The Green Transition: Renewable Energy Technology, Climate Change Mitigation, and the Future of Work in New Jersey

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EXECUTIVE SUMMARY

Meeting the goals of New Jersey's *Global Warming Response Act* will require a rapid transition toward renewable energy technologies that will alter the future of work in New Jersey. This report provides insight into the following questions: What is the magnitude and nature of the new jobs that are likely to be created? What types of skills will be required? What magnitude of job displacement can be expected? And what steps can be taken to ensure that efforts to address climate change are reducing rather than exacerbating the existing problems of social and economic inequality in the state? Given the breadth of technologies explored in this report, the findings should be considered a preliminary analysis and an invitation to further modelling around the likely impacts of each specific technology. Notable findings include:

Investments in renewable technologies will create tens of thousands of jobs across dozens of occupations in New Jersey, particularly in construction and blue-collar occupations:

- A transition to 100% renewable power sources will create over 80,000 construction jobs and 50,000 operations jobs according to the Solutions Project at Stanford University. This report finds that a 3500MW offshore wind project would create between 14,000 and 16,000 jobs and that doubling rooftop solar capacity from 3.5% to 7% would create over 3,000 additional solar jobs in the state.

- A large share of jobs resulting from wind and solar projects are in the manufacturing sector—local procurement requirements and other economic incentives could bring these jobs to New Jersey.

- Investments in clean vehicle infrastructure and expanding mass transit would bolster employment in engineering, construction, installation, maintenance, repair, sales, production, and transportation occupations.

- About 31,679 New Jersey residents currently work in energy efficiency, with over 60% in the construction trades, earning an average annual income of $60,710. Employment in this non-outsourceable sector is expected to grow 9% this year and continue expanding.

The green transition will require investments in education and worker training:

- Most new jobs will not require higher levels of education than existing energy jobs, but the demand for new workers may outstep the capacity of existing education programs.

- According to the *2018 U.S. Energy and Employment Report*, over 70% of energy efficiency employers reported difficulty finding qualified workers, with 26% noting it was "very difficult." The retirement of baby boomers from the workforce will further contribute to the shortage of skilled blue-collar workers in the state.

- Investments in specialized technical training at the high school and college level as well as through trade apprenticeships and other training programs will be needed.

Transitioning to 100% renewable energy will reduce employment in fossil fuel industries:

- Approximately 20,000 New Jersey residents are employed in fossil fuel industries, including about 8,000 in oil and gas production, 1,900 in petroleum refining, 5,500 in coal- and gas-fired power plants, and another 5,000 in related occupations.

- Fossil fuel power plant jobs will be directly impacted by the transition to 100% renewable energy. Petroleum-related jobs would likely experience a more prolonged market-based decline resulting from the decline in demand for petroleum products. Plant and refinery operators earn an average annual income of $72,000, a higher salary on average than most blue-collar renewable energy jobs at this time.

- Business leaders, policy-makers, and labor organizations should work together to negotiate solutions that ensure a fair and just transition for these workers. This is not only the right thing to do for workers who are the victims of energy policy decisions but is also a prerequisite for ensuring the broad-based support that is needed for the enactment and implementation of any serious climate mitigation strategy.

The green economy is already more diverse than the old energy sector, but still stratified:

- 28% of workers in the four biggest solar job categories in New Jersey were non-white in 2017 compared to 17% in the biggest fossil fuel occupations. About 65% were male for both industries, reflecting the prevalence of blue-collar occupations in the energy sector.

- Most of the diversity in the solar industry is found in the lower-paying rooftop solar installation positions.

With the right policy mix, the green transition can be a vehicle for not only addressing climate change but also many of the state's existing social, economic, and environmental inequalities. Some recommendations include:

- Inclusion of historically marginalized communities that have suffered the most and benefited the least from the existing energy system into dialogues and decision-making processes related to climate change, including job training and recruitment programs.

- Strong worker protections, including: the right to organize a union free from intimidation; a "green prevailing wage" to ensure that new energy jobs are of similar quality as old energy jobs and to advantage law-abiding, in-state contractors; a fair and just transition for displaced workers; a "green new deal" to put unemployed workers to work creating green infrastructure while simultaneously reducing unemployment at the margins of the labor market; and clear career ladders for green jobs to ensure the retention of skilled workers and to serve as a vehicle for spreading diversity into higher level occupations.

INTRODUCTION

Humanity is facing a climate emergency. Bold and immediate solutions are required to avert the worst impacts of climate change. Societies are also facing unprecedented levels of income and wealth inequality—often along the lines of race and gender—which threaten the very foundations of democratic governance. Previous attempts to address these two problems separately have often erupted in conflicts of "jobs vs. the environment" and ended with losses of both (Hyde and Vachon, 2018; Kazis and Grossman, 1982; Obach, 2002, 2004; Vachon and Brecher, 2016). From the struggles over old growth forests in the Pacific Northwest to pipeline projects in the heartland to natural gas fracking here in the Mid-Atlantic, it is abundantly clear that efforts to protect the environment which place the economic burden solely on workers are both unjust and likely doomed to fail in the court of public opinion.

The motivation for the current research is derived from this historically situated knowledge which tells us that to effectively solve either one of these grand problems—climate change or inequality—policymakers must consider both problems simultaneously (Brecher, 2014). Such solutions will invariably alter the future of work in New Jersey. New industries will rise, old industries will fall. Jobs will come, and jobs will go. Depending upon the information at hand and the policies prescribed, state leaders can either: 1) protect the climate and reduce inequality; 2) protect the climate and exacerbate inequality; or 3) not protect the climate and either reduce or exacerbate inequality. The first option not only leads to the most societally optimal outcome but is the only one that can build the broad base of support that is required for the successful enactment and implementation of a strong climate protection program. This report aims to provide relevant information about the likely employment impacts of various climate change mitigation strategies to help inform public policy that can lead to the optimal outcome.

The Climate Crisis and the Future of Work

Recent reports by the Intergovernmental Panel on Climate Change (IPCC) as well as the U.S. Government's *Fourth National Climate Assessment* warn us that ever-growing levels of fossil fuel use are stretching planetary limits by raising greenhouse gas (GHG) emissions and air pollution to dangerous levels (Intergovernmental Panel on Climate Change, 2018; U.S. Global Change Research Program, 2018). The current carbon-based energy system is negatively affecting the health and quality of life of the world's population and is disproportionately affecting marginalized populations, whom have contributed the least to the problem. Record global temperatures and warmer ocean temperatures are increasing the odds of devastating hurricanes and extreme rain events in some locations and prolonged droughts and wildfires in others.

New Jersey has already experienced some of the impacts of a warming planet in the form of extreme storms, coastal and inland flooding, and extended heatwaves. Superstorm Sandy alone caused more than $70.2 billion worth of damages in 2012. With rising and warming oceans, the frequency, intensity, and duration of extreme weather events will only accelerate. Without substantial reductions in our levels of GHG emissions, the state will be forced to confront a reality where the Jersey shore is in a perpetual state of emergency, urban areas suffer frequent deaths from pro-longed heatwaves, and inland river flooding rises to the steps of the state capitol in Trenton.

To address the looming threat of climate change, the New Jersey state government enacted the *Global Warming Response Act* (GWRA) into law in 2007. The Act seeks to limit the level of statewide GHG emissions to 80% below the 2006 level by the year 2050. As presented in Figure 1, the state has made some moderate progress in achieving its goals, but significant work remains to be done. The eminent decommissioning of the state's (mostly) carbon-free nuclear power plants in the coming decades will intensify the challenge of meeting the 2050 goals. However, the new administration of Governor Murphy has vowed to take steps to meet the goals of the GWRA. The Governor's Environment and Energy Transition Advisory Committee made several recommendations which the Governor has indicated support for, including: 1) a rapid transition to renewable energy sources,[1] 2) a significant reduction in statewide GHG emissions,[2] and 3) a real effort to address environmental justice issues which have plagued the state for decades.[3]

[Figure 1 about here]

The pursuit of these recommendations would trigger significant changes within the New Jersey workforce in terms of the number of jobs, the types of jobs, and the types of workers who get the jobs. Compared to the baseline "business-as-usual" scenario, compliance with the GWRA will require fewer workers in extraction, oil and gas production, and non-renewable electricity production, such as coal-and gas-burning plants. However, it will also require much larger numbers of workers in energy efficiency programs, green infrastructure construction, and renewable energy production. This report seeks to address the following five questions:

1. What magnitude of job displacement can be expected as a result of the technological transition? What types of workers are likely to be impacted?

2. What is the magnitude and nature of new jobs that are likely to be created as a result of the transition toward renewable technologies?

3. What types of skills will be required for these new jobs compared to existing energy jobs?

4. How do the wages for these new "green jobs" compare to those in the existing energy sector?

5. What steps can be taken to ensure that efforts to address climate change are reducing rather than exacerbating the problems of social and economic inequality in the state?

Regarding job numbers, a simple survey of the contemporary labor market offers some insight. Currently, the solar industry accounts for upwards of 7,000 jobs in New Jersey, with about half in installation and the other half in project development, sales, and manufacturing. Conversely, power plant operators in traditional coal-fired, gas-fired, and nuclear power plants account for just 690 jobs. In line with previous research, this anecdote suggests that on average, the total number of new jobs created will outpace the total number of jobs lost. However, this numerical fact will be of little or no comfort to the individual workers who face the loss of *their* job (Dixon and Van Horn, 2003). To remedy this social cost associated with policies that are required to protect public health and safety, a series of just transition measures could be considered, including early retirement for workers that are nearing the end of their careers and job training and placement programs for younger workers. Understanding who the impacted workers are can help inform such policies.

Looking at job skills, most blue-collar jobs in the green energy sector will not require a college degree, as was also the case for fossil fuel-related jobs. However, the level of investment in green infrastructure that will be required to meet the emissions reduction targets laid out in the GWRA suggests a likely need to expand apprenticeship programs in the skilled trades to prepare workers for the construction of offshore wind farms, commercial-grade solar installations, and electric vehicle charging stations, to name just a few of the new technologies that will be adopted. The increased number of professional jobs in civil and environmental engineering, the sciences, and education and training will also require an increase in the number of skilled workers with specialized training in these fields. Taking stock of the likely occupations needed to successfully implement the GWRA can help inform and shape educational programming at the high school and post-secondary level as well as in professional schools and apprenticeship programs.

Likely, one of the great challenges of the green transition will be to ensure that the new "green jobs" are also "good jobs." The blue-collar fossil fuel jobs of the old economy have benefitted from generations of subsequent collective bargaining agreements which have secured livable wages and ample employment-based fringe benefits. Many new jobs, such as those related to the construction of offshore wind farms, will also pay livable wages and offer good benefits if the right labor agreements are in place. However, existing green jobs in other areas, particularly residential solar, are yet to offer such wages and benefits. For example, the median annual salary for a solar installer in New Jersey is currently $43,620. Compare that to power plant operators who earn a median annual salary of $80,530 and it becomes clear why some workers are reluctant to trade in their old "dirty" job for a new green one. Some possible solutions to the green job wage gap could be strong protections for the rights of workers to unionize in the sector or the creation of a "green prevailing wage" measure for all green economy jobs. In sum, a closer examination of the wage composition of green economy jobs can help to inform fair wage and labor standards governing employment in the sector.

The remainder of this report will consider in greater detail the jobs and wages associated with the major sources of GHG emissions as well as the climate mitigation technologies that are most likely to be deployed in New Jersey.

DATA AND METHODS

This report will utilize employment, wage and occupational data from the Bureau of Labor Statistics (BLS) *Occupational Employment Statistics* (2018a), BLS *Occupational Outlook Handbook* (2018b), and the U.S. Census *Current Population Survey* (2018) in conjunction with previous research on green jobs to determine occupations that are most likely to experience growth as a result of the green transition. Energy production and greenhouse gas emissions data from the U.S. Energy Information Administration will be used to determine the sectors that are most likely to be targeted by technologically-driven climate mitigation strategies in New Jersey. This report will focus solely on energy-related drivers of climate change as they are the most relevant when considering employment impacts.

Upon identifying the most logical mitigation strategies, the study will utilize the Jobs and Economic Development Impact (JEDI) modelling procedure developed by the National Renewable Energy Laboratory at the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy to generate approximate job projections for some projects, particularly wind and solar (National Renewable Energy Laboratory, 2018). Based on user-entered project-specific data or default inputs (derived from industry norms), JEDI estimates the number of jobs and economic impacts to a local area that can reasonably be supported by the project. Jobs outputs are distributed across three categories: project development and onsite labor impacts, local revenue and supply chain impacts, and induced impacts. JEDI model defaults are based on interviews with industry experts and project developers. Economic multipliers contained within the model are derived from Minnesota IMPLAN Group's IMPLAN accounting software and state data files.

This report categorizes types of jobs that would be created using the Department of Labor's Standard Occupational Classification (SOC) system. The 2018 SOC system is a federal statistical standard used by federal agencies to classify workers into occupational categories for the purpose of collecting, calculating, or disseminating data. All workers are classified into one of 867 detailed occupations according to their occupational definition. To facilitate classification, detailed occupations are combined to form 459 broad occupations, 98 minor groups, and 23 major groups. Detailed occupations in the SOC with similar job duties, and in some cases skills, education, and/or training, are grouped together.

The analytical method of this study will proceed in three stages. First, I will review the primary sources of GHG emissions in the state of New Jersey to identify the most effective and plausible climate mitigation strategies. I will then identify the major occupations which will experience a decline in employment as a result of transitioning to renewable energy sources. Finally, I will explore the occupations that will most likely experience growth as a result of these mitigation technologies and the skills that will be needed to perform these jobs. Given the short timeframe provided for completing this analysis and the large number of mitigation strategies considered, the employment projections are meant to be suggestive of the types of changes that can be expected in the state labor market. Future research should investigate the economic and job impacts of each mitigation strategy separately and in greater detail.

CLIMATE CHANGE, MITIGATION, AND JOBS

Addressing the issue of climate change requires reducing the levels of GHG emissions into the Earth's atmosphere—our home. Fossil fuels have powered the growth of capitalist economies since the industrial revolution. They have provided the electricity for businesses, fuel for transportation, and heat for homes that helped to build the American middle class. History tells us that this story was not always joyous for all involved and that the rewards and consequences of the dual rise of fossil fuels and capitalism were not always evenly distributed. At this critical juncture, as we stand at the precipice of a new energy world order, it is imperative that we look to our past and build from our successes and try to avoid our mistakes. In our collective hands we hold an opportunity to not only save the Earth's climate for our children and grandchildren, but to help ensure a more fair and just distribution of jobs and resources for our family members, friends, neighbors, and ourselves.

In this section I will briefly describe the major sources of GHG emissions in New Jersey and consider some of the occupations that are reliant on the continued extraction, production, transportation, and consumption of the fossil fuels that emit these climate changing gases. While they will be categorized and referred to as jobs, it is important to remember that in each job is a living human person who has hopes and dreams and who has a family that relies on the income from that job. If addressing climate change means eliminating jobs that are related to fossil fuels—which it does—then addressing climate change also means addressing the needs of the workers who through no fault of their own will face job loss. That is the minimum ticket price for participating in any meaningful and morally intact discussion of climate change mitigation as a public policy.

Major Sources of GHG Emissions and Associated Jobs

Figure 2 outlines New Jersey's energy-related CO_2 emissions as reported by the U.S. Energy Information Administration (U.S. Energy Information Administration, 2018). As indicated by the blue section of the pie, more than half of all emissions in the state are from the transportation sector (52%). Electrical power generation contributes 16%, residential and commercial buildings combined contribute 23.5%, and industrial processes 8.6%. The bar portion of the figure looks at emission levels by fuel type. As indicated by the red bar, petroleum use emits 68.4 MMTCO2 into the atmosphere each year and natural gas contributes 41.3 MMTCO2.

[Figure 2 about here]

Considering transportation's contribution to greenhouse gas emissions it should be no surprise that petroleum is the major fuel source driving emissions in the state, accounting for

61% of emissions by fuel type. The second major source of emissions, natural gas, which accounts for 37% of emissions, is utilized for electricity generation as well as for heating, cooking, and hot water in residential and commercial buildings. The relatively minor contributions by coal are a testament to New Jersey's shift away from coal to other power sources in recent decades (McDonald, 2017).

Using BLS data, Table 1 outlines the major occupations that are related to the extraction, production, and consumption of petroleum, natural gas, and coal in New Jersey. According to the U.S. Energy Information Administration (EIA), New Jersey has no crude oil reserves or production, but the state has two operating oil refineries which produce a range of refined products, including gasoline, diesel fuel, and heating oil. Four refineries were closed in the state between 2010 and 2017, but the northern portion of the coastline, along the New York harbor, is still home to the largest petroleum product hub in the northeast. One third of the 1-million-barrel federal Northeast Home Heating Oil Reserve is stored at Port Reading. New Jersey is crossed by major petroleum pipeline systems and receives petroleum product imports by tanker from all over the world that supply northeastern markets. New Jersey also serves as the primary distribution hub for ethanol that is blended with gasoline across the East Coast.

[Table 1 about here]

Since 2010, natural gas consumption for electricity generation has increased by more than one-third in New Jersey, replacing several coal-fired power plants due to reduced costs as well as environmental and health benefits. Three out of four households in the state use natural gas as their primary home heating fuel. When it comes to natural gas production, New Jersey does not produce any, nor does it hold any reserves. This is due largely to the opposition by state residents to the use of hydraulic fracturing ("fracking") for natural gas production which can have negative effects on local drinking water supplies. In response to public opinion, New Jersey's state government in early 2018 supported a ban on fracking in the Delaware River Basin. Although it does not produce any natural gas of its own, New Jersey is crossed by several interstate pipelines that are primary carriers of natural gas. About half of the natural gas entering New Jersey is consumed by state residents and the other half is shipped on to other states. New pipeline sections are currently under construction in the state to transport more natural gas from Pennsylvania through New Jersey and on to the Northeast, but many new natural gas pipeline projects in the state have been met by public opposition.

When it comes to coal, New Jersey does not have any coal reserves or mined coal production. The state also uses very little coal for electricity generation as most of the coal-fired power plants have been shut down or converted to natural gas. The state's sole remaining coal-fired electricity generating plant and two co-generation stations at industrial sites receive coal by rail, usually from Pennsylvania, West Virginia, and Virginia. The last remaining coal-fired power plant will be converted to natural gas when a fuel supply pipeline is available.

Taken together, approximately 20,000 New Jersey residents are directly employed in the fossil fuel industry, including about 8,000 in oil and gas production, 1,900 in petroleum refining, 5,500 in coal- and gas-fired power plants, and another 5,000 in related occupations (The Solutions Project, 2018). The demographics of workers in the five biggest occupations in the fossil fuel industry in New Jersey—production workers, first line supervisors, miscellaneous managers, chemical engineers, and plant and system operators—are 62% male, 83% white, and the average age is 45 years old with about 24% of workers aged 55 or older and 23% under the age of 35.

As the state makes the shift to 100% renewable energy, jobs in natural gas and coal will begin to phase out. The fate of jobs in oil refining and petroleum products is less clear as they are more likely to be determined by market forces such as declining demand for petroleum products than by public policies. However, it is not inconceivable that the state could place a restriction on fossil fuel production as a means of addressing climate change just as the state has banned the fracking of natural gas in order to protect water supplies. Whichever scenario comes to pass, it will be the responsibility of the state in conjunction with employers and workers to establish a plan for an orderly transition away from fossil fuels that protects the livelihoods of all displaced workers. This issue will be discussed further in the concluding remarks at the end of this report.

Plausible GHG Mitigation Strategies and Potential Jobs in these Sectors

For New Jersey to reduce its GHG emissions in accordance with the targets set by the GWRA, major changes will be needed to reduce the use of petroleum, natural gas, and coal. This will require a transformation in the ways we commute to work and travel, heat our homes and businesses, and how we as a state generate electricity—all of which will have ramifications for the future of work in the state. There is not one magic bullet to eliminate GHG emissions (Pacyniak, Kaufman, Bradbury, Veysey, Macbeth, Goetz, et al., 2017). The most plausible strategy for meeting the state's mitigation goals will involve a combination of: 1) electrification of vehicles and expansion of mass transit to reduce petroleum use, 2) a switch to 100% renewable energy sources for electricity generation to reduce natural gas and coal use, and 3) investments in energy efficiency for homes and businesses.[4] The jobs associated with each of these strategies will be reviewed below.

Transportation

Being the single largest contributor to GHG emissions, changes to the New Jersey transportation system can make tremendous contributions to achieving the goals of the GWRA. There are two primary means by which the state can reduce petroleum consumption: 1) the electrification of public and private vehicles that are currently powered by combustion engines, and 2) the expansion of mass transit to reduce single-passenger vehicle use.[5]

Based upon New Jersey's current mix of electricity sources, plug-in electric vehicles (EVs) emit 8,991 less pounds of CO_2 per year than traditional combustion engine vehicles (U.S. Department of Energy, 2018a).[6] The use of mass transit in place of driving a single-passenger combustion engine vehicle for a 20-mile round trip commute to a full-time, year-round job will reduce CO_2 emissions by 4,800 pounds annually (American Public Transportation Association, 2008). The substitution of mass transit for all combustion engine vehicle use by one person can reduce their CO_2 emissions by 11,435 pounds per year on average. In addition to reducing GHG emissions, increased electric vehicle use would also reduce particulate air pollution and the expansion of mass transit would reduce traffic on congested highways, parkways, and streets.

To switch from a transportation system that is dominated by single-passenger combustion engine vehicles to one that is based upon EVs and the increased use of mass transit will require significant shifts in employment in the state. Each of these strategies will be detailed below.

Electrical Vehicle Charging Infrastructure

The electrification of public and private motor vehicles will require a massive expansion of electric vehicle charging infrastructure in the state (Herb, 2010). As of August 2018, New Jersey had 76 publicly accessible DC Fast Charging outlets at 42 locations and 46 Tesla Supercharger outlets at 7 locations (compatible only with Tesla car models). For most individual commuters, the lion's share of charging will be done with Level 1, slow chargers at home. However, Level 2 charging infrastructure at workplaces, public parks, and shopping centers will also be needed to support the increased demand for chargers as EVs supplant combustion engine vehicles. Level 3, fast chargers will be needed along highways and other frequently travelled roads for passengers making longer journeys (Center for Automotive Research, 2018). Special attention will also have to be given to multi-family living quarters such as apartment complexes and condominiums.[7] Public fleet vehicles will require massive fast-charging stations at their depots.

Whether directed by government agencies, private companies, electric utilities, or individual consumers, the expansion of EV charging infrastructure will have many employment impacts. Table 2 outlines the types of occupations that will likely experience growth (signified with pink boxes for EV charging occupations) as a result of these investments as well as the average entry-level education level for each occupation, the number of workers currently employed in each occupation in the state, and the average annual income for each occupation in New Jersey.

[Table 2 about here]

In the planning phase for larger charging stations in public spaces, various scientists, architects, engineers, and legal occupations will be employed. These workers will require a college education, ranging from bachelor's degrees to PhDs and will also earn on average upwards of $84,000 annually.[8] The manufacturing and construction phases will require a variety of managerial occupations, educators, and technical trainers who will also on average hold a bachelor's degree. The average annual income for construction managers in New Jersey is $138,980 and for educators and trainers it is $72,778. It is uncertain whether the manufacturing jobs associated with EV chargers will be in New Jersey, but should there be production facilities, these jobs would range from managerial jobs to line workers, who earn on average $39,480 and require just a high school diploma. Many of the new jobs generated from EV charging infrastructure will likely be in the skilled trades, including operating engineers, carpenters, laborers, and especially electricians who will do the actual work of preparing charging station sites, installing the equipment, and finishing the parking areas. These workers earn an average annual income of $60,710.

Once publicly accessible charging stations are constructed, the question rises whether the facilities will require station managers or charging attendants (as is required for gas stations in the state). Management activities for a station or cluster of stations might include managing driver access, billing, providing driver support, and monitoring the station. Based upon the data for current gas station attendants in New Jersey, the annual income for these jobs is likely to be rather low, around $18,000. Charging stations will also require maintenance on occasion as hardware wears out and technology advances. This will create service and repair jobs which currently pay on average, $45,530 in New Jersey and require little more than a high school education or post-high school technical training program.

Given the variation of potential charging station styles, the unknown mix between public and private chargers that will be needed to sustain the current 2.8 million registered vehicles in New Jersey, and the rapidly changing technology, it is difficult to accurately project the extent of job growth that can be expected from EV charging infrastructure. However, following current trends, we can anticipate most chargers will be at private residences and installed by local electrical contractors. If the installation of one in-home charger takes approximately 8 person-hours of work, then the installation of an EV charging unit in each of the 1.8 million detached, single-family homes in the state would create approximately 500 full-time electrician jobs for 10 years.[9] These electricians will need to be trained and licensed and their final work inspected, creating dozens of additional full-time jobs for trainers and inspectors. The sale of residential charging units will also create jobs in the wholesale and retail sales and office and administrative occupations which pay on average $43,438 and require at least a high school diploma with some jobs such as accountants requiring a bachelor's degree.

Larger scale charging stations at workplaces, shopping centers, parking garages and along highway corridors will create short-term construction jobs. According to Sustainable Jersey (2017), the installation cost, minus materials, for the installation of DC fast chargers ranges from approximately $100,000-$200,00 per station. Given the average construction salary of $60,710 in New Jersey, it can be roughly estimated that each DC fast charger station project will support somewhere between 1.6 and 3.3 full-time, full year jobs. By this estimate, the construction of 100 new fast charge stations would create between 160 and 330 middle class jobs. However, it should be noted that due to the variety of site-specific issues that can be encountered at different project locations, it is difficult to reliably estimate the number of jobs that will be created on these projects. For example, a location with a readily available hook up for the 240v line will require considerably less work than a site that requires trenching or boring over a great distance to access electricity. Retrofitting existing parking spaces also requires a different combination of workers than the development of new sites.

When it comes to preparing the workforce, EV charging infrastructure represents a new, but relatively simple technology, with the majority of jobs requiring little training beyond high school.[10] However, the increase in demand for skilled trades workers, especially electricians, will increase the burden on existing programs which may or may not have the capacity to accept an influx of new pupils. Increases in demand for architects, engineers, scientists, and educators will also result in an increased demand for college-educated workers with technical or scientific backgrounds.

Mass Transit

The extent of mass transit use is largely determined by the capacity and efficiency of the public transportation system that is in place. Luring drivers away from congested highways and onto trains and buses will require an expansion of the services offered. Such investments in mass transit would create many construction jobs in the short run as well as long term permanent jobs in the transportation, installation and repair, and service sectors. Table 2 outlines the types of occupations that will likely experience growth as a result of these investments (signified by blue boxes for mass transit).

In FY 2017, New Jersey Transit alone had over 269 million passenger trips (154 million by bus and 115 million by rail) that transported riders over 3.4 billion miles (New Jersey Transit, 2017). This saved over 1.5 $MMTCO_2$ emissions compared to travelling the same distance with single passenger combustion engine vehicles.[11] The New Jersey transportation sector currently employs over 10,500 rail and bus transportation workers earning an average of $61,623 for rail workers and $46,800 for bus operators. These jobs require little more than a high school diploma and offer a clear pathway into the middle class for many workers in the state. The transportation sector also employs thousands of other workers in vehicle maintenance and repair, infrastructure maintenance and repair, retail sales, customer service, and office and administrative occupations.

Expanding mass transit options in the state will require the work of urban planners, engineers, architects, and scientists during the planning phase. The construction phase will create hundreds of jobs for construction workers from the skilled trades, including carpenters, laborers, operating engineers, electricians, and others, working to upgrade the existing, ailing and overburdened infrastructure and to construct new infrastructure to increase rail capacity. Dedicated bus lanes, such as have been adopted in Connecticut and other states (see CT Fastrak for example), will also create hundreds of construction and highway jobs. As the capacity of rail and bus lines increase, the number of workers employed as operators, sales representative, and back office positions will also increase proportionately. For example, doubling bus capacity would increase the number of bus operators from 7,350 to 14,700.

Other considerations include the electrification of rail and bus systems and could likely be implemented more quickly than the costlier and longer-term investments needed to expand overall capacity. These technological upgrades will contribute to the growth of many of the same occupations detailed in the electric vehicle charging infrastructure section above. It is also unclear what impact such investments would have on manufacturing employment in the state. Signaling a large-scale investment in such technologies coupled with the right mix of public policies and business incentives could trigger growth in the green manufacturing sector in New Jersey and replace some of the many thousands of manufacturing jobs the state has lost in recent decades.

Electric Power Generation

The use of natural gas, and to a lesser extent coal, to generate electricity leads to the emissions of 17.9 $MMTCO_2$ into the atmosphere each year. Nuclear power—which emits very few GHGs—accounts for approximately 40% of New Jersey's electricity generation, but the longevity of these plants is in question as they continue to age and rely on state subsidies to operate. For a variety of reasons that will not be elaborated here, the construction of new nuclear plants is not likely in the state, which makes the adoption of renewable sources like wind and solar more urgent in order to meet the GHG reduction goals of the GWRA.

[Figure 3 about here]

Based on an assessment of each state's environmental resources, *The Solutions Project* at Stanford University and the *Carbon Free America* project by National Geographic have projected the likely energy mix for each state to be powered by 100% renewable sources. For New Jersey, that mix, represented in Figure 3, includes 55% of electricity being generated from offshore wind, 27% from solar plants, 10% from land-based wind farms, 7% from rooftop solar (3.5% residential and 2.8% commercial and government), and 1% from tidal devices. According to the U.S. Department of Energy's JEDI modelling package, offshore wind generates approximately .18 construction and .66 operations jobs per MW of electricity. Solar plants create .90 construction and .30 operations jobs per MW. Land-based wind generates .10 construction and .15 operations jobs per MW. And rooftop solar creates approximately 1.50 construction and .46 operations jobs per MW. Taken together, the Solutions Project estimates that achieving the goals laid out in Figure 3 will create 86,000 40-year construction jobs and 58,000 40-year operations jobs in New Jersey. Each technology will be considered in greater detail below.

Wind Technology

Globally, the wind industry employed 1.2 million people in 2017, a 7% increase from 2015. Wind employment in the U.S. increased by 28% in 2016 to 102,500 jobs (International Renewable Energy Agency, 2015). There are currently an estimated 84,000 offshore wind jobs across the world (Gould and Creswell, 2017). The European Union increased its number of offshore wind jobs 12-fold, from 6,370 jobs to 75,000 jobs, between 2007-2014. The United States has just one offshore wind farm to date, the Block Island Wind Farm off the coast of Rhode Island, but several northeastern states have taken steps to begin harnessing the power of wind. New Jersey has tremendous potential for offshore wind power generation as well as moderate capacity for land-based wind power. Governor Murphy has vowed to make the state a national leader in this sector, outlining a plan to have 3,500MW of offshore wind power up and running by the year 2030 – enough energy to power 1.5 million New Jersey homes and businesses and avoid emissions equivalent to removing over 873,000 cars from the road.

Using the U.S. Department of Energy's JEDI models for employment impacts, we can estimate that the proposed 3500MW offshore wind project will create somewhere between 14,000 and 16,000 jobs directly, including 5,000-6,000 project development and construction jobs, and another 5,000-8,000 jobs from induced impacts.[12] Table 3 breaks down the job growth projections by occupational categories. Meeting the target of 55% offshore wind power would create upwards of 17,000 project development and construction jobs.[13] Meeting the target of 10% land-based wind power generation would create between 3,000 and 4,000 direct jobs and 1,500-2,500 induced jobs according to the JEDI models. Among the direct jobs, roughly one third would be in project development and construction and about two thirds would be in turbine manufacturing and supply chain activities which may or may not take place in New Jersey depending upon the procurement requirements that are established through public policy. In short, local sourcing requirements would lead to more in-state jobs.

[Table 3 about here]

These numbers should be interpreted with caution as the projections will fluctuate depending upon a variety of factors for which we currently lack sufficient information, including turbine type—which impacts the number of turbines. The distance to shore and depth of water for offshore projects can influence the number of workers required. The selection of foundation-type alone for offshore wind can have a significant impact on the number of jobs. Gravity-based foundations would be constructed in New Jersey close to the port, creating additional local jobs, as opposed to monopiles which would likely be built in Europe or steel jackets which are predominantly made in the southern states along the Gulf of Mexico. The estimates above are for steel jackets which are typically the least expensive of the alternatives.

Table 2 outlines the types of occupations that are likely to experience growth by increased investments in wind power (signified by green boxes for wind). Previous studies of the industry, particularly the offshore wind sector, have found that wind power projects require a diverse technical workforce spanning over 70 occupations.[14] For example, the workforce involved in the construction of the Block Island Wind Farm included cement masons, commercial finance, dockworkers, electricians, engineers, health and safety experts, laborers, lawyers, mechanics, machinists, operating engineers, pipefitters, plumbers, project managers, regulatory, scientists, training professionals, truck drivers, vessel builders, vessel operators, and welders, to name a few. The Block Island project tapped into local unions, contractors, and businesses based in Rhode Island and, according to public statements by the plant operator, created more than 300 local jobs during the construction of the small, 5-turbine wind farm which generates approximately 30MW of electricity.

Solar Technology

Solar photovoltaic (PV) power was the largest renewable energy employer in 2017, with 3.1 million jobs globally, up 12% from 2015 (International Renewable Energy Agency, 2017). According to the 2017 National Solar Jobs Census, the U.S. solar industry employed 250,271 solar workers last year, a 168% increase from the 93,000 workers employed in the industry in 2010 (The Solar Foundation, 2017). A similar report by the U.S. Department of Energy (2018b) found that more Americans work in solar (374,000) than in natural gas or coal power plants (187,117). The report also estimates that over 7,000 workers are currently employed in the solar industry in New Jersey, including over 3,500 installation jobs, 650 manufacturing jobs, 800 sales and distribution jobs, and 1,700 project development jobs. According to these estimates, solar employment in New Jersey grew by 1,000 jobs, or approximately 17% between 2016 and 2017—nearly 17 times faster than the U.S. economy in the same period.[15]

To meet the targets of the GWRA, New Jersey will need to expand both rooftop solar (on private homes as well as commercial and government buildings) as well as construct commercial solar PV power plants. The types of occupations that will experience growth as a result of these two forms of solar technology—listed in Table 5 (signified by yellow boxes)—are similar, however, the rate of pay for commercial solar construction is likely to be greater than for residential rooftop PV.[16] In fact, one of the largest critiques of the rooftop solar industry by fossil fuel workers has been its relatively low wages for installer jobs. The critique is especially poignant considering the higher than average representation of black and Latino workers in the rooftop solar industry (over 20% of installers are black in New Jersey according to the National Solar Jobs Census). Commercial construction workers who would build solar PV power plants earn on average $60,000 per year in New Jersey, whereas rooftop PV installers earn just $43,620. The key distinction is the presence of unions in the commercial sector.

The 2,646MW of solar capacity currently installed in New Jersey accounts for about 3.3% of electricity generation in New Jersey (Solar Energy Industries Association, 2018). From this figure we could roughly estimate that the amount currently installed needs to be doubled for rooftop PV and increased 8-fold for commercial solar plant capacity to meet the goals of 7% and 27% respectively. Based on this estimate, the DOE's JEDI models project that approximately 8,000 construction jobs and 2,400 operations jobs would be needed in the rooftop industry, approximately 3,200 more jobs than currently exist in the sector. For commercial solar plants, we could project that between 15,000-20,000 construction jobs and between 4,000-6,000 operations jobs would be needed based upon the National Solar Survey figures.[17]

Residential and Commercial

Most GHG emissions in the residential and commercial sectors come from energy used for lighting and heating. As such, the primary method for reducing emissions is to increase energy efficiency in buildings by upgrading doors, windows, insulation and heating/cooling equipment in order to reduce energy waste and installing new smart gird technologies to reduce overall consumption. The job impacts of these technologies will be reviewed below.

Energy Efficiency Upgrades

Energy efficiency, as defined by the American Council for an Energy Efficient Economy (2018), is “the use of less energy to provide the same or better products, services, or amenities.” Increasing energy efficiency “allows more control over energy use, lowers costs, and provides multiple benefits for households, businesses, and the environment.” For example, adding insulation to a private residence reduces its annual energy consumption while simultaneously increasing its comfort. Increasing the energy efficiency of a manufacturing or industrial process can enhance the competitiveness of a business in the marketplace. Reducing the overall energy used by society also reduces pollution, including the emission of climate-changing GHGs.

Molina, Kiker and Nowak (2016) find that energy efficiency programs, appliance standards, utility programs, and building codes have saved the equivalent of 313 power plants worth of electricity since 1990. Energy saving programs in 2015 alone saved U.S. consumers an average of $840 on energy bills per household and reduced GHG emissions by 490MMTCO_2. Addressing the 32% of GHG emissions that are still emitted from the residential and commercial sectors in New Jersey will require major investments in energy efficiency in existing buildings in addition to stricter codes for new buildings.

According to the EIA (2018), commercial buildings in the Northeast region are the largest buildings of the 4 U.S. Census regions. Cities in the Northeast are well established and have had very large buildings in place for many years—the median age for buildings in the Northeast is 46 years, in contrast to 29 years for those in the South. In the Northeast, buildings are, on average, 4,000 to 5,000 square feet larger than buildings in other regions also. Unfortunately, older plus larger equals less energy efficient. The Mid-Atlantic has on average the largest buildings among the 9 U.S. Census Divisions, averaging 22,300 square feet. Containing just 9% of all commercial buildings in the U.S., the Mid-Atlantic accounts for 19% of the total commercial floorspace. These buildings include offices, warehouses, stores, schools, restaurants, hotels, hospitals, sports and concert arenas, and more.

Making New Jersey's millions of square feet of commercial and public buildings and private residences more energy efficient will create jobs for workers with a variety of skills. Many of the occupations likely to experience growth are listed in Table 2 (signified by the cyan-colored boxes on the table). According to the U.S. Department of Energy, the energy efficiency industry already employs over 31,000 workers in New Jersey, including workers who manufacture EnergyStar appliances and LED lighting systems (6,250 jobs), workers who design and install more efficient heating, ventilation and air conditioning systems (15,246 jobs) and workers who install advanced materials and insulation to reduce energy waste (2,184 jobs) (O'Boyle and Blumenthal, 2018). Other jobs include LEED (Leadership in Energy and Environmental Design) consultants and inspectors to advise energy efficiency projects and certify buildings based upon their green building certification program (U.S. Green Building

Council, 2018). The use of tools like integrated energy and daylight modeling air management and monitoring plans and green housekeeping protocols will also create jobs for workers from across the skills spectrum, ranging from scientists and engineers to building and grounds cleaning and maintenance occupations. Taken together, about 64% of energy efficiency jobs in the state are construction jobs, earning an average of $60,710 per year (Johnson, 2018).

Nationwide employment in this sector grew by twice the national average in 2017 and is expected to grow another 9%-11% this year (National Association of State Energy Officials, 2018). For New Jersey that would mean an additional 2,800 jobs, including more than 1,800 construction jobs. It also means an expansion in workforce development, education, and technical training programs will likely to be needed. According to the *2018 U.S. Energy and Employment Report*, as presented to the U.S. Senate in May 2018, over 70% of employers reported difficulty finding qualified workers, with 26% noting it was “very difficult” (National Association of State Energy Officials, 2018). While there is no equivalent data for New Jersey, it is reasonable to assume that employers in the state are also likely to encounter a shortage of properly trained workers in the energy efficiency sector.

Smart Grid Technology

Due to population growth, an increase in home size and air conditioning use, and the proliferation of computers and other electronics, New Jersey’s energy needs have increased tremendously in the last few decades. According to the U.S. Department of Energy, growth in peak demand for electricity has outpaced growth in power transmission by almost 25% per year since 1982. However, the current power grid—the network for transmitting and distributing electricity from power sources to consumers—evolved during the late 19th and early 20th centuries and hasn’t changed much in more than a century.

Modernizing the system through “smart grid” technology is seen as the primary means of improving the way we store and get power. Smart grid technology allows utilities and other electricity suppliers to steadily monitor electricity flow and make real-time adjustments to distribution in order to maximize efficiency. Smart grid technology also makes better use of energy generated from alternative sources, including solar panels, wind turbines, and other renewable energy sources, through improved storage and transmission. Many companies are currently working on gridless or “post-grid” electricity generation technologies which can help reduce grid congestion, cut expenses associated with peak energy demand, and strengthen the resiliency of U.S. electricity systems by providing a backup power source when conventional power goes down in times of crisis or natural disaster.

Updating and upgrading to a smart grid will also provide jobs in various occupations, including engineering, construction, installation, and sales, and once the smart grid is set up, other workers will be needed to operate and maintain it. According to research by the energy consulting firm DNV KEMA, work related to the smart grid is expected to result in about 280,000 new jobs. A report by the Bureau of Labor Statistics (2013) provides an overview of employment and wages for occupations related to smart grid work, primarily in the electric power generation, transmission, and distribution industry. These occupations and others related to smart-grid technology are listed in Table 2 of this report (signified by the orange boxes). The major occupational groups include computer and mathematical occupations, architecture and engineering occupations, installation, maintenance and repair occupations, production occupations, and other occupations including electricians, meter readers and urban planners.

To prepare for smart grid jobs, some workers already have many of the skills they need but will require additional training to transition to the new technologies. Other workers, such as meter readers, may need extensive retraining to gain higher level skills for new smart grid jobs. Training for workers in computer jobs span a range of requirements, from professional certification through a graduate degree. Engineers typically have a bachelor’s degree; however, a significant number of employers require workers to have a master’s or doctoral degree. Engineers are also expected to participate in continuing education to keep up with rapidly changing technology. Installation, maintenance and repair occupations often require an associate degree from a community college or technical school, although a high school education is sufficient for many jobs. Workers in production occupations generally require little more than a high school diploma, but in some settings additional training could be required, often on the job.

DISCUSSION

As this report and previous research has made clear, the green transition to address climate change will be a huge jobs creation project. The exact number of jobs created will be shaped by various policies and incentive programs. For example, in-state procurement requirements could double the number of jobs associated with offshore wind technology by ensuring much of the manufacturing takes place in New Jersey. However, the green transition will also involve job destruction in various fossil fuel-related occupations. Depending upon the policy mix which governs our transition, this inevitable labor market churning can either exacerbate or help to remedy some of the existing deep economic and social inequalities within the state. This brief discussion section will synthesize the major findings of this report and explore several policy-related topics regarding the transition from black to green energy technologies.

First, most new green technology jobs are likely to be blue collar jobs. There will of course be increased demand for highly trained specialists such as scientists and engineers, but due to the labor-intensive nature of the energy transition, the majority of new jobs will be in construction, installation, transportation, and production occupations. The growth in skilled occupations such as electricians and wind turbine technicians are likely to strain the existing educational and apprenticeship systems that are in place. Accompanied by the retirement of many baby-boomers from the workforce, the demand for skilled blue-collar workers is also likely to encounter an insufficient supply of qualified job candidates; a problem many employers have already noted (National Association of State Energy Officials, 2018). For this reason, workforce development is an area where pro-active planning can help to ensure that the in-state workforce reaps the maximum benefit of the new green jobs. Apart from a skills shortage, another likely cause for the dearth of skilled blue-collar workers is the increased pursuit of college and white-collar employment by so many young workers. This could in part be rectified by ensuring that the blue-collar energy jobs are of equal quality in terms of wages, benefits, and workplace environment to their more sought-after white-collar counterparts. Direct recruitment and jobs training programs in high unemployment areas could also reduce the labor shortage while simultaneously increasing social mobility.

Second, early statistics on renewable energy employment suggest that the green workforce is slightly more diverse than the workforce in the traditional energy sector. However, looking more closely, we see that most of the diversity can be found in lower paying occupations, such as rooftop PV installers. Ensuring that entry-level jobs have clear career ladders can help to increase diversity in the higher paying occupations. Job training and workforce recruitment programs can also help to ensure the growing green workforce is more representative of the state's population by targeting communities that have historically suffered rather than benefitted from the energy system (Rodgers III, 2005). As the governor's energy transition task force has recommended, all state agencies involved in energy and environmental matters could incorporate environmental justice issues into the core of their operations, which could include jobs programs. Most importantly, any such programs would benefit greatly by receiving input from and having participation by members from the effected communities.

Third, many of the entry-level positions in renewable energy, particularly in solar, pay a much lower rate than their equivalent jobs in the fossil fuel sector. Much of the difference between the starting wages in these new jobs and jobs with equal skill requirements in the old energy industry can be attributed to the history of unionization and collective bargaining in the fossil fuel sector. As was recently noted in a report by Rutgers LEARN (Merrill and Vachon, 2019), employer hostility toward unions has stymied the ability of workers in emerging occupations in recent decades to capture a fair share of the economic growth created by their labor. Something like a "green prevailing wage" could help to ensure that workers in new green energy jobs are paid fair wages by protecting their right to organize if they so choose and levelling the playing field between high-road and low-road contractors by removing wages from competition in the bidding process.

Other means to ensure that green jobs are good jobs include increasing the state minimum wage to a living wage or creating a state jobs guarantee for all workers in order to end involuntary unemployment. In this vein, the idea of a "Green New Deal" has received much attention in the media since the start of the 116th Congress. While the details of such a plan are yet unclear, the center piece would be large-scale public investment in renewable energy infrastructure through public entities to both address the climate crisis as well as create good-paying jobs for workers in need. Taking this publicly-driven, as opposed to the current market-driven approach to addressing climate change could accelerate the green transition as well as ensure that green jobs are good jobs.

Finally, the transition away from fossil fuel-based transportation, electricity generation, and heating will inevitably lead to a decline in many occupations that are associated with the extraction, production, and consumption of those fuels. For the green transition to be fair and just, policymakers should meet with employers and workers and consider measures to protect the livelihoods of displaced workers, including early retirement programs for workers approaching retirement age and job training and placement programs for younger workers. These types of programs have come to be called a "just transition" and stem from an older concept once called the "superfund for workers" (Mazzocchi, 1993).[18] The rationale for a just transition is the basic principle of fairness. The burden of policies that are necessary for society—like protecting the environment and addressing climate change—shouldn't be borne by a small minority of the population, who through no fault of their own happen to be victims of their side effects.

While it is true that on balance, environmental policies tend to create more jobs than they eliminate (Goodstein, 1999), this fact is of little comfort to the workers in the fossil fuel sector who are likely to lose *their* jobs as a result of climate protection policies. Protecting these workers is not only the right thing to do for them and their families but is a prerequisite to building the broad-based support that is required for the implementation of strong climate change mitigation measures. Unless workers and communities have a say in policy formation and are protected against the unintended effects of climate policies, there is likely to be a backlash that threatens the whole effort.

CONCLUSION

When Governor Murphy signed the "Renewable Energy Bill" (A-3723) into law in May of 2018, New Jersey reclaimed its role as a national policy leader on climate change and opened the door to a clean energy economy. The state now joins California, Hawaii, New York, and

Vermont as the only five states requiring 50% renewable energy by 2030. Together, these states boast some of America's largest clean energy workforces per capita—led by California's 520,000 green jobs—and all have thriving economies with annual GDP growth rates that are higher than the U.S. average (O'Boyle and Blumenthal, 2018). Understanding the changes currently underway in New Jersey provides valuable insight into one element of the future of work in our state.

The adoption of climate-safe energy technologies will not only reduce GHG emissions but will also create tens of thousands of new jobs across dozens of occupations with a variety of skill sets. The transition will unfortunately also mean the erosion of some existing jobs in the fossil fuel sector. Some of the new energy jobs require similar skills as current energy occupations, but there is not likely to be a one-to-one match. Through an assortment of policy options, state policy-makers can shape the character of the green transition to ensure that New Jersey's workers are taken care of and the benefits of green technology are maximized while any unwanted side effects are minimized. By leading the way on climate mitigation, environmental justice, and just transition, New Jersey can set a strong example for other states to follow.

While this report was able to offer some insight into the types of occupational changes that are likely to occur by meeting the state's commitments in the GWRA, it suffers from many limitations. In particular, the broad scope of the report has limited the depth of the assessment. Future research should build from this preliminary analysis by doing a deep dive into each of the mitigation strategies in greater detail. More extensive economic modelling can provide a more detailed picture of the jobs impacts that can be expected as well as the likely timeframe for implementation of each mitigation strategy.

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ENDNOTES

[1] The committee recommended jumpstarting the state's most promising new clean energy industry, offshore wind—the governor has since called for 3,500 MW by the year 2030. Other recommendations include stabilizing the state's solar market, utilizing 100% of the Clean Energy Fund to advance energy efficiency and grow the clean-energy economy, and utilizing the multi-state Memorandum of Understanding (MOU) on Zero Emissions Vehicles as a springboard for the electrification of the state's transportation system.
[2] The committee recommended rejoining the Regional Greenhouse Gas Initiative (RGGI) and committing to emissions reduction goals laid out in the Paris Climate Agreement. The committee also recommended reinstating the DEP Office of Climate Change, advancing statewide climate literacy programs in schools, and promoting "Green STEM" initiatives and other trainings to prepare the workforce for new climate technologies.
[3] The committee recommended a comprehensive environmental justice initiative that includes an interagency environmental justice task force. They recommend that every state agency should consider environmental justice issues in all of their actions, including analyzing cumulative impacts to reduce health disparities, creating new initiatives to improve communities' quality of life such as the provision of open space, clean energy, walkways and bike paths, and green jobs opportunities for historically marginalized workers.
[4] Changes to industrial processes will also be required but are beyond the scope of this report.
[5] Other clean vehicle technology such as fuel cell vehicles are also an option, but due to space limitations are not evaluated in this report.
[6] Combustion engine vehicles emit 11,435lbs of CO_2 per year. Based on New Jersey's current electricity mix, EVs emit 2444lbs of CO_2 per year, plug-in hybrid vehicles emit 4,841lbs of CO_2 per year, and hybrids emit 6,258lbs of CO2 per year. The GHG reductions for these electric and hybrid vehicles will increase as electricity generation is sourced more from renewable energy sources.
[7] The European Union, Greenway, and Clean Technica have compiled a useful handbook titled *Electric Vehicle Charging Infrastructure: Guidelines for Cities*, which can be accessed at: https://www.drivegreen.nj.gov/GuidelinesforCities.pdf
[8] Public planners should see Agenbroad and Holland 2014 for a detailed discussion of the various types of charging stations and associated planning processes.
[9] Estimate of work hours derived from Austin (2014). Estimate of number of detached homes derived from U.S. Census Bureau (2000).
[10] For a first-hand description of the job of electrical vehicle charging station installer, see U.S. Department of Energy (2014a).
[11] Based upon the estimated average that 1 mile travelled by car emits 1 lb of CO_2 (Megna 2016)
[12] Direct jobs include development, manufacturing, construction, and other onsite jobs. Induced jobs are those created by the spending that is supported by the project (for example in retail and service occupations).
[13] These estimates are in line with previous projections by the Northeast Wind Center (2017) which utilized an economic model developed by the University of the Highlands and Islands in Scotland and estimated the creation of 36,300 full time wind jobs throughout the region, including New Jersey. Importantly, early adopters will gain the most employment benefits.
[14] For a detailed discussion of occupations and workforce development pertaining to offshore wind construction, see Gould and Cresswell's (2017) study on New York.
[15] The Bureau of Labor Statistics (2018a) offers considerably more conservative estimates of just 750 solar PV installer jobs in New Jersey in 2017. The discrepancy likely comes from the different definition of occupations as well as the employment of construction trades occupations in commercial solar installation—a situation that would lead the solar institute to count the job as a solar installer, but the BLS to classify it as a carpenter, laborer, welder, etc. based on their own occupational classification system.
[16] For a comprehensive review of occupations in the solar industry, see the Bureau of Labor Statistics' "Careers in Solar Report" at https://www.bls.gov/green/solar_power/ .
[17] Using the more conservative BLS occupational classification for solar installers, the estimated growth in solar installer jobs would be much greater as the starting point would be just 750 workers. However, given the number of other occupations involved in solar installation projects, it seems more appropriate to begin with the more

liberal baseline estimate from the National Solar Survey which yields more conservative estimates for solar job growth.

[18] Examples of proposed just transition policies include the *Clean Energy Worker Just Transition Act* at the federal level (https://www.congress.gov/bill/114th-congress/senate-bill/2398) and the *Climate and Community Investment Act* in New York State (https://www.nysenate.gov/legislation/bills/2017/s7645).

Figure 1. New Jersey's Total CO_2 Emissions Levels, 2000-2015

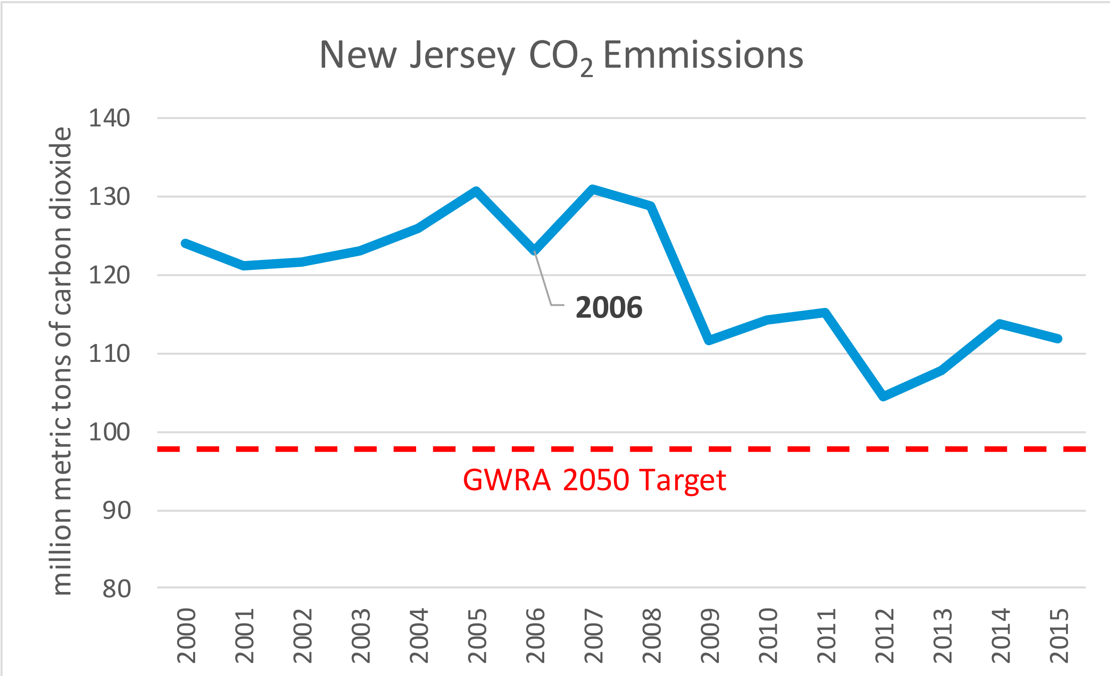

Figure 2. New Jersey's Energy-Related CO_2 Emissions, 2015

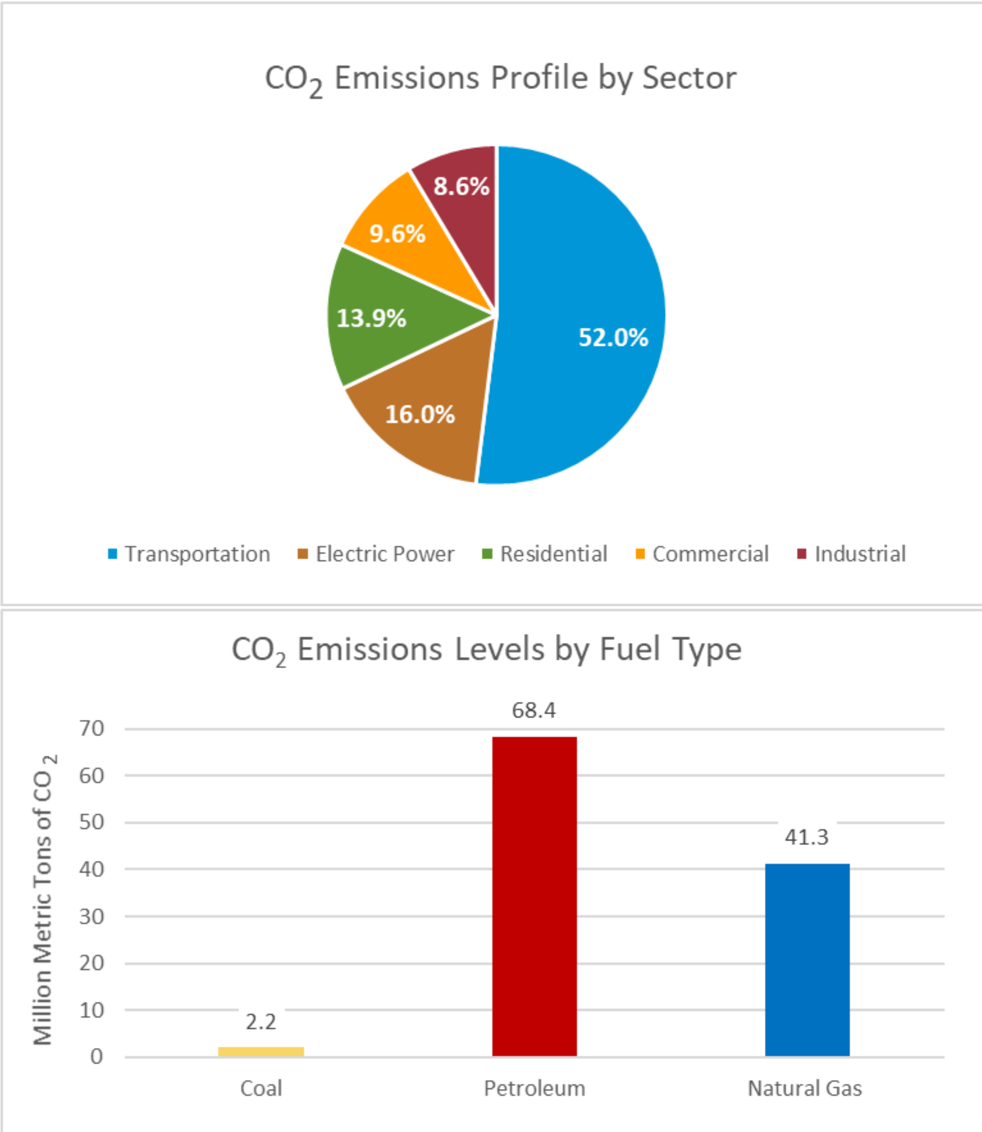

Figure 3. Projected Energy Mix for 100% Renewable Electricity in New Jersey

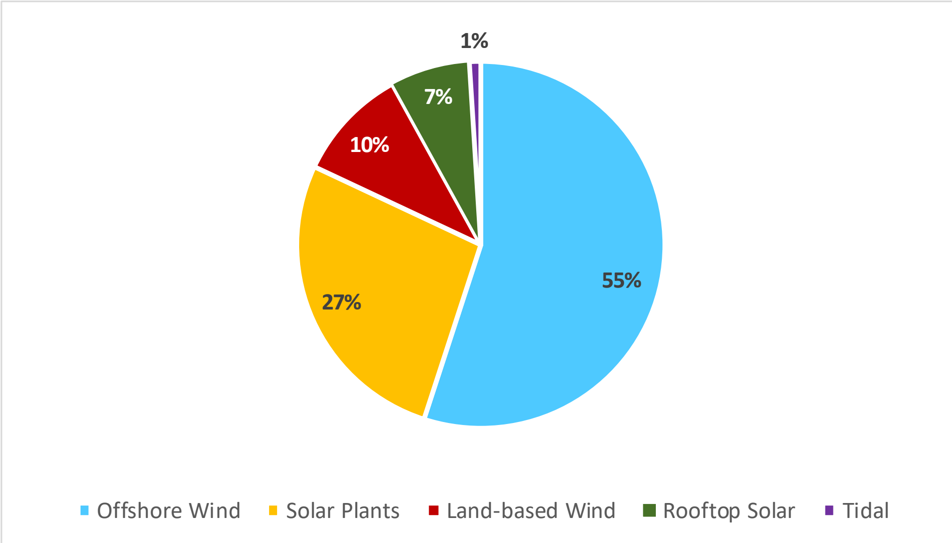

Table 1. Occupations that Would Likely Decline as a Result of Climate Change Mitigation in New Jersey

Occupation [a]	Typical Entry-Level Education	Total Number of Workers Employed [b]	Average Annual Income (FTE)
Architecture and Engineering Occupations			
Chemical Engineers	Bachelor's	1,270	111,540
Petroleum Engineers	Bachelor's	190	187,370
Construction Trades			
Boilermakers	HS, Apprenticeship	300	64,030
Carpenters	HS, Apprenticeship	16,360	61,390
Electricians	HS, Apprenticeship	16,490	70,850
Pipefitters and Plumbers	HS, Apprenticeship	9,070	70,680
Installation, Maintenance and Repair			
Maintenance and Repair Workers, General	HS, On-the-job training	30,530	45,530
Life, Physical, and Social Science Occupations			
Geological and Petroleum Technicians	Associate's	60	66,930
Management Occupations			
General and Operations Managers	Bachelor's	42,930	167,790
Miscellaneous Managers	Bachelor's	19,170	140,080
Office and Administrative			
Administrative Assistants	HS, some college	63,420	41,470
Bookkeeping and Accounting	HS, some college	43,590	46,120
Production, Planning, and Expediting Clerks	HS, On-the-job training	6,810	51,330
Production Occupations			
Chemical Plant and System Operators	HS, On-the-job training	630	64,390
First Line Supervisors	HS, Previous Experience	12,300	69,140
Gas Plant Operators	HS, On-the-job training	160	76,030
Inspectors, Testers, Sorters, Samplers, Weighers	HS, On-the-job training	12,740	41,410
Machinists	HS, Apprenticeship	4,110	49,910
Petroleum Pump and Refinery Operators	HS, On-the-job training	440	69,110
Power Distributors and Dispatchers	HS, On-the-job training	260	88,770
Power Plant Operators	HS, On-the-job training	570	80,530
Welding, Soldering, and Brazing	HS, Tech training	770	33,750
Other Plant System Operators	HS, On-the-job training	300	64,830
Miscellaneous Production Workers	HS, On-the-job training	5,530	31,850
Sales and Related Occupations			
Sales and Related	HS, On-the-job training	406,090	45,470
Service Occupations			
Gas Station Attendants	On-the-job training	n/a	18,720
Transportation Occupations			
Drivers/Sales Workers	HS, On-the-job training	8,610	33,400
Laborers and Freight, Stock, and Material Movers	On-the-job training	120,110	29,810
Pumping Station Operators	On-the-job training	570	51,475

Sources: Bureau of Labor Statistics *Occupational Outlook Handbook* (2018b)*;* Data USA (2018); U.S. Census, *Current Population Survey* (2018)

a -- this list is not exhaustive, but is rperesntative of the occupations directly employed in fossil fuels industries

b -- total includes all workers employed in this occupation in New Jersey, not just in natural gas power plants, oil refineries, etc.

Table 2. Occupations that Would Likely Grow as a Result of Climate Change Mitigation in New Jersey

Technology	Occupation [a]	Typical Entry-Level Education	Total Number of Workers Employed [b]	Average Annual Income (FTE)
	Architecture and Engineering			
	Architects	Bachelor's	2,140	84,070
	Civil Engineers	Bachelor's	7,500	102,170
	Electrical Engineers	Bachelor's	3,630	107,370
	Environmental Engineers	Bachelor's	1,220	91,730
	Health and Safety Engineers	Bachelor's	450	104,720
	Marine Engineers	Bachelor's	130	85,590
	Mechanical Engineers	Bachelor's	5,080	93,100
	Architectural and Civil Drafters	Associate's	2,710	52,980
	Engineering Technicians, except Drafters	Associate's	880	74,800
	Surveying and Mapping Technicians	HS, On-the-job training	550	48,750
	Other Architecture and Engineering Occ.s	HS, On-the-job training	30,230	91,490
	Arts, Design, Entertainment, Sports, and Media			
	Public Relations Specialists	Bachelor's	4,100	69,810
	Building and Grounds Cleaning and Maintenance			
	Building Cleaning and Maintenance	On-the job training	126,370	31,400
	Business and Financial Operations Occupations			
	Accountants and Auditors	Bachelor's	37,110	91,400
	Compliance Officers	Bachelor's	10,800	81,440
	Computer and Mathematical Occupations			
	Computer User Support Specialists	Bachelor's	13,900	64,440
	Computer Systems Analysts	Bachelor's	13,170	105,750
	Network and Systems Administrators	Bachelor's	11,850	100,220
	Operations Research Analysts	Bachelor's	2,580	107,270
	Software Developers	Bachelor's	9,110	117,080
	Construction Trades			
	Boilermakers	HS, Apprenticeship	300	64,030
	Carpenters	HS, Apprenticeship	16,360	61,390
	Cement Masons	HS, Apprenticeship	2,980	60,740
	Electricians	HS, Apprenticeship	16,490	70,850
	Insulation Workers	HS, Apprenticeship	970	57,230
	Iron Workers	HS, Apprenticeship	1,300	80,650
	Laborers	HS, Apprenticeship	23,440	52,220
	Line Installers and Repairers	HS, Apprenticeship	1,630	81,490
	Operating Engineers	HS, Apprenticeship	5,550	71,250
	Pile Drivers	HS, Apprenticeship	180	78,940
	Plumbers and Pipefitters	HS, Apprenticeship	9,070	70,680
	Solar Photovoltaic Installers	HS, Apprenticeship	750	43,620
	Inspectors	HS, On-the-job training	4,430	65,890
	Other Trades	HS, Apprenticeship	51,460	60,710
	Education and Training			
	Post-Secondary Teachers	PhD	37,540	93,529
	Technical Education Teachers	Bachelor's, Masters	2,370	70,930
	Other Instructors and Trainers	Bachelor's	4,275	53,875
	Installation, Maintenance and Repair			
	Electrical and Electronics Repairers	HS, Technical Training	500	82,820
	Electrical Power-line iIntallers, Repairers	HS, On-the-job Training	1,630	81,490
	First-Line Supervisors	HS, previous experience	12,250	74,140
	HVAC Mechanics and Installers	HS, Apprenticeship	9,680	58,770
	Telecommunications Equipt Installers, Repairers	HS, Technical Training	4,280	58,900
	Wind Turbine Service Technicians	HS, Technical Training	<100	57,500
	Maintenance and Repair Workers, All Other	HS, Technical Training	30,530	45,530
	Legal Occupations			
	Lawyers	Juris Doctorate	20,730	140,340
	Paralegals and Legal Assistants	Associate's	8,060	81,650

Life, Physical, and Social Science Occupations			
Urban and Regional Planners	Masters	410	7,890
Biological Scientists	Master's, PhD	6,220	83,425
Environmental Scientists	Master's, PhD	2,790	86,740
Materials Scientist	Master's, PhD	200	104,340
Other Life and Physical Scientists	Master's, PhD	720	91,910
Science Technicians	Bachelor's	750	52,570
Management Occupations			
Construction Managers	Bachelor's	5,720	138,980
General and Operations Managers	Bachelor's	42,930	167,790
Human Resources Managers	Bachelor's	3,740	162,540
Industrial Production Managers	Bachelor's	4,880	131,400
Public Relations Managers	Bachelor's	1,830	161,860
Purchasing Managers	Bachelor's	1,850	161,130
Miscellaneous Managers	Associate's, Bachelor's	19,170	140,080
Office and Administrative			
Administrative Assistants	HS	63,420	41,470
Bookkeeping, Accounting, and Auditing	HS, Some College	43,590	46,120
Meter Readers, Utilities	HS, On-the-job Training	1,030	43,410
Other Office and Administrative Support	HS, Some College	544,990	40,690
Production Occupations			
Computer Control Operators and Programmers	HS, Tech Training	3,620	53,955
Engine and Other Machine Assemblers	HS, On-the-job Training	300	41,130
First-Line Supervisors	HS, previous experience	12,300	69,140
Forming Machine Setters, Operators, Tenders	HS, Tech Training	2,100	36,320
Machinists	HS, Apprenticeship	4,110	49,910
Power Distributors and Dispatchers	HS, On-the-job Training	260	88,770
Structural Metal Fabricators and Fitters	HS, On-the-job Training	7,120	47,180
Welding, Soldering, and Brazing	High School, Tech training	770	33,750
Assemblers and Fabricators, All Other	HS, On-the-job Training	18,830	39,480
Sales and Related Occupations			
Sales and Related	HS, On-the-job Training	406,090	45,470
Service Occupations			
Charging Station Attendants	On-the-job Training	n/a	18,720 [c]
Transportation Occupations			
Bus Operators	HS, CDLTraining	7,350	46,800
Drivers/Sales Workers	HS, On-the-job Training	8,610	33,400
Industrial Truck and Tractor Operators	HS, On-the-job Training	17,640	36,760
Laborers and Freight, Stock, Material Movers	On-the-job Training	120,110	29,810
Rail Transportation Workers	HS, On-the-job Training	3,255	61,623
Water Transportation Workers	HS, Credentialing	1,200	55,732

KEY

Transportation	EV Charging Infrastructure
	Mass Transit
Electric Power Generation	Wind Power
	Solar Power
Residential, Commercial, Industrial	Energy Efficiency
	Grid Modernization

NOTES

Source: Bureau of Labor Statistics *Occupational Employment Statistics* (2018)

a -- this list is not exhaustive, but represents occupations most likely to grow

b -- total includes all workers employed in this occupation in New Jersey, not just those employed in wind, solar, etc.

c -- this is the current salary of the over 10,000 gas station attendants who could transition to the job of charging station attendant

Table 3. Projected Job Growth and Salaries by Occupational Group for a 3,500MW Offshore Wind Project in New Jersey

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Occupational Group	Projected Number of Jobs Created for 3,500MW Project	Average Annual Salary in New Jersey
Management Occupations	2,000-2,200	149,770
Business and Financial Operations Occupations	600-800	84,950
Computer and Mathematical Occupations	100-200	100,540
Architecture and Engineering Occupations	1,200-1,400	91,490
Life, Physical, and Social Science Occupations	40-60	95,430
Legal Occupations	40-60	112,690
Education, Training, and Library Occupations	40-60	59,840
Arts, Design, Entertainment, Sports, and Media Occupations	80-100	60,030
Protective Services	40-60	55,700
Food Preparation and Serving Related Occupations	80-100	26,320
Building and Grounds Cleaning and Maintenance Occupations	80-100	31,400
Sales and Related Occupations	100-200	45,470
Office and Administrative Support Occupations	500-700	40,690
Construction and Extraction Occupations	400-600	60,710
Installation, Maintenance, and Repair Occupations	3,800-4,200	53,170
Production Occupations	4,000-4,500	39,100
Transportation and Material Moving Occupations	700-900	37,300
	Total Jobs: 14,000-16,000	**Average Salary:** 67,329

Projections based upon the harmonization of JEDI estimates and occupational growth figures from previous offshore wind studies