussed in Section 5 of this report, and described in a Wikipedia article.⁴⁸

Figure 1 shows that 21 states have emission targets. Delaware is not yet one of them. It’s not easy to compare the targets because the states have a variety of ways of expressing their goals, yet some comparisons are obvious. GHG emissions in 1990 are most often the goal that states hope to reach, though some of the more ambitious goals reach for levels even below those of 1990. States that plan to get their emissions down to 1990 levels by 2020 or 2025 include Washington State, California, Montana, Illinois, New Jersey and Florida. For the short term,

Vermont's goal is the most ambitious: 25% below 1990 levels by 2012. Keep in mind, however, that Vermont's energy portfolio includes 36% hydropower and 36% nuclear power, so reaching



25% below 1990 levels may not be as difficult a challenge for them as it is for other states with neither nuclear nor hydropower resources. On the longer term, Vermont aims to be 50% below 1990 GHG emission levels by 2028.⁴⁹

Figure 2. Source: Ackerman et al, Greenhouse Gases and the American Lifestyle: Understanding the Interstate Differences in Emissions. April 2009.)

You'll see from Figure 2 that Delaware is 12th from the highest in terms of per capita carbon

dioxide emissions.

Not great. In the least enviable position is Alaska, where carbon dioxide emissions resulting from transportation is probably the reason that its emissions have ratcheted up to such a high level, with much of its commuting done by airplane. Down on the left end of the chart you see Vermont, New York, Oregon, Rhode Island and California, states where CO₂ emissions are well below the national average. The first three of those states use an abundance of hydropower for electricity generation, while Rhode Island uses natural gas, which emits only half the CO₂ per kWh as coal.⁵⁰

Stanton et al.⁵¹ point out that the American predilection for high energy use is based on the false assumption that high emissions are related to a high standard of living. Although we see from Figure 2 that there is a six-fold variation from the lowest emitting states to the highest, per capita income varies only two-fold: from \$37,600 in Washington, D.C., to \$18,000 in Mississippi. While accounting for wide variations in climate, the writers conclude that two factors seriously affect state-to-state differences in per capita CO₂ emissions: energy prices (including gasoline taxes) and public transit infrastructure. They find that the following factors are common among low-emitting states:

- Citizens drive less per person
- Use less electricity per person in their homes
- Have higher gasoline and electricity prices
- Rely more on public transportation
- Use less oil for heating and less coal for electricity generation

And finally, Stanton and her colleagues find that states with the lowest per capita transportation and residential emissions (New York, Washington, D.C., Oregon, California, Rhode Island, Washington, Vermont, New Hampshire) are all above average in per capita income.

Figure 3. Renewable Portfolio Standards. Source: from Figure 2 in Reference 1.

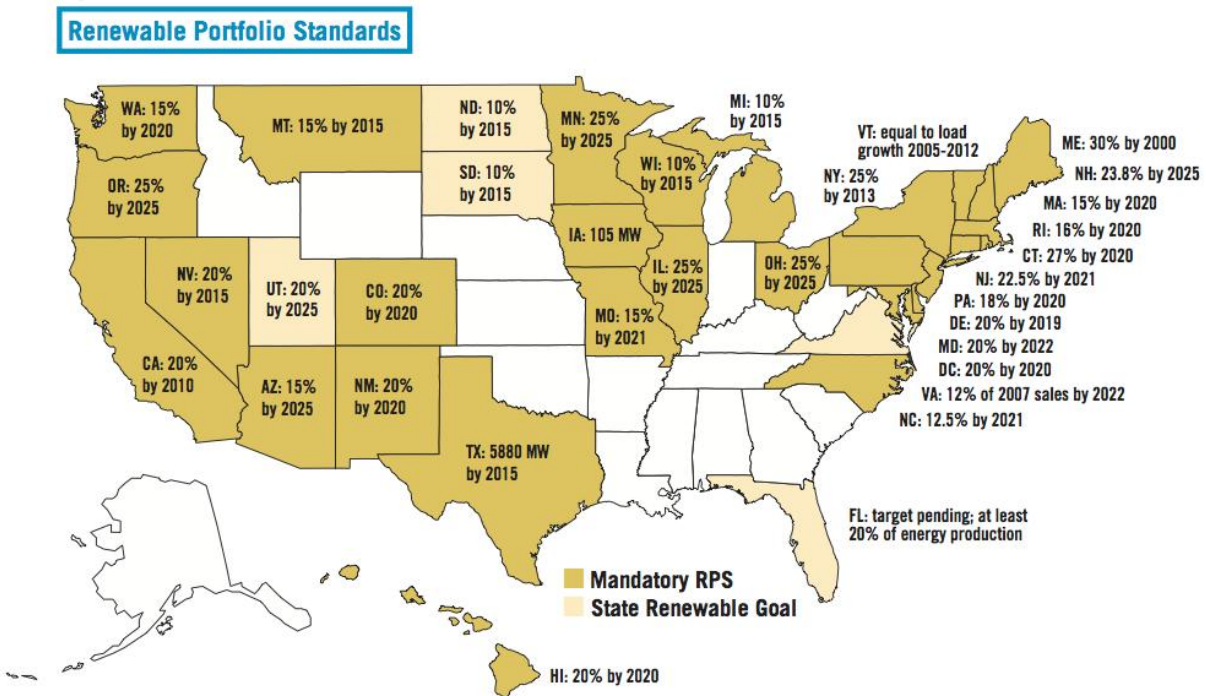


Figure 3 indicates that twenty-nine states and the District of Columbia have statutes that establish compulsory Renewable Portfolio Standards (RPS), requiring that some fraction of total electrical energy used be generated by renewable energy sources, such as wind and solar. A Delaware law signed in 2010 requires that 25% of the electricity produced in the state by 2025 come from renewable sources, with 3.5% from solar.⁵² California, on the other hand, had a goal of buying 20% of its energy from renewable sources by 2010. Maine, another state on the forefront in this area, pledged that 30% of their energy would come from renewable sources by 2000, with an additional 10% by 2017. Although these Maine goals seem ambitious, they are not a serious

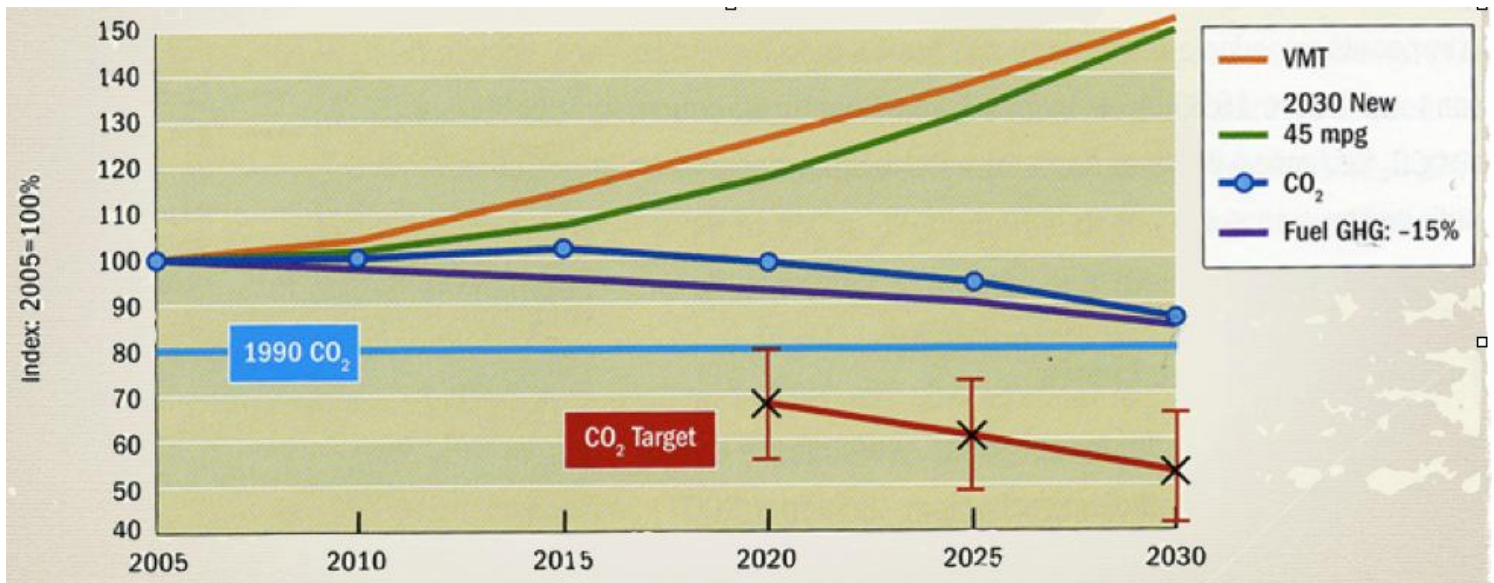
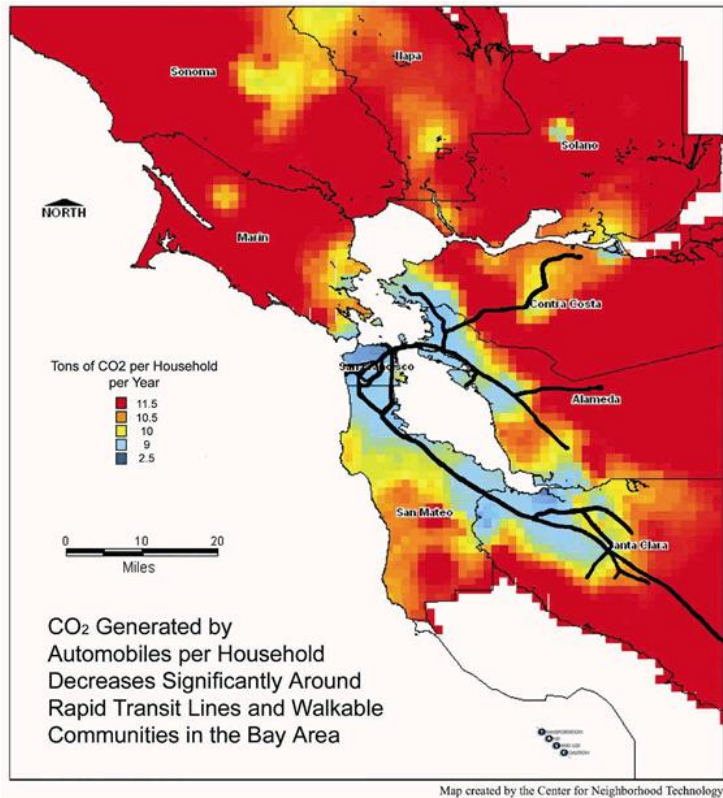


Figure 4. Projected Growth in CO₂ Emissions from Cars and Light Trucks, Assuming More Stringent Nationwide Vehicle and Fuel Standards. Source: Ewing, Reid, et al, Growing Cooler, Urban Land Institute, 2008.

challenge for the state, since renewable energy---largely hydropower---currently makes up 50% of its electricity portfolio.⁵³ Texas and a number of other southern states do not support any initiatives to increase energy from renewable sources or to reduce GHG emissions, nor do Idaho, Wyoming and several midwestern states.

A state with intriguing activity in the climate change mitigation arena is California. California, you will recall from Figure 2, is 5th from the bottom in carbon dioxide emissions per capita. Since it is the lowest-ranking per capita CO₂ emitter without a majority of its electricity generation coming from renewables (14% in 2010), it is more comparable to Delaware in terms of its renewable portfolio. In 2006 California passed Assembly Bill (AB) 32, the Global Warming Solutions Act. This act requires that California reduce its GHG emissions to 1990

levels by 2020. A separate Executive Order calls for bringing the emissions down even further - to an ambitious 80% below 1990 levels by 2050.⁵⁴ Recently court challenges to AB 32 have proved to be a setback, though the complaints are procedural in nature, and will probably just delay its implementation. Proposition 23, an attempt to repeal AB 32, was rejected by voters in 2010.⁵⁵



Lawmakers may have looked at the projections we see in the graph below and realized that without a significant land use element in their planning, they would not meet their goals. Lowering the carbon fuel standard (purple) and improving the energy efficiency of vehicles (green line) would not do the trick, given the dramatic projected rise in vehicle miles traveled (VMT), represented by the red line. SB 375 became law in 2008. This legislation recognizes that transportation contributes 40% of California's GHG emissions. The bill is designed to reduce these emissions by improving land use patterns and offering more housing and transportation choices to Californians. In September of 2010 the California Air Resources Board determined targets for GHG reductions

for each region in the state. Each of the 18 metropolitan planning organization regions, in turn, will work with local government to design a Sustainable Communities Strategy (SCS) for achieving the regional target. An SCS will detail how and where growth and development will take place, and how the region's transportation system can support that growth in a way that reduces GHG emissions.

Central to the concept of SB 375 is that compact, walkable communities require less infrastructure and consume less electricity, water, and natural gas than sprawling, car-centric communities. Figure 5 shows how households in areas with fewer transportation choices and longer driving distances emit much more transportation-related CO₂ per household in a year. In compact, mixed-use communities, the trips are usually shorter. In addition to cutting down on GHG emissions, planners find that better land use practices reduce growth pressure on open space and working farms, and residents of walkable communities are 2.4 times more likely to get in a daily half-hour walk.⁵⁶

Incentives built into SB 375 include streamlining the environmental approval process and some transportation funding. Penalties include legal sanctions and court-imposed jurisdictions for those regions that do not comply with the regulations.⁵⁷

Many Delawareans hope that we can renew our original role as “The First State” by assuming leadership in the area of reducing per capita GHG emissions. A number of states are already well ahead of us, so attaining such a goal will not be easy. Though Delaware is small, it could lead by example---showing that we can improve our economy while protecting our future from the worst consequences of climate change.

SECTION 8. DELAWARE’S RENEWABLE ENERGY RESOURCES

Introduction

This section documents three critical ideas for the development of renewable energy - especially

Figure 5. Transform, Windfall for All: how connected, convenient neighborhoods can protect our climate and safeguard California’s economy; report highlights. [date unknown] <http://www.climateplanca.org/TransformWindfallReportSummary.pdf>

from wind and solar PV (photovoltaic) power - for Delaware’s energy future. They are: 1) these technologies are technically mature and capable of providing significant amounts of clean energy; 2) they can produce a significant amount of electricity without disrupting electrical grids, while reducing CO₂ and other emissions; and 3) their manufacture is being aggressively pursued worldwide. States or nations that fail to encourage their development will miss out on the greatest new economic engine of the 21st century.

Delaware has two excellent resources for electricity that do not involve burning natural gas or coal, which can release CO₂ and other pollutants such as nitrogen oxides (NO_x), sulfur dioxide (SO₂) and mercury, or fissioning uranium, which creates radioactive waste. These are off-shore wind, and solar PV. Delaware has negligible on-shore wind or hydropower resources, and only a small biomass resource. Willett Kempton did an analysis of Delaware’s renewable energy

resources for a 2009 report of the Governor’s Energy Advisory Council, comparing them to the average power the state uses for electricity and transportation. The results are shown in Figure 1.

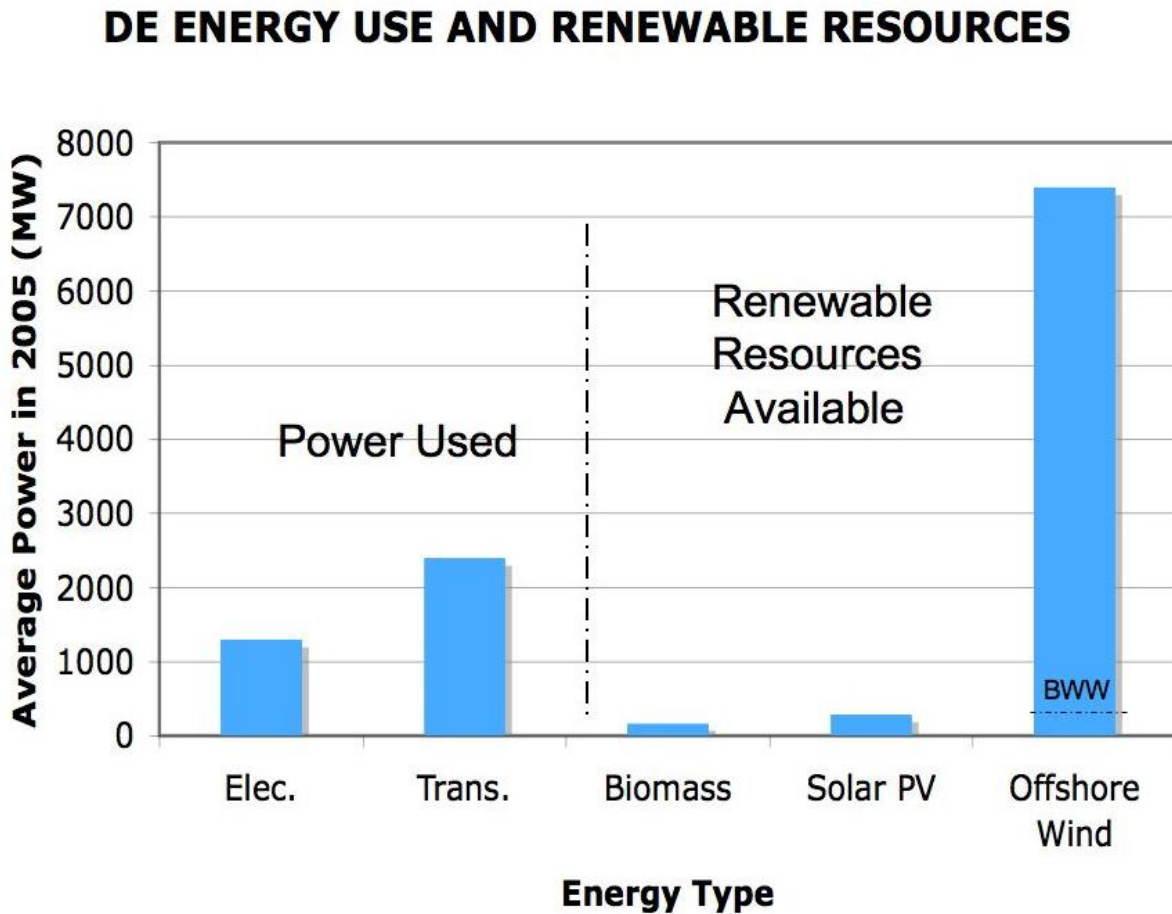


Figure 1. Delaware’s average power use for electricity and transportation and its available power in megawatts (MW) from its renewable energy resources.⁵⁸

The power used for transportation (Trans.) in Figure 1 comes from the burning of gasoline and diesel fuel. The Solar PV resource is assumed to be the tops of all buildings in the state with flat or south-facing roofs, for which Kempton estimated an average potential power source of 288 MWa.⁵⁹ He found an additional 59 MWa on about 1000 acres of fallow agricultural land not suitable for development. The dashed line labeled BWW on the Offshore Wind bar is the 200 MW going from Bluewater Wind to Delmarva Power – clearly only a small fraction of the available resource.

Environmental benefits

Once installed, solar and wind systems generate negligible CO₂ emissions. Within 1-2 years, a solar array ‘pays back’ the energy required for its manufacture. For off-shore wind, this energy pay back time is less than a year. Thus, for the rest of their 20 (wind) or 25-30 (solar) year

lifetimes, every kWh⁶⁰ they generate is emission free energy. Thus, they are ideal technologies to prevent CO₂ and other harmful emissions.

There are data to support this. In 2010, the American Wind Energy Association used the U.S. Department of Energy’s (DOE’s) data on emissions from Colorado’s power plants over time. Table 1 shows that as wind energy increased from providing 2.5% of Colorado’s electricity in 2007 to 6.1% in 2008, CO₂ emissions fell by 4.4%, nitrogen NO_x and SO₂ emissions fell by 6%, coal use fell by 3% (571,000 tons), and electric sector natural gas use fell by 14% (DOE citations for each data point are listed in the hyperlink).

Change in Colorado Power Plant Fossil Fuel Use and Emissions from 2007-2008, as Wind Jumped from Providing 2.5% to 6.1% of Colorado Electricity

CO2 emissions	SO2 emissions	NOx emissions	Coal use	Natural gas use
Down 4.4%	Down 6%	Down 6%	Down 3%	Down 14%

Table 1. Reductions in Emissions from Colorado as wind power increased

Requirements for Wind and Solar PV in Delaware

In 2010, the Governor signed Renewable Portfolio Standard (RPS) legislation requiring Delaware to obtain 25% of its electricity from renewable sources by 2025. A minimum of 3.5% must be from solar PV within the state. This will require installing about 350 MW of PV.⁶¹ To meet this 3.5% goal will require only 0.1% of our land area - about a quarter of the area covered by DE golf courses. As of 2010, Delaware had about 10 MW of grid connected PV installed. This will double with the completion in 2011 of the 10 MW Dover Solar Park. Delaware receives plentiful sunlight - about 75-80% as much as California or Florida.

When completed, the Bluewater Wind/NRG project will supply up to 200 MW to Delmarva Power, or about 15% of Delaware’s average electrical power. Figure 1 shows that the resource is much larger than that. Additional transmission lines will be needed to carry the energy from off-shore to on-shore and then to distribute across the peninsula. Google has offered to invest in a 350 mile 6,000 MW underwater transmission line off the coast from New Jersey to Virginia to help kick-start the industry.⁶² The Department of Energy estimates that the U.S. has 54,000 MW of offshore wind capacity.

Small scale solar PV does not require additional transmission lines because it is a distributed energy source, with the energy used near where it is generated. In fact it reduces grid congestion on hot summer days. Wind farms require additional transmission lines because much more power is produced. Most economic analyses of solar fail to account for its two main advantages from a utility perspective. First, as a distributed source, solar arrays avoid some transmission and distribution (T+D) losses. Second, the peak generation nearly coincides with summer peak demand, driven by late afternoon air conditioning. Thus, solar provides premium value energy.

As we evolve into time-of-use rate charges, solar electricity will be valued even more. One of the nation's largest utilities, Pacific Gas and Electric of California, studied the value of distributed solar generation from a 500 kW PV installation and concluded that the value of the plant to the utility was nearly double the value of the electricity generated once external costs, avoided maintenance, avoided T+D losses, and reduced peaking congestion issues were accounted for⁶³. A much more recent study of the US energy picture state-by-state concluded the same thing using different criteria: namely, small scale distributed energy sources like residential or commercial solar arrays have an economic impact which is more than double centralized, outsider-owned facilities, partially due to the increased employment and services it supports⁶⁴. Studies performed by University of Delaware for Delmarva Power and Light in the early 90's similarly highlighted the value of PV as a demand-reduction (called demand side management) tool to offset peak summer demand.⁶⁵

Solar Installation Issues

Potential residential or commercial PV customers often worry "Does my roof have the right slope? Does my house have good solar exposure?" Other experts ask "Can roof-top mounted solar make a significant impact on our electricity generation?"

In fact, solar modules can be installed at a wide range of tilts and south-facing orientation with little difference in output. Many people are surprised to find that annual output is only weakly dependent on tilt, hence the slope of their roof. In fact, nearly any reasonable tilt - even no tilt (horizontal on flat roofs) - is good. The reason is that the sun's angle varies from 27° to 72° between winter solstice (Dec. 21) to summer solstice (June 21) at our latitude.

What about orientation? For solar installations in the northern hemisphere, the optimum orientation is 'true south'. But again, output is not very sensitive to small deviations because an array oriented to the southeast will get more sunlight in the morning and less in the afternoon.

A recent study by the University of Delaware concluded that roof-top solar arrays in Newark could supply 75% of the city's total daylight (9 AM-6 PM) electricity demand, taking into account tree shading, roof orientation, and structural limits⁶⁶. It did not consider installations over parking lots or ground mounted arrays. Regarding costs, the report concludes "*The results of the modeling of the PV installations in the City show financial feasibility of PV installations for all building sectors – residential, commercial/industrial and university. All configurations are found to be viable, attaining positive net present values (NPV) and benefit-cost ratios (BCR) of greater than 1.00 at both SREC values of \$150 and \$250.*"⁶⁷

You can install modules on motorized supports that track the sun in its daily East to West motion across the sky or its daily and seasonal variation in angle of elevation. However, while these can increase the sunlight collected by 15-40%, they require 5-10 times more land space than stationary arrays. This might be a deterrent in a small state like Delaware. Of course, costs for tracking arrays are higher than for fixed mount arrays. Fortunately, we can easily utilize roof-

mounted and small ground-mounted systems instead of large tracking power stations (on the order of 1-20 MW capacity) that are being installed with increasing frequency in California and Nevada.

So are there any limits to the location for the installation of an array on a roof or in a field? Yes! The array must not have much shadowing on it during the peak production hours from 9 AM to 3 PM (solar time). Even a slight shadow, such as due to a thin pole or leafy tree, on a corner or edge of a module could dramatically reduce the output from the shadowed module and also from the entire array. The shadow issue may present a significant limit in cities or towns with lots of trees or tall buildings, like Newark or Wilmington. A proper pre-installation design will include a shading analysis.

A legal barrier to more widespread application of solar arrays is their ban by most deed-restricted communities, presumable for aesthetic reasons. A significant fraction of Delaware's housing stock is in such communities. Across the country, concerned homeowners have fought such restrictions in court, and won. Last year, Delaware passed legislation preventing future deed-restricted contracts from banning solar arrays, but it did not address the existing covenants. Lifting these would be a significant benefit for solar installation in the state.

Below in Figure 2 are examples of typical rooftop and ground mounted solar installations in Delaware.







Figure 2. Roof mounted and ground mounted residential and commercial PV systems in Delaware. The residential homes are 6.2 kW and 1.8 kW (upper left and right, respectively); the church is Limestone Presbyterian (18 kW). The ground mount is 2.4 kW, all in New Castle County. The bottom photo is a poultry farm (63 kW) in Ellendale in Sussex County.

Large scale wind and solar grid integration issues

Wind and solar are intermittent resources. The time scale for variability can be minutes (e.g., a cloud passing over a solar panel), hours or days. The ability of the grid to reliably accept intermittent energy generation is of great concern to utilities, grid managers, and consumers alike. It is widely recognized the grid needs significant modernization, especially to evolve into the ‘smart grid’ that includes customer initiated demand reduction, consumer choice, remote monitoring and control of individual appliances, and the integration of intermittent energy sources. Many studies have been done to estimate the maximum penetration of intermittent sources into the grid before problems occur. Generally, these studies find that there is no problem with 10-15% wind or solar generation, and even higher levels can be achieved.

Energy storage would allow even higher levels of solar and wind power, but no cheap storage method appears on the horizon. Pumped hydro storage⁶⁸ such as Muddy Run near Conowingo MD is already used and compressed air⁶⁹, grid-tied electric vehicle batteries (when parked and plugged in) called V2G (Vehicle to Grid)⁷⁰, and new battery technologies are being actively explored. The problem of electricity storage is not specific to the intermittent production of electricity; it is a general need for grid management. Electricity demand is quite variable with the

hour of the day and the season; differences of 60% are possible between daily peak (maximum) load and base (minimum) load. Thus, the electric operators, who have a knowledge of the demand behavior, plan the connection or disconnection of power plants to produce enough energy to approximately match demand. In Spain and Denmark, there have been days when wind has provided nearly 100% of the electricity. In Spain and Germany, two countries with a large fraction of wind and solar, it is common for them to provide 10-20% of the power on a given day without any loss of reliability.

Baseload coal or nuclear power generators are normally connected 24/7 (except for occasional full shut downs for repairs or replacing nuclear fuel) and run at full power. As the wind/solar fraction grows (assuming no storage), on windy/sunny days when the intermittent generation alone can meet the demand, some of the wind/solar generation will have to be shut down, because conventional baseload plants cannot be disconnected or decreased quickly. A cheap storage, such as pumped hydro plants, would permit more penetration of intermittent renewable electricity. Either way, in any grid (even without intermittent renewable energy) there is always some idle generation capacity and the associated financial losses but this can be increased by excessive intermittent generation. Researchers at the US NREL in Golden Colorado have shown that PV might provide 10-20% of the load of a traditional grid system⁷¹ while grid modernization and storage might to allow up to 50% penetration of PV.⁷² Mark Jacobson and Mark Delucci at Stanford have shown how California could get all of the electricity it needs by 2030 with a combination of wind, solar, water and geothermal power.⁷³ Of course the availability of renewable energy sources can vary a lot by region. The U.S. Department of Energy provides resource maps for the United States.⁷⁴

Worldwide Solar Installation

Solar energy installation has been growing at 40-50% per year for over a decade. Despite the worldwide recession, it continued strong growth in 2009 and 2010, largely due to various national subsidies and the explosive growth of inexpensive highly automated factories in China.

As of 2011, there is at least 25 gigawatts (GW)⁷⁵ of PV installed worldwide, with at least 15 GW installed just last year (2010). Taking into account cycles of day and night, and cloudiness, this PV generates about as much energy annually as about 5 coal fired power plants. Clearly much greater capacity is needed to offset more coal plants but at the current rate we will double our installed capacity in just another 2 years.

Although we have extolled the value of small (<1 MW) PV installations, the worldwide trend is toward much larger plants. There are over a 1000 plants in the world of ≥ 1 MW, totaling 4.5 GW. There are 45 plants larger than 20 MW - mostly in Spain, Germany, Italy, Korea, Canada and China. The U.S. has only three that large, despite our having more sunny non-agricultural land than most other countries. In 2009 it took less than a year to install 60 MW at Olmedilla de Alarcón, Spain. A typical 1000 MW nuclear plant would require at least 10 years to build, so utility scale PV can be built much faster.

Economic Impact

A 2008 report from the Department of Energy's National Renewable Energy Laboratory identified the direct and indirect jobs created by the solar industry, and projected their needs to 2030⁷⁶. Table 2 shows that nearly half the jobs per MW of installed power in 2008 were in installation. These are local jobs that cannot be outsourced. However, this cost and those for project construction and those for cell and module manufacture must be reduced for much lower cost solar energy to be achieved. Improvements include standardization of design and installation practices, and less complex mounting methods. Even with these improvements, solar is a strong net job generator, creating far more jobs per MW than burning fossil fuels.

Sector	2008 Jobs per MW	2025 Jobs per MW
Operation	0.6	0.6
PV project construction	5.0	2.9
Rooftop installation	20.0	8.8
Silicon and wafers	3.5	1.3
Cell manufacture	5.0	1.9
Module manufacture	6.0	2.2
Inverters	1.3	0.8
Research	0.4	0.15
Development and services	0.2	0.4
TOTAL	42	19

Source: New Energy Finance, 2009

Table 2. Number of jobs per MW (megawatt) of PV installed in 2008 and estimated for 2025. Note that most jobs are currently in the construction and installation category.

In 2008, solar PV employed 75,000 people in Spain, with a comparable number for Germany. Both have very aggressive incentives called production credits or feed-in tariffs, where the payment for feeding solar electrical energy into the grid is larger than the cost of buying energy from the grid. California is the leading U.S. state for clean energy policies; Governor Schwarzenegger has touted the importance of green economic development in his speeches.⁷⁷ California is home to 12,000 green companies. One wind farm in Kern County has created 1,000 jobs. Solar thermal will create 2,000 jobs. Greentech jobs have grown ten times faster than jobs in other sectors, with 500,000 created in the state since 2005. "Green jobs are the single largest source of job growth in California," he said.

The U.S. Conference of Mayors released a report in 2008⁷⁸ that finds the U.S. economy currently has more than 750,000 green jobs, while over the next 30 years, an emphasis on clean energy could cause the number to grow to over 4.2 million. Engineering, legal, research, and consulting currently dominate the green jobs in the United States and could grow by 1.4 million in 30 years, while renewable electricity production will create 1.2 million, alternative transportation fuels 1.5 million, and building retrofits another 81,000. The report notes that most of today's jobs are in metropolitan areas, led by New York City, Washington, D.C., Houston, Texas, and Los Angeles, California; it lists current and projected green jobs by metropolitan area.

Delaware has a professional solar installer's organization called the Delaware Solar Energy Coalition (DSEC) to promote pro-solar policies, grid interconnection regulations and training programs. It represents many of the installers in the state. According to their website,⁷⁹ "DSEC's six installer member companies have created more than 130 full- and part-time jobs throughout Delaware. Since 2007, they have contributed more than \$27 million to Delaware's green economy through the installation of 3,269 kW (3,269,000 watts) of clean, renewable, distributed solar generation." Hiring of qualified technicians and designers is a major limit to their ability to provide more timely estimates and installations. This is a bright spot for the local economy that should be aggressively promoted.

Costs of Solar and Wind Power

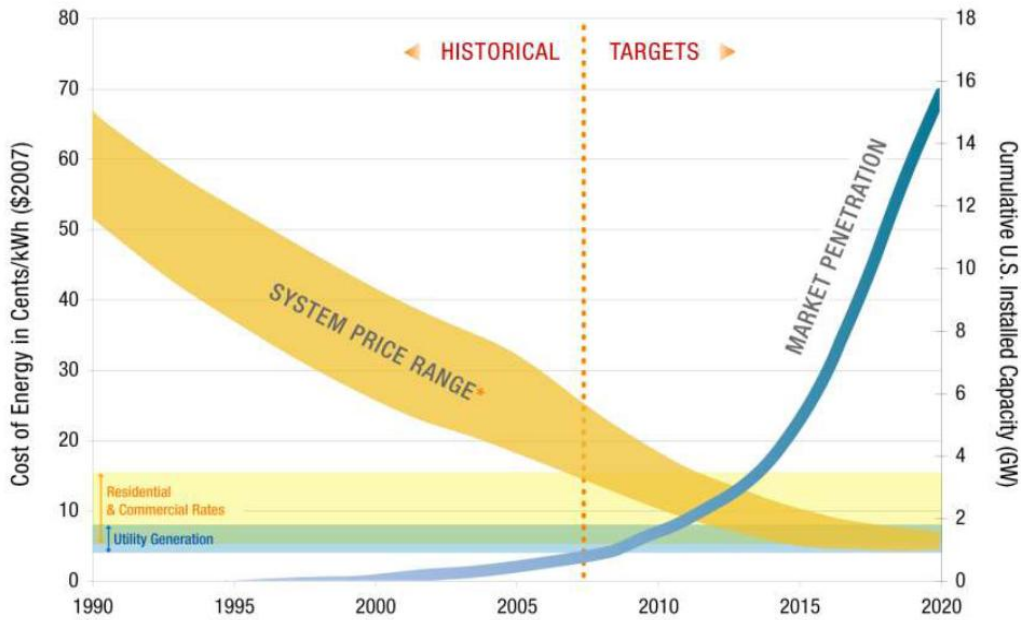
Establishing prices for electrical energy from solar PV and wind is complicated and depends on many factors. In both cases there are economies of scale; larger installations cost less per kWh than small ones. Costs of both technologies have been dropping as market shares have increased and improvements in component manufacturing have been made.

For solar installations installed costs depend on: the type of installation, the size, competitive demand (prices are lower in states with active solar programs due to competition), financing, permitting fees, etc. Component prices vary with demand and by country of manufacture. Prices for both components and installation have been decreasing steadily for decades.

The critical economic parameter in comparing electrical generation technologies is not the installed price in \$/Watt but the levelized cost of energy (LCOE), which is the average amount of energy generated over the lifetime of the system divided by the total costs over that same time. For a solar or wind system you are essentially paying for 25 years of energy up-front, since there is no monthly fuel bill. LCOE calculations take into account the initial cost, available sunlight or average wind speed, the annual degradation rate (typically 1% annually for solar PV), replacement of any parts, maintenance (negligible with solar, larger for wind), financing charges, depreciation, and the length of service (typically 25 years).

Figure 3 shows the solar PV LCOE (shown as SYSTEM PRICE RANGE) vs year from 1990 (historical) to 2020 (projected). The LCOE decreases steadily over time due to decreased manufacturing and installation costs. Note that the figure shows the utility rates constant over

time, when in fact they are increasing. So the break-even point where solar and conventional electricity will cross can be expected sooner than shown. But all such projections are based on assumptions, it is clear that solar PV electricity is destined to achieve cost equivalence with grid power within 10 years.



U.S. Department of Energy Solar Energy Technologies Program 20
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Figure 3. LCOE (SYSTEM PRICE RANGE), utility electric rates vs year for solar PV. The installed U.S. capacity in GW is shown on the right axis.⁸⁰

Jacobson and Delucci have tabulated current (2007) and projected future (2020 and beyond, abbreviated as 2020+) LCOE for a variety of energy sources that can be used for electricity generation.⁸¹ Table 2 shows those applicable to Delaware.

Table 2. Approximate LCOE for Electricity Generation in Delaware

Energy Technology	Annualized Costs in 2007 (¢/kWh)	Annualized Costs in 2020+ (¢/kWh)
Wind	4-7	<4
Fossil Fuels in U.S.	7	8
Wave	>11	4
Solar PV	>20	10

The figures for wind in the table are for onshore wind, which has lower capital investment and operating costs than offshore wind. The Power Purchase Agreement between Bluewater Wind/ NRG and Delmarva Power called for a price of about 11¢/kWh, for up to 300 MW of offshore wind power, increasing by 2.5% per year to account for inflation.⁸² Jacobson and Delucchi expect significant reductions in the costs of all of the renewable energy sources shown, with increases in fossil fuel prices.

ENDNOTES

¹ **LWV US Toolkit for Climate Action**. At: http://participate.lwv.org/c/9217/t/6398/p/salsa/web/common/public/content?content_item_KEY=3766

² **Climate and Energy Policy**, Mary G. Wilson, President, LWVUS, Letter to the Members of the U.S. House of Representatives. At: <http://www.lwv.org/AM/Template.cfm?Section=Home&TEMPLATE=/CM/ContentDisplay.cfm&CONTENTID=13392>

³ **League of Women Voters Applauds Progress on Climate Change Action**, Sandy Spence, President, LWVDE, Letter to the Editor of the Cape Gazette, Dec. 8, 2009. At: de.lwv.org/docs/SpenceClimateLet12-8-09.doc (Download Word document)

⁴ **Dire Predictions – Understanding Global Warming – The Illustrated Guide to the Findings of the IPCC** (Intergovernmental Panel on Climate Change), by Michael E. Mann and Lee R. Kump, DK Publishing, Inc., New York, 2008.

A good source for more information on climate change, including some excellent web resources, can be found in **Section II. The Basics of Climate Change** in the LWV *Toolkit for Climate Action* at: http://participate.lwv.org/c/9217/t/6398/p/salsa/web/common/public/content?content_item_KEY=3769

⁵ **Carbon Dioxide and Climate: A Scientific Assessment**, Jule Charney, Chair. *National Academy of Sciences*, Climate Research Board (1979). Washington, DC: National Academy of Sciences. At: http://www.nap.edu/catalog.php?record_id=12181

⁶ **Target atmospheric CO₂: Where should humanity aim?**, James Hansen et al., *Open Atmospheric Science Journal*, Volume 2, 217-231 (2008); <http://dx.doi.org/10.2174/1874282300802010217>

⁷ **Delaware Sea Level Rise Advisory Committee**, Delaware Coastal Programs, DNREC. At: <http://www.swc.dnrec.delaware.gov/coastal/Pages/DESLRAdvisoryCommittee.aspx>

⁸ **Positive Feedbacks and Climate Runaway – The Need to Act Without Delay**, Chad Tolman, LWVUS Climate Change Task Force. At: http://www.lwv.org/Content/ContentGroups/StudyTaskforces/GlobalClimateChange/CCTF_BP_PositiveFeedback.pdf

⁹ Data from: http://www.eia.doe.gov/states/sep_sum/plain_html/rank_use_per_cap.html

¹⁰ **Delaware Energy Plan 2009-2014**, Governor's Energy Advisory Council, March 2010, p. 27.
At: http://sites.energetics.com/madri/pdfs/DE_Final_Energy_Plan.pdf

¹¹ From: http://switchboard.nrdc.org/blogs/ljohnson/interstate_differences_in_gree.html
This graph was posted in 2009 and probably refers to data from 2008.

¹² Data from: http://en.wikipedia.org/wiki/List_of_countries_by_carbon_dioxide_emissions_per_capita

¹³ **UD's V2G technology takes national stage**, *UDaily*, Feb. 23, 2010. At: <http://www.udel.edu/udaily/2010/feb/aaasv2g022310.html>

¹⁴ Environmental Protection Agency, "Future Temperature Changes," 2010. <http://www.epa.gov/climatechange/science/futuretc.html>

¹⁵ Delaware Department of Natural Resources and Environmental Control, "Climate Change: Delaware's Agriculture." <http://www.dnrec.delaware.gov/ClimateChange/Pages/ClimateChangeDelawareAgriculture.aspx>

¹⁶ Climate Change Science Program, 2009: Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic Region. A report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. James G. Titus (Coordinating Lead Author), K. Eric Anderson, Donald R. Cahoon, Dean B. Gesch, Stephen K. Gill, Benjamin T. Gutierrez, E. Robert Thieler, and S. Jeffress Williams (Lead Authors)]. U.S. Environmental Protection Agency, Washington D.C., USA, 320pp. http://www.epa.gov/climatechange/effects/coastal/slrmmaps_ma_db.html (map showing lands susceptible to sea level rise)

¹⁷ Wilmington Area Planning Council, "Air Quality Conformity," 2010. <http://www.wilmapco.org/aq/>

¹⁸ Op. cit., "Climate change and Delaware."

¹⁹ Ibid.

²⁰ Doug Denison, “Group warns global warming promotes severe weather,” Dover Post, Sept.10, 2010.

²¹ Dee Ross, “Making Resources ‘Climate Ready’ the Subject of New Report,” Estuary News, Summer, 2010.

²² Molly Murray, “The State We Know Is in Peril,” Wilmington News Journal, Feb. 22, 2009.

²³ Op. cit., “Climate Change and Delaware.”

²⁴ Peter Schultz, Principal with ICF International, October 2010, conversation.

²⁵ Delaware Department of Natural Resources and Environmental Control, “Climate Change: Shoreline erosion and migration.” <http://www.dnrec.delaware.gov/ClimateChange/Pages/ClimateChangeShorelineErosion.aspx>

²⁶ Kenneth McGill, “How Important is Tourism to Delaware?” 2008. http://dedo.delaware.gov/information/tourism/Delaware-TSA-final_Feb2008.pdf

²⁷ Bill Swiatek, “Sea-level Rise: Transportation Vulnerability Assessment,” presentation before the Technical Advisory Committee of the Wilmington Area Planning Council, Sept.16, 2010.

²⁸ Environmental Protection Agency, “Climate Change: Health and Environmental Effects; Health,” 2010. <http://www.epa.gov/climatechange/effects/health.html>

²⁹ <http://www.dnrec.delaware.gov/News/Pages/GovernorMinnerSignsRGGIInitiative.aspx>

³⁰ <http://www.standardsolar.com/blog/?tag=rps>

³¹ [http://legis.delaware.gov/LIS/lis145.nsf/vwLegislation/SS+1+for+SB+119/\\$file/legis.html?open](http://legis.delaware.gov/LIS/lis145.nsf/vwLegislation/SS+1+for+SB+119/$file/legis.html?open)

³² <http://camddataandmaps.epa.gov/gdm/index.cfm?fuseaction=emissions.wizard>

33 <http://bcap-energy.org/node/415>

34 **Climate Change and Delaware.** EPA 230-F-97-008h (1997). At: http://www.awm.delaware.gov/Info/Regs/Documents/de_impct1.pdf

35 http://www.swc.dnrec.delaware.gov/coastal/Documents/SeaLevelRise/DNREC_SLR_Policy.pdf

36 <http://www.swc.dnrec.delaware.gov/coastal/Documents/SLR%20Advisory%20Committee/SLR%20Advisory%20Cmte%20Member%20without%20contact%20info.pdf>

37 <http://www.swc.dnrec.delaware.gov/coastal/Pages/DESLRAdvisoryCommittee.aspx>

38 <http://www.swc.dnrec.delaware.gov/coastal/Pages/SeaLevelRiseAdaptation.aspx>

39 **Delaware Climate Change Action Plan.** Available in PDF format at: http://www.udel.edu/ceep/publications/energy/reports/energy_delaware_climate_change_action_plan/deccap.htm

40 Table ES-1 of the Delaware Climate Change Action Plan (2000)

41 **State by State Carbon Dioxide Emissions by Year 2000-2008.** At: www.eia.doe.gov/oiaf/1605/ggrpt/excel/tbl_statetotal.xls

42 The term ‘CO₂-equivalents’ was used because methane, a powerful GHG, can be generated by bacteria in landfills containing organic waste. A ton of methane has the global warming potential of 25 tons of CO₂.

43 Amardeep Dhanju, Phillip Whitaker, Willett Kempton, **Assessing offshore wind resources: An accessible methodology**, *Renewable Energy* (2008). At: <http://www.ceoe.udel.edu/windpower/docs/DhanjuWhitKemp-proof-RE07.pdf>

44 **Bright Ideas for Delaware’s Energy Future**, Sept. 2003. At: <http://www.dnrec.delaware.gov/Admin/Documents/Delaware%20Energy%20Task%20Force%20full%20text%20version.pdf>

⁴⁵ **Delaware Energy Plan 2009-2014**, published on behalf of the Governor’s Energy Advisory Council March 26, 2009. At: <http://www.dnrec.delaware.gov/energy/Documents/Energy%20Plan%20Council%20report%20-%20Final.pdf>

⁴⁶ Conversation with Morgan Ellis, who supplied the LWV DE Energy Committee with an Excel table tracking the recommendations in early 2011.

⁴⁷ Pew Center on Global Climate Change, Climate Change 101: State Action, Jan.2009. http://www.pewclimate.org/docUploads/Climate101-State-Jan09_1.pdf

⁴⁸ **Emissions Trading**, Wikipedia. At: http://en.wikipedia.org/wiki/Emissions_trading

⁴⁹ Vermont Agency of Natural Resources, Department of Environmental Conservation, Air Pollution Control Division, **Vermont Greenhouse Gas Emissions Inventory Update 1990-2008**. Sept. 2010. At: http://www.anr.state.vt.us/anr/climatechange/Pubs/Vermont%20GHG%20Emissions%20Inventory%20Update%201990-2008%20FINAL_09272010.pdf

⁵⁰ Institute for Energy Research, Rhode Island, **Select Economic and Energy Data** [date unknown] <http://www.instituteforenergyresearch.org/states/rhode-island/>

⁵¹ Stanton, E., F. Ackerman and K. Sheeran, **Why Do State Emissions Differ So Widely?** Economics for Equity and Environment. December 2010. http://www.e3network.org/papers/Why_do_state_emissions_differ_so_widely.pdf

⁵² Delaware Senate Substitute 1 for Senate Bill 119, at: [http://www.legis.delaware.gov/LIS/lis145.nsf/vwLegislation/SS+1+for+SB+119/\\$file/legis.html?open](http://www.legis.delaware.gov/LIS/lis145.nsf/vwLegislation/SS+1+for+SB+119/$file/legis.html?open)
See also: <http://www.acore.org/files/pdfs/states/Delaware.pdf>

⁵³ American Wind Energy Association, “State-Level Renewable Energy Portfolio Standards (RPS),” [date unknown]. At: <http://api.ning.com/files/7u1eapyLI6jqSyq7JVXPVxmYUipTwVYRs4cpvYTXF22hftW3qe4TMxjrwJEMewPWqgktaGS83T75VGhQ5EYXYLuasOvYTT3V/AWEAStateLevelRenewableEnergyPortfolioStandardsFactSheet.pdf>

⁵⁴ ClimatePlan Partners, **ClimatePlan: Strategic Plan, 2009-2011**, [date unknown]. http://www.climateplanca.org/StrategicPlan_web.pdf

⁵⁵ Proposition 23 Rejection Legitimizes Climate Policy, Verdantix, Nov. 3, 2010. At: http://www.verdantix.com/index.cfm/papers/Products.Details/product_id/172/proposition-23-rejection-legitimizes-climate-policy/

⁵⁶ ClimatePlan Partners, **ClimatePlan: addressing the land use decisions that shape our climate and our lives.** glossy brochure [date unknown].

⁵⁷ Mintier-Harnish, Regional Planning and Climate Change: Understanding SB 375, [date unknown]. At: http://www.mintierharnish.com/_pdfs/SB375_2010-05-02.pdf

⁵⁸ The figure was made using data from Willett Kempton, **Reducing the Environmental Footprint of the Energy Delawareans Use Work Group**, Report to the Governor's Energy Advisory Council, Appendix C, pp. 48-61. At: <http://www.dnrec.delaware.gov/Admin/Documents/Footprint%20Work%20Group%20-%20Final%20Report%20rev%201-21-09a.pdf>

⁵⁹ M_{Wa} is the average power in MW over a period of a year.

⁶⁰ A kilowatt hour (kWh) is a unit of energy and is what you pay for on your utility bill.

⁶¹ The 350 MW of peak power assumes that the average electrical power consumed in 2025 will be 1600 MW and that the Capacity Factor for PV in Delaware is 0.16. The Capacity Factor is the power, averaged over a year, that one actually gets divided by the maximum power possible (sun directly overhead on a cloudless day in the case of PV).

⁶² **Offshore Wind Power Line Wins Praise, and Backing**, *NY Times*, Oct. 12, 2001. At: <http://www.nytimes.com/2010/10/12/science/earth/12wind.html>

⁶³ T. Hoff, H. Wenger "The value of photovoltaics in the distribution system: PVUSA's Kerman Grid Support Project" Final Report 007.5-94-15 to US DOE (1994).

⁶⁴ Farrell, Morris "Energy Self-Reliant States", published on-line by the New Rules Project (May 2010), <http://www.newrules.org/energy/publications/energy-selfreliant-states-second-and-expanded-edition>

⁶⁵ Two reports are available at: <http://ceep.udel.edu/energy/publications/index.html>

They are:

[“Photovoltaic Technology as a Dispatchable, Peak-Shaving Option.”](#) 1995. John Byrne, Ralph Nigro and Young-Doo Wang. *Public Utilities Fortnightly* (Sept. 1), and

[“Photovoltaics as a Demand-Side Management Technology: An Analysis of Peak-Shaving and Direct Load Control Options.”](#) 1994. John Byrne, Young-Doo Wang and Steven Hegedus. *Progress in Photovoltaics*, Vol. 2: 235-48.

⁶⁶ “CREATING A SOLAR CITY : Determining the Potential of Solar Rooftop Systems in the City of Newark” Final Report August 2009, Renewable Energy Applications for Delaware Yearly (READY) Project (<http://ceep.udel.edu/energy/publications/index.html>)

⁶⁷ SRECs (Solar Renewable Energy Credits) earn payments from utilities to owners of solar PV systems for the energy they generate, in units of \$ per MWh of electricity. A MWh (megawatt hour) is 1000 kWh, so an SREC of \$150/MWh would pay 15¢/kWh.

⁶⁸ Fthenakis V., Kim H., Alsema E., *Environmental Science Technology* 42 (2008) 2168-2174.

⁶⁹ Fthenakis V.M., Mason J., Hansen T., Zweibel K., Proc. 33rd IEEE Photovoltaic Specialists Conference, (2008 San Diego).

⁷⁰ Kempton, W. and J. Tomić, *J. Power Sources* 44 (2005), 268-279.

⁷¹ Denholm P., Margolis R., *Energy Policy* 35 (2007) 2852-2861.

⁷² Denholm P., Margolis R., *Energy Policy* 35 (2007) 4424-4433.

⁷³ Mark Jacobson and Mark Delucchi, *Scientific American*, Nov. 2009, **A Path to Sustainable Energy by 2030**. At: <http://www.stanford.edu/group/efmh/jacobson/sad1109Jaco5p.indd.pdf>

⁷⁴ U.S. Dept. of Energy, *Energy Efficiency and Renewable Energy, Maps and Data*. At: http://www1.eere.energy.gov/maps_data/renewable_resources.html

⁷⁵ 1 GW = 1000 MW, and 1 MW = 1000 kW.

⁷⁶ Barry Friedman “NREL PV Jobs/labor Intensity Project” available at <http://irecusa.org>

⁷⁷ <http://www.greentechmedia.com/articles/read/arnold-lashes-out-at-valero-prop-23-opponents>

⁷⁸ U.S. Conference of Mayors, Green Jobs in U.S. Metro Areas, October 2008. At: <http://www.scribd.com/doc/9666206/US-Conference-of-Mayors-Green-Jobs-in-US-Metro-Areas-October-2008>

⁷⁹ Delaware Solar Energy Coalition. At: www.delsec.org

⁸⁰ **Innovation & Commercialization: What’s Being Done? Presentation** by John Lushetsky, Manager U.S. Department of Energy Solar Energy Technology Program at Solar Leadership Summit 2010 (solartech.org)

⁸¹ From Table 6 in Mark Jacobson and Mark Delucchi, **Evaluating the Feasibility of a Large-Scale Wind, Water, and Sun Energy Infrastructure**. At: <http://www.stanford.edu/group/efmh/jacobson/WindWaterSun1009.pdf>

⁸² Report on Final Power Purchase Agreement between Delmarva Power and Bluewater Wind LLC, Delaware Public Service Commission Docket No. 06-241, July 3, 2008. At: <http://www.ceoe.udel.edu/Windpower/DE-Qs/NEO%20Report%207-3-08%20FINAL.pdf>