Reducing the Environmental Footprint of the Energy Delawareans Use Work Group
Report to the Governor's Energy Advisory Council

I. PERSPECTIVE AND SUMMARY RECOMMENDATIONS

The Environmental Footprint Work Group framed its activities as follows:

> *The best way to reduce the environmental footprint from our energy use is to reduce consumption. For the consumption that remains, reducing the footprint necessitates increasing the percentage supplied by cleaner or renewable sources of energy.*

Therefore, the work group focused its efforts on addressing the central question "How can we increase the percentage of clean and renewable energy to meet Delaware's future energy needs?"

Delaware shares our national goals of energy security and environmental sustainability. However, by virtue of it size, location, economy, etc., its needs, incentives and policy directions may be distinct in important ways from those of the nation as a whole. For example, because of its coastal location and low elevation, Delaware is one of the most vulnerable states to sea level rise resulting from climate change. While our absolute contribution to US greenhouse gas (GHG) emissions is small (0.3%), this provides considerable incentive for Delaware to take a leadership position. At the same time, the form of that leadership must acknowledge Delaware's size. We can make the greatest difference by demonstration of the effectiveness of our technology and policy innovations to meet leading-edge energy and environmental targets, rather than by leveraging a large market as, for example, California might. The actions that we take should not only demonstrate leadership, but should have considerable impact on the environmental footprint of Delaware's energy use.

Delaware's record in the energy arena is decidedly mixed. At present, our per capita energy use is higher than the US average by ~10% and higher than that of neighboring mid-Atlantic states by 15 to 33%. Our electricity generation within the state is dominated by coal, and more than 90% of the CO_2 generated by electricity production in state is produced from burning coal. Also, electricity generated within the state is equivalent to only about 2/3 of the electricity consumed in the state. Thus, in seeking to increase the share of clean and renewable energy supplies in our portfolio, it is important to consider tools that can be applied within our borders, as well as those that can effectively influence the energy supplies that we rely upon that are outside the State. Renewable energy sources evaluated by surveys of work group members and subsequent capacity analysis identified distributed solar and off-shore wind as the most promising options for renewable power in-state.

Delaware leads neighboring states in some areas and trails in others with respect to reducing the impact of its energy use. Its 2003 Energy Plan, to which this report is a successor, was an important example of leadership. Its Sustainable Energy Utility (SEU) legislation is regarded as an innovative model that is being closely watched by others. Its Renewable Portfolio Standard (RPS) is commensurate with those of many other states, although, like many of those, it does not apply uniformly to all electricity suppliers. Delaware has been less aggressive than some other states in revisiting and increasing its RPS. Its Public Benefits Charge is among the lowest, and it lags neighbors such as Maryland in the establishment of a state Climate Change Commission or of energy efficiency and renewable resource criteria for public expenditures.

The recommendations summarized below represent a series of actions aimed at restoring Delaware to a forefront position within realistic time and cost constraints. They include specific actions to increase the development and deployment of renewable energy resources, as well as the establishment of structures to maintain the focus on critical energy and environmental issues on a continuing basis. Finally, they reflect our recognition that opportunities exist to coordinate state activities in energy and to reduce regulatory and statutory impediments to the reduction of our energy footprint, and suggest ways to capitalize on them.

Recommendation Summary

The recommendations listed below are discussed in detail in the final section of the report.

Recommendation 1: Climate Change Commission

The Governor should establish a greenhouse gas reduction goal and a Climate Change Commission to develop a detailed Climate Change Action Plan for Delaware, including a trajectory for the reduction in greenhouse gas emissions and an adaptation plan, incorporating periodic review and evaluation of the plan.

Recommendation 2: Energy Planning Governance

Energy Policy should be elevated to the Governor's office by creating a Governor's Executive Office for Energy Policy that would provide for coordinated development and implementation of Delaware Energy Policy, including a review and evaluation of the governance structure regarding energy issues among executive bodies including but not limited to: DNREC, the Energy Office, the Public Service Commission, the Public Advocate, the Governor's Energy Advisory Council and the Governor's Office.

Recommendation 3: Public Buildings and Facilities

The State should promulgate or enact a policy that sets standards and requires renewable energy systems to be incorporated in new construction and renovations of public facilities.

Recommendation 4: Renewable Energy Portfolio Standards

A. *The Renewable Energy Portfolio Standard (RPS) should be expanded to apply to the Delaware Electric Cooperative (DEC) and Delaware Municipal Electric Corporation (DEMEC).*
B. *In 2010, the Governor should have an evaluation conducted to determine whether or not to increase the RPS requirement to be greater than the current specification of 20% by 2020.*

Recommendation 5: Net Metering
Legislation should eliminate forfeiture provisions from the Net Metering Law

Recommendation 6: Solar/Renewable Energy Access
Solar and renewable energy rights should be available to the citizens of Delaware. Barriers, and methods to relieve those barriers, need to be examined and addressed. One approach to consider is legislation that would reduce barriers, including deed restrictions and covenants, to installation of new renewable energy systems.

Recommendation 7: Green Energy Program
The Green Energy Program should be examined and aligned to complement other programs, including the SEU, to help achieve Delaware's renewable energy goals and solar carve-out. The review of the Green Energy program should include the Public Benefit Charge, including the question of application of the charge equally state-wide.

Recommendation 8: Biomass Energy
A. An updated "Delaware Biomass Supply Assessment" should be conducted, including current and potential biomass feed stocks and by-products from all agricultural & forestry activities in the urban and rural communities of the state.
B. Delaware Senate Bill 280, enacted during the 140th General Assembly, should be amended to eliminate unconstructive impacts on Delaware's biomass utilization and economic growth both in the urban and agricultural communities.

Recommendation 9: The Role of Delaware's Local Governments in the State's Energy Plan

A. *Local governments should be encouraged to develop climate change action plans.*
B. *Local governments should be asked to identify specific state policies and programs and forms of assistance that would be helpful to them in developing and implementing their climate action plans.*
C. *The State should develop and implement specific policies and programs that are complementary to these local plans; and provide financial assistance, technical assistance, planning grants and other incentives that will help local Delaware governments to overcome the financial and technical obstacles that prevent their developing and successfully implementing these climate change plans and projects, which could include but not be limited to, the following:*

a. *Establish and fund a Local Government Liaison/Assistance unit within the State Energy Office which will develop expertise in best practices for local government climate change plans and activities, provide climate change planning grants to local governments, and ongoing technical assistance.*
b. *Develop and/or acquire greenhouse gas (GHG) inventory tools that can be shared with local governments so that they can determine baselines, effectively track emissions and monitor progress in reaching the goals of their climate change plans.*
c. *Examine how the State can support the process underway to "write the official Protocol for GHG inventory for all U.S. local governments" which has been undertaken by the International Council for Local Environmental Initiatives (ICLEI).*
d. *If and when the federal Energy Efficiency and Conservation Block Grant (EECBG) program is funded, the Local Government Assistance unit should establish a process for providing sub grants to non-entitlement communities in the state.*
e. *Require that all Comprehensive Land Use Plans include an "element" for Energy and Conservation. This element should identify an existing Climate Change Plan or the process and timetable for developing one within a prescribed timeline*.
f. *Revise the state formula for Municipal Street funding to give additional funding to those municipalities that have a Climate Change Plan and/or are achieving pre-determined levels of GHG emissions reductions.*
g. *Identify "green energy" purchasing policies and identify awarded contracts as containing "green" items on the state's contracting web site.*

<u>Recommendation 10: Electric End-Use Substitution Demonstration Project</u>
The State should develop a demonstration project for electric end-use substitution, storage and control, focusing on alternatives to non-renewable heating fuels.

<u>Recommendation 11: Public Education & Outreach</u>
The State should develop and implement a comprehensive public education and outreach program that includes:

1. *Informing citizens about public policies (such as the Renewable Energy Portfolio Standards and Regional Greenhouse Gas Initiative) and the incentives available from the State, the Sustainable Energy Utility and the Federal government.*
2. *Educating citizens about the importance and benefits of reducing the state's greenhouse gas emissions--including the economic benefits, new jobs and improved public health, and the potential costs of not doing so.*
3. *Educating citizens on how to determine their personal GHG footprint and actions they can take to reduce it.*
4. *Establishing criteria by which the educational plan can be evaluated objectively on a regular basis.*

It should be recognized that this is not an exhaustive list and that there are other prospective means of reducing the environmental footprint that results from energy use in Delaware, including carbon sequestration and other methods of mitigating carbon emissions. Since the work group's mandate was focused on ways to increase our reliance on renewable energy, these strategies

were not considered further. However, such methods could contribute in the future to further reducing Delaware's carbon footprint and may merit further review by the Governor's Energy Advisory Council, as well as seeking DOE funding for R&D and pilot projects.

II. WORK GROUP COMPOSITION AND PROCESS

The work group was developed to represent a diverse group of energy related companies, utilities, state and local government, universities, energy or environmental non-profits, citizen groups and energy consultants. Members of the workgroup are shown in appendix A.

The work group held monthly meetings (May through December, 2008), initially focused on clarifying the scope of the work group's efforts, then providing background information and education to work group members on relevant topics, development of a qualitative resources matrix and identification of potential recommendation topics, review and discussion of recommendation strawmen developed by work group members, and finally, decisions on recommendations to forward to the Governor's Energy Advisory Council.

Presentations given to the work group and meeting notes were posted on the energy plan website so members could keep up to speed if they needed to miss a meeting. The work group operated by consensus, agreeing to include in the report a discussion of issues and recommendations that did not achieve consensus.

The work of this work group mainly intersects with that of the other four work groups, but most directly with that of Work Group 1 – Reducing Delaware's Energy Use, and Work Group 5 – Supporting Delaware's Clean Energy Business Community, as shown in figure 1.

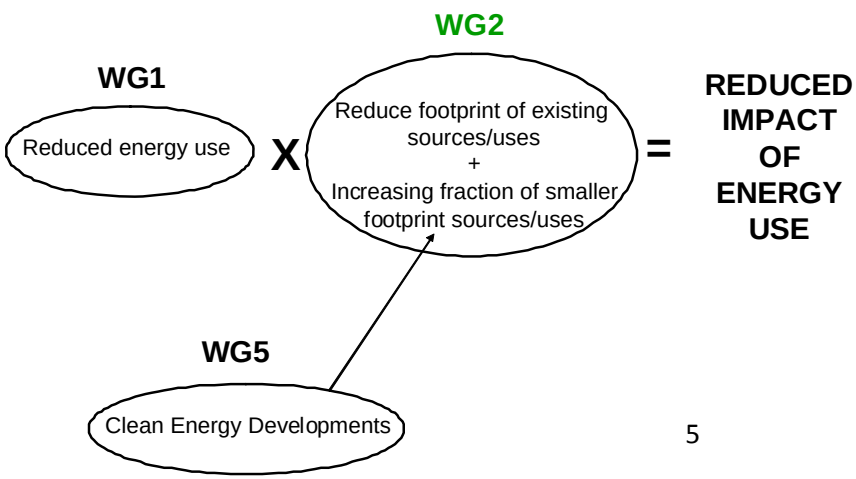

Figure 1. Intersection of Work Groups 1, 2 and 5.

III. CONTEXT OF THE ENVIRONMENTAL FOOTPRINT OF DELAWARE'S ENERGY USE

As they are nationally, Delaware's current energy use patterns and pollutant emissions profile (greenhouse gases and other air pollutants) are the driving force for the need to reduce the environmental footprint from energy use. Delaware's energy position mirrors other States in many respects, but also includes several situations unique to Delaware or the region. The recommendations developed by the work group are based, in part, on a review of the following information.

A. Energy Consumption

Annual world energy consumption is approximately 400 Quads[1], with the US representing about one-quarter of that at approximately 100 Quads per year. Annual energy consumption in Delaware is approximately 0.3% of total US energy consumption.

Total Delaware energy use in 2005 was 312.6 trillion BTUs (or 0.313 Quads). In 1999, total Delaware energy use was 280 trillion BTUs.[2] Total energy use grew 11.6% over the 6 year period. Per capita use was ~357 million BTUs in 1999, and 372 million BTUs in 2005, a growth of 4.2% over the 6 year period.

Although Delaware's total energy use represents only 0.3% of US energy consumption, per capita energy use in Delaware is higher than the national average (339 million BTUs in 2005). In fact, Delaware ranked as the 19th largest per capita user of energy. The States with the lowest and highest 2005 per capita energy use were:

- Rhode Island 213 million BTU
- New York 217 million BTU
- California 232 million BTU
- Wyoming 912 million BTU
- Alaska 1,192 million BTU

In addition, 2005 per capita use was lower than Delaware's in all neighboring states:

- Delaware 372 million BTU

[1] One Quad = One Quadrillion BTU.
[2] The 2003 Energy Task Force utilized 1999 data, the most current at the time.

- Maryland 279 million BTU
- New Jersey 315 million BTU
- Pennsylvania 327 million BTU

B. Energy Use and Sources by Sector

Energy use in Delaware is distributed among the four conventional sectors similarly to the overall national distribution. In Delaware, less energy is used, relatively, for transportation, and more in the residential and industrial sectors, figures 2 and 3 below. The changes in the pattern of energy use in Delaware between 1999 and 2005 included 3% increases in both the residential and commercial sectors (from 20 to 23% residential and 16 to 19% commercial) and corresponding decreases in the percentages of the use in industry and transportation (from 39 to 35% industry and 25 to 23% transportation).

Figure 2: US Energy Use by Sector, 2006

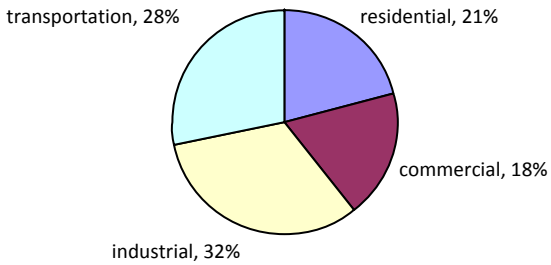

Figure 3: Delaware Energy Use by Sector, 2005

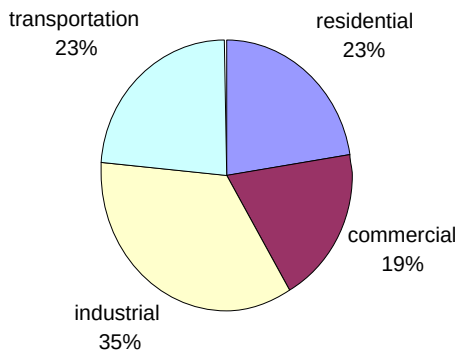

Figure 4 shows US primary energy consumption by source and sector in 2006 (quadrillion BTUs).[3] The lines represent the percentages of fuel sent to each sector and percentage of the sector's fuel that comes from that source. With the exception of nuclear power, which is only used for electricity generation, all fuels are used in multiple sectors, although petroleum use for electricity generation is quite small.

[3] Source: http://www.eia.doe.gov/basics/energybasics101.html

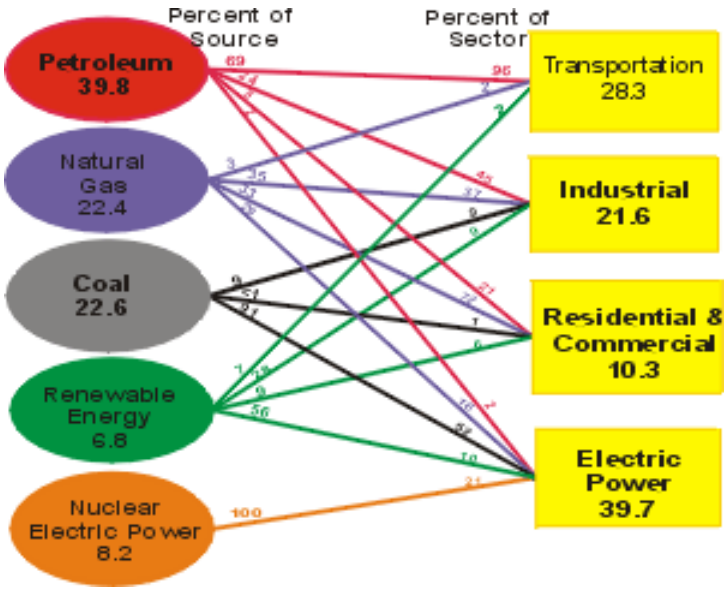

Figure 4: US Primary Energy Consumption by Source & Sector, 2006

C. Electricity Generation and Consumption

Electricity is generated within Delaware mainly by burning coal, although there are also generation units fueled by natural gas and oil. Generation from renewable and landfill gas (shown as "Other" in Figure 5) represents a small but growing percentage of Delaware's in-state generation.

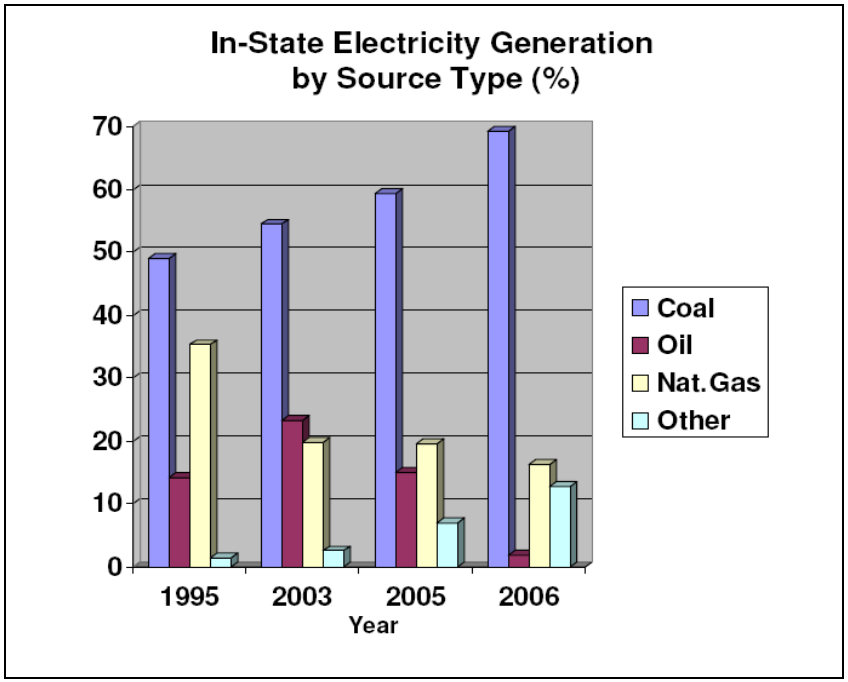

Figure 5

Figures 6 & 7 focus on fuels used for electricity generation. They show the percentage of each fuel used nationally and in the PJM region, which supplies electricity to Delaware, the District of Columbia, and twelve other states. Both charts show heavy reliance on coal for electricity generation, followed by nuclear and natural gas. In PJM, there is a much heavier use of nuclear-generated electricity and less on natural gas than nationally. The PJM region also uses relatively less oil, hydroelectric and renewables in the mix of fuels.

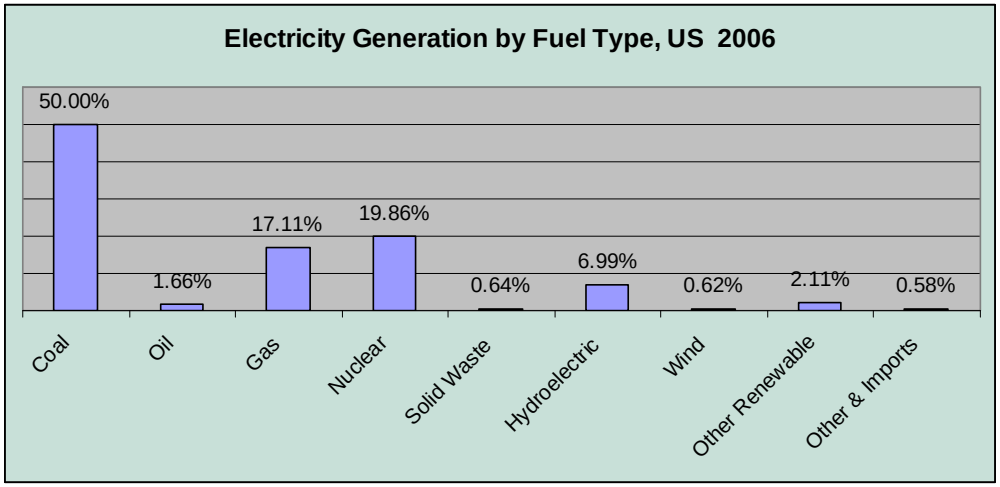

Figure 6

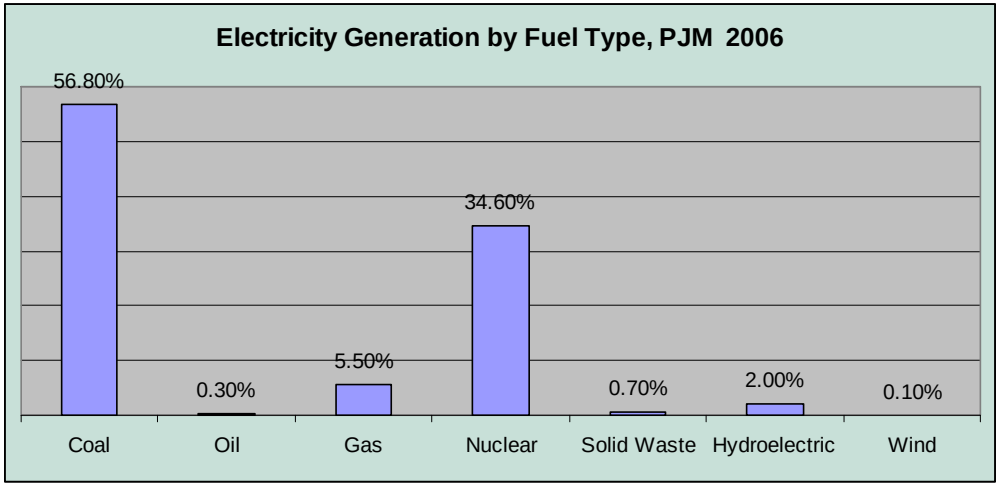

Figure 7

Electricity is generated in Delaware at facilities shown in Table 1.[4] The main and secondary fuels for each facility are shown. Two landfill gas to energy operations in Kent and Sussex counties became operational in 2007, with combined generation of 7 MW (Kent: 4 MW, Sussex: 3 MW).

[4] Source: Delaware Department of Natural Resources & Environmental Control, Air Quality Management Section. Analysis of 2002 Emissions from Delaware Electricity Generating Units (EGUs). Email from David Fees, 2/15/2008

Table 1. Electricity Generation Facilities in Delaware, 2006 [SOURCE: DNREC Air Emissions Inventory]

Plant Name	Main Fuel	Other Fuels	Nameplate Capacity (MW)
City of Dover			
McKee Run	Residual Oil	Natural Gas	151.2
Van Sant	Natural Gas	Distillate Oil	45.1
City of Lewes[5]	Distillate Oil		1
City of Seaford[6]	Distillate Oil		1.43
Conectiv			
Christiana	Distillate Oil		45
Delaware City	Distillate Oil		14
Edge Moor	Coal	LFG, WWTP Gas, Natural Gas, Distillate Oil	251.8
Edge Moor	Residual Oil	Natural Gas, Distillate Oil	446
Edge Moor	Distillate Oil		12.5
Hay Road	Natural Gas	Distillate Oil	705
Hay Road	Waste Heat		237
Madison Street	Distillate Oil		14
West Substation	Distillate Oil		14
Invista[7]	Coal	Residual Oil, Natural Gas	30
NRG			
Energy Center Dover	Coal	Natural Gas	18
Energy Center Dover	Natural Gas	Distillate Oil	100
Indian River	Coal	Distillate Oil	782.4
Indian River	Distillate Oil		17
Premcor[8]			
Refinery	Refinery Gas		119
Refinery	Refinery Gas	Syngas	63
Refinery	Syngas	Distillate Oil, Natural Gas	180
Warren F. Sam Beasley Station	Natural Gas	Distillate Oil	45
Ameresco	Landfill Gas		7

[5] Peak power generation only
[6] Ibid
[7] Internal power generation only
[8] Ibid

TOTAL			**3299.43 MW**

It is important to note the distinctions between Delaware's electricity generation and consumption vs. the PJM region. Since there are no nuclear power plants in Delaware, that component is absent from the in-state generation portfolio. As a result, power plants in Delaware are proportionately more dependent on coal than the PJM region average. According to the US Energy Information Agency, in 2006 nearly 70% of the electricity generated in Delaware was from burning coal.[9] As shown below, this also increases to relative emissions from electricity generation units (EGUs) compared to PJM region averages.

The overall production of electricity in Delaware is less than the amount of electricity consumed within the state. In 2006, net electricity generation within the state was 7,182,179 MWh, while total retail electricity sales were 11,554,627 MWh.[10] Thus net electricity generation in Delaware represents only 62% of electricity consumption in Delaware. Since this imbalance is not likely to shift in the near future, it indicates that strategies to reduce the environmental footprint of Delaware's energy use need to consider the environmental footprint of electricity supplied from out of state, as well as that of EGUs within the state.

D. Environmental Footprint of Electricity Generation in Delaware

The work group reviewed presentations of emissions information, and concentrated its efforts on emissions of CO_2 and other greenhouse gases. The other air pollutants associated with energy generation/use, such as SO_2, NOx, mercury and other toxics, are being addressed by current and proposed regulations, as discussed below.

The major sources of CO_2 emissions from electricity generation in Delaware are the coal-fired generation units, as shown in Figure 8. This reflects both the difference in emissions levels based on fuel source and the percentage of the in-state electricity generation that is fueled by coal. Coal produces about twice as much CO_2 per kWh of electricity generated as does natural gas.

The 2006 air emissions from each electricity generation plant in Delaware are shown in Table 2.[11] The emissions are combined for all units at each site. Mercury data are not included in this chart.

[9] Source: http://www.eia.doe.gov/cneaf/electricity/st_profiles/delaware.html

[10] Source: http:// www.eia.doe.gov/cneaf/electricity/st_profiles/e_profiles_sum.html

[11] Source: Delaware Department of Natural Resources & Environmental Control, Air Quality Management Section. Analysis of 2002 Emissions from Delaware Electricity Generating Units (EGUs). Email from David Fees, 2/15/2008

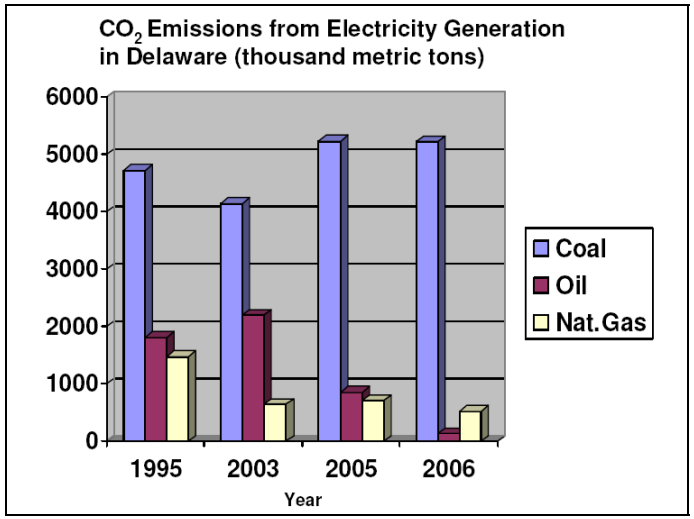

Figure 8

Table 2. Electricity Generation Facilities in Delaware, Air Emissions, 2006

Plant Name	CO2 (TPY)	SO2 (TPY)	NOx (TPY)	PM2.5 (TPY)	VOC (TPY)
City of Dover McKee Run	19,959	55	47	3	1
City of Dover Van Sant	2,538	0	2	0	0
Conectiv Christiana	1,257	2	5	0	0
Conectiv Delaware City	724	1	2	0	0
Conectiv Edge Moor	1,657,418	7,982	1,665	416	24
Conectiv Hay Road	564,024	3	269	30	9
Conectiv West Substation	474	0	1	0	0
Invista	270,946	4,143	1053	249	3
NRG Energy Center Dover	127,498	1,531	382	95	2
NRG Indian River	3,573,125	20,706	6,373	2,346	33
Premcor Refinery	1,665,563	496	779	21	4
Warren F. Sam Beasley Station	9,360	0	2	1	0
Total	7,892,886	34,919	10,580	3,161	76

Air pollution emissions from electricity generating units as a percentage of all sources of emissions were evaluated for 2002. The results are shown in Table 3.[12]

Table 3. Percentage Contribution of Electricity Generation Facilities to Air Pollution Emissions, 2002.

% Contribution of Electricity Generating Units to:	NOx	SO2	PM2.5	Hg
All point sources	73%	87%	65%	27%
All point and mobile sources	22%	78%	45%	27%
All sources	21%	76%	29%	24%

E. Current Regulations on the Impact of Emissions of Greenhouse Gases (GHG) and Other Pollutants

Regional Greenhouse Gas Initiative

The Regional Greenhouse Gas Initiative (RGGI) is a collaborative program encompassing 10 states in the Northeast and Mid-Atlantic region designed to reduce carbon dioxide emissions from power plants. The states (MD, DE, NJ, NY, CT, RI, MA, VT, NH, ME) have started a cap and trade program for CO_2 emission allowances, the first such program in the country. Each allowance corresponds to one short ton of CO_2. The program was designed to hold CO_2 emissions constant through 2015 (based on 2000-2002 average annual emissions), and then reduce emissions 2.5% per year to reach 10% by the end of 2019. The program applies to any fossil fueled electric generating unit of greater than 25MW, if that unit sells more than 10% of the electricity it generates on the commercial market.

The RGGI program will officially begin in January 2009 and is composed of four, three year "compliance" periods. At the end of each compliance period, affected facilities will be required to surrender a number of CO_2 emission allowances equal to their total tons of CO_2 emitted over the preceding 3 years. Allowances will be made available by each state's regulatory agency through auctions, sales or allocation (given free of cost) conducted on a periodic basis throughout the compliance period. Allowances will also be "created" through development of specific offset projects conducted by or for affected facilities. Each participating state is required to adopt its own regulations to implement the program. All states are to have required regulations in place by the close of 2008.

[12] Source: Ibid. Data reflects reduced SO_2 emissions from Premcor's non-EGU units.

Delaware has developed legislation and regulation to implement RGGI and will be one of the few participating state that will actually provide a reduction greater than 10% as soon as 2011.

Delaware Air Pollution Regulations that Apply to Power Plant Emissions

- New Source Review: A delegated federal program that applies to power plants based on the date of construction/ modification.
- Regulation No. 1112, NOx RACT: A state program that defines a minimum level of NOx control. Developed to aid in the attainment of the ozone standard.
- NOx Budget Program: A collaboration among 13-states to reduce NOx emissions to aid in the attainment of the ozone standard. This program was succeeded by the federal NOx SIP Call.
- Regulation No. 1144, Stationary Generators: Designed to aid in ozone standard attainment by reducing NOx emissions from generators that have high peak day emissions, yet were uncontrolled because of low annual emissions.
- Regulation 1146 Multi-pollutant: Designed to reduce emissions of SO2, NOx, and Hg to aid in the attainment of ozone and fine particulate matter standards, and to reduce impacts of mercury emissions. Promulgated due to the ineffectiveness of federal programs for Delaware units.
- Regulation 1147, Regional Greenhouse Gas Initiative: Reduces CO2 emissions as a first step to address climate change.
- Regulation 1148, Peaking Units: Designed to aid in ozone standard attainment by reducing NOx emissions from combustion turbines that have high peak day emissions, yet were uncontrolled because of low annual emissions.

The past and projected emissions as the regulatory requirements become effective are shown in Figures 9 through 12.[13]

[13] Mercury and carbon emissions were not subject to regulation and/or tracking prior to the start of the data in their figures (11 and 12). The figures are not meant to imply that there were no emissions prior to those start dates.

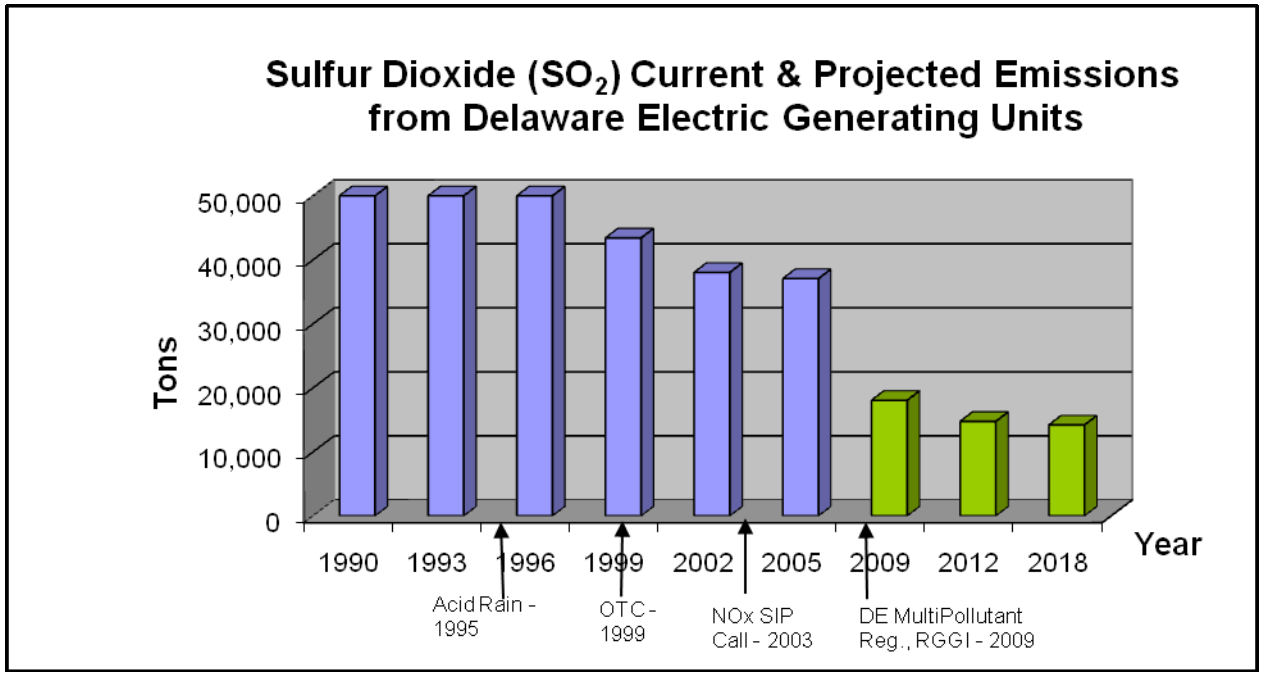
Sulfur Dioxide (SO_2) Current & Projected Emissions from Delaware Electric Generating Units
Tons
50,000
40,000
30,000
20,000
10,000
0
1990
1993
1996
1999
2002
2005
2009
2012
2018
Year
Acid Rain - 1995
OTC - 1999
NOx SIP Call - 2003
DE MultiPollutant Reg., RGGI - 2009

Figure 9

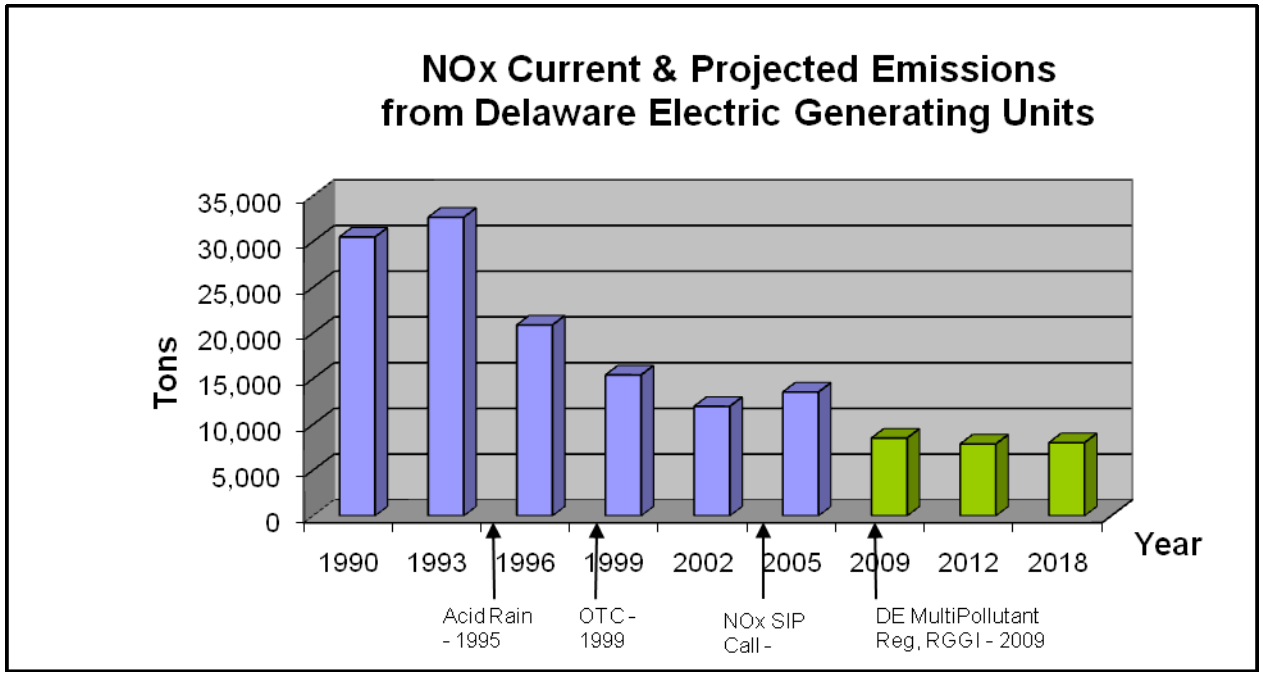
NOx Current & Projected Emissions
from Delaware Electric Generating Units
Tons
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1990
1993
1996
1999
2002
2005
2009
2012
2018
Year
Acid Rain - 1995
OTC - 1999
NOx SIP Call -
DE MultiPollutant Reg, RGGI - 2009

Figure 10

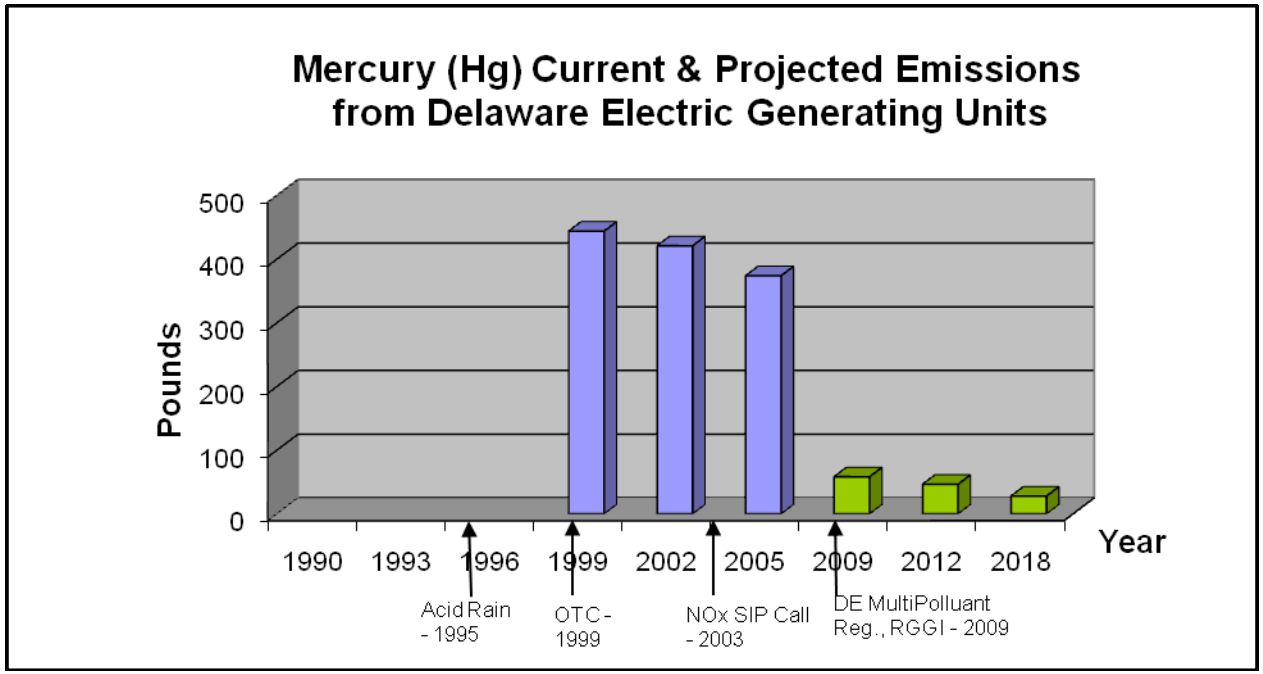
Mercury (Hg) Current & Projected Emissions from Delaware Electric Generating Units
Pounds
500
400
300
200
100
0
1990
1993
1996
1999
2002
2005
2009
2012
2018
Year
Acid Rain - 1995
OTC - 1999
NOx SIP Call - 2003
DE MultiPolluant Reg., RGGI - 2009

Figure 11

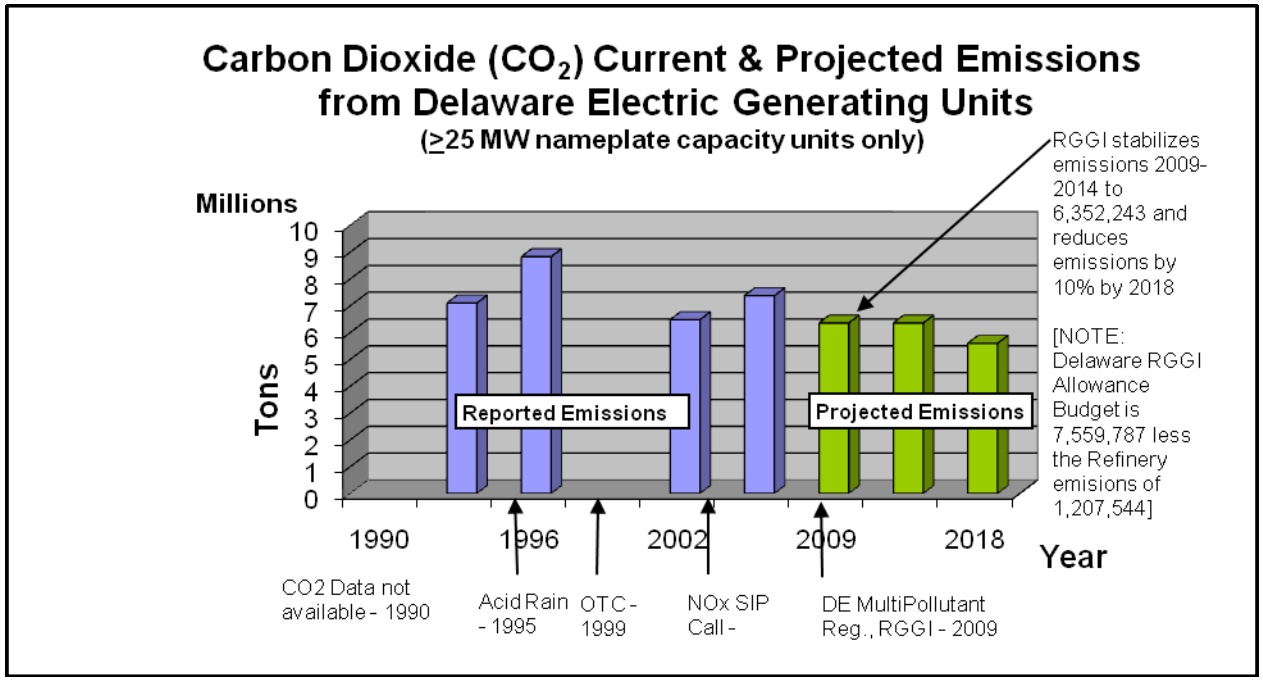

Figure 12

F. Progress toward Increasing Renewables

Over the past 5 years, the two fastest growing sources of renewable energy in the US have been biofuels and wind, as shown in Table 4. It is sobering however, to realize that, in spite of the two to three-fold growth of these sources over that period, renewables, including conventional hydroelectric, contribute less than 7% of the nation's energy needs.

Table 4. U.S. Energy Consumption from Renewable Energy Sources, 2003-2007[14]

(Quadrillion Btu) Energy Source	2003	2004	2005	2006	2007
Renewable	6.150	6.261	6.444	6.922	6.830
Biomass[a]	2.817	3.023	3.154	3.374	3.615
Biofuels	0.414	0.513	0.595	0.795	1.018
Waste	0.401	0.389	0.403	0.407	0.431

[14] Source: http://www.eia.doe.gov/cneaf/alternate/page/renew_energy_consump/table1.html.

Wood Derived Fuels	2.002	2.121	2.156	2.172	2.165
Geothermal	0.331	0.341	0.343	0.343	0.353
Hydroelectric Conventional	2.825	2.690	2.703	2.869	2.463
Solar/PV	0.064	0.065	0.066	0.072	0.080
Wind	0.115	0.142	0.178	0.264	0.319

[a] Biomass includes: biofuels, waste (landfill gas, MSW biogenic, and other biomass), wood and wood-derived fuels.

MSW=Municipal Solid Waste.

The Delaware Green Energy Program has helped to increase the deployment of renewable energy in Delaware. This program has provided grants for the installment of 118 photovoltaic systems, 162 geothermal systems, 6 solar water heating systems, and 2 wind systems throughout the state. The total capacities of the installed systems are shown in Table 5.[15]

Table 5. Green Energy Program Installed Capacity

Technology	*Installed Capacity*	*Units*
Nonresidential Installed Capacity		
Photovoltaic	879.89	Kilowatts
Geothermal	94.50	Tons[a]
Solar Water Heating	0	Square Feet
Wind Turbines	1.8	Kilowatts
Residential Installed Capacity		
Photovoltaic	413.82	Kilowatts
Geothermal	779.50	Tons[a]
Solar Water Heating	490.0	Square Feet
Wind Turbines	2.4	Kilowatts

[a] One ton of heating/cooling capacity = 3.5172 kilowatts

Installations of the various technologies by county are shown in the chart in Figure 13. As of mid-2008, PV and geothermal systems have had the greatest number of installations through the fund.

[11] Source: Delaware Department of Natural Resources & Environmental Control, Energy Office. Green Energy Program: Fiscal Year 2008 Status Report.

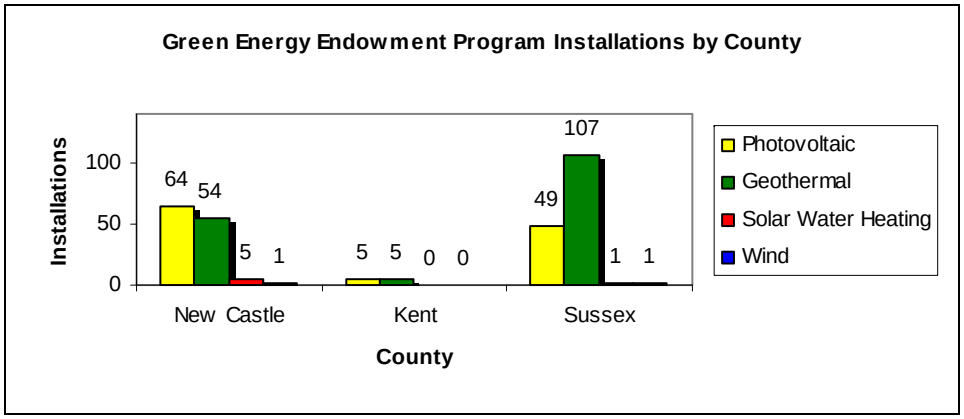

Figure 13

In addition to the Green Energy Fund for Delmarva Power customers, the electric cooperatives have also been providing grants for renewable generation projects. The Delaware Electric Cooperative's (DEC) Renewable Resource Fund has provided grants to member-owners for renewable generation projects such as solar and wind. To date 16 solar and 3 wind projects have been completed or are under construction, representing over 80 kW of member-owned renewable capacity. Delaware Municipal Electric Corporation (DEMEC) customers have installed a total capacity of 48 tons of geothermal (= 170 kW) and 30 kW solar photovoltaic.

G. Legislative & Programmatic Changes Affecting the Use of Renewable Energy Resources in Delaware since the 2003 Energy Plan
Several pieces of legislation have been enacted between 2003 and 2007 that can impact the sources of electricity generation in Delaware:

Net Metering
Delaware's net energy metering standards were amended to increase the net-metering capacity limit for non-residential facilities to 2 megawatts per DP&L meter, 500 kilowatts per DEC meter, and 500 kilowatts per municipal electric meter. Also allows all net-metering customers to carry over excess energy credits from month to month during a 12 month period to account for seasonal variance in generation and energy consumption.

Renewable Portfolio Standards
A renewable portfolio standard was enacted in 2005 and amended in 2007 to increase the required minimum percentage of electrical energy sales to Delaware end-use customers from renewable energy resources increase each year to 20% in 2019. The law requires that, between 2009 and 2019, the minimum percentage of sales from solar photovoltaics (referred to as the 'solar

carveout') increase from 0.03% to 2%. The law also set a solar annual compliance payment that can be adjusted by the Delaware Energy Office at an amount higher than, but not more than 20% higher than, the estimated competitive market cost for purchasing renewable energy credits (RECs).

Delaware Sustainable Energy Utility (SEU)
In addition to sponsoring energy efficiency projects, the SEU will provide funding for customer-sited renewable energy, including assuming management of the Green Energy Fund, funding for which was doubled by a separate piece of legislation.

Delaware Electric Cooperative's Renewable Energy Rider
DEC sells renewable energy to its member-owners through REC's derived from a landfill gas-to-energy plant. Over 2 million kWh have been sold since the plants startup in 2006.

The work group determined that the GHG emission reductions resulting from implementation of the regulations, legislation and current programs will likely not be enough to sufficiently reduce our footprint, particularly given current projections of increases in energy use. Thus we need to do more to increase the amount of Delaware's electricity generated by low- or no-GHG emitting renewable energy resources.

IV. RESOURCE MATRIX

As part of its discussions of the different potential energy resources for Delaware, the work group developed a qualitative matrix to help in evaluating the issues surrounding energy resource decisions. The matrix, shown in Appendix B, included the following resources: centralized and distributed photovoltaics, solar heating, on-shore and off-shore wind, ground source heat pumps, geothermal electricity generation, cellulosic materials and other bioresources, nuclear, IGCC/CCS, waste utilization, fuel cells, energy storage/batteries, tidal flow, generation/transmission from out of state, and demand response/load control. The matrix utilized rankings of 'positive', 'neutral' and 'negative' for: effectiveness in meeting carbon reduction target, current cost, cost outlook in 10-20 years, reliability, nameplate capacity, safety/health impacts, and feasibility in Delaware. The matrix exercise led to further discussions of each of the resources and the issues, often raising more questions than providing answers. This section of the report presents a short overview of the resource and the workgroup ranking. The full report examining the matrix, developed by Dr. Willett Kempton and presented to the work group, is included in Appendix C.

Solar PV (Centralized): A photovoltaic (PV) system converts sunlight, whether direct and diffused, directly into electricity. A centralized PV system is a collection of interconnected photovoltaic modules, all in one location, that function as a centralized power

plant. Such plants would typically be rated in megawatts (MW), in contrast to building PV systems that would typically be rated in kilowatts (kW). In addition to simply providing bulk power, centralized PV may be planned in order to meet peak load (as the solar peak is close to the load peak during the summer), or in order to strengthen the electric distribution system.[16]

Work-Group Ranking: The work group ranked Centralized PV 'positive' in meeting the carbon reduction target, but concluded that cost effectiveness was not likely before the 10-20 year time frame. It scored 'positive' for reliability, 'negative' for nameplate capacity, 'very positive' on minimal safety and health impacts, and a 'negative' rank for feasibility in Delaware.

Solar PV (Distributed): We assume that distributed solar PV would be on building rooftops and would be grid-connected. This takes advantage of unused space and uses the existing grid connection as backup. The next generation of building solar will not only be placed on roofs, but will be integrated with roofing and siding, materials, which should greatly lower the cost of an off-grid system sized to the household electric load. Since most distributed solar modules are installed on rooftops, they are also known as building integrated photo-voltaic (BIPV) systems.

Work Group Ranking: The work group ranked distributed PV 'very-positive' in meeting the carbon reduction target, with a cost competitive outlook in the next 10-20 years. It was ranked 'neutral' in reliability and nameplate capacity, 'very-positive' in safety/health impacts and 'positive' for feasibility in Delaware.

Solar Heating: These systems harness the power of the sun to provide solar thermal energy for hot water and space heating. The systems consist of solar collectors, optionally with some thermal storage. The sun's energy is used to heat air or a liquid, which then transfers heat to a building.

Work Group Ranking: Solar heating ranked 'very-positive' in meeting the carbon reduction target, 'positive' for development at current costs and 'very positive' for future cost outlook. It was ranked 'positive' in reliability and nameplate capacity and very positive in safety/ health impacts category. It ranked 'positive' in the feasibility in Delaware category.

Wind On-shore: Uses the kinetic energy of terrestrial wind flows to create mechanical energy in a wind turbine that is then converted into electricity. Today's wind turbines range from a few kW to as large at 5 MW.

Work Group Ranking: On-shore wind power ranked 'positive' in meeting the carbon reduction target, 'neutral' for development at current cost, 'very-positive' for future cost outlook, 'negative' for reliability, 'negative' for nameplate capacity, 'very-positive' for safety/health impacts, and 'negative' for feasibility in Delaware.

Wind Offshore: Wind turbines can be installed in the oceans and great lakes to capture these wind flows and generate electricity. This requires specialized installation vessels and different engineering and permitting processes than on-shore wind. Before 2008,

[16] Zahedi, A. (April 2006). Solar photovoltaic (PV) energy; latest developments in the building integrated and hybrid PV systems. Renewable Energy, 31 (5), doi:10.1016/j.renene.2005.08.007

there was no off-shore wind industry in the US, but due to Delaware's lead, these facilities are now being planned or built by three companies in the Mid-Atlantic. Wind is stronger and more constant over the ocean and large bays (such as the Delaware Bay) than it is on land. Unlike most land-based wind, it tends to coincide with peak load in the coastal regions, and not to depend on the hour of day further out to sea.

Work Group Ranking: The work group rated off-shore wind 'very positive' in effectiveness in meeting carbon reduction targets, 'neutral' for development at current costs, 'very positive' for future cost outlook, 'negative' on reliability, 'very positive' on nameplate capacity and safety/health impacts, and 'very positive' for feasibility in Delaware.

Ground Source Heat Pumps (building "geothermal"): These are electrically powered systems that tap into the earth's relatively constant temperature to provide space heating, cooling, and hot water for homes and commercial buildings.

Work Group Ranking: The work group rated these systems 'very positive' in effectiveness in meeting carbon reduction target, 'neutral' in affordable current costs, 'positive' for affordable cost outlook in near future, 'positive' on reliability, 'neutral' on nameplate capacity, 'very positive' for safety/health impacts' and for feasibility in Delaware.

Geothermal Power: Hot temperatures from geological formations closer to the Earth's mantle are used to produce steam, which is used for electricity production. Some air and water pollution may be associated with discharge of steam and/or water from the facility, but generally, emissions are far less than those from fossil fuel power plants and do not produce net CO2 emissions.

Work Group Ranking: In Delaware, suitably hot geological formations are very deep, and not economically efficient to exploit with current technology. We do not discuss this further.

Biomass/ Cellulosic Materials: Biomass is any organic matter which is available on a renewable basis including forest residues, agricultural crops and wastes, wood and wood wastes, animal wastes, livestock operation residue and aquatic plants.[17] The most common value of biomass-based fuels are for transportation, but it can also be used to produce electricity.

Work Group Ranking: It was rated 'positive' in effectiveness in meeting carbon reduction target, 'neutral' in affordable current costs, 'positive' for affordable costs outlook in near future, 'very positive' in reliability, 'negative' in name-plate capacity, 'neutral' in safety/heath impacts, and 'positive' in feasibility in Delaware.

Nuclear: Controlled nuclear reactions in fissionable materials generate heat, which turns water to steam to run a turbine and generator. Delaware currently draws about ¼ of its electricity from PSEG's 3,000 MW Salem/Hope Creek complex across the Delaware River in New Jersey. Nuclear as an energy resource is very low carbon and low pollution and provides baseload power, but has very high capital costs and issues related to the disposal of nuclear waste.

[17] Based on U.S. Department of Energy definition.

Work Group Ranking: The work group ranked nuclear as non-feasible for a new plant in Delaware and was not discussed further.

IGCC/CCS: In the IGCC (Integrated Gasification/Combined Cycle) process, coal is gasified with oxygen and steam,and about half the carbon is separated as CO2 before combustion. The remaining hydrogen-rich gas is burned in a combined-cycle combustion turbine. Carbon capture and storage (CCS) refers to additionally sequestering the carbon in deep geological storage. An IGCC plant, with and without CCS, was proposed as part of the bidding for power under HB6, so Delaware actually has an administrative record for the total costs of IGCC.

Work Group Ranking: IGCC was ranked just above neutral for carbon reduction, 'slightly negative' for both current and future cost outlook, 'positive' for reliability and nameplate capacity, 'neutral' for health/safety impacts, and slightly positive for feasibility in Delaware.

Waste Utilization, Methane Recovery, Liquid fuels: Organic materials in the waste stream can be combusted to produce electricity, or may be converted to liquid fuel. The latter requires addition of agricultural waste, because municipal waste is too mixed a feedstock.

Work Group Ranking: The work group ranked this resource as positive in all categories except health/safety, which was slightly negative.

Fuel Cells: Fuel cells convert hydrogen and atmospheric oxygen to electricity and low-grade heat. The primary source of hydrogen today is from reforming of natural gas, a fuel cycle that provides no CO_2 benefit over burning the natural gas in a combustion turbine.

Work Group Ranking: The work group ranked fuel cells as 'positive' for carbon reduction, depending upon the source of the hydrogen, 'very negative' on current costs, 'neutral' for nameplate capacity and 'positive' to 'very positive' in all other categories.

Energy Storage: Centralized: Centralized storage may be useful for ancillary services, and in larger quantities to complement to wind or solar. The current technology is pumped hydro, which requires large vertical elevation changes. Currently-prototyped technologies include compressed-air energy storage (CAES), flywheels, and batteries meant for power applications.. Pumped storage and CAES, and to some extent flow batteries, can provide bulk storage, as increasing the energy capacity is achieved by simply enlarging the reservoir. Flywheels and non-flow batteries are short-term power devices. For example, Ballard has a building-sized 20 MW unit with 5 MWh of energy storage capacity, thus it can run at full power for just 15 minutes. These devices are better for power applications such as ancillary services and mitigating unexpected ramps. Another form of "centralized storage" is the General Compression use of wind turbines producing positive-pressure air rather than electricity, with a centralized generator—this incorporates storage into wind at very little incremental cost. This wind/storage hybrid is just now being prototyped and would require at least 8-10 years for development. Several of these centralized storage technologies may be useful in the 10-20 year time

frame, especially if Delaware moves to large fractions of generation from renewable energy.

Work Group Ranking: The work group ranked centralized energy storage as 'neutral' for carbon reduction and health/safety, 'negative' for current cost and nameplate capacity, and 'positive' for reliability and feasibility.

Energy storage/batteries in end-use devices: End use devices that convert electricity to easily stored energy forms, such as hot water or compressed air, can be dispatched to shift load. Storage in end-use devices refers to the possibility of two-way power flow with the electric grid.

Work Group Ranking: The work group ranked this resource as 'positive' to 'very positive' for carbon reduction, reliability and feasibility, 'very negative' for current costs, and 'neutral' for all other categories.

Tidal flow: Multiple firms are testing tidal generators in New York, Maine, and abroad. One plan to tap tidal flow in the Indian River Inlet would have produced tens of MW. The plan was conceptually disapproved by DNREC, however it has recently received a grant to continue research and development in alternate applications.

Work Group Ranking: The work group ranked tidal flow 'positive' for carbon reduction and health/safety, 'very negative' for current cost and nameplate capacity, and 'neutral in all other categories.

Generation/Transmission from out-of-state: Bringing in electricity generated outside of Delaware through added/upgraded transmission lines and systems.

Work Group Ranking: This approach was rated 'negative' in effectiveness in meeting carbon reduction targets, 'positive' in affordable current costs, 'neutral' in affordable cost outlook in future, 'positive' for reliability, 'very positive' for name plate capacity, 'negative' for safety/health impacts, and 'positive' for feasibility in Delaware.

Demand Response/Load control: In 'demand response' or 'direct load control' electric utility programs, a utility signal is used to reduce the load of customer equipment. For example, air conditioners and water heaters can be switched off and on for 15 minute cycles during peak demand. This is an economic alternative to construction of more generation equipment that might be used only a few hours each year.

Work Group Ranking: Demand response/load control was ranked 'very positive' across all categories.

V. RECOMMENDATIONS

Recommendation 1: Climate Change Commission

The Governor should establish a greenhouse gas reduction goal and a Climate Change Commission to develop a detailed Climate Change Action Plan for Delaware, including a trajectory for the reduction in greenhouse gas emissions and an adaptation plan, incorporating periodic review and evaluation of the plan.

Background

It is important that both the state government and Delawareans understand what the impacts of climate change can be on the state and what the options are both to mitigate and adapt to those changes. Developing this knowledge will require the dedicated study and input from experts in a number of fields, including, but not limited to the scientific community, industry, technology experts, agriculture, state agencies, educators, architects, environmental groups, public health advocates, legislators, and general public.

Delaware developed its first Climate Change Action Plan in 1990. This plan, and the recent plans developed by neighboring states, such as Maryland, can serve as resources to inform the new Commission.

To be most effective, the plan should include a long-range greenhouse gas reduction target and intermediate targets by which progress can periodically be assessed. A process should also be established for the periodic review of the action plan and progress towards achieving goals.

Cost

Costs could range from a low of about $50,000 to several hundred thousand for consultants, contractors and studies, taking into account the cost of state employee time devoted to the Commission's work. Most of the Commission and working group members will be volunteers, participating as part of their regular jobs.

Recommendation 2: Energy Planning Governance

Energy Policy should be elevated to the Governor's office by creating a Governor's Executive Office for Energy Policy that would provide for coordinated development and implementation of Delaware Energy Policy, including a review and evaluation of the governance structure regarding energy issues among executive bodies, including but not limited to: DNREC, the Energy Office, the Public Service Commission, the Public Advocate, the Governor's Energy Advisory Council and the Governor's Office.

Background

Energy policy impacts nearly every facet of life in Delaware. It impacts the cost of energy and thus the profitability of Delaware's businesses, and state, local, and household budgets. Energy policy impacts economic security by the extent to which it insulates

Delawareans from volatile fuel prices. Energy policy impacts air quality and the health of our citizens. And, energy policy impacts the cost of doing business, whether existing businesses remain competitive and whether new businesses chose to locate in Delaware as well as whether Delaware draws new business development in "green" industries.

While the Delaware Code establishes responsibility for development of an energy plan, it does not appear to clearly establish responsibility for looking at the whole picture of energy in Delaware and developing policy.[18] An integrated perspective from a body that looks at all the players and sets a consistent policy could strengthen Delaware Energy Policy. Currently many parties and agencies in Delaware have responsibility for and impact on Delaware Energy Policy, including the Administration, the General Assembly, DNREC (including the Energy Office), the Public Service Commission, the Division of the Public Advocate, the Governor's Energy Advisory Council, municipalities, utilities, generators, the regional electric grid operator, PJM, the Federal Energy Regulatory Commission, and a number of non-governmental organizations (NGOs). There are numerous examples of the diffuse nature of energy policy planning including:

- The Administration: The Administration established the Governor's Energy Advisory Council, which includes representation of the diverse parties involved with Delaware Energy Policy, including NGOs. The Administration also issued the original energy plan in 2003, *Bright Ideas*, and in response to the significant increase in electricity prices in 2006, issued Executive Order 82 that resulted in the 2006 report: *Ensuring Delaware's Energy Future*. The Administration makes major energy policy decisions, such as the State's participation in the Regional Greenhouse Gas Initiative.
- The Governor's Energy Advisory Council: The Governor's Energy Advisory Council has, among other things, responsibility to monitor Delaware's Energy system and identify and propose actions to enhance the system, and to spearhead the updating of the Energy Plan.[19]
- The Energy Office: From within DNREC, the Energy Office operates the State Energy Program under the US Department of Energy, serves as a focal point for energy efficiency and renewable energy assistance to citizens, government agencies and private sector interests, coordinates the activities of the new Sustainable Energy Utility, staffs the Energy Advisory Council and assists in the development of the five year energy plan.
- DNREC: Houses the Energy Office, but also has regulatory responsibilities concerning energy facilities and their impacts on public health and the environment. DNREC is also represented on the Energy Council, the Cabinet Committee, the Sustainable Energy Utility (SEU) Board and other bodies and organizations impacting energy policy.

[18] See, for example, Title 29 of the Delaware Code, Chapter 80, Subchapter I, § 8003 (16), and Subchapter II, § 8051 (b) (5 and 6) which address responsibilities of the Energy Office but do not specify development of a comprehensive energy policy. Similarly, Subchapter II, § 8055 addresses responsibilities of the Governor's Energy Advisory Council but also does not specify development of a comprehensive policy. http://delcode.delaware.gov/title29/c080/index.shtml#P-1_0

[19] Title 29 of the Delaware Code, Chapter 80, Subchapter II, § 8055.

- The General Assembly: The General Assembly can set energy policy through legislative actions. Recent examples include: HB6, which resulted in the Power Purchase Agreement between Delmarva Power and Bluewater Wind; formation of the SEU; funding levels and program design for the Green Energy Fund; and establishment and enhancement of Delaware's Renewable Energy Portfolio Standards.
- The Public Service Commission: The Public Service Commission has regulatory oversight of energy utilities, including Delmarva Power and Chesapeake Utilities, and as such, impacts and determines energy policy impacting rates, and development of demand response, Automated Metering Infrastructure and Smart Grid programs. The PSC does not have regulatory authority over the Delaware Electric Cooperative nor the Delaware Municipal Electric Corporation. The PSC can have oversight over energy policy such as establishing mechanisms to achieve long term funding for generation development in Delaware.
- The Division of the Public Advocate: The Public Advocate intervenes on the behalf of Delaware ratepayers in issues before the Public Service Commission and participates on PJM committees.
- Utilities: Utilities are involved in energy policy as they develop demand response programs and work with the SEU to design energy efficiency programs. Delmarva is required to submit an Integrated Resource Plan to the Public Service Commission estimating how much electric power it will need in coming years and how it will meet the demand. Utilities participate on the Governor's Energy Advisory Council and in PJM policy decisions.
- Generators: Generators decide how much and, with regulation by DNREC, what kind of generation they will build, and how much energy they will produce. They also participate in PJM policy decisions.
- Delaware Economic Development Office : This entity has been left out in many regulatory and legislative initiatives; it needs to be a significant part of the process.

A Governor's Executive Office for Energy Policy could evaluate all the energy programs in place in Delaware and recommend any programmatic or structural changes or additions necessary to fulfill Delaware's energy and climate goals. An issue for consideration is to what extent this office should address climate change. Although climate change policy reaches beyond energy to include other sources of greenhouse gases (such as agricultural sources) as well as adaption and mitigation policies, energy use is the key driver of climate change.

Cost

The cost to implement this recommendation would depend on whether new personnel are needed, or whether current employees are reassigned to fill the new functions.

Recommendation 3: Public Buildings and Facilities

The State should promulgate or enact a policy that sets standards and requires renewable energy systems to be incorporated in new construction and renovations of public facilities.

Background

The purpose of this initiative is to provide a reduction in building use energy and carbon intensity, provide energy funding for building owners, provide educational opportunities for school children that will give them hands on experience and reinforce environmental awareness, and have the government lead by example. Applicable buildings include any building owned or funded by a local or state government agency such as schools, maintenance buildings, office buildings, hospitals, libraries, prisons, etc.

Although several states have statutes or executive orders mandating the use of environmentally sustainable standards in the design, construction and operation of public facilities, there are only few states that mandate the use of renewable energy systems in those facilities. Each of these programs weighs the investment in alternative energy on a cost/benefit basis. Examples include:

- Texas: requires state government departments to compare the cost of providing energy alternatives for new and reconstructed state government buildings and for certain construction or repair to energy systems and equipment. A review committee determines economic feasibility for each function by comparing the estimated cost of providing energy for the function using conventional design practices and energy systems with the estimated cost of providing energy for the function using alternative energy devices during the economic life of the building. If the use of alternative energy devices for a particular function (including space heating and cooling, water heating, electrical loads, and interior lighting) are economically feasible, then the use of alternative energy devices must be included in construction plans.
- Minnesota: state facility designs must consider the impacts of supplying a portion of the building's total energy use with on-site or off-site renewable or cleaner distributed generation systems. Separate portions of Minnesota law added at different times require that certain state building designs specifically evaluate the possibility of using active and passive solar systems; earth-sheltered construction; meeting 2% of building energy use with on-site solar or wind (Minn. Stat. 16B.32); and using geothermal and solar thermal applications for heating and cooling (Minn. Stat. 16B.326).
- Vermont: statutes contain an incentive funding structure for locating renewable energy systems in school buildings. The amount of an award for the incremental costs associated with the installation of a space heating, water heating, cooling, or refrigeration system that uses biomass, a geothermal/ground source, wind, or solar energy as the primary heating or cooling source is 75 percent of the approved cost of those elements of the project specifically related to the renewable fuel source being used (as compared to 30 percent for other costs).

In Delaware, specific standards should be adopted to fit into the existing structure. A detailed review of these programs to include their experience (good and bad) to date should be initiated. A Delaware program should be initiated in three categories:

1. Educational facilities – Any new school, school renovation (within a certain cost threshold) must be designed using "green code" or LEED principles. Cost/benefit analyses using the standards set in the policy should be completed for the incorporation of renewable energy systems into new construction. The components of any program would require a learning tool where students can participate in the operation of the project and where the technology basics can be in a science class curriculum. Curriculum would be developed on a school by school basis, depending on the technologies installed and aligned with existing climate change/renewable energy curriculums already in place.
2. New Construction – Any publicly funded building must be designed using "green code" or LEED principles. Further, the facility should be encouraged to be a research laboratory for new technologies. Cost/benefit analyses using the standards set in the policy should be completed for the incorporation of renewable energy systems into new construction.
3. Renovation – Any public funded building must use "green technology" where feasible and within certain cost parameters. Cost/benefit analyses using the standards set in the policy should be conducted for the incorporation of renewables into the renovation.

Cost

Along with the mandates and code revisions, incentive funding resources would be needed to make these project options cost effective to the building design and to provide incentives. SEU funding and programs should be incorporated into the program and made available for eligible buildings.

Currently, at the state level, Delaware law contains several mechanisms for the funding of public capital projects. These are as follows:

- Funding through direct appropriations in the capital budget for state facilities.
- Funding of the state share of public school projects. These projects are designed using a cost per square foot basis.
- Funding for capital projects at the University of Delaware, Delaware State University and Delaware Technical and Community College.
- The state funds 50% of public library construction.
- Community redevelopment programs

Funding incentives for state capital projects could take the following forms:

- Grant funding for incremental costs associated with renewable energy systems (similar to previous Stripper Well program). Funding to be divided to qualifying projects based on cost, payback and environmental benefit.
- Incremental cost per square foot for renewable energy systems for school projects.

- Revolving loan fund whereby the loan is paid back through energy savings,possibly through a partnership with the SEU.

Recommendation 4: Renewable Energy Portfolio Standards

A. *The Renewable Energy Portfolio Standard (RPS) should be expanded to apply to the Delaware Electric Cooperative (DEC) and Delaware Municipal Electric Corporation (DEMEC).*

B. *In 2010, the Governor should have an evaluation conducted to determine whether or not to increase the RPS requirement to be greater than the current specification of 20% by 2020.*

Background

Senate Bill 19 as amended by House Amendment 1, passed by the 144th Delaware General Assembly, called for an increasing percentage of electricity sold in the state to Delmarva customers to come from renewable energy sources. The percentage started at 2% in 2007 and increases each year to 20% in 2019. The legislation also created a "solar carve-out", increasing to 2% per year in 2019.[20] This bill replaced the first RPS bill, which was passed by the 143rd General Assembly.[21] The new legislation both raised the percentage requirements from the initial bill and created the solar carve-out, which was not included initially.

Currently, twenty-four states and the District of Columbia have RPS policies in place; four others have nonbinding goals for adoption of renewable energy. The more aggressive requirements are California, which has a requirement of 20% by 2010, and Oregon and Illinois, which both have requirements of 25% by 2025.[22]

Electricity production in Delaware and the rest of the nation is a significant source of CO2 and other pollutants with more direct and immediate health impacts such as fine particulates, SOx, NOx and mercury. While major reductions in Delaware's greenhouse gas (GHG) will already occur from the generation sector, additional reductions may be desired and suggest a further transition from energy sources for electricity from fossil fuels to renewable energy sources. Delaware has a potential supply of clean renewable energy in the form of off-shore wind and contract arrangements for out of state on-shore wind energy. Further, additional development of the offshore wind resource (excluding shipping lanes, migratory bird flyways, etc.) to a depth of 50 m could provide

[20] SB 19 as amended by HB 1, AN ACT TO AMEND THE DELAWARE CODE TO INCREASE THE RENEWABLE ENERGY PORTFOLIO STANDARD. http://depsc.delaware.gov/electric/sb19ha1.pdf

[21] SB 74 as amended by SA 1,2 and 3 and HA 1, AN ACT TO AMEND TITLE 26 OF THE DELAWARE CODE RELATING TO RENEWABLE ENERGY PORTFOLIO STANDARDS. http://depsc.delaware.gov/electric/rpsact.pdf

[22] US Department of Energy, Office of Energy Efficiency and Renewable Energy, *States with Renewable Portfolio Standards*, June 2007. http://apps1.eere.energy.gov/states/maps/renewable_portfolio_states.cfm

potential power of 6200 MW if fully developed – over 4 times the state's total electrical power consumption (1300 MW by all users.)[23]

Recommendations for reducing GHG emissions have included a reduction in global carbon dioxide emissions by 80% by 2020[24] and/or producing 100% of our electricity from carbon-free sources within 10 years[25]; Increasing the percentage of electricity from renewable energy sources is integral to most climate change mitigation proposals.

In Delaware, a reason for increasing the standard is that, should all its existing wind contracts come to fruition, Delmarva Power will exceed the 20% requirement before 2019.[26] Although not required to meet the RPS standard, DEMEC and DEC are required to meet the demands of their customers for renewable energy. Each has established a program through which customers can elect to pay more for renewable or "green" power. DEMEC has also entered into a contract to purchase power from the Bluewater Wind off-shore wind project.

Work Group Discussion

The DEC was not present for the vote on the recommendation and afterwards has expressed their disagreement with concept of expansion of the RPS to the other distribution companies. The workgroup also discussed a potential recommendation to increase the RPS above 20% by 2019. Given concerns expressed regarding the question of whether or not all the current contracts will come to fruition, and what the impacts on cost and reliability will be as these projects are brought on line, the workgroup could not reach consensus on making that recommendation now, but did reach consensus on recommendation 4B above, to evaluate the situation in 2010 to determine whether to increase the renewable requirement.

Cost

There is no direct cost to state government of expanding the RPS to additional distribution companies or increasing the renewable energy requirement. The costs will be borne by the ratepayers of the various companies. The 25-year PPA between Delmarva Power and Bluewater Wind provided for an electricity cost to Delmarva Power of 11¢/kWh, increasing at an annual rate of 2.5% per year to compensate for inflation, which has been greater than that for a number of years.

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[23] Amardeep Dhanju, Phillip Whitaker and Willett Kempton, "Assessing offshore wind resources: An accessible methodology", *Renewable Energy*, 2007. http://www.ocean.udel.edu/windpower/docs/DhanjuWhitKemp-proof-RE07.pdf

[24] Lester R. Brown, Plan B 3.0 – Mobilizing to Save Civilization, W.W.Norton & Co., New York, 2008.

[25] Al Gore, "The Climate for Change", New York Times, Nov. 9, 2008, p. WK 10. http://www.nytimes.com/2008/11/09/opinion/09gore.html?hp

[26] With an estimated 22% from on- and off-shore windpower. Glen Moore, Delmarva Power, Workgroup meeting, November 12, 2008.

Recommendation 5: Net Metering

Legislation should eliminate forfeiture provisions from the Net Metering Law

Background/Discussion

In Delaware, as required by the RPS, a certain percentage of electricity sold in the state must come from renewable generation sources, and a certain portion of that must be from solar photovoltaic generation, reaching 2% by 2019. Utilities may satisfy their solar requirements by purchasing Solar RECs from the owners of photovoltaic systems.

Delaware has a net metering law which allows electric customers to get a credit against their electricity bills for electricity they generate using renewable resources. Electricity generated using renewable resources creates Renewable Energy Credits (RECs). RECs are an attribute separate from the energy itself and are tradable commodities.

The Delaware Code provides that any excess generation in a billing period may be carried forward as a credit to the customer's bill until the end of a 12 month period. At that point, the excess credits are forfeited to the Green Energy Fund. The customer's credits are calculated at the retail rate. Forfeitures, however, are calculated at the wholesale supplier's cost. The customer may choose whether her/his 12 month period ends July 31 or December 31.

The idea behind allowing customers to choose their anniversary dates was to allow them to build up credits for use later in the year, and to pick the anniversary date that best matches their generation/usage pattern. The Delaware Energy Office, however, has received calls from customers expressing problems with both dates. December 31 is a problem because some customers use the summer to build up a credit to satisfy electric costs past December into February. July 31 is a problem for these same people because it forfeits 2/3 of their summer and previous month productions. It should also be noted that under current law, even a customer who generates exactly what he/she consumes may well have to make net payments for the year. This can occur because credits are carried forward, but charges are not. Elimination of the forfeiture provision would eliminate this anniversary issue.

The Code further provides that SRECs associated with the forfeited energy costs are given to the electric supplier. Thus, if a customer has used less than he/she generated, SRECs associated with the excess are conveyed to the customer's electric supplier. It is arguable that the customer, who paid for the generating facility, should retail ownership of all his/her SRECs. This treatment would be comparable to the way other generators are treated.

Delaware law limits the net metering provisions to systems that are sized to meet the needs of the customer. Eliminating this restriction and forfeiture provisions would support increased installation of photovoltaic systems. The current forfeiture

arrangement means that customers have a financial incentive to install less solar power than they think they will need, in order to provide a cushion from forfeiture, whereas, as public policy, we want to encourage the installation of more solar power. There are additional anti-energy conservation and anti-efficiency consequences of the forfeitures provisions:

- Solar owners who have installed enough solar power to meet or almost meet their power requirements have no financial incentive to reduce further their electric use because they will forfeit the value of their energy savings.
- Solar owners who have generated more electricity than they have used will lose SRECs associated with the excess power. Currently SRECs are trading in excess of $200/SREC. Thus, a customer with excess solar generation would lose greater than $200 for each megawatt-hour of excess generation. This customer has a significant financial incentive to *increase* his power use to be sure he does not forfeit his SRECs.

Prior to the 2007 revision to the net metering law, if a customer produced more energy than she/he used, the customer could receive a check from the utility company for the excess.

Cost

The Green Energy Fund would lose the value of forfeited excess generation. The amount of this loss is expected to be very small because of the very limited amount of excess generation installed. The utilities would lose the value of forfeited SRECs. Again, this value is expected to be very small.

Recommendation 6: Solar/Renewable Energy Access

Solar and renewable energy rights should be available to the citizens of Delaware. Barriers, and methods to relieve those barriers, need to be examined and addressed. One approach to consider is legislation that would reduce barriers, including deed restrictions and covenants, to installation of new renewable energy systems.

Background

The Delaware Energy Office has received complaints from citizens over the last three years that homeowner associations have prevented individuals from installing renewable energy systems. The reasons have varied from fear of the impact on home values to aesthetics.

In response to these calls the Energy Office conducted a study of the current solar covenant and easement laws around the country, and found that several states have enacted legislation to address similar issues. SB 238/SA 1 and HS 1 for HB 344, introduced during the 144th General Assembly, were developed based upon this review. The purpose of these bills was to enact legislation that would prohibit restrictive covenants on roof mount solar and wind turbine systems respectfully. SB 238 passed the Senate but was not acted upon in the House; HB 344 was not acted upon.

Maryland recently amended its Code (HB117) to provide more detailed protections for solar energy systems. Under the new law (effective October 1, 2008) restrictions on use that act to significantly increase the cost of a solar collector system or significantly decrease its efficiency are prohibited. The definition of "restrictions on use" includes any covenant, restriction, or condition contained in a deed; declaration; contract; bylaws of a homeowners or condominium association; security instrument; and any other instrument affecting the transfer or sale of real property or interest in real property. The only condition for this protection is that the owner either owns or has rights for the exclusive use of the roof or exterior walls of a structure.
DGB Comment, suggest adding - Such legislation must include addressing neighbor property rights and means to resolve or mitigate potential claims.

Cost
No costs to the State.

Recommendation 7: Green Energy Program
The Green Energy Program should be examined and aligned to complement other programs, including the SEU, to help achieve Delaware's renewable energy goals and solar carve-out. The review of the Green Energy program should include the Public Benefit Charge, including the question of application of the charge equally state-wide.[27]

Background
The solar carve-out in the RPS was designed to provide incentives for much more photovoltaics than the Green Energy Program is able to help fund. The current Public Benefit Charge (PBC) is 0.000356 cents/kWh for Delmarva Power customers and a 0.000178 cents/kWh charge used to create the related funds for the electric cooperatives. Ideally, with a PBC or RPS, the policy is trying to provide enough of an incentive to make the installation of renewable energy a rational economic choice. It needs to be enough of an incentive so that people don't perceive the investment taking forever to pay off. But it should only provide just enough of an incentive so that there is not excessive freeloading -- freeloaders are people who would have made the investment anyway but take advantage of an incentive that is more generous than it needs to be. Ideally, the incentive also provides for a steady and sustainable development of the industry so it avoids booms and busts.

[27] Similar to Recommendation 4, the DEC was not present for the vote on the recommendation and does not support the review of the question of applying the Public Benefit Charge equally statewide.

A PBC can do this if it has sufficient funding and is continually crafted and adopted to changing economic conditions. However, New Jersey and California[28] are both moving away from the PBC because of the political difficulty of increasing PBCs. Both states are moving toward an approach of smaller customers receiving the up-front incentives and larger customers receiving incentives through SRECs.

With the establishment of the SEU, additional options for incentivizing renewable energy systems may be developed. Depending upon the programs offered by the SEU, a restructuring of the Green Energy Program should be evaluated.

Cost

Costs for the evaluation should be minimal.

Recommendation 8: Biomass Energy

A. An updated "Delaware Biomass Supply Assessment" should be conducted, including current and potential biomass feed stocks and by-products from all agricultural & forestry activities in the urban and rural communities of the state.

B. Delaware Senate Bill 280, enacted during the 140th General Assembly, should be amended to eliminate unconstructive impacts on Delaware's biomass utilization and economic growth both in the urban and agricultural communities.

Background

Consuming biomass[29] for heating/cooling and transportation needs is not a new concept. Humans have utilized combustion of organic plant material for heating, cooking and transportation fuels for centuries. Current available technologies and others in various development stages have made combustion techniques environmentally feasible, capping emissions below restrictions imposed by federal & state laws. Combined heat and power (CHP) facilities, along with co-generation plants operated solely on herbaceous biomass are currently providing electricity (and steam) around the nation and world, including in our neighboring states.

Due to the limitations embedded in SB280, no biomass facility will be built in Delaware. This creates a significant economic loss; the National Arbor Day Foundation estimates a single 75 megawatt wood fuel plant will add 500 direct & indirect jobs to the local economy.

[28] Current cent/kWh PBC's in NJ and CA are 0.000860 and 0.000790, respectively.

[29] Based on the U.S. Department of Energy definition, Biomass is any organic matter which is available on a renewable basis including forest residues, agricultural crops and wastes, wood and wood wastes, animal wastes, livestock operation residue and aquatic plants.

Legislation should be developed to encourage the use of renewable resources grown and utilized within our own state for bio-energy projects, based on 'emission levels' and not 'feedstock material'. Biomass derived from woody & herbaceous plant material is currently available to support a feedstock for local consumers using combustion and gasification technologies. In 1994, the Delaware Forest Service released a study titled: "Delaware Waste Biomass Resource Survey", in which harvested wood from silviculture activities and site conversion, along with primary/secondary industry mill residues, waste paper, corrugated cardboard, solid wood from used pallets/construction/demolition residues and poultry wood-residue material were evaluated. Although this report contains outdated numbers, it clearly showed that there was, at that time, sufficient feedstock for bio-energy facilities. This report did not generate results from urban wood residues. Moisture content and heating values of individual woods vary greatly between feedstock sources and need to be evaluated in feasibility studies for combustion and gasification technologies.

Currently, forests cover over 30% of Delaware, or 382,900 acres, including land in rural and urban communities. Private landowners hold 93% of this land with the other 7% in public ownership. Through continued sustainable management of our forestland, local bio-energy facilities could be supported, while developing a wood utilization market for our forest landowners.

In addition, there are significant acres of dedicated 'open space' required via sub-division regulations. This land could be developed into short-rotation woody biomass plantations instead of expansive unproductive mowed-grass fields. Establishing short-rotation plantations at these sites would not only eliminate the need for maintaining required grass heights using gas-powered machinery, but could also contribute to the creation of 'carbon-sink' areas, along with providing valuable habitat for neo-tropical birds and ground wildlife.

Cost

Initial cost to prepare a current Delaware Biomass Supply Assessment would be approximately $50,000, but would be an invaluable tool for further feasibility studies for specific biomass energy projects.

Recommendation 9: The Role of Delaware's Local Governments in the State's Energy Plan

A. Local governments should be encouraged to develop climate change action plans.

B. Local governments should be asked to identify specific state policies and programs and forms of assistance that would be helpful to them in developing and implementing their climate action plans.

C. The State should develop and implement specific policies and programs that are complementary to these local plans; and provide financial assistance, technical assistance, planning grants and other incentives that will help local Delaware governments to overcome the financial and technical obstacles that prevent their developing and successfully implementing these climate change plans and projects, which could include but not be limited to, the following:

a. Establish and fund a Local Government Liaison/Assistance unit within the State Energy Office which will develop expertise in best practices for local government climate change plans and activities, provide climate change planning grants to local governments, and ongoing technical assistance.
b. Develop and/or acquire greenhouse gas (GHG) inventory tools that can be shared with local governments so that they can determine baselines, effectively track emissions and monitor progress in reaching the goals of their climate change plans.
c. Examine how the State can support the process underway to "write the official Protocol for GHG inventory for all U.S. local governments" which has been undertaken by the International Council for Local Environmental Initiatives (ICLEI).
d. If and when the federal Energy Efficiency and Conservation Block Grant (EECBG) program is funded, the Local Government Assistance unit should establish a process for providing sub grants to non-entitlement communities in the state.
e. Require that all Comprehensive Land Use Plans include an "element" for Energy and Conservation. This element should identify an existing Climate Change Plan or the process and timetable for developing one within a prescribed timeline.
f. Revise the state formula for Municipal Street funding to give additional funding to those municipalities that have a Climate Change Plan and/or are achieving pre-determined levels of GHG emissions reductions.
g. Identify "green energy" purchasing policies and identify awarded contracts as containing "green" items on the state's contracting web site.

Background

Reducing the environmental footprint in Delaware will require active participation of its local governments, especially in cities where the majority of the state's residents live and the state's economic activity takes place. The energy consumed by government itself and by households, businesses, and associated activities within these geographic areas account for much of the state's GHG emissions, although the sizes of their carbon footprints vary by area. Local governments have:

> "a great deal of control over the day-to-day activities that determine the amount of energy used and waste generated as well as the long-term planning for the community – from land use and zoning decisions to control over building codes and licenses, infrastructure investment, municipal service delivery and management of schools, parks and recreation areas. Local government leaders are also uniquely positioned to influence citizen behaviors – their transportation options, energy consumption patterns and general consumer decisions".[30]

Local governments can effectively tackle global warming, given the will, sufficient resources, and realistic "climate change action plans". Many local governments are thinking "globally" about climate change, but acting "locally" by developing their own plans for energy efficiency and conservation and the reduction of GHG emissions. Most are doing this by signing on to national and even

[30] http://www.iclei-usa.org/programs/climate.

international agreements aimed at reducing GHG emissions.[31] In Delaware, New Castle County (NCC) and two local governments, Wilmington and the City of Dover, have signed on to climate change agreements.[32]

These local government agreements or plans should be seen as critical efforts in helping the State to achieve its own energy and GHG reduction goals. Without complementary state or federal policies, programs, and assistance, The Institute for Local Self Reliance (ILSR) found that these local efforts are likely to fail. The ILSR survey also found that almost all of the cities surveyed were expecting to realize a significant portion of their GHG reductions as a result of actions taken by higher levels of government (e.g. a state-level renewable portfolio standard or an increase in federal fuel economy standards). [33]

Cost

Cost estimates for establishing the Local Government Assistance unit and GHG tools need to be developed as the implementation specifics for the recommendation are determined.

Recommendation 10: Electric End-Use Substitution Demonstration Project

The State should develop a demonstration project for electric end-use substitution, storage and control, focusing on alternatives to non-renewable heating fuels.

Background

To meet Federal and State CO_2 emission reduction goals it will be necessary to reduce direct fuel use, in addition to reducing the CO_2 emissions from power plants. Given Delaware's large wind resource, there will be an opportunity to electrify direct end uses of energy that now are CO_2-intensive. For example, automobiles and oil-based home heating use expensive fuels that can be displaced by electricity, often for lower cost. This makes the most economic sense if the end uses are designed to take advantage of fluctuations in wind electric power output; a program can be designed similar to off-peak pricing, except it would be "excess wind

[31] For example, see http://usmayors.org/climateprotection/

[32] For information on these efforts see:
NCC: http://www.co.new-castle.de.us/executive/home/webpage14.asp
Wilmington : http://www.ci.wilmington.de.us/climateplan/index.htm
Dover: "A Report on the City of Dover's efforts to Implement the recommendations of the U.S. Conference of Mayors Climate Protection Agreement. June 9, 2008.

[33] Institute for Local Self Reliance. *Lessons from the Pioneers: Tackling Global Warming at the Local Level*. January 2007. http://www.newrules.org/de/pioneers.html.

pricing". For example, car batteries would be charged when the wind is blowing. At times of insufficient wind generation, electric cars might even feed power back into the grid.

A well-designed program would accomplish three goals: 1) reduce the cost to consumers of heating fuel, gasoline, and other direct fuel uses, 2) increase the amount of "dispatchable load" that can usually be activated at times of excess wind-generated electricity, thus allowing larger wind development without providing too much power at any one time, and 3) reduce CO2 emissions, due both to the direct effect of using carbon-free electricity in place of on-site fuel consumption, and by enabling larger wind penetration.

A demonstration project could be designed to focus on space heating. The program could use commercially-available electric heaters with internal heat storage, along with controls used by utilities for direct load control. For balancing offshore wind, electrification of heating has the additional advantage that it is matched to seasonal wind patterns in our area, with considerably more wind power in cold weather. The most economic first step would be to displace Delaware's expensive heating fuels—fuel oil, kerosene, and LP gas—with electricity. These fuels are used in 35% of Delaware homes, 111,540 housing units. If all of the systems using these fuels were switched to electricity, 823 MW_a load would be added during the three winter months, or 1,800,000 MWh of electricity demand per year.

Currently-marketed electric heaters have storage for 2-3 days, using high-temperature ceramics within an insulated heater enclosure. If made responsive to signals, these heaters could be switched between 1646 MW and 0 MW. This would provide a huge and inexpensive method for balancing wind power fluctuations to other loads that, unlike heating, must have power at the second it is generated. If off-peak electricity for responsive space heating were sold at 11 cents/kWh retail, it would reduce heating bills to customers by 25% (bills that are now $165M would be $132M). If building efficiency improvements were performed during the same visit as the heater installation, consumer savings would be greater. About the same number of households, but a larger amount of fuel savings, would be achieved by displacing natural gas. A program to replace natural gas heating may be viable in the future, depending on subsequent market and policy decisions, but at current prices it would represent an increase in consumer costs.

The heating program could begin with a demonstration project involving approximately 100 households, in each of the state's utilities, and in both urban and rural settings, with implementation in year 1 and evaluation in year 2.

Cost

This project could either be conducted as a University research project or through the SEU, or a combination of the two, with a variety of potential funding sources. Specific cost details have yet to be developed.

Recommendation 11: Public Education & Outreach

The State should develop and implement a comprehensive public education and outreach program that includes:

1. *Informing citizens about public policies (such as the Renewable Energy Portfolio Standards and Regional Greenhouse Gas Initiative) and the incentives available from the State, the Sustainable Energy Utility and the Federal government.*
2. *Educating citizens about the importance and benefits of reducing the state's greenhouse gas emissions--including the economic benefits, new jobs and improved public health, and the potential costs of not doing so.*
3. *Educating citizens on how to determine their personal GHG footprint and actions they can take to reduce it.*
4. *Establishing criteria by which the educational plan can be evaluated objectively on a regular basis.*

Background

Education on energy, climate change, and the health impacts of fossil fuel use will be critical in gaining widespread public participation in support of Delaware's goals to reduce energy use and mitigate climate change.

While public policy leaders and elected officials must provide leadership, any plan to reduce Delaware's energy use and its greenhouse gas (GHG) footprint will require the enthusiastic support and participation of its citizens, if it is to succeed. Comprehensive energy and climate outreach and education was called for in the 2001 Delaware Climate Change Action Plan. The Introduction to Chapter 8, Public Education and Outreach, states the importance of an outreach and education effort to effective implementation of the plan as a whole, "Implementation of the Delaware Climate Change Action Plan … will require the participation, collaboration and cooperation of a broad spectrum of agencies, organizations and officials. In fact, it will require the participation of Delawareans in general. In order to be effective and to be sustained over time, such participation will have to be cultivated. A well-conceived public education and outreach program will be critical to efforts to implement the Climate Change Action Plan."[34]

The Delaware State Curriculum Standards for public education K-12[35] include a number of concepts and achievement objectives in science and math that relate to energy[36] and climate change.[37] The standards need to be updated to include some important additional topics, as well as new developments in science, science education, and public policy.

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[34] University of Delaware, Center for Energy and Environmental Policy, The Delaware Climate Change Action Plan, January 2001. http://www.udel.edu/ceep/publications/energy/reports/energy_delaware_climate_change_action_plan/chapter08.pdf

[35] Delaware Department of Education, *Curriculum Standards.* http://www.doe.k12.de.us/infosuites/staff/ci/default.shtml

[36] Delaware Department of Education, *Science Standard 3, Energy and Its Effects, Grade Level Expectations.* http://www.doe.k12.de.us/ddoe/files/pdf/science_Standard3.pdf

[37] Delaware Department of Education, *Science Standard 3, Earth's Dynamic Systems, Grade Level Expectations*. http://www.doe.k12.de.us/ddoe/files/pdf/science_Standard5.pdf

Current Department of Natural Resources & Environmental Control (DNREC) outreach and education efforts include publications available at the Delaware Energy Office and a Climate Change web site (which includes information from the 2007 IPCC reports and links to other sources of information).[38] In addition, DNREC was a co-sponsor with the Delaware Chapter of the American Institute of Architects of a symposium in December 2007, *Sustainable Solutions to Climate Change in Delaware*.[39]

These efforts can serve as the initial base to be built upon as Delaware moves forward with a comprehensive energy and climate education and outreach program. The education plan should be updated at regular intervals to include new science and policy developments.

Costs

Estimates of the costs of a public education and outreach program will need to wait until the program is better defined. Potential funding sources include the SEU and administrative funding under the Regional Greenhouse Gas Initiative (RGGI).

VI. STRAWMAN THAT DID NOT ACHIEVE CONSENSUS

Appendix D includes the strawman developed for the work group that did not achieve consensus. The work group agreed that the issue still warranted being brought forward to the Governor's Energy Advisory Council, albeit without a recommendation for action from the work group. This section of the report will describe the strawman recommendation that was presented to the work group and will present the discussion and issues raised leading to lack of consensus. The full strawman is included in appendix D.

Strawman: A Target Trajectory for Delaware's Carbon Footprint Reduction

Recommendation: The Environmental Footprint Workgroup recommends to the Governor's Energy Advisory Council that Delaware take a national leadership position in achieving the lowest per capita greenhouse gas (GHG) emissions of any state in the U.S. by 2050. We recommend a 90% reduction by 2050 in all Delaware's GHG emissions, from a 2000 baseline. That trajectory should include interim goals of reducing GHG emissions by at least 20% by 2020, 40% by 2030 and 65% by 2040, with adjustment of those interim and final goals as science and our progress relative to other leading states change with time. We further recommend

[38] http://www.dnrec.delaware.gov/ClimateChange/Pages/Climate%20change%20and%20Delaware.aspx
[39] AIA Delaware, *Sustainable Solutions to Climate Change in Delaware*, UD Virden Center, Dec. 11, 2007. http://www.aiadelaware.org/pdf/2007events/SustainConf07.pdf

that our next Governor convene a new Energy and Climate Change Commission to develop a detailed climate change action plan for achieving our goals, reassessing them at periodic intervals.

Reason for Lack of Consensus: The Work Group spent parts of several meetings discussing the concept of recommending a specific carbon reduction goal or target. The group agreed that Delaware needs to develop a climate change action plan with an aggressive goal (see Recommendation 1); however there was disagreement as to whether this group was the appropriate one to be recommending what that goal should be. The main concerns were regarding the scope of the work group not fully encompassing all the sectors that need to be involved in determining a climate change goal. In the end, the work group was split between those wanting to recommend a specific goal and those who felt that it was not within the purview of the work group to make such a recommendation.

APPENDIX A
Reducing the Environmental Footprint of the Energy Delawareans Use Work Group – Members

Chair – Mark Barteau, University of Delaware Energy Institute
Dot Abbott, University of Delaware Renewable Energy Program
David Bacher, NRG Energy
Neeloo Bhatti-McAndrew, University of Delaware Energy Institute
Elaine Bittner, Eastern Shore Natural Gas
Bruce Burcat, Delaware Public Service Commission
Sarah Buttner, Energy Transition Consulting LLC on behalf of the Public Advocate
Philip Cherry, DNREC
Daniel Corrigan, Delaware Municipal Electric Corporation, Inc.
Jay Fuess, White Pine Energy
Valerie Gray, Air Quality Management, DNREC
Willett Kempton, University of Delaware, College of Marine and Earth Studies
Andrea Maucher, Delaware Public Service Commission
Glenn Moore, Delmarva Power
Mark Nielson, Delaware Electric Cooperative
Elizabeth Pertzoff, League of Women Voters
Gene Ruane, Dover City Council
Bert Scoglietti, Delaware Office of Management & Budget
Charles Smisson, State Energy Office, DNREC
Doyle Tiller, Delaware Office of Management & Budget
Chad Tolman
Brian While, Lally-White LLP
Consultant – Andrea Kreiner, A.Kreiner Company
Staff – Scott Lynch, State Energy Office, DNREC
Non-Member Regular Attendee – Paul Sample, Technical Advisory Office, Legislative Council

Appendix B: Energy Resource Criteria Matrix

Fill in the chart below with -, 0, + for each criteria as you see it for the resource on the left.

"Effectiveness in Meeting Carbon Reduction Target " refers to a combination of the amount of reduction and the size of the resource

"Cost: Current" refers to current cost to the consumer in cents/kWh

"Cost: Outlook in 10-20 years" refers to anticipated costs to the consumer in cents/kWh

"Reliability" refers to the resources ability to provide consistent power when it is needed rather than at random times

"Nameplate Capacity" refers to the amount of energy that can be generated

"Safety/Health Impacts" refers to the risks and impacts associated with the resource

"Feasibility in Delaware" refers to both the technical and political feasibility of siting/using the resource in Delaware

Energy Resource\Criteria	Effectiveness in Meeting Carbon Reduction Target	Cost: Current	Cost: Outlook in 10-20 yrs	Reliability	Nameplate Capacity	Safety/ Health Impacts	Feasibility in Delaware
Solar PV: Centralized	-,-,+,+,+,+,+,+,+,+,0,0,0	-,-,-,-,-,-,-,-,-,-,0,+	0,0,0,0,+,+,+,+,+,+,+,+	-,-,0,0,0,0,0,+,+,+,+,+	-,-,-,-,-,-,-,0,0,+,+	0,0,+,+,+,+,+,+,+,+,+,+,+	-,-,-,-,-,-,0,0,0,0,+,+,+
Solar PV: Distributed	-,-,0,0,0,+,+,+,+,+,+,+,+,+	-,-,-,-,-,-,-,-,-,-,0,0,0,+	-,0,0,0,0,0,+,+,+,+,+,+,+,+	-,-,-,-,-,+,+,+,0,0,0,0,0,0	-,-,-,-,0,0,0,0,0,+,+,+,+,+,+	0,0,+,+,+,+,+,+,+,+,+,+,+,+	0,0,0,0,0,+,+,+,+,+,+,+,+,+
Solar Heating	0,0,0,+,+,+,+,+,+,+,+,+	-,-,-,-,-,-,-,-,0,0,+,+,+,+,+	+,+,+,+,+,+,+,+,0,0,0,0,0	-,-,+,+,+,+,+,+,0,0,0,0,0,0	-,-,-,-,+,+,+,0,0,0,0,0,0	+,+,+,+,+,+,+,+,,+0,0,0	0,0,-,-,+,+,+,+,+,+,+,+
Wind: On-shore	-,-,-,0,0,+,+,+,+,+,+,+,+,+	-,-,-,-,-,0,0,0,0,0,0,+,+,+	+,+,+,+,+,+,+,+,0,0,0,0	-,-,-,-,-,-,-,-,-,-,-,0,0,0,0	-,-,-,-,-,-,-,-,-,-,0,+,+	+,+,+,+,+,+,+,+,+,0,0,0,0,0	+,+,-,-,-,-,-,-,-,-,-,-,-,-
Wind: Off-Shore	+,+,+,+,+,+,+,+,+,+,+,+,+,+	-,-,-,-,-,-,-,-,0,0,0,0,0,+	+,+,+,+,+,+,+,+,+,+,0,0,-	-,-,-,-,-,-,-,-,-,-,-,0,0,0,+	-,-,-,0,0,0,+,+,+,+,+,+,+,+	+,+,+,+,+,+,+,+,+,+,0,0,0,0	-,0,0,+,+,+,+,+,+,+,+,+,+,+
Geothermal: Ground Source Heat Pumps	0,+,+,+,+,+,+,+,+,+,+	-,-,-,-,-,-,-,-,-,-,/0,0,0,0,+,+,+	+,+,+,+,+,+,+,+,+,0,0,0	+,+,+,+,+,+,+,+,+,+,+,+,0	-,-,+,+,0,0,0,0,0,0	+,+,+,+,+,+,+,+,+,+,+	0,0,+,+,+,+,+,+,+,+,+,+
Geothermal: Producing heat or electricity from w/n earth	-,-,0,0,+,+,+,+,+,+,+	-,-,-,-,-,-,-,-,-,0,+,+	-,-,+,+,+,+,0,0,0,0	-,+,+,+,+,+,+,+,+,+,0	-,-,-,-,+,+,0,0,0,0	0,+,+,+,+,+,+,+,+,+	-,-,-,-,0,+,+,+,+,+,+
Biomass/Cellulosic Materials	-,-,-,-,0/-,0,0,0,0,+,+,+,+++,	-,-,-,-,-,0,0,0,+,+,+	+,+,+,0,0,0,0,0,0,0,0	+,+,+,+,+,+,+,+,0,0,0	-,-,-,-,-,+,+,0,0,0,0,0	-,0,0,0,0,0,+,+,+,+,+,+	-,-,-,0,0,0,0+,+,+,+,+,+,+
Other Bioresources	?,?,-,-,-,0,0,0,0,0,+,+	-,-,-,-,-,-,-,0,0,0	0,0,0,0,0,0,0,0,+	0,0,0,0,0,+,+,+,+,+	-,-,-,0,0,0,0,0,+,+	0,0,0,0,0,+,+,+,+,+	-,-,-,0,0,0,,+,+,+,+,+
Nuclear	-,-.+,+,+,+,+,+,+,+,+,+,+,+	0,0,0,-,-,-,-,-,-,-,-,-,+	0/-,-,-,-,-,-,-,-,0,0,0,+	0,+,+,+,+,+,+,+,+,+,+,+,+	+?,+,+,+,+,+,+,+,+,+,+,+,+	+,+,+,0,0,0,-,-,-,-,-,-,-,-,-	-,-,-,-,-,-,-,-,-,0,0,0,0,0,+
IGCC/CCS	-,-,-,0,0,0,0,0,+,+,+,+,+	-,-,-,-,-,-,-,0,0,+,+	-,-,-,-,-,-,0,0,0,-/0,+,+	0,0,0,0,0,+,+,+,+,+,+,+,+,+	+,+,+,+,+,+,+,+,+,+,+,+,0,0	-,-,-,-,-,0,0,0,0,0,+/-,+,+,+	-,-,0,0,0,0,0,0,+/0,+,+,+,+
Waste Utilization: Methane Recov.,liquid fuels	-,0/-,0,0,0,0,0,+,+,+,+,+	-,-,-,0,0,0,0,+,+,+,+	+,+,+,+,+,0,0,0,0,0,0	+,+,+,+,+,+,+,0,0,0,0,0	-,-.+,+,+,+,+,0,0,0,0,0	-,-,-,-,0,0,0,0,0,0,0,+,+	-,-,0,0,0,0,+,+,+,+,+,+,+
Fuel Cells	-,-,0,0,0,+,+,+,+,+,+,+,dep. On how H2 made	-,-,-,-,-,-,-,-,-,-,0,0	0,0,0,0,+,+,+,+,+,-,-,-	+,+,+,+,+,+,+,+,+,+,0,0,0	-,-,-,-,-,+,+,+,0,0,0,0	-,0,0,0,0,0,0,0,+,+,+,+,+	0,0,0,0,+,+,+,+,+,+,+,+,+
Energy Storage/Batteries: Centralized	-,-,-,0,0,0,0,0,0/-,?,+if enables wind/solar,+,+,+	-/0,-,-,-,-,-,-,-,-,-,0	0,0,0,0,0,-,-,-,-,+,+	0,0/+,+,+,+,+,+,+,+,+,+	0,0,0,0,-,-,-,-,-,+	0,0,0,0,0,-,-,+,+,+	-,0,0,0,0,0,+,+,+,+,+
Energy Storage/Batteries: in End-Use Devices	-,0/-,0,0,0,0,0,0,?,+if enables wind/solar,+,+,+,+	-,-,-,-,-,-,-,0,0	-,-,0,0,0,0,0,+,+,	0,0,0,0,0/+,+,+,+,+,+	-,-,-,0,0,0,0,+,+	-,-,-,-,0,0,+,+,+,+	-,0,0,+,+,+,+,+,+,+,+
Tidal Flow	+,+,+,+,+,+,+,0,0,-,-,-	-,-,-,-,-,-,-,0,0,+	-,-,-,-,0,0,-/0,+,+,+	-,-,-,-,+,+,+,+,0,0,0,0	-,-,-,-,-,-,-,-,-,0,0,0,+	0,0,0,+,+,+,+,+,+,+,+,+,-	-,-,-,0,0,0,0,0,0,0,0,0,+,+
Generation/Transmission from Out-of-State	-,-,-,-,-,-,0,0,+,+,depends on generation source	0,0,0,0,0,0,-,+/-,+,+,+,+,+	0/-,-,-,-,0,0,0,0,+,+,+,	+,+,+,+,+,+,+,0,0,0,0,0,0	0,0,+,+,+,+,+,+,+,+,+,+,+	-,-,-,0,0,0,0,0,0,+,+,+	+,+,+,+,+,+,+,+,0,0,0,0,NA,-
Demand Response/Load Control	-,+,+,+,+,+,+,+,+,+,?,0,0	-,0,0,+,+,+,+,+,+,+,+	-,0,0,+,+,+,+,+,+,+	0,0,0,+,+,+,+,+,+,+,+,+	-,0,0,0,0,+,+,+,+,+,+,+	0,0,0,+,+,+,+,+,+,+,+,+	-,0,+,+,+,+,+,+,+,+,+,+

APPENDIX C

Quantitative review of Delaware Energy and Power options (rev. 1/20/09**)**

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This workgroup is assigned the task of proposing ways for Delaware to reduce its carbon footprint from electric generation. Since that task may be costly or difficult, the workgroup will also project the implications of implementing this goal.

The workgroup identified 18 technologies that could contribute to this goal. This document defines each briefly, then estimates how much of that resource is available to Delaware in the near term (within 10 years) and in the longer term (10-20 years).

As a quick look at points of agreement and disagreement, members of the workgroup rated each of these technologies. For some technologies the group seemed to think there was sufficient information, for others they requested that a more systematic review be undertaken of existing data. Both are used in this summary.

The work-group participants ranked these options on a five point scale (very-high, high, average, low, very-low). We review this ranking, then follow it with recommended estimates proposed as a strawman for the workgroup.

1. **Solar PV (Centralized):** A photovoltaic (PV) system converts sunlight, whether direct and diffused, directly into electricity. A centralized PV system is a collection of interconnected photovoltaic modules, all in one location, that function as a centralized power plant. These would typically be rated in megawatts (MW), in contrast to building PV systems that would typically be rated in kilowatts (kW). In addition to simply providing bulk power, centralized PV may be planned in order to meet peak load (as the solar peak is close to the load peak), or in order to strengthen the electric distribution system.[40]

   Work-Group Ranking:
   The working group ranked Centralized PV high in meeting the carbon reduction target, but that cost effectiveness was not likely before the 10-20 year time frame. It scored high for reliability, low for nameplate capacity, very high on minimal safety and health impacts, and a low rank for feasibility in Delaware.

   Strawman Assessment: We agree with the workgroup rankings. Quantitatively, we calculate the total state resource of centralized PV. To estimate resource, we assume that large installations would be used, and assume that parks or lands suitable for development would not be used. As a rough guide, we assume all fallow agricultural land in the state, approx. 998 acres,[41] would be used. This would provide a peak capacity of 369 MW, and an average output of 59 MW_a. (See appendix II for supporting calculations for each number not directly from a footnoted reference.) A centralized unit might sell for $5,000/kW capacity, not including land and permitting costs. At 16% CF that is a capital cost of $31,200/$kW_a$.

[40] Zahedi, A. (April 2006). Solar photovoltaic (PV) energy; latest developments in the building integrated and hybrid PV systems. Renewable Energy, 31 (5), doi:10.1016/j.renene.2005.08.007
[41] USDA National Agricultural Statistics Service, 2002 Census of Agriculture Delaware State Data

2. **Solar PV (Distributed):** We assume that distributed solar PV would be on building rooftops and would be grid-connected. This takes advantage of unused space and uses the existing grid connection as "storage" or backup. The next generation of building solar will not only be placed on roofs, but will be integrated with roofing materials, which should greatly lower the cost of an off-grid system sized to the household electric load. Since most of the distributed solar modules are installed on rooftops, it is also known as 'building integrated photo-voltaic (BIPV) system.

   Work Group Ranking:
   Working group ranked distributed PV 'very-high' in meeting the carbon reduction target, with a cost competitive outlook in the next 10-20 years. It was ranked 'average' in reliability and nameplate capacity, 'very-high' in safety/health impacts and 'high' for feasibility in Delaware.

   Strawman Assessment:
   At current residential PV installed cost, distributed PV is about $30,000 for a 4 kW system. Without any subsidy, calculations show Delaware distributed solar costs at about 35- 40 ¢/ kWh. In the summer, a large fraction of this generation is on-peak, so it can be compared with the cost of peak power. In 2009, there are Federal, State subsidies, and high RECS payments, the cost borne by the customer is competitive. However, there is not currently enough revenue in the state fund to expand the installation rate. To estimate the total potential, one can take a manageable area, the city of Newark. Based on City records and aerial surveys (see Appendix), one can estimate about 2,100,000 m^2 of rooftop area in Newark; if we assume about ¼ suitable for solar installations, that is 525,000 m^2. Taking an average industry figure of .11 kW/m^2 capacity and average capacity factor for solar in the Delaware of .16, that yields an average output of 57.5 MW_a. . Extending the Newark analysis to the whole state based on population ratio, rooftop PV installations have an average potential of 288 MWa[42], which could meet 22% of the state's electric load if all suitably available rooftop surface is used (See Appendix I). However, due to the currently-high per-kWh costs, expansion to the 288 MWa potential would be very costly--to building buyers, ratepayers or taxpayers.

3. ***Solar Heating*:** It harnesses the power of the sun to provide solar thermal energy for hot water and space heating. The system consists of solar collectors, optionally with some thermal storage. Sun's energy is used to heat air or fluid, which then transfers heat to a building.

   Work Group Ranking: Solar heating ranked 'very-high' in meeting the carbon reduction target, 'high' for development at current costs and 'very high' for future cost outlook. It was ranked 'high' in reliability and nameplate capacity and very high in safety/ health impacts category. It ranked 'high' in the feasibility in Delaware category.

   Strawman Assessment:
   Solar thermal can supply up to 25% of the energy use in residential, commercial and industrial sectors in Delaware.[43] Solar heating can be an important resource but its performance in limited by weather conditions (cloudy days), building direction and need for heat storage to ride through diurnal

[42] Capacity factor: 16%.
[43] Source: Brian P. Gallagher, "Solar Thermal Energy in Delaware" presentation to Delaware Sustainable Electric Utilities, March 06, 2007, www.seu-de.org/docs/Solar_Thermal_Presentation_Gallagher_3-06.pdf
Assuming solar thermal provides 50% of energy used for water heating, space heating and cooling.

constraints.

4. ***Wind On-shore*:** It uses the kinetic energy of terrestrial wind flows to create mechanical energy in a wind turbine that is then converted into electricity. Today's wind turbines range from a few kW to as large at 5 MW.

   Work Group Ranking: On-shore wind power ranked 'high' in meeting the carbon reduction target, 'average' for development at current cost, 'very-high' for future cost outlook, 'low' for reliability, 'low' for nameplate capacity, 'very-high' for safety/health impacts, and 'low' for feasibility in Delaware.

   Strawman Assessment: Workgroup ranking of low for reliability accurately corresponds to the lower capacity factor and output predominantly at night time. Workgroup ranking of low feasibility in Delaware corresponds to low amount of resources in Delaware. According to the Department of Energy (DOE) assessment, on-shore wind power at 50 m height is marginal and economically unviable in Delaware.[44] However, a more detailed resource assessment of Delaware' coastal regions may find a few tens of MW that are economically worthwhile and not excluded for environmental or community resistance reasons. A guess would be between 10 MW – 100 MW total in state.

5. ***Wind Offshore*:** Wind turbines can be installed in the oceans and great lakes to capture these wind flows and generate electricity. This requires specialized installation vessesl and different engineering and permitting processes than onshore wind. Before 2008, there was no industry in the US, but due to Delaware's lead, these facilities are now being planned or built by three companies in the Mid-Atlantic (Bluewater Wind, PSEG and Deepwater Wind). Wind is stronger and more constant over the ocean and large bays such as the Delaware Bay. Unlike most land-based wind, it is on-peak in the coastal regions, and either day-peaking or time-of-day level, further out to sea. A countervailing factor is that it is more expensive to install wind turbines in the ocean than on land.

   Work Group Ranking: It is rated 'very high' in effectiveness in meeting carbon reduction targets, 'average' for development at current costs, 'very high' for future cost outlook, 'low' on reliability, 'very high' on nameplate capacity and safety/health impacts, and 'very high' for feasibility in Delaware.

   Strawman Assessment: The workgroup's ranking, offshore wind is feasible now, has a high total potential, but does not provide steady power. Based on peer-reviewed literature, the practical offshore wind power potential off Delaware is approximately 19,000 MW[45] capacity with a production output of 7,400 MW_a.[46] This resource is large enough to supply the entire electric load in Delaware, five times over. As a cost benchmark, the BWW contract is at 9.9 ¢/kWh, with firming power and capacity payment (roughly .5/kWh each), those sum to about 11¢/kWh, the current cost of all-in wholesale load-following power. In other words, the contracted price is close to the current market price. Comparing in capital cost, the original 600 MW full build would have been $1.6B; or, at 37%CF, a capital cost of $7,200/$kW_a$.

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[44] Delaware Wind Resource Map (2003), Wind and Hydropower technologies program, Department of Energy. Accessed from, www.windpoweringamerica.gov/maps_template.asp?stateab=DE

[45] Assumptions: Areas out to 50m depth, excluding all conflicting uses such as shipping lanes, bird flyways and other competing uses.

[46] Dhanju, Whitaker, Kempton (2008). Assessing offshore wind resources: An accessible methodology, Renewable Energy 33, 55-64.

6. ***Ground Source Heat Pumps (building "geothermal")***: They are electrically power systems that tap into the earth's relatively constant temperature to provide heating, cooling, and hot water for homes and commercial buildings.

Work Group Ranking: It is rated 'very high' in effectiveness in meeting carbon reduction target, 'average' in affordable current costs, 'high' for affordable cost outlook in near future, 'high' on reliability, 'average' on nameplate capacity, 'very high' for safety/health impacts' and for feasibility in Delaware.

Strawman Assessment: This is an efficient technology which should be encouraged. However it is more properly grouped with other efficiency technologies so we do not analyze it further. This grouping could be revised if there is agreement by Workgroup Two that this is within our scope.

7. Geothermal power: Hot temperatures from geological formations closer to the Earth's mantle are used to produce steam. The steam is used for electricity production. Some air and water pollution may be associated with discharge of steam and/or water from the facility but generally, this is far less than fossil fuel power plants and does not produce net CO_2.

Strawman assessment: At shallow depths, for example in parts of California, current technology can produce power at market rates. However, in Delaware, suitably hot geological formations are very deep, not economically efficient to exploit with current technology. We do not discuss this further.

8. Biomass/ Cellulosic Materials: Biomass is biological material such as corn, switch grass that can be converted into liquid fuel. The highest value of this fuel is for transportation, but it can also be used to produce electricity.

Work Group Ranking: It is rated 'high' in effectiveness in meeting carbon reduction target, 'average' in affordable current costs, 'high' for affordable costs outlook in near future, 'very high' in reliability, 'low in name-plate capacity', 'average' in safety/heath impacts, and 'high' in feasibility in Delaware.

Strawman Assessment: All the corn, soybean and wheat harvest make up 86% of the harvest acreage in the state. These can all be converted into biofuels. As an upper bound, we calculate the fuel output of converting 100% of Delaware's output of these three crops into biofuels. This would result in production of 1,327,638 barrels (155,785,043 liter) of ethanol plus biodiesel. This amount of fuel would meet 9.5% of the transportation fuel needs of the state. For comparison, 155,785,043 liters of these fuels is the energy equivalent of 169 MW_a (calculations in Appendix III). Liquid fuel would not actually be used to produce electricity because transportation is a higher value use.

9. Other Bioresources: (What was intended here--Agricultural waste?)

10. Nuclear: Controlled reactions in fissionable materials generate heat, which boils water and runs a turbine and generator. Delaware currently draws about ¼ of its electricity from PSEG's 3,000 MW Salem/Hope Creek complex across the Delaware River in New Jersey. Within a few years, this is anticipated to need approximately $2 billion in upgrades to the steam system to keep running. Nuclear is very low carbon and low pollution and provides baseload power. Ramping is discouraged and is slow, so it is not a good fill-in generator for intermittent renewables.

Strawman Assessment: A nuclear power plant on the Delmarva Peninsula would pose daunting challenges for evacuation planning. The evacuation problem would be apparent to the public and would

likely lead to very substantial opposition. Also, current capital costs, per FERC, appear to imply very high costs of electricity despite recently-expanded Federal financial subsidies.

11. **IGCC/CCS**: In IGCC, coal is gasified and about half the carbon is separated before combustion. The remaining hydrogen-rich gas is burned in a combined-cycle combustion turbine. Carbon capture and storage (CCS) refers to additionally sequestering the carbon in deep geological storage. An IGCC plant, without CCS, was proposed as part of the bidding for power under HB6, so Delaware actually has an administrative record for the total costs of IGCC.

    Strawman Assessment: The IGCC bid received as a result of HB 6 was evaluated as being about 11 to 12 ¢/kWh. It was projected to achieve 50% - 80% reduction in criteria pollutants but no reduction in CO_2, since CO2 was to be separated and then vented, not sequestered. Future costs of electricity from such a plant would be dependent on future costs of coal and CO_2 compliance costs. On these bases, this generation technology was not awarded the bid. If the costs are brought down and sequestration is demonstrated, IGCC/CCS could be re-evaluated. Commercial IGCC/CCS is projected by MIT and other independent analysis to be in the 20 year time frame, not 1-10 and only the very end of 10-20 years. It may make sense for Delaware to be an early adopter when IGCC and CCS are ready, but since these plants are likely to be long-lived, the amount of reduction should be consistent with eventual carbon goals., e.g. 80% or 90% reduction over existing technology, not 50% or 60% reduction.

12. **Waste Utilization, Methane Recovery, Liquid fuels**: Organic materials in the waste stream can be combusted to produce electricity, or may be converted to liquid fuel. The latter requires agricultural waste, because municipal waste is too mixed a feedstock. However, combustion of mixed waste streams may introduce pollution that is difficult to monitor and control, due to the variable input materials.

    Strawman Assessment: We have not quantified this resource, but it is believed to be very small in comparison to other Delaware resources. Utilization of waste generally provides GHG benefits over simply letting methane outgas from landfills, thus it could be a sensible part of a GHG reduction strategy. Because it is small and has dedicated opposition, the Workgroup may wish to not make a recommendation one way or the other.

13. **Fuel Cells**: Fuel cells convert hydrogen and atmospheric oxygen to electricity and low-grade heat. The primary source of hydrogen today is from reforming of natural gas, a fuel cycle that provides no CO_2 benefit over burning the natural gas in a combustion turbine.

    Strawman Assessment: Since there is currently no low-cost source of hydrogen, this is not a practical generation technology for scale implementation. It may make sense in some applications for building-sited cogeneration or for grid support.

14. **Energy Storage: Centralized:** Centralized storage may be useful for ancillary services, and in larger quantities for compliment to wind or solar. Current technology is pumped hydro, which requires large vertical elevation changes. Currently-prototyped technologies include compressed-air energy storage (CAES), flywheels, and batteries meant for power application such as flow batteries. Pumped storage and CAES, and to some extent flow batteries, can provide bulk storage, as increasing the energy capacity is achieved by simply enlarging the reservoir. Flywheels and non-flow batteries are short-term power devices. For example, Ballard has a building-sized 20 MW unit with 5 MWh, thus it can run at full power for just 15 minutes. These devices are better for power applications such as ancillary services and

mitigating unexpected ramps. Another form of "centralized storage" is the General Compression use of wind turbines producing high-pressure air rather than electricity, with a centralized generator—this incorporates storage into wind at very little incremental cost. This wind/storage hybrid is just now being prototyped and would require at least 8-10 years development. Several of these centralized storage technologies may be useful in the 10-20 year time frame, especially if Delaware moves to large fractions of generation from renewable energy.

Straw man Assessment: For large-scale energy storage, none of these centralized technologies seem practical in the 1-10 year time frame. For quick response such as ancillary services and buffering of transients on renewables, flywheels may be practical today. Centralized energy storage using CAES, flow batteries, or storage integrated with wind turbines may be practical and economic in the 10-20 year time frame.

15. Energy storage/batteries in end-use devices: End use devices that convert electricity to easily stored energy forms, such as hot water or compressed air, can be dispatched to shift load (discussed below as 18). Storage in end-use devices refers to the possibility of two-way power flow with the electric grid. (Here put in use of end use devices for storage, low cost, needs control mechanisms. V2G as low-hanging fruit, possibly also electric heating.)

16: Tidal flow: Delaware has concentrated tidal flow in two locations: The mouth of the Delaware Bay and the Indian River Inlet. Damming such ecologically sensitive areas is very unlikely to be prudent, for ecological and other reasons. Thus, we only consider "open water" devices. One plan to tap tidal flow in the Indian River Inlet would have produced tens of MW. Multiple firms are testing tidal generators, in New York, Maine, and abroad.

Strawman Assessment: The size of this resource and the environmental impacts of tidal devices are unknowns. Tidal flow in the Delaware Bay is not measured but could plausibly be able to produce one or two hundred MW. If the Workgroup wanted to recommend movement on this resource, potential impacts should be studied with respect to specific types of devices. Small-scale implementation could be available late in the 10-20 year time frame.

17: Generation/Transmission from out-of-state:

Work Group Ranking: It is rated 'low' in effectiveness in meeting carbon reduction target, 'high' in affordable current costs, 'average' in affordable cost outlook in future, 'high' for reliability, 'very high' for name plate capacity, 'low' for safety/health impacts, and 'high' for feasibility in Delaware.

Strawman Assessment: Currently, approximately 38% of Delaware's electric load was serviced by imports from neighboring states. Due to insufficient power transmission interconnections, Delaware and Delmarva Peninsula suffers from transmission congestion. This is reflected in the locational marginal price (LMP) of electricity in the region. LMP is a market-based approach to manage the efficient use of transmission system and assets—power at a point in the transmission system with insufficient generation is bought at a higher price than the power that was put in hundreds of miles away, stimulating the use of local generation that would otherwise be too expensive to compete in the power market. If the transmission system was unconstrained and there were no losses, all the LMP's in an ISO region would be equal. Delmarva Power and Light territory average congestion component of LMP in 2007 added $ 6.09 / MWh to the cost of power. Major transmission projects such as Mid-Atlantic Power Pathway (MAPP) that will create new transmission across the Chesapeake Bay and Delaware river will

reduce this congestion. MAPP will cost approximately $ 1 billion dollars[47]. If Delaware decides to build any of the generation options above that could be expanded at rates above Delaware 2% growth, or if energy efficiency achieve reductions greater than growth, it could reduce the need for transmission. On the other hand, if Delaware's large resources were tapped in significant quantities (2,000 to 4,000 MW), more transmission would be very useful for both exporting power during high wind periods, and for importing power when wind were at low periods. Thus, transmission may be an important part of an overall energy plan for Delaware, but it cannot be properly planned in isolation from other power decisions. High renewables in Delaware combined with large transmission to the west would also essentially let large renewables in Delaware reduce CO_2 and criteria pollutants in Maryland and Virginia, because carbon-free power sources are likely to continue to be given "first dispatch" status for reasons of both economics (no fuel cost) and policy.

18: **Demand Response/Load control:**

In so called "demand response" or "direct load control" electric utility programs, a utility signal is used to reduce load of customer equipment. For example, air conditioners and water heaters are switched off and on for 15 minute cycles during peak demand. This is an economic alternative to construction of more generation equipment that would be used only a few hours each year.

To facilitate high penetration of renewable fluctuating power sources, a similar method could be used. The two high load, most cost-effective end-use devices are space heating and automobiles.

Heating is well matched to offshore wind for two reasons. Wind is strongest and most consistent during winter months, so shifting space heating from fuels to electricity improves seasonal balance of wind power with load. And, some heating devices are available with very economical storage, so that heating end-use devices can be used to buffer fluctuations in wind output at low cost.

Most figures in the auto industry now consider electrification of the automobile "inevitable". These plug-in cars will be a mix of plug-in hybrid and pure electric vehicles, both of which refuel from an electric plug when parked. The University of Delaware, working with Pepco Holdings, PJM, the State of Delaware, and other partners, is the world leader in using plug-in vehicles for electric grid resources. Most relevant to this discussion, plug-in vehicles can be used to absorb excess bursts of wind power, like storage heaters, but vehicles can also release stored energy to the electric grid, like a storage device.

Strawman assessment: Initial load-responsive heaters should be deployed to replace LP gas, fuel oil or kerosene—heating fuels which already have high fuel costs. Properly-done fuel substitution would result in a consumer savings as well as improved power management. In Delaware, 12% of households use LP gas for heating, and 21% use fuel oil or kerosene. After those fuels, 37% have natural gas, which would require a mechanism for mitigating fuel cost before they are switched. *[Need to calculate switch of current electric resistance heating.]*

If all residential bottled LPG and fuel oil were converted to electric resistance heating, it would require switching heating units 111,540 housing units (34.8 % of total housing units). If the heat were run at constant power 24 hours for 3 months, it would increase in the winter load = 823 MW_a[48]. That is an average load increase per house of 7.4 kW or 31 Amp at 240VAC. Although many of the Delaware residences with these expensive fuels have smaller electrical service (100 amp, some 50 amp), most could run an electric storage heater at 2x or 3x average power during the night, or when dispatched.

[47] Source: Mid-Atlantic Power Pathway website: www.powerpathway.com/overview.html

[48] Average load for three winter months (92 days)

Some would not be able to run much above the average value without electrical upgrades, which would increase the installation cost. In the table we assume only 2x as an average value for LP, fuel oil and kerosene.

A similar switch of natural gas heating would involve 119,819 housing units (37.4% of housing units) in Delaware. At constant power over 3 winter months, this would add load of 955MW_a. Electrical service in natural gas houses is on average higher power, so I assume 2.5x for a higher power dispatch to a heat-storage heater.

Commercial heating fuels are considered in the appendix.

Summary tables

The item by item explanations above, augmented by calculations in the appendices, are summarized in the following tables. Table C1 gives the energy resources of Delaware. As noted, some are based on extensive measurement and calculations (distributed solar, offshore wind) whereas others are estimates (tidal, land-based wind). Blank cells indicate either numbers not appropriate for that type of fuel, or numbers not yet estimated. Columns give: the current, unsubsidized cost to DE ratepayers,

Table C1. Delaware resource estimates. Calculations, assumption, and references are given in Committee background document by Dhanju and Kempton. The "total average output" is the best measure of the size of the resource in Delaware.

	Current cost to DE ratepayers ¢/kWh	Unsubsidized capital cost $/kW	Unsubsidized capital cost per output $/$kW_a$	Years until available & practical on commercial scale	Capacity (MW) in Delaware	Fraction on-peak (% of MW)	Total average output (MW_a)	Comments
Central PV[i]		$5,000	$31,200	10-20	369	80%	59	
Distributed PV (rooftop only)	35-40[ii]	$7,500	$46,800	1-10 (higher cost), 10-20 (more competitive cost)	1797	80%	288	Only using rooftops
Wind on-shore	6-8[iii,iv]	$1,200		Now	50 ?	5%[v]	15 ?	Estimates; strongest winds at night
Wind off-shore	11[iv]	$2,600	$7,200	Now	19,000	20%[v]	7,400	On-peak % higher in Bay or near shore
Biomass						100%	169	Highest value as liquid, not electricity
Transmission	0.5 adder			Now	2,000 – 20,000	100%	n.a.	
(Comparison: 2008 all-in power)	11			Now	3283	100%	1,300	

i. Assuming all fallow land used for centralized PV, no other lands used.

ii. The individual purchasing the system can get up to a 50% credit. However, this comes from other DE ratepayers under the clean energy fund, so it does not reduce the DE ratepayer impact. There are additional RECS

payments, some of which come from other states. Also, PV produces near to peak hours, so it is more valuable than if produced off peak.

iii. In this region, on-shore wind production is 2/3 overnight, 1/3 during the day, so—conversely to PV, onshore wind's value to the power system is lower than the straight cents/kWh value shown.

iv. No state subsidy for wind, so this is the true impact on DE ratepayers. Federal subsidies add up to about 4 ¢/kWh, comparable or less than nuclear. Offshore is based on Bluewater PPA, 9.9 ¢/kWh + .5 for capacity + .5 for market firming power (estimated), total about 11 ¢/kWh.

v. Offshore is level output by hour of day, 5 hour peak is 20% of day. Coastal wind peaks in afternoon due to sea breeze. In PJM region, on-land wind peaks at night.

Table C2 gives the resources for storage and release of electrical energy, and the load-responsive resources for absorbing power. These are primarily substitution of electricity for liquid or gaseous fuels.

Table C2. Delaware energy storage and buffering capabilities created by displacing fuels at end use. Row labels give the end use – and the fuels displaced. Quantities are based on maximum capacity, that is, 100% displacement of existing fueled devices.

	Average power draw of new electric load (MW_a)	Capacity for responsive load (MW)	Capacity to release from storage (MW)
Heat – expensive fuels only (LP, fuel oil, kerosene)	823 (winter)	1646	0
Heat – Natural gas	955 (winter)	2,388	0
Light vehicles- gasoline	320 (640 if off peak)	9,000	9,000

Appendices and backup calculations

by Amardeep Dhanju and Willett Kempton

Appendix CI: Delaware Roof top Solar Power Potential

Rooftop solar potential can be estimated based on southfacing or flat roof area. As a rough guide one can start with a manageable area, such as the city of Newark. Based on City records[49] and aerial mapping[50], one can estimate about 2,100,000 m^2 of rooftop area in Newark; if we assume about ¼ suitable for solar installations, that is 525,000 m^2. Taking an average industry figure of .11 kW/m^2 capacity and average capacity factor for solar in the Delaware of .16[51], that yields an average output of 57.5 MW_a. Extending the Newark analysis to the whole state based on population ratio, rooftop PV installations have an average potential of 288 MWa[52],

We scaled the Newark PV potential to calculate Delaware's potential, using the ratio of Newark population (including student population) to the State's population. The same capacity factor was used while calculating Delaware's potential. Newark is not typical of the state of Delaware, it has more shade, higher population density, and more rooftop from industrial and University buildings. Some differences would raise the potential solar area, others would lower it. Thus, lacking a more detailed estimate beyond Newark, we use the Newark ratio for the state. These approximations show that using the existing south facing rooftop space, building mounted photovoltaic installations can meet 22% of the state's electric load.

[49] See www.cityofnewarkde.us

[50] e.g, Delaware Research & Data Management Services, at maps.rdms.udel.edu

[51] Figure for Delaware, based on PV Planner.

[52] Capacity factor: 16%.

	Population	Electric Consumption (Mwh)	Electric Consumption (MW_a)	Solar power potential (MW)	Potential @ Cap. factor (MW_a)[53]	Potential as % of Load
Newark	28,000[54]	436,400[55]	49.7	57.5[56]	9.2	18.5%
Delaware	864,764[57]	11,554,672[58]	1318.2	1797	288	22%

Appendix CII: Using Fallow Land for Centralized PV Power Plants

1. Summer fallow land PV Potential:
Summer fallow land in Delaware[59]: 998 acres = 43,472,880 sq feet
Accounting for 15% of land as access and maintenance areas = 36,951,948 sq feet

2. Land requirement for servicing all Delaware electric load with centralized PV:

Delaware Electric load is 1,318 MW_a[60]. In this area, 1 MW_a average power output requires 19.17 acres of land for centralized PV. Thus, the total land required to serve Delaware average load is 25,277 acres.

This could be accomplished by using all the land under four lower-value categories[61]:

1. Cropland used only for grazing : 6,851 acres
2. Idle cropland or used for soil improvement: 9,662 acres
3. Summer Fallow land: 998 acres
4. Pastureland and rangeland: 6,540 acres

The above total 24,051, so adding approximately 1,200 acres of the land in lots and wasteland gets up to the needed 25,277 acres. Thus, categories of land 1 – 4 some of lots and wasteland, would produce all fuel needed for Delaware.

Total harvested cropland in Delaware for year 2002 is 433,105. If all this producing agricultural land were used for PV instead, it would provide 22,592 MW_a average power output. Conversely, to meet all state electric need with PV would require 5.8% of the harvested land. However, these scenarios seem less practical than rooftop PV both because they reduce agricultural productivity and because there is a cost in both money and a cost to society of removing land from agricultural production.

Appendix CIII: Delaware Bio-fuel Potential

[53] Capacity factor is 16% as used in PV planner calculations.
[54] Includes students living on campus at the University of Delaware.
[55] Source: Delaware Municipal Electric Corporation (DMEC) Data year 2005.
[56] Approximation, based on above.
[57] Source: Census.gov Data year: 2007
[58] Source: www.eia.doe.gov Table no EIA-861: 1990 - 2006 Retail Sales of Electricity by State by Sector by Type of Provider
[59] USDA National Agricultural Statistics Service, 2002 Census of Agriculture Delaware State Data
[60] Average load. Source: Energy Information Administration (EIA). Year 2006.
[61] USDA National Agricultural Statistics Service, 2002 Census of Agriculture Delaware State Data.

Crop Production in Delaware (2007)[62]

Crop	Harvested Acres	Yield	Production
Corn	185,000	97.0 bushels (2,463.8 kg/ acre)	17,945,000 bushels (455,803,000 kg)
Soybean	145,000	24.0 bushels (652.8 kg/acre)	3,480,000 bushels (94,656,000 kg)
Wheat	55,000	68.0 bushels (1850 kg/acre)	3,740,000 bushels (101,728,000 kg)

Corn, soybean and wheat make up 86% of the harvested acreage in the state.

1) Ethanol from harvested corn in Delaware:
Moist Corn production in DE (2007): 17,945,000 bushels = 455,803,000 kg
1 equivalent bushel is defined as 56 pounds (25.4 kg) of corn grain that contains 15 % of moisture by weight (Bender and Hill, 1997)
Therefore, Dry Corn production in DE (assuming 15% moisture content): 387,432,550 kg

1 kg of dry corn may yield 0.374 kg of water free ethanol (Patzek, 2004).
Therefore, Ethanol potential: 144,899,774 kg
The density of ethanol is 0.789 g/cm^3, or 0.789 kg per liter.
Therefore, the potential in liters is: 183,649,903 liter
Potential in gallons: 48,520,450 gallons. (1,155,249 barrels)

2) Ethanol from corn on fallow land:
Summer fallow land: 700 acres.
Moist Corn potential: (700 * 2463.8) = 1,724,660 kg
Dry corn potential: 1,465,961 kg
Ethanol potential from summer fallow land: 548,269 kg
Potential in gallons: 183,982 gallons (4,381 barrels)

3) Bio diesel from soybeans:
Soybean production in DE (2007): 94,656,000 kg
5.5 kg of soybean yields 1 kg of bio diesel (Pimentel and Patzek, 2005)
Soy Biodiesel potential of DE: 17,210,182 kg
Biodesiel density is 0.88 kg/liter.
Therefore, potential in liters is: 19,546,798 liter
In gallons: 5,171,111 gallons (123,122 barrels)

4. Ethanol from Wheat:
Wheat production in DE (2007): 101,728,000 kg
Typical moisture content: 16%
Dry wheat grain (3% moisture content): 85,451,520 kg
3.03 tones of dried wheat grain gives 1 ton of ethanol (source: Low Carbon Vehicle Partnership 2004)
Therefore, ethanol potential: 28,201,822 kg
Taking into account ethanol density: 108,303,574 liters
Production in gallons: 28,651,739 gallons (682,184 barrels)

[62] source: USDA National Agricultural Statistics Service, DE State Agriculture overview 2007

5. Total Ethanol potential for DE: 1,841,814 barrels
Taking into account the energy density of ethanol, which is 2/3 that of regular gasoline, potential is: 1,215,597 barrels.

6. Bio diesel production: 123,122 barrels
Taking into account the energy density of pure (B100) bio diesel which is 8.65% lower than the petro diesel (source: National Biodiesel Board, 2005), the potential is: 112,041 barrels.

7. Total Biofuel potential for DE:
Adding the ethanol and biodiesel potentials: 1,327,638 barrels = 155,785,043 liters
Converting liters into MW_a 169 MW.

Conclusion:
Diverting all the corn, wheat and soybean production in DE to produce biofuels will meet 9.5% of the transportation fuel needs of the state. This does not consider the negative aspects of removing all these crops from production.

References:
Bender, K. and Hill, L. (eds.) 1997, Adjusting for Moisture - Equivalent Bushel Workshop, Vol. AE4720, Urbana-Champaign, University of Illinois, Department of Agricultural and Consumer Economics.
Energy Information Administration (EIA) (2006). Table F9a: Total Petroleum Consumption Estimates by Sector, 2006. Retrieved August 26, 2008, from http://www.eia.doe.gov/emeu/states/sep_fuel/html/fuel_use_pa.html
Low Carbon Vehicle Partnership (October 2004). Well-to-Wheel Evaluation for Production of Ethanol from Wheat. A Report by the LowCVP Fuels Working Group, WTW Sub-Group. Report number: FWG-P-04-024. Retrieved August 29, 2008, from http://www.lowcvp.org.uk/assets/viewpoints/Biofuels%20WTW%20final%20report.pdf
National Biodiesel Board, Energy Content. Retrieved September 01, 2008, from http://www.biodiesel.org/pdf_files/fuelfactsheets/BTU_Content_Final_Oct2005.pdf
Patzek, T. W. (2004). Thermodynamics of the Corn-Ethanol Biofuel Cycle. Critical Review in Plant Sciences, 23(6): 519-567.
Pimentel, D. and Patzek, T. W. (March 2005). Ethanol Production Using Corn, Switchgrass, and Wood; Biodiesel Production Using Soybean and Sunflower. Natural Resources Research, 14 (1): 65-76. DOI: 10.1007/s11053-005-4679-8
USDA National Agricultural Statistics Service (2007). Delaware State Agriculture Overview 2007. Retrieved Aug 25, 2008, from http://www.nass.usda.gov/Statistics_by_State/Ag_Overview/AgOverview_DE.pdf

Appendix CIV. Delaware storage potential in end-use heating

1. Delaware Residential Sector Energy Consumption for Space Heating
The table below gives the number of housing units in Delaware, divided by fuel type and the amount of energy used per household. Apart from electricity and solar, the other fuels are primarily used for heating. The total number of housing units in Delaware is 320,110. This table is used to analyze the fuels that could be shifted to electricity. The reason for doing this analysis is that there is a plausible short-term argument for a simultaneous implementation of wind power and switching from some fuels to electricity. Shifting from fuel oil, kerosene or LP gas to electricity involves switching from an expensive fuel with an uncontrolled price to an expensive fuel (electricity) with a potentially level price.

We calculate a price example from the table below. The current use of 6.1 BTU of fuel oil, about 1055,000 barrels of crude or 55,000,000 gallons. At $3 gallon of fuel oil (not considering refining) that would be $165 million. The equivalent heat from electric resistance would be 1,201,000 MWh, at Delmarva Power retail of 16¢/kWh is $192 million. However, at either the wholesale cost of 11¢ or the overnight rate in many locations

of 5¢, the price would be $132 M and $60 M, respectively. These simple examples show that with a modest level of time-shifting credit, the cost of energy would be reduced from today's fuel prices.

Fuel Type	No. of Housing Units[63]	% of Housing Units	Energy Use Trillion BTU[64]	Delivered heat for Space Heating Trillion BTU[65]	MWh	MW_a[66] for 3 winter months
Utility Gas or Natural Gas	119,819	37.4 %	10.7	7.2	2,108,700	955
Bottled, tank, or LP gas	38,341	11.9 %	3.2	2.1	615,037	279
Electricity	88,751	27.7%	-	-	-	-
Fuel oil, kerosene	67,162	20.9 %	6.1	4.1	1,200,787	544
Coal or coke	668	0.20%	-	-	-	-
Wood	3,725	1.16%	-	-	-	-
Solar Energy	0	0	-	-	-	-
Other Fuel used	1,219	0.38%	-	-	-	-
No fuel used	425	0.13%	-	-	-	-
Total	**320,110**	**100%**	**20**	**13.4**	**3,924,524**	**1,778**

We consider three possible cases of fuel switching.

Case 0:

All current electric resistance heating is employed for load management. This could be done on approximately a 15-minute cycle with little impact on comfort. Or, if coil-to-air electric resistance heat were replace with storage-type electric resistance, much more load management would be possible with no impact on comfort at all. Neither of these options is quantified yet, so we do not consider them in our totals.

Case I:

If all residential bottled LPG and fuel oil were converted to electric resistance heating, it would require switching heating units 111,540 housing units (34.8 % of total housing units). If the heat were run at constant power 24 hours for 3 months, it increase in the winter load = 823 MW_a[67]. That is an average load increase per house of 7.4 kW or 31 Amp at 240VAC.

A per –house added load of 31 Amp is reasonable even at the low-power housing type. Old mobile home parks could have 30 or 50 amp service, so this could not be pushed into too small a heating time window. Newer trailer home parks recommend 100 or 200 amp service, and new homes are 200 or 250 amp, so in these there is a lot of extra distribution capacity that couuld be used for responsive load.

Case II:

If all residential piped utility natural gas is converted to electric resistance heating, it would require switching heating units of 111,819 housing units (34.9% of total housing units). If the heat were run at constant power 24 hours for 3 months, it would increase winter load = 955 MW_a, an average load increase per house of 8.5 kW or 35.4 Amp.

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[63] U.S. Census Data, B25117. Tenure by House Heating Fuel- Universe: Occupied Housing Units, year 2006.

[64] Residential energy delivered, by fuel. Source: Energy Information Administration (year 2005, Table S4. Residential Sector Energy Consumption Estimates, 2005. Accessed from, www.eia.doe.gov/emeu/states/sep_sum/html/sum_btu_res.html

[65] We estimate that the fuels in this column are at least 75% used for space heating (the remaining 25% mostly for water heating and cooking). Of the heating fuel input, was assume 75% furnace efficiency. So the prior column * .9 * .75 yields this column.

[66] The total MWh of delivered heat Is treated as being all consumed within the three winter months, to yield an average MW_a load for three winter months (92 days).

[67] Average load for three winter months (92 days)

Total Potential:
If both Case I and Case II are implemented, but not Case 0, they will add 1,778 MW_a to Delaware's winter load. Currently the existing annual average load is 1,318 MW_a, but that may be a little lower in the winter.

2. Delaware Commercial Sector Energy Consumption[68]:

Fuel Type	Energy Use Trillion BTU	Energy Use for Space heating Trillion BTU[69,70]	MWh	MW_a[71] for 3 winter months
Utility Natural Gas	8.7	5.8	1,698,675	769
Fuel oil, kerosene & LPG	2.1	1.4	410,025	186
Total	**9.8**	**7.2**	**2,108,700**	**955**

Again assuming that 75% of these fuels are used for heating (this 75% may be a bit high in the commercial sector), switching all them to electric resistance heating will add an average winter load of 955 MW_a.

In total, if all the above conversions were made (Case I and Case II, for both residential and commercial), it would add 2,733 MW_a for three coldest winter months, to the existing statewide load.

3. Delaware vehicles

To calculate total storage resource, we calculate the amount of storage if all vehicles were electrified, at 15 kW grid interface per vehicles. At home voltage of 240 VAC, this would mean an 80 amp grid interface, which is adequate for most houses in Delaware.
Electric vehicles would add load, although technology being developed at UD, and by several utilities working with automakers, would insure charging is off-peak. This would not be built into the initial batch of mass-produced vehicles from automakers, but is likely to follow after utilities demonstrate the technologies. Implementation of time-of-charge, or more generally, vehicle-to-grid technologies would make electric vehicles of value to the grid. Electrical load from a vehicle driving 14,000 miles/year would be 14,000mi* 250 Wh/mi = 3,500 kWh/year/car. If that load were leveled over 24 hours, that would be 400 watts average per car (0.4 kW_a), over 800,000 cars that is 320 MW_a. With nighttime charging but no V2G, 800,000 cars would be 640 MW added for 12 hours each day.
Vehicle-to-grid technology makes it possible to use these vehicles as a resource for the power grid, both to charge more quickly when there is excess power and to discharge when there is not enough. To calculate the maximum resource, if Delaware's 800,000 vehicles were plug-connectable at 15 kW, and assuming that only ¾ are parked and available at any one time, that is 600,000 * 15 kW = 9,000 MW. The entire state of Delaware currently draws 1,300 MW, with a peak of approximately 3,600 MW. If each vehicle had a battery of 30 kWh, with half available for the grid, they could discharge at 1,300 MW for 6.9 hours. These are maximum "resource" numbers, like those for power sources, but they show that electric vehicles with V2G could make possible higher penetration of renewable generation sources than is now contemplated.

[68] Source: Energy Information Administration (year 2005, Table S5. Commercial Sector Energy Consumption Estimates, 2005. Accessed from, www.eia.doe.gov/emeu/states/sep_sum/html/sum_btu_com.html
[69] Source: Energy Information Administration (year 2005, Table S4. Residential Sector Energy Consumption Estimates, 2005. Accessed from, www.eia.doe.gov/emeu/states/sep_sum/html/sum_btu_res.html
[70] Assuming 90% use of fuel for space heating and 75% furnace efficiency.
[71] Average load for three winter months (92 days).

APPENDIX D
Complete text of strawman recommendation that did not achieve consensus

A TARGET TRAJECTORY FOR DELAWARE'S CARBON FOOTPRINT REDUCTION

Recommendation

The Environmental Footprint Workgroup recommends to the Governor's Energy Advisory Council that Delaware take a national leadership position in achieving the lowest per capita greenhouse gas (GHG) emissions of any state in the U.S. by 2050. We recommend a 90% reduction by 2050 in all Delaware's GHG emissions, from a 2000 baseline. That trajectory should include interim goals of reducing GHG emissions by at least 20% by 2020, 40% by 2030 and 65% by 2040, with adjustment of those interim and final goals as science and our progress relative to other leading states change with time. We further recommend that our next Governor convene a new Energy and Climate Change Commission to develop a detailed climate change action plan for achieving our goals, reassessing them at periodic intervals.

Background/Objective

Climate change is a complex but extremely important challenge that scientists around the world have studied intensively for decades. The International Panel on Climate Change (IPCC)--composed of thousands of the world's finest climatologists, meteorologists, and earth scientists—has concluded with near certainty that human activities, particularly the combustion of fossil fuels, are changing Earth's climate as a result of emissions of carbon dioxide and other pollutants, leading to increased global temperatures, ocean acidification, sea level rise, and other impacts that will negatively affect the health and well being of humans, plants and animals on a large scale.[i] Governments around the globe have vowed to become stewards of the earth and to reduce harmful emissions so as to stabilize atmospheric concentrations of carbon dioxide at levels that will not increase the global average temperature more than 2°C (3.6°F) above its preindustrial level--understanding that some temperature increase beyond the 0.8°C seen so far is inevitable--given past practices, the lifetimes of GHGs in the atmosphere, and the political difficulties inherent in such a large global undertaking. Delaware, having an interest and duty to act in the best interests of its citizens and their progeny, should lead the hundreds of state and national governments in setting aggressive goals for reducing the emissions that cause climate change.

Discussion

Of the various negative impacts of anthropogenic climate change, the greatest threat to Delaware, because of its coastal location and low average elevation, is sea level rise. Delaware has the lowest average elevation (60 ft or about 20 m) of any state in the U.S.,[ii] and rising seas could submerge our beaches and wetlands, damage tourism, and result in serious property losses to homes, businesses, and infrastructure. Sea level at Lewes rose by a foot during the past century and may rise by two or more feet in the coming century.[iii] Potentially exacerbating that projected rise in sea level are other warming feedback mechanisms that are accelerating the melting of the polar ice caps, causing considerable uncertainty in predicting coastal impacts. Because of sea level rise and the fact that Delaware has higher annual per capita carbon emissions (5.8 metric tons (mt) in 2000) than the U.S. national average,[iv] (5.5 mt)--one of the highest national averages in the world--Delaware should take the issue of climate change and carbon footprint reduction very seriously and provide both leadership and a sense of urgency in setting its own goals. Though we can't control emissions outside our state, we can, through leadership and excellence, show what can be done and encourage others to follow our example.

In response to the studies of the IPCC, the U.S. National Academy of Science and a number of other scientific groups, and to a growing international interest in reducing GHG emissions, legislation has been introduced in the U.S. Congress setting reduction targets for GHG emissions as high as 80% below current levels

by 2050 (Attachment A). Many U.S. states have also set statewide reduction goals, with varying reduction percentages and timing (Attachment B). The most aggressive proposed so far (by California) calls for an 80% reduction below 1990 levels by 2050. However, since the goals in Attachments A and B were set, credible evidence has been published showing that Earth's climate sensitivity is actually greater than presumed earlier, leading experts to conclude that we need to exceed the 80% emission reduction goal and actually reduce atmospheric CO_2 concentrations below current levels.[v] This implies the need to reduce emissions as rapidly as is humanly possible, and then to remove CO_2 from the atmosphere by carbon capture and storage—probably by large scale afforestation. The plan for achieving reductions in GHG emissions is as important as the goals--perhaps more important. Delaware has a climate change action plan that was published in 2000[vi] and is in need of re-examination. Clearly the science of climate change has progressed considerably since then, and the existing plan is no longer adequate; however, it can serve as a starting point for a new effort. Many states have utilized advisory panels to help define climate mitigation and adaptation plans, and Delaware should be no different. Only by assembling a broad array of expertise in science, economics and policy, and working on a number of efforts in parallel, including educating the public, can we develop a plan that is well balanced, achievable, and publicly supported. Delaware's next Governor should appoint a new Energy and Climate Change Commission to initiate a planning process that will outline the steps necessary to achieve a 90% reduction in 2000 emissions by the year 2050. The challenge is immense, but it is dwarfed by the consequences of inaction.

Cost and Analysis of Opportunity and Risk

Some discussion of the costs of mitigation and adaptation, and the costs of delaying action, can be found in reports by Stern[vii] and McKinsey.[viii] The McKinsey Report explores a variety of emission abatement opportunities with costs ranging from negative (cost savings) up to $50/ ton CO_2e[ix] and concludes that the U.S. could reduce its GHG emissions by 3.0 $GtCO_2e$ by 2030 with an increase of 1.5% of the capital expenditures anticipated during the period. This translates to an annual per capita emissions reduction by 2030 of about 10 tons of CO_2 (2.5 tons of carbon) at an average annual cost of about $170 per person. That reduction in Delaware would get us to the 40% goal by 2030.

There is relatively little cost to conducting an inventory of GHG emissions, setting a reduction goal, or convening a new Commission to prepare a plan. The real costs and opportunities cannot be known in advance and will become clear only while implementing the plan and learning as we go. We will clearly need a combination of conservation, improved energy efficiency and the deployment of renewable energy sources--with which we are blessed--aided by the participation of the business community and world-class research at Delaware's colleges and universities.

Continuing business as usual, or token efforts at footprint reductions here and around the world, will eventually result in the nearly complete inundation of Delaware by rising seas.[x] By becoming a leader in reducing our own emissions, fostering new industries, and leading by example in the transition from an economy based on fossil fuels to one based on renewable energy sources, we maximize the chances that global climate change will slow to a rate to which we can adapt while providing new jobs and economic opportunities for our citizens.

Attachment A

PEW CENTER Global CLIMATE CHANGE

Economy-wide Cap-and-Trade Proposals in the 110th Congress

Includes Legislation Introduced as of October 18, 2007

Bill	Scope of Coverage	2010-2019 Cap	2020-2029 Cap	2030-2050 Cap	Offsets	Allocation	Other Cost Controls	Early Action	Technology and Misc.
Lieberman-Warner S. 2191 – 10/18/2007 America's Climate Security Act	All 6 GHGs Economy-wide, "hybrid" – upstream for transportation fuels; downstream for electric utilities and large sources	2005 level in 2012	15% below 2005 level in 2020	33% below 2005 level in 2030 52% below 2005 level in 2040 70% below 2005 level in 2050	15% limit on use of domestic offsets 15% limit on use of international credits	Increasing auction: 24% in 2012, rising to 73% from 2036-2050 Some sector allocations are specified including: 20% each to power plants and industry (transitions to zero in 2036), 9% to states, 10% to load serving entities (LSEs) 5% set-aside of allowances for agricultural and forests	Borrowing up to 15% per company Creates Carbon Market Efficiency Board to monitor the trading market and implement specific cost relief measures	5% of allowances for early action in 2012, phasing to zero in 2017	Bonus allocation for carbon capture and storage Funds and incentives for technology, adaptation, & mitigating effects on poor Cap-and-trade system performance and targets subject to 3-year NAS review
Bingaman-Specter S. 1766 – 7/11/2007 Low Carbon Economy Act	All 6 GHGs Economy-wide, "hybrid" – upstream for natural gas & petroleum; downstream for coal	2012 level in 2012	2006 level in 2020	1990 level in 2030 President may set long-term target ≥60% below 2006 level by 2050 contingent upon international effort	Provides certain initial categories including bio sequestration and industrial offsets President may implement use of international offsets subject to 10% limit	Increasing auction: 24% from 2012-2017, rising to 53% in 2030 Some sector allocations are specified including: 9% to states, 53% to industry declining 2%/year starting in 2017 5% set-aside of allowances for agricultural	$12/ton CO2e "technology accelerator payment" (i.e., safety valve) starting in 2012 and increasing 5%/year above inflation Allows banking	From 2012-2020, 1% of allowances allocated to those registering GHG reductions prior to enactment	Bonus allocation for carbon capture and storage Funds and incentives for technology R&D Target subject to 5-year review of new science and actions by other nations
McCain-Lieberman S.280 – 1/12/2007 Climate Stewardship and Innovation Act	All 6 GHGs Economy-wide, "hybrid" – upstream for transportation sector; downstream for electric utilities & large sources	2004 level in 2012	1990 level in 2020	20% below 1990 level in 2030 60% below 1990 level in 2050	30% limit on use of international credits and domestic reduction or sequestration offsets	Administrator determines allocation/auction split; considering consumer impact, competitiveness, etc.	Borrowing for 5-year periods with interest	Credit for reductions before 2012 Early actors may use offsets to meet 40% of reductions	Funds and incentives for tech R&D, efficiency adaptation, mitigating effects on poor
Sanders-Boxer S.309 – 1/16/2007 Global Warming Pollution Reduction Act	All 6 GHGs Economy-wide, point of regulation not specified	2010 level in 2010 2%/year reduction from 2010-2020	1990 level in 2020	27% below 1990 level in 2030. 53% below 1990 level in 2040 80% below 1990 level in 2050	Includes provision for offsets generated from biological sequestration	Cap and trade permitted but not required. Allocation criteria include transition assistance and consumer impacts	"Technology-indexed stop price" freezes cap if prices high relative to tech options	Program may recognize early reductions made under state or local laws	Standards for vehicles, power plants, efficiency, renewables, certain categories of bio sequestration
Kerry-Snowe S.485 – 2/1/2007 Global Warming Reduction Act	All 6 GHGs Economy-wide, point of regulation not specified	2010 level in 2010	1990 level in 2020 2.5%/year reduction from 2020-2029	3.5%/year reduction from 2030-2050. 62% below 1990 level in 2050	Includes provision for offsets generated from biological sequestration	Determined by the President; requires unspecified amount of allowances to be auctioned	Not specified	Goal to "recognize and reward early reductions"	Funds for tech. R&D, consumer impacts, adaptation Standards for vehicles, efficiency, renewables, certain categories of bio sequestration

Bill	Scope of Coverage	2010-2019 Cap	2020-2029 Cap	2030-2050 Cap	Offsets	Allocation	Other Cost Controls	Early Action	Technology and Misc.
Olver-Gilchrest H.R. 620 – 1/22/2007 Climate Stewardship Act	All 6 GHGs Economy-wide, "hybrid" – upstream for transportation sector; downstream for electric utilities & large sources	2004 level in 2012	1990 level in 2020	22% below 1990 level in 2030 70% below 1990 level in 2050	15% limit on use of international credits and domestic reduction or sequestration offsets	Administrator determines allocation/auction split; considering consumer impact, competitiveness, etc.	Borrowing for 5-year periods with interest	Credit for reductions before 2012 Early actors may use offsets to meet 35% of reductions	Funds and incentives for tech R&D, efficiency adaptation, mitigating effects on poor
Waxman H.R.1590 – 3/20/2007 Safe Climate Act of 2007	All 6 GHGs Economy-wide, point of regulation not specified	2009 level in 2010 2%/year reduction from 2011-2020	1990 levels in 2020 5%/year reduction from 2020-2029	5%/year reduction from 2030-2050 80% below 1990 levels in 2050	Not specified	Determined by the President; requires unspecified amount of allowances to be auctioned	Not specified	Goal to "recognize and reward early reductions"	Standards for vehicles, efficiency, renewables

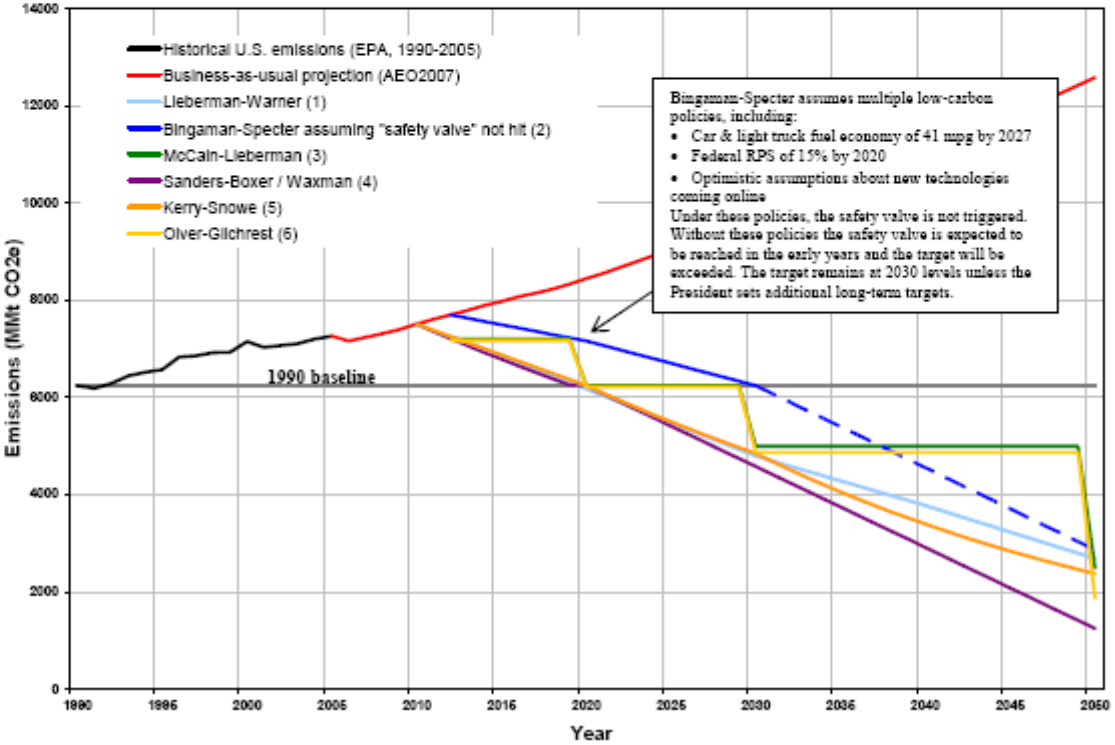
Illustration of Total U.S. Emissions Targets

This chart provides a rough comparison of the reduction targets for U.S. emissions contained in each legislative proposal. The percentage of emissions to be covered under a cap-and-trade program varies across the bills, as does the specificity regarding which entities and sectors are covered.

(1) Lieberman-Warner includes an overall goal of reducing total U.S. emissions through a combination of a cap on approximately 75% of U.S. emissions (transportation, electric power, and industrial sectors) and complementary policies (e.g., energy efficiency standards). The projected total reductions in U.S. emissions are reflected in the chart.
(2) Bingaman-Specter includes a cap on about 88% of U.S. emissions and assumes multiple low-carbon policies, including:

- Car & light truck fuel economy of 41 mpg by 2027
- Federal RPS of 15% by 2020
- Optimistic assumptions about new technologies coming online

Under these policies, the safety valve is not triggered. Without these policies the safety valve is expected to be reached in the early years and the target will be exceeded. The chart reflects these optimistic assumptions. In addition, the overall emissions targets (e.g., 1990 levels in 2030) are applied to total U.S. emissions; however, emissions from uncovered sectors may continue to grow.
(3) McCain-Lieberman includes a cap on about 87% of U.S. emissions (transportation, electric power, industrial, and commercial sectors). The chart assumes these targets (e.g., 20% below 1990 levels by 2030) apply to total U.S. emissions; however, emissions from uncovered sectors may continue to grow.
(4) Both Sanders-Boxer and Waxman include targets for total U.S. emissions, however, the percentage of emissions or sectors to be covered by the cap are not specified in the bill. The chart reflects these overall targets.
(5) Kerry-Snowe includes targets for total U.S. emissions, however, the percentage of emissions or sectors to be covered by the cap are not specified in the bill. The chart reflects these overall targets.
(6) Olver-Gilchrest includes a cap on about 87% of total U.S. emissions (transportation, electric power, industrial, and commercial sectors). The chart assumes these targets (e.g., 22% below 1990 levels by 2030) apply to total U.S. emissions; however, emissions from uncovered sectors may continue to grow.



Appendix B – State GHG Targets – Compiled 9/07						
State	Target	Implementation	Administered By:	Advisory Board(s)	Climate Action Plan	Date
Arizona	-2000 levels by 2020 -50% below 2000 by 2040	Executive Order 2006-13 (September 2006)	Arizona Dept. of Environmental Quality	-Climate Change Advisory Group -Climate Change Executive Committee	Climate Change Action Plan	Sept 2006
California	Reduce carbon intensity of passenger vehicle fuels by 10 percent by 2020	Executive Order S-01-07 (January 2007)	-Cal. Air Resources Board -Cal. Env. Protection Agency		1997 Global Climate Change Report: Greenhouse Gas Emissions Reduction Strategies for California	January 1998
California	-2000 levels by 2010 -1990 levels by 2020 -80% below 1990 by 2050	Executive Order S-3-05 (June 2005)	California Environmental Protection Agency			
California: Major industries state-wide	1990 levels by 2020	AB 32 (California Global Warming Solutions Act of 2006)	California Air Resources Board	-Environmental Justice Advisory Committee -Economic and Technology Advancement Advisory Committee	Proposed Early Actions to Mitigate Climate Change in California	April 2007
Connecticut	-1990 levels by 2010 -10% below 1990 by 2020 -75-85% below 2001 levels in the long term	Connecticut Climate Change Action Plan (February 2005)	Governor's Steering Committee on Climate Change	Climate Change Coordinating Committee	Connecticut Climate Change Action Plan	February 2005
Florida: State-wide/Electric Utilities	-2000 levels by 2017 -1990 levels by 2025 -80% below 1990 levels by 2050	Executive Order 07-127 (July 2007)	Florida Department of Environmental Protection	Governor's Action Team on Energy and Climate Change		*In Progress*
Hawaii	1990 levels by 2020	Act 234 (July 2007)	Department of Business, Economic Development, and Tourism	Greenhouse Gas Emissions Reduction Task Force	Hawaii Climate Change Action Plan	November 1998
Illinois	-1990 levels by 2020 -60% below 1990 levels by 2050	Press Release (February 2007)		Climate Change Advisory Group Executive Order 2006-11	A Climate Change Action Plan for Illinois	June 1994
Maine	-1990 levels by 2010 -10% below 1990 by 2020 -75-80% below 2003 long-term	LD 845 (HP 622) (September 2003)	Department of Environmental Protection	Stakeholder Advisory Group	Maine Climate Action Plan	December 2004
Massachusetts	-1990 levels by 2010 -10% below 1990 by 2020 -75-85% below 1990 long-term	Massachusetts Climate Protection Plan of 2004 (stresses voluntary mechanisms)	State Office for Commonwealth Development		Massachusetts Climate Protection Plan	May 2004
Massachusetts: Electric Utilities	10% below 1997-1999	CO_2 target only: 310 CMR 7.29				

Maryland	-1990 levels by 2020 -80% of 2006 levels by 2050	Executive Order 01.01.2007.07 (April 2007)		Commission on Climate Change	Comprehensive Climate Change Impact Assessment	*In Progress*
Minnesota	-15% below 2005 levels by 2015 -30% below 2005 levels by 2025 -80% below 2005 levels by 2050	Next Generation Energy Act of 2007 (May 2007)		Minnesota Climate Change Advisory Group	Climate Mitigation Action Plan	*In Progress*
New Hampshire	-1990 levels by 2010 -10% below 1990 by 2020 -75-85% below 2001 long-term	The Climate Change Challenge	Department of Environmental Services		The Climate Change Challenge	December 2001
New Hampshire: Electric Utilities	-1990 levels by 2006 (CO_2) -NOx reduced 70% from 1999 levels by 2006 -SOx emissions reduced 87% from 1999 levels by 2006	HB 284 (The New Hampshire Clean Power Act)	Department of Environmental Services			
New Jersey	-1990 levels by 2020 -80% below 2006 levels by 2050	Executive Order No. 54 (February 2007) Global Warming Response Act (July 2007)	Department of Environmental Protection	Various State Agencies, led by the Department of Environmental Protection		*In Progress*
New Mexico	-2000 levels by 2012 -10% below 2000 by 2020 -75% below 2000 by 2050	Executive Order 05-033 (June 2005)	Various State Agencies, led by New Mexico Environment Department	Climate Change Action Council Climate Change Advisory Group	New Mexico Greenhouse Gas State Action Plan	September 2002
New York	-5% below 1990 by 2010 -10% below 1990 by 2020	State Energy Plan of 2002	New York State Energy Planning Board	New York GHG Task Force Center For Clean Air Task Force	Recommendations to Governor Pataki for Reducing New York State Greenhouse Gases	April 2003
Oregon	-Stabilize by 2010 -10% below 1990 by 2020 -75% below 1990 by 2050	Oregon Strategy for Greenhouse Gas Reductions (December 2004) House Bill 3543	Oregon Department of Energy		Oregon Strategy for Greenhouse Gas Reductions	December 2004
Rhode Island	-1990 levels by 2010 -10% below 1990 by 2020	Rhode Island Greenhouse Gas Action Plan (July 2002)	Rhode Island Department of Environmental Management Rhode Island State Energy Office Governor's Office	Rhode Island Greenhouse Gas Stakeholder Project	Rhode Island Greenhouse Gas Reduction Plan	July 2002
Utah	Currently setting goals	Western Climate Initiative Statement of Regional Goal	Utah Department of Environmental Quality	Blue Ribbon Advisory Council	Greenhouse Gas Reduction Goal	*In Progress*

Vermont	-25% below 1990 levels by 2012 -50% below 1990 levels by 2028 -75% below 1990 levels by 2050	Executive Order 07-05 (December 2005) Act. No. 168 (S.269) (2006)	Vermont Agency of Natural Resources	Governor's Commission on Climate Change Plenary Group	Final Report and Recommendations of the Governor's Commission on Climate Change	October 2007
Washington	-1990 levels by 2020 -25% below 1990 levels by 2035 -50% below 1990 levels by 2050	Executive Order 07-02 (February 2007)	Department of Ecology Governor's Office Department of Community, Trade and Economic Development		Greenhouse Gas Mitigation Options for Washington State	April 1996
					Seattle Climate Action Plan	September 2002
					Washington Climate Change Challenge	*In Progress*
Western Climate Initiative	15% below 2005 levels by 2020	Western Climate Initiative Statement of Regional Goal				
Regional Greenhouse Gas Initiative: CO2 emissions from power plants	-Cap emissions at current levels in 2009 -Reduce emissions 10% by 2019					
New England Governors and Eastern Canadian Premiers: Regional economy-wide	-1990 levels by 2010 -10% below 1990 by 2020 75-85% below 2001 long-term	Climate Change Action Plan of 2001				

[i] IPCC Fourth Assessment Report: Climate Change 2007. At: http://www.ipcc.ch/ipccreports/assessments-reports.htm

[ii] Wickipedia, **List of U.S. States by Elevation**. At: http://simple.wikipedia.org/wiki/List_of_U.S._states_by_elevation

[iii] EPA, **Climate Change and Delaware**, Washington, D.C., National Technical Information Service, Pamphlet 2230-F-97-008h, 1997. At: http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/SHSU5BPQKV/$File/de_impct.pdf

IPCC Fourth Assessment Report, Synthesis Report, p. 45, Table 3.1.
At: http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf

[iv] Oakridge National Laboratory (ORNL), **Year-by-year, state-by-state carbon dioxide emissions for the USA**, 2005. At: http://www.esd.ornl.gov/highlights/2005/blasing_highlight.pdf

ORNL Carbon Dioxide Information Analysis Center (CDIAC), **Graphs of Annual Fossil-Fuel CO2 Emitted for Each State in the U.S.A. and the District of Columbia for Each Year from 1960 through 2001**, 2004. At: http://cdiac.ornl.gov/trends/emis_mon/stateemis/graphics/graphics.html

Note that metric tons of carbon (the common international units) can be converted to short tons of carbon dioxide (the units used for RGGI) by multiplying by a factor of 4.0.

[v] James Hansen et al., **Target atmospheric CO2: Where should humanity aim?,** April 7, 2008. At: http://arxiv.org/abs/0804.1126v1

[vi] UD Center for Energy and Environmental Policy, **Delaware Climate Change Action Plan**, 2000. At: http://ceep.udel.edu/publications/globalenvironments/reports/deccap/fullreport.pdf

[vii] Nicholas Stern, **Stern Review Report on the Economics of Climate Change**, Cambridge University Press, 2006. The 700 page report is available from: http://www.cambridge.org/us/catalogue/catalogue.asp?isbn=9780521700801.
A 27-page executive summary can be found at:
http://news.bbc.co.uk/1/shared/bsp/hi/pdfs/30_10_06_exec_sum.pdf.

[viii] McKinsey & Company, **Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?,** December 2007. At: http://www.mckinsey.com/clientservice/ccsi/pdf/US_ghg_final_report.pdf

[ix] The abbreviation CO2e means CO2 equivalent. It includes other greenhouse gases like methane and nitrous oxide, weighted according to their global warming potential over a 100-year time span. See: EPA, Greenhouse Gases and Global Warming Potential Values, 2002. At: http://yosemite.epa.gov/oar/GlobalWarming.nsf/UniqueKeyLookup/SHSU5BUM9T/$File/ghg_gwp.pdf

[x] Willett Kempton and Amardeep Dhanju, **Sea Level Rise and Its Effect on Delaware**, UD College of Marine and Earth Studies, 2007. At: http://co2.cms.udel.edu/SeaLevel_DE.htm