MARYLAND'S CLEAN ENERGY FUTURE

Climate Goals & Employment Benefits

LABOR NETWORK FOR SUSTAINABILITY

Synapse Energy Economics, Inc.

Contents

INTRODUCTION

This report presents a Clean Energy Future (CEF) plan that reduces Maryland's net emissions of greenhouse gases (GHGs) 80 percent below the 2006 level by 2050 – while adding more than ten thousand jobs per year. With a state strategy to encourage and expand the growing industries of the future, Maryland's employment gains could be considerably greater.

Maryland has often been told that doing its share to save the earth's climate will threaten its workers' jobs. "Maryland's Clean Energy Future: Climate goals and employment benefits" refutes that claim. This report lays out a climate protection strategy that will produce an estimated 10,000 more jobs per year over business as usual projections through 2050. Almost two-thirds of the jobs created will be in the high-wage construction and manufacturing sectors.

The report also indicates that Maryland can use the burgeoning state and national demand for clean energy to create good, stable jobs in a growing climate protection sector: manufacturing jobs, jobs for those who have been marginalized in the current labor market, and jobs for skilled union workers in the construction trades. Maryland needs a robust job creation and clean industry development strategy to realize that potential.

This report was prepared by the Labor Network for Sustainability (LNS)[1] with research conducted at Synapse Energy Economics by Dr. Frank Ackerman, Tyler Comings, and Spencer Fields.[2] It is based on the national study "The Clean Energy Future: Protecting the Climate, Creating Jobs, and Saving Money" released October 14, 2015.[3] That study lays out an aggressive strategy for energy efficiency and renewable energy that will:

- Transform the electric system, cutting coal-fired power in half by 2030 and eliminating it by 2050; building no new nuclear plants; and reducing the use of natural gas far below business-as-usual levels.
- Reduce greenhouse gas emissions 86 percent below 1990 levels by 2050, in the sectors analyzed (which account for three-quarters of US GHG emissions).
- Save money – the cost of electricity, heating, and transportation under this plan is $78 billion less than current projections from now through 2050. With additional expenditure, GHG emissions could be reduced even more and even faster.

[1] The Labor Network for Sustainability (http://www.labor4sustainabilty.org) was founded in 2009 based on an understanding that long-term sustainability cannot be achieved without environmental protection, economic fairness, and social justice. LNS believes we all need to be able to make a living on a living planet.
[2] Synapse Energy Economics (http://www.synapse-energy.com) is a research and consulting firm specializing in energy, economic, and environmental topics. Since its inception in 1996, Synapse has grown to become a leader in providing rigorous analysis of the electric power sector for public interest and governmental clients.
[3] Labor Network for Sustainability, "The Clean Energy Future: Protecting the Climate, Creating Jobs, and Saving Money" http://www.labor4sustainability.org/wp-content/uploads/2015/10/cleanenergy_10212015_main.pdf

- Create new jobs – more than 500,000 per year over business as usual projections through 2050. With additional expenditure, even more jobs could be created.

The Clean Energy Future plan does not depend on any new technical breakthroughs to realize these gains, only a continuation of current trends in energy efficiency and renewable energy costs. Most of the additional jobs will be in manufacturing and construction. Such jobs tend to have higher wages and better benefits than average, providing new opportunities for American workers. Because some jobs will be lost in fossil fuel related industries, the report calls for a vigorous "just transition" program to provide new, high-quality jobs and/or dignified retirement for those affected through a "superfund for workers." The report also advocates deliberate policies to create new opportunities and job pipelines for those groups who have been most excluded from good jobs.

The national study covers the entire electric system, light vehicle transportation (cars and light trucks), space heating and water heating, and waste management. It assumes conversion of all gasoline-powered light vehicles and most space heating and water heating to 100 percent renewable electricity. This strategy achieves three-fourths of the total emissions reduction needed, nationally, to reach the 80 percent by 2050 target. "Maryland's Clean Energy Future" shows what this plan would mean for Maryland and what additional measures will make it possible for the state to reach its target for reduction in GHG emissions by 2050.

1. CUTTING MARYLAND'S CARBON EMISSIONS

In February 2016, the Maryland Senate passed one of the country's strongest state regulations for limiting carbon emissions. The bill reauthorizes and strengthens the 2009 Greenhouse Gas Reduction Act (GGRA), reaffirming the GGRA target of 25 percent reduction below 2006 emissions by 2020 – and adding a new target of 40 percent reduction below 2006 emissions by 2030.[4]

Is it possible to slash emissions at that pace and still create jobs? The GGRA also calls on the state to prepare a plan to meet further, long term reductions by 2050 while promoting in-state job growth.[5] This report addresses the longer-term goal, examining options for nearly eliminating greenhouse gases by 2050, while creating thousands of new jobs in the state. Our study of Maryland draws on our national Clean Energy Future, and should be read in conjunction with that report.[6]

The national Clean Energy Future describes a scenario in which:

- Energy efficiency programs are greatly expanded
- A renewable portfolio standard requires 70 percent renewable electricity nationwide by 2040
- Coal is phased out nationwide – half by 2030, entirely by 2050
- No new nuclear plants are built, while existing ones are phased out after 2030
- Electric vehicles replace all gasoline-powered cars and light trucks
- Electric heating replaces most fossil-fueled space and water heating

This Clean Energy Future scenario is compared to a business-as-usual Reference Case, which assumes the continuation of existing policies, but no new environmental regulations or greenhouse gas reduction initiatives. For instance, the Reference Case assumes compliance with all existing state renewable portfolio standards (RPS), such as the Maryland RPS which calls for 20 percent of electricity to come from renewable sources by 2022. The Clean Energy Future assumes compliance with a more demanding national RPS of 70

[4] Ovetta Wiggins, "Maryland sets bolder target for cutting greenhouse gas emissions", Washington Post, February 24, 2016.
[5] Maryland Senate Bill 278, Greenhouse Gas Emissions Reduction Act of 2009, paragraph 4. Available at: http://mgaleg.maryland.gov/2009rs/bills/sb/sb0278e.pdf
[6] As described in "The Clean Energy Future", a report from Labor Network for Sustainability, 350.org, and Synapse Energy Economics, available at http://www.labor4sustainability.org/wp-content/uploads/2015/10/cleanenergy_10212015_main.pdf.

percent renewable electricity by 2040.[7]

In this report we explore the implications of the Clean Energy Future for Maryland, and then discuss available options for even greater reduction in state emissions.

Maryland's role in the national Clean Energy Future goes a long way toward reducing state emissions by 2050. Table 1-1 shows the reduction achieved by the Clean Energy Future in electricity generation, heating, automobile use and waste management, assuming that emissions in other sectors remain unchanged at their 2011 levels (with the sole exception that all iron and steel industry emissions are excluded, to represent industrial emissions after the closing of Sparrows Point). Gross emissions drop from 107.2 million tons of CO_2-equivalent (CO_2-eq) to 26.6 million, a 75 percent decline. Emissions net of carbon sinks (that is, emissions net of carbon sequestration in forests and soils) drop from 95.4 million to 14.8 million tons, a decline of 85 percent.

CO_2-eq (Million Metric Tons)

	2006 Emissions	Clean Energy Future, 2050 or 2011 Actual	Percent Reduction from 2006 Emissions
Power	42.5	2.3	95%
Cars & Light Trucks	23.8	0.5	98%
Residential Heating	5.4	0.6	88%
Commercial Heating	3.6	0.2	94%
Coal Mining	0.1	0.0	100%
Waste Management	2.3	0.0	100%
Total CEF Sectors	**77.6**	**3.6**	**95%**
Transportation (Except Cars)	11.7	10.5	10%
Industrial (Non-Electric)	13.8	8.6	38%
Agriculture	1.8	1.7	6%
Residential/Commercial Other	1.5	1.6	-2%
Natural Gas Extraction	0.8	0.7	14%
Total Other Sectors	**29.6**	**23.0**	**22%**
Global Emissions	**107.2**	**26.6**	**75%**
Emission Sinks	-11.8	-11.8	0%
Net Emissions	**95.4**	**14.8**	**85%**

Table 1-1. Maryland GHG emissions: 2006 and projected 2050

Source: Data for 2006 and 2011 are from the Maryland Greenhouse Gas Inventory. One correction to the non-car transportation calculation for 2011, incorporated here, is explained in section 3.5 below (see footnote 33). Industrial emissions of 8.6 MMTCO_2-eq represent 2011 emissions from all Maryland industries except iron and steel (i.e., removing emissions from Sparrows Point, which closed in 2012). Emissions in 2050 for the power sector are based on state-specific results from the national Clean Energy Futures study, including emissions attributable to net electricity purchases from other states (assumed to have the same carbon intensity as in-state generation in 2050). Projected emissions from cars and light trucks, residential heating and commercial heating are Maryland's share of national emissions as calculated in the Clean Energy Futures study.

[7] The effective difference between the two standards is even greater because the Maryland RPS counts black liquor, a paper industry byproduct, as a renewable energy source, while the Clean Energy Future's national RPS does not. See the discussion of black liquor in Section 3.4, below.

The other big reduction shown in Table 1-1, the drop of 5.2 million tons in industrial emissions, could be entirely due to the closing of the massive Sparrows Point steel mill; emissions from other Maryland industries may have increased from 2006 to 2011.[8] Almost three-fourths of the emissions in the second column of the table, i.e. emissions remaining after adoption of the Clean Energy Future scenario, are in non-car transportation (largely trucking) and industry.

The GGRA set a goal of achieving a 90 percent reduction in emissions by 2050, relative to a 2006 baseline. It called for preparation of a plan to achieve that goal, although there is not yet an official plan. Our Clean Energy Future achieves most but not all of the long-term reduction goal. For a 90 percent reduction in gross emissions by 2050, the state would need to cut another 15.9 million tons beyond the measures included in Table 1-1.[9]

We begin with a description of the implications of the Clean Energy Future for Maryland's energy system and employment, and then turn to the options for achieving further emission reductions.

[8] This surprising conclusion is based on a comparison of the supporting details in the state's 2006 and 2011 greenhouse gas inventories. The 2006 inventory includes 3.6 million tons of CO_2-eq process (non-fuel) emissions from the iron and steel industry, but does not report fuel use in the steel industry. The 2011 inventory, covering a year when Maryland steel production was much lower than in 2006, reports 0.9 million tons of process emissions and 1.2 million tons of emissions from fuel use at Severstal (Sparrows Point). If fuel use in the steel industry in 2006 generated at least 1.6 million tons of emissions, which seems likely, then the demise of the state's steel industry accounted for the entire decline in industrial emissions shown in Table 1-1, and perhaps even more (implying a net increase in other industries).
[9] Discussion of Maryland GHG reduction targets usually is based on gross emissions. For emissions net of carbon sinks, the standard often used by EPA in discussion national targets, a 90 percent reduction requires only another 5.3 million tons of cuts beyond the Clean Energy Future.

2. A CLEAN FUTURE FOR ENERGY AND EMPLOYMENT

a. Energy technologies

The Clean Energy Future will transform Maryland's energy system by mid-century, building nearly 34,000 MW of solar power. This will come from large-scale utility solar facilities, individual rooftops, and other small residential and commercial installations. The state will also have over 1,300 MW of wind turbines, mostly on-shore. New storage technologies, such as high-tech batteries, will be increasingly important to make renewable energy available around the clock.

Renewable sources of electricity will supply the massive new demand from electric cars and electric heating, along with existing uses of electricity. At present Maryland has roughly 3.5 million gasoline-powered cars and light trucks[10] – all of which will be replaced, in the Clean Energy Future, by electric vehicles by 2050. Meanwhile, an active energy efficiency program will reduce the demand for electricity by 2 percent every year.

The national study contrasts that scenario to a Reference Case, assuming the continuation of existing trends and policies, but no new initiatives to promote renewable energy or reduce emissions. Figure 2-1 compares Maryland's solar power capacity under the two scenarios. By 2050, the state has 33,610 MW of solar capacity in the Clean Energy Future, versus 6,121 MW in the Reference Case. Both include growth far beyond today's levels, but by 2050, the Clean Energy Future calls for installing more than five times as much solar capacity. Even this ambitious solar agenda uses less than one-tenth of the state's technical potential for solar power, according to the National Renewable Energy Laboratory (NREL).[11]

[10] Calculated from Federal Highway Administration data for 2011.
[11] According to NREL, Maryland has the technical potential for 404 GW (404,000 MW) of photovoltaic capacity. See Anthony Lopez et al. (2012), "U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis", http://www.nrel.gov/docs/fy12osti/51946.pdf.

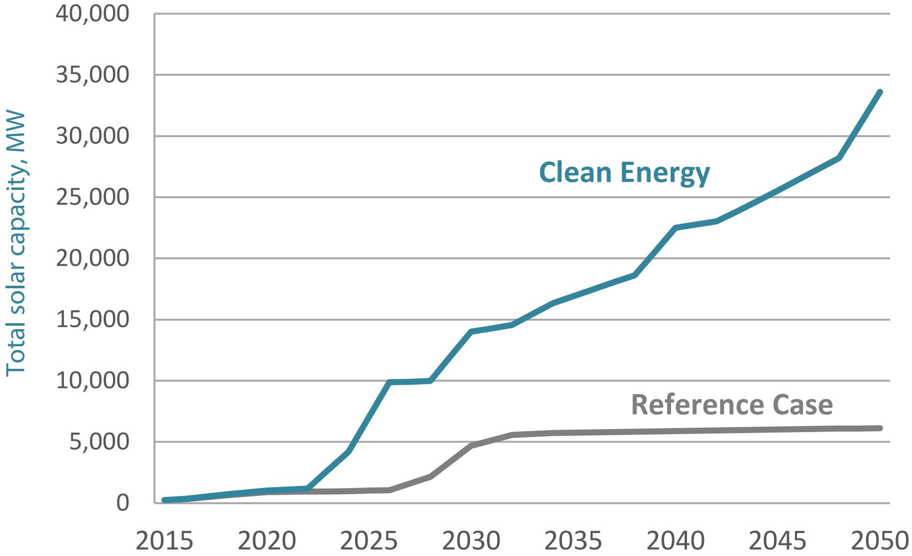


Figure 2-1. Solar power capacity in Maryland under two scenarios.

A similar comparison for wind power appears in Figure 2-2. By 2050 Maryland has 1,345 MW of wind power in the Clean Energy Future, almost all on-shore, versus 771 MW in the Reference Case.[12] Although wind is an important component of the Clean Energy Future in Maryland and the nation, it plays a larger role in other, windier states.

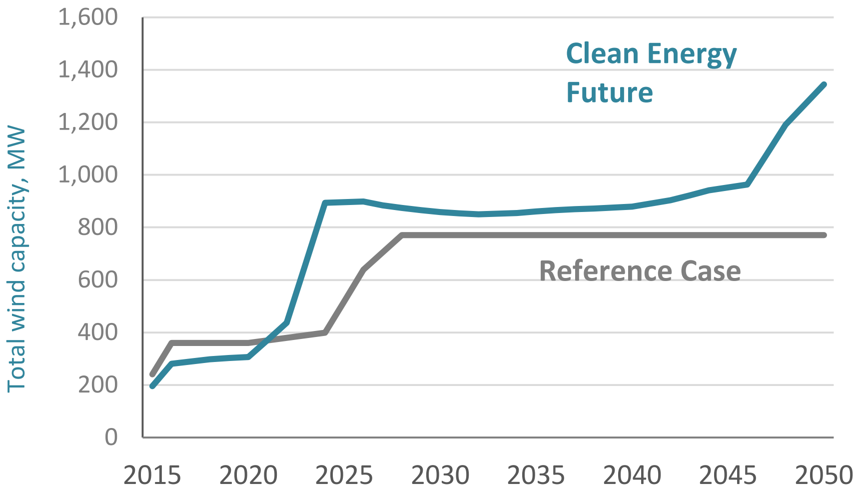


Figure 2-2. Wind power capacity in Maryland under two scenarios.

Fossil generation changes significantly between the two scenarios. Beginning in the 2030s, natural gas

[12] The Clean Energy Future uses the state's full capacity for on-shore wind, as identified by NREL; there is another 52 GW of offshore wind capacity available, although at a higher cost.

capacity in Maryland is modestly higher in the Clean Energy Future than in the Reference Case.[13] However, it is consistently lower than the state's natural gas capacity in 2015, as shown in Figure 2-3. In contrast, all of the state's existing coal capacity is retired by 2036 in the Clean Energy Future, as shown in Figure 2-4, while most of it remains on-line through 2050 in the Reference Case.

Both scenarios assume that nuclear plants will shut down 60 years after they began commercial operation, which implies retirement of both units of Calvert Cliffs by 2037.

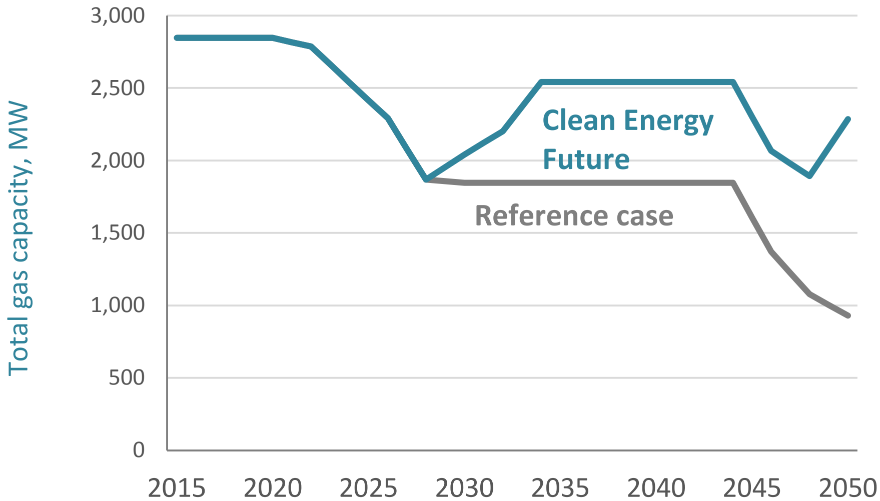


Figure 2-3. Natural gas-fired generating capacity in Maryland under two scenarios.

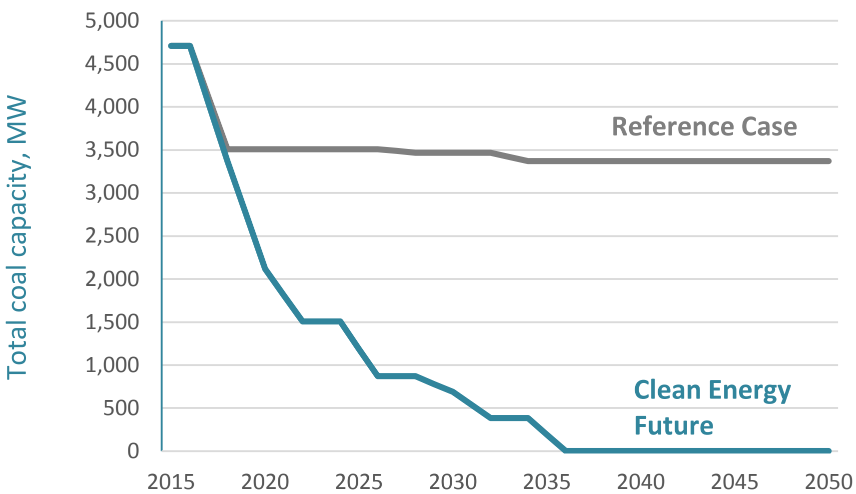


Figure 2-4. Coal-fired generating capacity in Maryland under two scenarios.

[13] If Maryland was an isolated or self-contained electric system, it would need more natural gas or other dispatchable capacity to generate electricity when the sun is not shining and the wind is not blowing (at least until the development of low-cost, large-scale electricity storage technologies). However, Maryland is part of the PJM interconnection, a regional transmission organization that links all or parts of 13 states and the District of Columbia. Intermittent renewables (wind and solar power) and conventional power sources need to be balanced for PJM as a whole, not for individual states. In our model, Maryland has a larger share of the region's solar power than of its natural gas capacity.

The huge expansion of solar power is needed both to replace coal and to serve the new electric vehicle and heating loads in Maryland and the region. The Clean Energy Future involves investment in energy efficiency, reducing the demand for electricity, but this is more than balanced by the expansion of electric vehicle and heating markets – accomplishing a massive substitution of renewable electricity for gasoline, fuel oil and natural gas.

A similar pace of renewable capacity expansion will be required throughout the country to create the Clean Energy Future. Indeed, the ambitious expansion plans projected for Maryland, as described here, include less than 0.2 percent of the wind capacity and 3.3 percent of the solar capacity needed nationwide in 2050.

Maryland is currently a large net importer of electricity, getting more than one-third of its electricity from other states. Emissions from electricity imports are included in the Maryland greenhouse gas inventory. The Clean Energy Future reduces but does not eliminate the dependence on imports; in that scenario Maryland is 85 percent self-sufficient in electricity by 2050.[14]

b. Employment in the Clean Energy Future

The Clean Energy Future creates an annual average of 10,000 more jobs in Maryland, compared to the Reference Case. This is a net gain of about 0.3 percent of total employment in the state in 2013, as shown in Table 2-1. Almost two-thirds of the new jobs are in construction and manufacturing, the industries with the greatest percentage increases in employment. The only economic sectors projected to have net job losses under the Clean Energy Future are utilities, and mining and extraction (including gas drilling).

How many jobs could be created in Maryland?

The calculation of Maryland employment in the Clean Energy Future was derived from the national study.[15] A key assumption in this calculation is that the distribution of industries among states is unchanged through 2050: Maryland remains a leader in sectors where it is already ahead, and never catches up in sectors where it is currently behind. With a state strategy to encourage and expand the growing industries of the future, Maryland's employment gains could be considerably greater.

Our national study used NREL's ReEDS model to project expansion plans for the electric system, and then applied the IMPLAN model to calculate the resulting employment impacts. IMPLAN reports three categories of employment: direct jobs (such as construction workers who install wind turbines); indirect jobs created at suppliers (such as steel mill workers who make steel for the turbine blades); and induced jobs (created when the construction workers and steel mill workers spend their paychecks, stimulating other industries).

For direct jobs, we used the actual location of existing and projected new energy facilities, as reported by the ReEDS model. Direct jobs are created in Maryland to construct and operate energy facilities located in the state, as estimated by ReEDS. For indirect and induced jobs, we assumed that jobs in each industry would be distributed in proportion to current employment. For example, Maryland currently has about 2 percent of national employment in computer and electronic products manufacturing. So 2 percent of all new indirect and induced jobs in computer and electronic products are assumed to be located in Maryland – regardless of where the demand for these products originates.

[14] The remaining electricity imports are assumed to have the same average carbon intensity as in-state generation. Emissions from those imports are included in the Clean Energy Future electric power emissions shown in Table 1-1.
[15] See http://synapse-energy.com/sites/default/files/Clean-Energy-Future-15-054.pdf for the national study and http://synapse-energy.com/CEF_Appendix for the technical appendix.

Changes to this assumption, based on state industrial development strategies, could increase the number of Maryland jobs created by clean energy.

	2013 Employment	New Jobs in Clean Energy Future	
		Annual Average	As Percentage of 2013
Total, All Industries	3,527,847	10,028	0.3%
Above Average Growth			
Construction	222,915	5,312	2.4%
Manufacturing	114,400	954	0.8%
Wholesale Trade	94,489	585	0.6%
Management of Companies & Enterprises	27,859	156	0.6%
Below Average Growth			
Other Services (except Public Administration)	213,882	582	0.27%
Finance & Insurance	163,653	411	0.25%
Agriculture, Forestry, Fishing & Hunting	23,755	53	0.2%
Information	52,670	111	0.2%
Health Care & Social Assistance	422,882	819	0.2%
Arts, Entertainment & Recreation	87,223	136	0.2%
Real Estate, Rental & Leasing	167,428	239	0.1%
Educational Services	98,461	134	0.1%
Retail Trade	345,446	376	0.1%
Accommodation & Food Services	233,615	170	0.1%
Administrative, Support & Waste Management	277,945	135	0.1%
Transportation & Warehousing	102,027	55	0.1%
Professional, Scientific, & Technical Services	346,463	160	0.05%
Public Administration	566,715	76	0.01%
Job Losses			
Utilities	10,794	(88)	-0.8%
Mining & Extraction	5,225	(347)	-6.6%

Table 2-1. New jobs in Maryland in the Clean Energy Future - all sectors
Source: Bureau of Economic Analysis, and authors' calculations. New job figures represent annual averages (over 2016-2050) of net job increases or decreases under the Clean Energy Future, compared to the reference case (business as usual) projection.

Half of the state's new jobs are in construction, both for installation of energy efficiency measures and for construction of new renewable energy facilities. Occupations with the largest increases in employment will include electricians, plumbers, heating and air conditioning technicians, power-line installers and repairers, and construction laborers.

More detail on manufacturing employment is shown in Table 2-2. A majority of the new manufacturing jobs are in three sectors: fabricated metal products, machinery, and electrical equipment and appliances. Among the branches of manufacturing shown in the table, none are projected to have losses. Electrical equipment and appliances, the fastest-growing manufacturing sector, benefits from increased demand for new energy-efficient lighting and appliances, as well as new equipment needed by electric utilities as they adapt to renewable energy.

	2013 Employment	New Jobs in Clean Energy Future	
		Annual Average	As Percentage of 2013
Manufacturing, Total	114,000	954	0.8%
Above Average Growth			
Electrical Equipment & Appliances	2,063	154	7.5%
Primary Metals	831	22	2.7%
Machinery	6,842	168	2.5%
Fabricated Metal Products	8,620	211	2.4%
Plastics & Rubber Products	6,264	94	1.5%
Nonmetallic Mineral Products	4,397	62	1.4%
Transportation Equipment	5,281	47	0.9%
Paper	2,815	20	0.7%
Computer & Electronics	18,161	77	0.4%
Textiles, Apparel & Leather	4,191	15	0.4%
Chemicals	12,705	42	0.3%
Below Average Growth			
Printing	8,700	23	0.26%
Furniture & Wood Products	6,922	11	0.16%
Food Products & Misc. Manufacturing	26,608	9	0.03%

Table 2-2. New jobs in Maryland in the Clean Energy Future – manufacturing
Note: "Above average" and "below average" categories are based on the average for all sectors, from Table 2-1.

The Clean Energy Future will help create good jobs in Maryland, but it is not enough, in the state or the country as a whole, to transform the economy and end unemployment. It is a positive contribution, which could be one of several parts of a broader jobs strategy for the twenty-first century.

c. Comparison to other job creation estimates

Ours are not the only estimates of Maryland jobs that could be created by climate strategies. The Regional Economic Studies Institute (RESI) at Towson University has projected the employment that will be created by compliance with the near-term goals of the Greenhouse Gas Emission Reduction Act.[16] RESI's conclusion

[16] Maryland Department of the Environment (2015), "2015 Greenhouse Gas Emissions Reduction Act Plan Update", Chapter 6 and Appendices C and K-1.

is that basic measures sufficient to comply with the state's emission reduction goals would create 26,000 new jobs in 2020, while a set of enhanced measures that go even farther would create 33,000 jobs. These are large numbers, on a short timeline: the enhanced measures would, according to RESI, increase total employment in Maryland by about one percent, within the next four years.

The RESI study is based on a series of judgments about specific policies. It calculates job impacts from federal as well as state policies, including the effects of rules such as federal auto fuel economy standards and the Maryland RPS. In contrast, we calculate the difference between our "business as usual" Reference Case and our Clean Energy Future scenario. Existing auto fuel economy standards and state RPS policies, for example, are included in both of our scenarios, and therefore do not affect the difference between scenarios that is reported in our analysis. That is, we calculate the jobs created by going beyond current policies to a much more ambitious program of emission reduction; RESI calculates jobs created both by current policies and by new initiatives.

Like RESI, a number of other analysts have, at times, projected that job creation from a climate agenda could be larger than our estimates. Frequently this is based on assuming much greater spending, accelerating the transition to clean energy. We, too, would like to go faster, but that is not the focus of our analysis. Our plan is designed to show how much can be done *with no increase in costs*. If it is politically feasible to spend more, it is surely desirable to do so. Our Clean Energy Future represents a floor, not a ceiling, on ambition, a demonstration of how much can be achieved for what we are already spending. There are good arguments for doing more, but there is no reason at all for doing less. (Moreover, climate protection is not the only pressing social need that requires labor, effort and creativity. Jobs can and should be created in multiple arenas in the construction of a humane, just and sustainable society.)

3. BEYOND THE CLEAN ENERGY FUTURE

As noted above, the Clean Energy Future scenario reduces most but not all categories of greenhouse gas emissions. To achieve the state's target for 2050, Maryland might need as much as 15.9 million tons of additional emission reductions, primarily in industrial emissions and trucking. Here we discuss the nature of Maryland's industrial emissions, and then focus on four promising areas for additional reductions: ozone-depleting substances; the cement industry; the paper industry; and trucking.

a. Maryland's top emitters

The Environmental Protection Agency collects and reports facility-level data from major sources of greenhouse gases throughout the country.[17] In 2014, the 25 facilities in Maryland with emissions of more than 100,000 tons of CO_2-eq accounted for more than 24 million tons of emissions, as seen in Table 3-1. This is roughly a quarter of the state's total emissions. Most of these emissions came from coal-burning power plants (the top seven energy facilities in the table), but other categories are significant as well: after the coal plants, the next biggest emitters are the leading industrial facilities. The state's two cement mills and one paper mill had combined emissions of 3 million tons. As noted earlier, the Clean Energy Future will phase out emissions from coal plants and waste management facilities, but additional plans are needed to reduce industrial emissions.

Facility	City	CO_2eq (Metric Tons)	
Energy			19,444,000
Morgantown	Newburg	5,731,000	
Brandon Shores	Baltimore	5,104,000	
Chalk Point	Aquasco	3,048,000	
Warrior Run	Cumberland	1,367,000	
Wagner	Baltimore	1,346,000	
Dickerson	Dickerson	1,242,000	
Crane	Baltimore	600,000	
Brandywine	Brandywine	416,000	
Baltimore Gas & Electric Company	Baltimore	241,000	
Cove Point LNG Facility	Lusby	177,000	
Rock Springs	Rising Sun	172,000	
Industrial			3,263,000
Lehigh Cement	Union Bridge	1,695,000	
Luke Paper	Luke	802,000	
Holcim (Cement)	Hagerstown	527,000	
W.R. Grace	Baltimore	137,000	
American Sugar Refining	Baltimore	102,000	
Institutional			543,000
National Institutes of Health	Bethesda	190,000	
University of Maryland	College Park	131,000	
U.S. Navy Support Facility	Indian Head	112,000	
Johns Hopkins Hospital	Baltimore	102,000	
Waste Management			890,000
Wheelabrator	Baltimore	294,000	
Montgomery County Resource Recovery	Dickerson	227,000	
Central Sanitary Landfill	Newark	139,000	
Brown Station Road Sanitary Landfill	Upper Malboro	121,000	
Eastern Sanitary Landfill	White Marsh	109,000	
All Large Facilities, Total			**24,140,000**

[17] See the EPA FLIGHT (Facility Level Information on Greenhouse gases Tool) data, http://ghgdata.epa.gov/ghgp/main.do.

Table 3-1. Top greenhouse gas emitters in Maryland, 2014. All emissions have been rounded to the nearest 1,000 tons.
Source: EPA FLIGHT data, http://ghgdata.epa.gov/ghgp/main.do.

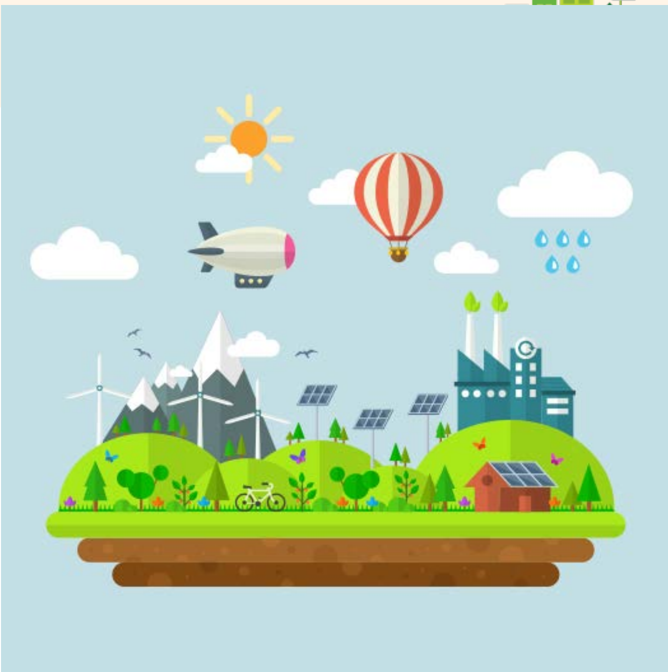
Another perspective on industrial emissions is provided by the Maryland greenhouse gas inventory. For 2011, the inventory showed the following major categories of industrial emissions:

	CO_2-eq (Million Metric Tons)		
Industry	Process (Non-Fuel) Emissions	Fuel Use Emissions	Total
Ozone-Depleting Substances	2.3	0	2.3
Cement	0.9	0.7	1.6
Paper	0	0.9	0.9
Other	0.3	3.5	3.8
Total	**3.5**	**5.1**	**8.6**

Table 3-2. Maryland industrial emissions, 2011
Source: Maryland Greenhouse Gas Inventory, 2011. Iron and steel industry emissions omitted. Fuel use emissions are from direct on-site use of fuel; emissions from generation of electricity used in industry are not included.

More than half of the industrial emissions in Table 3-2 come from just three sectors: ozone-depleting substances, the cement industry, and the paper industry.

b. Ozone-depleting substances



One high-priority opportunity for reducing greenhouse gases results from the unintended consequences of solving a different environmental problem. The threat of depletion of the ozone layer, recognized in the 1980s and addressed by the Montreal Protocol, led to the replacement of ozone-depleting substances, particularly in refrigeration and air conditioning. The first round of replacements, beginning in the 1990s, involved chemicals such as hydrofluorocarbons (HFCs), which are potent greenhouse gases (they have very high global warming potential, or "high GWP"). As a result, there is a substantial climate benefit to capturing these gases when refrigeration and air conditioning units are repaired, refilled, or discarded.

Newer chemicals are being developed that can avoid damaging either the ozone layer or the climate.[18] It is important to recover and control high-GWP substances, such as refrigerants, when equipment containing these substances is overhauled, scrapped or recycled. With careful efforts in this area, it seems reasonable to anticipate that high-GWP emissions could be eliminated before 2050.

c. Cement

Cement production is one of the most carbon-intensive branches of manufacturing. In the most common process, limestone is heated to very high temperatures, converting it to lime. Cement is largely a mixture of powdered lime, silica and gypsum, often with small amounts of additives to modify and improve its properties as a building material.

There are two major sources of greenhouse gas emissions in the cement industry. Large amounts of energy are needed for heating limestone; much or all of this energy typically comes from fossil fuels, particularly coal. And the conversion of limestone (calcium carbonate) to lime (calcium oxide), a chemical process known as calcination, releases carbon dioxide that was formerly part of the limestone.

According to the 2011 Maryland greenhouse gas inventory,

[18] Suely Carvalho, Stephen O. Andersen, Duncan Brack, and Nancy J. Sherman (2015), "Alternatives to High-GWP Hydrofluorocarbons", Institute for Governance and Sustainable Development, http://igsd.org/documents/HFCSharpeningReport.pdf.

emissions at the Lehigh (Union Bridge) and Holcim (Hagerstown) cement mills were slightly more than half from calcination, with most of the rest from coal combustion and very small contributions from other fuels. Lehigh used 248,000 metric tons of coal in 2011, and Holcim used 82,000 tons.[19]

Both companies have invested in modernization and environmental improvement. Lehigh's new state-of-the-art equipment and improvements in energy management helped win EPA's ENERGY STAR certification in 2013, recognizing the plant as a top performer in the industry. EPA reports that Lehigh has now replaced 63,000 tons of fossil fuel use with sewage sludge (biosolids), a renewable biomass fuel.[20] However, this is only one-fourth of the plant's consumption of coal in 2011, leaving ample room for additional improvement.

Holcim, until recently, spent little on modernizing its aging facility. That changed in 2013, with the company's settlement with EPA under the Clean Air Act.[21] In 2003-2007 Holcim had modified the plant to burn used tires as a fuel, significantly increasing sulfur emissions without obtaining the required permits. As part of the settlement Holcim agreed to spend $20 million on new pollution controls. This became part of a larger package of investments, creating 200 to 300 construction jobs during the two years of construction.[22] The pollution controls covered in the settlement with EPA will reduce nitrogen and sulfur emissions and increase energy efficiency, but do not directly address greenhouse gases.

A wide range of measures and innovations can reduce greenhouse gas emissions in the cement industry.[23] There are opportunities for energy-saving changes throughout the production process. Substitution of low-carbon or no-carbon fuels for coal remains an important goal. And the industry is beginning to explore the production of "alternative cementitious materials" that have the desirable properties of cement, while reducing or eliminating the use of limestone and the associated emissions.[24] It may even be possible to incorporate carbon dioxide emissions from power plants into the cement-making process, resulting in permanent storage of carbon dioxide in the final product.[25]

There is no simple recipe for applying these measures. Extensive work in collaboration with the cement companies will be required to develop appropriate plans for emission reduction. However, given the size and the carbon footprint of Maryland's cement plants, it will be essential to include them in a plan for long-run reduction in the state's greenhouse gas emissions. Although it is difficult to predict the exact employment impacts of such plans, measures that reduce cement plant emissions generally seem to require more, not less, labor to install and operate new equipment.

[19] Holcim coal consumption, reported in the inventory in short tons, was converted to metric tons. All coal data are rounded to the nearest 1,000 tons.
[20] EPA (2015), "ENERGY STAR Plant Profile: Union Bridge Plant", http://www.energystar.gov/index.cfm?fuseaction=labeled_buildings.showplantProfile&plantprofile_id=p_10060.
[21] EPA (2013), "Holcim (US) Inc. Settlement", http://www.epa.gov/enforcement/holcim-us-inc-settlement.
[22] C.J. Lovelace (2014), "Holcim breaks ground on $95 million project in Hagerstown", http://www.heraldmailmedia.com/news/local/holcim-breaks-ground-on-million-project-in-hagerstown/article_6f176d0d-5759-5420-9bcf-9be3b39a4aef.html.
[23] Ernst Worrell and Christina Galitsky (2008), "Energy efficiency improvement and cost saving opportunities for cement making", Lawrence Berkeley National Laboratory, http://www.energystar.gov/ia/business/industry/LBNL-54036.pdf.
[24] James K. Hicks, Michael A. Caldarone and Eric Bescher (2015), "Opportunities from alternative cementitious materials", *Concrete International*, http://www.concretesdc.org/CI3704Hicks.pdf.
[25] David Biello (2008), "Cement from CO2: A Concrete Cure for Global Warming?", *Scientific American*, August, http://www.scientificamerican.com/article/cement-from-carbon-dioxide/.

d. Paper

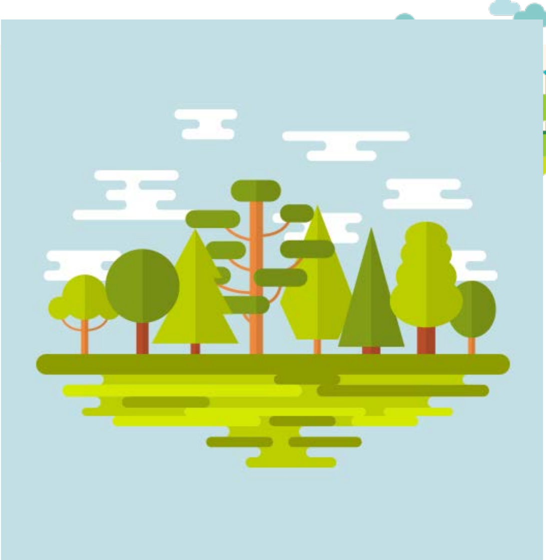
Integrated pulp and paper mills, such as Luke Paper in western Maryland, use vast quantities of steam for heating, drying, bleaching and other stages of production, along with electricity for pumps, fans, and other motor-driven processes.[26] In chemical pulping, the process used by Luke Paper and most of the industry, wood chips are heated for several hours in a chemical bath or "liquor" to dissolve wood fibers. The residue after the fibers are separated, "black liquor", is an energy-rich liquid filled with wood wastes, and is almost universally burned on site to reduce the need for purchased energy. The paper industry as a whole gets 58 percent of its energy from waste fuels, primarily black liquor, and has installed nearly 3,900 MW of black liquor-fired combined heat and power capacity.[27]

Like others in the industry, Luke Paper gets a significant amount of energy from its own wastes, reporting that 40 percent of its energy needs are met by burning black liquor.[28] Nonetheless, its purchased energy requirements remain substantial: in 2011 it consumed 386,000 tons of coal, accounting for virtually all of its greenhouse gas emissions that year.[29]

On the one hand, the Luke mill emissions could be reduced, with no other process changes, by substituting other fuels for coal. Replacing coal with natural gas, if available, could reduce the mill's emissions of carbon dioxide and other harmful air pollutants. In the long run, it might even be possible to develop a renewable, biomass-based process to generate hydrogen as an industrial fuel, with almost no carbon emissions.

On the other hand, there are many opportunities for energy efficiency upgrades and process improvements that can reduce emissions at pulp and paper mills. Improvements are possible in the preparation of wood chips, the chemical recovery process for black liquor, paper stock and sheet formation, and other processes. More than 45 commercially available state-of-the-art technologies have been identified to reduce energy use and carbon dioxide emissions at pulp and paper mills, along with advanced technology options including black liquor gasification and alternative drying mechanisms.[30] Detailed examination of existing operations at the Luke mill would be needed to determine the appropriate strategy for emission reduction.

[26] Klaus Jan Kramer, Eric Masanet, Tengfang Xu and Ernst Worrell (2009), "Energy efficiency improvement and cost saving opportunities for the pulp and paper industry", Lawrence Berkeley National Laboratory, http://www.energystar.gov/ia/business/industry/downloads/Pulp_and_Paper_Energy_Guide.pdf.
[27] US Energy Information Administration (2013), "Waste fuels are a significant energy source for U.S. manufacturers", http://www.eia.gov/todayinenergy/detail.cfm?id=13531#. See also American Forest & Paper Association (2014), "2014 AF&PA Sustainability Report", p.22, for generally similar data: http://afandpa.org/docs/default-source/sust-toolkit/2014_sustainabilityreport_final.pdf?sfvrsn=2.
[28] New Page (2013), Luke Mill Fact Sheet, Available at: https://www.versoco.com//wps/wcm/connect/61bcfb004bd7bc23aca1eec28b3513b1/Luke+Mill+Fact+Sheet_June+2013.pdf?MOD=AJPERES
[29] Maryland GHG inventory for 2011, assuming that Luke Paper's reported 425,900 tons of coal are short tons.
[30] Martin, N., Anglani, N., Einstein, D., Khrushch, M., Worrell, E., and L.K. Price (2000), "Opportunities to Improve Energy Efficiency and Reduce Greenhouse Gas Emissions in the U.S. Pulp and Paper Industry," Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory. Available at: https://www.energystar.gov/ia/business/industry/LBNL-46141.pdf.



Maryland state policy currently includes a blunt and misdirected measure to promote emission reduction in the paper industry. The state's renewable portfolio standard (RPS) counts black liquor as renewable energy, eligible for the most valuable (tier one) renewable energy credits (RECs). Luke and at least one out-of-state paper mill have been able to earn RECs for their black liquor use, and can sell the RECs to other firms that need them for compliance with the RPS. As the *Washington Post* has reported, RECs for black liquor are a large part of the Maryland program: "… in 2010, paper mills burning black liquor provided 42.8 percent of credits used to meet the tier one [RPS] requirements… and 58 percent of the new credits purchased to meet future standards came from those paper mills."[31]

Black liquor is a renewable, biomass-based fuel – but it is one that paper mills routinely burn for energy, with or without RECs. Burning black liquor saves money by reducing requirements for purchased energy; doing anything else would involve a costly disposal process. Use of black liquor as a fuel clearly improves the corporate bottom line. But providing RECs for something that would be happening anyway, with or without state support, does not increase the use of renewable energy in Maryland or the region.

There are other reasons for concern about the health of major industries such as Luke Paper, which employs 800 workers and is a mainstay of the local economy. According to both the company and the United Steel Workers, which represents Luke Paper employees, the mill would close if it lost the level of state support provided by the current RECs arrangement. This issue deserves careful attention, although it is beyond the scope of this report.

But even if the state is going to support an industry such as Luke Paper, distortion of a renewable energy program does not seem like a desirable channel for that support. There is no benefit to Maryland workers and taxpayers in providing RECs for black liquor use in other states, as the current program has done. And there is no benefit to the environment in providing RECs to existing activities and processes that would have occurred without new incentives, in the paper industry or elsewhere. Doing so could create the false impression that Maryland has stimulated new renewable energy production, equal to the full amount of available RECs. A better solution might be to offer RECs only for new solar, wind, geothermal and small hydro resources – perhaps combined with grandfathering of the existing level of benefits to a few in-state sources such as Luke Paper.[32]

e. Fuel efficiency in trucking

Transportation accounts for about one-third of Maryland greenhouse gas emissions at present. Although the Clean Energy Future scenario eliminates virtually all emissions from cars and light trucks, the remaining transportation emissions amount to more than 10 million tons of CO_2-eq. A further breakdown of these

[31] Mufson, S. (2013), "Md. D.C. utilities pay paper mills burning 'black liquor' for alternative fuel credits." *Washington Post* February 22, 2013, Available at: https://www.washingtonpost.com/business/economy/md-dc-utilities-pay-paper-mills-burning-black-liquor-for-alternative-fuel-credits/2013/02/22/440078da-696b-11e2-95b3-272d604a10a3_story.html
[32] This strategy has been proposed by Arjun Makhijani of the Institute for Energy and Environmental Research.

emissions is shown in Table 3-3. On-road diesel emissions, largely from trucks, represent more than half of non-car transportation.

	Million Metric Tons of CO_2-eq
Transportation, Total	**33.0**
On-Road Gasoline (Cars & Light Trucks)	22.5
All Other	**10.5**
On-Road Diesel (Trucks & Buses)	5.7
Off-Road Diesel (mainly Construction)	2.2
Off-Road Gasoline	0.5
Aviation	1.1
Rail, Marine, & Other	1.0

Table 3-3. Transportation emissions in the 2011 Maryland GHG inventory[33]

The heaviest trucks on the road, Class 8 tractor-trailers, account for most trucking emissions. Federal fuel efficiency standards for trucks have just begun to take effect; Phase 1 standards require 6 percent improvement in fuel efficiency by the 2017 model year.[34] Phase 2 standards, which have been proposed but not adopted, will require an additional 18 to 24 percent improvement beyond 2017 levels by 2027.[35] A number of innovative companies, spurred by the Department of Energy's "Supertruck" program, have already demonstrated that much more can be done, even with existing technology. Tractor-trailers on the road average about 6 mpg today, and business-as-usual projections from the Energy Information Administration reach only about 8 mpg in 2050. In contrast, new, ultra-aerodynamic truck prototypes have already achieved 10 – 13 mpg under actual highway conditions.

Other categories of trucking, notably deliveries in urban areas, could be converted to electric power, as could urban buses. Major cities and institutions are already testing electric buses; after successfully testing two electric buses for more than a year, the Chicago Transit Authority is now adding dozens of electric buses to its fleet.[36]

[33] An incorrect formula in the published inventory spreadsheet, Transportation sheet, cell E66, leads to a significant overestimate of emissions from off-road gasoline use. Data reported here and used elsewhere in this report are based on correcting the formula to parallel those in cells E67-E69.
[34] EPA and NHTSA (2011), "Final Rulemaking to Establish Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles", p.5-7. (A wide range of standards are developed for different classes of trucks; this is the CO_2 emission reduction required from Class 8 truck engines under Phase 1.)
[35] EPA and NHTSA (2015), "Proposed Rulemaking for Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engings and Vehicles-Phase 2", page ES-13.
[36] Stephen Edelstein (2016), "Chicago Transit Authority to Add Dozens of Electric Buses after Successful Tests", *Green Car Reports*, January 31, http://www.greencarreports.com/news/1102130_chicago-transit-authority-to-add-dozens-of-electric-buses-after-successful-tests.

If the average tractor-trailer on the road reaches the fuel efficiency of today's Supertruck prototypes by 2050, and comparable improvements are made in other classes of trucks and buses, then current on-road diesel emissions could be cut in half. For Maryland, this could represent a savings of as much as 2.8 million tons of CO_2-eq. Even more could conceivably be done to improve fuel economy and lower truck emissions, with another 35 years of technological development.

It is not possible for Maryland to set its own fuel economy or truck emission standards. However, there are steps that can be taken at the state level to reduce truck emissions. Heavy trucks often spend several hours per day idling at truck stops, in order to keep air conditioning and other services running. Regulations to limit idling time, particularly if combined with facilities to provide electricity to parked trucks, could achieve reductions in emissions and improvement in air quality. Retrofitting the oldest on-road and off-road diesel engines, including construction equipment as well as trucks and buses, and replacing older lawn equipment, can also reduce carbon emissions and other air pollutants.

4. CLIMATE CHANGE ADAPTATION

Maryland is actively evaluating how to both mitigate and adapt to the impacts of climate change. Our Clean Energy Future focuses on the mitigation side: lower carbon emissions from Maryland and the rest of the US will reduce the impacts from those emissions on Maryland as well as globally. However, Maryland will still need to adapt. The Chesapeake Bay region is one of the most vulnerable areas to rising sea levels in the US. At the same time, increasing temperatures will affect the state's health, productivity and energy needs. New investments will be needed, and jobs will be created, in the process of adaptation to the impacts of climate change in Maryland.

The Maryland Climate Change Commission (MCCC) claims that "it is prudent to plan for a relative sea-level rise of 2.1 feet by 2050" above the level in 2000.[37] Maryland is particularly sensitive to sea level rise since its land is simultaneously sinking.[38] The state also has a significant amount of low-lying development on the Chesapeake Bay and Atlantic coasts that are already vulnerable to erosion and flooding. Rising sea levels will exacerbate both of these actions. The American Climate Prospectus, an in-depth assessment of climate risks facing the United States, estimates that "$9 billion of Maryland's coastal property is likely to be below sea level in the coming decades..."[39] The MCCC has identified several strategies for dealing with this issue, including:

- More coordinated state planning and information-gathering on sea-level rise.

[37] Maryland Commission on Climate Change (MCCC), Scientific and Technical Working Group, *Updating Maryland's Sea-level Rise Projections*, p. 16. Available at: http://www.umces.edu/sites/default/files/pdfs/SeaLevelRiseProjections.pdf
[38] Maryland Commission on Climate Change (MCCC), Adaptation and Response Working Group, *Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change*, Chapter 5, p.3. Available at: http://www.mde.state.md.us/assets/document/Air/ClimateChange/Chapter5.pdf
[39] Maryland Department of the Environment (MDOE), *2015 Greenhouse Gas Emissions Reduction Update*, Appendix D, p.1. Available at: http://www.mde.maryland.gov/programs/Air/ClimateChange/Documents/2015GGRAPlanUpdate/2015GGRAPlanUpdateAppendices/D_SummaryAmericanClimateProspectus.pdf

- Changing building codes to mitigate impacts of rising sea-levels, such as elevation requirements or use of different foundation material.

- Locating future businesses and properties in less vulnerable areas and restoring low-lying areas.

With the likelihood of more extreme weather, storm water and rainwater management will be important areas for adaptation. New approaches to construction will be needed, including more porous concrete that allows water to seep through and be filtered, rather than just running off an impervious surface.

Peak demand for electricity is also expected to increase with rising temperatures. This will lead to further investment and adaptation requirements from electric utilities.[40] The Clean Energy Future would reduce the need for large-scale investments, such as large power plants or expanded transmission, to meet this higher demand. Our scenario includes a large increase in solar PV which is most useful during summer peak hours, reducing the need for other resources. Electrification of the vehicle fleet also leads to a more adaptable electric system. With complementary infrastructure in place, electric vehicles' batteries can be used for storage, providing power when the grid needs it most.

The Clean Energy Future shows that Maryland will create thousands of new jobs while mitigating its impact on climate change. Maryland will also require new infrastructure investments, which are beyond the scope of this study, to adapt to the impacts of climate change in the future. It will be important to conduct an in-depth of Maryland's needs for adaptation.

[40] *Ibid.*, p.21.

5. CONCLUSION: WHY WAIT?

Maryland's Clean Energy Future, as laid out in this report, represents a practical plan to reduce GHG slash emissions by 2050 – which climate scientists say is needed to limit climate catastrophe. It shows that climate protection will produce at least ten thousand more jobs per year than continuing on a fossil fuel "business as usual" pathway, most of them well- paid, family-supporting jobs in manufacturing and construction.

The Clean Energy Future plan provides a floor, not a ceiling, for what can be accomplished. It shows that meeting our climate goals will create more jobs. But we can, and indeed should, do more. For example, the plan uses less than 10 percent of Maryland's technical potential for solar power; faster growth of solar power could reduce GHG emissions to near zero – while creating even more manufacturing and construction jobs. Maryland can achieve such goals just by accelerating and adjusting the same basic plan.
Maryland can achieve many of its other goals while implementing an aggressive climate protection plan, but to realize these "co-benefits" it will need policies designed to do so:

- The Clean Energy Future will entail the creation of more than ten thousand new jobs. Although most are in the high-wage manufacturing and construction sectors, there is no guarantee that they will be good jobs. Indeed, depending on other economic trends, spending on climate protection could increase inequality and provide increasingly insecure, contingent work. We can design our climate protection plan to maximize the number of good, secure, permanent jobs with education, training, and career advancement. We can institutionalize economic planning that will provide sustained, orderly development for an expanding climate protection sector and prevent boom-and-bust cycles that are devastating for workers and industries. Since the deterioration in the quality of jobs is directly related to the reduction in the size and bargaining power of labor unions, reinforcing the right of workers to organize and bargain collectively should be an explicit part of public policy for climate protection.

- About 435 jobs in mining and utilities will be lost in the Clean Energy Future. That's less than one-twentieth as many as will be added in the rest of the economy. But the workers in those jobs must not be thrown on the scrapheap. We need a vigorous program to provide new, high-quality jobs and/or dignified retirement for workers in those industries. State energy policy should require that utilities make new jobs available to any workers adversely affected by climate protection; that utilities negotiate transition plans with their employees; that utilities fund a transition program to assist any workers they do not reemploy; and that the state establish an earmarked fund to ensure a just transition for affected workers.

- The Clean Energy Future plan opens up new opportunities to counter racial, gender, geographic and other inequalities. Climate protection programs should include earmarking of funding, renewable energy and energy efficiency, and jobs for low-income communities, and communities of color.

The Clean Energy Future represents a pathway away from climate destruction that is also far better for workers than our current pathway based on fossil fuels. Maryland can start moving now to gain its share of the benefits of the Clean Energy Future. "Maryland's Clean Energy Future" shows it can be done.