THE ECONOMIC, LEGAL, AND POLICY IMPLICATIONS OF RENEWABLE ENERGY AND CLIMATE CHANGE MITIGATION

by

Lance Noel

A dissertation submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Marine Studies

Fall 2015

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ACKNOWLEDGMENTS

I wish to thank all the people who have helped me along the way of finishing my dissertation. First, I would like to thank my adviser, Jeremy Firestone, as well as Willett Kempton, George Parsons, Benjamin Sovacool, and Cristina Archer, for their support and assistance during my education. I would also like to thank my colleagues Regina McCormack and Joe Brodie for their help developing and coauthoring the research of my dissertation. Finally, I must thank my parents, Robert and Leslie Noel, as well as my girlfriend, Phoebe Zeng, for the love and support requisite to finishing a dissertation.

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ABSTRACT

The problem of climate change poses one of the most substantial threats humans have ever faced. On the other hand, climate change mitigation poses several significant tradeoffs, and despite the impacts of climate change, implementation of renewable energy to mitigate the climate change contributions of energy systems has developed slowly and unevenly. This dissertation explores these tradeoffs through various perspectives to understand the optimal implementation of renewable energy. The dissertation is comprised of three separate chapters, discussing different economic and environmental impacts of energy systems, including climate change, human health impacts, and wildlife population impacts. The first chapter investigates the cost effectiveness of an electric bus that is vehicle-to-grid (V2G) capable, by conducting a cost benefit analysis. Next, the second chapter will evaluate the relationship between the public trust doctrine and the ensuing implications for electricity production and its impacts on water and wildlife resources. The third chapter employs electric system modeling to determine the optimum of electricity and transportation technology mix if externalities such as health costs and social costs of carbon were incorporated. These three essays are tied together by their implications for energy, environmental and climate change policy.

Chapter 1

INTRODUCTION

Climate change is the most dangerous environmental hazard mankind has faced (IPCC 2014). Anthropogenic emissions of carbon dioxide will continue to increase the acidity of the ocean, which will have devastating effects on various marine biota (Doney, et al. 2009). Climate change will also cause ocean waters to thermally expand, as well as lead to the melting of glaciers, both of which will contribute to sea level rise (Meehl, et al. 2012). In addition, climate change will increase the frequency of hurricanes, as well as worsen their intensity (Mudd, et al. 2014). It also has the potential to eradicate wildlife populations, causing the sixth mass extinction in the earth's history (Bellard, et al. 2012).

Beyond the environment, climate change will also impact societies. First, climate change will hinder economic growth and decrease global productivity (Moyer, et al. 2014). In North America, climate change will alter and impair crop yields and lessen food production (IPCC 2014). Climate change will also increase heat-related mortality and morbidity, and increase the incidence of infectious diseases (Patz, et al. 2005).

Despite the looming threats of climate change, the mitigation of climate change has been unevenly developed. Focusing on the United States, climate change emissions have grown by 5.9% since 1990 (EPA 2015), in spite of the growing concern of the impacts from climate change. Likewise, while both emissions and concern grow, the federal government has not yet enacted comprehensive climate change mitigation regulation. The United States has not participated in recent international climate change mitigation treaties (Rosen 2015). Instead, much of the leadership in climate change mitigation has come from pockets of state and local actors.

One reason that there has not been broad implementation of mitigation policies is due to the fact that climate change mitigation requires significant tradeoffs. Climate change mitigation could require substantial behavioral change, which would entail overcoming psychological barriers to mitigate their climate change emissions (Gifford 2011). Additionally, climate change mitigation would involve major implementation and investment of novel technologies. Behavioral change and technology implementation both come at costs to society. To ensure that climate change mitigation is implemented to the correct and most reasonable extent, it is essential to fully weigh these economic and behavioral costs against their substantial environmental benefits. This dissertation explicitly focuses on these tradeoffs in the context of renewable energy, especially focusing on the transportation and electricity sectors, which together comprise nearly 60% of United States climate change emissions (EPA, 2015), and have commercially available carbon-free alternatives. .

To fully explore the intricacies of mitigation, this dissertation explores the economic, legal and policy implications of climate change mitigation and renewable energy policy. As such, the dissertation is split into three papers, each providing a distinct perspective on the efficacy of climate change mitigation and renewable energy. The first paper concerns renewable energy decision making at the local level. It investigates the economics of implementing a vehicle-to grid (V2G) capable electric school bus in comparison to a traditional diesel bus. The paper calculates the benefit of V2G revenues and operation and maintenance savings against the comparatively higher capital cost of an electric bus over a 14 year lifespan, as opposed to the typical diesel bus currently used by school districts. .

Next, the second chapter explores the possibility of states, and citizens of those states, to use the public trust doctrine as a legal tool to regulate the environmental impacts of electricity production. The public trust doctrine is a common law (judge-made as opposed to legislatively-enacted statutory law) doctrine that places natural resources that are either too important for or incapable of private ownership in the hands of the state, which holds these resources as a trustee for the benefit of the public. As trustee, the state owes a duty to the public to ensure reasonable protection of natural resources, specifically water and wildlife. The public trust doctrine requires full contextual consideration of all environmental impacts to state resources from both conventional and renewable electricity technologies. Given that renewable electricity generally causes less environmental damages than conventional electricity, the public trust doctrine could be used by citizens to compel states to more aggressively implement renewable energy, as well as by states to defend against legal challenges to its actions promoting renewable energy. In order to show the application, the paper investigates four individual states as case studies.

Finally, the third paper models the costs of implementing renewable energy against the benefits of mitigating conventional energy's externalities, including health damages and the social cost of carbon. To make the exercise realistic in terms of both resources and dispatch, it models one Regional Transmission Operator, the PJM

Interconnection.[1] The model considers the construction of various renewable electricity technologies, as well as electrification of light-duty vehicles and building heat. The model creates combinations of potential energy systems that can meet electric and heating needs for every hour over four continuous years. The model then calculates the lifetime cost of each energy system under various externality scenarios.

Together, these three papers analyze climate change policies from a local, state, and transmission operator perspective, which is necessarily regional. By focusing on subnational policies, the dissertation is a reflection of the current lack of federal climate change action and the more proactive local and state actors in the mitigation of climate change. In sum, this dissertation is comprised of three separate papers, each providing a methodologically and regionally different perspectives on renewable energy policy.

[1] The PJM Interconnection is a large regional transmission organization (RTO) that manages the generation and transmission of electricity. Its territory ranges from Chicago to New Jersey and includes about 61 million people.

Chapter 2

A COST BENEFIT ANALYSIS OF A V2G-CAPABLE ELECTRIC SCHOOL BUS COMPARED TO A TRADITIONAL DIESEL SCHOOL BUS

2.1 Abstract

Fuel expenses, diesel exhaust health externalities, and climate change are concerns that encourage the use of electric vehicles. Vehicle-to-grid (V2G) policies provide additional economic incentives. This analysis evaluates the costs and benefits associated with the use of electric vehicles and determines the cost effectiveness of using a V2G-capable electric school bus compared to a traditional diesel school bus. Several factors were analyzed, including fuel expense, electricity and battery costs, health externalities, and frequency regulation market price. The V2G-capable electric bus provides the school savings of $6,070 per seat in net present value and becomes a net present benefit after five years of operation. Without externalities, the net present benefit would be $5,700 per seat. If the entire school district's fleet switched to V2G-capable electric buses, the net present savings would be upwards of $38 million. A sensitivity analysis was conducted to determine how the factors influenced the costs and benefits. In all cases, purchasing an electric school bus is consistently a net present benefit. Policies could be set into place to incentivize public school adoption of electric buses, encourage more efficient batteries, and develop V2G capabilities.

2.2 Nomenclature

Variable	*Variable Definition*	*Value Used*
B_D	Cost of Diesel Bus	$110,000
B_E	Cost of the Electric Bus (Including Charger)	$260,000
B_R	Cost of Replacement Battery	$300/kWh
C_D	Seating Capacity of Diesel Bus	32
C_E	Seating Capacity of Electric Bus	24
C_{er}	Average Electricity Carbon Emission Rate	1.18 lbs/kWh
C_{dr}	Diesel Carbon Emission Rate	22.2 lbs/kWh
D	Miles Driven per year	8,850
D_C	Annual Cost of Diesel Fuel	$6,351*
D_D	Annual Diesel Demand	1,393 gallons
E_C	Annual Cost of Electricity	$714*
E_{CAP}	Capacity of the Charger	70 kW
E_D	Annual Diesel Externalities	$1,214
E_D	Annual Electricity Demand	6,613 kWh
E_E	Annual Electricity Externalities	$280
E_S	Battery Storage Capacity	80 kWh
f_1	V2G Adjustment Factor	0.1
f_2	Battery Capacity Factor	0.2
h_{dr}	Per-Mile Cost of Diesel Health Emissions	$0.08
h_{er}	Per-Mile Cost of Electricity Health Emissions	$0.0149
$H_{V2G/Y}$	Hours per Year Performing V2G	7,647.8
H_{V2G}	Hours per Day Performing V2G	18.25 (24)[†]
i_d	Diesel Inflation Rate	8.50%
i_e	Electricity Inflation Rate	1.90%
L_B	Estimated Life of the Battery	9 years
L_r	Labor Cost to Refuel	$225/year
M_D	Annual Maintenance Cost of Diesel Bus	$9,075
m_{dr}	Per-Mile Diesel Bus Maintenance Rate	$1

M_E	Annual Maintenance Cost of the Electric Bus	\$1,770 (\$25,770)‡
m_{er}	Per-Mile Electronic Bus Maintenance Rate	\$0.20
N_{Cycle}	Rated Life Cycle of Battery	2,000
NPB	Calculated Net Present Benefit of Electric Bus	\$6,070
P_D	Price of Diesel	\$4.20/gal
P_E	Price of Electricity	\$0.106/kWh
P_R	Regulation Price for V2G Revenue	\$28/MWh
R	Range of Battery	100 miles
r_d	Discount Rate	3%
R_{V2G}	Annual V2G Revenue	\$15,274*
SCC	Social Cost of Carbon	\$36/MTCO$_2$e
Y	Year in the Model	N/A
μ_d	Diesel Engine Efficiency	6.35 mpg
μ_e	Battery Efficiency	747 Wh/mile

*These numbers represent the first year of the model and will change in ensuing years with inflation.
† Hours performing V2G on school day (Hours performing V2G on non-school day).
‡ Annual maintenance cost (Annual maintenance cost including battery replacement).

2.3 Introduction

Electric vehicles address several problems that traditional petroleum vehicles cause: health risks due to exhaust, dependency on foreign oil, and carbon emissions that perpetuate climate change. Diesel exhaust contains pollutants that cause respiratory irritation, heart disease, and lung cancer, posing substantial health risks for those frequently exposed to diesel exhaust [1]. Petroleum is the primary fuel for transportation, and transportation accounts for 28% of energy consumption in the U.S. [2]. While domestic resources provide 60% of U.S. oil demand, 40% is imported, with Canada providing the most imports, followed by Saudi Arabia, Mexico, and Venezuela, among other countries [3]. Climate change induced effects include global warming, sea-level rise, and extreme weather events that can displace people from their homes and wildlife habitat [4]. These concerns and innovative vehicle-to-grid technology (V2G) are the impetus of this cost benefit analysis of the choice to purchase a V2G-capable school bus versus a traditional diesel school bus.

Electric vehicles can provide services to the electric grid using V2G technology. Demand for electricity fluctuates continually depending on consumer actions. The frequency regulation market accounts for this fluctuation and enables the electric grid to match electricity generation to load. Combustion-based turbines, hydroelectric pumps, and flywheels are typically used for storage by the frequency regulation market, but electric vehicles offer novel storage capabilities that are more efficient. When electric vehicles are parked and connected to a charger, they can provide storage for the electric grid. In turn, vehicle owners can participate in the frequency regulation market and receive compensation for that service [5]. Revenue received for electric vehicle storage capability provides incentive for the adoption of electric vehicles. The literature has shown that V2G technology has been established as a potential revenue source as a participant on frequency regulation market [5] [6]. In addition, while many have detailed the economic toll of mitigating climate change and have investigated minimizing these costs [7] [8], there has been less of a focus on minimizing the costs of mitigating climate change effects due to transportation, especially with consideration of V2G technology.

Despite the advantages electric vehicles provide, electric vehicles face several limitations that prevent them from widespread implementation. Barriers include battery cost, vehicle range, and availability of charging stations [9] [10]. Hidrue et al. [9] found that battery cost discourages potential buyers. Likewise, Lemoine, et al., found that adoption of plug-in hybrid electric vehicles would not occur unless there were significant decreases to battery costs (or significant increases in gasoline prices) [11]. Also, batteries require several hours to fully charge and have driving ranges that are typically less than a petroleum vehicle's range. This requires electric vehicle drivers to adjust driving habits and refueling behavior [12]. Furthermore, charging stations are less abundant than gas stations, requiring drivers to plan their routes ahead of time.

The aforementioned limitations for electric vehicles are relevant particularly for private vehicle owners; however, this study analyzes the cost effectiveness of a V2G-capable, electric public fleet vehicle, as it is anticipated that public fleet vehicles will face less of these challenges. Compared to privately owned vehicles, public fleet vehicles may more successfully support V2G applications given they have predictable routes of limited range and are not in use for driving purposes for extended periods of time. After public fleet vehicles conduct their typical routes, they can be plugged in for the entirety of the time they are not in use, enabling them to collect revenues for V2G services for several hours per day. Though this analysis focuses on school buses, the analysis can be applied to other large public fleets such as city buses, garbage and recycling trucks, mail trucks, and other commercial fleets that fit within the same major assumptions of this paper.

Of all public fleet vehicles, school buses are of particular interest because they cause disproportionate health effects, especially on school children's health [13]. Health concerns arise because diesel buses release particulate matter and other harmful pollutants, and these emissions can be disproportionately higher within the cabin of the bus compared to ambient pollution levels [14]. In fact, it is estimated that up to

0.3% of in-cabin air comes from a bus's own exhaust [15]. School buses, for example, have a significant impact on local aerosol levels that could directly influence the health of children [16]. Such concern has been the impetus for several policies requiring the reduction of school bus exhaust pollution. For this reason, the cost-effectiveness of an electric school bus is analyzed because it avoids such health impacts.

While other studies have investigated the costs and benefits of electrifying privately owned vehicles [11], this analysis is novel for its focus on public fleet vehicles and V2G capabilities. For example, Al-Alawi and Bradley compared the costs and benefits of privately-owned conventional vehicles and plug-in hybrids, and found a payback period of 7 to 10 years [17], but did not include the possibility of V2G revenues, which the analysis found to be essential for cost-effectiveness. Feng and Figliozzi found that the electric commercial fleet vehicles were not competitive with conventional diesel commercial vehicles unless either battery costs decreased by 10 to 30% or both the diesel fuel economy was particularly low and vehicles were highly utilized [18]. However, this differs from this analysis in that it does not include V2G revenues and focuses on commercial rather than public fleet vehicles. Furthermore, articles that focus on buses tend not to focus on the costs and benefits, but rather the performance and fuel efficiency of differing types of buses. Hu et al. found that plug-in hybrid buses were more efficient than diesel buses from tank to wheel, and that increases in battery capacity further increased tank to wheel efficiency [19]. While the article determines the efficiencies of the buses, it does not account for any costs, and also does not include V2G capacity. In addition, Dawood and Emadi compared the different fuel efficiencies of differing types of buses, and found that parallel electric hybrid buses had the highest fuel economy and fastest acceleration [20]. Likewise, the article does not explore purely electric buses, V2G capacity, or account for any costs. Peterson et al. investigate the economics of using plug-in hybrid electric vehicle for V2G services, and found benefits of $10 to $120 per year [21] per vehicle. However this paper does not include frequency regulation participation, driving behavior, or purely electric vehicles with higher capacity as this analysis does.

The analysis investigates the cost-effectiveness of using a V2G-capable electric bus compared to a traditional diesel bus. Benefits were assessed such as reduced impacts on climate change, health externalities, and energy efficiency. Limitations were considered such as driving behavior, battery use, and infrastructure challenges. The analysis supports the adoption of V2G-capable vehicles for large fleets as a net benefit and provides implications for transportation policy.

2.4 Material and Methods

2.4.1 Bus Costs

The electric bus considered in this study is the Smith Newton eTrans electric school bus.[2] The eTrans costs $230,000 and can carry 24 adults plus two wheelchair accessible locations. The eTrans can be equipped with a battery pack ranging from 40 kWh to 120 kWh (Personal Communication, Brian Barrington, January 2013)[3]. For this analysis, the eTrans was fitted with an 80 kWh battery that has a range of 100 miles. The eTrans was compared to the counterfactual, a traditional diesel Type C

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[2] Model EN200DSFP900

[3] See http://www.transtechbus.com/

school bus of comparable size and seating capacity. This bus carries 32 adults plus two wheelchair accessible locations [22][4]. The typical cost of a Type C diesel bus is $110,000 [23], and the average fuel economy is approximately 6.35 miles per gallon [24], including the effects of idling on efficiency.

The number of years a school system is allowed to use the buses is regulated by the states. This analysis considered the cost-effectiveness of an electric bus throughout the lifespan of a traditional diesel bus (14 years under Delaware law).[5] Unlike a traditional diesel bus, the eTrans has additional costs because it requires charging infrastructure. It was assumed that a school bus operator would need to purchase a high capacity battery charger with the purchase of an eTrans. This analysis did not consider diesel infrastructure because it was assumed that bus operators would have access to diesel refueling stations. There are varieties of battery chargers, ranging from 3 kW up to over 70 kW. An on-board charger was instead used in the analysis, the EPiC 150 Automotive inverter, because it has a larger capacity. It can charge the battery at 70 kW continuously and discharge at a maximum of 140 kW for a minute, only requiring 208 V three phase plug [25]. The hypothetical cost of installing the

[4] Though the Type C diesel bus and the eTrans are nearly the same size, 12’ by 7.5’, the eTrans has a slightly roomier interior, seating fewer passengers. The Type C diesel bus is commonly named a 66-passenger bus because child passengers are smaller than adults and several more children can fit in the seats.

[5] In adherence to the state of Delaware’s 13 DE Reg 1086, after the fourteenth year, a school bus is required to be replaced for regular use but may be occasionally used as a spare. In addition, if the bus owner chooses, a bus can be replaced before fourteen years. If a bus has been driven 190,000 miles total, 130,000 miles in nine years, or more than ten years, a bus operator can elect to replace a bus. For the purpose of this cost benefit analysis, both buses are assumed to be in regular service for fourteen years.

EPiC 150 is approximately $30,000 (Personal Communication, Allen Abela, June 2013), assuming it was included in the design and construction stage of an eTrans. The overall cost of the eTrans in this paper includes both the actual cost of the bus, and also the charger, totaling $260,000.

2.4.2 Driving Behavior

Driving behavior was estimated based on data collected by the Red Clay School District in Delaware. The average bus route for the Red Clay School District is 50 miles a day and operates on the roads for 5.75 hours each day (Personal Communication, Ron Love, August 2012)[6]. It was assumed that each bus would operate only during the normal school year, which is 177 days, and that there would be no change in driving behavior. When a bus is not in operation, it would either be charging lost energy from driving or performing V2G services.

2.4.3 Energy Costs and Revenues

2.4.3.1 Diesel Costs

The cost of diesel was estimated to be approximately $4.20 per gallon, the average cost of diesel in the Central Atlantic region in 2012 [26]. However, diesel prices are highly volatile and change irrespective of the inflation rate. Though diesel prices have both dramatically increased and decreased, over the last two decades, the average annual price of diesel has increased by 8.5% [27]. The average inflation rate was chosen for this analysis.

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[6] Ron Love is the Education Associate, Pupil Transportation for the Delaware Department of Education.

2.4.3.2 Electricity Costs and Revenues

School buses are usually stored in a parking area, or a bus depot, which is where the eTrans would likely be stationed to connect to the grid and charge. Because they are neither residential nor industrial, schools and their bus depots pay the commercial rate. The average commercial rate for electricity in Delaware is 10.6 cents per kWh [28].

An eTrans would participate in and gain revenues from the regulation market. Federal Energy Regulatory Commission (FERC) recently issued Order 755, finding that the current regulation payment structures were discriminatory towards actors like batteries. FERC required that regional transmission organizations like PJM, the regional transmission organization that operates in Delaware, to restructure payments to include not only capacity but also the amount of total energy charged and discharged and how accurately the regulation market participant reacted to the signal from the market [29]. Due to this order, batteries are paid more than the average regulation market participant because they are a more efficient frequency regulatory market participant. Batteries are more efficient because they can respond to a market change in a matter of seconds, whereas a traditional combustion-based regulation market participant responds in up to 10 minutes [30]. Because batteries respond quicker, batteries are able to charge and discharge more energy than traditional energy sources. Since the PJM's implementation of FERC Order 755, the effective overall market clearing price for regulation services has risen to approximately $28/MWh [31], which was the value used for the analysis.

The cost of electricity also varies widely from year to year, inflating and deflating at a rate independent of the normal inflation rate. Annual electricity inflation rates were calculated according the U.S. average retail price of electricity between

1990 and 2011 [32] . Electricity has fluctuated less dramatically than diesel fuel, ranging between -2% and 9%, per year. The average rate of 1.9% is used for this analysis.

2.4.4 Maintenance

2.4.4.1 Diesel Bus Maintenance Cost

Two factors were included in the maintenance cost. First, to estimate the costs of replacing and repairing parts of the diesel bus, the Federal Land Management Agencies cited a diesel bus maintenance cost of $1 per mile [23]. In this report, other studies were cited with significantly higher per mile maintenance costs, so this should be seen as a conservative estimate. The second factor included in the maintenance cost was the estimated costs of labor to refuel the bus. On average the operators refuel each bus 1.5 times a week, costing $225 annually [33]. It should be noted that the minimal time used to plug the eTrans into the charger was not included in the analysis because the labor requirements are negligible in comparison to the labor used to refuel the traditional diesel bus. The labor requirements of the bus driver for the eTrans would be simply plugging in the bus once it is parked.

2.4.4.2 Electric Bus Maintenance

The eTrans would require much less maintenance because the drive system is simple compared to a diesel bus with less moving parts. Due to this simplification, it is expected the maintenance cost for the electric bus would be significantly less than the traditional diesel bus. Despite this expectation, there are no sources of data concerning average maintenance costs of electric vehicles, making it impossible to be certain of actual maintenance cost.

The major cost of electric vehicle maintenance is battery replacement, depending on the life of the battery and the cost of replacement. A key factor in the lifespan of a battery is the number of cycles of discharge and charge that the battery can withstand before it loses a certain percentage of nameplate capacity. The maximum cycle is estimated based on the depth of discharge in each cycle and the percentage capacity lost. There is not a uniform test for life cycle. For example, the test depth of discharge ranges from 80-100, where as in practice an eTrans would normally not approach this depth of discharge given that it only drives the average 50 miles a day. In addition, the percentage capacity lost before battery replacement can range from 70-90% of original capacity, depending on the standards of the battery manufacturer. As the range of an eTrans with original capacity is double the length of the average daily transit, battery capacity could deteriorate much less that 90% without affecting a bus's daily activities. The battery of an eTrans, an A123, is estimated to last approximately 2,000 cycles given 100% depth of discharge and 90% of original capacity, and more than 7,000 cycles given 100% depth of discharge and 80% of original capacity [34]. The input variable for the lifespan of the battery was 2,000 cycles and should be seen as a conservative estimate for the replacement time of the battery.

Currently, the price of batteries has dropped significantly to $500 to $600 per kWh [35]. However, since the replacement of the battery will not occur until nine years in the future (See Equation 2), and considering that batteries will continue to decrease in the next nine years, this range was not used. Rather, the price used in this analysis is significantly less than current prices, estimated to be $300 per kWh, based on projected goals by the Department of Energy [36]. This is a conservative estimate considering other authors have estimated that prices will be less than that by 2020 [35]. Assuming that an eTrans is replaced with the same capacity battery, a new 80 kWh battery should cost approximately $24,000. While this should represent nearly all the maintenance costs for the electric vehicle, there could be other maintenance costs associated with an eTrans. A similar cost benefit analysis simply estimated that electric vehicles' maintenance costs would be approximately half of that of conventional vehicles [18]. This assumption was used as well for this analysis. Thus, the expected per mile cost of the eTrans should be approximately $0.50. Subtracting the per mile cost of future replacement of the battery, the remaining, miscellaneous cost is $0.20 per mile, the expected cost of all other maintenance.

2.4.5 Health and Environmental Externalities

2.4.5.1 Diesel Externalities

A traditional diesel bus has two externalities associated with the consumption of diesel fuel. First, carbon is emitted during the burning of diesel while driving the traditional diesel bus. The traditional diesel bus will directly emit approximately 22 pounds of carbon through its tailpipe for each gallon of diesel consumed [37]. For the analysis, monetization of the cost of carbon dioxide was based on an average of the social cost of carbon. Over the next decade, the average social cost of carbon is $36 per metric ton of carbon dioxide [38].

In addition to environmental externalities associated with carbon emissions, a diesel bus also emits conventional pollutants that affect public health. The combustion of diesel fuel releases particulate matter, ozone, sulfur dioxide, nitrous oxide, and other pollutants. Such pollutants cause heart disease, respiratory issues, and increased risk of cancer. Based on the weight of a Type C school bus [39], it is classified as a Class 7 Heavy Duty vehicle [40]. The estimated cost of health externalities for a Class 7 Heavy Duty diesel vehicle is $0.08 per mile [41].

2.4.5.2 Electric Externalities

Unlike a traditional diesel bus, an eTrans would have no direct emissions and have only indirect emissions generated by electricity production to charge the battery. The carbon emission rate depends on the generation mix of PJM Interconnection, which is currently dominated by coal, natural gas and nuclear power generation [42]. After multiplying carbon emission rates for each of the generation types [43] by the PJM generation mix, an average emission rate of 1.18 pounds of carbon per kWh was found. Thus, the total carbon emission associated with charging an eTrans' battery was calculated to be 3.56 metric tons a year. This figure is conservative given fuel switching that has already occurred since that study was undertaken (natural gas has been replacing coal and wind and solar energy has increased). Again using the social cost of carbon of $36 per metric ton of carbon dioxide, the yearly cost of carbon for the eTrans was estimated to be $130 a year.

Similar to the traditional diesel bus, pollutants that cause health risks are released via electricity production from fossil fuel sources such as coal, natural gas, and oil. The estimated cost for an electric vehicle is $0.0172 per mile in 2005 and projected to be $0.0149 by 2030 [41]. Because electric generation has changed drastically since 2005 and even since 2013, in that there has been a significant switch from coal to natural gas, and the increased penetration of renewable energy [44], $0.0149 is a more accurate estimate of the health externality associated with an eTran's electricity needs.

2.5 Theory/calculation

The cost benefit analysis was conducted by summing the costs and benefits of each of the respective buses over the fourteen year bus lifespan. Then, each sum was converted into the net present value, using a discount rate of 3%. Since a traditional diesel bus and an eTrans have different seating capacities, the net present value was divided by the capacity, converting the number into a net present value per seat. The traditional diesel bus's net present value per seat was subtracted from the eTrans's net present value per seat to yield the net present benefit of choosing the eTrans over the traditional diesel bus, as seen below.

Equation 2.1 Net present benefit calculation. Refer to the Nomenclature and Appendix A sections for definitions and calculations of variables.

$$NPB = \frac{\sum \frac{R_{V2G} - (E_C + M_E + E_E + B_E)}{(1 + r_d)^y}}{C_E} - \frac{\sum \frac{D_C + M_D + E_D + B_D}{(1 + r_d)^y}}{C_D}$$

Annual V2G revenues were estimated by calculating the price of regulation per hour and the total hours performing V2G per the capacity of the charger. In addition, these revenues would be influenced by the electricity inflation rate. According to these calculations, annual V2G revenues could be approximately $15,000. Receiving this revenue every year greatly reduces the cost of ownership of an eTrans. Annual electricity costs are estimated at a little more than $700, dwarfed by the revenue from V2G, while also significantly less than the annual diesel cost, which was approximately $6,000 per year. The cost of electricity would increase year to year according to the electricity inflation rate as well. Likewise, the diesel cost would also fluctuate with the diesel inflation rate.

As previously mentioned, the annual electric bus maintenance cost was determined by the per-mile maintenance rate, the miles driven a year, and the cost of the battery. The estimated life of the battery was also calculated, according to the equation below.

Equation 2.2 Life of battery calculation. Refer to the Nomenclature and Appendix A sections for definitions and calculations of variables.

$$L_B = \frac{N_{Cycle}}{\frac{d}{r} + f_1 \times H_{V2G/Y} \times f_2 \times \frac{E_{CAP}}{E_S}}$$

The life of the battery is dependent on the uses of the batteries, including driving, charging, and V2G services. The equation above is the life cycle rating of the battery, divided by the uses that impact the battery, resulting in the life of the battery in years. However, each of these uses has a different impact on the life of the battery and needs to be adjusted accordingly. The battery capacity factor, f_2, (also known as the dispatch to contract ratio) determines how the battery degrades according to normal operation and is dependent on several factors such as temperature and state of charge [45] [5]. The battery capacity factor was estimated to be approximately 0.2 [46], which would lead to a conservative estimate of battery life, as other sources have concluded that the battery capacity factor is lower at 0.08 [5]. Meanwhile, the V2G adjustment factor, f_1, or how much performing V2G impacts the life of the battery, is much more uncertain as the market for V2G is now just emerging. Since V2G occurs at a lower state-of-charge with fewer fluctuations, it will not have the same impact as driving. For small states of charges Kempton and Tomic calculated that using Saft batteries and a small fluctuation of state-of-charge (3% depth of discharge), f_1 would be approximately 1/10 of the impact as normal state-of-charge fluctuations [5]. Thus this analysis used an f_1 of 0.1. This factor should be considered conservative because others have found that the increased cycling due to V2G "poses no significant contribution to the overall aging of the battery" [45]. Using the stated equation, the 2,000 estimated life cycles would require a battery replacement in the ninth year. A123 estimates that their batteries will last approximately fifteen years [34], but this does not include potential wearing of the battery due to V2G. The assumption used here is a conservative estimate of battery life, since other sources have documented that using V2G can extend battery life by as much as sixty percent [45]. The authors concluded that the life of battery was extended since V2G services keep the battery at a medium state of charge, thus limiting the time that the battery is in a stressful high state of charge. The equation used in this analysis did not assume that V2G would extend the life of the battery and instead assumed that it would wear the battery, but if the authors' conclusions are true, it is possible that the battery would not need to be replaced at all.

Annual per-mile maintenance costs for each bus was calculated using the per-mile rate and the miles driven each year. Outside of the cost of the replacement battery, the average annual electric bus maintenance cost was calculated to be $1,770, a significant savings compared to the calculated annual diesel bus maintenance cost, $8,850. This leads to significant savings over the lifespan of the bus.

The electricity externalities were calculated based on the annual emission and health externality rates and electricity demand each year. An eTrans's annual externality costs totaled $241, while a diesel bus's totaled $1,060.

In conclusion, the annual fuel, maintenance, and externality costs all represented significant savings from the perspective of an eTrans, while an eTrans additionally provided an equally significant benefit in annual V2G revenues.

2.6 Results

The results are shown below as the net present value, per seat, of an eTrans minus the net present value, per seat, of a diesel bus. Choosing an eTrans rather than a diesel bus would save a school district \$6,000 for every seat or approximately \$230,000 per bus (although this does not account for different seating capacities) over the fourteen year lifespan of each bus. After the large initial investment of purchasing an eTrans, the school bus operator would begin to receive net positive gains from the eTrans in comparison to the traditional diesel bus after five years. If school districts purchase an eTrans, they could save a large amount of money while also shifting away from the consumption of diesel and enhancing school children's health.

2.6.1 Results Without Considering Externalities

While many are interested in the costs of the externalities, school bus operators that purchase buses would not normally include these considerations as a part of their budget. Even without considering the social cost of health and climate change externalities, the net present benefit per seat of selecting the eTrans is still significantly positive, at \$5,700. Thus, selecting a V2G-capable electric bus could provide significant savings for the school bus operator, even when not including any externalities such as benefits for public health and abatement of climate change.

2.6.2 Results Without Considering V2G Revenue

It is clear that V2G revenues are essential to the cost effectiveness of the eTrans. While the net present benefit per seat of the V2G-capable eTrans is $6,070, without V2G capacity, the eTrans would be a have a net present cost per seat of $2,000 (or a net present benefit per seat of -$2,000). However, it makes little sense to pay for a charger with such a large capacity without participating on the regulation services. If one were to buy a simpler, cheaper 15kW charger, for an approximate price of $2,500[7], instead of the 70 kW inverter, the net present cost per seat for the eTrans is merely $115. Considering several other public health impacts that were not monetized (e.g. local health impacts to children on the bus), it is possible that the electric bus, without V2G capabilities, could be as cost effective as a traditional diesel bus. However, the school bus operator would be losing significant potential revenues.

2.6.3 Scaled Results

The Red Clay School District has 179 buses, which serve approximately 13,000 students. Normalized for the seating capacity, the net present benefit of switching their entire fleet could reach nearly $38 million dollars (in 2012$) or nearly $3,000 per student served. In addition, the carbon reductions of switching the entire fleet would be approximately 2,000 tons of carbon dioxide each year, or nearly 30,000 tons over the lifespan of the fleet. The total regulation capacity of this fleet would be about 18 MW, which would be approximately 3% of the overall regulation market capacity on an average hour in PJM. However this likely overestimates the benefits of

[7] The approximate cost of the 15kW charger used for V2G purposes at the University of Delaware.

the switching, since it is unlikely that 3% of all regulation capacity would be situated all in one place. Also the implementation of having 16 MW of capacity on the same local grid would be problematic and likely would require significant investments. Nevertheless, there would still be a clear significant benefit of switching the school bus fleet to V2G-capable eTrans.

2.6.4 Limitations of the Model

There are four key items that were not included in this cost benefit analysis. First, the eTrans would provide a benefit in that it would not pollute the cabin environment while idling, avoiding many health effects to children. Unfortunately, it was difficult to monetize this benefit due to lack of data regarding average idling and health costs.

Another important consideration is that batteries will continue to become more important in the future, especially with the large-scale implementation of renewables, namely wind and solar power. As a larger percentage of the electricity mix is derived from renewable sources, the more intermittent and unpredictable the load will be. This will increase the demand for regulation services and the demand for battery storage. As the grid becomes entirely renewable, there will be a need for large scale implementation of battery storage technology. Using current technology to participate on the frequency regulation market can be seen as a stepping stone to help phase in the large scale implementation of battery storage for the grid. Without these storage capabilities, the costs and reliability of large scale renewable energy could be doubted. The monetization of this benefit was not included in the cost benefit analysis but should be considered as a factor for policy makers.

It was assumed that the power electronics would not need to be replaced in the fourteen-year scope. The power electronics are an integral part of an electric bus's drive system, converting electric power into propulsion. While the power electronics should last longer than fourteen years, it could potentially require a replacement.

Again, while the cost per electric bus model would be similar, several calculations would be different if this analysis was scaled up to several V2G-capable electric buses. For example, unlike a single electric bus, a fleet of V2G electric buses would likely require infrastructure upgrades, including increasing the capacity of local distribution lines, which was not included in the results.

It was also assumed that the electric bus would charge separately from participating in the regulation market. In all likelihood it is possible that an eTrans could charge while performing V2G services, but forecasting of such a model is outside the scope of this analysis. As such, the estimate of hours spent a year participating in the regulation market is conservative.

2.7 Discussions

2.7.1 Sensitivity Analysis

To investigate the effects of individual variables on the net savings, several sensitivity analyses were executed around key variables, including regulation price, the regulation capacity, the electricity inflation rate, diesel inflation rate, miles driven per day, battery replacement cost, the social cost of carbon, and the percent of renewable energy on the grid. The possible range of values for each variable was tested for sensitivity while holding all other inputs constant as the original values used in the cost benefit analysis. The results can be seen in Graph 1.1. The different variables analyzed are discussed below.

The first variable that was analyzed was the regulation price. While the regulation price used in the analysis was $28/MWh, the 8-month PJM average since implementing FERC Order 755, the actual price of regulation varies depending on the market each hour. The actual price that an eTrans will receive for its regulation services will be highly variable from day to day. In addition, the future of regulation prices is likely to increase with increasing presence of wind and solar on PJM's grid. These renewable electricity sources are incapable of tailoring their electricity production to demand, requiring more frequency regulation. A range from $13/MWh, the regulation price in PJM before the implementation of FERC Order 755, to $61/MWh, the 95th percentile of the regulation price in PJM since FERC Order 755 implementation, was examined. Regulation price has a very large effect on the net present benefit per seat of an electric bus, ranging from as little as $1,700 to as much as $15,500 per seat. For an eTrans and a diesel bus to be equally cost-effective, the price of regulation would have to be as low as $6.95/MWh, nearly a quarter of the current average price. Thus, while the regulation price has a substantial effect on the net present value of the bus, it is not influential enough to reasonably cause an electric bus to be less cost-effective than a diesel bus.

Regulation capacity of an eTrans is more influential on the cost-benefit analysis. While 70 kW was used in the analysis for regulation capacity, there are many other potential charging options, and thus capacity options, for an eTrans. Chargers typically range from 3 kW at the lowest capacity, up to more than 70 kW. For the sensitivity analysis, a range of 3 kW to 105 kW was chosen to give a fuller picture of the impact of regulation capacity. While even 70 kW is relatively high on the scale, it is important to note that the EPiC 150, if allowed to bid asymmetrically, could average a regulation capacity of approximately 105 kW. The maximum regulation capacity of 105 kW would nearly double the net present value of the electric bus to $9,450. The increase of regulation capacity increases V2G revenues, which also increases the net present value of the bus. The minimum regulation capacity of 3 kW, assuming that the cost of the charger varies with capacity, decreases the net present benefit of the electric bus to $178. Thus, no matter the capacity chosen, the analysis shows that the eTrans would still be a net present benefit. It should be noted that it is unrealistic that an owner of an eTrans would select such a low level charge, but the analysis supports that the capacity of the charger is influential on the cost benefit analysis. The analysis stresses the importance of maximizing regulation capacity. The value of allowing asymmetrical bids is also highly significant, as changing this rule increases the net present value per seat of the bus by nearly $3,500.

The following variables were not as influential on the cost benefit analysis. The first of these variables, the battery replacement cost, is one such example. Because the future of battery costs is uncertain, the cost to replace the battery, expected in the ninth year, is indeterminate. Using a range from a low of $100 per kWh, a very generous expected future cost of batteries, to a high of $650 per kWh, which is slightly above today's average cost [35], the net present benefit per seat of the eTrans ranges from $6,600 to $5,200, respectively. Many may have expected the price of batteries to be a barrier to the widespread adoption of electric vehicles, but the cost of replacing the battery in nine years makes little difference in the cost effectiveness of the electric bus. This means that while much of the research and money is invested into the decreasing the cost of batteries, the analysis implies that it would be more effective if resources were invested into something else, like increasing the capacity of the charger. In addition, a sensitivity analysis was conducted on the miscellaneous maintenance rate, and even if the eTrans had the same maintenance cost as a diesel bus, there would still be a net present benefit of $4,000 per seat.

Prior to the analysis, it was assumed that the cost of diesel fuel and savings resulting from switching to electricity were major factors that would influence the rate of adoption of electric vehicles; however, the sensitivity analysis suggests otherwise. A sensitivity analysis of the diesel inflation rate was conducted ranging from 0% to 17%. The lower bound assumes that diesel prices stay the same for the next fourteen years, while the upper bound assumes that diesel prices increase at twice the rate than historically expected. If diesel prices stay stagnant, the net present benefit of the electric bus would still be $4,200 per seat. Likewise, if the diesel inflation rate was twice the historical average, the net present benefit of the eTrans would increase up to $9,700 per seat. While it seems highly unlikely that either of these scenarios will indeed happen, it should be noted that for both scenarios, the eTrans is still cost effective. Similarly, the future of the cost of electricity does not change the intuition of the cost benefit analysis. Like the diesel inflation rates, the electricity inflation rates of the sensitivity analysis ranged from zero change in electricity costs to double the expected rate. If electricity rates do not increase, and thus the cost of refueling stays the same throughout the fourteen years, the eTrans will be slightly more beneficial, at a net present benefit of $6,110 per seat. If the cost of refueling the eTrans increased by twice the amount as expected, there would be a slight decrease of the net present benefit to $6,006 per seat. In addition, regardless of the combination of diesel and electricity inflation rates, the eTrans will remain cost effective as seen in Table 1.1 below. In the worst case where diesel prices do not increase at all, and electricity inflation is double the historical average, the eTrans is still a net present benefit of $4,200. On the other hand, if electricity prices do not increase and diesel inflation is double the historical average, then the eTran's net present benefit jumps to $9,800 per seat.

Table 2.1 Net Present Benefit Per Seat For Various Energy Inflation Rates

Net Present Benefit (2012 $) Per Seat		Electricity Inflation Rate (%)		
Diesel Inflation Rate (%)		*0*	*1.9*	*4*
	0	4,300	4,270	4,200
	8.5	6,110	6,070	6,000
	17	9,800	9,780	9,700

Two variables that had a negligible effect on the analysis are the social cost of carbon and the level of renewable energy supplying the electric grid. Varying the social cost of carbon from $10/MTCO_2e$ to $100/MTCO_2e$ only changed the net present benefit of an eTrans by approximately $300, less than 5% of the base case net present benefit. Varying the level of penetration of renewable energy penetration on the grid and the carbon emissions associated with the charging of the battery vary from zero to a hundred percent changed the net present benefit by less than 1%. This may mean that the benefits of climate change mitigation, when monetized, are unlikely to influence an economic analysis of electric vehicles; instead, other benefits of electric vehicles need to be considered.

A commonly held belief is that climate change mitigation could be achieved by implementation of a carbon tax [47] [48]. One of the implications of this analysis is that a potential carbon tax on its own would not incentivize the adoption of electric vehicles for fleets such as school buses. Even a strict carbon tax would have little impact on the cost effectiveness of electric vehicle adoption. If adoption of electric vehicles is required to mitigate climate change, other factors, such as potential V2G revenues, are better economic incentives.

The analysis also suggests that electric vehicle research can be better prioritized. Research should focus first and foremost on increasing the capacity of chargers to perform regulation services for the market. Maximizing potential revenues for regulation services would provide the highest economic incentive to utilize electric vehicles. Though increasing the price and value of regulation services is a key component, increasing the capacity of the charger would have greater effect. For heavy duty electric vehicles with limited daily range, research should be invested into the development of high kW capacity chargers rather than other factors, such as decreasing battery costs.

A simple way to increase capacity in chargers instantaneously is to allow asymmetrical bidding on the regulation market. Asymmetrical bidding would allow frequency regulation participants to bid different capacities for charging and discharging (regulation up and down, respectively). An eTrans equipped with existing technology such as the EPiC 150 inverter is capable of benefiting significantly from such a rule change, increasing the net present value of V2G revenues by 50%.

Asymmetrical bidding also would incentivize the development of inverters that can provide even more benefits than the EPiC 150 can provide for electric heavy duty vehicles. Allowing asymmetrical bidding would require PJM to split its frequency regulation market into two separate markets, a regulation up (or charging) market, and a regulation down (or discharging) market, which would be complicated. Nevertheless, it would be important to consider the potential future of electric vehicles and how they could both benefit from and shape asymmetrical bidding in the regulation market.

Table 2.2 Effects of Individual Variables on Net Present Benefit

Variable	10% Δ in Variable Leads to X% Δ in NPB
Regulation Price	13.3%
Regulation Capacity	13%
Battery Replacement Cost	1.1%
Diesel Inflation Rate	3%
Electricity Inflation Rate	1.7%
Social Cost of Carbon	0.2%
Renewable Penetration	0.06%

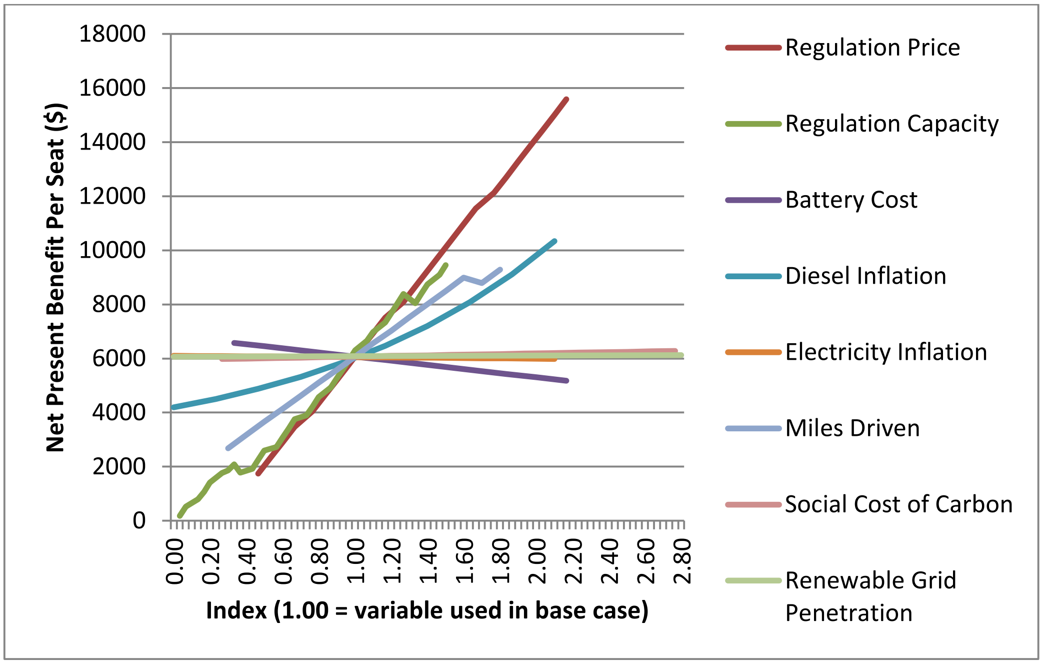

Figure 2.1 Spider Graph of Sensitivity Analysis of Various Variables

It should be noted that regulation capacity has slightly less of an effect on net present value than regulation price given identical percentage change in values for each. However, regulation capacity has a much greater upside, with larger changes in regulation capacity much more likely to occur than regulation price. This supports the conclusion that regulation capacity is the most influential variable, but both capacity and price are essential to the analysis.

2.7.2 International Feasibility Analysis

While the analysis supports the use of grid integrated electric school buses in PJM, there are many other areas of the world that are encouraging the development of electric vehicles and renewable energy. Two similar cases to PJM are the Reseaux de Transports d'Electricte (RTE) of France and Energinet.dk of Denmark. It was assumed that all factors except diesel cost, electricity cost, and regulation price were the same as the United States in France and Denmark. The average price of regulation market for France and Denmark was $23 per MW-h and $25 per MW-h respectively [49]. The diesel price in France was calculated as $7.68 per gallon, and the electricity price was $0.10 per kWh [50]. The diesel cost in Denmark was calculated to be $8.00 per gallon, and the electricity price was $0.13 per kWh [50]. Due to significantly higher diesel prices, the cost-effectiveness of a V2G school bus in France was significantly higher, at a net-present benefit per seat of $7,852. Likewise, Denmark's net present benefit was higher still, at $8,617 per seat. Thus, the analysis highly encourages the development of V2G in fleet vehicles in Europe as well.

2.8 Conclusion

The cost benefit analysis first and foremost shows that with the inclusion of V2G capabilities, adoption of electric heavy duty vehicles is not only possible but imperative. Choosing an electric bus with V2G capabilities over a traditional diesel bus would save $6,070 per seat. Without V2G revenues, an electric bus would not be cost effective, costing thousands of dollars per seat ($2,000 per seat). Yet, the eTrans and the EPiC 150 inverter were both originally designed without consideration of V2G. Electric vehicles cannot afford to not include V2G capabilities in their designs, otherwise adoption of electric vehicles, especially in fleet operations, may be postponed until either the costs of electric vehicles significantly decrease or the costs of traditional vehicles drastically increase. Although making electric buses V2G-capable would require some alterations to the design, such as allowing the discharging of electricity while plugged into the grid, these changes would be comparatively small. Education and outreach thus have a large role to play in helping to ensure that electric vehicle manufacturers and consumers are cognizant of benefits of V2G and its potential to drastically reduce the lifetime cost of ownership of electric vehicles. As well, it is highly recommended that investment (private or government) be made in V2G to further encourage the adoption of electric vehicles.

One problem with the implementation of this model is that the initial costs of an eTrans, coupled with an EPiC 150 inverter may exceed the annual transportation budget of an average school bus operator or other similar fleet manager, as it requires an additional $150,000 in capital costs than a traditional diesel bus. Despite an eTrans being an economically better choice over the lifespan of a bus, it is conceivable a school operator would be forced to choose the less economic traditional diesel bus simply due to budget restraints. Meanwhile, the net present value of the V2G services provided over the fourteen years is approximately $190,000, which would significantly reduce the upfront cost of purchasing the electric vehicle. This situation is apt for a third party that has the capacity for large investments of capital with low risk return over long periods of time. A third party could pay the difference between the traditional diesel bus, making the eTrans just as costly as the traditional diesel bus for the school operator. Meanwhile, the third party could retain the revenues from V2G services performed by the eTrans and would profit a net present value of $40,000, a return of investment about 27%. It is recommended that policies are put in place to encourage V2G and the development of methods for third parties to operate V2G- capable fleets.

Though vehicles that drive limited miles per year may not contribute as much to climate change on a per person-mile basis as other forms of transportation, such as an individually owned private vehicle, this analysis shows that significant contributors to climate change such as buses and other fleet vehicles can be readily replaced by electrified options. Limited range fleet vehicles face fewer obstacles to adoption than individually owned private vehicles, such as range anxiety and lack of charging infrastructure, making fleet operators key potential first adopters of electric vehicles. Inclusion of V2G could incentivize fleet operators to utilize electric vehicles and could be a stepping stone to an eventual widespread adoption of electric vehicles by individual owners. Similarly, the growth of V2G capacity through increased adoption of V2G-capable electric vehicles would encourage and potentially validate high penetration of intermittent renewable energy sources such as wind and solar energy. In conclusion, a V2G-capable electric school bus could save a school district thousands of dollars per seat over the lifespan of the bus, while avoiding health and environmental externalities, and encouraging the further adoption of electric vehicles and the growth of renewable energy.

REFERENCES

[1] Krivoshto I.N., Richardsternet J.R., Albertson T.E., Derlet, R.W. The Toxicity of Diesel Exhaust: Implications for Primary Care. J Am Board Fam Med 2008; 21: 55-62.

[2] Energy Information Association [Internet].Washington DC: Annual Energy Review: Section 2.0 Primary Energy Consumption by Source and Sector, 2011 [Updated 2012, cited 2013 July 8] Available from: http://www.eia.gov/totalenergy/data/monthly/pdf/flow/primary_energy.pdf

[3] Energy Information Association [Internet]. Washington DC: Energy In Brief: How dependent are we on foreign oil? [Updated 2013 May 10, cited 2013 July 8] Available from: http://www.eia.gov/energy_in_brief/article/foreign_oil_dependence.cfm

[4] Intergovernmental Panel on Climate Change. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. Cambridge: Cambridge University Press; 2012.

[5] Kempton W, Tomic, J. Vehicle-to-grid power fundamentals: Calculating capacity and net revenue. J. Power Sources 2005; 144: 268-79

[6] Han S, Han S. Economic Feasibility of V2G Frequency Regulation in Consideration of Battery Wear. Energies 2013; 6: 748-65.

[7] Duan, H., Fan, Y., Zhu, L. What's the most cost-effective policy of CO_2 targeted reduction: An application of aggregated economic technological with CCS? Appl Energy 2013; 112: 866-75.

[8] Budischak C, Sewell D, Thomson H, Mach L, Veron, D, Kempton, W. Cost-minimized combinations of wind power, solar power and electrochemical storage, powering the grid up to 99.9% of the time. J Power Sources 2013; 225: 60-74

[9] Hidrue MK, Parsons GR, Kempton W, Gardner M. Willingness to pay for electric vehicles and their attributes. Resour Energy Econ 2011; 33: 686-705

[10] Zhang L, Brown T, Samuelson S. Evaluation of charging infrastructure requirements and operating costs for plug-in electric vehicles. J of Power Sources 2013; 240: 515-24

[11] Lemoine DM, Kammen DM, Farrell AE. An innovation and policy agenda for commercially competitive plug-in hybrid electric vehicles. Environ Res Lett 2008; 3

[12] Pearre N, Kempton W, Guensler R, Elango, V. Electric vehicles: How much range is required for a day's driving? Trans Res Part C 2011; 19: 1171-84.

[13] Beatty TKM, Shimshack JP. School buses, diesel emission and respiratory health. J. Health Econ 2011; 30: 987-99.

[14] Sabin LD, Behrentz E, Winer A, Jeong S, Fitz D, Pankratz DV, et al. Characterizing the range of children's air pollutant exposure during school bus commutes. J Expo Anal Environ Epidemiol 2005; 15: 377-87

[15]Behrentz E, Fritz DP, Pankratz DV, Sabin L, Colome S.D, Fruin SA, et al. Measuring self-pollution in school buses using a tracer gas technique. Atmos Environ 2004; 38: 3735-46.

[16] Li C, Nguyen Q, Ryan PH, LeMasters GK, Spitz H, Lobaugh M, et al. School bus pollutions and changes in the air quality at schools: a case study. J Environ Monit 2009; 11: 1037-42.

[17] Al-Alawi BM, Bradley TH. Total cost of ownership, payback and consumer preference modeling of plug-in hybrid electric vehicles. Appl Energy 2013; 103: 488-506.

[18] Feng W, Figliozzi M. Conventional vs electric commercial vehicle fleets: A case study of economic and technological factors affecting the competitiveness of electric commercial vehicles in the USA. Proced Soc Behav Sci 2012; 39: 702-11.

[19] Hu X, Murgovski N, Johannesson L, Egardt B. Energy Efficiency analysis of a series plug-in hybrid electric bus with different energy management strategies and battery sizes. Appl Energy 2013; 111: 1001-9

[20] Dawood V, Emadi A. Performance and fuel economy comparative analysis of conventional, hybrid, and fuel cell heavy-duty transit buses. Veh Technol Conf 2003; 5: 3310-5

[21] Peterson SB, Whitacre JF, Apt J. The economics of using plug-in hybrid electric vehicle battery packs for grid storage. J Power Sources 2010; 195: 2377-84.

[22] North Carolina Department of Public Instruction [Internet]. 2009 Model Buses: 66 (50) Passenger with Wheelchair Lift. [Updated 2012, Cited 2013 July 8] Available from: http://www.ncbussafety.org/SchoolBuses.html

[23] Kay M, Clark M, Duffy C, Laube M, Lian FS [Internet]. Bus Lifecycle Cost Model for Federal Land Management Agencies.[Updated 2011 December, Cited 2013 July 8] Cambridge: U.S. Department of Transportation, Research and Innovative Technology Administration. 2011 Available from: http://ntl.bts.gov/lib/44000/44200/44244/Bus_Lifecycle_Cost_Model_User_s_Guide.pdf

[24] Hallmark S, Sperry B, Mudgal A. In-Use Fuel Economy of Hybrid-Electric School Buses in Iowa. J Air & Waste Manag Assoc 2011; 61:5, 504-10.

[25] EPC Power [Internet]. Poway: EPiC 150 Automotive Inverter. [Updated 2013 January, cited 2013 July 8]. Available from: http://www.epcpower.com/epic-automotive

[26] Energy Information Association [Internet]. Washington, DC: Petroleum and Other Liquids: Weekly Central Atlantic (PADD 1B) No.2 Diesel Retail Prices. [Updated 2014 February 3, cited 2013 July 8]. Available from: http://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_r1y_w.htm

[27] Energy Information Association [Internet]. Washington, DC: Petroleum and Other Liquids: Weekly Retail Gasoline and Diesel Prices [Updated 2014 February 3, cited 2013 July 8] Available from: http://www.eia.gov/petroleum/gasdiesel/

[28] Energy Information Association. [Intenet] Washington, DC: Electricity: Average Electricity Consumption, Commercial. [Updated 2013 December 12, cited 2013 July 8] Available from: Average Electricity Consumption, Commercial. EIA

[29] Federal Energy Regulation Commission [Internet]. Washington DC: Order No. 755. 137 FERC 61,604, 18 CFR Sect 35 Docket No. RM11-7-000, AD10-11-000. [Updated 2011 October 20, cited 2013 July 8] Available from: https://www.ferc.gov/whats-new/comm-meet/2011/102011/E-28.pdf

[30] Makarov Y, Ma J, Lu S, Nguyen TB. Assessing the value of regulation resources based on their time response characteristics. Richland, WA: Pacific Northwest National Laboratory; 2008 June PNNL 17632 Contract No. DE-AC05-76RL01830. Sponsored by Department of Energy.

[31] PJM [Internet]. Audubon, PA: PJM Regulation Zone Preliminary Billing Data [Updated 2014 January, cited 2013 July 8] Available from: http://www.pjm.com/markets-and-operations/market-settlements/preliminary-billing-reports/pjm-reg-data.aspx.

[32] Energy Information Association [Internet]. Washington, DC: Electricity: Average Price by State by Provider, Back to 1990 (Form EIA-861) [Updated 2013 December 12, cited 2013 July 8]. Available from: http://www.eia.gov/electricity/data.cfm

[33] Doss, R [Internet]. Pensacola: CNG in Escambia School District Buses. Escambia County School District [Updated 2012, cited 2013 July 8] Available from: http://old.escambia.k12.fl.us/adminoff/trans/Downloads/CNG%20in%20Escambia%20School%20District%20Buses.pdf

[34] A123 Systems, Inc [Internet]. Nanophosphate Basics: An Overview of the Structure, Properties and Benefits of A123 Systems' Propreitary Lithium Ion Battery Technology [Updated 2012, cited 2013 July 8] Available from: http://www.a123systems.com/resources-overview.htm

[35] Hensley R, Newman J, Rogers M [Internet] Battery technology charges ahead [Updated 2012 July, cited 2013 July 8] Available from: http://www.mckinsey.com/insights/energy_resources_materials/battery_technology_charges_ahead.

[36] Howell D. 2009 Annual Progress Report: Energy Storage Research and Development. Washington, D.C.: US Department of Energy 2010.

[37] Environmental Protection Agency. Emissions Facts: Average Carbon Dioxide Emissions Resulting from Gasoline and Diesel Fuel EPA420-F-05-001. Washington, D.C.: Office of Transportation and Air Quality 2005

[38] Interagency Working Group on Social Cost of Carbon. Technical Support Doccument: Technical Update of the Social Cost of Carbon for Regulatory Impact Anlaysis Under Executive Order 12866. Washington, D.C.: United States Government 2013.

[39] The Fourteenth National Congress on School Transportation. National School Transportation Specifications and Proceedures. Warrensburg, MO: Missouri Saftey Center, Central Missouri State University 2005.

[40] Office of Operations, US Department of Transportation [Internet]. Figure 21. Law Enforcement Vehicle Identification Guide. [Updated 2013 August 2, cited 2013 July 8]. Available from: http://ops.fhwa.dot.gov/publications/fhwahop10014/long_f21.htm

[41] National Research Council. Hidden Costs of Energy: Unpriced Consequeneces of Energy Production and Use. Washington, D.C.: National Academy of Sciences 2010.

[42] PJM Interconnection [Internet]. Delmarva Power & Light – Delaware - Fuel Resource Mix [Updated 2012 March 28, cited 2013 July 8] Available from: http//www.delmarva.com/_res/documents/2011fuelresourcemix.pdf.

[43] Moomaw W, Burgherr P, Heath G, Lenzen M, Nyboer J, Verbruggen A. Annex II: Methodology. In: Pichs-Madruga O, Edenhofer R, et al editors. IPCC Special Report on Renwable Energy and Climate Change Mitigation. Cambridge, UK: Cambridge University Press 2011.

[44] Energy Information Association. Annual Energy Outlook 2013 with Projections to 2040. Apr 2013. DOE/EIA-03838.

[45] Lunz B, Yan Z, Gerschler JB, Sauer DU. Influence of plug-in hybrid electric vehicle charging strategies on charging and battery degradation costs. Energy Policy 2012; 46: 511-19.

[46] Fertig E, Apt J. Economics of compressed air energy storage to integrate wind power: A case study in ERCOT. Energy Policy 2011; 39: 2330-42.

[47] Pearce D. The Role of Carbon Taxes in Adjusting to Global Warming. Econ J 1990; 101: 938-48.

[48] Stern N. *The Economics of Climate Change: The Stern Review.* Cambridge and New York: Cambridge University Press, 2007.

[49] Codani P, Kempton W, Levitt A. Critical Rules of Transmission System Operators for Grid Integrated Vehicles Providing Frequency Control. Forthcoming.

[50] Europe's Energy Portal [Internet]. Fuel Prices, Electricity Industry [Updated 2014 February 5, cited 2013 September 23]. Available from: http://www.energy.eu/

Chapter 3

PUBLIC TRUST DOCTRINE IMPLICATIONS OF ELECTRICITY PRODUCTION

3.1 Introduction

The public trust doctrine is a key aspect of property law that places natural resources in the hands of the states who act as trustees on behalf of the public. As a common law doctrine, the public trust doctrine is of particular interest as it imposes a fiduciary duty on the state to protect the environment, as the trustee of these resources for the public, as a principle of sovereignty. In the wake of environmental awareness since the 1970's, the public trust doctrine has grown to be of increasing importance. The doctrine is a unique tool of environmental stewardship.

One of the largest modern impacts on the environment, and thus on public trust resources, is electricity production. Although all types of electricity production have impacts on the environment, conventional electricity's impacts[8] vastly outweigh the impacts of renewable electricity, namely solar and wind. Despite this, the shift from conventional electricity to the more environmentally-benign renewable electricity has been slow and uneven. This paper explores the applications of the public trust doctrine to electricity production, and how this might further incentivize state action towards renewable energy implementation. This paper proposes that applying

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[8] As will be discussed below, this Article defines conventional electricity as electricity derived from coal, natural gas, and nuclear fuel.

individual state's public trust doctrine to the water and wildlife impacts of electricity production presents a better legal argument than previous attempts to apply the public trust doctrine to climate change and electricity production.

The paper focuses on how four states, California, Wisconsin, Hawaii and New Jersey, would potentially consider the public trust doctrine implications of electricity production. However, first, the central argument will be laid out, along with a general history of the public trust doctrine and a brief overview of the environmental impacts of electricity production. Lastly, the paper will conclude with examination of the trust doctrine's application beyond the four cases studies, and a discussion weighing the benefits of the application of the public trust doctrine to wildlife and energy law and policy.

3.2 Applications of the Public Trust Doctrine to Electricity Productions

As will be discussed below, the various environmental impacts of electricity production on water and wildlife resources are also clear impacts to public trust resources.[9] Furthermore, the trustees, mostly states, but also potentially the federal government, clearly have duties and obligations under the public trust doctrine that directly apply to electricity production. Electricity production impacts do not concern questions of title, only the usufructuary rights subject to the public trust doctrine.[10] Thus, in applying the public trust doctrine, the question is whether the "use" of water and wildlife is acceptable within the parameters of the public trust doctrine according

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[9] *See infra* n. 201-264 and associated text.

[10] There are different state responsibilities regarding the title to public trust resources and the regulation of the use of public trust resources. *See infra* n. 66-170.

to the public interest, and not whether the sovereign ownership of these resources are being infringed. It is clear that current electricity production policy does not adhere to the basics of the public trust doctrine. Current wildlife law, as it applies to electricity, is largely based on economic aspects of wildlife, whereas public trust doctrine requires equal consideration of all wildlife interests. Additionally, current electricity production practices clearly conflict with trust responsibilities. The state allows conventional electricity production to use and harm both wildlife and water at practically no cost. Similarly, the benefits to trust resources from renewable energy, given displacement of conventional energy, are undervalued and renewable energy is under-implemented. As a result, states are abdicating their fiduciary duties to protect these public trust resources.

The three actions emanating from the public trust doctrine can be applied to current electricity generation resulting in the enforcement of public trust duties and incorporation of public trust values in decision-making and planning of future generation.[11] First, the states must have a comprehensive, long-term plan regarding the allocation of wildlife and water to the electricity sector.[12] Secondly, the state has an affirmative duty to minimize harm to wildlife[13] and water resources to the maximum extent feasible.[14] Third, the state must ensure that the use of wildlife and

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[11] *See infra* n. 52-68. It is important to note that while these duties are distilled from the implications of current public trust case law, none directly apply this framework to electricity production, and as such an application of these principles to state regulation of electricity production would be novel.

[12] *See United Plainsman*, *infra* n. 89-92. *See also Waiahole I*, *infra* n. 108, at 143.

[13] It should be noted that the wildlife aspect of the public trust doctrine is not as universally accepted as the water aspect of the public trust. *See infra* n. 118-170 and associated text.

[14] *See National Audubon Society, infra* n. 96, at 425-426. *See also Waiahole I, infra* n. 110, at 153.

water does not substantially impair the public interest and is both reasonable and beneficial. If electricity producers unnecessarily harm trust resources, the state has a fiduciary obligation to sue for remuneration for the loss of trust resources and to enjoin actions that continue to damage trust resources.

The application of public trust obligations on current generation can provide a means for the state to enforce wildlife and water mitigation policies. For example, states can require conventional generation to retrofit open-cycle cooling water intake systems (CWIS) to closed cycle CWIS to minimize harm. Likewise, states can also apply these trust duties to wind energy and require bat mortality mitigation policies.[15] Essentially, the public trust doctrine allows states to continually supervise and feasibly mitigate electricity production's impacts on state resources.[16] In sum, the public trust doctrine authorizes states to sue electricity producers to change their behavior in regards to impaired trust resources.

Next, the public trust doctrine requires that the trustee have a comprehensive plan on the allocation of trust resources in respects to electricity production. Principally, the state must develop an electricity plan from a long-term perspective that considers the public interest. Subsequently, given the reduction in harm to trust resources that renewable electricity provides, incorporating the public trust doctrine in electricity planning will necessarily encourage increased development of renewable electricity. Though the public trust doctrine does not guarantee that a certain type of electricity production must be favored, the state must show due consideration and

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[1515] Wind energy has non-trivial impacts on bats, but mitigation techniques are available though not legally required. *See infra* n. 234-236.

[16] *See National Audubon Society*, *infra* n. 97, at 446-7.

weight of public trust values in the plan. Since renewable electricity provides such a significant benefit to the public interest, it will presumably be favored over conventional electricity.[17] Additionally, since trust planning duties are from a long-term, global perspective,[18] integration of climate change impacts is apt and underscores the implementation of renewable energy.

Another application is that states can cite the public trust doctrine as a legal defense for both aggressive renewable electricity policies and requirements for conventional electricity wildlife and water mitigation policies. When conventional electricity producers object to state and federal regulations on the bases of economic impacts, the public trust doctrine can provide a legal basis to go beyond the economics of regulations.[19] The fiduciary duty to prevent impairment to trust resources based on feasibility rather than cost effectiveness gives the states more leeway to enforce environmental regulations while recognizing the non-market values of trust resources.

Beyond the authority and role of the state to implement electricity policy and planning coherent with the public trust doctrine, the public trust doctrine provides a tool for private individuals to force state agencies to adhere to their duties and protect wildlife and water resources that are currently unprotected and impacted by conventional electricity. In states that have public support for, yet limited

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[17] While protection of public trust resources, and thus renewable electricity, are presumed to be favored, this does not mean that renewable electricity must *always* be selected over conventional electricity. It only requires full consideration of all impacts on public trust resources and selection of the type of electricity that minimizes these damages.

[18] *See Waiahole I, infra* n. 108, at 143

[19] *See* Entergy v. Riverkeeper 556 U.S. 208 (2008) (where the plaintiffs appealed a decision that a cost benefit analysis of CWIS regulation was not permissible since it did not account for non-market values).

development of, renewable electricity, citizens can utilize the public trust doctrine to spur state action to implement renewable electricity technology.

Despite the substantial impacts of electricity production on the environment, and the appropriateness of the trust doctrine, there has been practically no such application of the public trust doctrine to electricity production. The case closest resembling this application, Alec v. Jackson, along with a string of other cases, comprise a recent effort to use the atmospheric aspect of the public trust doctrine to force states to act on climate change,[20] known as atmospheric trust litigation.[21] As the atmosphere is incapable of private ownership, "air resources would seem the natural resource most susceptible of treatment as a foundational public trust resource."[22] Yet, air resources have never been the focus of the public trust doctrine, and recent efforts to use the public trust doctrine to mitigate climate change have not made significant progress.[23] These efforts suffer from the uncertainty of whether the public trust doctrine even includes the atmosphere in its *res*. Additionally, because *Alec* sued the federal government to act, the case suffers from the uncertainty to what the federal

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[20]Alec v. Jackson 863 F. Supp. 2d 11 (U.S. Dist 2012), *aff'd by* Alec v. McCarthy, 261 Fed. Appx. 7 (2014), *cert. denied* 2014 U.S. LEXIS 8246 (U.S., Dec. 8, 2014)(No. 14-405).

[21] *See generally* Mary Christina Wood & Dan Galpern. *Atmospheric Recovery Litigation: Making the Fossil Fuel Industry Pay to Restore a Viable Climate System*. 45(2) Envtl. Law Rev. 259 (2015).

[22] Richard M. Frank. *The Public Trust Doctrine: Assessing Its Recent Past & Charting Its Future.* 45 U.C. Davis L. Rev. 665, 679 (2012).

[23] *See* Michael C. Blumm & Mary Christina Wood. *The Public Trust Doctrine in Environmental and Natural Resources Law*. (Carolina Academic Press, 2013) 377 (detailing some state cases attempting to use the public trust doctrine and the atmospheric trust to force states to act on climate change). Though the state versions of Alec v. Jackson originally made some progress, they have not resulted in any significant changes in either the public trust doctrines of those states nor in their climate change policies.

government's role in the public trust doctrine actually is.[24] While the efforts of the plaintiffs in *Alec* to use the public trust doctrine to address climate change, though laudable, were misguided, especially by relying on a federal, atmospheric trust.

Surprisingly the plaintiffs in *Alec* failed to bring claims regarding the water and wildlife impacts of climate change, even though these two resources have a much more concrete trust history and legacy.[25] Climate change will indubitably affect uniquely federal interests in wildlife and water, such as ocean acidification and sea level rise. Additionally, climate change will also impact the state environments that wildlife relies on, and are already within the jurisdiction of the well-defined state public trust doctrine. This Article proposes that a better public trust argument would focus specifically on electricity production. Electricity production, while damaging the "air resource", also damages nearly every other public trust resource both during generation,[26] and through the emission of conventional pollutants and greenhouse gases (GHGs).[27] Electricity production's direct impacts to water and wildlife are clear public trust violations of a state's responsibility as trustee of the public interest, and climate change mitigation could occur within state jurisdictions without addressing any questions regarding the existence of federal trust doctrine. In conclusion,

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[24] As discussed below, *infra* n. 171-200, it is uncertain whether the federal government has any public trust responsibilities, and the current case law is conflicting on the issue.

[25] From a different perspective, one could view the purpose of *Alec* as to bring attention to exclusively climate change, regardless of other public trust resources. So perhaps it is unsurprising that the plaintiffs in *Alec* focused exclusively on the "air resource" as their central strategy, rather than peripheral, albeit more concrete, trust resources.

[26] *See infra* n. 205-221.

[27] *See infra* n. 241-263.

applying a state's public trust doctrine to the water and wildlife impacts presents a stronger legal argument in application to the environmental impacts of electricity production than the one proposed in *Alec* or other atmospheric trust litigation.

Despite the expansion of the public trust doctrine throughout history,[28] there has been little application in the realm of electricity planning and policy. Although some cases attempt to bring public trust implications to some of the environmental impacts of electricity production,[29] there has been little or no application to the full context of electricity policy, with consideration of each individual electricity type's impact on public trust resources. This lack of complete discussion is striking given the legal and social importance of electricity production, especially in the face of climate change.

This Article will investigate the potential application of the public trust doctrine in four states as case studies to explore these differences and illustrating the benefit of applying the water and wildlife aspects of the trust to electricity production. However, first, the Article will provide a history of the public trust doctrine, as well a brief summary of the environmental impacts of electricity production.

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[28] *See* Frank (2012), *supra* n. 22.

[29]*See Alec*, *supra* note 20, (the federal government does not have an applicable public trust doctrine to climate change), New Jersey Department of Environmental Protection v. Jersey Central Power & Light Co. 133 N.J. Super. 375 (1975) (*Jersey Central*) (a nuclear plant is responsible for fish killed during a reactor shutdown under the public trust doctrine) and CBD v. FPL (the public trust doctrine applies to avian life killed by wind farms).

3.3 History of the Public Trust Doctrine

The public trust doctrine first appeared in the Roman code of law Institutes of Justinian,[30] applying state trusteeship over all things that could not be owned by any individual-"the air, running water, the sea, and consequently the sea shore."[31] These environmental properties were classified as *res communis*, implying communal ownership of these resources. Similarly, wildlife was also discussed, however, animals, including birds and fish, were determined to have no owner until capture, and categorized as *res nullius*.[32] In respects to many modern iterations of the public trust doctrine, the doctrine found in the Institutes of Justinian has a more expansive *res*, with applications to many environmental aspects now seen as controversial, such as air.[33] Furthermore, these codes of Justinian were the foundation for the public trust in England, and thus were also the basis for public trust doctrine law in the United States.

An important progression that occurred during the incorporation of the public trust doctrine into English common law was that the ownership of *res communis* was conferred from the general community to the sovereign Crown.[34] The transfer of ownership, however, came with a limitations of power, binding the Crown only to act

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[30] J.B. Moyle trans., Oxford, 1911.

[31] *Id*. at 18.

[32] *Id.* At 19. This distinguishes wildlife, with no owner from water resources, which had communal ownership.

[33] This is especially true due to litigation associated with public trust doctrine's application to climate change. *See Alec*, *supra* note 20, (denying applications of the public trust doctrine to the federal government in respect to climate change mitigation), other courts caution to apply to the air, *See also* Bosner-Lain v. Texas Commission on Environmental Quality, Case No. D-1-GN-11-002194 (201st Dist. Ct. 2012).

[34] *See* Matthew Hale. *De Jure Maris* for a description of the public trust doctrine in England. *See also* Jan Stevens. *The Public Trust: A Sovereign's Ancient Prerogative Becomes the People's Environmental Right.* 14 U.C. Davis L. Rev. 196 (1980). Though the public trust doctrine in England was relatively limited in practice, Stevens argues that the public trust doctrine was theoretically just as expansive as the original Roman doctrine.

"for the benefit of the public."[35] In addition, the scope of the public trust doctrine became relatively limited in practice, with American courts later noting that public trust doctrine jurisdiction in England largely relied on "the existence of tide waters."[36]

Upon the American Revolution, the English public trust doctrine was incorporated into United States law, and the rights and duties granted to the Crown were transferred to the individual states.[37] Though American cases expanded the public trust doctrine beyond tidal waters into freshwater,[38] the American public trust doctrine case law was, for the most part, relatively narrow in comparison to the original Roman public trust doctrine, with most cases limited to the submerged lands, rivers, and game wildlife.[39]

Early public trust doctrine law in America culminated in Illinois Central Railroad v. Illinois. Though decided over 100 years ago, it is considered the

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35 Martin v. Waddell 41 U.S. 367, 370 (1842). To determine the ownership of submerged land in New Jersey, the Court found that Crown's sovereignty over natural resources was limited by the Magna Carta. *See also* Arnold v Mundy 6 N.J.L. 1, 2 (1821), where the Court also concluded that "the king… is restrained by Magna Charta" in his power to grant a fishery to a private individual.

36 Illinois Central Railroad v. Illinois 146 U.S. 387, 434 (1892)(*Illinois Central*).

37 *Arnold* at 2.

38 *See* Stevens at 201. Navigability based on the ebb and flows of the tide "was early rejected in states with large navigable freshwater rivers and lakes where it simply made no sense, especially as steamboats capable of passage upriver were developed." *Id.*

39*See Arnold* (public submerged lands could not be converted into private property), *Martin* (public navigable lands cannot be conferred to private individuals) Carson v. Blazer 2 Binn. 475 (Supreme Court of Pennsylvania 1810) (the State owns the Susquehanna river and the fisheries within that river, and the private owners have the banks have no claim to ownership of the fisheries), Geer v Connecticut 161 U.S. 519 (1896) (the state has the right to regulate the common right to hunting wildlife to the benefit for the people as a trustee) *Illinois Central* (a state's land grant of submerged lands to a private company was void due to the public trust doctrine).

"lodestar" public trust doctrine case.[40] The case concerned a grant, and subsequent revocation, of a substantial portion of the Chicago harbor by the Illinois legislature to the private company, Illinois Central Railroad Company.[41] The legality of the revocation was brought to the Supreme Court. The Court decided that the state did not have the authority to alienate these lands, and thus necessarily had power to rescind the statue, concluding that "trusts connected with public property, or property of a special character…cannot be placed entirely beyond the direction and control of the State."[42] The Court added that public trust resources can only be alienated from the state if either it promotes or does not substantially impair the public interests in the resource.[43] This two-part "substantial impairment" test would become a hallmark of public trust doctrine cases.[44]

However, after *Illinois Central*, there was little progression and evolution of the public trust doctrine in the ensuing decades. In many ways, Joseph Sax revived the public trust doctrine in 1970 with his seminal article, *The Public Trust Doctrine in Natural Resources Law: Effective Judicial Intervention*. In this article Sax argues that:

> "Of all the concepts known to American law, only the public trust doctrine seems to have the breadth and substantive content which might make it useful as a tool of general application for citizens seeking to

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[40] Joseph Sax. *The Public Trust Doctrine in Natural Resource Law: Effective Judicial Intervention.* 68 Mich. L. Rev. 471, 489 (1970).

[41] *Illinois Central* at 439.

[42] *Id*. at 453.

[43] *Id.* at 452.

[44] Reaffirmed in Shively v. Bowlby 152 U.S. 1, 47 (1894) *See also* Stevens at 212.

> develop a comprehensive legal approach to resource management problems."[45]

Since its publication, Sax's article "is perhaps the most heavily-cited law review article" and has "had a catalytic effect among courts and environmental policymakers throughout the country."[46] The revival of the public trust doctrine has resulted in a *res* that has rapidly expanded beyond the traditional American corpus. Applications of the public trust doctrine grew over the decades since Sax's article, and depending on the state, it has been applied to groundwater,[47] non-game wildlife,[48] air quality,[49] and general ecosystem benefits.[50] Furthermore, there is discussion of the application of the public trust doctrine in new novel areas, such as the Economic Exclusive Zone (EEZ),[51] and the atmosphere, given climate change.[52]

3.4 Substance and Scope of the Public Trust Doctrine

The public trust doctrine puts a fiduciary duty on the state, who acts as a trustee on behalf of the public to protect all public trust resources. The duties and

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45 Sax at 474.

46 Frank, *supra* note 22, at 667.

47 In the Matter of the Water Use Permit Applications *(Waiahole I)* 94 Haw. 97, 135 (2000).

48 Center for Biological Diversity v. FPL Group, Inc. 166 Cal. App. 4th 1349, 1361 (2008)("*CBD v. FPL*").

49 National Audubon Society v Superior Court 33 Cal. 3d 419, 434 (1983) (*National Audubon Society*).

50 Marks v. Whitney 6 Cal. 3d 251, 259 (1971).

51 Mary Turnispeed et al. *The Silver Anniversary of the United States' Exclusive Economic Zone: Twenty-Five Years of Ocean Use and Abuse and the Possibility of a Blue Water Public Trust Doctrine*. 36 Ecology L. Q. 1 (2009).

52 Angela Bosner-Lain et al v. Texas Commission on Environmental Quality No. D-1-GN-11-002194 (2012).

rights of the public trust doctrine of the state are intrinsic to the aspects of sovereignty, and "can only be destroyed by the destruction of the sovereign." [53] The three major principles of the public trust doctrine, as summarized by Sax, are:

> "Certain public interests are so important to the population as a whole that private ownership is unwise,
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> Such interests should be freely available notwithstanding economic status since they partake so much of the bounty of nature, rather than of individual enterprise and,
>
> The principal purpose of government is to promote the interests of the general public rather than to preside over the redistribution of public goods to restricted private benefit."[54]

Thus the essence of a state's duty under the public trust doctrine is to affirmatively protect and control public natural resources,[55] promote reasonable public access to these resources[56] and "seek damages for injury to the object of its trust"[57] from private individuals. In addition to the state's duty to preserve and protect public access and enjoyment of public trust resources, the state "cannot destroy or alienate the public's right or abdicate its control of public trust resources without a compelling

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[53] U.S. v. 1.58 Acres of Land 523 F. Supp. 120, 123 (1981).

[54] Catherine Redgwell. *Intergenerational trusts and environmental protection* 40 (Juris Publishing 1999)(citations omitted). Summarizing and analyzing Sax, *supra* note 40, at 485.

[55] *Jersey Central.* at 391.

[56] Charles Wilkinson. *The Headwaters of the Public Trust: Some Thoughts on the Source and Scope of the Traditional Doctrine.* 19 Envtl. L. 425,462 (1989)[hereinafter Wilkinson, *Headwaters*]. Professor Wilkinson concludes that "the right of the public to obtain access [to public trust waters and resources]…is the essence of the public trust doctrine."

[57] State Department of Fisheries v. Gillette 27 W. App. 815, 820 (1980).

public purpose."[58] Furthermore, the state has the responsibility to consider any action that will affect the public rights and uses of trust lands as a matter of general public interest, and should only so permit if the state has given full consideration of the public interest.[59] Beyond these considerations, the only way that the state can alienate control over a public trust resource is if it does not "substantially impair the public interest" in the trust resource.[60] The state is burdened with an inalienable duty to protect and preserve public resources and to prevent alienation of resources that substantially impair the public's interest.[61]

3.5 Scope of Public Trust Doctrine & Electricity Production

The public trust doctrine, as it applies to electricity production, varies both in scope and in character with the varied geographic location of the resources. The public trust doctrine varies from rivers to tidal areas, to the first three nautical miles (nm) of the ocean,[62] and finally to the "federal Territorial Sea", which ranges from 3

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[58] Gary D. Meyers. *Variation on a Theme: Expanding the Public Trust Doctrine to Include Protection of Wildlife*. 19 Envt. L. 723, 726 (1989).

[59] Sax at 531.

[60] *Illinois Central* at 452.

[61] It is important to note that this does not prevent the state from alienating of public trust resources in cases that could damage environmental resources, so long as it promotes, or at least does not impair, the broadly-defined public interest. For example, *see infra* n.272-275 and associated text, where California courts found that drilling for oil does not impair the public interest, but rather promotes the public interest, and thus does not violate the public trust doctrine.

[62] It should be noted that while the states currently own title to the first three nautical miles of the ocean, this was not originally recognized as a common law public trust resource. *See* United States v. California 322 U.S. 19, 32-34, 40 (1947)(California cannot claim title to ocean waters below the low water mark under the equal footing doctrine since the original states did not own title to the three mile belt, and instead belonged to federal government, which held these interests in trust for all people). Instead, the state authority is derived from the Submerged Lands Act of 1953, 43 U.S.C. 1301 et seq. It should be noted that certain states, such as Texas and the

nm to 12 nm, and the EEZ, 12 nm to 200 nm [the federal Territorial Sea and the EEZ hereinafter shall be referred jointly to as the EEZ]. The application of the public trust doctrine to each of these locations, and their wildlife, varies due to the significant differences in each ecosystem and legal jurisdiction.

In addition, each type of electricity production is found in geographically disparate areas. Conventional electricity, including coal, nuclear and natural gas, are commonly found near water bodies, such as rivers, estuaries, or the open ocean, due to their cooling requirements. On the other hand, onshore wind and solar energies are rarely near water bodies, while offshore wind will be placed in the ocean and thus under either state or federal jurisdiction.[63] Each of these will have different applications of the public trust doctrine, as their impacts to trust resources vary accordingly. While conventional electricity has more direct impacts to public trust resources, often being located on navigable waters, the nexus between land-based renewable electricity (i.e. onshore wind and solar) and the public trust doctrine is, for the most part, limited to the wildlife aspect of the public trust doctrine. Finally, offshore wind will be installed on federal lands in the EEZ,[64] and thus the only public trust doctrine implications would either be based on the existence of a federal public

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Gulf Coast of Florida claims the first three marine leagues (equivalent to nine nautical miles) of the ocean in state jurisdiction.

[63] Offshore wind could be within state jurisdiction if it is sited in the Great Lakes, bays or the first 3 nm.

[64] It should be noted that it is possible that offshore wind can be installed within the first 3 miles, and thus remain in state jurisdiction; however, to the extent wind power is considered in oceanic waters, the EEZ is the focus of this paper as it has substantially higher potential capacity.

trust or the extension of state jurisdiction into the EEZ.[65] Thus, the three areas of public trust applications in regards to electricity production are state waters, wildlife, and federal waters.

3.5.1 State Waters

State waters, especially rivers and tidelands, were the original focus of the public trust doctrine. The first example of public trust aspects in American law is found in the Northwest Ordinance of 1787, which decreed that "the navigable waters leading into the Mississippi and St. Lawrence, and the carrying places between the same, shall be common highways and forever free."[66] Many credit the Northwest Ordinance as establishing the public trust doctrine in America,[67] and it is worthy to note that the focus is on navigable rivers, which were at the time highly valued due to commercial transportation, sustenance from fisheries, as well as recreational use. Early applications of the public trust doctrine in rivers regarded title ownership of navigable rivers, as many private citizens attempted to claim these valuable resources as private property.

After the early establishment of public trust principles, the first legal challenges in the courts focused on private citizens who claimed title ownership of a navigable river on the basis of grants that pre-dated statehood. For example, in Carson v. Blazer, the plaintiff contended that he owned part of the Susquehanna River, from a

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65 Hope M. Babcock. *Grotius, Ocean Fish Ranching, and the Public Trust Doctrine: Ride 'em Charlie Tuna*. 26 Stan. Envtl. L.J. 3, 6 (2007)[hereinafter Babcock, *Grotius*].

66 Northwest Ordinance. Article IV. (1787).

67 Matthew J. Festa. *Property and Republicanism in the Northwest Ordinance*. 45 Ariz. St. L.J. 409, 461 (2013)

grant from William Penn, and could exclude others from fishing in the river, since it was not affected by the ebb and flow of the tide, nor saltwater.[68] However, the Pennsylvania court was quick to reject both claims. First, the court dispelled any conceptualizations that navigability would be determined by the salt content of the water or the fluxes of the tide, and instead the title to the river, and right to fisheries, is "vested in the state and open to all."[69] This reasoning was built upon over the next thirty years, in two cases regarding oyster beds and title to navigable waters; Arnold v. Mundy[70] and Martin v. Waddell.[71] In each of these two cases, the plaintiff claimed that he owned the riverbed on which he planted oysters and could exclude the public. Like the Pennsylvania court before them, the private citizen's claim to riverbed title was decidedly rejected by the respective courts. An alienation that entirely divested all citizens of their common right to use navigable rivers, ports, bays, or coasts of the sea, "would be contrary to the great principles of our constitution, and never could be borne by a free people."[72] Upon the American Revolution, each state gained independent sovereignty and owned the absolute right to all their navigable waters and

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[68] *Carson*, *supra* note 39, 2. Binn. 475 (1810). The ebb and flow rule was the common test for navigability in English common law.

[69] *Id.* at 495

[70] *Arnold*, *supra* note 35, 6 N.J.L. 1 (1821).

[71] *Martin*, *supra* note 35, 41 U.S. 367 (1842).

[72] *Arnold* at 13.

lands below them, but subject to the common use of its public and the rights surrendered to the Constitution.[73]

Soon after *Martin*, the U.S. Supreme Court next addressed the question of title of a submerged tidal land of a new state, Alabama, in Pollard's Lessee v. Hagan.[74] Hagan claimed title to this land based on a pre-statehood grant from Spain, whereas Pollard claimed title to the same land based on an Act of the United States Congress, which had held the lands as a territory. The Court was wary of the potential abuse of federal powers, worrying that granting the federal government power to transfer citizens title to navigable waters "might be wielded greatly to the injury of state sovereignty."[75] Accordingly, to protect the sovereignty of new states, the Court held that because the federal government could not alienate any lands in the original states, it could not in new states either since the "new states have the same rights, sovereignty, and jurisdiction over this subject [navigable waters] as the original states."[76] This has come to be known as the equal footing doctrine, and is closely related to the title ownership aspects of the public trust doctrine.

The focus on states continued in in Shively v. Bowlby.[77] The facts of that case mirror Pollard v. Hagan and other title ownership cases: Shively, the plaintiff in error

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73 *Martin* at 410. The rights surrendered to the Constitution include navigational servitude, interstate commerce and international obligations.

74 Pollard v. Hagan 44 U.S. 212 (1845).

75 *Id.* at 230.

76 *Id.* The Court cites the Commerce Clause of the U.S. Constitution as the basis for the equal footing doctrine, as it requires the equal treatment of all states, *see Id.* at 229, which some note as the potential source of a federal public trust doctrine. *See* Wilkinson, *Headwaters*, *supra* note 56, at 456.

77 *Shively*, *supra* note 44, 152 U.S. 1 (1894).

was granted land bordered by the Colombia River in territorial Oregon by Congress, whereas Bowlby received a grant from the Oregon legislature to construct a public wharf on the same land. Here, the Court clarified at the federal government *does* have the power to dispose of territorial submerged lands below the high water mark, but it is restrained by the public interest in the promotion of commerce, navigation, and access to fisheries, as well as fulfilling international obligations, and lastly, consideration of the equal footing doctrine.[78] However, since the federal grant to Shively served none of these purposes,[79] the Court ruled that determination of proper use resided in the states, as "each state has dealt with the lands under the tide waters within its borders according to its own views of justice" and only the states had the power to grant rights "therein to individuals and corporations, whether owners of the adjoining upland or not, as it is considered for the best interests of the public."[80] As a result, the main focus of public trust doctrine has been in *state* law. Moreover, the public trust doctrine in each state varies based on the individual states' views of justice.

These first court cases focused on the title ownership and powers of state governments, careful neither to alienate these crucial waterways to private property owners nor grant the federal government too much power over state resources. It follows that "the most traditional application of the public trust doctrine has been to

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78 *Id.* at 47-50.

79 Furthermore, the federal grant never made any explicit mention of granting Shively the submerged lands under the Colombia River, and as a result, did not explicitly authorize Shively to use the land for any of these purposes.

80 *Id.* at 26. *See also* Phillips Petroleum Co. v. Mississippi, 484 US. 469 (1988) (the states and their legislatures exclusively determine the extent of the public trust doctrine).

tidal and submerged lands."[81] Because of this, there is a strong historical association between the public trust doctrine with state title ownership and property law of submerged lands. However, these cases also held the state's power in public trust lands subject to the public's interest and use. As controversies of title were resolved, the focus turned to the extent of the responsibilities and duties the state holds to the public.

The quintessential example regarding the powers of the state is Illinois Central Railroad v. Illinois.[82] The oft-cited court case regarded a grant from the Illinois legislature to the Illinois Central Railroad Company to develop and own in title over 1,000 acres of the land and waters of the Chicago harbor. The Illinois legislature later changed its mind and revoked the grant. Illinois Central sued the state, arguing the revocation was illegal, while the state defended its position by claiming that state did not have the power to alienate submerged lands in the first instance.

The court ruled that "it is settled law of this country that the dominion and sovereignty over lands covered by tide…belong to the respective States within they are found."[83] However, this sovereignty is "held in trust for the people of the State"[84] and thus qualified by the state's duty to the public and subject to the "substantial impairment" test, as discussed above.[85] Furthermore, the state is burdened with this

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[81] Frank, *supra* note 22, at 672.

[82] *Illinois Central, supra* note 36, 46 U.S. 387 (1892).

[83] *Id.* at 435.

[84] *Id*. at 452.

[85] *See supra* notes 37-38 and associated text.

trusteeship, and "can no more abdicate its trust over the property in which the whole people are interested… than it can abdicate its police powers in the administration of government and the preservation of the peace."[86]

Based on this reasoning, each state has an inalienable duty to the public to maintain and prevent impairment of the public's interest in the waters held under the public trust doctrine.[87] However, while title ownership is clear, the extent of the "public interest" is much vaguer, and depends on the interest and use of public trust waters. In accordance with the state determination of public trust doctrine, the extent of what is incorporated in the usufructuary rights of the public in trust waters is determined within each state. Given the significant change of public attitudes regarding water use since the 19th century, it follows that the public's relationship to state waters has considerably changed in respect to the way in which the public uses waterways. As a result, the "most significant expansion of public trust principles has been in the context of the doctrine's application to water rights."[88] Over the last forty years, as the public became more cognizant of the limits of water resources and their importance to the environment, the public interest shifted from the navigation and commerce to environmental protection and conservation. The development led to the ongoing definition and evolution of the public's interest and the public usufructuary right in public trust resources.

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86 *Id.*

87 In Justice Fields' broadly written opinion in *Illinois Central*, he was careful to keep the trust applicable to any property of a special character, and not just lands under navigable waters. See *Id.* at 454.

88 Frank, *supra* note 22, at 675. While the public's relationship to the environment as a whole has evolved over the decades, this public trust expansion in regards to water can be explained by the trust's historical connection to submerged lands.

The extent of a state's duty to protect such public interests was first addressed in United Plainsmen Association v. North Dakota State Water Conservation Commission. The plaintiffs filed a complaint against the Commission and the State Engineer in an attempt to prevent a water allocation permit to a coal fired plant.[89] The United Plainsmen claimed that under North Dakota statutes and the common law public trust doctrine, the State Engineer could not allocate water to the coal fired plan until there was a comprehensive short and long term plant for the conservation and development of North Dakota's natural resource. The court ruled that there was no mandatory planning responsibilities due to statutory law, yet found that "the discretionary authority of state officials to allocate vital state resources is not without limit, but is circumscribed by what has been called the Public Trust Doctrine [sic]."[90]

The court continued that in "performance of this duty of resource allocation consistent with the public interest, the Public Trust Doctrine [sic] requires, at a minimum, a determination of the potential effect of the allocation of water on the present water supply and future water needs of this state."[91] Thus, the power of the state to alienate public trust resources is burdened by some proof of consideration of the public trust implications. In conclusion, the court agreed with the plaintiffs, that under the common law public trust doctrine, the state is required to show that the public interest in the resources has been incorporated before issuing a permit. The

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89 United Plainsman v. North Dakota State Water Conservation Commission 247 N.W.2d 457 (1976)(*United Plainsmen*).

90 *Id.* at 460. The Court cites *Illinois Central* as a foundation for the public trust interests that would require such planning.

91 *Id.* at 462.

court also clarified that the analysis of present supply and future needs of natural resources is part of the most traditional conceptualization of the public trust doctrine and this would not be an expansion of the public trust doctrine.[92]

The implication of the state's duties under the public trust doctrine was further developed in National Audubon Society v. Superior Court of Alpine.[93] The National Audubon Society sought an injunction against the Los Angeles Division of Water and Power (DWP) and the California State Water Resources Control Board (SWRCB) to prevent the diversion of waters from the rivers that feed Mono Lake. Due to the diversion of practically the entirety of four of the five Mono Lake tributaries, the surface area of the lake had decreased by nearly 30%.[94] The drop in the lake's level caused significant declines in local and migratory wildlife populations, due to new access by predators. The plaintiffs claimed that the diversions from these tributaries were impairing the public interest in Mono Lake, specifically, the recreational and ecological value provided by the lake.

While recreational and ecological values were not considered traditional aspects of the public trust doctrine, the Court agreed with the plaintiffs that it is clear that the public trust doctrine "protect[s]…the scenic views of the lake and its shore,

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92 *Id.* at 463. As this opinion was written after Sax, *supra* note 40, which argued for the expansion of the public trust doctrine to new frontiers of environmental problems, the Court was sure to distinguish this application from new potential applications of the public trust doctrine.

93 *National Audubon Society*, *supra* note 49, 33 Cal. 3d 419 (1983).

94 *Id.* at 429.

the purity of the air, and the use of the lake for nesting and feeding by birds."[95] Furthermore, the court held that the core of the public trust doctrine places not only a sovereign authority in the hands of the state, but more than that, also burdens the state with an affirmative duty to "attempt, so far as feasible, to avoid or minimize any harm to those interests."[96] In the view of the court, the state must include public trust values into planning and allocation of water resources, show the costs and benefits of any decision regarding trust resources, and continually supervise the taking and use of the water allocated.[97] Therefore, the state must actively and continually plan and protect trust uses, and whenever *feasible* avoid any and all impacts to trust resources.

The implications of this case are potentially far-reaching: essentially any decision that the state has made regarding water resources not only must include consideration of the navigational and commercial interests of the public, but also the public's interest in any recreational and ecological uses of the water. Furthermore, *National Audubon Society* implies that these water allocation decisions are forever and continually ripe for review under the public trust doctrine. However, while many believed that this would encourage further development of the public trust doctrine, in the immediate decades after the decision practically, "no court outside of California ha[d] adopted the full extent of *National Audubon Society*."[98] To be sure, *National*

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95 *Id*. at 435. In fact, the Court went on to also include local air quality as part of the trust resources that needed to be considered in this decision (since dropping water levels left soil particulates open to the air, and were being transported by winds to local areas).

96 *Id.* at 425-6. This was in response to the SWRCB claiming that there was nothing that could be done, even under the public trust doctrine, since they had no authority to change previously permitted water allocations.

97 *Id*. at 446-7.

98 Gregory Weber. *Articulating the Public Trust: Text, Near-Text, and Context*. 27 Ariz. St. L.J. 1155, 1171 (1995). Weber also argues that *National Audubon Society* left several doctrinal questions unanswered, and the case

Audubon Society presented a somewhat extreme case in which the permitted owner of the water rights was non-local and politically controversial, and caused substantial decreases in the area of the second largest lake in the state (from 85 mi^2 to 60.3 mi^2). This in turn impaired *all* public trust uses, including boat navigation and a local commercial brine shrimp fishery in addition to the recreational and ecological uses of the lake – all while an obtuse Water Board refused to take any action. Nevertheless, the state's duty to protect the public interest under the public trust doctrine continued progressing 20 years later in Hawai'i.

In the case In the Matter of the Water Use Permit Applications (*Waiahole I*),[99] the Hawaiian Supreme Court was presented a controversy on water allocation permits within the Waiahole Ditch System on the Hawaiian island of Oahu. Waiahole Ditch, originally built over 1913 to 1916, transported water from fresh surface water and groundwater from the windward side of Oahu to the leeward side, originally for a sugar plantation.[100] In 1992, the Commission on Water Resources Management (CWRM) of Hawaii designated five aquifer systems as ground water management areas, including the Waiahole Ditch System, requiring all existing users to apply for use permits within a year. Upon this, the sugar plantation then announced the

law has not resolved these issues. But also note that several public trust cases adopting *National Audubon Society* have occurred since 1995, *see e.g. Waiahole Ditch I, infra* note 115. *See also infra* notes 292-301 (discussing the development of the California public trust doctrine beyond *National Audubon Society*).

[99] *Waiahole I*, *supra* note 47, 94 Haw. 97 (2000).

[100] *Id.* at 111. As a result of continued over-allocation of water for the plantation, many had noticed significant impairment to the windward streams, affecting ecosystem and human productivity.

cessation of its operations, meaning that this water could be allocated to other users.[101] Over 25 parties submitted permit applications for water allocation, and uses included agriculture, restoration of streams, along with other uses, such as golf course irrigation.[102]

After consolidating the permit applications into a series of combined contested hearings in 1995 and 1996, the CWRM made its final decision of water allocation. Of the 27 million gallons per day (mgd) of total flow available, the Commission allocated 6 mgd to in-stream flow restoration, 12.2 mgd for various agricultural uses, 1.29 mgd for a state prison, a cemetery and a golf course, 5.39 mgd for a "non-permitted groundwater buffer" and 1.58 mgd reserved for future agricultural development.[103] The non-permitted ground water was designated as groundwater that could be used for further allocations in the future, and was explicitly not included as part of the flow restoration of the windward streams, meaning that the CWRM allocated nearly three quarters of the available water to human use and consumption.

The CWRM designated the 6 mgd to in-stream flow restoration as a competing use along with the agricultural and non-agricultural uses, and cited scientific uncertainty preventing the CWRM from knowing the ecologically optimal standard for in-stream flow. The CWRM effectively assigned "the windward streams the water remaining after it had approved the bulk of the offstream [sic] use permit requests."[104]

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[101] *Id.* at 111-112. During the interim, the excess water was used to restore the windward streams, having an immediate and apparent positive effect.

[102] *Id.*

[103] *Id.* at 116-118.

[104] *Id*. at 153

While the CWRM uses the public trust doctrine as the basis for many of its decision, however, it did not apply public trust responsibilities to the water allocation of the windward streams. Many of the 25 parties appealed the CWRM's decision to the Hawaiian Supreme Court, with the central issue regarding the limited allocation of water to in-stream restoration.[105] The appellants claimed the CWRM failed its public trust responsibilities by not protecting the public interests of the windward streams.

To determine the validity of the CWRM's allocation, the court first explored the extent of state agency responsibilities under the public trust doctrine. The court held that the CWRM has "the authority and duty to maintain the purity and flow of our waters for future generations and to assure that the waters of our land are put to reasonable and beneficial use."[106] The Court continued that the "[u]nder the public trust, the state has both the authority and duty to preserve the rights of present and future generations in the waters of the state"[107] and "also requires planning and decisionmaking [sic] from a global, long-term perspective."[108] Finally the state is compelled by the public trust doctrine "to consider the cumulative impact of existing and proposed diversions on trust purposes and to implement reasonable measures to

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105 Other periphery issues included; potential conflicts of interest, illegal pressuring from the governor, potential over-allocation of water beyond agriculture's stated water need, improved measurement of water allocation, the Commission's lack of alternative water source analysis, and the merits of allowing for ditch system losses in permit allocation.

106 *Id.* at 138 (citations omitted).

107 *Id.* at 141.

108 *Id.* at 143.

mitigate this impact, including use of alternative sources."[109] In sum, the CWRM has an affirmative duty to preserve the intergenerational rights of water resources from a global, cumulative perspective, while assuring also the water resources are being utilized in a reasonable and beneficial manner that lacks any practical alternative.

The court held that "the Commission has an affirmative duty under the public trust to protect and promote instream trust uses"[110] antecedent to allocating water for other uses. Likewise, those who seek water allocation permits are burdened to "justify them in light of the purposes protected by the trust."[111] As a result, the court found that the Commission, under its comprehensive public trust duties, *must* designate the in-stream flow protection standards *before* it authorizes off-stream diversions – otherwise it is impossible to know if these diversions are "potentially detrimental to public instream uses and values."[112] In light of the CWRM's public trust duty, and the uncertain scientific knowledge of the ecological benefits of in-stream flow, the court "did not consider the Commission's decision…overly protective", instead it appears "to provide close to the least amount of instream use protection practicable under the circumstances."[113] As a result, the court vacated much of the CWRM's

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[109] *Id.* Highlighting the importance of alternative water sources the court directed two parties to show that there was no practical alternative to their proposed diversion, *See Id.* at 189.

[110] *Id*. at 153

[111] *Id*. at 142.

[112] *Id.* at 148.

[113] *Id.* at 155.

water allocation, and remanded back to the CWRM to determine the optimal in-stream flow standards consistent with the court's ruling.[114]

The implications of *Waiahole I* go beyond the prioritization of public trust duties over other uses of water. Building upon *National Audubon Society*, the *Waiahole I* court required the state to plan allocations of water sources from a global and cumulative perspective while remaining cognizant of the intergenerational rights to the water resource. In addition, *Waiahole I* also incorporated a reasonable-beneficial use test as an aspect of the public trust doctrine, stating that any proposed use of water must not only not conflict with the public interest in these waters, but also that it not be wasteful or unnecessary.[115]

In conclusion, over the last 40 years, the public usufructuary right, and associated duty of the state to protect the public interest in the public trust waters has been slowly evolving towards three key ideas: the planning of public trust resource allocation, minimizing harm to trust resources when feasible, and ensuring that the uses that potentially conflict with public trust values are both beneficial and reasonable, and do not cause substantial impairment. First, the state must plan water trust resource allocation in a way that is comprehensive, intergenerational, and global. Second, the state, as the trustee for the public, has an affirmative duty to continually

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[114] *Id.* at 189. However, the controversy persisted many years after the conclusion of this case, and continued in In the Matter of Water Use Permit Applications 105 Haw. 1 (2004) (*Waiahole II*) (upon remand, the Commission failed to adequately determine the optimal in-stream flow of the windward streams on the best science available, remanding to the Commission again) and In the Matter of Water Use Permit Applications 103 Haw. 346 (Haw. Ct. App. 2010) (*Waiahole III*) (the Commission's third decision did not err in establishing the in-stream flow standards, but did err in granting a golf course a permit without sufficient proof that it would actually use the water).

[115] See *Id.* at 160-1, discussing the definition of a reasonable use, including, the purpose of the use, its economic value, the potential damages to society, and potential mitigation of waste or harm.

look for ways to minimize harm to water resources. Lastly, for the uses of water resources that are permitted, the state must ensure that the use is reasonable and beneficial, i.e., not wasteful.

The application of these three aspects to the impacts from electricity production on water resources[116] are clear. First, it is evident that these impacts fall within the jurisdiction of state's public trust doctrine powers and duties, not as a matter of title or sovereign ownership, but rather as the part of the state's duty to protect the public interest in the usufructuary rights of state waters. As a result, the state must have a comprehensive plan regarding its allocation of water for electricity production CWISs, should continually look for feasible ways to minimize the harm caused by electricity production, and ensure that the water allocated to electricity production plants does not substantially impair is beneficial to society and do not unreasonably waste water.

3.5.2 Wildlife

Electricity production also significantly impacts wildlife. While there is now a significant nexus between the water and wildlife aspects of the public trust doctrine, the wildlife trust doctrine evolved as a separate doctrine. Like title ownership of submerged lands, the wildlife aspects of the public trust doctrine can be similarly traced to England, as several cases decreed royal ownership of various forms of wildlife, including oysters, salmon, swans and whales.[117] Likewise, in the earliest American public trust cases, wildlife, namely oysters and other fisheries, was present

[116] *See infra* note 201 and associated text.

[117] Blumm & Wood, *supra* note 23, at 195.

and the rights to use such wildlife were integral to these cases.[118] But since the focus of these cases was commerce rather than wildlife, per se, early wildlife trust case law only explicitly focused on the public's right to access commerce.

Moreover, wildlife was not explicitly incorporated into the American public trust doctrine until Geer v. Connecticut in 1896.[119] In that case, the state of Connecticut passed a statute that made it unlawful to transport wild game birds outside the state.[120] The plaintiff was charged with violating this statute when he attempted to transport birds, which he had killed legally, across state lines. The plaintiff sued Connecticut, claiming that the statute was in violation of the Commerce Clause.

The Supreme Court disagreed with the plaintiff, deciding that the right to take wild animals has always been "subject to the control of law-giving power."[121] The Court likewise cited the common law of England as a source of the American wildlife trust, based "upon the principle of common ownership, and therefore treated it as subject to governmental authority."[122] The Court held that wild game belonged to the people in their collective sovereign capacity, and that this ownership of wildlife is held by the state as a trustee for the benefit of the people.[123] As a result, the right of a

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[118] *See Arnold* and *Martin*, *supra* note 35. *See also Carson*, supra note 39.

[119]Geer v. Connecticut, *supra* note 39, 161 U.S. 519 (1896).

[120] This law, along with other similar statues in other states, was enacted in response to the decimation of game birds by market hunters. *See* Michael Blumm & Lucus Ritchie. *The Pioneer Spirit and the Public Trust: American Rule of Capture and State Ownership of Wildlife*. 35 Envtl. L. 673, 696 (2005).

[121] *Geer* at 522.

[122] *Id.* at 526

[123] *Id.* at 529.

private individual to take wildlife is qualified by the power of the state. The Court ruled that since the Connecticut statute which qualified Geer's right to acquire any animal was "for the common benefit… [it] clearly demonstrates the validity of the statute of the State of Connecticut here in controversy."[124]

Typical of early cases, *Geer* describes the authority of the state to regulate its trust resources. Yet, while the *Geer* Court's analysis anchored on the "sovereign ownership" theory of wildlife, the wildlife trust at that time was disconnected from the other aspects of the public trust doctrine.[125] In fact, though *Geer* is seen as one of the cornerstones of establishing the wildlife aspect of the public trust doctrine, it does not cite *Illinois Central*, despite occurring only four years after *Illinois Central* was decided.[126] This difference is intuitive since it is much easier to determine title to a parcel of land, albeit submerged, than a specimen of wildlife. Atypical of other early public trust doctrine cases, *Geer* also presents a conflict between state and federal power, specifically the Commerce Clause. Due to the transboundary nature of the ecological and commercial aspects of wildlife (especially in comparison to submerged lands), this case thus presented a unique conflict between the public doctrine and access to commercial activities.[127] Although public trust doctrine cases had

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124 *Id.*

125 *See supra* note 43-62, and associated text.

126 While *Illinois Central* was not cited, the language of *Geer* parallels *Illinois Central*, especially regarding the inherent sovereignty of the state to regulate common trust resources as an exercise of its police power. *Compare Illinois Central*, *supra* note 36, 146 U.S. at 459, and *Geer* at 534.

127 In *Geer*, the wildlife trust was used to constrain interstate access to commerce. *Compare Arnold*, *supra* note 35, where the public trust doctrine was used to guarantee open access to the commercial activities of submerged lands.

previously found that state powers regarding trust water resources were subject to the rights of the federal government under the Constitution,[128] the *Geer* Court held that the statute in question was immune because it was benefiting the public of Connecticut which "owned" the wildlife. As a result, "in the years following the decision, states' rights advocates routinely ignored this limiting language [subjecting state trust powers to the federal government], adopting Geer's most expansive interpretation and maintaining that, as owners of wildlife, states were entirely beyond the reach of federal authority."[129] As a result, most of the early wildlife trust cases focused on the conflict between state and federal powers.

The expansive powers of states to regulate wildlife beyond federal constraints were limited over the next several decades. In addition, because wildlife is an example of *res nullius*, implying the impossibility of true ownership, the "sovereign ownership" theory presented in *Geer* was questioned and eventually overturned. First, the Supreme Court addressed the treaty power of the federal government in Missouri v. Holland.[130] Despite state statutes attempting to protect various species of birds, their populations were continually and consistently "in danger of extermination through lack of adequate protection."[131] As a result, the United States and Great Britain, acting on behalf of Canada, signed a treaty to protect migratory birds, leading Congress to enact the Migratory Bird Treaty Act (MBTA) in 1916, to prohibit the

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128 *Martin*, *supra* note 35, 41 U.S. at 410, and *Shively*, *supra* note 44, 152 U.S. at 14.

129 Blumm & Ritchie, *supra* note 120, at 700. The authors note that this is likely not what the court in *Geer* had intended, and in fact was careful to show that state powers were still subject to federal preemption.

130 Missouri v. Holland 252 U.S. 416 (1920).

131 *Id*. at 431.

killing, capturing or selling of any migratory bird without a permit from the federal government. The state of Missouri sued the federal government, saying that such regulations directly conflicted with the rights reserved to the state.

The Supreme Court disagreed with Missouri, concluding that while there is "no doubt it is true that as between a State and its inhabitants, the State may regulate the killing and sale of such birds…it does not follow that its authority is exclusive of paramount powers."[132] The Court ruled that since the birds protected under the MBTA were of such significant value as a food source and a form of pest control, "it is not sufficient to rely upon the States…, [so] the treaty and statute must be upheld."[133] Furthermore, the court held that since wild birds are incapable of being possessed by anyone, and possession is the hallmark of ownership, the state's claim to title ownership "is to lean upon a slender reed."[134] Essentially, not only could the states not truly claim title to wildlife and the associated rights of title ownership, but whatever rights, powers, and duties a state does possess are constrained by the paramount power of the federal government.

The Supreme Court continued to poke holes in the superiority of the "sovereign ownership" theory. In a case regarding a state questioning a federal program of killing and removing excess deer on federal lands, the Supreme Court declared that "the power of the United States to thus protect its lands and property does not admit of doubt, the games laws or any other statute of the state to the contrary

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132 *Id.* at 434.

133 *Id.* at 435. The Court was clear that even if it was sufficient to rely on the States, it is still well within the treaty powers of the United States to preempt the state's right to regulate wildlife.

134 *Id.* at 434.

notwithstanding."[135] Thus, state's power under the "sovereign ownership" theory was further restricted by the Property Clause. Next, the Supreme Court further constrained state authority under the Equal Protection Clause. In a case where California denied a legal alien a fishing permit based on the fact of California's ownership of wildlife and its powers under the public trust doctrine, the Supreme Court rejected California's claim and held:

> To whatever extent the fish in the three-mile belt off California may be "capable of ownership" by California, we think that "ownership" is inadequate to justify California in excluding any or all aliens who are lawful residents of the State from making a living by fishing in the ocean off its shores while permitting all others to do so.[136]

As a consequence, these cases, along with a few other peripheral Supreme Court cases, "destroyed the argument that state ownership of wildlife superseded federal species legislation" and while none of these cases explicitly overturned *Geer*, they paved the way for *Geer*'s Commerce Clause rationale to be overruled.[137]

This would occur in Hughes v. Oklahoma.[138] The facts of this case are similar to *Geer*: the plaintiff purchased legally caught minnows in Oklahoma, but was

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[135] Hunt v. United States 278 U.S. 96, 100 (1928).

[136] Takahashi v. Fish and Game Commission 334 U.S. 410, 421 (1948) (emphasis in original). The Court went on to further distinguish California's claim of ownership of wildlife from a state's claim to ownership of land. While skeptical of continued validity of California's power to discriminate against aliens in cases regarding land ownership, the Court differentiated cases that supported such discrimination as being "supported on reasons peculiar to *real* property." *Id.* at 422 (emphasis added).

[137] Blumm & Ritchie, *supra* note 120, at 703-704. As further examples of the Supreme Court undermining the ownership theory the authors also cite Toomer v. Witsell 334 U.S. 385 (1948) (state ownership of wildlife is subject to the Privileges and Immunities Clause of the Constitution) and Kleppe v. New Mexico 426 U.S. 529 (1976) (state ownership of wildlife is subject to the power under the Property Clause to protect wildlife on federal lands).

[138] Hughes v. Oklahoma 441 U.S. 322 (1979).

arrested by an Oklahoman game warden when attempting to transport the minnows across state lines for the purpose of reselling the minnows in Texas in violation of an Oklahoman statute. The plaintiff challenged the statute, claiming it was in violation of the Commerce Clause, whereas Oklahoma defended its statute based on the "sovereign ownership" theory in *Geer*. The Supreme Court rejected the "sovereign ownership" theory as "no more than a 19th legal fiction expressing the importance to its people that a State have [sic] a power to preserve and regulate the exploitation of an important resource... and therefore expressly overrule *Geer*."[139]

In rejecting the "sovereign ownership" theory as legal shorthand, the Court held that any power of the state to regulate the possession of wildlife was subject to the paramount powers of federal government, including the Commerce Clause. The court consequently treated the Oklahoma statute using the general rule regarding conflicts with interstate commerce.[140] Although the Court ruled that the Oklahoma statute served a legitimate local purpose under the public trust doctrine, it was far from the least discriminatory alternative available.[141] Citing the aforementioned cases, the Court held that the "sovereign ownership" theory had been nearly eroded to the point of extinction, and could no longer be used by the state to immunize itself from federal powers.[142]

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139 *Id*. at 335 (citations omitted).

140 *Id.* at 336.

141 *Id.* at 337. The dissent, however, argued that while the "sovereign ownership" theory was in fact legal shorthand, it does not dispel the effect of said theory: that states are warranted to use broad authority in order to protect wildlife. Furthermore, the dissent argued that the statute allowed interstate commerce of hatched minnows, only barring transportation of natural minnows, and the impact to interstate commerce is negligible, *See Id.* at 345.

142 *Id*. at 331.

Thus, the main question in Hughes v Oklahoma was not whether the public trust doctrine applies to wildlife, but rather, whether or not wildlife regulation is subject to the Commerce Clause. In fact, the *Hughes* court was careful to show that, as long as a state law was compatible with the Commerce Clause, its ruling made "ample allowance for preserving…the legitimate state concerns for conservation and protection of wild animals."[143]

As *Hughes* only addressed the powers of the state to regulate wildlife when they conflict with federal guarantees, practical implementation of the "sovereign ownership" theory within states remained intact.[144] Accordingly, state courts have embraced state authority and duty to protect wildlife resources as a trustee of the public while still relying on the sovereign ownership theory by either distinguishing the case from *Hughes* due to an absence of federal controversy, or simply ignoring *Hughes* entirely.[145]

While "[s]tates clearly have broad powers and discretion to conserve their wildlife" inasmuch as those regulations are "consistent with constitutional limits and guarantees,"[146] the nature of the wildlife trust is distinct from the trust in submerged lands and their waters. Because states cannot own title in the wildlife, the state can only regulate the usufruct rights of wildlife. Perhaps due to the difficult characteristics

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[143] *Id.* at 335-6.

[144] Moreover, a recent U.S. Supreme Court case as breathed new life into the state's ownership of *ferae naturae* wildlife, possibly reopening the sovereign ownership theory. *See* at Horne v. Department of Agriculture, 576 U.S. ___ (2015) at 14.

[145] Blumm & Ritchie, *supra* note 120, at 707-708. The authors also note that "[r]ecent scholarly commentary overwhelmingly confirms this interpretation." *Id.* at 706.

[146] *Id.* at 711.

of the property aspects of wildlife, "few cases directly address the duties and obligations of a state" under the public trust doctrine.[147] Despite nearly universal claims of public trust ownership of wildlife,[148] few state cases have discussed any affirmative duties under the trust doctrine as is present in the water aspects of the public trust doctrine.[149] Moreover, despite the fact that over the last few decades, people have become more concerned in the ecological and natural aspects of wildlife as compared to its commercial aspect, "public trust principles have remained relatively static over the past 30 years with respect to the doctrine's applicability to fish and wildlife resources."[150]

Although nearly all states still claim ownership and authority over wildlife, "recognition of the obligations that derive from that authority has been far less common."[151] As the public interest in wildlife evolved, case law has frequently focused on the state's ability and duty to seek remuneration under its trusteeship of wildlife.[152]

Remuneration based on trust principles was first developed in New Jersey Department of Environmental Protection v. Jersey Central Power & Light Co (*Jersey*

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147 *Id*. at 714.

148 Michael Blumm & Aaron Paulson. *The Public Trust in Wildlife*. 6 Utah L. Rev. 1438, 1462 (2013). The only exceptions are Delaware and Nebraska.

149 See n. 177-204 and associated text.

150 Frank, *supra* note 22, at 679.

151 Blumm & Paulson at 1465.

152 Blumm & Ritchie, *supra* note 120, at 715.

Central).[153] In that case, a nuclear power plant operator had found a potentially hazardous leak, resulting in a relatively sudden shutdown. This shutdown halted the release of higher temperature effluent waters into the waterway that the plant was situated on. This caused a drastic drop in temperature killing over 500,000 menhaden. The state sued the power plant under the public trust doctrine, seeking compensatory damages for the deaths of the menhaden.[154] While the state was awarded $935 by a trial court, the nuclear plant operators objected, saying that "the State does not have a proprietary right to fish in its waters sufficient to support an action for compensatory damages."[155] The New Jersey court found not only that "the State had the right and the fiduciary duty to seek damages of all wild life which are part of the public trust… it is questionable whether anyone but the State can be considered the proper party to sue for recovery of damages."[156] Not only does the state have the authority to sue for compensation, their sole proprietary interest in wildlife burdens them with a duty to do so due to the public trust doctrine.

The shift from "sovereign ownership" theory to the public trust doctrine continued in State Department of Fisheries v. Gillette.[157] In that case, the defendants had reconstructed a bank of a waterway bordering their property without the requisite permit, and by so doing, destroyed a salmon fishery. The Washington Department of

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153 *Jersey Central*, *supra* note 29, 133 N.J. Super. 375 (1975), *rev'd on other grounds by* New Jersey Department of Environmental Protection v. Jersey Central Power & Light Co. 69 N.J. 102 (1976).

154 *Id.* at 388-394.

155 *Id*. at 392.

156 *Id*.

157 *Gillette*, *supra* note 57, 27 Wn. App. 815 (1980).

Fisheries filed suit against the defendant, and was awarded $3,150 by a trial jury. The defendants appealed the decision, claiming that the state does not have standing to sue for damages to the salmon fishery. The Washington Court of Appeals held that since the state holds title to fish as trustee for the common good, it necessarily has the standing to bring suit against the defendants.[158] In addition to the right of action to sue for damages, "the State… has the *fiduciary obligation* of any trustee to seek damages for injury to the object of the trust."[159]

The state's responsibilities under the public trust doctrine and the "sovereign ownership" theory were further distinguished in In re Steuart Transportation Co (Steuart).[160] Steuart had caused a significant oil spill, resulting in the death of approximately 30,000 migratory birds. The state of Virginia, along with the federal government, sued Steuart for the value of the birds, but Steuart filed a motion for summary judgment, alleging that, since the state of Virginia did not own the migratory waterfowl, it could not recover damages for their loss.[161] While the court agreed that it is clear that Virginia does not own the migratory birds, "[u]nder the public trust doctrine the State of Virginia … [has] the right and the duty to protect and preserve the public's interest in natural wildlife resources. Such right does not derive from ownership of the resources but from a duty owing to the people."[162] Thus, regardless

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158 *Id*. at 820. The court, citing *Jersey Central*, also added that if the State did not have standing to sue for damages, then "no one would have standing to recover for the injury." *Id*. at 821.

159 *Id*. (emphasis added).

160 In re Steuart Transportation Co. 495 F. Supp. 38 (1980)(*In re Steuart*).

161 *Id*. at 39.

162 *Id*. at 40.

of any state claim to "sovereign ownership", each state has a separate duty to the people to protect the public interest in wildlife.

Nevertheless, beyond these cases that mostly affirm that wildlife is a trust resource, "few wildlife cases have fleshed out the fiduciary obligations of the states… [though] the duties imposed by the Illinois Central and Mono Lake courts seem applicable to the wildlife context."[163] States already have a clear fiduciary obligation to seek compensation for damages to wildlife, but it is also reasonable to assume their fiduciary duties go beyond remuneration. For example, one state jurisdiction found that the based on the history of the public trust doctrine, the constitutional codification of the public trust doctrine "was intended to engraft certain trust principles guaranteeing access to the fish, wildlife and water resources of the state," and thus struck down a regulation giving preferential treatment for access to hunting grounds.[164] Next, in California, while reaffirming that wildlife is a public trust resource, the court found that private parties could invoke the public trust doctrine to force state agencies to perform the trustee obligations – to minimize harm to wildlife resources when feasible, under *National Audubon Society*.[165]

Although the case law is minimal on this issue, much of the academic commentary contends that the fiduciary duty under the wildlife trust is the same as with water and other public trust resource. Since wildlife, like water, has no owner in its natural state and ownership is an aspect of sovereignty, "the common interest in

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[163] Blumm & Ritchie, *supra* note 120, at 715.

[164] Owsichek v. State of Alaska 763 P.2d 488, 496 (1988). The Court described the state's duty as requiring it to prohibit monopolization of wildlife resources.

[165] *CBD v. FPL, supra* note 48, 166 Cal. App. 4th 1349, 1366-1367 (2008).

wildlife is sufficiently like the common interest in water to justify similar public trust doctrine protection for wildlife."[166] Accordingly, the academic literature argues that states must consider potential impacts to avoid substantial impairment, "take steps to prevent harm to wildlife where feasible… [and] continually supervise actions that may imperil animals ferae naturae."[167] Finally, it has recently been argued that "the public trust in wildlife has a solid historical foundation and therefore likely to be an employed by an increasing number of courts in the coming years."[168]

Ultimately, the state's regulatory relationship with wildlife has evolved significantly since the "sovereign ownership" theory to the public trust doctrine. Early conflicts with federal powers left the wildlife trust comparatively undefined. Given implied trusts in wildlife from the case history and the scholarly commentary, it is reasonable to assume that the public trust doctrine implies state obligations to protect wildlife. Moreover, given the non-economic value of the species impacted by electricity production, the public trust doctrine could provide a novel and necessary legal tool to shift regulatory focus.[169] If states do have the same fiduciary duty to protect wildlife resources as other public trust resources, it follows that the state would have to 1) comprehensively plan the "allocation" of wildlife 2) minimize harm to wildlife resources when feasible, and 3) ensure that "uses" of wildlife are reasonable

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166 Meyers, *supra* note 58, at 728-729.

167 Blumm & Ritchie at 715.

168 Blumm & Paulson, *supra* note 148, at 1466. The authors based the future implementation of the public trust doctrine for wildlife on the states' nearly unanimous assertion of ownership of wildlife, historic connection of early public trust doctrine cases to fishery resources and public access thereto, and the increasing public interest in wildlife.

169*See* Meyers at 735.

and beneficial, and do not substantially impair the public interest.[170] Specifically, before any further allocation of wildlife, the state must first have an intergenerational, comprehensive plan on specifically how to minimize impacts to wildlife from electricity production. States also must continually ensure that any actions which impact wildlife are both reasonable and beneficial, implying that electricity production cannot needlessly kill wildlife if it could be otherwise avoided.

3.5.3 Federal Waters & Wildlife

The last potential application of the public trust doctrine to electricity production relates to federal jurisdiction over waters and wildlife. There are three potential electricity production implications of the federal public trust doctrine; the impacts from offshore wind turbine installments in federal or state waters, climate change impacts from conventional electricity on federal waters, and the co-trusteeship of the water resources and wildlife that are found in both state and federal jurisdictions.[171] In theory, there are currently two bases for public trust doctrine application to the EEZ (and thus to wildlife): "(1) the public domain nature of the EEZ to which the federal common law might apply and (2) the potential extension of state common law beyond state waters."[172] However, the existence of a federal public trust doctrine is at best unsettled, as there is conflicting court opinions on the matter.

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[170] It should be noted that none of these tests have been explicitly applied to wildlife, but, there is also no reason to think that these duties could not or should not apply to wildlife. In fact, the cases that developed these tests (e.g. *Waiahole I* and *National Audubon Society*) discuss wildlife as a trust resource peripherally, and do not distinguish wildlife resources from other public trust resources to which these tests do apply.

[171] *See* Frank, *supra* note 22, at 680.

[172] Babcock, *Grotius*, *supra* note 65, at 6.

As with most public trust issues, the question of a federal public trust doctrine begins with *Illinois Central*.[173] Though *Illinois Central* focused on a state grant, the "[l]anguage in the opinion suggests that the Court was announcing rule based on federal law universally applicable to all state legislatures."[174] Furthermore, beyond binding all state application, "the Court made it clear that the trust *derives* from federal law,"[175] implying that the public trust doctrine duties are a matter of federal law. While the public trust doctrine is not directly mentioned, "from about 1888 through 1970, there are some eighteen opinions in [federal] public land law using trust language to describe the role of the United States."[176] Nevertheless, though there had been development of some type of trust relationship regarding the federal government in natural resources and lands, the federal public trust doctrine is markedly different, and much more ambiguous, than its state counterpart. Scholarly commentary implies that the federal public trust doctrine is a baseline of sorts – that it guarantees basic public interests, such as public access to trust resources, and prevents states from abrogating the public trust entirely, but it is up to each state to define how expansive its individual public trust doctrine will be.[177] The basis of any such federal public

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173 *Supra* note 170.

174 Richard J. Lazarus. *Changing Conceptions of Property and Sovereignty in Natural Resources Law: Questioning the Public Trust Doctrine*. 71 Iowa L. Rev. 631, 639 (1986)

175 Wilkinson, *Headwaters, supra* note 56, at 453 (emphasis added).

176 Charles Wilkinson. *The Public Trust in Public Land Law*. 14 U.C. Davis L. Rev. 278, 281 (1980-1981).

177 *See* Wilkinson, *Headwaters, supra* note 56, at 463-464. For example, while the federal government held land in trust for new states under the equal footing doctrine, it was up to each state to develop the usufructuary and title rights associating with these lands according to each state's view of justice. *See Shively, supra* note 44, 152 U.S. at 26.

trust doctrine are areas of "uniquely federal interests" where the authority and duties of the federal government "as a sovereign are intimately involved."[178]

Early federal public trust doctrine cases agreed with and further developed this reasoning. The first case to directly address the existence of a federal public trust doctrine was In re Steuart Transportation Co.[179] As discussed previously, the federal government, along with the state of Virginia, sued the plaintiffs after the deaths of some 30,000 birds. The plaintiffs argued, based on Missouri v. Holland,[180] that neither the state nor the federal government could sue, as they did not truly own the birds. As a general matter, the Court held that in addition to the state of Virginia, the federal government has both "the right and the duty to protect and preserve the public's interest in natural wildlife resources."[181] The court did not distinguish between the rights and duties of the state and federal governments, but did emphasize

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178 Babcock, *Grotius*, *supra* note 65, at 58 (citations omitted).

179*In re Steuart*, *supra* note 160, 495 F. Supp. 38 (1980). As an aside, an earlier series of cases also discussed trust obligations before this case, however, courts in those cases found the source of the trust obligation to come from statute and did not consider the public trust doctrine. *See* Sierra Club v. Department of Interior 376 F. Supp. 90, 95-96 (1974) (National Parks System Act and the Redwood National Park Act "impose[d] a legal duty on the Secretary to utilize the specific powers given to him whenever reasonably necessary for the protection of the park" against damages from adjacent logging activities). *See also* Sierra Club v. Department of Interior 398 F. Supp. 284, 293 (1975)(Interior Department officials acted "unreasonably, arbitrarily, and in abuse of discretion have failed, refused and neglected to take steps to exercise and preform duties imposed upon them by the National Park Systems Act…and the Redwood National Park Act"). Finally, *See also* Sierra Club v. Department of Interior 424 F. Supp. 172, 175 (1976) (Interior acted in good faith to properly discharge its statutory obligations to protect the Redwoods National Park).

180 Missouri v. Holland 252 US. 416 (1920).

181 *In re Steuart* at 40.

that these were rights and duties associated with sovereignty, implying that all sovereignties were endowed with public trust.[182]

If *Steuart* was equivocal on the role of the federal government, the United States v. 1.58 Acres of Land was not.[183] In that case, the United States government condemned lands below the low watermark to further develop a Coast Guard center in Boston. Though the private owners of the waterfront property came to an agreement with the United States, the Commonwealth of Massachusetts argued that the transfer would violate the public trust, as the state would neither be able to control nor protect for the benefit of the public, and that the federal government may use the property eventually for uses that conflict with the trust duties. However, the court held that the transfer of property to the federal government as valid and dismissed the state's claim because the lands under federal control would still be subject to the public trust doctrine. The court concluded that the federal government implements the public trust doctrine through "Congress in its capacity as trustee of jus publicum."[184] The states are reserved powers and duties regarding the public interest that are not preempted by the federal government, and these are "administered by state legislature in their capacity *as co-trustee* of the jus publicum."[185] The court reasoned that, based on the dual sovereignty of state and federal governments, the trust over the property "is

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[182] *Id*. at 39. The court did however make two other distinctions: state rights and duties are preempted by federal powers, and that the state of Virginia had additional duties under the *parens patria* doctrine. Other than these distinctions, both governments had the same responsibilities under the public trust doctrine.

[183] United States v. 1.58 Acres of Land, *supra* note 53, 523 F. Supp. 120 (1981).

[184] *Id*. at 123.

[185] *Id.* (emphasis added).

administered jointly by the state and federal governments by virtue of their sovereignty, neither sovereign may alienate this land free and clear of the public trust."[186] Ergo, the court dictated the strongest language treating the existence of a federal public trust doctrine, indicating, that as an aspect of sovereignty, the only way for a federal government to not have a public trust duty, is "by the destruction of the sovereign."[187] As a result, because the federal government is incapable of destroying the sovereignty of Massachusetts, it cannot destroy trust or the obligations associated with the trust.[188]

U.S. v. 1.58 Acres, was however, the high water mark, for the proposition that the federal government, as sovereign, necessarily had similar power and duties to the state under the public trust doctrine, with recent case law heavily suggesting the opposite. The change in perspective began in the Supreme Court's opinion in PPL Montana v. Montana.[189] The facts of this case focused on several hydroelectric facilities, owned and operated by the plaintiffs. The rivers upon which these facilities were based were deemed non-navigable, and thus title did not transfer from the federal government to Montana, meaning that plaintiffs paid rent to the federal government instead of the state of Montana. The state of Montana claimed, that since the rivers were partly navigable in certain segments, that under the equal footing doctrine, title to these rivers should belong to the state, and thus the plaintiffs owed Montana, not the

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186 *Id.* at 124. This also insinuates that the federal government, under its duty of the public trust, must also protect the public interests in these lands.

187 *Id*.

188 *See Id.* at 125.

189 PPL Montana v. Montana 132 S. Ct. 1215 (2012).

federal government, rent. The Montana Supreme Court found that title belonged to the state, and held the plaintiffs owed the state $41 million in rent. The plaintiffs appealed to the U.S. Supreme Court.

The Supreme Court ruled that the Montana courts had erred when finding these rivers navigable, by over relying on present day evidence, overly liberal construction of navigability, and failure to consider the segmentation of the rivers.[190] Since the navigability of these rivers were highly segmented at the time of statehood, the Court found that the lands upon which the facilities were located were never transferred to Montana under the equal footing doctrine. While the main crux of this case regarded the equal footing doctrine and title ownership of the rivers, the state of Montana also claimed that without title ownership of the river, it will be unable to guarantee public access to the waters for the purposes of navigation, fishing and other recreational uses, undermining the state's public trust doctrine.[191] However the Court rejected this claim, saying that "the public trust doctrine remains a matter of state law…the contours of that public trust do not depend upon the Constitution."[192] Thus, while the state of Montana could determine the scope of the public trust over waters within its borders, only federal law determines riverbed title. However, the court did not address either In re Steuart Transportation Co. or U.S. v. 1.58 Acres.[193] Despite not

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190*Id*. at 1226.

191 *Id*. at 1234.

192 *Id*. at 1235.

193 While not citing In re Steurt Trans. Co., *supra* note 160, and U.S. v. 1.58 Acres, *supra* note 53, the Court relies on cases focusing on title, such as Shively v. Bowlby, *supra* note 44, which does not directly discuss the existence of a federal public trust doctrine.

addressing either of these cases nor focusing directly on the public trust doctrine, the reasoning in PPL Montana v. Montana became the foundation for discussing the federal public trust doctrine in future cases.

The next case of interest is Alec v. Jackson,[194] *supra* note 0, in which the plaintiffs brought suit claiming that the federal government was violating its fiduciary duty under the public trust doctrine by failing to take action to mitigate climate change, thus damaging the atmosphere, which the plaintiffs claimed was a public trust resource. The plaintiffs asked the District Court to declare that the atmosphere is a public trust resource, and that the federal government has a fiduciary duty, as a trustee under the public trust doctrine, to mitigate climate change and minimize damage to the atmosphere.[195]

The court denied the application of the public trust doctrine to the federal government, relying on the Supreme Court's reasoning in *PPL Montana* that the public trust doctrine is a matter of state law that does not depend on the Constitution.[196] Though the plaintiffs argued that this was merely dictum, the court rejected this claim, and found that even if it were dictum, Supreme Court dictum is generally treated as authoritative.[197] Furthermore, the court cited dicta in a D.C. Circuit court case that also suggested that the public trust doctrine was a creature of

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194 *Alec, supra* note 20, 863 F. Supp. 2d 11 (U.S. Dist. 2012), *aff'd by* Alec v. McCarthy, 261 Fed. Appx. 7 (2014), *cert. denied* 2014 U.S. LEXIS 8246 (U.S., Dec. 8, 2014)(No. 14-405).

195 *Id*. at 13-14. The plaintiffs specifically asked the Court to define the federal government's fiduciary duty as reducing "global atmospheric carbon dioxide levels to less than 350 parts per million during this century."

196 *Id*. at 15, citing *PPL Montana* at 1235.

197 *Id.*

state law.[198] Lastly, the court held that even if there was some type of federal public trust doctrine, it has since been subsumed by the Clean Air Act, or other applicable federal regulations.[199] Because the court held that the public trust doctrine claim did not apply to the federal government, it did not directly decide whether the atmosphere is a trust resource. However, the court decided that the determinations of appropriate levels of atmospheric carbon dioxide "are best left to the federal agencies that are better equipped" than to have the courts make these determinations.[200]

Though *Alec* may have begun to close the door to the possibility of a federal public trust doctrine, there are still unresolved inconsistencies regarding the federal trust obligations and responsibilities. Similar to *PPL Montana*, the court in *Alec* did not address any of the federal court opinions that held there were some applications of the public trust doctrine to the federal government due to the system of dual sovereignty. Consequently the reasoning in *Alec* remains in conflict with the co-trusteeship theory found in earlier cases. In sum, the role and obligations of the federal government as a trustee is at this time inconclusive.

Unlike state governments, it is uncertain whether the federal government has any common law trust duties to protect its water and wildlife beyond statutory requirements. Generally, public trust theory has regarded duties and responsibilities as

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[198] *Id.*, citing District of Columbia v. Air Florida 750 F. 2d 1077, 1084 (1984). It should be noted that citing this case is questionable since the District Circuit court explicitly refrained from ruling on the application of the public trust doctrine to the federal government: "We emphasize that we imply no opinion regarding…the applicability of the public trust doctrine to the federal government."

[199] *Id*. at 16. However, this ignores other case law suggesting that the public trust doctrine can never be subsumed (*See Waiahole I*, *supra* note 47, at 130), and the role of common law in respect to statutory law, *See* Hope Babcock. *The Public Trust Doctrine: What a Tall Tale They Tell* 61 S.C.L. 393, 405 (2009) ("[o]ne function of common law in a statutory legal regime is to fill gaps left in the legal framework")[hereinafter Babcock, *Tall Tale*].

[200] *Id*. at 17.

a trustee as an aspect of sovereignty and implying the federal government necessarily has public trust obligations as part of its sovereignty. At best, the federal government is a co-trustee of wildlife and water resources and has an obligation to protect uniquely federal interests in these resources. On the other hand, it could be constructed that all of the common law responsibilities of the federal government have been subsumed by statutory law. In this Article, it thus will be assumed that the federal government has only basic public trust responsibilities that are shared with the state and that protects only the most basic public interests in federal water and wildlife resources.

3.6 Electricity Production and the Environment

Electricity production, in all of its potential forms, has a myriad of environmental impacts. Conventional electricity, defined as being fueled by coal, nuclear and natural gas, accounted for 86% of the electricity generated in 2014 in the United States.[201] For the purposes of this article, the renewable electricity types discussed will consist of onshore and offshore wind, as well as solar photovoltaic.[202] These three were chosen because they are currently the most prevalent renewable

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201 Energy Information Administration (EIA). *Electricity Data Browser*. (2015) *available at* http://www.eia.gov/electricity/data/browser. As an aside, many of the same arguments in this Article can be made regarding hydroelectric power. Though hydroelectric power was left out of this summary since it contributes substantially less electricity than other conventional electricity sources (6% of 2014 generation), hydroelectric substantially impairs trust resources, especially fish and large scale ecosystem modification. *See* Dan Tarlock *Hydro Law and the Future of Hydroelectric Power Generation in the United States* 65 Vand. L. Rev. 1723, 1735-1745 (2012). The public trust doctrine could be applied to hydroelectric during FERC relicensing decisions.

202 In addition to these sources, another potential renewable electricity technology is hydrokinetic energy, including wave, tidal and current electricity projects. Generally, these projects would be placed on the seafloor in state jurisdiction, and have the potential to cause negative environmental impacts. Consequently, an application of the public trust doctrine to hydrokinetic renewable electricity sources is appropriate. However, these technologies were not considered in this paper as they are not commercially viable yet, and have limited national maximum capacity – only 80 to 90 GW of maximum capacity. *See* Jeffrey Thaler & Patrick Lyons. *The Seas Are Changing: It's Time to Use Ocean-Based Renewable Energy, the Public Trust Doctrine, and a Green Thumb to Protect Seas from Our Changing Climate.* 19 Ocean & Coastal L.J. 241, 267-278 (2014).

electricity production types,[203] as well as the focus of future large-scale implementation of renewable energy.[204] The four major impacts caused by electricity production discussed below include direct impacts to water ecosystems, wildlife mortality, and climate change.

3.6.1 Water Ecosystem Impacts

Conventional electricity generation's first impact to the environment is to water body quality and health. Since conventional electricity creates electricity via heating water and then passing steam through a turbine, cooling water is required to prevent extra heat from interfering with operation. Cooling water intake systems (CWIS) are used to implement required cooling, and fall into two categories; open- and closed-cycle.[205] Open-cycle CWIS withdraws significant amounts of water, on the order of 57 to 839 gallons per kilowatt-hour (kWh),[206] consuming a portion of that water, and returning the portion that is not consumed, known as effluent, to the water body at a lower water quality due to higher temperature, lower dissolved oxygen content and presence of biocides such as chlorine.[207] On the other hand, closed-cycle

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203 Onshore wind currently is the largest renewable electricity provider in the U.S., with 4% of overall electricity production, *See Id.*

204 *See, e.g.* Cory Budischak et al. *Cost-minimized combinations of wind power, solar power and electrochemical storage, power the grid up to 99.9% of the time*. 225 J. of Power Sources 60 (2013).

205 Olivia Odom. *Energy v. Water.* 37 Ecology L. Q. 353, 358 (2010).

206 Kristen Ayert et al. *Freshwater Use by U.S. Power Plants: Electricity's Thirst for a Precious Resource*. 13 (2011). See also Regina McCormack & Lance Noel. *Mitigation of electricity production externalities imposed on water resources and fishing industries in the Delaware River estuary and implications for offshore wind energy* policy. Unpublished 13 (2015).

207 Environmental Protection Agency (EPA). *Environmental and Economic Benefits Analysis for Proposed Section 316(b) Existing Facilities Rule*. 2-5, Doc. No. 821-R-11-002 (2011). The EPA details that CWIS can lead to hypoxia, decreasing distribution, growth rates, and nutrition cycles of fish and macroinvertebrates. In addition,

CWIS greatly reduces these impacts – 93 to 98% less,[208] but coming at higher costs and consuming greater quantities of water. As of 2014, of the conventional power plants surveyed, 27% employed closed-cycle CWIS and 63% open-cycle CWIS.[209]

Conventional electricity also can impact water quality through catastrophic fuel spills. For example, coal ash can contaminate the water with dissolved arsenic and selenium and lower pH,[210] and nuclear generation can contaminate water systems and aquatic food chains by accidentally releasing radionuclides as effluents.[211] Additionally, water quality is also routinely degraded during the other stages of the life cycle of conventional fuel. The life cycle impacts of coal would also include water quality implications from acid mine drainage[212] and mountaintop mining.[213]

"toxic pollutants, such as metals, polycyclic aromatic hydrocarbons (PAHs), pesticides, biofouling chemicals, or chlorine" are routinely found in CWIS effluents, which have "greatly altered biological communities due to chronic impacts on viability, growth reproduction, and resistance to other stressors."

208 Electric Power Research Institute. *Closed-Cycle System Retrofit Study: Capital and Performance Cost Estimates*. At 7-27 (2011)

209 EPA. *Economic Analysis for the Final Section 316(b) Existing Facilities Rule* 2A-15, 2A-16 Doc. No. 821-R-14-001 (2014). It should be noted that this analysis only focused on certain facilities, which represented less than half of the nation's electricity capacity and 9% of total facilities. The overall CWIS mix of all the nation's conventional electricity plants may differ from the reported numbers. *See also* Joan F. Barber et al. *Estimated Use of Water in the United States in 2005*. 38 (U.S. Department of the Interior 2005)(noting that of all power plants, 8% employed closed-cycle CWIS, and 93% open-cycle CWIS).

210 Laura Ruhl, et al. *Environmental Impacts of Coal Ash Spill in Kingston Tennessee: An 18-Month Survey*. 44 Environ. Sci. Technol. 9272 (2010).

211 J.D. Peles et al. *Ecological half-life of ^{137}Cs in fish from a stream contaminated by nuclear reactor effluents.* 263 The Science of the Total Environment 255, 256 (2000).

212 D. Barrie Johnson & Kevin B. Halberg. *Acid mine drainage reduction remediation options: a review*. 338 Science of the Total Environment. 3 (2005)

213 Katherine Paybins et al. *Water Quality in the Kanawha-New River Basin: West Virginia, Virginia, and North Carolina 1996-1998, in* Mountaintop Mining/Valley fills in Appalachia Final Programmatic Environmental Impact Statement. 120 (2005)

Uranium mining and milling for nuclear power plants uses a significant amount of water, consuming 12,000 to 760,000 gallons per ton of usable uranium.[214] Natural gas extraction via hydraulic fracturing can contaminate local ground and surface waters with heavy metals such as arsenic, selenium strontium and barium that can exceed safety limits.[215] Nonetheless, because the majority of fuel sources of the four states studied in this paper are imported from other states, this Article will focus on the impacts from generation, as the other parts of the lifecycle would affect other state's jurisdiction.

In comparison, renewable electricity production has very limited impacts on water. Other than the minimal water requirements for manufacturing for the steel, silicon and concrete used in wind turbines and solar panels, the lifecycle water consumption is orders of magnitude less than the conventional fuel sources, implying that switching from conventional electricity sources to renewable electricity would significantly benefit water body health.

3.6.2 Wildlife Mortality

The wildlife impacts of electricity production are widespread and expansive, impacting fish and aquatic organism, as well as birds and bats. Both conventional and renewable electricity have direct impacts on wildlife. While comparisons of wildlife impacts across electricity types are appropriate and necessary, comparisons between different types of wildlife, e.g. birds to bats to fish, are intrinsically unequal because

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214 Gavin Mudd & Mark Diesendorf. *Sustainability of Uranium Mining and Milling: Toward Quantifying Resources and Eco-Efficiency*. 42 Environ. Sci. Technol. 2624, 2628 (2007).

215 Brian E. Fontenot et al. *An evaluation of water quality in Private Drinking Water Wells Near Natural Gas Extraction Sites in the Barnett Shale Formation*. 47 Environ. Sci. Technol. 10032, 10034-10036 (2013).

each has their own length of life and reproduction rate, implying one fatality has different population impacts across various types of wildlife.

Conventional electricity sources, while withdrawing water for CWIS operations, cause the impingement and entrainment (I&E) of aquatic organisms, with each power plant's CWIS killing at least hundreds of millions of fish each year. Due the lack of effective EPA rulemaking,[216] I&E remains prevalent and as one commentator has noted, causes "the most obvious and direct environmental harm from thermoelectric power plants" and their CWIS "are the largest single predator of our nation's waters."[217] In addition to I&E, conventional electricity, especially coal, impacts fish and other aquatic organisms through mercury emissions and bioaccumulation. In 2005, the average freshwater fish had a mercury concentration of 0.23 µg/g,[218] and over 30% of the locations studied had fish tissue mercury concentration over the EPA advisory level for protection of human health of 0.30 µg/g.[219] Fishery consumption advisories limit humans' use of natural resources, 80%

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216 *See generally* Cronin v. Browner 898 F. Supp. 1052 (S.D.N.Y. 1995) and ConocoPhillips v. EPA 612 F. 3d 822, 825 (2010)(suggesting that "effective rulemaking…has been elusive" in regards to I&E regulations). *See also* Odom, *supra* note 205, at 367.

217 Odom at 368 (citation omitted). Furthermore, the current regulation of I&E ignores non-commercial and non-recreational important species, essentially disregarding 98.2% of fish species impacted. *See Id.* at 369.

218 Ann Chalmers et al. *Mercury trends in fish from rivers and lakes in the United States, 1969-2005.* 175 Environ. Monit. Assess. 175, 177 (2011).

219 *Id.* at 183.

of which were issued due to mercury contamination,[220] by causing people to eat other types of fish that are not under an advisory or forego eating fish at all.[221]

While onshore wind and solar have no impact on aquatic life, offshore wind can have moderate to minor effects on fish behavior during construction.[222] More substantially, the noise from construction can cause either temporary or permanent hearing damage to marine mammals.[223] Nevertheless, with proper mitigation effort, it is expected that impacts noise can be reduced to levels below thresholds that would cause even temporary hearing damage.[224] Beyond construction, offshore wind also provides a potential artificial reef effect while the farm is in operation.[225] While the

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220 David C. Evers. *Mercury in the Great Lakes region: bioaccumulation, spatiotemporal patterns, ecological risks and policy*. 20 Ecotoxicology 1487, 1489 (2011). Citing the EPA, the authors find that these consumption advisories covered 16.8 million lake acres and 1.3 million river miles.

221*See generally* Food and Drug Administration. *Mercury Levels in Commercial Fish and Shellfish (1990-2010)*. (2010) *available at* http://www.fda.gov/food/foodborneillnesscontaminants/metals/ucm115644.htm (last modified April 16, 2013)(advising against any consumption of king mackerel, sharks, swordfish, and tile fish due to their high mercury concentrations).

222 Christina Meuller-Blenke et al. Effects of0 Pile-Driving Noise on the Behavior of Marine Fish. (COWRIE 2010) It should also be noted that offshore wind construction also poses potential threats to sea turtles, but this has not been studied as extensively as fish or marine mammals.

223 Sven Koschinski & Karin Lüdemann. *Development of Noise Mitigation Measures in Offshore Wind Farm Construction 2013* 1 (2013)

224 National Oceanic and Atmospheric Administration (NOAA) *Draft Guidelines for Assessing the Effects of Anthropogenic Sound on Marine Mammals: Acoustic Threshold Levels for Onset of Permanent and Temporary Threshold Shifts* (2013) 27. According to this report, with proper mitigation, offshore wind construction can avoid Level B harassment, the temporary hearing damage threshold, under the Marine Mammal Protection Act (MMPA), *See* 16 U.S.C. 1362 (18)(A)(i) & (ii). *See also* Koschinski & Lüdemann at 15-23, 30-37.

225 Olivia Langhammer. *Artificial reef Effect in relation to Offshore Renewable Energy Conversion: State of the Art*. 2012 The Scientific World Journal 1, 4 (2012)(finding that offshore wind can create a net of 650-677 m^2 of new habitat per turbine). Langhammer also notes that if one purposefully designed for artificial reefs in scour protection, the net habitat and expected biomass created would be tripled to quadrupled.

actual benefits of artificial reefs are far from certain,[226] many studies have concluded that there is some evidence of a local artificial reef effect. [227] As offshore wind development continues, and the artificial reef effect matures, offshore wind farms may provide long-term benefits by enhancing that local ecosystem services."[228]

The most significant wildlife impact of renewable electricity is collision mortality,[229] as birds and bats often collide with wind turbines and solar towers.[230] In 2013, it was estimated that approximately 234,000 birds collide with wind farms per year in the entire United States.[231] However, the magnitude of these impacts are

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226 H.J. Lindeboom et al. *Short term ecological effects of an offshore wind farm in the Dutch coastal zone; a compilation.* 6 Environ. Res. Lett. 1, 11 (2011). The authors found that the higher fish density in the wind farm was due to natural seasonal variation, not the artificial reef effect.

227 Mathias H. Andersson & Marcus C. Öhman. *Fish and sessile assemblages associated with wind-turbine constructions in the Baltic Sea*. 61 Marine and Freshwater Research 642, 648 (2010). *See also* Degrear et al. at 161. *See also* J.T. Reubens et al. *The ecology of benthopelagic fishes at offshore wind farms: a synthesis of 4 years of research*. 727 Hydrobiologia 121, 130 (2014). The authors could not conclude that there was production of fish on a regional scale and suggested against allowing commercial fishing within the wind farm. In addition, the main benefit to fish in the wind farm area was the prohibition of commercial fishing activities rather than the artificial reef effect.

228 Lena Bergströmm et al. *Effects of an offshore wind farm on temporal and spatial patterns in the demersal community.* 485 Marine Ecology Progress Series 199, 208 (2013).

229 While not as significant, it should also be noted that that renewable electricity also has direct impact on land transformation that are much greater than their conventional counterparts, resulting in habitat displacement and disruption. However, when including the lifecycle impacts of conventional electricity (e.g. mining and transportation of fuel), the magnitude of land transformation has been found to be approximately equal. *See* Vasilis Fthenakis & Hyung Chul Kim. *Land use and electricity generation: A life-cycle analysis*. 13 Renewable and Sustainable Energy Reviews 1465, 1469, 1466-1468 (2009). On the other hand, it should be noted that since much of the upstream portions of each fuel's lifecycle, many of these impacts occur beyond the jurisdiction of the states included in this analysis.

230 Other forms of solar power, such as rooftop photovoltaic (PV) do not pose significant collision risks to wildlife.

231 S.R. Loss et al. *Estimates of bird collision mortality at wind facilities in the contiguous United States.* 168 Biological Conservation 201, 205 (2013).

substantially less than other sources of anthropogenic avian mortality,[232] and there is evidence that wind energy does not pose any population risks to bird species.[233] Bat impacts are less understood, especially as the details of bat migration and behavior "remain almost completely unknown."[234] It is estimated that approximately 600,000 bats are killed nationwide by wind turbines, equating to approximately 3.5 bats killed per GWh,[235] but, mitigation can decrease fatalities anywhere from forty to ninety percent at relatively low economic costs, hypothetically reducing fatalities to 0.35 to 2.1 bat deaths per GWh.[236]

Collisions with land-based wind turbines causes anywhere from 0.26 to 1.4 bird deaths per GWh of energy produced,[237] while offshore wind turbines cause very

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232 See Meredith Blaydes Lilley & Jeremy Firestone. *Wind Power, Wildlife, and the Migratory Bird Treaty Act: A Way Forward*. 38 Envtl. Law. 1167, 1172 (2008) (summarizing the literature of anthropogenic avian mortality). For example, building collisions, motor vehicle collisions, power line collisions and domesticated cats each kill nearly 100 *million* birds a year.

233 J. Ryan Zimmerling et al. *Canadian Estimate of Bird Mortality due to Collisions and Direct Habitat Loss Associated with Wind Turbine Developments.* 8 Avian Conservation and Ecology 10, 15 (2013)(finding that Canadian wind farms killed less than 0.07-0.12% of any bird species per year). *See also* M. Wing Goodale & Anita Milman. *Cumulative adverse effects of offshore wind energy development on wildlife*. XX J. of Environmental Planning & Management 1, 8 (2014) (there has been little evidence that direct collision mortality and habitat loss or displacement caused by offshore wind has impacted population levels of birds).

234 Paul M. Cryan. *Wind Turbines as Landscape Impediments to the Migratory Connectivity of Bats*. 41 Envtl. Law 355, 360 (2011).

235 Mark A. Hayes. *Bat Killed in Large Numbers at United States Wind Energy Facilities*. 63 BioScience 975, 977 (2013). Like avian mortality, the magnitude of bat collisions varies significantly with geography, with the highest death rates occurring in the Appalachian region. However, *see also* Manueal M.P. Huso & Dan Dalthrop. *A Comment on "Bats Killed in Large Numbers at United States Wind Energy Facilities"*. XX BioSciences XX, 2 (2014) (criticizing the methodology utilized in Hayes (2013) as not statistically representing the seasonal variation of the impacts or current wind farm practices). The authors conclude that "[g]iven the shortcomings of the available data, an accurate estimate of total bat fatality is not currently possible."

236 Cryan at 369. Cryan notes that there is no legal mechanism to require such curtailment methods though.

237 See Benjamin Sovacool. *The Avian and Wildlife Costs of Fossil Fuels and Nuclear Power*. 9 J. Integrative Env. Sci. 255, 260 (2012) (estimating that wind power kills 0.26 birds per year). The higher estimate was calculated using S.R. Loss et al. total bird deaths and EIA wind production, *supra* note 1. It should be noted that

similar mortality rates: 0.24 to 1.791 birds deaths per GWh.[238] However, wind and solar energy will displace conventional electricity,[239] which in comparison, Professor Sovacool estimates that coal kills 0.2 to 9.36 birds per GWh and that nuclear plants kill 0.638 birds per GWh.[240] Of particular concern is the mercury bioaccumulation from coal generation, which emits over half of all the mercury in the United States.[241] Various species of songbirds across the Mid-Atlantic and Northeast have been put at risk due to mercury,[242] decreasing populations by as much as 20%.[243] In contrast to

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bird mortality per turbine varies significantly in S.R. Loss et al., depending on the region the wind turbine was sited.

238 McCormack & Noel (2015) *supra* note 206, at 18 (summarizing the literature of bird mortality from European offshore wind farms).

239 General Electric Energy Consulting. *PJM Renewable Integration Study: Executive Summary Report*. (Feb. 2014) 20. *Available at* http://www.pjm.com/committees-and-groups/subcommittees/irs/pris.aspx

240 Sovacool at 261. The higher range associated with coal is calculated by Professor Sovacool with consideration of the impacts of climate change on bird populations. It is important to note that climate change is the most serious threat to bird populations, but the numbers Sovacool calculates for climate change-related deaths are highly speculative. Sovacool also attributes the bird deaths due to climate change, 9.16 deaths per GWh, to natural gas and oil as well.

241 David Schmeltz et al. *MercNet: a national monitoring network to assess responses to changing mercury emissions in the United States*. 20 Ecotoxicology 1713, 1716 (2011) (suggesting a national scale monitoring program of mercury emissions). In the United States, coal is currently the single largest emitting sector. *But see* Marc Houyoux & Madeleine Strum. *Memorandum: Emissions Overview: Hazardous Air Pollutants in Support of the Final Mercury and Air Toxics Standard*. EPA, at 13. (2011) (No. EPA-HQ-OAR-2009-0234). This reduction causes coal and oil power plant's portion of overall mercury emissions to decrease from 42% down to 17%. *See also* National Emission Standards for Hazardous Air Pollutants From Coal- and Oil-Fired Electric Utility Steam Generating Units and Standards of Performance for Fossil-Fuel-Fired Electricity Utility, Industrial-Commercial-Institutional, and Small Industrial-Commercial-Institutional Steam Generating Units. 77 Fed. Reg. 9,304, 9,359 (February 16, 2012) (codified at 40 C.F.R. 60 and 63) (determining that the rule to requiring mercury reductions was done without the impacts to wildlife in mind, but rather technology costs and health co-benefits).

242 *Id*. at 29-57. Several species, such as the Rusty Blackbird, have had populations decline by 90%. Mercury bioaccumulation is one of several reasons for such a decline.

243 Claire W. Varian-Ramos. *Mercury Reduces Avian Reproductive Success and Imposes Selection: An Experimental Study with Adult- or Lifetime-Exposure in Zebra Finch*. 9 PLOS ONE 1, 2 (2014). The authors conducted an experiment to determine the effects of different mercury levels on songbirds, and found that depending on the mercury concentration, zebra finches, a model songbird, produced 16%-50% less offspring than a

the avian impacts from wind turbines, there are indications that "mercury levels in songbirds… throughout the Northeast are high enough to cause *detrimental effects to populations* inhabiting areas prone to bioaccumulation of mercury."[244] Additionally other types of birds beyond songbirds are substantially impacted, such as the piscivorous common loon, whose reproduction rates can be decreased as much as 50% due to current mercury levels in fish,[245] and bald eagles, another piscivorous bird, which are at risk of mercury contamination, with 14-27% of eagles studied in the Great Lakes region at risk of neurological impairment.[246]

Likewise, a study of mercury in bats on the east coast of the United States found that 81% of all adult bats sampled near point sources (e.g. coal plants) had mercury levels above a level that would have an adverse effect.[247] In addition, the five bat species that are listed, pending, or under consideration as endangered under the Endangered Species Act (ESA) all had even higher elevated mercury concentrations, "which may be of concern."[248] In comparison, the three bats impacted

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control group, and in reality the population impacts will be variable based on geographic location and species. *Id.* at 4.

[244] Osborne et al. at 70 (emphasis added).

[245] David Evers et al. *Adverse effects from environmental mercury loads on breeding common loons.* 17 Ecotoxicology 69, 70 (2007). However the authors concluded that only 16-19% of individual birds had mercury levels that posed threats, though this does not include the possibility of mercury "hot spots" that could be causing populations sinks.

[246] Jennifer Rutkiewicz et al. *Mercury Exposure and neurochemical impacts in bald eagles across several Great Lakes States*. 20 Ecotoxicology 1669, 1674 (2011). The authors base these percentages on other thresholds found in the literature, but encourage further research into thresholds specific to bald eagles.

[247] David Yates, et al. *Mercury in bats from the northeastern United States*. 23 Ecotoxicology 45, 53 (2014).

[248] *Id.* Since there has been little historical research into the behaviors of bats, the authors are careful to note that the many potential adverse impacts of mercury on bats, such as limited reproduction success, decreased survival

most by wind turbines,[249] are all listed as "Least Concern" in the International Union for Conservation of Nature's (IUCN) Red List.[250] Thus, although avian and chiropteran mortality is seen as the most significant wildlife impact of wind power, it has not been shown to pose an overall population risk, and is quite possibly less than other forms of electricity production. Lastly, it should be noted that mercury bioaccumulation can cause sub-lethal, but consequential, impacts on various other mammals, such as river otters,[251] beavers,[252] and Florida panthers.[253]

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rates, and other neurological implications need to be investigated further and validated in future research, though these would be the expected impacts to physiologically similar species.

[249] Cryan at 364. These three species are the hoary bad, the eastern red bad, and the silver haired bat.

[250] See IUCN. *The Red List of Threatened Species* (2013), *at* http://www.iucnredlist.org/. On the other hand, the Indiana Bat, which is widespread along the Midwest's wind resources, can create obstacles to wind energy due to its endangered status, even though it is not often impacted by collision mortality, requiring wind developers to make mitigation or curtailment efforts. *See* Kirsten S. Balzer. *Bats and Breezes Take on Federal Policy: The Windy Effects of Animal Welfare Institute v. Beech Ridge Energy LLC* 22 Vill. Envtl. L.J. 225 (2011)

[251] William Stansley et al. *Mercury and halogenated organic contaminants in river otters (Lontra Canadensis) in New Jersey, USA*. 29 Environmental Toxicology and Chemistry 2235, 2239 (2010) *See also* Peter Dornbos et al. *Mercury exposure and neurochemical biomarkers in multiple brain regions of Wisconsin River Otters (Lontra canadensis)*. 22 Ecotoxicology 469 (2013) (finding that average mercury concentrations of river otter in the Wisconsin area are significantly less than historical averages). *See also* Jonathan M. Sleeman et al. *Mercury Poisoning in a Free-Living Northern River Otter (Lontra canadensis)*. 46 J of Wildlife Diseases 1035 (2010) (finding the highest recorded mercury concentration in any land mammal, 150 µg/g, in the brain samples.

[252] Brenda Gail Bergman & Joseph K. Bump. *Mercury in aquatic forage of large herbivores: Impact of environmental conditions, assessment of health threats, and implications for transfer across ecosystem compartments*. 479-480 Sci. of the Total Environment 66, 74 (2014). The authors went on to criticize the EPA's threshold for beavers, since the beavers studied had concentrations well below the EPA's lethal level, however exceeded the EPA's reference dose for humans, which the authors suggested would cause neurological damage to the beavers such that it would affect the senses "that the animals depend upon for survival."

[253] J. Newman et al. *Historical and Other Patterns of Monomethyl and Inorganic Mercury in the Florida Panther (Puma concolor coryi)* 48 Arch. Environ. Contam. Toxicol. 75, 79 (2004). The authors investigated Florida Panther samples from museum collections, and found much higher concentrations of mercury after 1990 compared to before 1990. *But see* Marc G. Barron et al. *Retrospective and Current Risks of Mercury to Panthers in Florida Everglades*. 13 Ecotoxicology 223 (2004) (while historic mercury contamination likely had population impacts to the Florida Panthers in the past, there is only a 4% chance that mercury concentrations are high enough in any Florida Panther to cause death).

3.6.3 Climate Change

Finally, renewable energy mitigates the most significant threat to all wildlife populations and water resources: climate change. First, recent surveys of global wildlife populations suggest that wildlife is in a dire situation already, as populations are rapidly decreasing and extinction rates are significantly higher than historical averages.[254] Wildlife species and populations are particularly "difficult to quantify without intensive surveys", but estimates include 16-33% of all vertebrate species are threated or endangered, and populations on average have decreased by 28% over the last forty years.[255] While there are other drivers of wildlife population decline and extinction, it is expected that climate change will become the most important driver of both extinction rates and population decline.[256] Climate change has broad far reaching impacts on the environment and can impair wildlife populations in various ways, creating new problems and exacerbating existing problems for terrestrial wildlife. [257] Climate change also can impact ocean systems by increasing water temperatures causing significant declines in cold water fish, and increasing water

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[254] Richard Dirzo et al. *Defaunation in the Anthropocene*. 345 Science 401 (2014).

[255] *Id.* at 401 (citations omitted). It is also estimated that between 11,000 and 58,000 species, generally, are lost per year.

[256] *Id.* at 403. *See also* Céline Bellard et al. *Impacts of climate change on the future of biodiversity*. 15 Ecology Letters 365 (2012).

[257] *See, e.g.*, Catheryn H. Greenberg et al. *Climate Change and Wildlife in the Southern United States: Potential Effects and Management Options*, in *Climate Change Adaption and Mitigation Management Options: A guide for natural Resource Managers in Southern Forest Ecosystems*. 390 (James M. Vose & Kier D. Klepzig eds., 2014) (A 2ºC increase would result in the almost entire loss for all shorebirds in all of Texas by 2100). *See also Id.* at 399-411 (various case studies on how climate change will reduce the range and populations of small mammals, birds and amphibians in the Southern United States).

acidity causing decreases in coral and invertebrate productivity in North America.[258] While the wildlife impacts of climate change are highly uncertain and dependent on the magnitude of increased temperature, it has been estimated that anywhere from 1% to 80% of all species could be committed to extinction, with an average extinction estimate between 20% and 30%. [259] Depending on the amount of climate change mitigation society undertakes, and combined with other wildlife impacts, worst case scenarios lead to "extinction rates that would qualify as the sixth mass extinction in the history of the earth."[260] In conclusion, climate change, if not mitigated, obviously poses substantial population threats to all species.

Additionally, climate change can also impair water resources. Ocean waters are expected to increase in temperature, as well as in acidity.[261] Climate change also causes sea level rise, which in turn impacts groundwater resources via saltwater intrusion.[262] Surface freshwater resources, such as lakes and rivers, will dramatically be diminished as temperatures increase and overall precipitation decreases, causing water level drops and reduction in stream flows, limiting overall availability of water

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[258] IPCC. *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. XX (Ch 26, 20-1) (V.R. Barros et al. eds, 2014)[hereinafter IPCC, *Climate Change 2014*].

[259] IPCC. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. 242 (M.L Parry et al., eds. 2007). The range is based on a literature review of 78 articles each with variable extinction estimates. *See also* S.L. Pimm et al. *The biodiversity of species and their rates of extinction, distribution, and protection*. 344 Science 1246752-1, 1246752-5 (2014) (estimating a loss of 10 to 14% of species, but citing high uncertainty).

[260] Bellard at 375.

[261] *See generally* IPCC, *Climate Change 2014* at Ch. 6.

[262] Holly A. Michael et al. *Global Assessment of Vulnerability to Sea-Level Rise in Topography-limited and Recharge-limited Coastal Groundwater Systems*. 49 Water Resources Research, 2228 (2013)

resources.[263] As precipitation and temperatures become more extreme, freshwater quality is expected to be impacted by increases in dissolved organic carbon, higher acidity, higher toxicity, and lower dissolved oxygen.[264] In sum, climate change poses the most significant threat to both wildlife populations and water resources.

3.6.4 Environmental Impacts Synthesis

In conclusion, the environmental impacts of electricity production are diverse and complex. Renewable energy is not without its impacts, and can place differing environmental values in conflict with each other, such as protection of migrating birds and the mitigation of climate change. Nevertheless, the scientific literature attests that renewable energy is substantially less detrimental to wildlife, water resources, and the general environment in comparison to conventional energy. Given displacement effects, renewable energy has the potential to reduce the various environmental and wildlife impacts from conventional energy. Yet, since these impacts are complex and nuanced, the laws governing these impacts and protecting wildlife should likewise be nuanced and flexible, yet also comprehensive and comparative. While current wildlife laws governing electricity production at times provide stringent rules, they often are only focused on a single issue and do not weave the negative impacts and benefits together. In this Article, I will show that the public trust doctrine can apply to wildlife

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[263] Noah D. Hall & Brett B. Stuntz. *Climate Change and Great Lakes Water Resources: Avoiding Future Conflicts with Conservation* 31 Hamline L. Rev. 639, 647-651 (2008). *See also* IPCC, *Climate Change 2014* at Ch. 5.

[264] P.G Whitehead et al. *A review of the potential impacts of climate change on surface water quality*. 54(1) Hydrological Sci. J. 101 (2009).

and environmental impacts of electricity production and propose that it is an effective means to regulate the environmental impacts of electricity production.

3.7 Four Case Studies

To effectively show this application, it is necessary to investigate individual states as case studies. First, the public trust doctrine also varies significantly from state to state. The differentiation of the public trust doctrine across the states defines a state's responsibilities and duties. Nonetheless, as shown above, it is clear that the application of the public trust doctrine to the impacts of electricity production is appropriate. Likewise, each state has disparate electricity grids, and diverse renewable electricity policies. To fully explore the potential application of the public trust doctrine to electricity production, it is necessary to explore each state's unique public trust doctrine and electricity production in detail. This paper will now explore the applications of the public trust doctrine in four states; California, Wisconsin, Hawaii, and New Jersey. These four states were selected because each has a relatively well-developed, albeit distinct public trust doctrine in accordance to their own views of justice, currently generate electricity from different fuels, and have divergent renewable electricity policies.

3.7.1 California

3.7.1.1 Current Electricity System

The in-state electricity generation mix of California is dominated by natural gas, providing over 60% of annual generation.[265] After natural gas, various

[265] California Energy Commission. *Energy Almanac*: *Total Electricity System Power* (September, 25 2014) *available at* http://energyalmanac.ca.gov/electricity/total_system_power.html. It should be noted that California

renewable electricity sources comprise the next 20%, with mostly land-based wind, geothermal and solar. The remaining 20% is generated by hydroelectric and nuclear power plants.[266] Since California has very limited in-state coal (less than 1% of generation), but has legacy hydroelectric and nuclear plants, and has made a commitment to renewable electricity, the California generation mix has a very low carbon intensity. Likewise, the absence of coal production significantly diminishes the wildlife impacts of mercury bioaccumulation. Nonetheless, over 37% of California's conventional electricity capacity has open-cycle CWIS,[267] when combined with hydroelectric, I&E poses a significant problem to the state's waters and aquatic wildlife. Overall reliance on natural gas also contributes to climate change.

3.7.1.2 The Public Trust Doctrine in California

In addition to the *Institutes of Justinian* and English common law, California can also trace its public trust doctrine to Spanish and Mexican law. Namely, the common law public trust doctrine can be traced to Las Siete Partidas and the Treaty of

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imports nearly a third of the electricity consumed within the state, however since it is generated outside of the state, it was assumed that this generation would fall outside the jurisdiction of the California public trust doctrine. However, there could be public trust implications when deciding to import electricity, such as relying on climate change-inducing fuels, which will in turn impact California trust resources.

[266] *Id*. While this article does not focus on hydroelectric, the public trust doctrine can be readily applied to California's hydroelectric system, and its substantial environmental impacts on water and fish resources. *See* Tarlock, *supra* note 201. *See also* Sarah E. Null. *Optimizing the damned: Water supply losses and fish habitat gains from dam removal in California* 136 J. of Env. Mgmt. 121, 127 (2014)(removal of certain dams would present considerable fish habitat gains for Chinook salmon and steelhead trout, with only small reductions of water deliveries and hydroelectric generation).

[267] *See* California Environmental Protection Agency. *Ocean Standards – CWA §316(b) Regulation: Thermal Discharges- Cooling Water Intake Structures*. (June 18, 2012) *available at* http://www.swrcb.ca.gov/water_issues/programs/ocean/cwa316/powerplants. The state of California does not impose any CWIS regulations beyond than the federal requirements under the CWA.

Guadalupe Hidalgo.[268] Since statehood, the California courts immediately and continually have faced public trust doctrine issues. California courts first identified that alienation of lands under navigable water is always subject to the paramount authority of the state to enforce "the right of the public to use them for the purposes of navigation and fishery."[269] The state's authority in the navigable rivers "are paramount and controlling," but the state acts only as "trustee for a public trust for the benefit of the people."[270]

Likewise California courts early on after statehood, held that "[t]he wild game within a state belongs to the people in their collective, sovereign capacity" and the state have the authority to regulate wildlife subject to the "protection or preservation of wildlife, or the public good."[271] Furthermore, the public's right to wildlife is not tied to the navigability of waters, but rather "extends to all waters within the state, public or private, wherein these animals are habited or accustomed to resort for spawning or other purposes."[272]

Despite setting out the paramount authorities of the state and recognizing the public's right in trust resources in early cases, the state of California did not shy away from utilizing trust resources, so long as they benefitted the general public. California

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268 Stevens, *supra* note 34, at 197. *See also National Aubudon Society*, *supra* note 49, at 434 n. 15.

269 Ward v. Mulford 32 Cal. 365, 372 (1867).

270 People v. Gold Run Ditch & Mining Co. 66 Cal. 138, 151 (1884).

271 Ex parte Maier 103 Cal. 476, 483 (1894). However, *see also* People v. Brady 234 Cal. App. 3d 954 (Cal. Appl. 1st 1991)(state does not truly "own" wildlife such that an illegal take of fish equates to grand theft). *See also* Moerman v. State 17 Cal. App. 4th 452, 457 (Cal. Appl. 1st 1993)(California does not truly own nor control wildlife, thus damages resulting from wildlife restoration cannot constitute a taking).

272 People v. Truckee Lumber Co. 116 Cal. 397, 401 (1897)

courts have long recognized that the state, while executing the trust "may dispose of these lands in the administration of the trust in such manner as the interests of navigation may require."[273] Furthermore, it is the duty of the state under the trust to dispose of or adapt these lands if that would advance the public interest.[274] California courts have found that various non-environmental uses are consistent with the public interest. For example, California courts have found drilling for oil as a valid use of trust waters, because this use would further the public's interest in commerce.[275] The courts viewed the public trust as maximizing benefits to the state, construing the purpose of the trust "with liberality to the end of benefitting all the people of the state,"[276] and emphasized that the state, when determining the best means to serve the general welfare through the utilization of navigable waters, must be cognizant of the changes in the public interest as dependent on the modernization of society and development of scientific knowledge.[277]

In addition to the common law public trust doctrine, California has codified trust duties in several aspects. In accordance with the California Constitution, the

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[273] People v. California Fish Co. 166 Cal. 576, 597 (1913)

[274] *Id*.

[275] Boone v. Kinsbury 206 Cal. 148, 181 (1928). It should be noted that the Court, antecedent to ruling on the validity of using oil as a trust value, assumed that oil drilling operations would not seriously injure or destroy fish and aquatic wildlife. Thus it may be, that had the court found that there was substantial or unnecessary damage to fish or aquatic wildlife, it would have considered oil drilling to be an invalid use of public trust lands.

[276] Colberg v. California 67 Cal. 2d 408, 417 (Sup. Ct. 1967). The court reviewed previous public trust cases that had included using trust waters to build railroads, develop oil and gas interests, and reclaim land impacted by recent flooding, before holding that building a bridge over navigable waters was an acceptable use within the public interest.

[277] *Id*. at 422.

water of the state must "be put to the beneficial to the fullest extent of which they are capable, and that the waste or unreasonable use…of water be prevented… in the interest of the people and for the public welfare."[278] Likewise, state ownership of tidal lands below the high water mark has been codified,[279] as has the state's trust relationship to wildlife.[280]

The early adoption of an expansive and liberal public trust doctrine, and the codification in statutes and the state constitution set the stage for further expansion of the public trust doctrine in California towards more environmental principles. Over the past several decades, the public interest in the environmental aspects of trust resources grew. The courts acted accordingly, acknowledging in Marks v. Whitney that that while the public trust doctrine is "traditionally defined in terms of navigation, commerce, and fisheries… [it is] sufficiently flexible to encompass changing public needs."[281] The courts have recognized that one of the most important uses of tidelands, and thus encompassed within the public trust, is the preservation of those lands so that they "may serve as ecological units for scientific study, as an open space, and as environments which provide food and habitat for birds and marine life, and which favorably affect the scenery and climate of the area."[282]

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[278] Cal. Const. Art. X §2.

[279] Cal. Civ. Code §670.

[280] Cal. Fish & Game Code §711.7.

[281] Marks v. Whitney, 6 Cal. 3d 251, 259 (1971).

[282] *Id.* at 259-260. The court ensured that this was only a partial list: "It is not necessary to here define precisely all the public uses which encumber tidelands."

In Marks v. Whitney, the California Supreme Court made California among the first states to explicitly protect ecological processes for the benefit of the public. In two subsequent cases discussing alienation of tideland trust resources, the California Supreme Court used ecological principles incorporated into the public trust doctrine as a foundation for maintaining that privately held lands were still burdened by the public trust. The court held that the public's interest in these lands was expansive and much broader than the traditional triad of navigation, commerce and fishing, and includes recreation and "the right to preserve the tidelands in their natural state as ecological units for scientific study."[283] In both cases, the court held that the conveyance of land was not free from the trust, regardless of any riparian rights. As previously discussed, in order for any conveyance of land to be free of the public trust, it must either promote public interests or the state must clearly express an abdication in statute.[284] By acknowledging the great recreational and ecological importance of tidelands to the public,[285] the Court granted the state authorization to use ecological interests as basis for burdening conveyed lands to ensure protection of the trust resource.

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[283] City of Berkeley v. Superior Court of Alameda, 26 Cal. 3d 515, 521 (1980) (relying on *Marks*, 6 Cal. 3d at 259-260). *See also* State of California v. Superior Court (Lyon) 29 Cal. 3d 210, 230 (1981)("the public's rights are not confined to commerce, navigation, and fishing, but include recreational uses and the right to preserve the tidelands in their natural state")

[284] *City of Berkeley*, 26 Cal. 3d at 523-528. *See also supra* note 44 and associated text.

[285] *Lyon*, 29 Cal. 3d at 216. On the other hand, the court also ruled that the public trust doctrine no longer burdens lands that have long since been reclaimed, but only the tidal portions thereof. *See City of Berkeley*, 26 Cal. 3d at 535.

This brings us to the seminal case, *National Audubon Society*, previously discussed at length.[286] In *National Audubon Society*, the California Supreme Court extended the public trust doctrine beyond mere acknowledgment that the state had authority to regulate the ecological aspects of trust resources, to affirmatively require the state to consider these ecological aspects. In brief, the court held that agencies "should consider the effect of such [water] diversions upon interests protected by the public trust, and attempt, so far as feasible, to avoid or minimize any harm to those interests."[287] Citing Marks v. Whitney, the court affirmed that recreational and ecological values are clearly among the interests protected by the public trust doctrine,[288] and these need to be protected to the maximum extent possible.

Nonetheless, this affirmation of ecological values was only discussed in the context of navigable waters, albeit navigable waters affected by the diversion of water from non-navigable tributaries. While the focus of the early California public trust doctrine was navigation, the California courts have been consistently cognizant of the impacts that are peripherally, but indisputably, connected to navigable waters. The court first forbade pollution of non-navigable streams under the public trust doctrine, as the pollution would travel downstream and obstruct navigable waters.[289] Then, in 1896, the California Supreme Court took "judicial cognizance" that the non-navigable river in controversy was connected to large navigable bodies of water and therefore

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[286] *See supra* note 93 and associated text.

[287] *National Audubon Society*, *supra* note 49, 33 Cal 3d. at 426.

[288] *Id.* at 434.

[289] People v. Gold Run Ditch & Mining Co., *supra* note 270, 66 Cal. at 146-148.

the connecting river would be protected under the public trust doctrine.[290] Likewise, in *National Audubon Society*, the court refuted claims that the tributaries were not protected by the public trust doctrine by recognizing that the impacts to the tributaries were causing harm to navigable waters.[291] This connection to navigable waters is essential, since courts have declined to apply the public trust doctrine in cases where there is not enough of a nexus to navigable water. In a suit regarding the water impacts of a hydroelectric dam to a man-made stream, the court did not apply the public trust doctrine, distinguishing the case from *National Audubon Society* and other case law, because there were no impacts to navigable waters.[292] Thus, the California public trust doctrine does not apply to all waters of the state, but only applies to navigable waters or waters that are related to navigable waters.

This rationale is exemplified by a recent case regarding the impact of groundwater diversions on navigable waters. In Environmental Law Foundation v. State Water Resources Control Board, the Superior Court of Sacramento ruled that groundwater extractions, as they affect navigable waters, are protected under the public trust doctrine.[293] When applying the public trust doctrine, the court clarified that it did not find that "***groundwater*** itself is a resource protected by the public trust

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[290] People v. Truckee Lumber Co., *supra* note 272, 116 Cal. at 401. The court ruled that the river, and the fish central to the case, were protected regardless of the navigability of the river.

[291] *National Audubon Society*, 33 Cal. 3d at 437.

[292] Golden Feather Community Association v. Thermalito Irrigation District 209 Cal. App. 3d 1276, 1284 (1989). While the Court refuted the public trust claim, it was sure to note that when there is a public interest, "the state has broad powers to protect those interests, even where otherwise nonpublic trust properties are affected." *Id*. at 1286.

[293] Environmental Law Foundation v. State Water Resources Control Board, Case No. 34-2010-80000583 (2014).

doctrine,"[294] but rather, only the navigable water impacted by these diversions was so protected. Therefore, "the public trust doctrine applies when the extraction of groundwater causes harm to navigable waters harming the public's right to use those navigable waters for trust purposes," including recreational and wildlife interests.[295] Thus, the public trust doctrine applies equally to *any* indirect impact that impairs the public's interest in navigable waters as would a direct impact to navigable waters.

Notwithstanding the above discussion, wildlife is not exclusively dependent on the public trust connection to navigable waters. The wildlife trust is not determined by any qualification akin to navigability, instead any impact to wildlife, direct or indirect, merits consideration. While early California cases included wildlife as an aspect of the public trust doctrine, these cases generally considered a narrower question of the trust over water resources that serve as wildlife habitat. They did not directly address whether wildlife itself was protected by the public trust doctrine. In a recent case regarding the wildlife impacts of land-based wind energy, Center for Biological Diversity v. FPL Group, the public trust doctrine was clarified to encompass the protection and preservation of wildlife, regardless of its relation to submerged lands.[296] Specifically, the Center for Biological Diversity (CBD) claimed that birds that were being killed at the land-based wind turbines owned and operated by the FPL Group were protected by the public trust doctrine, and the state had failed its duty to protect these birds by allowing outdated turbines to continue to produce electricity.

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[294] *Id.* at 8 (emphasis in original).

[295] *Id.* at 9.

[296] *CBD* v. *FPL*, *supra* note 48, 166 Cal. App. 4th at 1363.

The court first decreed that "[w]ildlife, including birds is considered to be a public trust resource of all the people of the state, and private parties have the right to bring an action to enforce the trust," beyond the limited perspective relating only to tidelands and navigable water. [297] Despite this important declaration of the public trust application to wildlife, the court dismissed the case, ruling that CBD had sued the wrong party, and should have sued the state trustee instead of the private operator of the wind farm. In dicta, without ruling on the adequacy of the state agency's efforts, the court found that the state agency had not ignored the highly complex and value laden aspects of wind turbines, specifically the impacts to birdlife.[298] While it was clear that the agency had performed the basic duties of planning trust resources, the court left it to further proceedings to determine whether the agency was minimizing harm to wildlife resources as feasible as possible.[299]

In the first public trust application to the wildlife impacts of electricity production, the court was mindful to weigh the common law and statutory wildlife trust interests, while noting the "strong public interest in allowing for the development through the harnessing of wind powers."[300] Scholarly commentary has argued that

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[297] *Id.* at 1354-1360. In addition to the incorporation of wildlife into the common law public trust doctrine, California courts also have recognized a public trust duty derived from statute pertaining specifically to fish and wildlife, *See* Environmental Protection Information Center (EPiC) v. Department of Forestry and Fire Protection 44 Cal. 4th 459, 514 (2008). *See also* Cal. Fish & Game Code §711.7, *supra* note 280.

[298] *CBD v. FPL* at 1372.

[299] Though it would depend on the specific definition of feasible, it would appear that repowering the site with newer models of turbines would be a cost-effective mitigation policy since they would increase electricity production, and thus revenue, while simultaneously decreasing avian mortality given slower rotational speeds.

[300] Kathryn Wiens. *Center for Biological Diversity, Inc. v. FPL Group, Inc.: Encouraging Wind Energy Production While Protecting the Public Trust*. 32 Environs Envtl. L. & Pol'y J. 389, 393 (2009).

this litigation has increased knowledge of avian mortality and that improved wind turbine technology "may lead to greater protection of the birds while still allowing wind energy to develop into a significant source of power for the future."[301]

Despite the public trust application to wind energy, and the learning opportunities gained, there has yet to be an instance in which the wildlife public trust doctrine has been applied to conventional electricity production, even though, as noted above, those impacts are more substantial. In these cases there is a stark absence of comparison between electricity production sources, and the state's duty to plan and protect public trust resources to the maximum extent possible.

3.7.1.3 Overview of Current California Electricity Laws

One reason that there may not be applications of the public trust doctrine to conventional electricity is that California has developed comprehensive electricity policy that promotes development of renewable energy while also attempting to mitigate the impacts from conventional electricity. First, the State of California is required by state law to conduct an assessment of all aspects of the energy industry periodically.[302] These assessments must lead to energy policies that "protect the environment,"[303] and, additionally, California has the responsibility to develop and promote renewable generation and other climate change mitigation technologies.[304]

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301 *Id.* at 394.

302 Cal. Pub. Res. Code § 25301(a).

303 *Id*. See also Cal. Pub. Res. Code §25303(b) et seq.

304 Cal. Pub. Res. Code §25305(a-d).

Nevertheless, none of these statutes make any notice of the special public trust responsibilities the state has nor do they connect these duties to regulating electricity production.

California, like many states, also has a Renewable Portfolio Standard (RPS), which requires a certain amount of electricity come from renewable energy sources. In California, this required that 20% of all electricity generated to have been renewable as of 2013, and that 33% of all electricity generated must be renewable in 2020.[305] The definition of renewable encompasses many technologies, including "biomass, solar thermal, photovoltaic, wind, geothermal, fuel cells using renewable fuels, small hydroelectric generation of 30 megawatts or less, digester gas, municipal solid waste conversion, landfill gas, ocean wave, ocean thermal, or tidal currents, and any additions or enhancements to the facility using that technology."[306] These represent technologies that have renewable sources of fuel, but do not necessarily minimize damages to public trust resources.[307] Furthermore, nowhere in California law currently connects the objectives of renewable electricity implementation to the state's duties under the public trust.

The most significant California renewable energy law is Assembly Bill (AB) 32, The Global Warming Solutions Act [hereinafter referred to as AB 32].[308] AB 32

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305 Cal. Pub. Res. Code §399.11(a).

306 Cal. Pub. Res. Code §25741(a)(1).

307 For example, a biomass plant has similar direct impacts to water resources as a coal plant since it still requires a CWIS, although its implications for climate change would be less. Likewise, hydroelectric plants obviously have impacts to local water resources as well.

308 Cal. Hsc. Code §38500 et seq.

authorized the California Air Resources Board (CARB) broad authority to reduce its GHG emissions from all sectors, but especially including electricity production. Since AB 32's enactment in 2006, CARB has implemented several policies to reduce electricity's contribution to climate change, including a cap and trade program and the Million Solar Roofs Program, as well as incorporating other already existing renewable energy policies, such as the RPS.[309] Likewise, it is mandatory for all investor-owned utilities to report their GHG emission from electricity production, inclusive of transmission losses.[310] In brief, the cap and trade program allocates a certain amount of GHG allowances to the electricity production sector. Participants in the sector then must reduce their emissions or purchase additional GHG allowances at quarterly auctions. CARB has updated the scoping plan, but the policies remain largely unchanged, with recent focus on mitigation plans beyond 2020.[311]

The impact of these regulations is that California has significantly incentivized renewable energy to meet the emission targets of 80% below 1990 GHG levels by 2050.[312] Since 2010, California has added 8.3 GW of renewable generation capacity in order to comply with these regulations,[313] but the electricity sector is still facing

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309 California Air Resources Board. *Climate Change Scoping Plan* 30-53 (2008). However, many of these efforts are rightly not related electricity, including focuses on transportation and agriculture.

310 Cal. Hsc. Code § 38530(b)(2).

311 California Air Resources Board. *First Update to the Change Scoping Plan* 93-100 (2014).

312 *See generally* Michael Hanemann. *California's New Greenhouse Gas Laws* 2(1) Rev. of Environ. Econ. & Pol'y 114 (2008) (summarizing and describing the history and implications of AB 32).

313 *Id.* at 54.

significant additional required reductions of GHGs by 2020.[314] Moreover, from 2020 until 2050, the annual GHG reduction will be five times the current annual rate, with less allowances handed out.[315] Despite California's leadership in climate change mitigation policy, noticeably absent in California's renewable energy law is the consideration of wildlife.

Unlike its response to climate change, California implements rules on CWIS only based on, and does not go beyond, the minimum federal requirements under §316(b) of the Clean Water Act (CWA).[316] Despite the potential co-benefits of integrating aggressive climate change policies with wildlife protection policies, these two remain disconnected in California law.

In conclusion, California is a leader in renewable energy and climate change mitigation policy, actively promoting and implementing renewable energy for the betterment of the environment. However, renewable energy policies are still unconnected to the robust state public trust doctrine and the duties as required of the state.

3.7.1.4 Applications of the Public Trust Doctrine in California

There are two potential applications of the public trust doctrine to current California energy policy: utilizing the duties under the public trust to defend against legal challenges of California's renewable energy effort, and expanding the scope of

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[314] 17 CCR § 95481

[315] California Air Resources Board at 47.

[316] 22 CCR §2922.

renewable energy laws to further protect wildlife and encourage more development of renewable electricity.

First, California's substantial efforts to mitigate climate change have not been without their controversies and criticisms. California's seminal climate change law, AB 32 "has been challenged multiple times by greenhouse gas (GHG) emission-emitting parties, by parties outside the state engaging in interstate commerce, and by environmental and citizen groups."[317] The main focus of these cases have been on either potential conflicts with the dormant Commerce Clause, and arguments in favor for more concrete climate change mitigation. It is worth evaluating the effect the public trust doctrine might have on these challenges given the implications of the success of federal and state law challenges would be significant and such challenges are ongoing.[318] The public trust doctrine could be used to navigate and help resolve these issues.

Since the wholesale side of the electricity sector is highly regulated at the federal level and the electricity grid is highly interconnected between states, California's electricity regulations have often led to conflicts with federal laws and powers.[319] The most serious challenge to AB 32 is that it is discriminatory in nature

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[317] Steven Ferrey. *Carbon Outlasts the Law: States Walk the Constitutional Line*. 41 B.C. Envtl. Aff. L. Rev. 309, 353 (2014). Many of the court cases, however, are entirely unrelated to electricity production, and focus on other sectors, such as transportation.

[318] *Id*. at 362

[319] Kevin S. Golden. *Senate Bill 1078: The Renewable Portfolio Standard- California Asserts Its Renewable Energy Leadership* 30 Ecology L.Q. 693, 698 (2003). The author noted that there was potential for conflict between California's RPS law and the federal law Public Utility Regulatory Policy Act (PURPA) as well as the dormant Commerce Clause.

to interstate commerce and thus violates the dormant Commerce Clause.[320] There are several elements of AB 32 that have potential conflicts with the Commerce Clause including its differential treatment of in-state generators and out-of state generators in attempts to minimize GHG emissions.[321] On the other hand, to ensure the efficacy of the cap and trade program, California must prevent "leakage"- the idea that reducing GHG-intensive electricity production in-state may lead to increased importing of cheaper and equally GHG-intensive electricity production from out-of-state, negating any benefit. While current dormant Commerce Clause legal challenges have been focused on the regulation of the origin of transportation fuels in AB 32,[322] the interstate nature of electricity leads to the likelihood that California may face similar dormant Commerce Clause regarding out-of-state electricity production.[323]

The public trust doctrine may only be of assistance to the state's legal defense against such a challenge as highlighting the legitimate local purpose of the regulation.[324] While the Supreme Court has previously held that that the public trust doctrine, namely the wildlife trust, is not a legitimate enough reason to discriminate

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320 Ferrey at 328.

321 *Id*. at 330-331. Further implicating AB 32 is the fact that the Supreme Court views electricity production and transmission as one of the most basic elements of interstate commerce. *See Id*. at 329, citing Federal Energy Regulatory Commission v. Mississippi 456 U.S. 742, 757 (1982).

322 *Id.* at 322. *See* Rocky Mountain Farmers Union v. Goldstene 730 F. 3d 1070 (2013) (discussing whether AB 32's ethanol fuel standards facially discriminated against interstate commerce).

323 Daniel K. Lee & Timothy P. Duane. *Putting the Dormant Commerce Clause Back to Sleep: Adapting the Doctrine to Support State Renewable Portfolio Standards* 43 Envtl. L. 295, 349 (2013). It is worth nothing that the authors think the success of such challenges may be limited.

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against interstate commerce on its face,[325] the public trust doctrine may still provide the state an opportunity to show the legitimacy of the regulation. Under the public trust doctrine California can distinguish regulation of climate change from previous environmental defenses because climate change not only impacts the public's interest in environmental resources, but also threatens all public interests in all trust resources.[326] Under the public trust doctrine, the state has a fiduciary duty to minimize the damage to all trust resources, whether from in-state or out-of-state sources. [327] While the public trust doctrine does not immunize the state from the U.S. Constitution, using the public trust doctrine to highlight the societal importance of AB 32 in comparison to the impairment of interstate commerce may allow courts to take a more nuanced approach to a challenge of the regulation.[328]

More substantially, looking beyond the current constitutional legal challenges, the public trust doctrine could also be useful to the state in in-state challenges to the cap and trade program. Currently, 90% of electricity's emissions are being given away by the state as free allowances,[329] implying electricity production has not been

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325 *Hughes*, *supra* note 138, 441 U.S. 322 (1979). Furthermore, the courts has not to acknowledge any environmental purpose as negating the Commerce Clause. *See* Ferrey at 311.

326 Compare the purpose of AB 32, i.e. preventing the impacts of climate change on the state of California, to the purpose of the regulation in *Hughes*, which at best, restored a fish population. While the efficacy of using the public trust doctrine as a defense of a dormant Commerce Clause challenge may be limited, the magnitude of the local purpose may allow a court to distinguish this particular case from previous reasoning.

327 See *supra* notes 289-292 and associated text. Under this line of thinking, even if out-of-state actions indirectly impact trust resources, the state must take feasible action to prevent damage.

328 The courts may uphold AB 32 if they find the promotion of local legitimate purposes, which this Article purports the public trust doctrine can fulfill, and if there are no other non-discriminatory alternatives that adequately protect the local interest. *See* Lee & Duane at 308.

329 Steven Ferrey. *Courts Cap the "Trade": Regulation of Competitive Markets When Courts Overturn State and Federal Cap-and-Trade Regulation* 117 W. Va. L. Rev. 691, 708 (2014).

burdened by the amount of requisite mitigation action thus far. However, the electricity sector will face more stringent GHG reductions as CARB continues to enact regulations in accordance to their ambitious goal of 80% reduction below 1990 levels. These more stringent regulations may generate additional political and legal challenges from in-state electricity producers. Yet, CARB could defend nearly any climate change regulation, if it connects the dots between climate change and the public trust doctrine, relying on the state's fiduciary duty to reduce all damages *whenever feasible*.[330] Since climate change undoubtedly negatively impacts trust resources, the public trust doctrine further authorizes—indeed mandates—CARB to take action to mitigate these impacts so much as it is feasible. Thus, in case of legal challenges, CARB could utilize the public trust doctrine to validate its further implementation of the statutory requirements of AB 32.

Taking this a step further, the public trust doctrine could provide a tool for citizens to incentivize renewable energy development. There have been several legal challenges that CARB currently faces regarding AB 32 implementation from in-state citizen groups. First, in a recent case, an environmental justice citizen group argued that CARB's scoping plan did not achieve the maximum technologically feasible and cost effective reduction, and unfairly burdened already overburdened communities.[331] Despite the potential for further reductions and the inequalities of the plan, the court ruled that the Board was well within the bounds of reason when developing the plans,

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330 *See National Audubon Society*, 33 Cal. 3d at 426.

331 Association of Irritated Residents v. Air Resources Board 206 Cal. App. 4th 1487 (2012). Specifically, the plaintiffs, AIR, argue that CARB has failed to decrease health impacts to low-income communities.

and rejected the citizen group's claim.[332] Likewise, another citizen group sued CARB over the issue of offset credits available for purchase, questioning whether these offsets credits purchased were in addition to what otherwise would have been otherwise required.[333] Again, the court denied the citizen group's claim, finding that the standards set forth by CARB were reasonable and within the authority granted to it by legislation.[334] In both of these cases, citizen groups were looking to ensure and force CARB to implement further, more tangible environmental protections. However, though the goals of AB 32 are lofty, the actual bill is quite brief and gave CARB incredible discretion to implement climate change reductions,[335] resulting in courts granting great deference to the expertise of CARB. As a result, without the public trust doctrine in their quiver, these decisions reveal that the environmentalists "may have little recourse to advocate for their principles in the courts."[336]

Given deference by the courts to CARB, "it is not hard to see why environmental justice advocates feel aggrieved."[337] Instead of challenging the administrative reasonableness of the implementation of AB 32, these citizen groups may find more success utilizing the public trust principles. Though the California

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332 *Id*. at 1505.

333 Citizens Climate Lobby v. California Air Resources Board. No. CGC-12-519554 (CA Sup. Ct. 2013).

334 *Id.* at 33.

335 Ann E. Carlson *Regulatory Capacity and State Environmental Leadership: California's Climate Policy* 24 Fordham Envtl. Law Rev. 63, 68 (2013).

336Penni Takade. *Association of Irritated Residents v. California Air Resources Board: Climate Change and Environmental Justice* 40 Ecology L. Q. 573 (2013)

337 *Id.* at 582

courts have previously recognized health aspects in public trust doctrine decisions,[338] these citizen groups may be able to gain some recourse by using the public trust doctrine under recreational and environmental grounds, with the co-benefit of reducing health benefits to and ensuring further climate change mitigation. For example, these citizen groups could utilize the public trust doctrine on a peripheral, though connected issue: open-cycle CWIS. In California, 16.5% of 2014 generation resulted from plants employing open-cycle CWIS.[339] These are usually among the oldest, most-polluting, and least-efficient power plants. Since open-cycle CWIS have such a dramatic effect on trust resources, citizen groups could sue the state to force these electricity producers to go beyond the standards of §361(b) regulation to a standard based on the reasonable use provision under the public trust doctrine. Since there exists a myriad of feasible CWIS alternatives, such as closed cycle or air-drying, these citizen groups could argue that under the public trust doctrine, the state can require these inefficient older plants to implement these new technologies, to promote the reasonable and beneficial use of water.[340] Moreover, the citizen groups could directly challenge CARB's implementation of AB 32 under the public trust doctrine, and argue that the plants that employ open-cycle CWIS not only cause health damages

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[338] *National Audubon Society*, 33 Cal. 3d at 432-433 (recognizing the impact to human health from airborne silt matter from dry riverbeds while also recognizing the air as a traditional trust resource).

[339] California State Water Resources Control Board (SWRCB). *Ocean Standards – CWA §316(b) Regulation: Thermal Discharges- Cooling Water Intake Structures* (Feb. 5, 2015), available at http://www.waterboards.ca.gov/water_issues/programs/ocean/cwa316/powerplants/. *See also* EIA (Feb 2, 2015) *Form EIA-923* available at http://www.eia.gov/electricity/data/eia923/. Of the 16.5%, half of this generation uses nuclear as a fuel source, and the other half uses natural gas.

[340] The citizen groups need not worry about the issue of standing, as California courts have recognized the rights of members of the public to sue in order to protect the public interest in trust resources. *See Marks, supra* note 309, 6 Cal. 3d at 260.

to overburdened communities, but also violate the public trust doctrine. If CARB is requires these plants to mitigate their public trust impacts, this will increase the costs of this generation, forcing some to shut down[341] or the price increase would make renewable electricity more competitive.[342] Both of these options would indirectly decrease health impacts and mitigate climate change. Though this course of action does not directly coincide with the previous efforts of these citizen groups, the public trust doctrine offers another avenue of recourse for their voices to be heard.

In conclusion, the public trust doctrine can be utilized by the state as a legal defense and by citizen groups as a tool to encourage the further development of renewable electricity. California's leadership in climate change mitigation policy has relegated the public trust doctrine to a more auxiliary, though potentially helpful role. The next state, Wisconsin, provides a sharp contrast to California.

3.7.2 Wisconsin

3.7.2.1 Current Electricity System

Unlike California, Wisconsin relies heavily on coal as its main source of fuel for electricity. In the most recently available data, Wisconsin used coal for 54% of electricity generation, followed by natural gas and nuclear, which comprised 19% and 16.5% of annual generation.[343] Renewable generation, comprised mostly of wind and

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341 *See* SWRCB *Ocean Standards*.

342 McCormack & Noel, *supra* note 206, at 17. Of course, in addition to the CWIS argument, the citizen groups could also add undue health impacts to their argument under the public trust doctrine, though there is less legal basis for it.

343 Wisconsin State Energy Office (Aug. 20, 2013). *2013 Wisconsin Energy Statistics Book* available at http://www.stateenergyoffice.wi.gov/section_detail.asp?linkcatid=2847&linkid=1451&locid=160. Note that in

biomass, totaled about 5.6% of annual generation.[344] Because Wisconsin uses conventional electricity for over 89% of its generation, the Wisconsin grid is quite carbon intensive, and has substantial impacts on the local wildlife. For example, Wisconsin's reliance on coal has led to higher than previously recognized levels of mercury bioaccumulation in the Great Lakes region and "[m]ercury concentrations in fish and wildlife exceed human and ecological risk thresholds in many areas, particularly inland waters."[345] Despite significant regional reductions in mercury emissions, especially from sources other than coal, there have been recent increases in the bioaccumulation of methylmercury, which are "cause for concern" for walleye, lake trout, northern pike, common loons, and bald eagle nestlings in and around the Great Lakes region.[346] Likewise, coal and natural gas have significant impacts on water resources through their CWISs and substantially contribute to climate change.

3.7.2.2 Public Trust Doctrine in Wisconsin

Wisconsin is bordered by Lake Superior and Lake Michigan, and has more than 15,000 inland lakes and 12,000 rivers, leading one scholar to comment that it is "dripping with water resources."[347] Given the abundance of water resources, it is

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2012, Wisconsin imported about 13% of its generation needs, more than double the amount which has historically been needed.

344 *Id.* Finally, hydroelectric provides about 2.6% of generation needs. *See also* EIA (2015) *Form EIA-923, supra* note 339 (reliance on fossil fuel generation has increased in 2014, through November).

345 Evers et al., *supra* note 220, at 1495. Furthermore, the highest such concentrations are generally found in Lake Superior, *See Id*. at 1493.

346 *Id.*

347 Gabe Johnson-Karp. *That the Waters Shall be Forever Free: Navigating Wisconsin's Obligation Under the Public Trust Doctrine and the Great Lakes Compact* 94 Marq. L. Rev. 415 (2010).

perhaps unsurprising that the public trust doctrine has played a central role in protecting Wisconsin's water quality.[348] The origin of the public trust doctrine in Wisconsin, like the state itself, has roots in the Northwest Ordinance of 1787, which acknowledged the importance of public access to navigable waters. Upon statehood, this provision of the Northwest Ordinance was then incorporated into the Wisconsin Constitution, practically word for word, declaring that "the river Mississippi and the navigable waters leading into the Mississippi and St. Lawrence, and carrying places between the same, shall be common highways and forever free."[349] As will be discussed further below, this constitutional provision "both imposes a duty on and gives authority to the state to regulate navigable waters…[and] requires state action to preserve and promote the trust and it establishes rights to use trust property."[350]

Beyond its constitutional amendment, the state of Wisconsin has codified several aspects of the public trust doctrine into its statutes. Included in these statutes are the state's right to regulate navigation for the public interest,[351] state's right to protect and regulate state lands and fisheries,[352] the vesting of legal title of all wild animals in the state for the enjoyment, use, disposition, and conservation of the public,[353] and lastly, the right and duty to improve water quality, especially within

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348 *Id.* at 416.

349 Wis. Const. art. IX §1.

350 Melissa Kwaterski Scanlan. *The Evolution of the Public Trust Doctrine and the Degradation of Trust Resources: Courts, Trustees and Political Power in Wisconsin* 27 Ecology L.Q. 135, 141-142 (2000).

351 Wis. Stat. Ann. §30.01-30.99.

352 Wis. Stat. Ann. §23.11.

353 Wis. Stat. Ann. §29.011.

navigable waters, including the protection and promotion of interests in fulfillment of the state's role as trustee.[354] As a result of the broad powers of the state set forth in both the constitution and in state statutes, the Supreme Court of Wisconsin has wrestled with working out a "reasonable meaning for the public trust doctrine."[355]

Because the Wisconsin landscape is dominated by freshwater lakes, the Wisconsin Supreme Court has consistently grappled with the conflict between private riparian rights and public rights in navigable water. First, in the earliest cases, the Wisconsin Supreme Court clarified the state's title in navigable waters, holding that riparian title ends at the bank of a lake, while also rejecting that the ebb and flow test for state title to navigable waters.[356] Instead, the court employs a navigability-in-fact test. The court also has clarified that the state's title is held by "in trust only, for the public uses and purposes of navigation and fishing."[357] Citing *Illinois Central*, the court continued that riparian rights include constructing a landing or wharf, but the these rights are "subject to such general rules and regulations as the legislature may describe for the protection of the rights of the public" in which the state holds in these lands by "virtue of its sovereignty."[358]

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354 Wis. Stat. Ann. §281.11, .12, .31.

355 Sax, *supra* note 40, at 509.

356 Diedrich v. Northwestern Union Railway Co. 42 Wis. 248, 262-263 (1877). It should be noted that while riparian title ends at the bank for lakes, Wisconsin Courts have held that riparians hold title to lands underneath rivers and streams, though subject to the public trust doctrine. *See Willow River Club, infra* note 359, 100 Wis. at 95-97.

357 McLennan v. Prentice 85 Wis. 427, 443 (1893). The Court held that this title was subject to the paramount authority of Congress.

358 *Id.* at 444.

The court first addressed the conflict between riparian rights and public rights (as opposed to state ownership) in Willow River Club v. Wade.[359] In that case, the plaintiff claimed that the defendant had committed an act of trespass by taking fish while on a river which flowed through the plaintiff's land. The court rejected the plaintiff's claim of title to the fish, holding that "the public should have the right to fish in all the public navigable waters of the state, including all public navigable rivers and streams of the state."[360] This right to fish and hunt has since been rigorously protected by the Wisconsin courts, for example, holding that hunting and of fishing rights are held "incident to the right of navigation" and subjecting riparian rights to the public's guaranteed access to hunt and fish.[361]

Likewise, Wisconsin courts have recognized the state's title in wildlife and established the wildlife trust. In Krenz v. Nichols, the court acknowledged the state's broad authority in wildlife regulation, saying that "the state holds title to the wild animals in trust for the people...[and as] trustee for the people, the state may conserve wild life and regulate or prohibit its taking in any reasonable way it may deem necessary for the public welfare."[362] In addition, in Monka v. State Conservation Commission, Wisconsin Supreme Court decided that the regulation and conservation of wild animals is a uniquely statewide interest under the trust doctrine, as opposed to

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359 Willow River v. Wade 100 Wis. 86 (1898)

360 *Id*. at 102.

361 Diana Shooting Club v. Husting 156 Wis. 261, 268-269 (1914).

362 197 Wis. 394, 400 (1928).

a merely local concern.[363] Thus, the state, as the protector of the public rights in waterways and wildlife, has paramount authority above both local governments and private riparian owners.

Beyond affirming the state's paramount authority the court also documented the duty associated with these public rights. The court held that the public trust doctrine "reposed in the State is not a passive trust; it is governmental, active and administrative… [and] requires the law-making body to act in all cases where action is necessary, not only to preserve the trust but to promote it."[364] Preserving the public trust and promoting the public interest can at times be in conflict. In response, the court has attempted "to promote justice between all the parties interested therein, and particularly preserve the interests of the State in the trust."[365] Though the state must continually protect and promote the interests, this does not prevent development or alteration of trust resources. The state is not required to keep trust resources "in the same condition and contour as they existed of prior to the advent of the white civilization in the territorial area of Wisconsin" so long as these developments improve the public interest.[366]

Notably, one unique aspect of the Wisconsin public trust doctrine is that "scenic beauty" has been incorporated as one of the protected public interests in trust resources. In a case regarding a permit application for the construction and operation

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[363] 202 Wis. 36, 46 (1930).

[364] City of Milwaukee v. State 193 Wis. 426, 449 (1927).

[365] *Id.* at 446.

[366] *Id*. at 451-452. In fact, the state is required under the affirmative nature of the trust to improve trust resources to maximize benefits to the public.

of a hydroelectric dam, a private citizen sued to review the permit, arguing that the dam would negatively impact the public's recreation and scenic enjoyment of the navigable river.[367] The Wisconsin Supreme Court ruled that the "right of the citizens of the state to enjoy our navigable streams for all recreational purposes, including the enjoyment of scenic beauty, is a legal right that is entitled to all the protection which is given financial rights."[368] As a result, the court vacated the permit and remanded the issue to the Public Service Commission, the permit-granting agency, requiring that it consider the impacts of the dam on the public's recreational and aesthetic interests.

Next, in 1957, the court affirmed that "[e]njoyment of scenic beauty has been recognized as one of the public rights in navigable waters."[369] In addition to scenic beauty, the court recognized and protected *all* public uses of water, including pleasure boating, sailing, fishing, swimming, hunting, and skating.[370] Despite these protections, the court has not forbade any and all encroachments on the public trust lands. In twin cases, the court ruled that the construction of an auditorium and civic center, as well as the construction of a parking lot and highway on public trust lands were both valid promotions of the public interest and did not violate the state's public trust obligations.[371] To navigate the potential conflicts of preserving the public

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367 Muench v. Public Service Commission 261 Wis. 492 (1952).

368 *Id*. at 511-512.

369 City of Madison v. State 1 Wis. 2d 252, 258 (1957).

370 State v. Public Service Commission 275 Wis. 112, 118 (1957).

371 *Id*. *See also City of Madison*.

interest in trust resources with the duty to promote development in accordance with the public interest, the Wisconsin courts devised the following five-point test:

1. Public bodies must control the use of the area
2. The area will be devoted to the public purposes and open to the public
3. The diminution of the public trust resource will be very small compared with the whole of the public trust resource
4. No one of the public uses of the resource will be destroyed or greatly impaired.
5. The disappointment of those members of the public who may desire to use the public trust resource who no longer can will be negligible when compared with the greater convenience to be afforded those members of the public who would benefit.[372]

Subsequently the Wisconsin courts have stressed that the state must "weigh[] all the relevant policy factors including the desire to preserve the natural beauty of our navigable waters, to obtain the fullest public use of such waters, including but limited to navigation, and to provide for the convenience of riparian owners."[373]

Building on the foundation of the Wisconsin court's early history of grappling with complex public trust doctrine issues, the Wisconsin trust doctrine began to progress in both its scope and its application. First, the Wisconsin Supreme Court explicitly extended the public trust to water quality, as "[p]olluted waters do become

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[372] Paepcke v Public Building Commission of Chicago, 46 Ill. 2d 330, 343 (1970), citing and summarizing *City of Madison*, 1 Wis. 2d at 259-260 and State v. Public Service Commission, 275 Wis. At 118.

[373] Hixon v. Public Service Commission 32 Wis. 2d 608, 620 (1966).

less useful for most, if not all…public purposes."[374] Furthermore, the state actions to ensure the prevention of water pollution and protection of water quality are valid exercises of the state's police power, "as well as being part of the state's affirmative duty under the "public trust" [sic] doctrine."[375]

After incorporating water quality into the public trust doctrine, the court held in the ensuing case that the public trust doctrine can be a tool used by the state to avoid regulatory takings.[376] Wisconsin has the affirmative duty "to eradicate the present pollution and to prevent further pollution in its navigable waters. This is not, in a legal sense, a gain or a securing of a benefit by maintaining the natural *status quo* of the environment," but rather, to prevent a harm to the public interest.[377] In addition, the court, in that same case, after acknowledging "the interrelationship of wetlands, swamps, and [the] natural environment of shorelands to the purity of water, and to such natural resources as navigation, fishing and scenic beauty," extended the public trust out of navigable rivers to connected, albeit non-navigable waters,[378] much as California did in the *National Audubon Society* case.[379] As a result, the court began

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[374] Reuter v. Department of Natural Resources 43 Wis. 2d 272, 277 (1969). The Court recognized that the public's interest in sailing, rowing, caneoing, bathing, fishing, hunting, skating, and other public purposes would be impaired by water pollution.

[375] Wisconsin Environmental Decade v. Department of Natural Resources 85 Wis. 2d 518, 533 (1978).

[376] *See generally* Lucas v. South Carolina Coastal Council 505 U.S. 1003, 1027-1029 (1992)(background principles of state or federal law which are antecedent to property rights can be used as a defense against takings claims).

[377] Just v. Marinette 56 Wis. 2d 7, 16 (1972). *See also* Lucas v. South Carolina Coastal Council 505 U.S. 1003, 1024-1032 (1992)(discussing the implications of conferring benefits or preventing harms on regulatory takings).

[378] *Id*. a t 16-17.

[379] *See supra* note 287-291 and associated text.

to emphasize that the "active trust duty of the state of Wisconsin in respect to navigable waters requires the state *not only* to promote navigation *but also* to protect and preserve those waters for fishing, recreation and scenic beauty."[380] The court confirmed this emphasis by displacing the common enemy doctrine with the reasonable-use doctrine regarding riparian water use and management,[381] holding that the riparian rights are subject to the public trust doctrine, and on remand, warned that "the economic social utility of land development of that impinges on the public trust is to be given far less value than tradition accorded it during the period of the industrial revolution."[382]

In recent public trust cases, the court has reiterated that the "rights of riparian owners… are qualified, subordinate, and subject to the paramount interest of the state and the paramount rights of the public in navigable waters."[383] Furthermore, state agencies, under the public trust analysis, are required "to go *beyond the statutory resumption* to determine what "reasonable use" is in light of the relevant facts particular to each situation."[384] Though Wisconsin has always cautiously weighed private riparian rights against the interests of the public, these recent cases reflect growing concern over the environmental and recreational interests of the public. This

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380 *Id.* at 17 (emphasis added).

381 Briefly, the common enemy doctrine is a common law doctrine that authorizes a landowner to fight surface waters in whatever way they deem appropriate, and if an adjacent landowner's property was damaged, there would be no cause of action. *See* State v. Deetz 66 Wis. 2d 1, 8 (1974).

382 *Id.* at 20-21.

383 R.W. Docks & Slips v. State of Wisconsin 244 Wis. 2d 497, 511 (2001). In this case, the court ruled a riparian owner who was denied a permit could not claim a regulatory taking since he never owned the trust resources.

384 Hilton v. Department of Natural Resources 293 Wis. 2d 1, 16 (2006) (emphasis added).

culminated in the recent case, Lake Beulah Management District v. Department of Natural Resources.[385] There, the Lake Beulah Management District (LBMD) sued the Wisconsin Department of Natural Resources' (WDNR) decision to issue a permit for a groundwater well, arguing that the groundwater diversions would have an adverse impact on nearby wetlands and navigable surface waters, thus violating the WDNR's public trust duty. On the other hand, WDNR denied any responsibility to consider the implications from groundwater, arguing that those waters are not subject to the public trust. The court addressed this reiterating the comprehensive statutory and constitutional trust responsibilities of the WDNR, including "the authority and general duty to consider whether a proposed high capacity well may harm waters of the state."[386] Similar to the recent California public trust case regarding groundwater,[387] the Wisconsin court held that the trustee is required to consider any action so far as it potentially impacts navigable waters. In order to comply with its duty as trustee, the WDNR "must consider the environmental impact… when presented with sufficient concrete, scientific evidence of potential harm to waters of the state."[388] The authority and duty of the Wisconsin trustee encompasses any aspect that has sufficient scientific evidence of a connection to navigable waters, regardless of *physical* location. As a result, Johnson-Karp notes that the Wisconsin trustee's obligations are "more

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[385] Lake Beulah Management District v. Department of Natural Resources 335 Wis. 2d 47 (2011) (*Lake Beulah*).

[386] *Id.* at 73.

[387] *See Environmental Law Foundation, supra* note 293 and associated text.

[388] *Id*. at 76. The court, however, concluded that this evidence had not been properly introduced procedurally, and thus the WDNR did not have sufficient scientific evidence that the groundwater well would impact navigable waters.

comprehensive than previously understood, in that the state is expected to engage in its fiduciary duties regarding public trust resources whenever there is evidence that those resources may be affected."[389]

Thus, generally, Wisconsin courts have required trustees to show that they have considered all relevant public and policy interests in trust resources so far as there is a scientific connection between the action and the potential impact. This has led to the geographic and legal expansion of the public trust doctrine in Wisconsin. The courts have generally deferred to the trustee in cases where the trustee has acted to protect public trust resources, and conversely, the court has closely scrutinized any proposed trustee action that appears to jeopardize trust resources.[390] Therefore, the Wisconsin courts have actively and expansively forced the trustee to protect public resources to garner the public the maximum beneficial protection and use of trust resources.

However, the progressive trend in the Wisconsin public trust case law recently took a sharp and sudden turn with the case, Rock-Koshkonong Lake District v. Department of Natural Resources.[391] The facts of this case concern the rehabilitation of an outdated dam. This rehabilitation caused flow to Lake Koshkonong to decrease, which had two impacts; first, it negatively impacted riparian access for residential and commercial lakeshore owners, and second, it benefited non-navigable wetland

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389Johnson-Karp, *supra* note 347, at 427 (discussing the appellate case which was partially affirmed, partially overturned on other grounds).

390 Scanlan, *supra* note 350, at 140-147.

391 Rock-Koshkonong Lake District v. Department of Natural Resources 350 Wis. 2d 45 (2013)(*Rock-Koshkonong*).

ecosystems, improving water quality in the lake, fish and wildlife in the navigable Lake Koshkonong. The Lake District petitioned the WDNR to re-raise the water levels in the economic interest of the residents, but the WDNR rejected the petition, stating that it was required to protect wetlands and its benefit to water quality in the lake under the public trust doctrine, and was not required to consider the economic impacts in its decision.

Despite the court's tendency to affirm WDNR orders when these efforts are to protect the public interest, the court closely scrutinized the WDNR decision. First, the court found that the WDNR decision was not entitled to a deference standard of "great weight."[392] Second, the court ruled that the WDNR had incorrectly relied on the public trust doctrine when considering the water quality of non-navigable private wetlands, and instead should have utilized its police powers to do so.[393] The court constrained public trust doctrine to exclusively navigable waters, arguing that the elimination of "the element of "navigability" from the public trust doctrine would remove one of the prerequisites for the [W]DNR's constitutional basis for regulating and controlling water and land."[394] Lastly, the court scrutinized the WDNR's decision to largely ignore the economic implications of its decision, and remanded the case to the WDNR to further consider these implications.[395] This decision is an abrupt

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392 *Id*. at 75.

393 *Id*. at 85-89. However, this appears to ignore the precedents set in *Just*, *supra* note 377, and *Lake Beulah*, *supra* note 385, both of which argue that the state has the authority and duty to consider all potential impacts to navigable waters, including non-navigable private wetlands, under the public trust doctrine.

394 *Id.* at 81.

395 *Id*. at 108-113.

departure from the court's precedent that and continuous depiction of the trust doctrine as an expansive tool to protect the public's interest in adjacent wetlands to navigable waters. The majority's decision was criticized by a hearty dissent as well as by scholarly commentary.

First, Eickelberg (2014) argues that the "majority's decision was inconsistent with the history and purpose of Wisconsin's PTD because it overlooked the relationship between wetlands and navigable waters"[396] and inconsistent with the court's precedent, thus doing "a disservice to Wisconsin's protection of public trust resources."[397] Likewise, the dissent in *Rock-Koshkonong* argues that the decision "needlessly unsettles our precedent and weakens the public trust doctrine… [and] represents a significant and disturbing shift in Wisconsin law."[398] The dissent argues that that majority decision essentially misses the point of the public trust doctrine:

> The heart of the public trust doctrine lies in protecting, preserving, and promoting the public's right to Wisconsin's waters, and this court has vigilantly guarded these rights. The public trust doctrine entrusts to the state the duty to protect, preserve, and promote the public trust. The majority untethers our constitutional jurisprudence from its foundation and attempts to transform 165 years of constitutional precedent into mere legislative exercise of the state's police power.[399]

Furthermore, the distinction made in the majority between using the police powers and public trust doctrine to regulate non-navigable wetlands is important

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[396] Christian Eickelberg. *Rock-Koshkonong Lake District and the Surprise Narrowing of Wisconsin's Public Trust Doctrine* 16 Vt. J. Envtl. 38, 62 (2014).

[397] *Id*. at 65.

[398] *Rock-Koshkonong,* supra note 391, 350 Wis. 2d at 116.

[399] *Id*. at 121. The dissent attempts to explain the "majority's puzzling holding" believing that it "confuse[s] the concepts of ownership of (or title to) the land with regulation pursuant to the public trust doctrine." *Id*. at 127.

because the public trust doctrine provides the state a complete defense to private landowner's taking claims, and burdens the state with an affirmative duty to actively maintain and protect public trust lands.[400] On the other hand, police powers does not provide the state a regulatory taking defense, and only gives the state the authority to enact regulations as opposed to burdening it with a fiduciary duty as the trust doctrine does. In conclusion, the majority decision was inconsistent with previous precedents that held waters that are adjacent or connected to navigable waters are subject to Wisconsin's public trust, and "upsets settled expectations without clearly explaining why the court has apparently changed the law."[401]

In light of this decision, the future application of the Wisconsin public trust doctrine is uncertain. This case conflicts with previous precedents, and calls into question the historical and expansive role the trust has played in Wisconsin. Although there also has been scholarly commentary calling for further expansion of public rights, such as drinking water,[402] the resolution of such calls for expansion and utilization of the public trust with the constricting *Rock-Koshkonong* decision remains to be seen.

3.7.2.3 Overview of Current Wisconsin Electricity Laws

Current Wisconsin law encouraging renewable energy is limited. Electricity planning and policies are largely delegated to Wisconsin's Public Service Commission (WPSC). The WPSC is required to develop a strategic energy assessment every two

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400 Eickelberg at 41. *See also Just*, *supra* note 377, 56 Wis. 2d at 16.

401 *Id*. at 65.

402 Johsnon-Karp, *supra* note 347, at 439.

years, and in this report, the WPSC must "identify and describe existing and planned generating facilities that use renewable sources of energy."[403] Prior to the construction of a new electricity facility, the utility must gain either a Certificate of Authority (CA)[404] or a Certificate of Public Convenience and Necessity (CPCN),[405] depending, among other things, the size of the project. Generally, the CPCN requires more analysis and affords ratepayers more protection than a CA would. Additionally, Wisconsin has stated the goal that "to the extent that is cost-effective and technically feasible, all new installed capacity for electric generation in the state be based on renewable energy resources."[406] Furthermore, the state has placed a priority on energy development, known as the Energy Priorities Law (EPL), in this order:

a. Energy conservation and efficiency
b. Noncombustible renewable energy resources
c. Combustible renewable energy resources
d. Nonrenewable combustible energy sources, in the order listed:
    1. Natural gas
    2. Oil or coal with sulfur content less than 1%
    3. All other carbon-based fuels.[407]

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403 Wis. Stat. Ann. §196.491(2)(a)9.

404 Wis. Stat. Ann. §196.49

405 Wis. Stat. Ann. §196.491(3)

406 Wis. Stat. Ann. §1.12(3)(b).

407 Wis. Stat. Ann. §1.12(4).

Though the EPL stresses the priority of renewable generation, it is up to the PSC to determine if renewable energy resources are both "cost-effective" and "technically feasible" when planning new electricity development. As will be discussed below, *infra* note 389, due to the discretion of the PSC, the EPL has not always lead to the selection nor incentivized the development of renewable energy.

Like California and many other states, Wisconsin also has an RPS. However, the goals of Wisconsin's RPS are significantly less ambitious than California's, with a requirement of only 10% by 2015.[408] For both the RPS and the EPL, the renewable technology includes: renewable-sourced fuel cells, tidal and wave power, solar thermal and photovoltaic, wind power, geothermal, biomass, and waste fuel.[409] Finally the WPSC is statutorily forbidden from imposing any other requirements to increase any electricity provider's renewable energy beyond the 10%.[410]

The state of Wisconsin does not have any comprehensive climate change or renewable energy legislation, as is the case in California. Instead, "over the past decade, the Wisconsin Legislature has declined to take any real significant steps toward developing a long-term renewable energy strategy."[411] While many of the

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[408] Wis. Stat. Ann. §196.378(2). Moreover, legacy hydroelectric and renewable had already comprised about 6% of total generation each year from 1990 to 2004. *See* Wisconsin State Energy Office, *supra* note 343

[409] Wis. Stat. Ann. §196.378(1)(h)

[410] Wis. Stat. Ann. §196.378(4m)

[411] Marvin C. Bynum II. *Testing the Waters: Assessing Wisconsin's Regulatory Climate for Offshore Wind Projects* 93 Marq. L. Rev. 1533, 1573 (2010).

statutes pertaining to the WPSC require that it consider the "public interest"[412] the language of the statute implies, and the courts have interpreted it to mean protection of ratepayers,[413] primarily in terms of electricity cost instead of the public's interest in other matters such as public health, climate and trust resources. Thus, the trustee's fiduciary obligations to protect public water and wildlife resources remain largely disconnected from the PSC's electricity planning and permitting responsibilities. By connecting the state's well-developed public trust doctrine to electricity planning and policy, the state of Wisconsin, and its citizens, can encourage renewable energy beyond its current lackluster renewable energy policies.

3.7.2.4 Applications of the Public Trust Doctrine in Wisconsin

Because Wisconsin's renewable energy laws are underdeveloped, the public trust doctrine could be utilized to contribute to their development. Specifically, citizens could cite WDNR's broad authority and general duty under the public trust doctrine to influence WPSC's electricity decision-making process, and encourage further development of renewable energy. Both the WPSC, and the Wisconsin Supreme Court, when reviewing WPSC orders, appear to have not considered or not be cognizant of the environmental and trust resource benefits from increased renewable electricity penetration. In the few legal challenges to recent WPSC electricity decisions, the courts have not recognized the larger social and public trust

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412 *See* Wis. Stat. Ann. §196.49(a)(a) (requiring "plans, specifications, and estimated costs of any proposed project which will…materially affect the public interest."). *See also* Wis. Stat. Ann. §196.491(3)(d)3 (the PSC is required to find that the design of the project is in the public interest to issue a CPCN).

413 *See* Wisconsin Industrial Energy Groups v. Public Service Commission 342 Wis. 2d 576, 603 (2012) (*WIEG v. PSC*)

benefits of renewable electricity development, and vice versa, has not recognized the consequences of continued conventional electricity production. Notably, in 2005, the Wisconsin Supreme Court was faced with a WPSC decision to grant the Wisconsin Electric Corporation (WEC) a CPCN to begin construction on two large coal-fired plants on the shores of Lake Michigan. A citizen's group, Clean Wisconsin, Inc., appealed the WPSC approval, arguing that the CPCN application was incomplete and that the WPSC did not properly give priority to non-coal sources of electricity, especially under the EPL.[414] On the other hand, the WPSC argued that the conditional approval of the incomplete CPCN was valid because it was conditioned on WDNR approval of permits. Despite coal-fired generation being the lowest priority on the EPL, its selection was valid because all higher priority technologies were either not "cost-effective" or "technologically feasible."

When it considered the validity of the WPSC's decision, the court first examined the level of deference due to the expertise of the agency. Under Wisconsin state law, there are three potential standards of review for an agency's interpretation of a statute; great weight deference, due weight deference, or no deference (also known as "de novo" deference).[415] Under great weight deference, courts will uphold an agency's interpretation so long as it is reasonable, even if it is not the *most* reasonable. Under due weight, the interpretation will be upheld only if there is not a more reasonable interpretation. Of these three potential standards of review, the court concluded that the WPSC decisions are to be accorded great weight so that Clean

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[414] Clean Wisconsin, Inc. v. Public Service Commission 82 Wis. 2d 250 (2005)(*Clean Wisconsin*).

[415] *Id*. at 307. *See also* Wis. Stat. Ann. §225.57 (determining the court's statutory scope of review).

Wisconsin had the burden to demonstrate that there is "*no rational basis*" for the WPSC order.[416]

The court's deference to the WPSC made Clean Wisconsin's challenge an uphill battle. By contrast, the court typically gives WDNR very little to no deference when the WDNR makes a decision that appears to impair public trust resources.[417] Thus, Clean Wisconsin, and other similar groups could have utilized the public trust doctrine to reframe that electricity decision by reframing the challenge as one under the public trust doctrine. Since the court has historically closely scrutinized decisions adversely impacting trust resources, Clean Wisconsin would likely have a more successful challenge.

Since the "prevailing purpose of Wisconsin public utility laws is to protect the consuming public, i.e. rate payers,"[418] instead of environmental protection, the WPSC order discounted the benefits of renewable energy and emphasized the economic benefits of the two coal plants. Moreover, the WPSC concluded that wind, biomass, and natural gas alternatives to the coal plants "are not cost-effective, technically feasible alternatives."[419] Clean Wisconsin criticized the WPSC's analysis for vastly underestimating the cost of fuel for coal, and for not including any health damages due to coal emissions.[420] In spite of potential harms to the environment and the public, the

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416 *Id*. at 321 (emphasis added).

417 Scanlan, *supra* note 350, at 140-147.

418 *WEIG v. PSC*, 34 Wis. 2d at 603.

419 *Clean Wisconsin*, 82 Wis. 2d at 338. The court also reviewed several previous orders and cases that repeatedly concluded that wind was neither "cost effective" nor "technologically feasible."

420 *Id*. at 355.

court upheld administrative decision, deferring to the WPSC. As a result, the court affirmed the WPSC's determination that neither land-based nor offshore wind would be able to replace the two coal-fired plants.[421]

Of particular interest to the potential application in Clean Wisconsin is the challenge to WPSC's approval of the WEC's open-cycle CWIS.[422] The WPSC found that despite the one billion gallons of water withdrawn per day, and the millions of aquatic organisms killed, the open-cycle CWIS would have "inconsequential" impacts on Lake Michigan's ecosystem.[423] The court deferred under the great weight standard, finding that the PSC had sufficed its responsibilities by taking a "hard look" at the environmental consequences of the coal plants.[424] However, this finding was based largely on an I&E monitoring study conducted in 1975, thirty years prior. In contrast to the majority opinion, the concurrence was not convinced by the WPSC's finding, failing "to see how the 'wholesale destruction of millions of fish and other aquatic life is of no consequence, irrelevant and lacking importance."[425] Likewise the dissent thoroughly questioned the majority's acceptance of the open-cycle CWIS,

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[421]Compare the WPSC's determination on the cost-effectiveness of wind without any health externalities (or other externalities of interest, such as climate change externalities) to the monetization of coal's externalities, which would necessarily increase the cost of coal to more than double the cost of wind energy. *See* Paul R. Epstein et al. *Full Cost accounting for the life cycle of coal* 1219 Annals of the New York Academy of Sciences 73 (2011) (the monetization of coal's externality would near 17 cents per kWh). *See also* Public Service Commission of Wisconsin. *Harnessing Wisconsin's Energy Resources: An Initial Investigation into the Great Lakes Development* Docket No. 5-EI-144 (2009) (finding that offshore wind energy in the Great Lakes is technically feasible).

[422] While the WPSC was the primary decision-making agency, the WDNR also contributed to and confirmed the decision, especially the environmental aspects. When the court deferred to the WPSC, they were also deferring to the WDNR.

[423] *Clean Wisconsin*, 282 Wis. 2d at 381.

[424] *Id*. at 387.

[425] *Id*. at 428.

contending that the WPSC did not seriously consider the substantial environmental and technological changes regarding closed-cycle CWIS over the last three decades.[426] Nevertheless, the majority emphasized the role of agency expertise and discretion in balancing various social and environmental values. The court upheld the WPSC's finding that WEC was not required to consider closed-cycle CWIS as an alternative, because the WDNR "does not have the authority to require closed-cycle cooling for this project" until such time as the WDNR and the U.S. EPA come to an agreement on how to implement §316(b) of the CWA.[427]

As there were several WDNR permits required antecedent to the WPSC's CPNC,[428] Clean Wisconsin also could have utilized the WDNR's public trust obligations as a basis to challenge the construction of the coal plants. [429] The WDNR has the affirmative duty beyond any statutory requirements, including the CWA, to protect public trust resources.[430] In connecting the public trust to the WPSC's order, the plaintiffs could have gained the advantage of a likely stricter standard of review, and a more serious consideration of the impacts of open-cycle CWIS as well as the

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[426] *Id*. at 435. The dissent also argues that there should have been no deference given to the PSC order.

[427] *Id.* at 388.

[428] *Id.* at 400

[429] The WPSC cannot grant approval to the permit without the required regulatory approvals from the WDNR, *see Id*. at 364 (though they can grant conditional approval of the permit). While the WPSC is the primary agency for electricity decisions, the WDNR has been designated as the primary agency for managing the public trust. Because the WPSC requires supplementary approval and permit information from WDNR before granting a permit, Clean Wisconsin can challenge the WPSC's decision by arguing the WDNR had failed faithfully discharge is fiduciary duty to consider the impacts of the proposed action on public trust resources, and thus the WPSC did not acquire the requisite regulatory approvals from the WDNR antecedent to permit approval. If the WPSC grants conditional approval of the CPCN, the permit applicant must still receive approval from the WDNR, including an analysis of the public trust doctrine.

[430] *See Hilton*, *supra* note 384, and associated text.

mitigation of other adverse impacts, such as mercury bioaccumulation and climate change, which would encourage the prioritization of renewable energy under the EPL. Since the court granted the PSC great weight deference, the environmental impacts of the two coal plants were not seriously investigated. If Clean Wisconsin had instead challenged the DNR, citing its trust obligations, the court would have likely scrutinized each of the potential impacts of the coal plants and the conclusion that coal was indeed the most "cost effective" and "technologically feasible."

In spite of the recent limitations on the trust doctrine in *Rock-Koshkonong*, the public trust can still be readily applied to electricity production. At worst, *Rock-Koshkonong* limited public trust questions to exclusively navigable waters. But, because the impacts from electricity production directly impact navigable waters and wildlife, there can be little question that the public trust doctrine applies. First, the two coal plants in *Clean Wisconsin* directly withdrew waters from the navigable Lake Michigan. Furthermore, these coal plants are only a portion of the cumulative electricity production impacts to water, as electricity, by withdrawing 3.6 billion gallons per day, accounts for 86% of the total annual Wisconsin water withdrawals from the Great Lakes watershed, due to the fact that the majority of thermal plants employ open-cycle CWIS.[431] Given these facts and the growing concern of continued Great Lake water diversion,[432] a less deferential standard of review should result in

[431] Great Lakes Commission. *Annual Report of the Great Lakes Regional Water Use Database: Representing 2013 Water Use Data* (2014) Available at http://projects.glc.org/waterusedata/annualreports.php. *See also* Great Lakes-St. Lawrence River Basin Water Resources Council. *Great Lakes Regional Water Use Baseline Database* (2015). Available at http://www.glslcompactcouncil.org/ViewWithdrawals.aspx (reporting plant-specific water withdrawals), *See also See also* EIA (2015) *Form EIA-923, supra* note 339.

[432] *See generally* Noah D. Hall & Bret B. Stuntz. *Climate Change and Great Lakes Water Resources: Avoiding Future Conflicts with Conservation* 31 Hamline L. Rev. 639 (2008)(climate change poses a severe threat to Great Lakes water resources, especially if diversions are not held in check).

the refutation of the idea that the impacts from open-cycle CWIS are "inconsequential," especially when considering the comprehensive and cumulative impacts to water and wildlife trust resources. Likewise, given the feasibility of closed-cycle CWIS and the significant reductions in impacts to trust resources, Clean Wisconsin could have made a much more convincing argument that the WDNR (not the WPSC) must require closed-cycle CWIS. While both WPSC and WDNR argues that the WDNR does not have authority under the CWA to do so, this argument ignores the fact that the coal plant's riparian rights to withdraw water from Lake Michigan is "qualified, subordinate, and subject to" the state's paramount public trust duties and rights.[433]

Going forward, environmental NGOs, in tandem with a CWIS argument, could encourage the reprioritization of renewable energy under the EPL by citing the public's interest in trust resources. Under the precedent set in *Lake Beulah*,[434] the WDNR has the responsibility to consider any potential adverse impact to trust resources, so long as it has been presented scientific evidence of a connection. In terms of electricity production, there are two impacts in addition to CWIS that have scientifically-proven connections between electricity production and trust resources; mercury emissions[435] and climate change.[436] Mercury emissions have been shown to impact wildlife resources and water quality in the Great Lakes region, and climate

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[433] R.W. Docks & Slips v. State of Wisconsin, *supra* note 383, 244 Wis. 2d at 511.

[434] *Lake Beulah*, *supra* note 385, 335 Wis. 2d 47.

[435] *See* Evers, *supra* note 220.

[436] *See* Hall & Stuntz.

change is expected to "lead to lower lake levels, impacts on fisheries and wildlife, changes in Great Lakes shorelines, and reduction of groundwater supplies."[437] In fact the climate change impacts from electricity production are the same impacts that the *Rock-Koshkonong* court was concerned that WDNR overlooked. Moreover, unlike the interests at issue in *Rock-Koshkonong*, climate change also adversely impacts wildlife, wetlands, aesthetics, and water quality concerns embodied in and protected by the public trust doctrine. Therefore, even in light of *Rock-Koshkonong*, climate change, mercury, and CWIS impacts from electricity production, especially coal, must be considered by the WDNR, and given the weight of the evidence, it is hard to fathom how the WDNR could not conclude that such impacts negatively impact the public's right and that, as such, construction or renewal of these plants would not be in the public's interest.

While the WPSC is not required to choose renewable electricity under the EPL if the environmental benefits are outweighed by other values,[438] adding the WDNR's paramount authority to protect the public interest in trust resources would serve to rebalance decision-making under the EPL. For example, notably absent from *Clean Wisconsin*, and another recent case authorizing construction of a wind farm,[439] is a discussion of the larger social benefit of encouraging development of renewable energy.[440] The application of the public trust doctrine to the EPL and the decision-

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[437] *Id*. at 676.

[438] *Clean Wisconsin*, *supra* note 414, 282 Wis. 2d at 375.

[439] *WEIG v. PSC*, *supra* note 413.

[440] Compare this to the California court in *CBD* v. *FPL*, *supra* note 296, which was cognizant of the larger benefits of wind energy, despite the potential impacts of avian mortality.

making process of the PSC and DNR would encourage the development of this discussion. While the literature has connected the public trust implications of wind, specifically the environmental and aesthetic impacts of offshore wind,[441] there has been no contextual comparisons of the public trust implications of renewable and conventional electricity. As an example, it may be useful to apply the five-point test developed in the Wisconsin public trust doctrine case law, see *supra* note 372 and associated text.[442]

It is important to consider these five-points not as they apply to one type of electricity production or another, but rather in a comparison between all types of electricity production. For example, consider the application to the choice between potential coal plant and a potential offshore wind farm. Under the first point, neither the coal plant nor the offshore wind farm would be truly controlling the use of an area: instead they would control the use of trust resources, such as water resources for the purposes of cooling or the "use" of wildlife via mercury bioaccumulation in the case of the coal plant or avian mortality in the case of the offshore wind.[443] On the other hand, offshore wind would likely exclude other public uses of the area that the farm is situated in by obstructing navigation, and having aesthetic impacts.[444] Second, neither the coal plant nor the offshore wind farm's purpose is to benefit the public at

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441 Bynum II, *supra* note 411, at 1570.

442 The five point test, while informative, does not translate perfectly in the application to electricity production, because it is used more to test the alienation of submerged lands and title, not the permitting of usufructuary rights.

443 While in both cases the state retains the authority to control the use of the area, both the coal plant and the offshore wind farm would necessarily occupy land and waters to the exclusion of other users.

444 Navigational interests may only be excluded at the turbine itself and a small buffer around it, but still allowing navigation and other interests in between the turbines.

large, and would thus unlikely be open to the public in either case. Thirdly, the overall diminution of trust resources by coal is orders of magnitude higher than the navigation, wildlife and aesthetic impacts from offshore wind, meaning coal diminishes a larger portion of the public trust resource as a whole than a properly cited wind farm.[445] Fourth, cumulatively, coal has substantially impaired wildlife and water resources, whereas it is unlikely that offshore wind would impair navigation, wildlife, or aesthetic trust resources beyond minor impacts.[446] Fifth, neither the coal plant nor the wind farm would provide direct public trust benefits, but both would have the public benefit of electricity production.[447] But assuming the same benefits of electricity and the substantially larger consequences of utilizing coal, it is clear that offshore wind in the Great Lakes, using the five-point test, would be the superior choice under the public trust doctrine. This conclusion can be weighed against the WPSC's findings of "cost-effective" and "technologically feasible" and can encourage the reprioritization of renewable energy under the EPL.

Because the WDNR has been granted broad statutory and constitutional authority to protect the public trust in all aspects feasible, and the Wisconsin courts have generally given "great weight" deference to the WDNR when acting to protect trust resources, the WDNR has the capability to take actions that would benefit

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[445] *See supra* notes 201-264 and associated text.

[446] For example, while there is continued concerns over the population impacts from mercury bioaccumulation for certain wildlife species and the future risks of extinction of wildlife and substantial alteration of water resources due to climate change, it unlikely that offshore wind poses a population risk to avian populations, often considered the most significant impact of offshore wind. However, if substantial amounts of offshore wind are constructed, there may be cumulative risks to navigation and to wildlife from habitat displacement. *See supra* note 201-264 and associated text.

[447] Moreover, the offshore wind farm would provide further public benefits by displacing coal and natural gas.

renewable energy. The courts have often required the WDNR to give full and careful consideration to all public trust interests, especially non-economic interests, something that is currently lacking in Wisconsin electricity planning and policy. Scanlan (2000) argues that the WDNR employees, especially Water Management Specialists (WMSs), have not fully utilized the public trust doctrine. Scanlan continues that the legal theory can authorize WMSs as well as the WDNR in general to take action on water quality:

> "Public [trust] interest considerations could give WMSs the ability to fill in the regulatory gaps left by other laws designed to protect navigable waters, such as the Clean Water Act (CWA). For instance, under its public interest analysis the [W]DNR could consider the impact of non-point source pollution from activities regulated by Chapters 30 and 31 even though it has limited authority to regulate these impacts under the CWA."[448]

Likewise, it is entirely reasonable given the scope of the Wisconsin public trust doctrine, and the current regulatory gap regarding environmental impacts from the Wisconsin electricity grid, that this same argument can be made to give WDNR the ability, and indeed the duty to regulate the impacts of electricity production beyond statutory requirements. Like any other riparian user, the rights of the electricity producers to use water and to adversely impact wildlife and water through its emissions are entirely subject to the power of the WDNR, whether the WDNR acts on that power or not. In conclusion, the WPSC's prioritization of maintaining cheap electricity over environmentally beneficial electricity emphasizes a common theme in electricity permitting decisions: the current structure of electricity laws in many states are primarily concerned with protecting ratepayers' interests in low electricity rates without regard to externalities, including those that impair trust resources.

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448 Scanlan, *supra* note 350, at 177.

Nevertheless, citizen groups like Clean Wisconsin can utilize the broad authority and general duty of the state of Wisconsin under its well-developed public trust doctrine to shift the focus and encourage protection of environmental resources and development of renewable electricity.

3.7.3 Hawaii

3.7.3.1 Current Electricity System

Much like Wisconsin, Hawaii overwhelmingly relies on fossil fuel. However, due to the isolated nature of the state, the overwhelming majority of Hawaii's electricity comes from oil. Each of the electric grids in Hawaii's six main islands are disconnected from each other, and are divided into four main electric utilities; Kauai Island Utility Cooperative (KIUC), Hawaiian Electric Company (HECO), Maui Electric Company (MECO), and the Hawaii Electric Light Company (HELCO).[449] In 2013, 18% of Hawaii's net electricity came from renewable sources, with the majority of that generation comprised of wind, residential solar PV, biomass and geothermal.[450] The other 82% of generation came from fossil fuel sources, and of that, more than three quarters oil-based, and the remainders from coal.[451] Though the percentage has

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[449] State of Hawaii Public Utilities Commission (HPUC). *Annual Report for Fiscal Year 2014* 22 (2015). *Available at* http://puc.hawaii.gov/reports/annual-reports/.

[450] State of Hawaii Energy Resource Coordinator. *Annual Report 2014* 20 (2014). *Available at* http://energy.hawaii.gov/resources/hawaii-state-energy-office-publications. In addition, the Bureau of Ocean Energy Management (BOEM) recently received two unsolicited offshore wind lease applications off the coast of Oahu. *See* AW Hawaii Wind LLC. *Hawaii Offshore Wind Energy Lease Application Oahu Northwest*. (2015) *available at* http://www.boem.gov/State-Activities-Hawaii.

[451] HPUC at 29. Note this does not include the HPUC's estimated role of energy efficiency on reducing overall generation needs, which HPUC determined accounted for a 12% reduction in demand. *See also* EIA (2015) *Form EIA-923, supra* note 339 (84% of electricity generated came from fossil fuels in 2014 through November).

decreased from 91% over the last ten years,[452] Hawaii's dependence on oil and coal still remains significant and has negative consequences for the environment. Oil and coal contribute to climate change and ocean acidification, require significant quantities of cooling water and emit a substantial amount of mercury.[453] Given Hawaii's isolation and lack of requisite infrastructure, it cannot benefit from less damaging conventional electricity production, such as nuclear or natural gas.[454] As a result, Hawaii has perhaps the most environmentally-damaging electric grid of the four states investigated in this paper, although it is also moving most aggressively towards a 100 percent renewable energy target.[455]

3.7.3.2 Public Trust Doctrine in Hawaii

Along with California, Hawaii is recognized for having one of the two "most progressive public trust doctrines in the nation."[456] Not only is it progressive, but it is comparatively well-developed, with Hawaiian courts having thoroughly examined the

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452 *Id*.

453 *See* William Moomaw, et. al. *Annex II: Methodology*, In *IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation* [O. Edenhofer et al. (eds)]. Cambridge University Press 982 (2011). *See also* Houyoux & Strum, *supra* note 241, (setting lower mercury standards for Hawaiian oil plants then continental oil plants).

454 Interestingly, it would be extremely difficult politically to bring nuclear power to Hawaii, because the Hawaiian Constitution includes a provision that construction of any nuclear fission power plant requires approval from two-thirds vote of each house in the legislature. Haw. Const. Art. XI §8.

455 In fact, there are currently two bills proposed in the Hawaii legislature that would increase the state's RPS to 100%, *see* Relating to Renewable Standards, HB 623, SB 715 (28th Leg. 2015), *available at* http://www.capitol.hawaii.gov/.

456 Kylie Wha Kyung Wager. *In Common Law We Trust: How Hawai'i's Public Trust Doctrine Can Support Atmospheric Litigation to Address Climate Change*. 20 Hastings W.-N.W. J. Env. L. & Pol'y 55, 77 (2014).

state's public trust obligations in water resources over the past few decades.[457] The public trust doctrine's historical development in Hawaii, however, is complicated, winding through four separate governance and judicial regimes. Prior to 1893, Hawaii was a constitutional monarchy and judges were appointed the King. In 1893, the monarchy was overthrown, and a republic form of government was instituted, and judges were appointed by that government. Next, Hawaii was annexed by the United States, and during this period the courts were appointed, by the President of the United States and approved by the United States Senate. Finally, Hawaii became a state in 1959.[458]

The common law regarding natural resource management took a similar path, metamorphosing though these fourth legal regimes and becoming a confluence of Hawaiian customs and American common law public trust doctrine, as well as American privatization. In the early 1800's, land and all natural resources were owned entirely by the King of Hawaii. However, in 1847, King Kamehameha III, responding to pressure from foreigners seeking title to lands, enacted the Great Mahele, a policy to divide the King's land. The King retained some of his lands for his private individual use, but the rest of the land was split into thirds; one portion to be retained by the Government in trust for the public, one portion was allocated to the chiefs and konohiki (agents of the chiefs), and the rest to the current tenants of the land.[459] These land divisions, also known as ahupua'as, conveyed appurtenant rights

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[457] On the other hand, Hawaiian courts have not spent as much time on the state's public trust obligations regarding wildlife resources, especially independent of the water aspects of the public trust.

[458] *See* Robinson v. Ariyoshi 65 Haw. 641, 668 at n. 25 (1982).

[459] *See* State v. Zimring 58 Haw. 106, 112 (1977).

to water in relation to parcels of land.[460] In addition to appurtenant water rights, the Hawaiian Kingdom acknowledged riparian rights by statute in 1850, as influenced by Massachusetts Christian missionaries.[461] Thus, early Hawaiian water law recognized both the appurtenant and riparian doctrines.

By contrast, the public trust doctrine was not recognized by the various iterations of the Hawaiian Supreme Court until 1899.[462] As with many early public trust cases, this case concerned title to submerged lands. The Republic of Hawaii had granted the Oahu Railroad company the power to condemn land to construct railways, but then attempted to reclaim a portion of the Honolulu harbor that had been conveyed to the Oahu Railroad. Oahu Railroad, which had begun to improve the submerged lands, claimed that the Republic did not have the authority to reclaim the land. The court, affirming the paramount authority of Hawaii, recognized that"[t]he people of Hawaii hold the absolute rights to all its navigable waters and the soils under them for their own common use. The lands under the navigable waters in and around the territory of the Hawaiian Government are held in trust for the public uses of navigation."[463]

As Hawaii transitioned into a U.S. Territory, the Hawaiian courts continued to recognize the Territory's authority in natural resources. First, courts recognized the

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460 Appurtenant rights are similar to riparian rights by granting water use to property owners along rivers, but unlike riparian rights, appurtenant water must be used for the appurtenant land (meaning it cannot transported to another watershed).

461 *See McBryde Sugar Co*., *infra* note 467, 54 Haw. at 191-198 (1973).

462 King v. Oahu Railway & Land Co. 11 Haw. 717 (1899)

463 *Id*. at 725 (citations omitted).

Territory's authority and duty in lands below the high water mark, including the duty to maintain, manage, and care for trust lands and to remove any obstruction along shorelines.[464] Likewise, in another case, the court held that all fisheries belonged to the Territory in trust for the people, and the trust's authority continually subjugates private fisheries to the Territory, when acting for the common good.[465] However, the public trust doctrine was noticeably absent in judicial opinions of the Territorial Hawaiian Court in its discussion of water rights. Indeed, in a series of cases, the Territorial Court consistently found in favor of private water rights and made no mention of the public interest in the waters.[466]

However, "despite this long line of cases treating water as a private property," the Hawaiian Supreme Court, which was constituted after statehood, saw it otherwise, and held that all freshwater within the state is "held in trust by the state for the common good of its citizens" in McBryde Sugar Co. v. Robinson.[467] The case revolved around several parties' competing claims to ownership and use of water from the Hanapepe, including private appurtenant and riparian rights, and the state claims to water. The Court clarified that both riparian and appurtenant rights to *use* water are subject to the State, and "ownership of water in natural watercourses, streams and

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464 Territory of Hawaii v. Kerr 16 Haw. 363, 376 (1905). *See also* County of Hawaii v. Sotomura 22 Haw. 176 (1973)(the state owns all lands below the high water mark as shown by the vegetation line even if due to erosion)

465 Bishop v. Mahiko 35 Haw. 608, 640-647 (1940)

466 Marie Kyle. *The "Four Great Waters" Case: An Important Expansion of Wai'ahole Ditch and the Public Trust Doctrine* 17 U. Denv. Water L. Rev. 21, 25 (2013), *citing* Hawaiian Commercial & Sugar Co. v. Wailuku Sugar Co. 15 Haw. 675, 680 (1904)(surplus water belonged to the konohikis and they could do whatever he pleases regardless of downstream impacts) *and* Territory of Hawaii v. Gay 31 Haw. 376, 377 (1930)(normal surplus water belongs to the private owner and the Territory cannot enjoin its use).

467 Kyle at 25. McBryde Sugar Co. v. Robinson 54 Haw. 174 (1973).

rivers remained in the people of Hawaii for their common good."[468] Overturning previous court decisions supporting private ownership of water, the court held that because water in its natural state *de facto* belongs to the State in trust, surplus storm and freshet water is reserved likewise to the State for the common good.[469]

Soon after *McBryde*, the court applied similar logic to Hawaii's land. In the first and only public trust case to deal with the question of new lands caused by lava overflow, the Hawaiian Supreme Court ruled that all lands, in their natural state, including newly lava-formed lands, belong to the State in trust, rather than to littoral or riparian owners.[470] Specifically, the Court held that "that the lava extensions vest when created in the people of Hawaii, held in public trust by the government for the benefit, use and enjoyment of all the people."[471] In addition to basing their decision on the public trust doctrine, the court was especially cautious of the inequitable and unwise economic benefits that granting these lands to private littoral owners would entail, so the court was sure to remind the state of its duty as a trustee to devote the new land to public uses, such as recreation.[472]

The public trust doctrine was transformed in 1978 when the Hawaiian Legislature amended the Hawaiian Constitution to further protect the state's natural

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468 *Id*. at 187. The court continued that no party can claim water rights by adverse possession against the State. *Id*. at 198.

469 *Id.* at 200.

470 State of Hawaii v. Zimring, *supra* note 459, 58 Haw. 106 (1977)

471 *Id*.

472 *Id*. The court continued that "[s]ale of the property would be permissible only where the sale *promotes a valid public purpose*" (emphasis added).

resources. In that year, the Legislature added Article XI regarding natural resources conservation. First and foremost, the Hawaiian Legislature applied the public trust to *all* natural resources:

> "For the benefit of present and future generations, the State and its political subdivisions shall conserve and protect Hawaii's natural beauty and all natural resources, including land, water, air, minerals and energy sources, and shall promote the development and utilization of these resources in a manner consistent with their conservation and in furtherance of the self-sufficiency of the State. All public natural resources are held in trust by the State for the benefit of the people."[473]

The Legislature continued to explicitly include water use, adding that the "State has an obligation to protect, control and regulate the use of Hawaii's water resources for the benefit of its people."[474] Additionally, the Legislature was required to set up a water resources agency to manage and conserve, as well as establish procedures for, the uses of Hawai'i's waters, which became the Commission on Water Resources Management (CWRM).[475] Lastly, the state reaffirmed the protection of all native Hawaiian traditional and customary rights, including subsistence and water uses.[476]

Less than a decade later, the Legislature adopted the State Water Code.477 The adoption of the State Water Code further recognized "that the waters of the State

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[473] Haw. Const. Art. XI §1.

[474] Haw. Const. Art. XI §7.

[475] *Id.*

[476] Haw. Const. Art. XII §7.

[477] HRS §174C. *See also* Kyle, *supra* note 466, at 27.

are held for the benefit of the citizens of the State."[478] In addition, the State Water Code is to "be liberally interpreted to obtain maximum beneficial use of the water of the state" and the State was called on to balance the benefits of domestic uses with the requisite "adequate provision… for the protection of traditional and customary Hawaiian right, the protection and procreation of fish and wildlife, the maintenance of proper ecological balance, and the preservation and enhancement of waters of the State."[479] The Water Code also includes a definition of "instream uses" which encompasses fish and wildlife habitats, recreation, ecosystem maintenance, aesthetic values, navigation, hydropower water quality, domestic water and protection of traditional and customary Hawaiian rights.[480] Moreover, the Water Code defines "reasonable-beneficial use" as "the use of water in such a quantity as is necessary for economic and efficient utilization for a purpose, and in a manner which is both reasonable and consistent with the state and county land use plans and the public interest"[481] and requires that any water use permit applicant establish reasonable-beneficial use.[482]

Thus, the Hawaiian public trust doctrine not only has a complex and pluralistic common law history, but also a detailed Constitutional and statutory one. Moreover, an important effect of incorporating the public trust as a constitutional provision is that

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[478] HRS §174C-2(a).

[479] HRS §174C-2(c).

[480] HRS §174C-3.

[481] *Id*.

[482] HRS §174C-49(a)(2).

the courts became the ultimate authority to interpret and protect regard natural resources, especially water use.[483] This greatly heightens the scrutiny of the court's judicial review in public trust cases.

In 1982, the Hawaiian Supreme Court was directed by the U.S. 9th Circuit Court of Appeals to clarify some of the unresolved issues of their *McBryde* decision.[484] Along with several other peripheral issues, the Hawaiian Supreme Court reaffirmed that "a public trust was imposed upon *all* the waters of the kingdom… and necessitate[d] a retention of authority and the imposition of a concomitant duty to maintain the purity and flow of our waters for future generations and… reasonable and beneficial use."[485] The court cited the recent Constitutional amendments in that"[t]he *McBryde* opinion was only the beginning of a necessary definition…of the State's authority and interest in Hawaii's waters."[486] The court concluded that "underlying every private diversion and application there is, as there always has been, a superior public interest in this natural bounty."[487]

In another case, the court declined to draw a distinction between surface water and groundwater, holding that any diversion, whether from the surface or the ground, is subject to other protected rights, including public and native Hawaiian rights.[488]

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483 *See Waiahole I*, *supra* note 47, 94 Haw. at 143. *See also* In re Wai'ola O Moloka'i Inc. 103 Haw. 401, 421 (2004).

484 *Robinson*, *supra* note 458, 66 Haw. 641 (1982).

485 *Id.* at 674 (emphasis added).

486 *Id.* at 677.

487 *Id*.

488 Reppun v. Board of Water Supply 65 Haw. 531, 555 (1982).

The court continued that the CWRM had intended to reserve the right of the state to regulate all water resources in accordance with the needs of the people, noting that prior courts had largely ignored the mandates of the Hawaiian government and the traditions of native Hawaiians "in their zeal to convert these islands into a manageable western society."[489]

The development of the Hawaiian public trust doctrine culminated at the turn of the millennia. As discussed previously, [490] the seminal Hawaiian public trust doctrine case is *In re Matters of Water Use Permit* (*Waiahole I*). To summarize, in *Waiahole I*, "native Hawaiians and local farmers sought to restore water to streams that some of the State's most powerful private interests had diverted including former sugar plantations whose predecessors participated in the overthrow of the Hawaiian Monarchy during the late 1800s."[491] Despite the substantial authority and duty delegated to the CWRM, it continued to stumble to adequately protect the state's water resources.[492]

Noting that "the people of this state have elevated the public trust doctrine to the level of a constitutional mandate,"[493] the *Waiahole I* court condensed its public trust jurisprudence into a couple of essential principles. First, the constitutional amendment "embodies a dual mandate [to the CWRM] of 1) protection and 2)

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489 *Id.* at 544-545.

490 *See supra* notes 99-114 and associated text.

491 Kyle, *supra* note 466, at 22.

492 *See supra* note 114 and associated text.

493 *Waiahole I*, 94 Haw. at 131.

maximum reasonable and beneficial use" of water resources.[494] Second, the CWRM is required to make plans and decisions regarding water "from a *global, long-term perspective*"[495] while protecting and preserving "the *rights of present and future generations* in the waters of the state"[496] as well applying the precautionary principle to trust resources.[497]

In the face of water use permit applications, the court held that the CWRM must begin with a presumption in favor of public trust resources, and likewise must burden the applicants with the duty to "justify the[ir water uses] in light of the purposes protected by the trust."[498] Likewise, the state is compelled to consider the water use application in the context of the cumulative impact of current and proposed diversions, potential alternatives, and the promotion of maximum beneficial use.[499] Stressing the importance of the utmost consideration by the state, especially towards the adequate provisions of ecological protection, the court summarized that "the state may compromise public rights in the resource pursuant *only to a decision made with a level of openness, diligence, and foresight* commensurate with the high priority these rights command under the laws of our state."[500]

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494 *Id*. at 139. This requires the CWRM to both protect and develop waters to the maximum extent practicable.

495 *Id*. at 143 (emphasis added).

496 *Id.* at 141 (emphasis added).

497 *Id.* at 155.

498 *Id.* at 142.

499 *Id.* at 143-146.

500 *Id*. at 143 (emphasis added)

In many ways, *Waiahole I*, like *McBryde* before it, was just the beginning of a new expansion of the state's public trust obligation. The court next used the public trust doctrine to hold groundwater well permit applications subject to native Hawaiian water reservations under the public trust doctrine. While diminishing the public trust importance of private commercial uses and concurrently recognizing "the heightened duty of care owed to the native Hawaiians," the court affirmed that "a reservation of water constitutes a public trust purpose."[501] The state has "public trust obligations to protect native Hawaiians' traditional and customary gathering rights" and must fully consider these rights as an aspect of the public trust doctrine.[502]

In addition, the court has applied the public trust doctrine to wildlife, where habitat was at risk,[503] and in another, to water quality, which was jeopardized due to soil erosion.[504] In each case, the court required the petitioners to show that a public trust violation had occurred. In each case, however, the court also concluded that the petitioner had been unable to demonstrate a threshold level of harm to trust resources.[505] Though the courts denied the public trust claims in both cases, it was

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[501] In re Wai'ola O Moloka'i Inc. 103 Haw. 401, 429-431 (2001)

[502] *Id*. at 443.

[503] Morimoto v. Board of Land and Natural Resources 107 Haw. 296 (2005)(*Morimoto*).

[504] Kelly v. 1250 Ocean Side Partners 111 Haw. 205 (2006).

[505] *See Morimoto* at 308 (the state had provided "substantial evidence" there would be minimal impacts to wildlife and included mitigation measure) *and* Kelly at 233 (t the petitioners failed to meet their burden of demonstrating that the State failed to uphold the public trust).

cautious to reiterate that the state and every political subdivision thereof, has a non-discretionary, affirmative duty to protect all public trust resources.[506]

While the court place the burden on petitioners to provide a trust violation when bringing a claim against a state agency, it also placed a burden on both state agencies and applicants when permit applications would authorize actions that would impact public trust resources. The court emphasized that "[c]larity…is all the more essential in a case such as this where the agency performs as a public trust and is duty bound to demonstrate that it has properly exercised the discretion vested in it by the constitution and the statue."[507] In ensuring this clarity, the court ruled that in order for the CWRM to properly discharge its public trust obligations, it must require applicants to demonstrate that there is an "absence of practicable alternatives" as well as show that there are no impacts on any existing rights, particularly native Hawaiian traditional customary gathering rights.[508]

In 2012, the Hawaiian Supreme Court further expanded its jurisdictional authority beyond permit applications to instream flow standards set by the CWRM, saying that the "ramifications of an erroneous IIFS [interim instream flow standard] could offend the public trust, and is simply too important to deprive parties of due process and judicial review."[509] In that case, the court said that "[w]hen…critical

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506 *Kelly* at 227-230.

507 In re Contested Case Hrg. On Water Use Permit Application filed by Kukui Inc. 116 Haw. 481, 495 (2007)(citing *Waiahole II* 94 Haw. at 163).

508 *Id*. at 496-509.

509 In re Īao Ground Water Mgmt. Area High-Level Source Water Use Permit Application & Petition 128 Haw. 228, 244 (2012)(*Four Great Waters*). It should be noted that there was no statutory requirement or authority of judicial review.

information is missing, the Commission must "take the initiative" to obtain the information it needs" to make a decision regarding public trust resources.[510] In particular, the court was skeptical of the CWRM's failure to determine whether the proposed instream flow standards would sufficiently protect native Hawaiian rights and other ecological and public trust uses of the water and to explore the existence of practicable alternatives and minimization of system losses.[511] Lastly, and most importantly, the court recognized the role of the public to utilize the public trust doctrine to challenge important water decisions under due process, which "opens the door for members of the public to challenge a whole host of State actions and decisions concerning the State's water resources trust."[512]

Lastly, in the most recent public trust case, regarding the bottling and sale of water, the court affirmed the state's manifest duty to require applicants to demonstrate that their actions will have no adverse impacts on the principles and purposes of the public trust doctrine.[513] Again, emphasizing that the private commercial uses are not protected by the public trust, and that public rights in trust resources are superior to

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510 *Id*. at 262.

511 *Id.* at 249-258. The court was not entirely critical of CWRM's instream flow standard, saying that a requirement forcing a sugar plantation to re-line its reservoir to reduce water losses "is commendable and shows the "diligence" and "foresight" expected of the Commission in its management of the public trust." *Id.* at 257.

512 Kyle, *supra* note 466, at 37. *See also* Justice Acoba's concurrence in *Four Great Waters,* 128 Haw. at 282 (a "public trust claim can be raised by members of the public who are affected by potential harm to the public trust" and arguing for further expansion of the Court's jurisdiction regarding public trust cases).

513 Kauai Springs, Inc. v. Planning Commission of the County of Kaua'i 133 Haw. 141, 174 (2014)(*Kauai Springs*).

private developmental interests,[514] the court distilled a framework of the public trust doctrine detailing the trust obligations of the state, based on prior case law:

a. The agency's duty is to maintain the purity and flow of state waters for future generations and to assure that the waters are put to reasonable and beneficial use.

b. The agency must determine whether the proposed use is consistent with trust purposes:

    i. The maintenance of waters in their natural state;

    ii. The protection of domestic water use;

    iii. The protection of water in exercise of Native Hawaiian and traditional and customary rights; and

    iv. The reservation of water enumerated by the State water code.

c. The agency is to apply a presumption in favor of public use, access, enjoyment, and resource protection.

d. The agency should evaluate each proposal for use on a case-by-case basis, recognizing that there can be no vested rights in the use of public water.

e. If the requested use is private or commercial, the agency should apply a high level of scrutiny.

f. The agency should evaluate the proposed use under a "reasonable and beneficial use" standard, which requires examination of the proposed use in relation to other public and private uses.[515]

In conclusion, the Hawaiian public trust doctrine, through its confluence of origins, has developed into a powerful constitutional and statutory tool that provides for the comprehensive protection of water uses. Further, the public trust doctrine has

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514 *Id.* at 173

515 *Id.* at 174.

"provide[d] the judiciary with broad authority to mandate concrete, substantive results and grants them wide latitude in fashioning outcomes that adequately protect State's trust resources."[516] However, surprisingly, the Hawaiian courts have not found a single wildlife trust violation in any of its cases, instead focusing on stringent protection on the water aspect of the public trust doctrine. In addition, despite the robust protection of water resources, there has been no application of the public trust doctrine to Hawaii's electricity production.

3.7.3.3 Overview of Current Hawaii Electricity Laws

Given the high economic and environmental costs of its fossil-fuel based energy economy, Hawaii has developed a number of renewable energy laws, and set lofty goals for itself. To begin with, Hawaii has required the statewide reduction of GHG emissions to 1990 levels by the year 2020.[517] To accomplish this goal, Hawaii enacted an RPS, requiring 15% renewable by 2015, increasing to 25% by 2020, and rising to a lofty 40% by 2030.[518] Unlike their Wisconsin counterparts, the Hawaiian Public Utilities Commission "may provide incentives to encourage electric utility companies to exceed their renewable portfolio standards or to meet their renewable portfolio standards ahead of time, or both."[519] In addition to the RPS, Hawaii has also developed an energy efficiency portfolio standard (EEPS), requiring a 30% by

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[516] Kyle at 50.

[517] Daniel A. Codiga. *Hawaii Clean Energy Law and Policy* 13 Hawaii B.J. 4 (2009). *See also* HRS §342B-72(a)(1) (instructing the Department of Health Director to establish measures to "achieve the maximum practically and technically feasible and cost-effective reductions in greenhouse gas emission").

[518] HRS §269-92(a).

[519] HRS §269-94.

2030.[520] While Hawaii is currently ahead of both their interim RPS and EEPS goals,[521] as of January 1st, 2015, energy efficiency stopped counting towards the RPS.[522] Combining the EEPS and the RPS, Hawaii hopes to accomplish 70% reduction in fossil fuel use and climate change emissions by 2030.

Like Wisconsin, Hawaii requires a certificate of public convenience and necessity (CPCN),[523] but has developed a specific permitting process for renewable energy projects, including a full-time Renewable Energy Facilitator position in order to streamline the development of renewable energy projects, known as §201N.[524] Likewise, to encourage the development of distributed energy, homeowners are guaranteed the authority to install any solar energy device under Hawaiian law.[525] Likewise, the state of Hawaii offers residents an investment tax credit of 35% of the total capital costs of a solar project, capped at $5,000, and 20% of capital costs of a wind project, capped at $1,500.[526] Lastly, the Hawaiian Public Utility Commission (HPUC) has implemented a feed-in tariff ("Hawaii FIT"), guaranteeing anywhere from 12 up to 31.5 cents per kWh, depending on the technology, for new renewable

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520 HRS §269-96. As an aside, there may be public trust implications of energy efficiency programs, such as the use of sea water to provide air conditioning. *See* Jonathan Lilley, et al.. *Cool as a (sea) cucumber? Exploring public attitudes toward seawater air conditioning in Hawai'i.* 8 Energy Res. & Soc. Science 173 (2015).

521 HPUC, *supra* note 449, at 26-29. In fact, in 2013, the HPUC found that Hawaii was ahead of schedule, already at its required 2015 levels.

522 HRS §269-92(b)(2).

523 HRS §269-7.5(a).

524 HRS §201N et seq. *See also* HRS §201-12.5 (establishing the duties of the Renewable Energy Facilitator)

525 HRS §196-7(a).

526 HRS §235-12.5.

energy projects, though the program is constrained to projects less than or equal to 5 MW in capacity.[527] Thus far Hawaii FIT has largely been used for distributed solar PV projects.[528]

3.7.3.4 Applications of the Public Trust Doctrine in Hawaii

Despite lofty renewable energy goals and the current environmentally damaging electric generation supply of Hawaii, the Hawaiian courts have not considered any substantive legal challenges to the state's electricity policy. Nonetheless, current electricity generation is directly in conflict with the common constitutional principles set forth in Hawaii's public trust doctrine case law. As the state has not faced any significant legal challenges to its renewable energy plans, it need not yet utilize the public trust doctrine as a legal defense, though it may need to in the future as renewable energy penetration increases. However, the public trust doctrine does provide a tool for the citizens of Hawaii to accelerate the transition to renewable energy, thus affording further protections of trust resources.

First, the Hawaiian public could utilize the strict protections on public trust water resources to attempt to force conventional electricity production plants to retrofit their open cycle CWIS to closed cycle. In 2013, pumps associated with electricity production withdrew 23 billion gallons or about 63 mgd,[529] which approximately

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527 Hawaii Electric Company *Feed-In Tariff* (2015) *available at* http://www.heco.com/heco/Clean-Energy/Clean-Energy-Generation.

528 Daniel A. Codiga. *Hot Topics in Hawaii Solar Energy* 17 Hawaii B.J. 4, 10 (2013)

529 Commission on Water Resources Management (CWRM). *Well Pumping Data* (Personal communication, Neal Fujii, State Drought and Water Conservation Coordinator, Mar. 2, 2015).

comprises 14 to 20% of Hawaii's overall water withdrawals.[530] Furthermore, the overwhelming majority of these power plants utilize open cycle CWIS, despite Hawaii's protectionist water resource laws.[531] Applying the framework from the public trust case law regarding water use to the electricity production's current water use clearly implicates the continued operation of open cycle CWIS. The courts have repeatedly emphasized that while private commercial uses of water are not forbidden, they must meet a high level of scrutiny and maximize benefits to society. To reiterate, the state has a duty to "implement reasonable measures to mitigate this impact, including use of alternative sources."[532] While this logic has been usually applied to private parties that as a result have to bear increased capital costs to access alternative *sources* of water, there is no reason this cannot, nor should not, be applied the capital costs power plant owners would have to incur to retrofit their CWIS to *greatly reduce* water demand. In addition, in accordance with the public trust doctrine, the state *must* require the permittee, i.e., the power plant owner, to demonstrate that there is an explicit absence of any practicable mitigating measures, such as retrofitting to a closed cycle CWIS. The state necessarily must place the burden on power plant owners to fully consider a CWIS retrofit under the public trust, especially given the reliance on limited water and wildlife resources of the islands.

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[530] Center for Island Climate Adaptation and Policy (ICAP). *Water Resources and Climate Change Adaptation in Hawai'i: Adaptive Tools in the Current Law and Policy Framework* (2012) 10 *available at* http://islandclimate.net/publications/. Moreover, since the CRWM does not keep track of CWIS that use ocean water, these figures and impacts are conservative and do not include all power plants. *See also* CWRM (2015) (reporting electricity production's withdrawal share to be 14% and including some brackish water withdrawals).

[531] Hawaiian Electric Company. *Hawaiian Electric Power Supply Improvement Plan*. Docket No. 2011-0206 (Aug. 26, 2014) 175 *available at* http://dms.puc.hawaii.gov/dms/.

[532] *Waiahole I*, *supra* note 493, 94 Haw. at 143.

Furthermore, Hawaii has set the stage for a monumental transformation of its energy supply, and the public trust doctrine can be a useful tool to guide both the state and interested citizens. Remembering that even if or when Hawaii reaches its 40% renewable goal, the likelihood is that the rest of the energy will come from oil or coal, and would still leave Hawaii with one of the dirtier energy supplies in the United States for the foreseeable future. Beyond the direct water and wildlife impacts of the continued use of conventional electricity, Hawaii faces substantial impacts from climate change on its resources due to its isolated, low lying nature. One of the impacts of climate change that is of particular concern to Hawaii is sea-level rise and salt water intrusion. Certain water management areas of Hawaii are likely vulnerable to impacts of sea level rise, which include salt water intrusion, reduction of freshwater pumpage, and a decrease in fresh groundwater discharge affecting chemical fluxes to estuaries and the ocean.[533] Because climate change, via sea-level rise will affect the present and future generation's interest in the use of groundwater, the state has the authority and duty to minimize these impacts under the public trust doctrine. Furthermore, the courts have adopted a perspective in the public trust case law that is highly conducive to the connection between climate change and public trust waters. For example, the courts have advised state agencies to adopt a global, intergeneration perspective and ignore "artificial distinctions" not borne out of the present practical realities or the current knowledge.[534] These principles, combined with the scientific

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[533] Holly A. Michael et al. *Global Assessment of Vulnerability to Sea-Level Rise in Topography-limited and Recharge-limited Coastal Groundwater Systems*. 49 Water Resources Research, 2228, 2230-2238 (2013). The areas most likely to be vulnerable to these impacts are topography-limited, whereas other areas of Hawaii are recharge-limited and unlikely to be as vulnerable to the impacts from sea-level rise. *See also* ICAP at 16.

[534] *Waiahole I* at 135-143.

knowledge of climate change's impact on Hawaii's natural resources, give the state a clear authority to regulate sectors that contribute to climate change to fulfill its duty to affirmatively protect *all* waters of the state, especially those reserved for public trust and native Hawaiian uses.

Despite the state's commitment to large-scale development of renewable energy and the enactment of §201N to facilitate renewable energy permitting, the "permitting process continues to be a main barrier to the development of renewable energy projects in Hawai'i."[535] Confounding this issue, the Hawaiian Department of Business, Economic Development & Tourism (DBEDT), whom the legislature charged with enacting the Renewable Energy Facility Siting Process (REFSP), recently conducted a study urging the legislature repeal §201N.[536] Specifically, the DBEDT argues that §201N fails to streamline renewable energy permitting, and may actually prolong permitting time for various reasons, including the perception that the DBEDT has become an unnecessary "middleman" who agencies are reluctant to commit to deadlines with, which in turn, makes the process undesirable to renewable energy developers.[537] On the other hand, repealing §201N would give the appearance that the DBEDT is relinquishing its duty to encourage renewable energy, and the

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535NREL. *Renewable Energy Permitting Barriers in Hawa'i: Experience from the Field*. 11 (2013) *available at* *http://www.nrel.gov/docs/fy13osti/55630.pdf.*

536 DBEDT. *Renewable Energy Facilitation Activities & the Renewable Energy Facility Siting Process*. (Dec. 2014) *available at* http://energy.hawaii.gov/wp-content/uploads/2011/10/Act-208-201N-Facilitator-Report_11-20-14_FINAL.pdf. *See also* HRS §201N, *supra* note 524.

537 *Id.* at 11-12.

DBEDT would be abdicating authority to grant permits encouraging renewable energy development, as well as potentially reducing community involvement.[538]

Essentially, §201N is an imperfect statute that has several useful provisions that are potentially lost in the inefficacy of the other provisions. While the DBEDT recommends repeal in the 2016 Legislature Session to give it time to prepare and communicate the renewable energy permitting process after such a repeal,[539] it remains to be seen whether the Legislature will agree with the DBEDT's recommendation. In this regulatory uncertainty, it is worthwhile to investigate the use of the public trust doctrine as a regulatory stopgap in the permitting process. While the DBEDT continues to contend that even after a repeal of §201N, it will remain committed to developing high-impact renewable energy projects, and will streamline permitting and siting tools, there is significant concern that the repeal would stall renewable energy development. Connecting the public trust doctrine to the responsibility of the state to protect its natural resources with planning energy decisions can help alleviate these concerns. In addition, recognition of the public trust doctrine's application in electricity policy can guide developers and permitting agencies under established expectations while the permitting statutes are repealed or amended, especially since the Hawaiian courts have ruled that the public trust can never be subsumed.[540] Utilizing the public trust doctrine framework can foster the

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[538] *Id.*

[539] *Id.* at 19.

[540] *Waiahole I* at 130-131 (the "suggestion that such a statute could extinguish the public trust, however, contradicts the doctrine's basic premise, that the state has certain powers and duties which it cannot legislatively abdicate").

state's dual mandate to protect trust resources and to develop renewable energy in the maximum reasonable and beneficial way. It may be useful to the State, in absence of §201N, to apply the public trust framework as laid out in *Kauai Springs* to electricity permitting, see *supra* note 515 and associated text.

Because the deployment of renewable electricity would increase the purity and flow of waters, returning water to its source from highly-scrutinized private, commercial CWIS, and back to the presumably favored uses of the public, while also reducing climate change and mercury pollution, the state has an affirmative obligation to implement renewable energy to properly discharge its fiduciary duty. This affirmative obligation could work to facilitate DBEDT's streamlining renewable energy permitting without it having to rely on the burdensome and ineffective §201N. Conversely, since the Hawaiian courts have highly scrutinized agencies when they appear to abdicate their public trust duties, and have generally recognized the public's right to judicial review, the public will have great assurance that the DBEDT will continue to implement policies to encourage renewable energy. Any failure to uphold its duties could then result in judicial intervention to force DBEDT to protect public trust resources.[541] Therefore, should §201N be repealed, the public trust doctrine can work to advance the best of both worlds; that the DBEDT can effectively encourage renewable energy in the absence of an effective statutory regime, and that the citizens of Hawaii are assured that the DBEDT will continue to implement renewable energy policies.

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541 While DBEDT was not originally burdened with any public trust duties, nor has it been burdened by the courts, Hawaii's Constitution dictates that *all* political subdivisions of the State shall conserve and protect *all* natural resources of Hawaii. *See* Haw. Const. Art. XI §1.

Moreover, the comprehensive framework provided by the public trust doctrine also protects against renewable energy deployment needlessly impacting public trust resources. For example, while wind energy provides significant benefits to public trust resources, namely water and fish resources, there are growing concerns of its impacts on the endangered Hawaiian Hoary Bat. While current impacts to Hawaiian Hoary Bats are minimal, the increased penetration of wind may be cause for concern.[542] While the science regarding bat collisions is still in development, there are currently several mitigation techniques proposed, such as increasing cut-in speeds.[543] Because the Hawaiian public trust doctrine authorizes and requires state agencies to continually reassess previous public trust-related permitting decisions, especially if the nature of the impact, or its possible alternatives, on trust resources have changed,[544] the state can require any and all electricity production, including wind energy, to implement further mitigation at any time, even if after it has already granted the operator a permit. This ensures the state implements the most reasonable and beneficial electricity production while concomitantly maximizing protection of trust resources and value to society.

Thus, while the Hawaiian public trust doctrine may not be of use to force the State to enact renewable energy policies, as it already has, or to provide legal justification to said actions, as it has not been challenged, the public trust doctrine can

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542 *See* Edward B. Arnett & Erin F. Baerwarld. *Impacts of Wind Energy Development on Bats: Implications for Conservation*, in *Bat Evolution, Ecology, and Conservation* [Rick A. Adams & Scott C. Pedersen eds.], Springer 444-445 (2013).

543 *Id*. at 449.

544 *See Waiahole I* at 149.

ensure that Hawaii continues to implement renewable energy in a way that maximizes value to society in accordance with its trust duties, bringing benefits both to the state and its citizens. Through the public trust doctrine, citizens are granted a legal tool to attempt to force the state to implement continuous environmental protections in electricity planning. Likewise, the state is authorized under the trust to take broad action to streamline permitting and implementation of renewable energy, which Hawaii may find particularly useful in the coming years as RPS goals become potentially more difficult to accomplish. In conclusion, legislative recognition of the public trust doctrine's application to the context of Hawaiian electricity planning and policy will improve decision-making, increase regulatory certainty, allow further community involvement and maximize protection of the environment.

3.7.4 New Jersey

3.7.4.1 Current Electricity System

New Jersey relies almost entirely on natural gas and nuclear for its electricity generation; together they comprised nearly 93% of electric generation in 2014.[545] The remaining 7% was comprised of primarily of coal, with solar, landfill gas, and oil each contributing around 1%.[546] Conventional electricity dominates the New Jersey grid, generating 97% of all electricity, but, the minimal penetrations of coal lead to an overall low-emission grid. High penetrations of nuclear and natural gas result in fewer toxic and climate change emissions, especially in comparison to other grids that rely

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[545] EIA (2015) *Form EIA-923*, *supra* note 339.

[546] *Id.* New Jersey has one wind farm, and represents only 0.3% of generation.

on coal or oil, such as Wisconsin and Hawaii.[547] Conversely, reliance on thermal power plants, especially nuclear, has substantial negative effects on water resources and aquatic organisms. Thus, the absence of renewable energy poses threats to New Jersey's water and aquatic wildlife resources, and to a lesser extent, to the mitigation of climate change and toxic emissions.

3.7.4.2 Public Trust Doctrine in New Jersey

New Jersey has developed a unique perspective on the public trust doctrine. New Jersey was the one of first states to recognize and apply the public trust doctrine in the United States in Arnold v. Mundy.[548] This hallmark public trust doctrine case "arose from a dispute in New Jersey over just a few bushels of oysters."[549] The case focused on the ownership of and access to oysters located on the bed of a navigable river and the New Jersey Supreme Court seized the opportunity to broadly enunciate public rights. The court first found that title to submerged lands under navigable rivers and the sea and the exclusive right to fish are reserved to the sovereign power of the state, which "hold[s] them subject to the common right of fishery of the citizens at large, of which they cannot deprive them."[550] Holding that the public must be guaranteed access to and use of all public trust lands by virtue of the state's

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547 On the other hand, New Jersey imports a substantial amount of its electricity, importing at least 25% of its electricity demands, most of which is coal-generated. *See* New Jersey Board of Public Utilities. *New Jersey Energy Master Plan* (2011) 26.

548 *Arnold*, *supra* note 35, 6 N.J.L. 1 (1821).

549 Timothy M. Mulvaney & Brian Weeks. *"Waterlocked": Public Access to New Jersey's Coastline* 34 Ecology L.Q. 579, 587 (2007).

550 *Arnold* at 31.

sovereignty, the court ruled that the oysters and the land they occupied could not belong to any private individual. Furthermore, the court forbade any action by the state that would alienate the public's right in water or fishery:

> The sovereign power itself, therefore, cannot, consistently [sic] with the principles of the law of nature and the constitution of a well ordered society, make a direct and absolute grant of the waters of the state, divesting all the citizens of their common right. It would be a grievance which never could be long borne by a free people.[551]

Though *Arnold* would become an influential case, impacting public trust cases in numerous jurisdictions for years to come,[552] its broad language did not immediately produce a broad public trust doctrine in New Jersey. Despite the lofty language used in *Arnold*, the New Jersey public trust doctrine "remained relatively quiet from the second half of the nineteenth century through the first half of the twentieth century."[553] However, in 1972, in its first major action on the public trust since *Arnold*, the New Jersey Supreme Court lifted the public trust doctrine out of the water, expanding it to guarantee the public's right to enjoy beach access. [554] In that case, Neptune City v. Borough of Avon-by-the-Sea, Neptune City sued the town, Avon-by-the-Sea, because Avon charged nonresidents higher fees for access to its beaches than

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551 *Id.* at 78.

552 Blumm & Wood, *supra* note 23, at 57 (*Arnold* was relied upon for the first U.S. Supreme Court public trust case, *See* Martin v. Waddell, *supra* note 125, 41 U.S. at 417). *See also Illinois Central*, *supra* note 36, 146 U.S. at 456 (*Arnold* is "entitled to great weight").

553 Mulvaney & Weeks at 587. The cases until that point usually focused on questions of title of submerged lands, *see e.g.* Bailey v. Driscoll 19 N.J. 363, 367 (1955)(title of riparian owners only extend to the high-water mark, and below that title belonged to the State in trust).

554 *See* David Cabroni. *Rising Tides: Reaching the High-Water Mark of the New Jersey's Public Trust Doctrine* 43 Rutgers L.J. 95, 102 (2012).

it did residents.[555] The court ruled that the public trust doctrine is sufficiently broad to include "public accessibility to and use of such lands for recreation and health, including boating and associated activities."[556] Thus, the court held that all members of the public must be treated equally in regards to access to the beach, and while reasonable fees can be charged for the maintenance of the beach, these fees must not be discriminatory.[557] In finding that "the public rights in tidal lands are not limited to the ancient prerogatives of navigation and fishing, but extend as well to recreational uses, including bathing, swimming and other shore activities," the court stressed that the "public trust doctrine, like all common law principles should not be considered fixed or static, but should be molded and extended to meet changing conditions and needs of the public it was created to benefit."[558] Consequently, this foundational case began a development in New Jersey that had a markedly pronounced public trust doctrine effect on beach access.[559] Since *Neptune City*, there has been a number of beach access cases that have substantially built upon the public rights first mentioned in *Neptune City*. Given that New Jersey is the most densely populated stated in the United States, and borders New York City as well, it is not surprising that "its

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555 Neptune City v. Borough of Avon-by-the-Sea 61 N.J. 296 (1972).

556 *Id*. at 306-307. It is worth noting that the Court went on to cite Sax, *supra* note 40, as an authority in the expansion of the public trust doctrine.

557 *Id*. at 310.

558 *Id*. at 309.

559 *See* Blumm & Wood at 257.

shoreline has been a battleground for competing public and private demands for access and use."[560]

After *Neptune City*, the New Jersey Supreme Court turned its attention to dry sandy upland beaches owned by municipalities. In a case where a municipally-owned casino attempted to exclude the public from accessing the dry sandy uplands, though it put no restriction on access to the waters themselves, the court held that "in New Jersey, a proper application of the Public Trust Doctrine [sic] requires that the municipally owned upland sand area adjacent to the tidal waters must be open to all on equal terms without preference."[561] While municipalities may adopt reasonable regulations on the use and enjoyment of the beach area in the interest of public health and safety as an aspect of their police power,[562] municipalities cannot bar outright public access to the beaches they own.

The court then moved to beach access to dry sand uplands owned by a quasi-public, quasi-private entity in Matthews v. Bay Head Improvement Association.[563] The Bay Head Improvement Association prohibited access to the waters via their beach, as well as the use of their foreshore for recreational purposes, but did not restrict use of the water itself. However, the court held that "[w]ithout some means of access the public right to use the foreshore would be meaningless" and would

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560 Mulvaney & Weeks at 582.

561 Van Ness v. Borough of Deal 78 N.J. 174, 179 (1978).

562 *Id.* at 179.

563 Matthews v. Bay Head Improvement Association 95 N.J. 306 (1984).

effectively eliminate the rights of the public trust doctrine.[564] Furthermore, the rights of the public is not limited to just access to the ocean water, but also includes the reasonable use of dry sands, whether public or private, for resting and relaxation in relation to other uses of the water.[565] Thus, the court held that because private dry sand uplands are, to some degree, subject to the public trust doctrine, a quasi-public body may not impair the public's basic right to access and use the beach. The court noted, however, that private beaches are not always subject to the rights of the public, and gave a four point test to determine when privately-owned dry sand uplands must be made available to satisfy the public's right:

1. Location of the dry sand area in relation to the foreshore.
2. Extent and availability of publicly-owned upland sand areas.
3. Nature and extent of the public demand.
4. Usage of the upland sand by the owner.[566]

Over the next two decades, beach access case law focused on the role of municipalities in the regulation of their beaches. The New Jersey courts reiterated that municipalities that own beaches are in fact trustees of these beaches, and have the same fiduciary duties and obligations as a state trustee, and as such, "the trustee owes the beneficiary [i.e., the public] a duty of loyalty, a duty of care and a duty of full

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564 *Id.* at 323.

565 *Id*. at 325

566 *Id.* at 326. The Court declined to rule that all private beaches are subject to the public trust, and to what extent, only deciding that private lands are not immune from public trust claims, *Id.* at 333.

disclosure."[567] Since the "public trust doctrine mandates the beach be open to all on equal terms without preference," municipalities cannot discriminate between residents and nonresidents, and must only charge a reasonable fee that is directly related to the expenses of beach operation and maintenance.[568] However, when the public safety and welfare is threated, the municipalities may act, in exercise of their police powers, to ban beaches and preclude public access in consonance with the public trust doctrine.[569]

The New Jersey courts next grappled with the relative roles of the state and municipalities. In Borough of Avalon v. New Jersey Department of Environmental Protection, a court ruled that the New Jersey Department of Environmental Protection (NJDEP) could not preempt a municipality's authority to regulate the operation and maintenance of its beaches by requiring specific provisions be made at the beach, such as a specific number of parking spaces or toilets, emphasizing a lack of statutory authority and granting no deference.[570] The NJDEP only could preempt a municipality's authority if the municipality had abused that authority to the detriment of the public's rights.[571]

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[567] Slocum v. Borough of Belmar 238 N.J. Super. 179, 188 (1989) (citations omitted).

[568] *Id.* at 189.

[569] State v. Oliver 320 N.J. Super. 405, 416 (1999) (conviction of surfers who entered a closed beach immediately after a hurricane did not violate the public trust doctrine), *cert. denied by* State v. Oliver 161 N.J. 332 (1999).

[570] Borough of Avalon v. New Jersey Department of Environmental Protection 403 N.J. Super. 590, 599 (2008), *cert. denied by* Borough of Avalon v. N.J. Dep't of Envtl. Prot. 199 N.J. 133 (2009)

[571] *Id.* at 600.

Two decades after *Matthews*, the New Jersey Supreme Court revisited the rights of the public to access, this time considering an entirely privately-owned, i.e. not municipally-owned, dry sandy upland in Raleigh Avenue Beach Association v. Atlantis Beach Club.[572] Reaffirming that "reasonable access to the sea is integral to the public trust doctrine,"[573] the court applied the *Matthews* four-point test, finding that since the sands were immediately connected to the foreshore, there was limited alternatives, public demand was high, and the sands were historically open to the public, and the court concluded that the public has a right to use and access these private lands.[574] The court rejected the defendant's contention that requiring that upland sands be available to the general public would constitute the loss of a property right, concluding that "exclusivity of use, in the context here, has long been subject to the strictures of the public trust doctrine."[575]

Most recently, the New Jersey Supreme Court applied this rationale to a takings claim. In an eminent domain proceeding, the landowners claimed that they were due compensation for dry sand uplands that was added to their property as a result of an expansive beach replenishment program.[576] The court ruled that the beach replenishment constituted an avulsion, not an accretion, and thus would not be part of any littoral rights. Furthermore, the court ruled that granting such a title to the

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572 Raleigh Avenue Beach Association v. Atlantis Beach Club 185 N.J. 40 (2005)

573 *Id.* at 53.

574 *Id*. at 55-59.

575 *Id*. at 59.

576 City of Long Branch v. Liu 203 N.J. 464 (2010).

landowners as an accretion "would be contrary to the public trust doctrine."[577] As a results, the court ruled that the landowners were not entitled to compensation because they never owned the land and because "under the public trust doctrine, the people of New Jersey are the beneficiaries of the lengthening of the dry beach created by this government-funded program" and thus the property belonged to the state.[578]

Despite a robust public trust doctrine, especially in applications to beach access and recreation, there has been no modern application of the public trust doctrine to water or wildlife resources. In fact, outside the scope of beach access, there has only been a spattering of New Jersey public trust doctrine cases. Though "New Jersey is the progenitor of the public trust doctrine in the United States, its jurisprudence in this area has been eclipsed over time by other states that have used the doctrine to confront emerging issues of far wider scope than beach access."[579] Nevertheless, there are aspects of New Jersey statutory and judicial case law that consider the water and wildlife aspects of public trust doctrine.

The case of most relevance to electricity production is New Jersey Department of Environmental Protection v. Jersey Central Power & Light Co. (*Jersey Central*), which as discussed previously,[580] held fish and wildlife to be trust resources.[581] The court held that the fish killed by the Oyster Creek nuclear power plant should be

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577 *Id.* at 482.

578 *Id*. at 486.

579 Cabroni, *supra* note 554, at 106.

580 *See supra* notes 153-155 and associated text.

581 *Jersey Central*, 133 N.J. Super. 375 (1975), *rev'd on other grounds by* New Jersey Department of Environmental Protection v. Jersey Central Power & Light Co. 69 N.J. 102 (1976).

considered "tidal resources, and that tidal resources have long been recognized as subject to the public trust doctrine."[582] The court then upheld the trial court's judge decision that "[t]he State has not only the right but also the affirmative fiduciary obligation to ensure that the rights of the public to a viable marine environment are protected, and to seek compensation for any diminution in that trust corpus."[583] Thus, the court agreed that under the public trust doctrine, the state has both "the right and the fiduciary duty to seek damages for the destruction of wild life which are part of the trust."[584] But despite these strong statements seemingly putting stringent protections on New Jersey's wildlife in the name of the public trust, there has been little development since this case.

The New Jersey courts also have held that even when the state conveys riparian lands, riparian rights are subject to the public trust, and the state "never waives its rights to regulate the use of the public trust property."[585] Thus, the court affirmed that the state has the power to deny a permit for construction of a dock on riparian lands because protection of potentially impacted shellfish and wildlife "fell within [the State's] police powers under the public trust doctrine."[586] Lastly, the court recently emphasized trust language in a case regarding endangered species, finding that the legislative policy underlying the regulation of endangered and threatened

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582 *Id.* at 392.

583 *Id.*

584 *Id.*

585 Karam v. New Jersey Department of Environmental Protection 308 N.J. Super. 225, 240 (1998) (citations omitted).

586 *Id*. at 241.

species "is to 'manage *all forms of wildlife* to insure their continued participation in the ecosystem' and to 'accord *special* protection' to endangered species."[587] The court continued that "[w]ildlife is the common property of all and held in trust by the State for all its people."[588] Nevertheless, this constitutes dicta, and the New Jersey courts have not since addressed if wildlife is part of the public trust doctrine, much less detailed the fiduciary duties of the state to protect wildlife. New Jersey courts also have applied the public trust doctrine to water in two other contexts. The court rejected a public trust claim that a permit would damage the public interest in filling of wetlands, citing a lack of evidence brought by the petitioner, and found that compensatory mitigation of other wetland areas "is a valid means to serve the public interest concerning its lands below and adjacent to tidally flowing and fresh waters… [resulting in] no violation of the public trust doctrine."[589] A New Jersey court also applied the public trust doctrine to drinking water, saying that" it is clear that since water is essential for human life, the public trust doctrine applies with equal impact upon the control of our drinking water reserves."[590]

Despite these examples, outside of beach access, the New Jersey public trust doctrine is not highly utilized and is underdeveloped. Indeed, although it was once

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[587] ZRB, LLC v. New Jersey Department of Environmental Protection 403 N.J. Super. 531, 553 (2008)(citing N.J.S.A. §23:2A-2)(emphasis added)

[588] *Id*. (quoting Assembly Agriculture, Conservation, and Natural Resources Committee, Statement to A.2151 (February 5, 1975)).

[589]In re Proposed Xanadu Redevelopment Project 402 N.J. Super. 607, 648-649 (2008) *cert. denied by* In re Proposed Xanadu Redevelopment Project 197 N.J. 260 (2008). The court also granted substantial deference to the decision of the state agencies in this decision, despite the potential impairment to public trust resoruces.

[590] City of Clifton v. Passaic Valley Water Commission 224 N.J. Super.53, 64 (1987) *aff'd by* Clifton v. Passaic Valley Water Commission 115 N.J. 126 (1989).

considered to be a public trust doctrine pioneer, "New Jersey now finds itself behind the curve in protecting the public's right to common ecological resources."[591] Furthermore, despite the notoriety of the New Jersey public trust doctrine, the state lacks any constitutional provisions codifying the public trust doctrine, and proposals to introduce one have not been successful.[592] Although the state statutes say that water resources are held in trust for the public,[593] no court has been called upon to adjudicate the scope and depth of the responsibilities that this statute places on the State. Therefore, the application of the New Jersey public trust doctrine to electricity production will rely largely on the common law aspects based on New Jersey's case law, especially as it relates to the public's right to recreation.

3.7.4.3 Overview of Current Renewable Electricity Laws

New Jersey's renewable electricity laws are largely comprised of its RPS standards and the associated Renewable Energy Credits (RECs), including carve-outs for solar and offshore wind in the standard, as found in the Electric Discount and Energy Competition Act (EDECA), first passed in 1999.[594] EDECA requires the New Jersey Board of Public Utilities (NJBPU) to adopt and implement an RPS, with

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[591] Cabroni, *supra* note 554, at 106.

[592] *Id*. at 122.

[593] *See* N.J. Stat. §58:1A-2 (saying "water resources of the State are public assets pf the State held in trust for its citizens")

[594] N.J. Stat. §48:3-49 et seq. *See also* Joshua S. Wirshafter. *The Solar Resurrection: Keeping New Jersey's Solar Industry Alive at the Expensive of Ratepayers* 38 Seton Hall Legis. J. 189, 193-194 (2013)(detailing the history of the New Jersey RPS law and its amendments).

several conditions and required consultations.[595] The NJBPU adopted a schedule that requires, by Energy Year (EY) 2015,[596] that all electricity providers achieve an RPS of 11.3%, broken into two classes; 8.8% must come from Class I renewables, and 2.5% must come from Class II renewables.[597] The required share of Class I renewables increases over time to 17.88% by EY 2021, while Class II renewables remains at 2.5%, equating to a total of just over 20% renewable by end of 2020.[598] Class I renewables are defined as electricity from solar, wind, fuel cells, geothermal, wave and tidal, small hydroelectric (less than 3 MW) and methane gas from either landfills or biomass, whereas Class II renewables are defined as electricity from resource recovery or large hydroelectric plants (more than 3 MW).[599] In addition to the overall RPS, EDECA also implements two carve-outs, requiring a certain amount of solar and offshore wind.

First, EDECA specifically requires that 2.45% of all generation in EY 2015 come from distributed solar energy, rising to 4.01% in EY 2028.[600] To meet this goal electricity providers can buy Solar Renewable Energy Credits (SRECs) from local solar project owners who obtain one SREC for every megawatt-hour (MWh) of solar

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595 N.J. Stat. §48:3-87(d). EY 2015 is defined as June 1st, 2014 to May 31st, 2015.

596 *See* N.J. Stat. §48:3-51.

597 N.J.A.C. §14:8-2.3(a).

598 *Id.*

599 N.J. Stat. §48:3-51. *See also* N.J.A.C. §14:8-1.2.

600 N.J. Stat. §48:3-87(d)(3).

energy they generate.[601] As a result of New Jersey's carve-out for solar, their SREC market is by far the largest in the nation, comprising of nearly three-quarters of all national SREC trading.[602] Alternatively, electricity providers also have the option of paying a "Solar Alternative Compliance Payment" (SACP) instead of purchasing SRECs to suffice the requirement.[603] In furtherance of the state's goal of encouraging and promoting residential solar energy, the New Jersey Legislature has passed the Solar Easements Act, allowing property owners to obtain an easement guaranteeing access to sunlight to ensure solar energy production.[604] Likewise, the Legislature has prohibited homeowner associations or the like from either adopting or enforcing "a restriction, covenant, bylaw, rule or regulation prohibiting the installation of solar collectors on certain roofs of dwelling units."[605] In 2012, SREC prices dropped substantially, decreasing from a high of $650 per SREC down to a low of $50 per SREC, due to an oversupply of SRECs compared to current SREC requirements.[606] To save the SREC market, the New Jersey Legislature passed the Solar Resurrection Law in 2012 which amended EDECA and included four main provisions; increasing the solar RPS carve out requirement, setting a longer term and decreasing the SACP, setting a limit on total non-residential or industrial solar capacity built per year at 80

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601 N.J.A.C. §14:8-2.4.

602 Lori Bird et al. *Solar Renewable Energy Certificate (SREC) Markets: Status and Trends* NREL Report No. TP-6A20-52868 (2011) 3, 19 *available at* http://www.nrel.gov/publications/.

603 N.J. Stat. §48:3-87(j)

604 N.J. Stat. §46:3-24-26.

605 N.J. Stat. §45:22A-48.2.

606 Wirshafter, *supra* note 594, at 198.

MW for EY 2014 to EY 2016, and finally introducing net-metering.[607] Nevertheless, current prices of SRECs of the last EY have held relatively steady at around $170/MWh,[608] implying the Solar Resurrection Law has reached mixed levels of success.

The second carve-out requirement under the New Jersey RPS directs the NJBPU to establish an offshore wind renewable energy certificate program to authorize offshore renewable energy credits (ORECs) "to support at least 1,100 megawatts of generation from qualified wind projects."[609] EDECA included, and the NJBPU adopted, rules on what constitutes a qualified offshore wind project, requiring applicants to show, among other things, a complete financial analysis of the offshore wind developer and of the project, a cost-benefit test that shows net benefits to the State, a proposed OREC price, along with whatever other information the NJBPU requires.[610] However, unlike the RPS and the solar carve-out, there is no time constraint on the state to implement the 1,100 MWs, and it ultimately depends entirely on the discretion of the NJBPU and its approval of qualified offshore wind projects.[611] To date the NJBPU has not approved a qualified offshore wind project and has not

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607 *Id*. at 202-203.

608 New Jersey Clean Energy Program. *SREC Pricing: Current SREC Trading Statistics Energy Year 2015* (2015) *available at:* http://www.njcleanenergy.com/renewable-energy/project-activity-reports/srec-pricing/srec-pricing.

609 N.J. Stat. §48:3-87(d)(4).

610 N.J.A.C. §14:8-6.5(a)(1-16). *See also* N.J. Stat. §48:3-87.1(a)

611 N.J.A.C.§14:8-6.2.

required any OREC obligations.[612] In conclusion, New Jersey renewable energy laws rely entirely on its RPS programs and carve-outs, which have reached mixed success to date.

3.7.4.4 Applications of the Public Trust Doctrine in New Jersey

Because New Jersey overwhelmingly relies on conventional sources of electricity, especially nuclear, the state causes substantial damages to water and wildlife resources through water withdrawals. For example, in 2009, the most recent data available, the NJDEP estimated that nearly half of all withdrawals in the state were by power plants, most of which still operate using an open-cycle CWIS.[613] This leads to damages not only to water quality, but also to aquatic organisms that are killed as a result of I&E. Additionally, the reliance on natural gas also contributes to climate change. With this in mind, there are two potential applications of the public trust doctrine to the impacts from electricity production; first, applying directly to the public interest in wildlife and water resources, and second, applying the water and wildlife impacts indirectly through the public's right to enjoy beaches and recreation.

As developed above there is some precedent for the direct application of the public trust doctrine to the wildlife impacts of electricity production,[614] and statutory support for a similar application regarding water impacts.[615] Although lightly

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612 For example, a recent offshore wind application by the developer Fishermen's Energy has been denied several times and faced substantial difficulties, *see infra* note 638 and associated text.

613 Jeffrey L. Hoffman. *Water Withdrawals in New Jersey from 2000 to 2009*. (2014) *available at* http://www.state.nj.us/dep/njgs/enviroed/infocirc/withdrawals2009.pdf.

614 *See Jersey Central*, *supra* note 581.

615 N.J. Stat. §58:1A-2.

developed compared to access to the dry sand beach, the relative silence of New Jersey jurisprudence on the public trust's application to wildlife and water does not necessarily imply that the courts will not apply it robustly in the future. In fact, the New Jersey courts have generally treated the scope of the trust doctrine as expansive.[616] Likewise, the New Jersey courts have continually emphasized that public trust doctrine is "not fixed or static, but should be modeled and extended to meet changing condition and the needs of the public the doctrine was created to benefit."[617] Given the public's growing concern for wildlife and the environment, especially as they are impacted by climate change,[618] it is reasonable to see how New Jersey courts could mold the heavily-beach access orientated public trust precedent to address the public's current needs; protecting the local wildlife and water resources from the direct impacts of conventional electricity production.

In fashioning such an application the New Jersey judiciary may look to public trust doctrine jurisprudence in jurisdictions beyond its boundaries, as it has in the past. For example, in the seminal *Neptune City*, the court reviewed case law from Massachusetts, Wisconsin, Oregon, and California to come to the conclusion that beach access is required under the public trust doctrine.[619] In the most recent public trust case, regarding the trust aspects of beach renourishment and takings, the New

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[616] For example, *see Arnold*, *supra* note 548, 6 N.J.L..at 12. See also Cabroni, *supra* note 554, at 126 ("the overall trend of the public trust doctrine in New Jersey has been to progressively recognize the public's changing needs").

[617] *Van Ness*, *supra* note 561, 78 N.J. at 179. *See also Neptune City*, *supra* note 555, 61 N.J.at 309.

[618]For example, *see* Michael R. Greenberg et al. *Public Support for Policies After Hurricane Sandy* 34(6) Risk Analysis 997, 1007 (finding 64% of New Jersey residents felt that climate change is a risk to them and their families).

[619] *Neptune City* at 309-310.

Jersey Supreme Court also incorporated rationale from the Florida and the U.S. Supreme Court, especially as the public trust doctrine relates to the law of avulsions.[620] By looking to other jurisdictions, as well as the expansiveness and flexibility of the New Jersey public trust doctrine, the New Jersey courts could, and indeed, should readily conclude that water and wildlife resources, as they are impacted by New Jersey electricity system, are included in the public trust *res*.

The direct application of the public trust doctrine to wildlife and water resources is not its only possible application to electricity production. While electricity production may also directly reduce the public's ability to enjoy New Jersey's beaches, by reducing opportunities to view wildlife and by degrading water quality,[621] the more substantial concern is that the New Jersey electricity system will continue to damage beaches via climate change's impact on hurricanes and sea level rise. Currently, the "most significant threat to beaches in New Jersey is not their heavy use but severe long-term erosion and destruction associated with major storm events."[622] Furthermore, climate change will significantly increase the intensity of hurricanes along the Mid-Atlantic,[623] leading to further destruction and impairment of New Jersey beaches protected by the public trust doctrine. In addition to destruction

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620 *City of Long Branch*, *supra* note 576, 203 N.J. at 476-478.

621 Mulvaney & Weeks, *supra* note 549, at 613.

622 *Id*. at 600-601.

623 Lauren Mudd et al. *Assessing Climate Change Impact on the U.S. East Coast Hurricane Hazard: Temperature, Frequency and Track*. 15(3) Nat. Hazards Rev. 04014001 (2014).

from hurricanes and other storm events, the New Jersey coast also faces the "looming threat of migrating shorelines due to sea level rise," as caused by climate change.[624]

Taking these factors together, it is appropriate for the state to act to protect the public interest in beach access and recreation from the damages caused by conventional electricity production. However, despite "all the importance of New Jersey's beaches, the state does not currently possess constitutional, statutory, or judicial policies to address the legal issues that migrating shorelines will create."[625] Cabroni (2012) argues for use of the public trust to facilitate adaptation to sea level rise, suggesting that because New Jersey courts have unequivocally held that the public has the right to enjoy beaches as trust lands, "it follows that the right to enjoy public trust lands also includes the right to have those lands preserved from destruction; otherwise, there would be no lands for the public to enjoy."[626] It also follows that if the public has this right, the state has the authority and duty to *prevent* this destruction. Given the legislature has failed to act on the sea level rise, arguing that "the judiciary may well be the only effective guardian…of the public interest in mitigating sea level rise.[627] And given the "crisis as to the availability to the public of its priceless beach areas" that will be endangered by sea level rise, the New Jersey courts themselves have recognized "[*p*]*rompt and decisive action by the Court is*

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[624] Cabroni, *supra* note 554, at 97.

[625] *Id.* at 98

[626] *Id*. at 126.

[627] *Id.*

needed."[628] Without substantial state action, New Jersey's beaches will be substantially impaired, begging the question, "what is the value of perpendicular public access to New Jersey's coastline…if the public cannot enjoy themselves when they get there?"[629]

In sum, in the interest of the public, the New Jersey courts could and should use the public trust doctrine to incentivize renewable electricity to protect the public's interest in water, wildlife, and beaches. Furthermore, public trust doctrine can alleviate two current renewable energy problems in New Jersey: the underperforming SREC market and the recent court appeal from the NJBPU denying of its most recent offshore wind permit application from the developer, Fishermen's Energy.

First, although the New Jersey legislature passed the Solar Resurrection Law in order to revive the flailing SREC market, it has achieved limited success, and has been characterized as "an effort that falls short because of a more demanding RPS schedule is vital to cure the ailing market."[630] Wirshafter (2013) argues that among other fixes, lawmakers must increase the RPS schedule to a higher percentage requirement to balance the SREC supply and demand.[631] While the NJDEP has the authority to consider increasing the RPS beyond what the legislature mandated,[632] the current

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628 *Van Ness*, *supra* note 561, at 180 (emphasis added).

629 Mulvaney & Weeks at 618.

630 Wirshafter, *supra* note 594, at 209.

631 *Id*. at 214.

632 N.J. Stat. §48:3-87(o).

SREC prices have remained depressed,[633] implying an oversupply of SRECs. Specifically, the NJBPU is required to consider the "reductions in air pollution, water pollution, land disturbance and greenhouse gas emissions" that increasing the RPS would cause.[634] The public trust doctrine could be utilized by citizen groups interested in solar energy implementation to require the NJBPU to update the RPS, cognizant of the public trust benefits, such that the SREC market would no longer be debilitated. Essentially, the citizen group, relying on the common law aspects of the trust doctrine, could argue that the NJBPU is abdicating its fiduciary obligation by allowing unnecessary damages to public trust resources as a result of failing to enact an RPS that protects trust resources to the maximum extent practicable. Given the oversupply and consequent low price of New Jersey SRECs and the falling prices of solar installations, an increased RPS standard is, at the very least, economically practicable.[635] The New Jersey courts, if convinced that the NJBPU, as a subdivision of the state,[636] has public trust responsibilities, may order the NJBPU to adopt higher RPS standards in accordance with the protection of public trust resources to the maximum extent practicable. Not only would this revitalize the SREC markets,

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633 New Jersey Clean Energy Program, *supra* note 608.

634 N.J. Stat. §48:3-87(o)(1).

635 If the court were to hold NJBPU to a higher standard, such as requiring it to protect public trust resources to the maximum extent *feasible*, the required amount of solar and renewables overall in the RPS would likely be substantially higher. *Compare Waiahole I, supra* note 493, 94 Haw at 139 (requiring the CWRM to protect waters to the maximum extent practicable) *and National Audubon Society, supra* note 49, 33 Cal 3d.at 426 (requiring protection of water and wildlife resources so far as feasible).

636 Since New Jersey has not fully developed the obligations of the public trust doctrine, no New Jersey court has addressed whether any other state agencies other than the NJDEP and municipalities have the fiduciary duties of a trustee. However, many other states hold that the public trust doctrine applies to all political subdivisions of the state. *See e.g. supra* note 506 and associated text.

improving the investments of New Jersey citizens who implemented solar, increasing the RPS to the "maximum extent practicable" standard under the public trust doctrine also would ensure that the NJBPU was requiring only climate change mitigation that was cost-effective, [637] and thus would be in the interests of the public as a whole.

Assuming that NJBPU is burdened by the public trust doctrine, it also would be useful to apply the public trust to the recent controversy regarding the potential construction of a 25 MW offshore wind farm off of Atlantic City by the developer, Fishermen's Energy. To briefly summarize the contentious last three years of the project development process, Fishermen's Energy proposed to construct five 5-MW wind turbines as a demonstration project, 2.8 miles offshore from Atlantic City.[638] As required by statute, Fishermen's Energy applied for approval to become a "qualified offshore wind project," and also submitted an OREC price for the NJBPU to consider.[639] Originally, Fishermen's Energy submitted an OREC price of $454.78/MWh, but as a result of switching turbine designs, the recent awarding of U.S. Department of Energy funding (*Phase II Subsidy*), and internalizing the risk of receiving the federal Investment Tax Credit (ITC), it reduced the proposed OREC price to $199.17/MWh.[640] In November 2014, after a remand from the New Jersey

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[637] Using a threshold of "maximum extent practicable" implies that the NJBPU is not required to ignore the increasing costs of raising the RPS, but rather should only raise the RPS to the extent that it is practicable, i.e. cost effective, for the state to adhere to, though it will depend on the definition of "practicable."

[638] Brief of Respondent New Jersey Board of Public Utilities at 8, *In Re Petition of Fishermen's Atlantic City Windfarm, LLC* (Jan. 15, 2015)(No. A-3932-13T3)(*NJBPU Brief*).

[639] N.J.A.C. §14:8-6.5(a)(1-16). *See also* N.J. Stat. §48:3-87.1(a).

[640] Brief on Behalf of the Petitioner/Appellant, Fishermen's Atlantic Windfarm, LLC at 14. *In Re Petition of Fishermen's Atlantic City Windfarm, LLC* (Dec. 15, 2014)(No. A-3932-13T3) (*Fishermen's Energy Brief*).

Superior Court, Appellate Division, the NJBPU denied Fishermen's Energy application, saying that its proposal did not provide a net economic benefit to the state, which NJBPU calculated using an OREC price of $263/MWh rather than $199.17/MWh because receipt of the ITC was uncertain.[641]

Fishermen's Energy has since appealed the permit denial. While other peripheral issues have been raised, the main focus of the appeal is whether the project passes the state Net Benefits Test.[642] Fishermen's Energy, using a model explicitly authorized by NJBPU,[643] found benefits to the state, which include wages from construction and operation, savings from decreased energy demand and capacity reduction, as well as environmental benefits, totaling greater than $1.1 billion.[644] Meanwhile, the NJBPU has a different view of benefits than Fishermen's. It ignored many of the benefits Fishermen's quantified, including the monetized environmental benefits, and found the benefits of the state to be only $218 million.[645]

On the other side of the equation, the costs to the state "are almost entirely a function of the OREC price, as the OREC Price directly correlates to the size of the Ratepayer Subsidy."[646] Using the higher OREC price of $263/MWh, the NJBPU

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641 *NJBPU Brief* at 42. Fishermen's Energy argues that the refusal to use the $199.17 OREC price out of concern of the project's viability if they do not receive the ITC is capricious, because this would only result in Fishermen's Energy's rate of return on the project decreasing from 9.78% to 7.49%, nowhere near a threshold for unviable, especially from the ratepayer's perspective. *See Fishermen's Energy Brief* at 56, 61.

642 N.J. Stat. §48:3-87(b)(1)(b)

643 N.J.A.C. §14:8-6.5(11)(i)(1)(a).

644 *Fishermen's Energy Brief* at 11.

645 *Id*. at 12.

646 *Id.*

found the total costs to the state would be $240.3 million in net present value, a bit higher than the NJBPU's state benefits findings, meaning the Fishermen's Energy application failed the Net Benefits test. Meanwhile, using $199.17/MWh, which Fishermen's Energy has claimed is their unequivocal suggested OREC price, the total cost to the state would only be $180.6 million, lower than the $218 million benefit as calculated by the NJBPU, and substantially lower than benefit of $1.1 billion as calculated by Fishermen's Energy. Thus, using this OREC price, Fishermen's Energy would easily pass the Net Benefits Test.[647] Fishermen's Energy has mostly focused on arguing that NJBPU acted arbitrarily and capriciously by refusing to use the OREC price of $199.17/MWh.

The public trust doctrine would be useful to the efforts of Fishermen's Energy in their appeal process in two ways; first, the public trust doctrine can be used to force the NJBPU to consider the monetized environmental benefits in the Net Benefits Test, and second, to reduce the level of deference the court should award the NJBPU.

First, given the arguments presented above,[648] Fishermen's Energy can argue that the NJBPU, as a political subdivision of the state, is burdened with the fiduciary duty to protect public trust resources. However, in this case, the state has not acted to properly discharge its obligations; indeed it has outright ignored consideration of environmental benefits in its decision-making process. Given that the duties under public trust require the state to consider monetized and non-market trust resource values, Fishermen's Energy can claim that the state is abdicating its responsibility to

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647 *Fishermen's Energy Brief* at 15.

648 *See supra* notes 613-629 and associated text.

affirmatively protect the public's interest in these resources. If successful, the NJBPU would be obligated by a non-discretionary duty to include the substantial environmental benefits, as calculated by Fishermen's Energy in its analysis. This would necessarily increase the calculated benefits to the state under the Net Benefits Test, which, when added to the other benefits, would in turn likely outweigh the costs of the project, regardless of which OREC price was selected.

Also at issue in Fishermen's appeal to the level of deference the court should grant NJBPU. The NJPBU argues that the court must confine its review to exclusively whether there exists "a *reasonable* basis for the Board's action."[649] The Board continues, asking for a high level of deference:

> "Respectfully, however, this Court may not substitute its own judgment for the Board's especially here where the Board evaluated an application under OWEDA for the first time and, after several years of review and vetting of the application, determined that approval was not in the best interest of New Jersey and its retail electric ratepayers."[650]

Fishermen's Energy replied to the NJBPU brief, arguing that the NJBPU should not be granted such a high level of deference, saying that "[t]he normal legal deference that the BPU implores this Court to afford it ended when the [NJ]BPU committed the fundamental errors detailed in Fishermen's Initial Brief."[651] Alternatively, had the NJBPU been burdened by the responsibilities of trustee, Fishermen's Energy would be able to argue that since NJBPU's decision is damaging

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649 *NJBPU Brief* at 45 (emphasis added).

650 *Id*. at 46.

651 Reply Brief on Behalf of the Petitioner/Appellant, Fishermen's Atlantic Windfarm, LLC at 14. *In Re Petition of Fishermen's Atlantic City Windfarm, LLC* (Jan. 23, 2015)(No. A-3932-13T3) (*Fishermen's Energy Reply Brief*).

trust resources, the courts must take a heightened level of scrutiny regarding the decision. Because Fishermen's Energy's offshore wind project would substantially mitigate damages to the state's trust resources, the court is burdened with a duty to take a "hard look" at NJBPU's decision, not grant it broad deference. One of the main purposes of judicial review regarding the public trust doctrine is as a check on the other branches of the government, which works to prevent the state from continuing to damage resources for political reasons, resources which it holds in trust for the benefit of the public. In conclusion, the public trust doctrine may provide a useful tool for Fishermen's Energy to ensure that the NJBPU and the New Jersey courts give due consideration to its proposal.

In sum, while New Jersey has not incorporated the public trust doctrine substantially beyond common law applications to beach access, the public trust doctrine is readily applicable to the impacts of New Jersey's electricity production grid. Not only would such application improve the resources held in trust for the public, but it would also benefit the energy policy and planning of the state, ensuring reasonable development of renewable electricity.

3.7.5 Conclusion: Lessons Learned from the Case Studies

As seen in these four case studies, the public trust doctrine can potentially provide a flexible legal tool to both citizens and governments to ensure the development of considerable renewable energy resources. At present, each of the four states remains inundated with conventional sources of electricity production, which continues to pose substantial environmental risks to the public interest. While each state's sense of justice has produced a varied public trust doctrine, electricity production impacts all trust resources, whether they are the traditional triad, or the emerging ecological aspects of the trust. Thus, each state can apply their public trust doctrine, regardless of their unique nuances and variations thereof, to their current electricity policies. As a result of this general applicability across states, the public trust doctrine is available to states that are implementing renewable electricity as well as to citizens of states that have failed to do all they can to advance renewable electricity.

As illustrated in these four case studies, the public trust doctrine can serve the following four purposes: (1), as a tool for citizens to force states to act on renewable electricity development; (2), as a legal defense for states to validate actions encouraging renewable electricity development; (3), as a means for courts to take a closer look at electricity decisions made by the state; and (4), as an opportunity for state agencies to supplement and guide imperfect statutes. Together, these four purposes of the public trust can ensure reasonable and timely development of renewable electricity as well as sufficient protection of trust resources.

3.7.6 Other Jurisdictions

Though these four states are of particular interest in both their electricity policies and their unique public trust doctrines, they are far from the only states where such an application of the public trust doctrine to electricity decisions is appropriate. Rather, the vast majority of states have developed the constitutional, statutory and common law bases for the public trust doctrine in ways similar to the four states on which this paper has focused. First, two out of every three states afford some protections of natural resources in their state constitution, and six of those states constitutionalize environmental rights on par with other political rights.[652] Moreover, practically every state has recognized the traditional public trust doctrine, with only a handful exceptions. Of the fifty states, only Nebraska and Nevada have done nothing to develop their public trust law,[653] with only Alabama, Missouri, and West Virginia only minimally doing so.[654]

As for other states, notably the Eastern states "vary widely in the breadth of public uses that they will protect",[655] especially as compared to Western states, that have been cautiously moving toward recognizing a nascent ecological trust, even outside California and Hawaii.[656] Many of the Western states that are not approaching the ecological perspectives of California and Hawaii instead have applied the public

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652 David Takacs. *The Public Trust Doctrine, Environmental Human Rights and the Future of Private Property*. 16 N.Y.U. Envtl. L.J. 711, 751. (2008). *See also* John C. Dernbach et al. *Robinson Township v. Commonwealth of Pennsylvania: Examination and Implications*. Widener Law School Legal Studies Research Paper No. 14-10 (2014) 15 *available at* http://ssrn.com/abstract=2412657 (states that include constitutional provisions to a substantive right to a quality environment include Pennsylvania, Hawaii, Illinois, Massachusetts, and Montana).

653 Robin Kundis Craig. *A Comparative Guide to the Western States' Public Trust Doctrine: Public Values, Private Rights and the Evolution Toward an Ecological Public Trust*. 37 Ecology L.Q. 53, 81 (2010)[hereinafter *Western States*].

654 Robin Kundis Craig. *A Comparative Guide to the Eastern Public Trust Doctrines: Classifications of States, Property Rights and State Summaries*. 16 Penn. St. Envtl. L. Rev. 1, 24. (2007)[hereinafter *Eastern States*]. Though these states have not developed their public trust doctrines to similar levels as other jurisdictions, this does not imply that these states do not have a public trust doctrine, production, but rather, it would merely be more of an uphill battle, as there would be little to no precedents to rely upon. As such, an application to electricity production as the first impression of the public trust doctrine might not be the best strategy to develop a robust state public trust doctrine.

655 *Id.* at 17.

656 *Western States* at 71, 91. The author argues that Western states will expand their public trust doctrines further, stressing that "the most recent cases demonstrate… the evolution of western states is not slowing." *See Id.* at 92. The author also notes, however, that Colorado and Idaho, both of which have recognized and developed a public trust doctrine, have limited themselves to only the most traditional applications of the public trust. *See Id*. at 76-77.

trust to novel areas, such as recreation or hunting.[657] Likewise, in many cases, various states have addressed the public trust doctrine using broad generic statements regarding the public's right to use resources, leaving these applications enigmatic and "potentially interesting for the future."[658] Furthermore, given states' overwhelming interest in maintaining wildlife populations, all but two states claim ownership of wildlife.[659] Because electricity production impacts nearly all public trust resources, including more traditional resources, such as water and fish, as well as more expansive resources such as non-fish wildlife, aesthetic and recreational values, and the implications of climate change, an application of the public trust to electricity production may not be exclusively dependent on that state's sense of justice as it relates to the trust corpus.

Underscoring this point, a recent case from Pennsylvania, Robinson Township v. Commonwealth of Pennsylvania,[660] expanded the public trust doctrine to natural gas exploitation and development, and could serve as a stepping stone for other states. Despite having constitutionalized the public trust doctrine, Pennsylvania had minimally extended public rights beyond the traditional navigation and fishing interests.[661] The central issue in *Robinson Township* was whether a recent statute, Act

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657 *Id.* at 72-73.

658 *Eastern States* at 18-19. *See also* Ivan M. Stoner. *Leading a Judge to Water: In Search of a More Fully Formed Washington Public Trust Doctrine* 85 Wash. L. Rev 391, 417 (2010)(a closer look at the Washington public trust case law implies that "the State has enforceable public trust duties" beyond alienation cases)

659 Blumm & Paulson, *supra* note 148, at 1462.

660 Robinson Township v. Commonwealth of Pennsylvania 83 A. 3d 901 (2013).

661 *See Eastern States* at 94.

13, was constitutionally valid. Act 13, passed in 2012, was enacted in reaction to the advent of unconventional hydraulic fracturing of natural gas wells in the Marcellus Shale, also known as fracking. The Act amended Pennsylvania's Oil and Gas Act to create a statewide system of permitting the unconventional wells.[662] The three sections of the law that were at issue in the challenge preempted all local regulations of natural gas wells. These provisions allowed only the state to enact regulations, required all local ordinances to allow for optimal oil and gas development while prohibiting the local governments from enacting more stringent rules, and finally, required Pennsylvania's Department of Environmental Protection to waive restrictions on well development near water resources if the developer submitting a mitigation plan.[663] Essentially, the state displaced all local authority and authorized natural gas fracking in every zoning district in order to incentivize oil and gas development. Individual citizens, citizen groups, and local governments sued the state, contending that the statute violated several provisions of the Pennsylvania Constitution, including the due process clause, the "special law" clause, the separation of powers doctrine, the takings clause, and finally, Pennsylvania's constitutional enactment of the public trust doctrine, known as the Environmental Rights Amendment.[664] Among all these challenges, the Pennsylvania Supreme Court saw that the central implication of the dispute as touching on a citizen's right to a quality life, and thus discussed the

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662 *Id*. at 913.

663 Dernbach et al., *supra* note 652, at 3-4. Furthermore, if local governments did not follow Act 13 requirements, they faced burdensome financial consequences such as paying for attorney's fee and ineligibility from collecting revenues from gas development.

664 *Robinson Township* at 930.

Environmental Rights Act and the public trust doctrine at great length.[665] Taking a step backwards, the Environmental Rights Amendment reads as follows:

> The people have a right to clean air, pure water, and to the preservation of the natural, scenic, historic and esthetic values of the environment. Pennsylvania's public natural resources are the common property of all the people, including generations yet to come. As trustee of these resources, the Commonwealth shall conserve and maintain them for the benefit of all the people.[666]

From this provision, the court enunciated three principles: first, the people have a right to an undamaged environment; second, the state is burdened with the public trust doctrine and has an affirmative duty to protect trust resources; and third, the state must protect said resources in such a way that is impartial to all of the public, including both present and future generations.[667] The court held that the Commonwealth has a fiduciary obligation to comply with the terms of the public trust as found in the State Constitution. To fulfill these duties, the court held that the state must "prevent degradation, diminution, or depletion of public natural resources, and… act affirmatively to protect the environment…*with the evident goal of promoting sustainable development*."[668] The court also found that these duties, as a matter of constitutional law, apply to all branches and subdivisions of government, including

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665 *Id.* at 940-943. The court ruled practically its entire reasoning on the public trust, despite the fact "that the parties do not develop their Environmental Rights Amendment arguments to the same extent" as their other claims. *Id.* at 943.

666 Pa. Const. art.1 §27.

667 *Robinson Township* at 957-959. *See also* Dernbach et al. at 12.

668 *Robinson Township* at 957-958 (emphasis added).

local governments.[669] While the public trust burdens the Commonwealth with "twin constitutional duties," requiring both promotion of the general welfare by permitting development and exploitation of natural resources and protecting the environmental resources of the state for the benefit of the people,[670] the court found that Act 13 entirely failed to consider its constitutional trust obligation to protect and preserve the natural environment, and instead found that the state's "constitutional commands have been swept aside."[671]

The court's continuing reiteration that the trust burdens the state to maintain resources and to foster sustainable development for both present and future generations, as well as its recognition that environmental impacts can have a compounding effect over generations[672] creates a foundation in the case law for a straightforward application of these principles to electricity production and climate change. At the very least, the broad language used by the court would allow for similar applications to the direct impacts to water and wildlife resources of electricity production.

Moreover, Dernbach et al. find dozens more state "provisions fairly characterized as recognizing that the state holds state resources in public trust" akin to the one found in Pennsylvania's Constitution.[673] It is not by any means a stretch for

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669 *Id.* at 977.

670 *Id*. at 978-979.

671 *Id.* at 975, 982.

672 *Id.* at 959, 974, 981.

673 Dernbach et al. at 15 (quotation marks omitted).

other states to utilize the reasoning in in *Robinson Township* in their future public trust cases, including applications to the electricity production's impacts on water, wildlife and climate change. Therefore, given the trend of the public trust doctrine and the strong foundation of public trust statutory and constitutional provisions across the nation, it is likely that many states will be capable of expanding their public trusts to electricity production in the coming years.

Beyond the fifty states, the public trust doctrine is well developed and utilized around the world. "The constitutions of about three-quarters of nations worldwide address environmental matters in some fashion"[674] the majority of which "specify the right to a healthy environment and/or the nation's obligations to prevent environmental harm" reminiscent of the public trust doctrine.[675] As a result, many of the courts of these nations are likely to turn to *Robinson Township* and other constitutional public trust case law for guidance.[676] In other cases, the public trust doctrines in some other countries may be broader than their American counterparts. For example, India, which essentially directly imported the American public trust doctrine in 1996, has begun to stretch the public trust doctrine well beyond its traditional and American bounds.[677] In addition to citing English and American common law as sources of the public trust doctrine, India's courts have tied the public

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674 *Id.* at 14.

675 Takacs, *supra* note 652, at 723.

676 Dernbach et al. at 15.

677 Paul A. Baressi. *Mobilizing the Public Trust Doctrine in Support of Publicly Owned Forests as Carbon Dioxide Sinks in India and the United States* 24 Colo. J. Int'l Envtl. L. & Pol'y 40, 56. *See* also Mehta v. Nath 1 SCC 388 (India 1996).

trust doctrine to India's constitution, even though it only guarantees individual quality of life and does not explicitly mention any environmental values.[678] Nonetheless, "Indian courts have gone further than almost any in naming environmental rights… [and] require[] an affirmative "fundamental duty" of every citizen to protect and improve the natural environment including forests, lakes, rivers, wildlife, and to have compassion for living creatures."[679] Additionally, South Africa is another example where the public trust has become foundational. Unlike India, South Africa explicitly includes fundamental environmental rights in its Bill of Rights.[680] The case law from South Africa implies that the government "state must affirmatively address and make progress towards achieving all the fundamental rights, including environmental rights."[681] Likewise, the Philippines have implied that public trust responsibilities, while enshrined in their constitution, are such basic rights that they "need not even be written in the Constitution for they are assumed to exist from the inception of humankind."[682]

Because the public trust doctrine "has expanded its reach to cover more of the Earth as interrelatedness of ecosystems becomes more defined,"[683] the public trust doctrine can became a useful tool around the world for development of renewable

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[678] *Id.* at 58. See also Takacs at 735.

[679] Takacs at 735-740 (citations and quotations omitted).

[680] *Id.* at 741.

[681] *Id.* at 742.

[682] Oposa v. Factoran 224 S.C.R.A. 792 (Phil. S. Ct. 1993). *See also* Blumm & Wood, *supra* note 23, at 5.

[683] Takacs at 760.

energy. In conclusion, the public trust doctrine is prevalent legal tool existing in nearly every state in the U.S., as well as many countries around the world. This Article proposes that the arguments and applications made in the four case study states can similarly be made in jurisdictions around the nation as well as around the world.

3.8 Discussion

If the public trust doctrine were to be applied to electricity production, there would be two lasting implications, as such application would substantially benefit (a) electricity planning and policy and (b) wildlife.

3.8.1 Implications for Renewable Electricity Planning & Policy

First and foremost, the public trust doctrine offers a legal tool for citizens to improve renewable electricity planning and policy. Despite public support for a nation-wide climate change mitigation effort and funding of renewable energy,[684] promotion of renewable electricity has been uneven thus far at a federal level, and to some degree, at a state level as well. The lack of progress may be explained by "a failure in the political process, a minority exercises undue influence over the executive and legislative branches to the detriment of the majority."[685] The public trust doctrine can provide a voice to citizens in the judiciary, citizens whose voices are often not

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684 *See* Edward Maibach et al. *Global Warming's Six Americas 2009: An Audience Segmentation Analysis* (2009) 93-94, Table 8 *available at* http://trid.trb.org/view.aspx?id=889822 (74% of Americans support at least a medium-scale climate change mitigation effort at medium costs, and 92% of Americans support funding for renewable energy research).

685 Gerald Torres & Nathan Bellinger. *The Public Trust: The Law's DNA* 4 Wake Forest J. L. & Pol'y 281, 311 (2014).

heard in the other two branches of government and encourage the reasonable development of renewable energy.

This democratizing aspect of public trust doctrine has long been recognized. Professor Sax described the public trust doctrine as “no more - and no less - than a name courts give to their concerns about insufficiencies of the democratic process."[686] The public trust doctrine has also been described as “an anti-monopolistic doctrine in that it favors diffuse public rights over particular private ownership.”[687] And even though “democracy may seem subverted when a court overrules the acts of elected officials [in the name of the public trust doctrine], such judicial acts in fact serve democracy by preserving rights invested in all the people.”[688] Essentially, the role of judiciary is to safeguard and preserve these dispersed public rights in trust resources, especially in cases of improper allocation of trust resources by the executive and legislative branches.

The heightened scrutiny, though usually associated with either unconstitutional or prejudicial statutes,[689] is an essential tool for courts to ensure that a politically strong minority does not damage public trust resources. Professor Ariaza draws connections between the procedural aspects of public trust doctrine and those

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686 Sax, *supra* note 40.

687 Eickelberg, *supra* note 396, at 43.

688 Takacs, *supra* note 652, at 715

689 William D. Araiza. *Democracy, Distrust and the Public Trust: Process-Based Constitutional Theory, the Public Trust Doctrine and the Search for a Substantive Environmental Value* 45 UCLA L. Rev. 385, 389 (1997).

embodied in the Equal Protection Clause.[690] While public trust scrutiny is distinct from Equal Protection scrutiny due to the trust's protection of a diffuse *majority* (rather than a minority), it bears resemblance in its protection of diffuse interests, as it is the "diffuseness of the [public trust] interest" that "makes it in most need of judicial protection."[691] Indeed, in other branches of government, there has been little to no consideration of the public trust interest[692] in planning and policy of electricity development, despite the direct and substantial impacts electricity production has on public trust resources, especially the impacts of climate change.

The procedural aspect of the public trust doctrine can provide citizens with the opportunity to bring their diffuse claims and the oversight by the other two branches of the government to the judiciary. Moreover, current electricity production and policy in particular highlights the appropriate role of the judiciary. It has been noted that, "Professor Joseph Sax had a vision of the public trust doctrine that would allow citizens to 'circumvent legislatures and administrative agencies' and 'take their concerns directly to the courts.'"[693] Since that time, Professor Sax's insight has only increased in significance, because, despite the substantial and growing importance of environmentalism, and the general inaction of administrative and legislative bodies,

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690 *See Id.* Professor Araiza finds that while there are echoes of the procedural aspects in the Equal Protection Clause, the public trust doctrine may only achieve similar procedural standards in tandem with state constitutional and statutory trust provisions.

691 *Id.* at 436-437.

692 Note that the "public trust interest" used here is distinct from the "public interest" often used in electricity decisions, which reflects the importance of reducing rate impacts to residential customers. For example, see the discussion of current Wisconsin electricity policy, *supra* note 443, saying that the central purpose of these policies is to protect ratepayers.

693 Kyle, *supra* note 466, at 46 (citing Sax at 560).

“the judiciary has lost its potency as a check on the administrative branch in the environmental realm…primarily due to the tendency of courts to give undue weight to agency decisions” in implementing their statutory and regulatory mandates.[694] Given the urgency of the impacts of electricity production, especially the impacts from climate change, it is essential for the judiciary to fill the void left from government inaction and force the government “to address climate change [and other trust impacts] in order to fulfill their fiduciary duty to the trust beneficiaries.”[695] While deference is also an essential principle of the judiciary, the procedural aspect of the public trust allow courts to review agency action with high scrutiny without second-guessing agency expertise, and allows the reemergence of a more potent judiciary in environmental and energy law.

Because the judiciary is only applying *procedural* scrutiny to the actions of the executive and legislative branches, the public trust doctrine does not require any specific result. That is, the public trust doctrine does not mandate a certain amount of renewable electricity to be built. This maximizes the benefit to the public by forcing states to weigh both the benefits and costs of electricity development in their full context.[696] This is in stark contrast to the current focus of state public utility commissions, and associated case law, that place almost exclusive emphasis on

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694 Mary Christina Wood. *“You Can’t Negotiate With a Beetle”: Environmental Law for a New Ecological Age*. 50 Nat. Ress. J. 167, 193 (2010)[hereinafter Wood, *Beetle*]. *See also Citizens Climate Lobby, supra* note 334, (implying that California courts will likely continue to defer to CARB’s expertise regarding climate change mitigation), *Clean Wisconsin, supra* note 419, (Wisconsin court refused to overturn PSC decision based on a high level of deference), and *NJBPU Brief, supra* note 649, (NJBPU requests the court to defer to its expertise).

695 Torres & Bellinger, *supra* note 685, at 313-314.

696 *Cf. Clean Wisconsin, supra* note 423 (glossing over the negative impacts of CWIS and entirely ignored the larger social benefits of renewable electricity), and *supra* note 648-649 (NJBPU ignored the contextual benefits of Fishermen’s Energy offshore wind project).

minimizing direct out-of-pocket costs to ratepayers. Admittedly, conventional electricity production has public benefits in that it delivers electricity to consumers at low cost, if one ignores externalities. Nonetheless, "[t]he fundamental obligation of government is not to us as consumers but to us as citizens."[697] On top of that, public benefits, no matter the magnitude, do not make any project immune to the public trust doctrine.[698]

The judiciary can require agencies to take a more nuanced approach to electricity planning and policy, which can better capture the public's interest in non-market aspects of electricity, and thus in the non-monetized benefits of renewable electricity, such as the reduction of I&E of fish, and reductions in climate change emissions. While current environmental law provides little consideration of these aspects, the flexible nature of the public trust doctrine allows it "to leap ahead of societal norms and meet changing needs."[699] Professor Takacs argues that Sax invoked the public trust doctrine to specifically make what had been considered valueless (e.g., the fish species ignored by CWA §316(b) analysis) to be recognized as a publicly-held good that "accrue[s] economic value comparable to that accorded private property."[700] In addition, it is the duty of the trustee to "illuminat[e] and

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697 Torres & Bellinger at 285.

698 *See* Lake Michigan Federation v. U.S. Army Corps of Engineers 742 F. Supp. 441, 450 (1990)(a conveyance of public trust lands to a university, no matter their reputability or good intentions, is still subject to the public trust doctrine).

699 Jeffrey Thaler & Patrick Lyons. *The Seas are Changing: It's time to Use Ocean-Based Renewable Energy, the Public Trust Doctrine, and a Green Thumb to Protect Seas From Our Changing Climate* 19 Ocean & Coastl L.J. 241, 284 (2014).

700 Takacs, *supra* note 652, at 716.

consider[] potential impacts unrecognized by citizens,"[701] such as these unvalued environmental benefits.

In sum, there is a substantial role for the judiciary to play in upholding the values in the public trust doctrine through heightened scrutiny of potentially politically-dysfunctional executive and legislative electricity-related actions. Such a role will protect the diffuse majority interests in trust resources, while also not supplanting the expertise of the administrative body with the court's own. Many courts have already recognized the substantial public interest in renewable energy development, especially regarding environmental concerns,[702] and the public trust doctrine would authorize these courts to ensure that the public interest in renewable energy is being served. If and when the public trust doctrine is incorporated into electricity planning and policy, citizens will be ensured that their concerns about trust resources, which usually go under-considered, are given due weight. Likewise, renewable energy developers can also put their environmental and economic impacts in context of other types of current electricity production under the trust doctrine, encouraging full consideration and ramifications of renewable electricity.

Given the current impacts of electricity production on water and wildlife resources, and the looming damages of climate change, society is running out of time. The public trust doctrine, in its role as common law, through the judiciary, can play an essential role in re-balancing democracy, preventing private property rights from

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701 Donald J. Decker et al. *Stakeholder Engagement in Wildlife Management: Does the Public Trust Doctrine Imply Limits?* 79(2) J. of Wildlife Mgmt. 174, 176 (active stakeholder engagement can substantially improve public trust administration).

702 *See* Wiens, *supra* note 300, at 393, discussing *CBD* v. *FPL*, supra note 48.

prevailing in inappropriate instances over the "more diffuse and often unenforceable public interest."[703] Judicial review of electricity policy not only can improve current practices, but also is drastically needed. Additionally, the imposition of trust duties on state electricity planning and policy can help state agencies develop "regulatory capacity," thus increasing regulatory sophistication and political agility.[704] To summarize, the public trust doctrine can be a useful tool for the judiciary to emerge as an important actor in energy law, which is increasingly intertwined with environmental law, for citizen groups to encourage protection of wildlife and development of renewable electricity, for renewable electricity developers to contextualize renewable energy's impacts and give full weight to environmental benefits, and finally, for states to obtain the authority and regulatory capacity to regulate modern environmental and electricity issues.

3.8.2 Implications on Wildlife Law Regarding Electricity Production

Secondly, if the public trust doctrine were applied to electricity production, there would be significant ramifications for and potential improvements to wildlife law and policy. Overall, the efficacy of modern environmental law has been questioned, with some authors going so far as concluding that "[a]cross the board, they have failed."[705] Whatever the merit of that statement more generally, in the context

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[703] Redgwell, *supra* note 54, at 4.

[704] Carlson, *supra* note 335, at 64 (the required duties under the public trust doctrine can forcibly develop state agency's expertise and ability, defined as "regulatory capacity"; this capacity is the reason that California is capable of leading on climate change and other environmental issues).

[705] Wood, *Beetle*, *supra* note 694, at 182. Wood continues by observing that based on the health of the planet, environmental law has clearly not been effective. *Id.* at 183. *See also* Mary Christina Wood. *Protecting the*

of electricity production, it is hard to come to any other conclusion except that environmental and wildlife law has, in most respects been ineffective.[706] Specifically, one considerable problem is a paucity of data and knowledge,[707] which has two significant implications to electricity policy: developers of new electricity projects, especially renewable generation, have little understanding of wildlife impacts at a population level; and conventional electricity's impacts on wildlife continue to be largely unknown in their entirety, preventing equitable comparison across the full range of electricity production.

First, renewable energy developers have the *de facto* onus of evaluating the impacts of their proposed project in the context of a more general overarching need to improve understanding of wildlife populations.[708] Not only does lack of population data place extra responsibilities on renewable energy developers, but the "lack of population data also make it difficult to set triggers for mitigation."[709] As a result, devising optimal mitigation efforts is challenging, if not impossible, especially given the lack of knowledge of current population trends, assessment and survival rates.[710] Furthermore, the data requisite to make intelligent wildlife-related decisions, e.g.

Wildlife: A Reinterpretation of Section 7 of the Endangered Species Act 34 Envtl. L. 605, 606-607 (2004) (the Endangered Species Act, specifically, "has failed to bring species to recovery")[hereinafter Wood, *ESA*].

706 *See*, *e.g.*, Odom, *supra* note 205, at 367 (EPA ignored several impacts of CWIS which should have been included and would have altered the Phase II rule). *See also* Cryan, *supra* note 234 (there is no wildlife law regulating bat impacts of wind turbines).

707 Goodale & Milman , *supra* note 233, at 8.

708 *Id.* at 15.

709 Arnett & Baerwald, *supra* note 542, at 452.

710 Goodale & Milman at 8.

mitigation policies, "are not likely to be available…in the near future."[711] At the end of the day, the only way to reduce the scientific uncertainty is through "collection, sharing and analysis of data, the responsibility for which remains distinctly unclear."[712] In the interim a renewable energy developer thus faces an unsavory dilemma: either accept the heighted responsibility and undertake the weighty research necessary to understand the regional impacts of his or her project, or relinquish this unreasonable responsibility and assume the likely proposition that damages to populations are minimal.

However, viewing this issue through the lens of the public trust doctrine, the responsibility become clear. Under the public trust doctrine, states have the fiduciary duty to prevent substantial impairment to wildlife resources. However, it is clearly impossible for a state to ensure this duty is being upheld if it does not know what the baseline populations are of the wildlife resources under its jurisdiction. It should be the duty of the state, and not of a given electricity production company, to estimate overall wildlife populations and trends. While developers have the duty to ensure that their proposed projects do not substantially impair these resources, the obligation to the public to ensure said impairment does not occur resides strictly in the state. The state, under its trust obligations, cannot grant a permit without reasonably knowing whether a proposed project will cause undue damage to trust resources.

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711 Arnett & Baerwald at 452. The authors suggest that in the absence of population data, offshore wind operators should "practice the precautionary principle and implement operational mitigation at sites where bat fatalities are high." *Id.*

712 Goodale & Milman at 13.

In addition to facilitating the acquisition of baseline population information and trends, the public trust doctrine also can work to ensure states adequately plan the "use" of trust resources, i.e., the take of wildlife. Essentially, it is the duty of a state to know how much of the population must be preserved in the face of electricity production appropriation, ensuring sustainable use of wildlife resources.

This application of the public trust doctrine is not limited to renewable electricity developments. In fact, despite more significant impacts to wildlife, the impacts from conventional electricity are largely unknown, and when known, ignored. For example, as discussed above,[713] the population impacts, from conventional electricity production, such as from I&E or mercury bioaccumulation, are largely unknown. Inequitably, conventional electricity plant operators are not burdened by their plants' external effects, as renewable electricity developers are, despite the greater impacts the former have on wildlife resources. Furthermore the wildlife law that currently regulates electricity production is a patchwork of isolated statutes that fail to provide sufficient overall protection to wildlife populations. The public trust doctrine would appropriately fill the gaps of current statutory wildlife law, affording the legal authority and duty to the state to protect wildlife populations.

The current regulatory scheme of environmental law as whole has been criticized as essentially ineffective and as encouraging further damages to the environment.[714] Professor Wood argues that the central paradox over the last 40 years of environmental law is that though "[t]his colossal damage to the Earth had its

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713 *See supra* notes 201-264 and associated text.

714 Wood, *Beetle*, *supra* note 694 at 191.

genesis in the Industrial Revolution… the real acceleration took place between 1970 and present- ironically, during the modern era of environmental law."[715] This narrative continues in the various federal environmental laws specific to electricity production. For example, the EPA, in its implementation of the CWA, "has failed to adequately consider the benefits in relation to all potential costs and monetize the appropriate costs."[716] Specifically, the EPA has continually and entirely "failed to consider the benefit of 98 percent of aquatic species that are not commercially or recreationally valuable."[717] In addition, despite twenty years having passed since the courts firsts intervened and created a timetable for promulgation of rules to regulate CWIS, the EPA's efforts remain lacking, and as a result it has been rightly criticized for "becoming more and more sensitive to the industry and less concerned with the environmental impacts that result from the alternatives [proposed in promulgations of rules]."[718] Similar to the CWA, other rules, such as those recently promulgated related to mercury emissions,[719] did not consider wildlife impacts or benefits in setting standards or in justifying the rule, despite the substantial and sustained history of coal damaging wildlife resources with little to no restrictions.

Federal statutes that directly address wildlife also fail to provide adequate protection. For example, the Endangered Species Act (ESA), despite being "the only

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715 *Id.* at 182.

716 Nicole M. Magdziak. *The Debate Over Regulation Alternatives for Cooling Water Intake Structures is Heating Up* 38 Seton Hall Legis. J. 413, 442 (2014). *See also* Odom, *supra* note 205, at 367.

717 Magdziak at 442.

718 *Id.* at 444-445.

719 *See supra* notes 220-253.

bright line" in wildlife regulation, has been criticized for acting only as a bottom line, "operating as giant vacuum that draws species of all varieties towards its irreducible *minimum of protection*."[720] Thus, in spite of "a powerful dual mandate" in the ESA, the federal agencies have essentially ignored their authority to actively promote and recover wildlife populations, not just prevent extinction.[721]

In the context of electricity production, the obstinate MBTA, presents a consequential regulatory conundrum "[b]y criminalizing the take of migratory birds without a permit and simultaneously granting no permits whatsoever for incidental take."[722] The MBTA, as it applies to electricity production (particularly wind energy), has been vague and conflicting thus far, and the growing concern for migratory birds provides no certainty in either their protection at a population level or its appropriate application to wind energy.[723] Worse yet, "none of the bat species currently known to be affected in large numbers by wind turbines are protected by federal conservation laws," other than the ESA, and because of that, there is no "mandate to either monitor or take conservation actions toward bat fatalities at wind turbines."[724] While these regulatory gaps have brought specific criticism in their application to wind power,

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720 Wood, *ESA*, *supra* note 705, at 613-614 (emphasis added).

721 *Id.* at 633.

722 Lilley & Firestone, *supra* note 232, at 1181. On the other hand, *See* Bald and Golden Eagle Protection Act (BGEPA), 16 U.S.C. 668 et seq., which like the MBTA, provides no statutory means to take eagles incidentally; yet the US FWS has since promulgated rules for incidental take permits under the BGEPA for wind energy farms. *See* 50 C.F.R. §§22.26-.28. *See also* Samuel J. Panarella. *For the Birds: Wind Energy, Dead Eagles, and Unwelcome Surprises* 20 Hastings W.-N.W. J. Env. L. & Pol'y 3, 20-24 (2014). The FWS presumably could act similarly with regards to the MBTA. Until such time, the public trust doctrine can provide a helpful guide.

723 *Id.* at 1198.

724 Cryan, *supra* note 234, at 367-368.

they are pertinent to all electricity production. "It is time to do away with disproportionate levels of scrutiny and consider avian- and, more broadly, wildlife impacts- in a context where wind power is assessed against a range of alternatives rather than against none at all."[725] To apply a high degree of scrutiny to wind developers, assuming they are conscientiously attempting to navigate and minimize harm to wildlife while contributing to the larger goal of climate change mitigation and displacement of fossil fuels, and especially given the criminal penalties of the MBTA, "is unconscionable and inconsistent with democratic ideals."[726]

While current federal wildlife laws with respect to electricity production are at times understandable, they also are at times incomprehensible.[727] Many wildlife populations impacted by electricity production are lost in the "millions of leaks in the membrane of environmental law" and "[t]o fix them, even a few of them, is a terribly complex endeavor."[728] It would appear unlikely that federal wildlife law, especially in the current political environment, will be substantially amended to afford reasonable and comprehensive protections to the wildlife lost in these regulatory gaps. In light of these obstacles, the public trust doctrine is an appropriate tool to fill regulatory gaps.

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725 Lilley & Firestone at 1205.

726 *Id.* at 1209. As an aside, this does not apply to all federal wildlife laws that wind developers will encounter. For example, the Marine Mammal Protection Act (MMPA) allows for incidental take permit for offshore wind development by statute, 16 U.S.C. 1371(a)(5)(A). Thsee authors note, that unlike other federal wildlife laws that provide minimum protections or are obtuse, the MMPA affords sufficient and specific protections to marine mammals while not unreasonably burdening renewable energy developers.

727 *Id.* (while protections for under the ESA are "understandable," provisions in the MBTA are "nonsensical").

728 Wood, *Beetle* at 198.

Although the wildlife branch of the public trust doctrine is nascent, and the application to electricity production novel, utilization of the public trust doctrine to fill regulatory gaps in current wildlife law can serve the purpose of common law, while also benefitting the rational regulation of wildlife populations. The core function of common law "in a statutory legal regime is to fill gaps left in the legal framework."[729] In other areas, scholars have revisited the public trust doctrine, suggesting "that the doctrine can provide remedies to perceived shortcomings in environmental law and policy."[730] The public trust doctrine can provide a legal framework that affords protection to *all* types of wildlife and placed in context of all electricity production, is "the type of foresight needed to help drive scientific advances that allow us to better predict and deal with emerging threats to migratory wildlife."[731]

The public trust doctrine is advantageous because it provides a "well-grounded mechanism for rebalancing private and public rights in the environment"[732] and "is particularly important when applied to natural resources of communal value that are under siege by private commercial interests because these resources are inadequately protected by positive law."[733] This regulatory gap-filling aspect is especially appropriate in regard to the impacts of all means of electricity production on bat

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729 Babcock, *Tall Tale*, *supra* note 199, at 405.

730 Craig, *supra* note 653, at 82.

731 Cryan at 370.

732 Craig at 83.

733 Babcock, *Tall Tale* at 406.

populations.[734] Under the public trust doctrine, the state would weigh impacts contextually, by comparing relative impacts of alternative means of electricity production, and make the most informed and beneficial decision regarding bat populations.

Another important purpose that the public trust doctrine can serve is offering "normative management standards that can guide resource managers."[735] Any perceived flaws in federal wildlife law can be buttressed by the public trust doctrine. For example, Professor Wood argues that "[t]rust principles provide a normative anchor for ESA interpretation" and they "are basic, logical, and geared towards sustaining society for generations to come."[736] Furthermore, applying these trust principles to the ESA would offer a foundation for government trustees to act affirmatively under section 7 of the ESA "to restore the wildlife trust where it has been damaged or depleted."[737] The CWA also would benefit from the normative basis of trust principles. Under trust principles, government agencies would be authorized, as well has be burdened by the duty, to act on behalf of the oft-ignored 98 percent of fish species in §316(b) analyses, and to require extra protections of these wildlife trust

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734 Cryan at 369 (there currently is an "absence of requirements for wind facility operators to minimize fatalities of unprotected bat species").

735 Babcock, *Tall Tale* at 408. To clarify, this normative guide can be useful to both federal and state resource managers. Either of these managers could rely on the potential federal public trust doctrine (though its existence is at the moment questionable), *see supra* notes 171-200 and associated text, or rely on the public trust doctrine of the state in which the electricity project would occur. Likewise, either federal or state natural resource managers could use either the federal or a state public trust doctrine to fill the gaps in wildlife regulation. However, because state natural resource managers, and state agencies in general, frequently address wildlife and electricity decisions, and because a state public trust doctrine is a more concrete legal tool than the federal public trust doctrine, focusing on the state may be more useful.

736 Wood, *ESA* at 612.

737 *Id.* at 631.

resources.[738] Lastly, the statute that would likely benefit most from reinforcement from the public trust doctrine is the MBTA. Because the MBTA offers no incidental take permit, it cannot reasonably govern the realities of present wildlife impacts. Applying trust principles would bolster the protections of the MBTA in a manner that is rational with the overarching purpose and spirit of the statute, while simultaneously offering reasonable expectations to all electricity developers who impact migratory birds.[739]

As a result, the public trust doctrine can be utilized both to fill the regulatory gaps and buttress current wildlife and environmental law. The public trust doctrine is a more reasonable, more flexible and more intuitive legal framework than the status quo that both improves and upholds current environmental laws. The dual prongs of the trustee's duty—that is, prevention of substantial impairment and affirmative minimization of harm to trust resources, when either practicable or feasible, present the best of both worlds. The "substantial impairment" principle would prevent undue criminal action being brought against well intentioned wind developers under the MBTA by allowing the fatality of one migratory bird to be put in context of the effect at the population level. Similarly, the "duty to minimize harm" principle can give states the authority to implement reasonable mitigation efforts otherwise not authorized in the current law, e.g., bat fatality mitigation. In tandem, these principles

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[738] *See, e.g. Clean Wisconsin, supra* note 419, where a Wisconsin court largely ignored the substantial impacts of a coal plant's CWIS.

[739] While one could argue that the stringent rules of the MBTA and continual threat of FWS prosecution affords substantial protection, or that the promulgation of rule creating an incidental take permit would afford greater protection to migratory birds than the public trust doctrine, the purpose of the trust is not to displace these protections but rather to normatively guide these protections in a reasonable way. Nor does the MBTA subsume (at least in theory) the public trust doctrine and its normative standards, *See Waiahole I, supra* note 205, at 130.

can afford reasonable and responsible protection of wildlife populations while also not unduly burdening electricity producers, especially renewable electricity developers. Additionally, the public trust doctrine offers a more democratic path, since each state can regulate wildlife impacts in accordance with its own sense of justice. It should be noted that "the fact there is a federal statute is not dispositive, because those statutes merely serve as a baseline."[740] Lastly, the utilization of the public trust doctrine "to address unregulated social ills may spur the development of positive law."[741] In sum, using the public trust doctrine to fill regulatory gaps and buttress current wildlife statutes, would be highly beneficial to both wildlife population and aspirations of renewable energy developers.

3.9 Conclusion

The public trust doctrine is not only an appropriate tool for the environmental impacts of electricity production, but also a beneficial and necessary application. This Article has attempted to show in four thorough case studies the suitability of an application of the public trust doctrine to that state's electricity planning and policy goals. This application would benefit both the protection of wildlife populations and electricity planning and policy and serve the important common law purpose of a regulatory stopgap. While the public trust doctrine has evolved over the last decades, there has been minimal application to electricity production, despite the substantial benefits said application would provide to the public. This Article

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740 Torres & Bellinger, *supra* note 685, at 300-301. The authors continue that if federal statutes did statutorily displace the public trust doctrine "then it would entirely destroy the ability for a court to examine whether or not a state fulfills the trustee's duty." *Id*. at 301.

741 Babcock, *Tall Tale* at 410.

encourages this application and finds that the public trust doctrine, while under-utilized, is a fitting and essential tool to improve, incentivize, and regulate the development of renewable electricity production.

Chapter 4

A COST MINIMIZATION OF THE PJM INTERCONNECTION WITH CONSIDERATION OF EXTERNALITIES

4.1 Introduction

The integration of large-scale renewable energy penetration have been of keen interest in recent years. Renewable energy has significant benefits for society, but very large penetration levels, say over 50% variable generation, have not yet been accomplishment, and management of such energy systems is not yet well understood. To begin with, renewable energy implementation will be essential for achieving international climate change mitigation goals. Other benefits of renewable energy include reduced water use, energy security and health benefits [1]. While the benefits are clear, prior analysis has left unanswered any questions regarding implementation and management of high-renewables energy systems. This paper builds on previous work yet takes a unique approach to modeling a large but coherent actively managed electric system. The unique approach is that rather than assuming a particular combination of renewable energy systems, we model 86 million possible energy systems. We then evaluate the costs and benefits of each of these possible energy systems, and find the ones that minimize total costs to society.

For perspective, our cost minimization calculations are not a reflection of current decision-making about energy systems. In the United States, as well as many other countries, decisions regarding electricity systems are reviewed and approved by a state public utility commission (PUC), who follow a statutory requirement to minimize the cost of delivering electricity to its end use consumers. In this PUC minimization, however, only costs internal to the electric system are counted, including the generation, transmission and distribution of electricity. Conversely, the PUC's minimization ignores the external costs of electricity to society, notably health and environmental externalities, including climate change externalities. Rather, we have a system of warring agencies – one (PUCs) concerned about minimizing internal costs of delivering electricity while others (environmental agencies) are concerned about reducing pollution. In this paper, we provide a common metric to frame the trade-offs between each minimization problem and compare the minimization of internal costs, as a PUC would conduct, to the minimization of energy systems including the social costs. Indeed, the central question of this paper is: "If we had devised policies to properly minimize the social cost, what would have our energy systems looked like today, given sunk costs and the possibility of new construction?"

A very high penetration of variable generation has been shown to be more easily managed with some storage. In addition to new generation we model purpose-built storage, in the form of hydrogen, and two forms of storage using end-use systems, electric vehicles with the ability to both charge and discharge, and heat storage also used for building heat. Thus, the full cost-minimized level includes renewable electricity generation as well as electrification of light-duty vehicles and building heat, touching upon the electricity generation, transportation and heat sectors. This is an extension of prior work that considers the integration of electric transport and building heat [2] [3]. Electrifying some transportation and building heat also have benefits and costs, which are included in this cost minimization analysis.

Nationally, these sectors represent more than two thirds of carbon emissions in the U.S. [4] and have commercially ready renewable alternatives.

To ensure the reliability of the energy system, our model is constrained to meet the hourly electric and heating load of the PJM territory from the calendar years 2010 to 2013, a total of 35,040 hours. PJM Interconnection manages an electric system with a generation capacity of 186 GW, and an average electric load of 86 GW_a [5]. The territory of PJM includes 61 million people [6], 52 million light duty vehicles [7], and approximately 30 million households. Residential and commercial buildings total an average heating load of 52 GW_a thermal and a maximum heating load over the 4 years of 180 GW thermal [3]. Similar to previous uses of the model, RREEOM is computationally constrained, and thus does not try to include additional considerations that would be computationally intensive, e.g. spatial consideration of transmission.

Whereas previous use of this model [2], has set the modeled energy systems to meet certain goals, e.g. 90% of hours to be covered entirely by renewables, we set no goals a priori. Instead we calculate the costs of each energy systems with the inclusion and exclusion of externalities, to explore the importance of pricing externalities in implementation of renewable energy. In addition, while previous work has primary focused on the present-end uses of electricity, this paper more comprehensively includes new loads and electrochemical storage systems, such as vehicle-to-grid (V2G) capable light duty electric vehicles (EVs) or hydrogen tanks, and electric heating (EH) systems. In setting up the model, the systems are constrained to require energy systems meet electric, driving, and heating needs. Among the systems that meet those needs, we identify those that are the least costly to when including and excluding different externality assumptions.

4.2 Literature Review

Previous papers have investigated the plausibility and benefits of large-scale renewable penetration. Jacobson and Delucchi [8] investigated the possibility of powering the entire world's energy demand by wind, water and solar power. The authors concluded that, although significant investments would be required, it is plausible for wind, water and solar to power the world energy demand, given resource capacity and physical and material constraints [8]. Furthermore, the lead author applied a similar analysis for the state of New York, and found that the entire state's energy demand could be met solely by water, wind and solar by 2030, costing less than conventional energy with externalities priced [9]. These studies only test the technical feasibility of reaching 100%, but do not model the hourly generation of the three sources in comparison to load, and do not find the cost minimized energy system.

Arent et al. [1] investigated the plausibility and benefits, but not the costs, of 80% renewable electricity penetration in the United States. The authors found that there would be significant benefits associated with estimated carbon emission reductions of up to 84%, as well as a 50% decrease in both water withdrawal and consumption. The authors also investigated the constraints of such large-scale renewable electricity implementation, including rare metal mining and production rates, concluding that it was unlikely that such constraints would significantly impair even the highest renewable electricity penetration. The authors suggested that more work should be done in the economic and environmental implications of large-scale renewable penetration, which this paper explores.

Mai et al. [10] investigated the economic, market, and institutional challenges of transitioning to high penetrations of renewable electricity for the entire United

States from 2010 to 2050. The authors found the least cost system that met load over two year periods, yet these were for the entire nation as a whole and thus did not reflect regional variations in fuel prices, variable generation, or sub-national decision making. The authors found that under several different scenarios, 80% of 2050 electricity generation can be met by various mixes of renewable electricity and would be only up to 30% more expensive than current generation costs [10]. The authors do not compare the additional costs of renewable electricity to other monetized benefits associated with renewable electricity, such as the mitigation of health and climate externalities.

Mileva et al. [11] investigated the price of solar technology as a result of the SunShot program, a research and development goal to decrease the cost of solar energy. The authors compare future potential electricity systems in implementation of 80% below climate emissions by 2050 in the Western Electricity Coordinating Council (WECC) using the capacity-planning model, SWITCH [11]. Investment into generation is optimized, and dispatch is verified in “study hours” subsampled from peak and median load days. The authors explored four scenarios, based on the technology available, such as carbon-capture and nuclear, and the price of solar energy. The authors found that 80% reduction in climate change can be accomplished by 2050 through various mixes of solar, wind, gas, hydro and nuclear. The authors concluded that the SunShot program could help increase solar implementation and save $20 billion per year. However, the authors did not include loads from electric vehicles or building heat; likewise they do not model V2G technology, nor calculate the costs of externalities of the system.

Nikolakasi & Fthenakis [12] investigated the potential large-scale implementation of solar and wind in the state of New York and the implications on grid flexibility. The authors found that when the grid was optimized to maximize renewable generation and minimize curtailed energy, that the optimal mix of renewables was 14.5 GW of solar PV and 11.1 GW of wind [12]. The authors assumed that solar and wind would never displace baseload generation and that the grid was not capable of implementing storage. Furthermore, the study did not include any economic considerations, and called for another study to analyze the cost of the energy system, especially regarding the costs of curtailed energy.

Budischak et al. [2] concluded that a significant percentage of hours could be covered with renewable energy, and that, at expected future costs, more than 90% of hours could be covered by renewable energy at a cost lower than current prices. Though our model is closely related to the RREEOM model used in Budischak et al., it differs in that they selected electricity systems that powered load from renewable sources for a required number of hours, whereas our model determines the cost-minimized electricity system under various sets of cost assumptions, regardless of hours met by renewable energy. Another difference is that we model a very large increase in electrical load needed, due to the increase in PJM territory, as well as due to our modeling of the electrification of transportation and heat.

This work additionally advances Budischak et al. in that there are several methodological improvements. These include: determining costs associated with electric and gasoline vehicles; more accurate modeling of PJM population and electric vehicle load; more thorough hourly resource assessment of renewable electricity; and lastly, further development of the externalities of conventional energy. See the methodology section.

Jacobson and Delucchi [9] and Budischak et al. [2] sought to answer the question of whether or not society could achieve large-scale implementation of renewable energy. In contrast, this model seeks to determine, given input costs, how much renewable energy is the most cost-effective for society to implement, assuming that total costs should be minimized. To answer, we consider the question in the face of three different assumptions: 1) exclusive of externalities; 2) including only local health externalities; and 3) including both health and climate change externalities. These different cost scenarios, and their respective least-cost renewable energy penetrations, have implications for the appropriate amounts of renewable energy. These assumptions also allow us to evaluate the results of various policy mechanisms and incentives in relation to the three scenarios.

This model also differs from previous ones [1] [10] in that it includes a comprehensive EV model. Specifically, it includes the increased load from EV driving, the storage capacities from using EVs capable of releasing energy from the vehicle's battery to the electric grid via V2G technology and the health and climate change mitigation benefits from displacing a corresponding number of internal combustion engines (ICE). Likewise, the model also integrates the increased load from, and displaced benefits of EH. This paper is further differentiated from these previous papers because it also investigates the hourly requirement of meeting load over four years. In conclusion, this paper presents a novel methodology to model the economic costs and benefits of large scale renewable energy penetration more comprehensively and includes more aspects than have been previously included.

4.3 Methodology

To explore the implications of large-scale renewable energy implementation, this study utilizes and modifies the Regional Renewable Electricity Economic Optimization Model (RREEOM), first developed by Budischak et al [2]. See Appendix B for improvements to the economic and modeling methodologies. Though this study attempts to incorporate more economic costs than the previous version, there are several distinctions between this model and other more typical economic-focused models, such as the valuation of people's preferences, the increasing marginal cost of implementation, and price elasticity.[742] Moreover, the scope of RREEOM is exclusively the PJM territory, and does not model the interaction with other regions, nor does it consider build-out constraints. Large scale implementation of renewable energy will certainly change people's behavior both inside and outside of the PJM territory, and will have cascading effects on secondary markets. However, this is outside of the scope of the present study. Instead, the purpose of this work is to show a focused perspective of the implications of monetizing externalities on the development of renewable energy within a specific region. See also the Model Assumption Section.

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742 To a certain extent, the model does include a portion of these costs. For example, stated preferences regarding electric vehicle adoptions are included in the model, as well as the increasing marginal cost for offshore wind.

4.3.1 Model Inputs

The model is comprised of three main sectors: electricity production; storage capabilities; and heat production. For each sector, the model requires two main inputs. First, the cost of technology, which consists of capital costs, operation and maintenance (O&M), and externalities. Second, the hourly load and resource assessment of each technology. The methodology for calculating the inputs for each of the sectors is discussed next, but see Appendix B for the full description. See also Tables 4.1 and 4.2, summarizing the inputs as calculated for the model.

4.3.1.1 Costs

First, electricity production was disaggregated into six generation types: offshore wind, land-based wind, solar, nuclear, natural gas, and coal. Offshore wind, land-based wind, solar, and natural gas were modeled as potential installations. New nuclear and coal power plants were not considered as these are much more costly than new natural gas plants [13], and currently PJM has little to no plans to add these types of generation. Indeed, of the nearly 60 GW of planned generation additions for the next ten years, over 95% of these additions are either wind or natural gas power plants [14]. There are no nuclear plants on queue in the PJM territory, and the current planned coal generation is about 1% of total PJM capacity [14]. In our mode, when renewable electricity (or storage) failed to meet load, and given the constraints of always meeting load, it was assumed that the residual load would be met by the current PJM system, see Figure 3.2 below. Currently in PJM, coal, natural gas and nuclear together make up 89% of power capacity and 95% of annual energy generation [6]. Thus, while the total PJM electricity capacity is 186 GW, and includes wind, solar, pumped hydro, and oil, for the purposes of modeling, this study includes only nuclear, coal, and natural gas capacity in current generation, which totals 165 GW. This assumption ignores the current renewable electricity generation already on the PJM grid, but these contributions are minimal, accounting for less than 2% of annual generation, and making up less than 1 GW of PJM's power capacity [14]. The model treats the capital costs of the existing and new generation very differently. The model assumes that the existing PJM system does not have any associated capital costs. For new installations, the capital costs for modeled installations (renewable electricity and natural gas) are based on 2013 estimated costs [15] [13]. These costs are inclusive of transmission and interconnection costs. The model accounts for the variation in the cost of installed offshore wind, which depends on the depth of the ocean and distance from shore.

Operation and maintenance cost were included for both existing and new installations. Operation and maintenance was divided into fixed (FOM) and variable (VOM). FOM includes O&M costs not associated with generation, such as routine maintenance independent of operating hours, while VOM depends on the utilization of the power plant and includes things like fuel and other consumable materials as well as maintenance that increases with use. Estimated FOM and VOM costs for each electricity type were drawn from EIA data [13] [16] [17].

Lastly, two categories of externality costs associated with electricity production were included: health and climate change. Health externalities were based on health impact studies per type of generation, drawn from three studies [18] [19] [20]. Climate change externalities were determined using lifecycle emission rates for each of the electricity type [21] and the federal government's mid-range and "realistic worst case" social cost of carbon (SCC) estimates [22], see Appendix B for more information. All costs are summarized in Table 4.1.

Storage was broken into two types: hydrogen storage (H_2) and V2G-capable electric vehicles. For H_2 storage, we assumed an electrolyzer would compress H_2 in an aboveground storage tank, and associated fuel cells would convert the H_2 back to electricity. Capital costs associated with H_2 were based on a solid oxide fuel cell (SOFC), an electrolyzer, and a steel tank [23]. Estimating the capital cost of V2G was more complex. V2G, can accomplish substantial cost savings because an electric vehicle's primary purpose is to serve as transportation. However, currently, most people are not choosing to buy an electric vehicle, therefore, we calculate the capital costs based on surveyed willingness-to-pay for an electric vehicle. These figures were based on a stated preference survey [24], compared to the average cost of a gasoline vehicle [25]. This difference was then converted into the cost per kWh of battery capacity. Unlike previous models, the willingness to pay for an electric vehicle in this model is heterogeneous across the populations, ranging from $110/kWh up to $947/kWh, see Figure 4.1. For further details regarding the capital cost calculation, Appendix B.

Next, H_2 storage uses no fuel, and thus there is no VOM cost, but the model includes an FOM cost based on the literature [26]. On the other hand, V2G VOM and FOM costs are calculated in the context of the displacement of ICE vehicles, which are generally found to be less expensive to maintain. To be conservative and given the lack of data regarding V2G FOM, the model assumes that there is no net change regarding FOM. On the other hand, V2G VOM provides a cost by adding load to the electric grid, but also a benefit in that gasoline consumption is displaced. Both of these are estimated on average miles driven per year and gasoline efficiency [27], and the current cost of gasoline with federal and state taxes removed [28].   These savings are calculated in as benefit per megawatt-hour (MWh) of V2G capacity per year. Likewise, the externalities associated with V2G were calculated as the health benefits from reduced gasoline consumptions [29] and climate change mitigation benefits [30] [22]. H_2 storage does not directly cause any externalities, and does not directly displace any significant externalities.

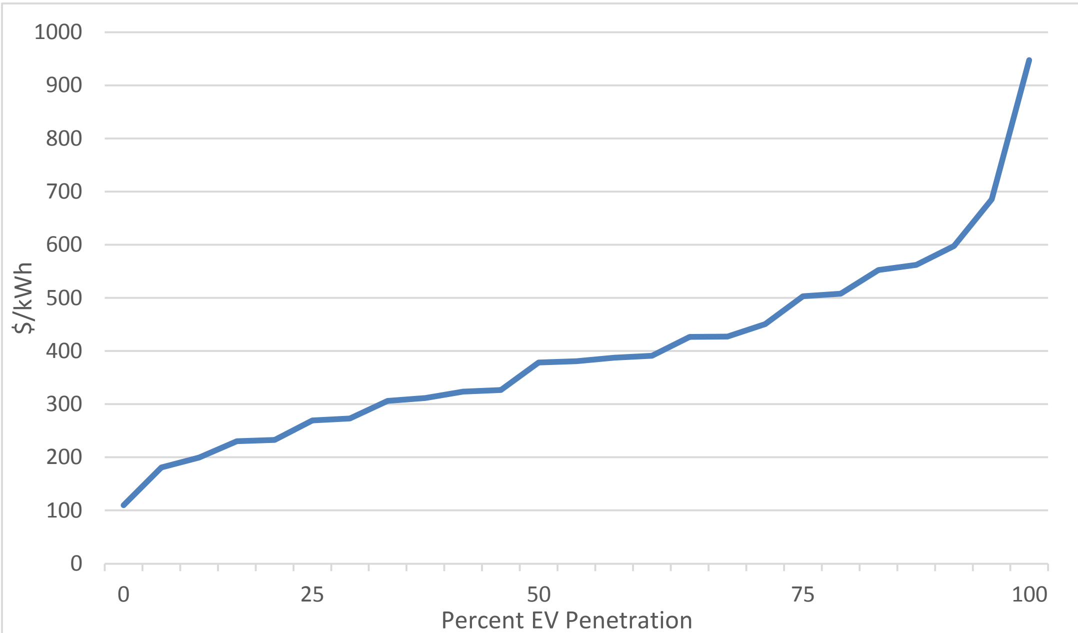

Figure 4.1 Additional costs of V2G EV as a Function of the Increased Penetration of EVs into population ($/kWh)

Third, large scale renewable penetration often implies that generation will exceed load during certain hours, which for land-based wind, would be especially likely to occur in the winter [2] [31]. It has been proposed that this excess generation can be used for heat, since the largest amount of excess generation of wind occurs in the winter [3] [2]. Our model assumes a hybrid system comprising of a heat pump (HP) and resistive heating with thermal energy storage (RHTS), both with their own benefit; HP provides high efficiency while RHTS has low capital costs and allows long-term heat storage. Similar to V2G storage, increased penetration of EH would displace natural gas heaters (NGH), which comprises about 75% of all non-EHs in

PJM [32]. The capital cost of each technology is based on [3]. The FOM of an HP/RHTS hybrid system is less than the FOM cost of a NGH system, implying a FOM savings as HP/RHTS penetration increases [3]. Meanwhile, we model the sole added component of VOM for heating as the fuel cost of natural gas. While EH will add to load, it will also displace natural gas consumption, thus, the VOM cost is based entirely on natural gas fuel savings [33]. Likewise, the externalities are exclusively based on the reduction of health damages due to natural gas combustion [34] [35], and reduction of climate change emissions [36], [37].

Table 4.1 Model Cost Inputs

Technology	Capital Cost ($/MW)	Capital Cost ($/MWh)	FOM ($/MW/yr)	VOM ($/MWh)	Health ($/MWh)	"Average" SCC ($/MWh)	"Worst Case" SCC ($/MWh)
Photo-voltaics	1,770,000[6]	0	25,000[4]	0	0	1.90[17]	5.2[17]
Offshore Wind	4,975,000-6,855,000[6]	0	74,000[4]	0	0	0.48[17]	1.4[17]
Onshore Wind	1,955,000[6]	0	39,550[4]	0	0	0.47[17]	1.4[17]
Current Coal	0	0	31,180[4]	25.13[8]	103.87[12]	40[17]	110[17]
Current NG	0	0	9,964[4]	35.02[8]	58.43[13]	19[17]	53[17]
Current Nuclear	0	0	93,280[4]	9.22[9]	14.3[14]	0.62[17]	1.73[17]
New Natural Gas	1,135,000[6]	0	15,370[4]	35.02[8]	58.43[13]	19[17]	53[17]
V2G Batteries	150,000[7]	110,000-987,000[1]	0	32,151/yr[10]	4,989/yr[15]	4,895/yr[18]	13,707/yr[18]
Hydrogen Storage	870,000[2]	15,535[2]	29,318[5]	N/A	N/A	N/A	N/A
Electric Heating	1,069,000[3]	33,500[3]	-3,265[3]	48.25[11]	0.9[16]	9.75[19]	27.3[19]

1. [24] [38]
2. [23]
3. [3]

4. [13]
5. [26]
6. [15]
7. [39]
8. [13] [16]
9. [13] [17]
10. [27], [28]. Remember that V2G cost is per MWh capacity, per year.
11. [40] [33]
12. [18]
13. [19] [41] [42]
14. [20]
15. [29]
16. [34] [35]
17. [21] [22]
18. [27] [30] [22]
19. [36] [22]

4.3.1.2 Resource Assessment

Resource assessment is broken into two aspects: the maximum potential capacity within the PJM territory and the hourly fluctuation of that generation. The maximum is used to set an upper limit in determining possible electrical systems we build each type of generation from zero capacity to the maximum. These two aspects were combined and compared to load for each hour over a four-year period. In our model, new natural gas and H_2 storage are limited neither by hourly fluctuations nor maximum capacity, so resource assessment did not apply to these sources. Resource assessment inputs are summarized in Table

4..

Land-based wind capacity was determined based on overall wind capacity in a PJM, based on state-by-state data [43]. But as some states are not entirely within PJM, these numbers were adjusted to reflect wind capacity within PJM's territory [44]. We calculate this capacity to total 201 GW. Moreover, the areas vary in how windy they are, and hence, how much wind energy could be expected to be generated over the course of a year. The model accounts for this by assigning areas into one of three capacity factor ranges. Hourly fluctuations of wind generation were included in the model based on four years of actual hourly wind generation data in PJM from 2010 to 2013 [45]. Because the vast majority of wind turbines operating during these four years have smaller rotor diameter than wind turbines now being installed [46] [47], the capacity factors were accordingly adjusted to reflect current turbine technology and practice. See Appendix B. After this adjustment, the average capacity factor across of all of PJM would have been 0.351 if the larger rotor diameter wind turbines had been deployed. We use this adjusted capacity factor as an expected capacity factor for new wind.

Solar capacity was also determined on a statewide basis [48].   To determine the proportion of states only partially covered by the PJM territory, Geographic Information System (GIS) data was used to find the relative household density within the PJM service area of each of these states [49], and compared to GIS solar capacity [50] [48], resulting in a maximum capacity of 96 GW in the PJM territory. Hourly solar data was gathered from all the locations within NREL's Meteorological-Statistical (METSTAT) solar model that would fall under PJM jurisdiction.   At each location, the solar radiance was modeled in watt-hours per square meter (Wh/m^2) based on the METSTAT model [51].[743] This was converted into a capacity factor by dividing modeled radiance by 1,000 Wh/m^2, the ideal solar radiance for maximum capacity, and then multiplying by 0.80 to account for losses, resulting in an average capacity factor over the four years of 0.134.

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743 Hourly solar data was only available up until 2010, thus the hourly solar of the four years from 2007 to 2010 were used in this model.

For offshore wind, the maximum capacity of offshore wind in PJM was based on areas that were available for offshore wind development from Virginia to New Jersey, with exclusion areas removed [52]. Based on this work, 78 GW of offshore wind could be developed and connected to the PJM area. However, this capacity was divided into two areas, based on water depth, with the deeper areas requiring greater capital costs, primarily due to increased foundation costs and associated financing [53]. Hourly generation of offshore wind over the four years was determined using the Weather Research & Forecasting (WRF) model. Using the hourly wind forecasts generated by the WRF model and a model turbine, the REpower 5MW turbine, the production of offshore wind, including losses, was calculated, resulting in an average capacity factor over the four years of 0.424.[744]

V2G maximum capacity is based on total vehicle registration within the PJM territory [27] [42]. The number of vehicles was multiplied by average battery capacity per car [24] to obtain the maximum potential V2G storage capacity in PJM of 1,950 GWh. Likewise it was assumed that for every EV there would be, on average, a 10 kW charger associated with it (some smaller; others larger), resulting in a maximum power capacity of 521 GW. From the perspective of the model, the total capacity of V2G is treated as one single aggregate battery. This battery was constrained each hour by three conditions: first, it must never go below its range buffer of 20% state-of-charge (SoC); second, its capacity is limited by the amount of time the vehicle is being driven, decreasing the capacity on average by 7% [54]; and

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[744] Modelling was done by Mike Dvorak of Sailor's Energy for the MAOWIT project (W. Kempton, PI) funded by US DOE grant DE-EE000537.

third, the aggregate battery loses 0.86% of its maximum capacity each hour from driving.

Lastly, maximum heating capacity is based on the maximum heat load, as calculated by Pensini, Rasmussen, & Kempton [3]. The authors also calculated the hourly load over the four years. Because heating systems are not dependent on meteorology nor do they have any secondary uses, it was assumed there were no hourly fluctuations limiting their capacity or heat production.

Table 4.2 Model Resource Assessment Inputs

Technology	Upper Power (MW) Limit of Resource	Upper Energy (MWh) Limit of Resource	Round Trip Efficiency (fraction)
Photovoltaics	96,708[3]	N/A	N/A
Offshore Wind	77,780[4]	N/A	N/A
Onshore Wind	201,653[5]	N/A	N/A
Current Coal	77,550[6]	N/A	N/A
Current NG	53,489[6]	N/A	N/A
Current Nuclear	32,951[6]	N/A	N/A
New Natural Gas	∞	N/A	N/A
V2G Batteries	521,773[1]	1,956,000[1]	0.81[7]
Hydrogen Storage	∞	∞	0.404[8]
Electric Heating	180,000[2]	1,350,000[2]	N/A

1. [7] [24]
2. [3]
3. [48] [50] [49]
4. [52]
5. [43] [44]
6. [6]
7. [2]
8. [23]

4.3.2 Description of the RREEOM Model

The model is based on the RREEOM, though significantly modified. The original RREEOM was constrained to meet hourly electrical load from renewable generation, storage, and back-up thermal generation, in the least costly mix possible. To capture the range of possible energy systems, Budischak et al. [2] created 1.6 billion different possible electricity systems, with 70 different possible values for each of the five input variables. The present model modifies several key aspects, including the incorporation of V2G driving behavior, minimum SoC, driving load, thermal load from heat demand, and the possibility of new natural gas development. Because these additions factorially increase the number of combinations, the updated RREEOM steps through 21, rather than 70, increments of possible values for each of the six input variables. This creates 85,766,121 million combinations of potential electricity, transportation and heating systems.

The model iteratively creates each energy system, then compares that system's renewable electricity generation for each hour to the hourly electricity load within PJM from 2010 to 2013 [5], 35,064 hours in total.[745] During those four years, the maximum actual PJM load was 158 GW, and the average hourly load was 86 GW. In parallel, the model also keeps track of the hourly heat load [3], which was a maximum of 180 GW_t with an average of 52 GW_t. If a given hour's renewable generation is less than the combined electric and thermal load, the model will use all available storage to meet those loads. Any more demand beyond this will be met by generation from the

[745] Note that while each energy system's reliability was tested for reliability over four years, the total *cost* of each system was calculated over twenty-five years.

current PJM system, as constrained by estimated ramp rates. If there is still more load, the model will then construct and then use requisite new natural gas.[746] Conversely, if a given hour's renewable generation exceeds electricity load, it will then be used to meet heat load. If there is still excess renewable generation, the excess generation will be put into electric storage, excess after that, into heat storage. If excess generation still remains, it will be spilled. It should be noted that this excess generation in practice would likely be sold in inter-regional markets, but this is outside the scope of the current model, which as a consequence, underestimates the value of excess generation. See Figure 4.2.

[746] In the Sensitivity Analysis section, we test the assumption that building new natural gas is more expensive than using existing generation, and conclude that it is cheaper to dispatch the current PJM system first.

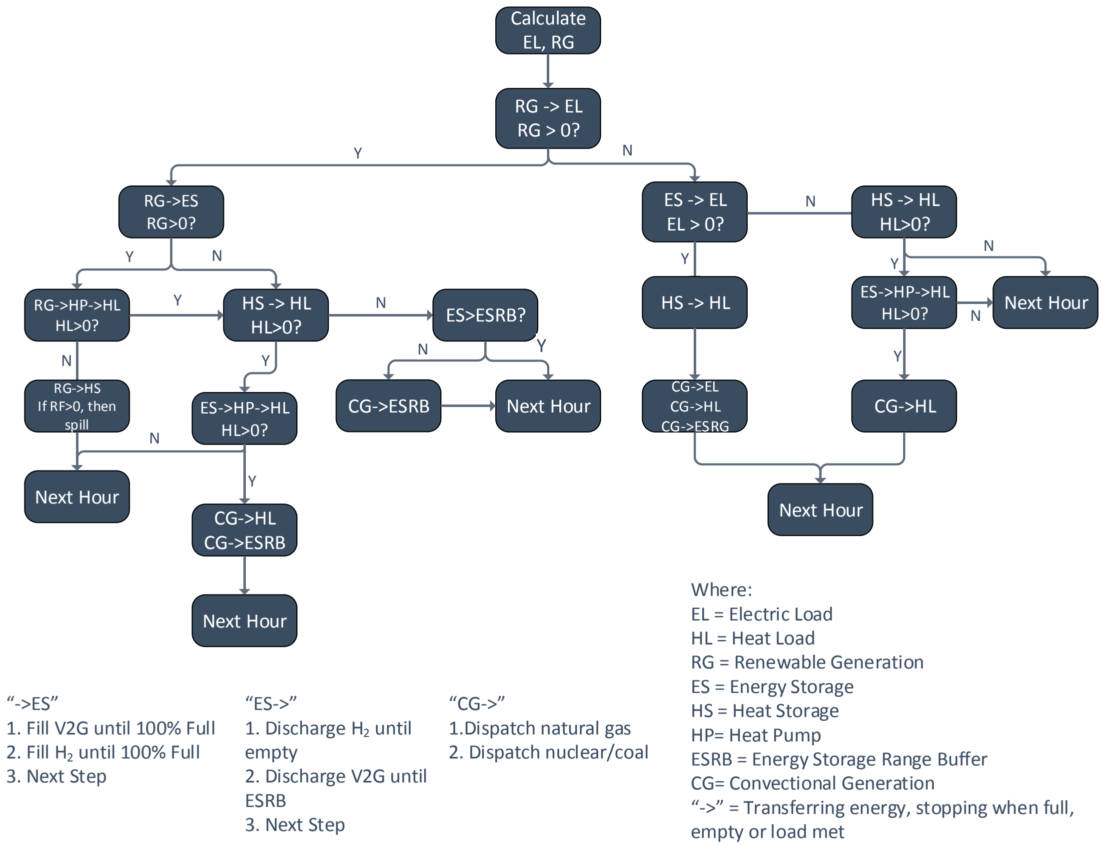


Figure 4.2 RREEOM Hourly Flow Chart

4.3.3 Model Assumptions

The model makes several simplifying assumptions. The model assumes that there is perfect transmission (the "copper plate" assumption). It assumes that no energy will be imported or exported to other connected TSOs; ignores reserve requirements, within-hourly fluctuations of load and generation, retirements of existing power plants, and does not include the possibility of demand-side management. Demand-side management, including demand-response and energy efficiency, were not included so as not to rely on assumptions as to the amount and cost of demand-side management; as well, their omission makes interpretation of the results more clear. In reality, demand-side management will be useful and cost-effective for matching generation to load in the actual implementation of renewable generation, but this is outside the scope of this paper.

The advantages that renewable energy development garners from these simplifying assumptions is likely outweighed by costs that would impede renewable energy development (See Budischak, et al. [2] at 62-63). Furthermore, many of these costs, such as ramp rates and hourly fluctuations of load, could be partly mitigated with improved weather forecasting, which would control hourly dispatch decisions [55]. Moreover, the purpose of this model is to show what an electricity system would look like and how it could work with various penetrations of renewable energy, it is not built to model hourly dispatch decisions. Furthermore, with large amounts of storage, over-generation due to ramp rates and within-hour fluctuations of load, and reserve requirements would be addressed by dispatch of quick storage [52]. Finally, to the extent a lowest cost model includes large amounts of storage, it would obviate the problem of ramp rates and fluctuations of load, especially sub-hour ones. Therefore, while the model does make some assumptions, we do not think that the sum of assumptions significantly favors renewable energy; more likely the assumptions disadvantage it.

4.3.4 Cost Calculation of the Model Output

Based on the results of the model, we calculate the cost for each system in net present value over a 25-year lifespan, using a 3% discount rate [37].[747] These costs are calculated based on the inputs, as previously discussed. The model also calculates the cost as if these hypothetical energy systems are built in the beginning of each run, and thus underestimates the build-out constraints and lower costs due to learning curves of renewable energy deployment, but is outside the scope of this work. The purpose of this paper is not to show *how* to develop energy systems, but rather what energy system would have we already developed, if we were minimizing total social costs. One novelty of the analysis is the variation in the extent to which externalities are captured in the cost minimization process, allowing for policy comparisons. As noted, costs for each energy system are calculated for various cost scenarios. The first scenario excludes all externalities, and only includes internal costs. The remaining scenarios include various combinations of health externalities, the average SCC, and the realistic worst-case SCC. For each scenario, the least cost system is found, and then compared to other least cost systems under alternate cost scenarios. See Equation 4.1.

Equation 4.1. 25 Year Net Present Cost Calculation

$$Cost = MW_k * Cap_{MW_k} + MWh_k * Cap_{MWh_k} + \sum_{i=1}^{25} \frac{MW_{i,k} * FOM_k + Gen_{i,k} * (VOM_k + H_k + SCC_k)}{(1+r)^i}$$

MW Installed Capacity

[747] Also note that this is a *social* discount rate, and not a consumptive discount rate, which would be much higher. To capture the benefits to society, a consumptive discount rate would be improper, though this may differ from discount rates used in, for example, project financing. See the Sensitivity Analyses Section.

	MWh		Installed Storage Capacity
	$Cap_{MW/MWh}$		Capital Cost per MW/MWh
	FOM		Fixed Operation Cost
Where	Gen	*Equals*	Average Annual Generation
	VOM		Variable Operation cost
	H		Health Externality
	SCC		Social Cost of Carbon
	r		Discount rate

For generation type k for year i

4.4 Results

4.4.1 Minimized Grids

The costs for each of the 85,766,121 energy systems were calculated in the four cost scenarios: without any externalities (the "No Externality" scenario), then adding health externalities to the market costs (the "Health" cost scenario), then adding to that the "Average Case" social cost of carbon to the health externalities and market costs (the "H+SCC1" cost scenario), and finally adding the "realistic Worst Case" social cost of carbon to the health externalities and market costs (the "H+SCC2" cost scenario). Through all possible combinations of the energy systems, and across all four cost scenarios the net present costs ranged from $1.91 trillion to $5.08 trillion. Under each cost scenario, the minimum cost energy system was found. See 4.3 for the power capacity mix and average energy generation mix for each of the four cost scenarios.

First, under the No Externality cost scenario, the minimized energy system builds no renewable electricity. The implication of this result is that without the monetization of externalities, it is not cost effective to develop GW-scale renewable electricity. On the other hand, the No Externality energy system would develop a substantial amount of EH and EVs, even without any consideration of externalities.

Thus, while fuel savings (i.e. VOM) costs) alone are not enough to incentivize the development of renewable electricity, it does incentivize the implementation of EVs and EH.

However, the minimized energy system in the Health cost scenario implements just over 121 GW of land-based wind and nearly 5 GW of solar PV. As distinguished from the minimized energy system in the No Externality cost scenario, adding health externalities to the market costs implies that the society would develop over a hundred GWs of renewable electricity. Implicit in this comparison is that there is a threshold effect for renewable electricity, where above a certain price, vast amounts of renewable electricity would be built, but below it, none would be built. Interestingly, in the Health cost scenario, there is substantially less EH. The reason for this is that the health benefits of EH are relatively minor, while the health impacts of using natural gas and coal to run EH are substantial. When 5% of EH capacity is added to this minimized system, it increases the energy used from coal and natural gas by 3.6% and 2.2%, respectively, and slightly increasing the net present cost of the energy system by .08%, even when including the displacement benefits of NGH's. Though this energy system develops large amounts of renewable energy, it only spills 1.8% of generation, implying that there is not a substantial amount of excess generation to power EH.

Next, adding the "average" level SCC to the market cost and health externalities almost doubles the combined amount of land-based wind and solar power capacity to just over 220 GW, with 191 GW of wind and 34 GW of solar. In stark contrast to the No Externality minimized energy system, the monetization of the damages associated with conventional energy would incentivize substantial implementation of renewable energy. Likewise, contrary to the Health cost scenario, the H+SCC1 develops a substantial amount of electric heat, converting 70% of all NGH's to EH, as well as converting 70% of all PJM ICEV to V2G-capable EVs. Because externalities incentivize higher penetrations of renewable electricity, there is sufficient excess generation to displace the negative externalities of ICEVs and NGHs.

Finally, when including both the health and the highest SCC to the market cost, the minimized energy system is dominated by renewable energy. In the H+SCC2 cost scenario, the optimal implementation of renewable electricity would total nearly 300 GW, as well as converting 100% of houses to EH and 80% of all vehicles to EVs. The H+SCC2 minimized energy system is the only system to implement any offshore wind, constructing 19.5 GW, and also the only to build the maximum amount of land-based wind, 201 GW.   Due to the fact that the electric load has increased from EVs and EHs, and in spite of the nearly 300 GW of renewable electricity, this energy system requires 159.5 GW of conventional electricity capacity, the most out of any of the minimized energy systems that consider externalities.

Throughout the four minimized energy systems under each cost scenario, there are several consistent trends. Each minimized energy system requires substantial conventional thermoelectric power capacity, yet outside of the No Externalities energy system, the requisite conventional power capacity is less than the current PJM grid. None of the minimized energy systems that include externalities require the construction of any new natural gas plants, even though these energy systems would have hundreds of GWs of renewable electricity capacity. Moreover, the average energy used from conventional sources decreases significantly as externalities are monetized, though only down to a lowest of 43 GW. Correspondingly, none of the minimized energy systems implement any hydrogen storage, and use very limited amounts of V2G storage to meet load. Essentially, it is cheaper to utilize the current legacy generation of PJM to meet load when renewable generation is insufficient rather than to build extra storage.

Table 4.3. Power Capacity and Average Energy Produced of the Minimized Energy Systems for Each of the Four Cost Scenarios

Technology	Power Capacity (GW)				Energy Produced (GW_a)			
Cost Scenario	*No Ext*	*Health*	*H+SCC1*	*H+SCC2*	*No Ext*	*Health*	*H+SCC1*	*H+SCC2*
Solar PV	0	4.8	33.9	77.4	0	0.7	4.54	10.4
Land Based Wind	0	121	191.6	201.7	0	41	58	61.1
Offshore Wind	0	0	0	19.5	0	0	0	8.25
V2G EVs	235	235	365	417	0	0.65	2.1	3.2
H_2 Storage	0	0	0	0	0	0	0	0
Conv Generation	181	156	153.5	159.5	111	59	50	43
PJM Electric Grid	165				86			
Electric Heat	180	0	126	180	52	0	37	52
PJM Heating	180				52			

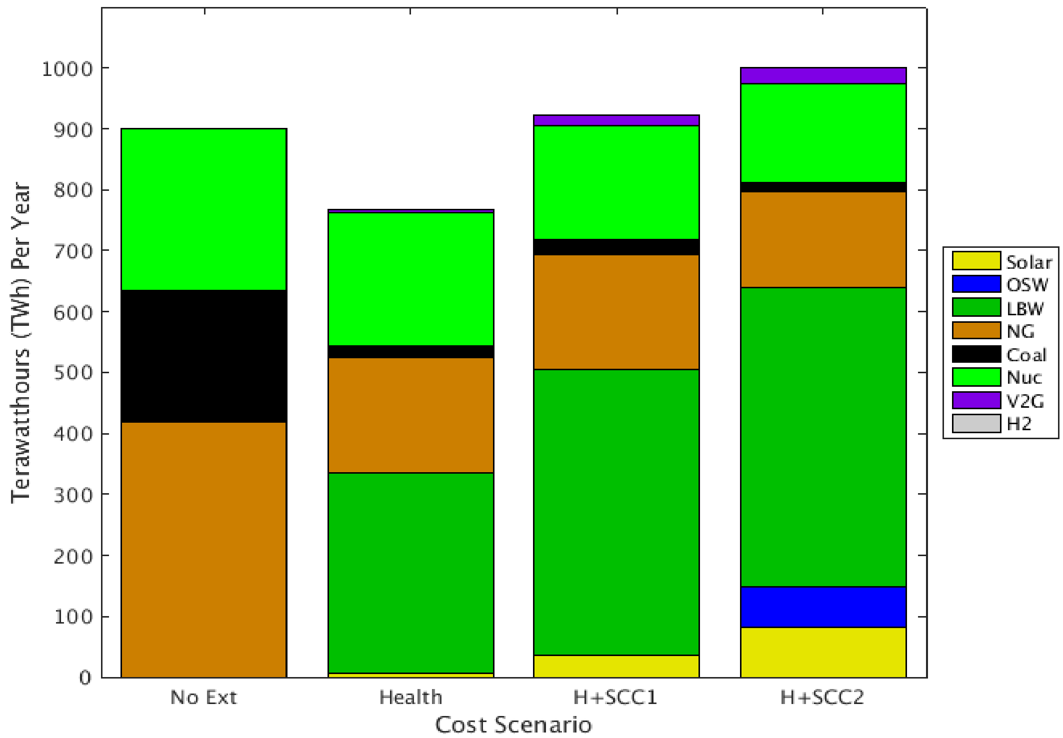
Figure 4.2 (a-c) summarize the annual generation mix, the total power mix, and the costs per inputs of each of the four minimized grids. Over the four cost scenarios, each of the total loads change, due to the fact that the electric load is changing depending on the amount of EVs and EHs in each energy system. For example, in the Health cost scenario, the total electric load substantially decreases because there is no EH in that minimized energy system. While no renewable electricity is built in the No

Externalities cost scenario, renewable energy provides 43.8% to 59.2% of the annual electricity production in the three externality cost scenarios. Note that despite huge amounts of V2G *power* capacity, V2G is not highly utilized as an energy source, providing 0.7% to 1.8% of annual generation in any of the minimized energy systems, and over the average hour, the minimized energy system uses less than 1% of V2G capacity to provide electricity to load. Instead, the minimized energy systems have substantial amounts of V2G power capacity mostly due to the benefits of displacing transportation-related costs, and rely on renewable and conventional electricity sources to meet the overwhelming majority of load. Likewise, because V2G and EH provide additional load as well as huge amounts of storage capacity, the amount of renewable energy spilled is typically 0%, with the only exception being the Health cost scenario energy system, which, without EH, spills 1.8% of the renewable energy produced.

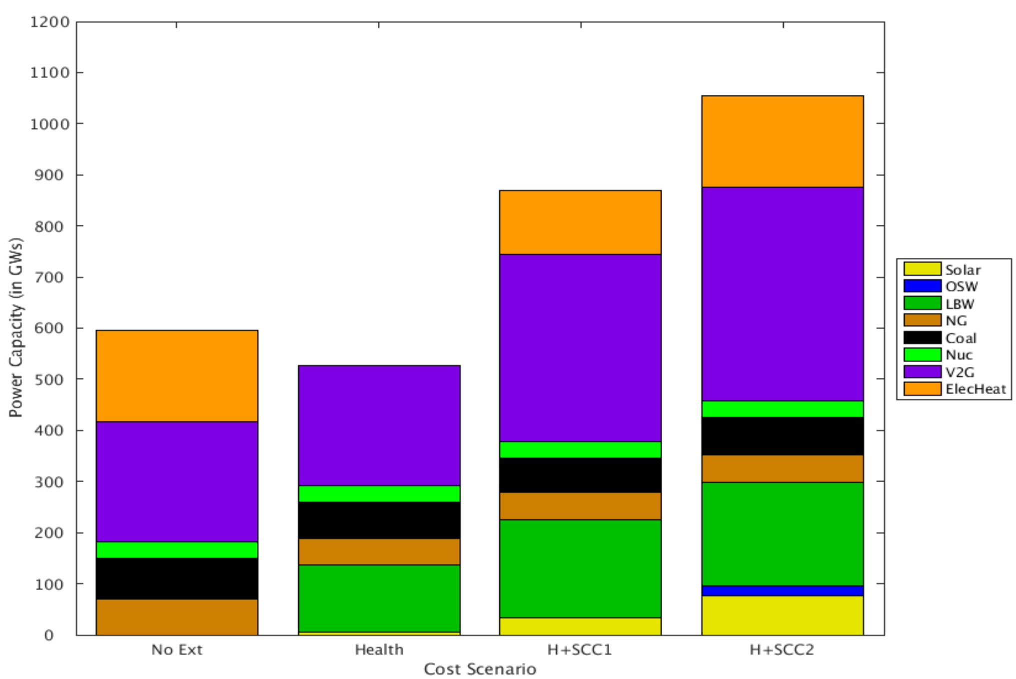
Land-based wind comprises nearly the entirety of the renewable electricity production in the three minimized energy systems that build any renewable electricity, contributing 76.6% to 98.4% of total annual renewable electricity generation. Solar only contributes 1.5% to 13% of annual renewable electricity production, yet comprises 3% to 21% of renewable electricity costs. Essentially, solar is not cost-effective for gross production of energy, but rather can displace conventional generation when land-based wind is not capable of doing so. This load coincidence shows the value of solar energy is highest when used to complement land-based wind.

On the other hand, conventional electricity generation is mostly met by natural gas and nuclear in the same three minimized energy systems. In the three minimized energy systems that include externalities (and thus renewable electricity), nuclear contributes 47% to 51% of total annual conventional electricity generation, whereas natural gas contributes 45% to 46%. And while coal composed 24% of total annual conventional electricity generation in the No Externality scenario, coal only contributes 5% in the scenarios with externalities. Despite the minimal share of electricity production, coal comprises about 45% of the conventional electricity capacity. Thus, while substantial amounts of coal power capacity is required, it is not highly utilized as an energy source.

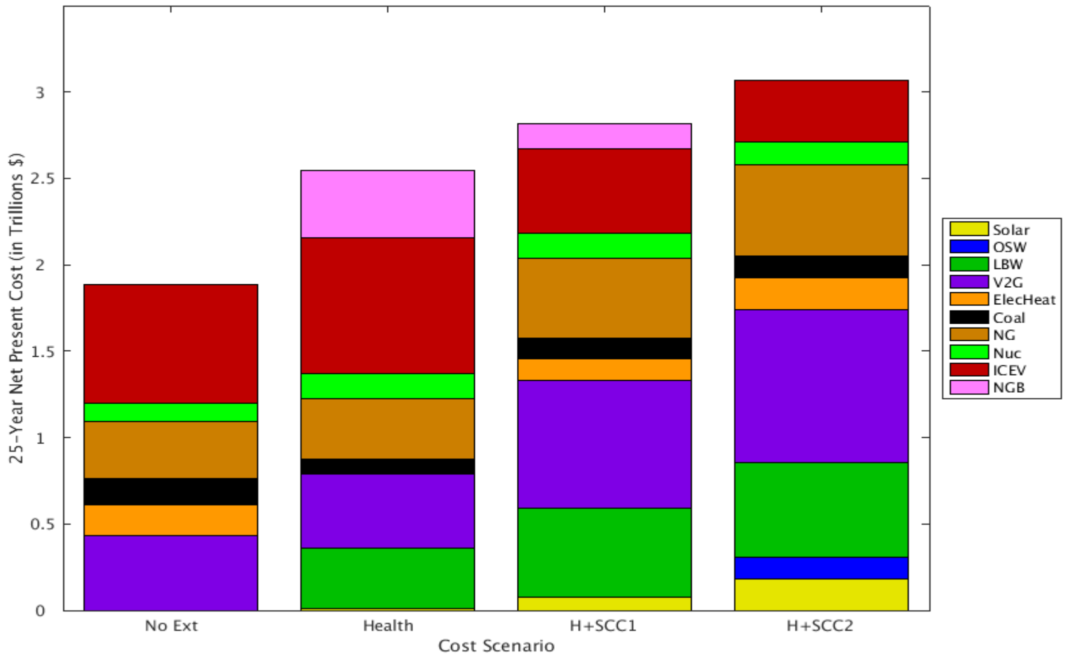
Across the four minimized energy systems, electricity costs make up 31% to 54% of the total, whereas transportation costs make 40% to 59% of the total, with the remaining 6% to 10% being delegated to heating costs. The calculation and integration of the transportation sector plays a large role in the overall minimization process. Conventional sources of energy make up 67% to 37% of the total cost through the four minimized energy systems, and renewable sources of energy make up the remaining 33% to 63% of costs. Thus, even in the H+SCC2 cost scenario, society is still paying a substantial amount for conventional sources of energy.



a) Annual Average Production (TWh), per Generation and Storage Type



b) Power Capacity, per Generation and Storage Type (GW)



c) Net Present Cost per Input

Figure 4.1. Summary Graphs for the Minimized Grids under Each Cost Scenario

Figure 4.2 shows the interaction among renewable generation, electric and heat storage, and conventional generation in the H+SCC1 minimized energy system over each hour of the four modeled years. Over the four years renewable generation ranges from 2.9 to 179 GW. Likewise, conventional electricity is required throughout the four years for both electric and heating loads. Heat storage is used only when excess generation and lower loads occurs, and only 0.8% of the total annual heat load is met via heat storage. While a substantial amount of energy is put into V2G—much more often than heat storage—the majority of that energy is used to meet the driving load, as opposed to being stored to meet electric or heat load at a future point. All in all, this energy system relies extensively throughout the hours on both renewable and conventional electricity, with only limited use of storage.

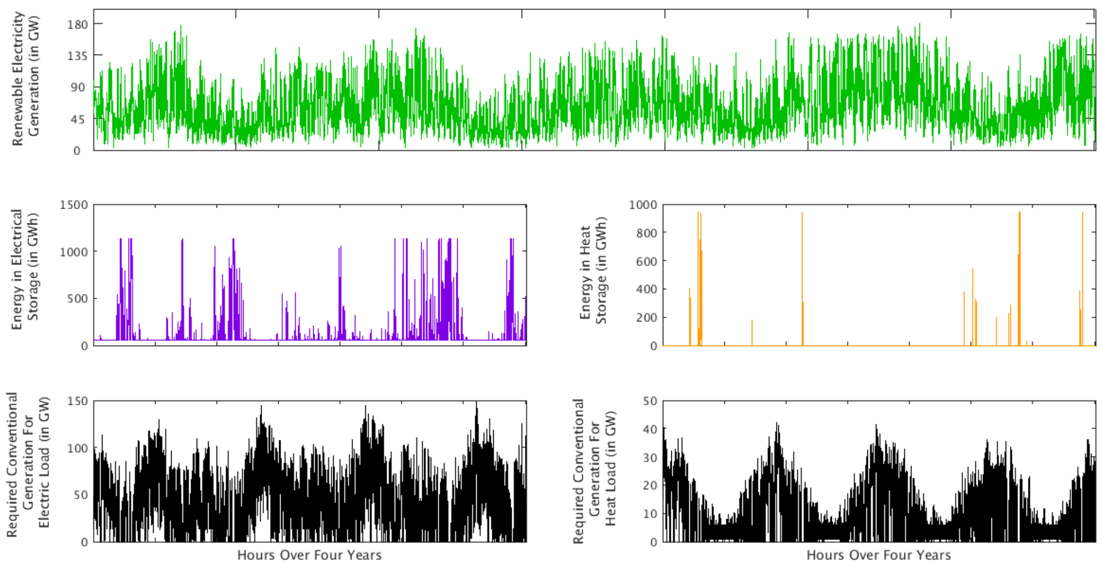


Figure 4.2. Hourly Generation and Storage State-of-Charge for the Minimized Energy System under the H+SCC1 Scenario

Table 4.4 shows the additional cost of implementing each of the four minimum-cost electricity grid's in comparison to today's. These additional costs are calculated for the four cost scenarios for each minimized grid for the point of comparison. The minimized energy systems under the four cost scenarios are not exorbitantly more expensive than today's grids. The H+SCC1 cost scenario's electric grid market cost would cost an additional 4.7 cents per kWh, an increase of 66%

above current average wholesale electricity prices in the PJM Territory [14].[748] However, the H+SCC1 energy system would achieve a 50% penetration of renewable electricity production, 70% penetration of renewable transportation, as well as a 70% penetration of renewable heating sector.

Table 4.4. The Additional Cost per kWh of each Minimum-Cost Grid Above Today's Cost (in cents per kWh)

Minimized Energy System / Cost Scenario	No Externalities Min Energy System	Only Health Min Energy System	Health +SCC1 Min Energy System	Health +SCC2 Min Energy System
Market Price	**1.3**[1]	4.2	4.7	5.4
Add Health	5.7[2]	**6.4**	6.2[2]	6.5
Add H + SCC1	7.6	7.2	**6.8**	6.9
Add H + SCC 2	10.9	8.6	7.8	**7.7**

1. This electricity cost is higher than today's grid (despite no added renewable electricity) because the total load has increased due to higher levels of EVs and EHs.
2. Note that these are actually cheaper per kWh then the minimized grids of that cost scenario, due to the fact that these numbers do not reflect to the total cost of the system, only the electricity-related costs. As a result, these estimates do not include costs from fossil-fueled transportation and heat.

One way to read Table 4 is if we take the "No Externalities" column, that is the electrical system that would be created if externalities were not included in decisions, the approach taken by PUCs today. The cost of electricity is close to today's actual wholesale price - just 1.3 cents per kWh above today's actual cost. However, society actually has to pay these external costs, so the actual cost to society is between 7.6 to 10.9 cents per kWh above today's wholesale price. Conversely, if we create the

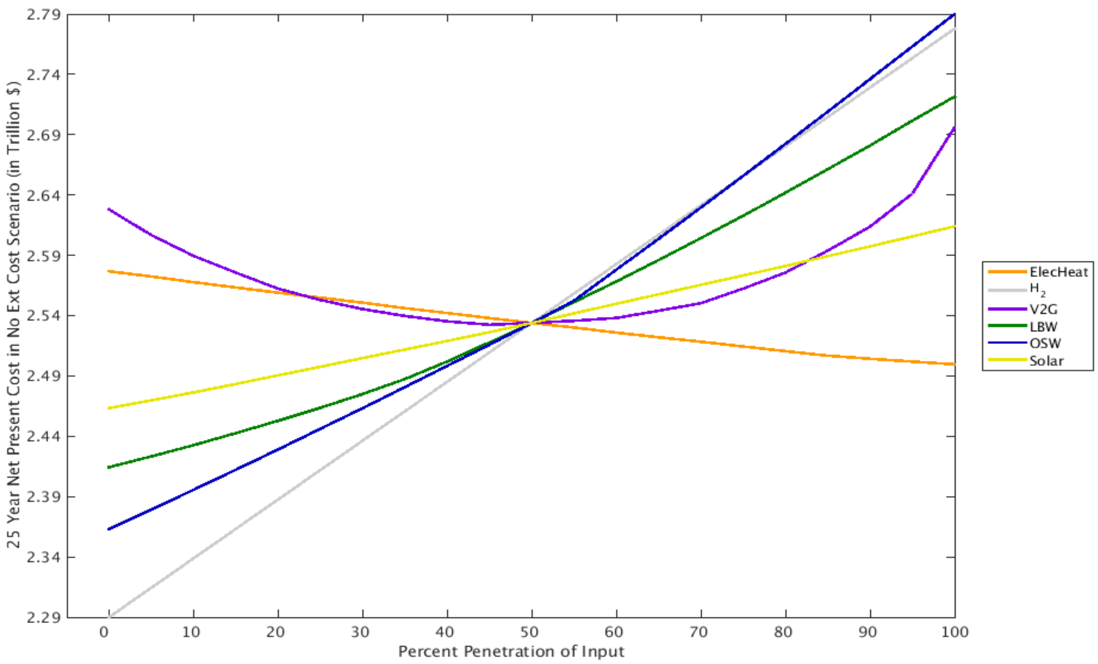
[748] This would make up a smaller percentage of average *delivered* electricity prices, which among other things, includes the costs of distribution.

lowest cost electric system under the H+SCC2 (the right most column), the total social cost is the cheapest –at only an additional 7.7 cents per kWh. On the other hand, that the cost of that energy system, under the PUC's perspective (i.e., only including internal costs) would cost an additional 5.4 cents per kWh.

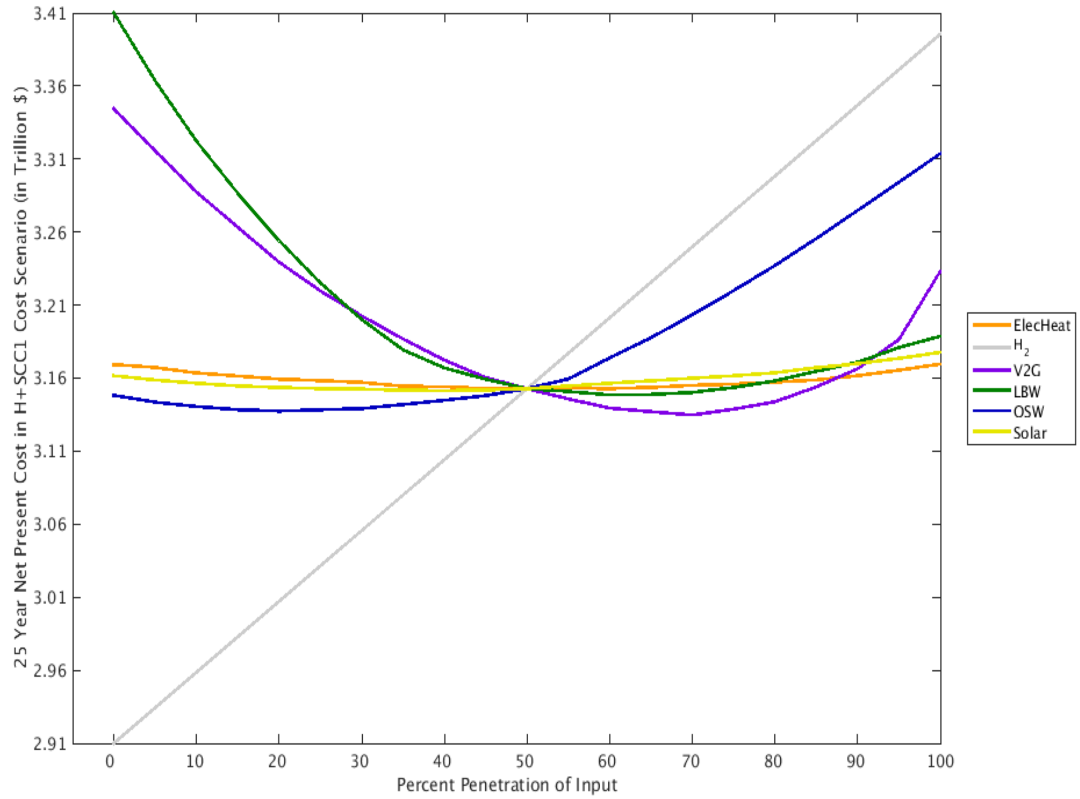
In sum, the monetization of externalities would fundamentally change the energy systems that we would build, via changing way society minimizes costs of energy. Including health and climate change externalities to the market cost of electricity would incentivize the extensive development of renewable electricity. Adding externalities to the transportation sector's market cost would also incentivize adoption of EVs. Additionally, even without externalities, if society discounted fuel savings at a social discount rate, significant adoption of EVs would be societally cost effective. However, even in the externality cost scenarios, conventional generation is still often used to provide both baseload and ramping at cheaper cost than either more storage or more renewable electricity.

4.4.2 Trends across Energy Systems

Beyond the individual minimized energy systems, there are several trends in the data. Specifically, comparisons can be made based on the relative implementation of each renewable energy technology, and its effect on cost. Figure 4.3 shows the relative cost effect of each renewable technology assuming all other technologies have 50% of their potential capacity installed, under both the No Externality and the H+SCC1 cost scenarios. First and foremost, the monetization of externalities leads to significant differences in the two graphs, and as such, each renewable technology's impact on cost varies based on the cost scenario. In the No Externality cost scenario, adding any renewable electricity technology adds linearly to the total cost of the energy system. In contrast, in the H+SCC1 cost scenario, increases in the penetration of land-based wind reduces the total cost of the energy system, solar's impact on reducing cost is relatively flat, and offshore wind does not increase cost as linearly, as is almost flat below 50% implementation. On the other hand, in both cost scenarios hydrogen storage linearly adds to the total cost as implementation of it increases, implying that its benefits to the grid do not outweigh its capital cost, even with 50% implementation of all renewable electricity capacities.   Likewise, V2G's impact on reducing cost between the two cost scenarios remains similar. In both cases, V2G parabolically impacts the total costs of the energy system, and is the next most significant cost reduction technology after land-based wind in the H+SCC1 cost scenario. Nonetheless, the exponential increase in V2G cost is due to people's decreasing willingness to drive EVs, as seen in Figure 4.1, and causes substantial increases in total cost as V2G implementation approaches 100%. Lastly, EH has minimal, though redcing, impacts on total cost of the energy system in both scenarios.



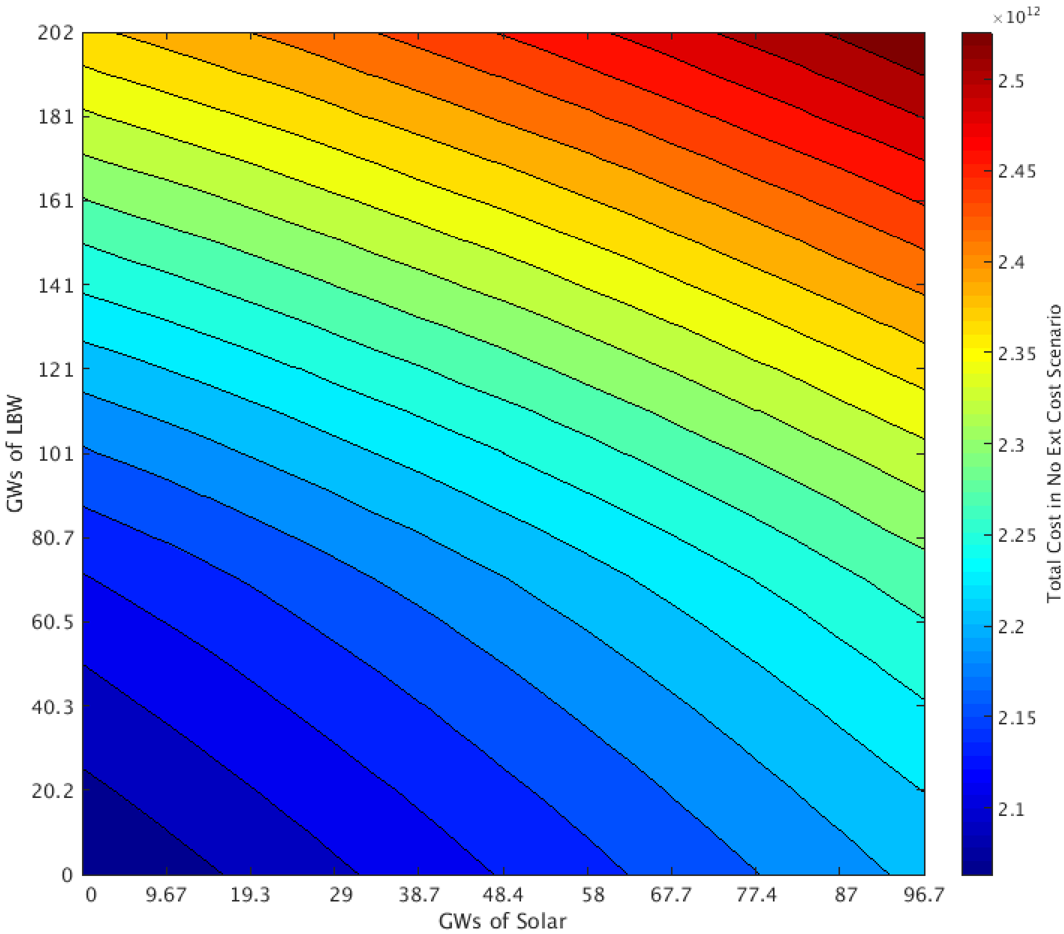
a) No Externality Cost Scenario



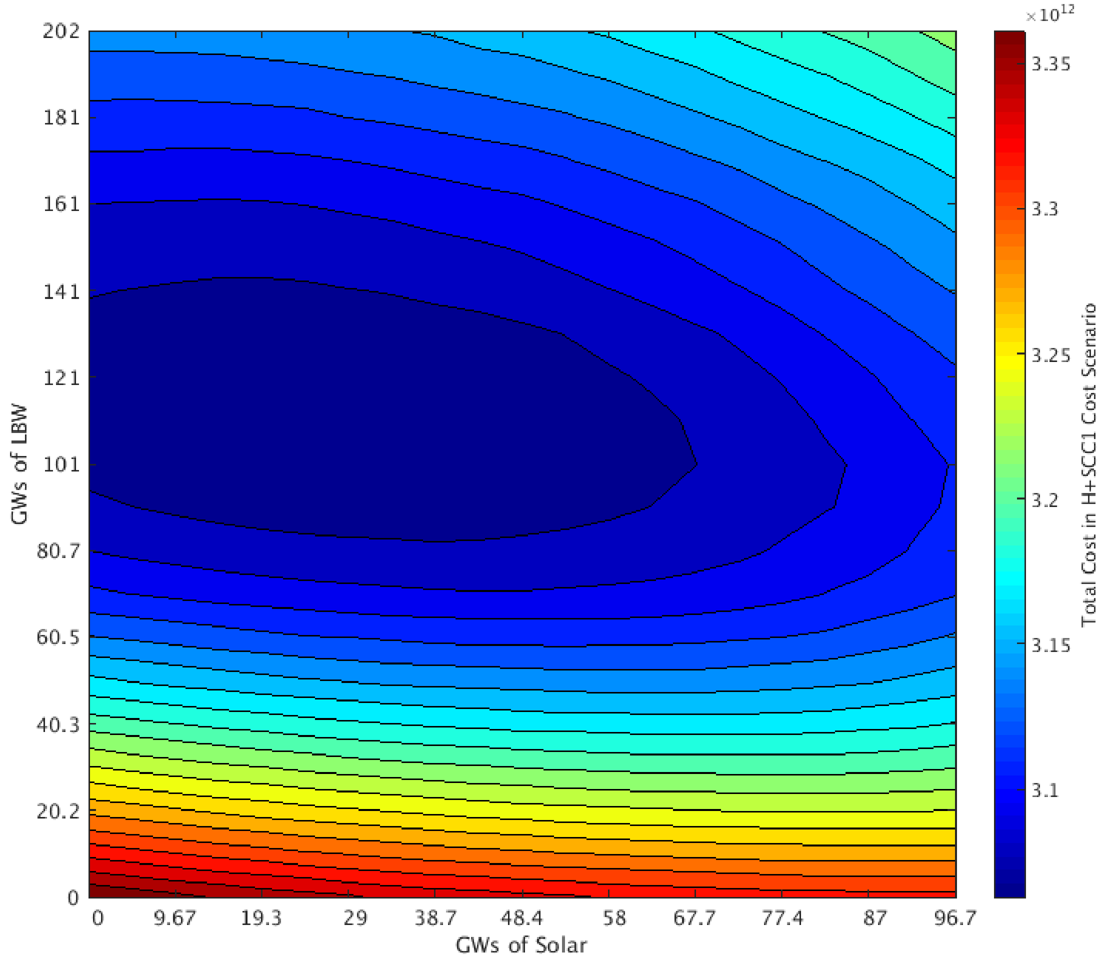
b) H+SCC 1 Cost Scenario

Figure 4.3. Spider Graph of All Inputs in the No Externality and H+SCC1 Cost Scenarios

Next, Figure 4.4 shows the relative impact of two technologies, solar and land-based wind, on total cost, assuming zero implementation of any other technologies, for both the No Externalities and the H+SCC1 cost scenarios. Again, the comparison across the two cost scenarios highlights the impact of externalities on the optimal development of renewable energy. Under No Externalities, neither additions of solar nor land-based wind decrease the total cost of the energy system. Conversely, in the H+SCC1 cost scenario, both solar and land-based significantly reduce the total cost. In fact, the cheapest point under the No Externality scenario – where 0 GW of both technologies is built – is now the most epensive area in the H+SCC1 cost scenario. Lastly, Figure 4.4 also shows that increasing capacity of land-based wind, in comparison to solar, has a much higher impact on reducing the cost of the energy system.



a) No Externality Cost Scenario



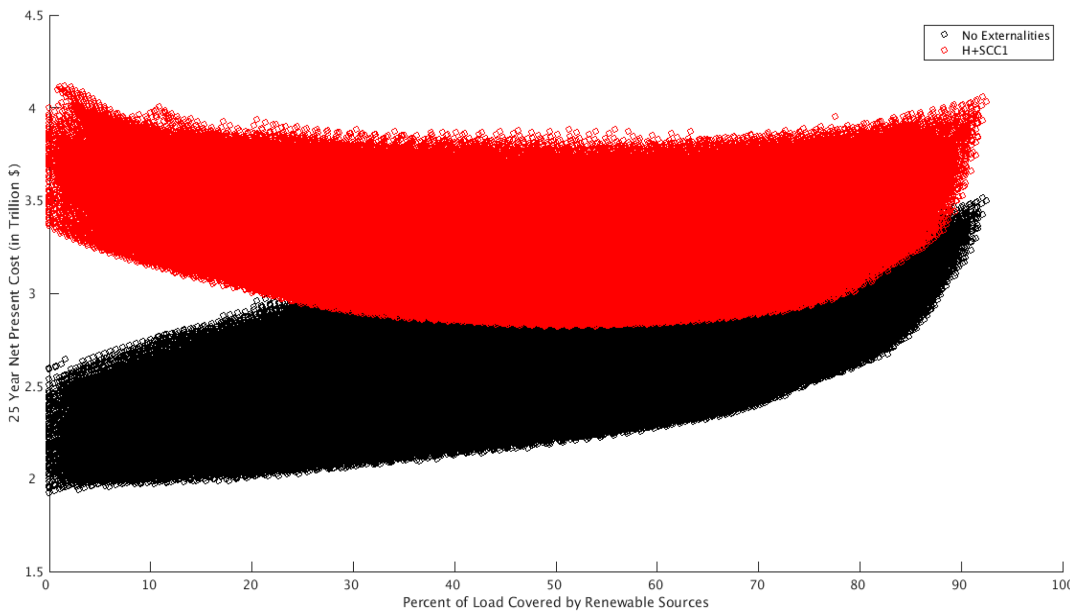
b) H+SCC 1 Cost Scenario

Figure 4.4. The Relative Impact of Installed Land-Based Wind and Solar in the No Externality and H+SCC1 Cost Scenarios

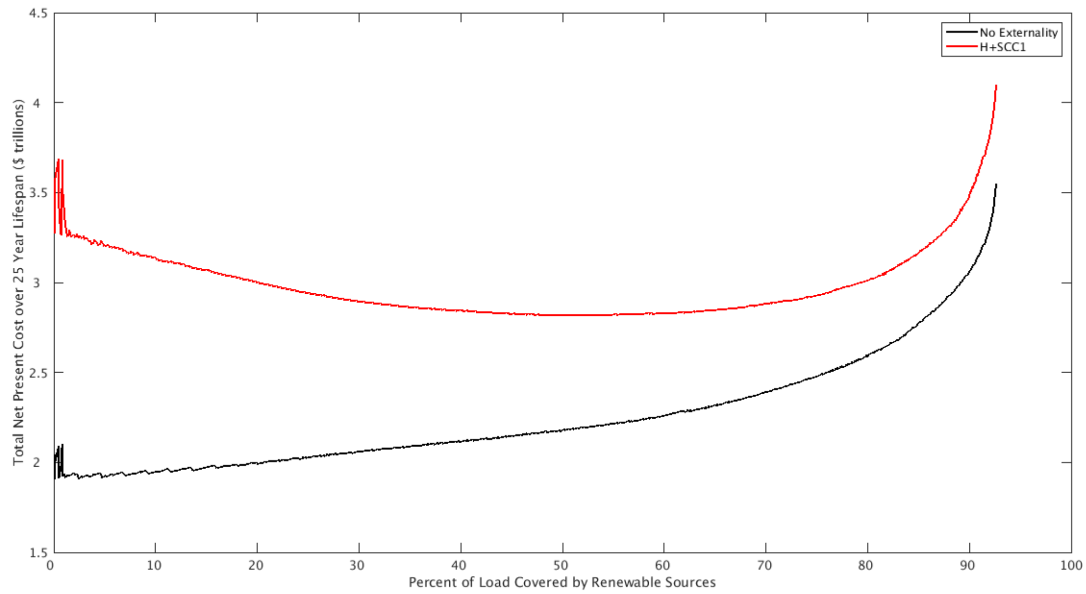
Figure 4.5 (a-c) compares the costs of all energy systems to the amount of load covered by renewable sources, the minimum cost energy system to reach that renewable coverage, and the power capacity mix of the minimum cost energy systems per renewable penetration of load. First, the maximum amount of load that could be met renewable sources was 92.6%. This figure is lower than the 99.9% calculated in Budischak, et al. [2] due to the increase in loads in PJM, as well as the calculation of load from EVs and EH. Generally, there is little overlap in the two cost scenarios, as seen in Figure 4.5 a). Essentially, the monetization of externalities increases the cost of *all* energy systems, but the energy systems in which renewables have less share of the show the largest discrepancy between the two cost scenarios. Moreover, the difference in between the minimum and maximum cost energy system remains relatively constant as renewable share of load increases.

Whereas 4.5 a) showed the costs for *all* energy systems, b) shows only the cost-minimized energy systems that reach a given percent of load met by renewable energy, and their cost under both the No Externality and the H+SCC1 cost scenarios. Surprisingly, the difference in reaching 20% renewable penetration of electricity production and reaching 70% is small, especially in the H+SCC1 cost scenario. Though increasing the renewable share of load in the No Externality cost scenario does also linearly increase the total cost, the marginal cost is not substantial. More precisely, increasing the renewable share of load from 20% to 70% would increase total energy system costs by 20% in the No Externality cost scenario, whereas in the H+SCC1 cost scenario the cost actually *decreases* by 4%. Nonetheless, 70% renewable coverage of load is 2.3% more expensive than the H+SCC1 cost minimized energy system, which has a renewable share of load of 50.3%. However, it becomes exponentially more expensive to reach 80% to 90% of load met by renewable sources.

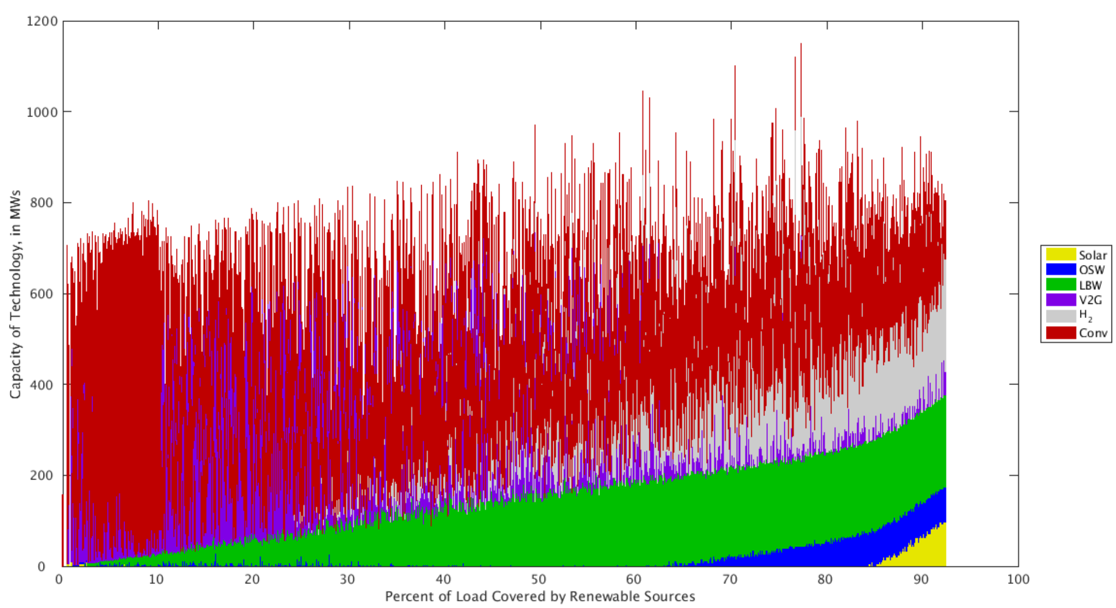
The power capacity mix of the cost minimum electric grids shown in Figure 4.5 b) are described in Figure 4.5 c). As renewable share of load increases, land-based wind is the priority renewable electricity technology implemented, followed by offshore wind and solar. As renewable share of load increases, V2G capacity tends to decrease. This is due to the fact that V2G increases total load thus reducing the renewable share of load. In the same vein, this graph shows the minimum cost to reach certain renewable thresholds of load, but does not minimize the total cost of the entire energy system, explaining why the power capacities of the minimum cost electric grids here vary slightly from the minimized energy systems as show in Table 4.3.



a) Cost of All Energy Systems And Renewable Coverage of Load



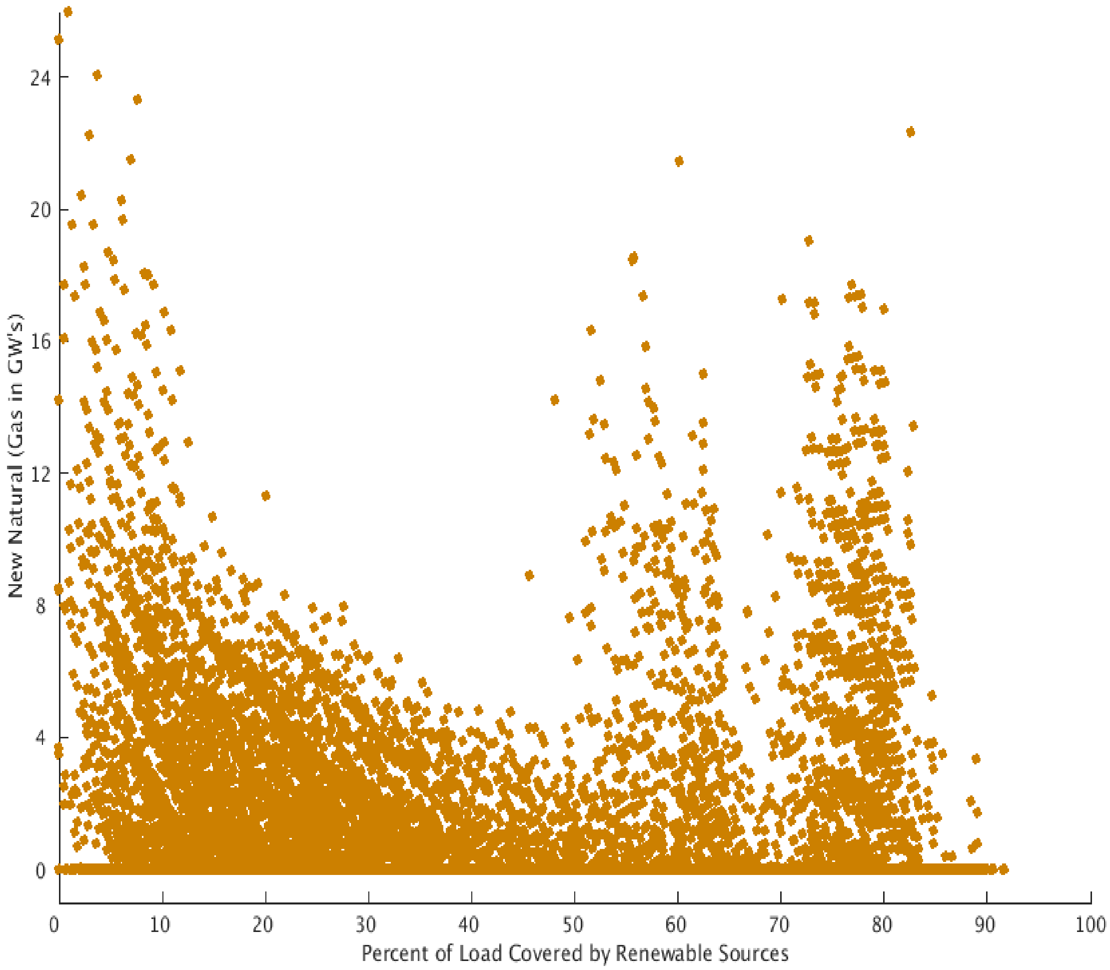
b) Minimum Cost Energy Systems For Each Renewable Cover of Load



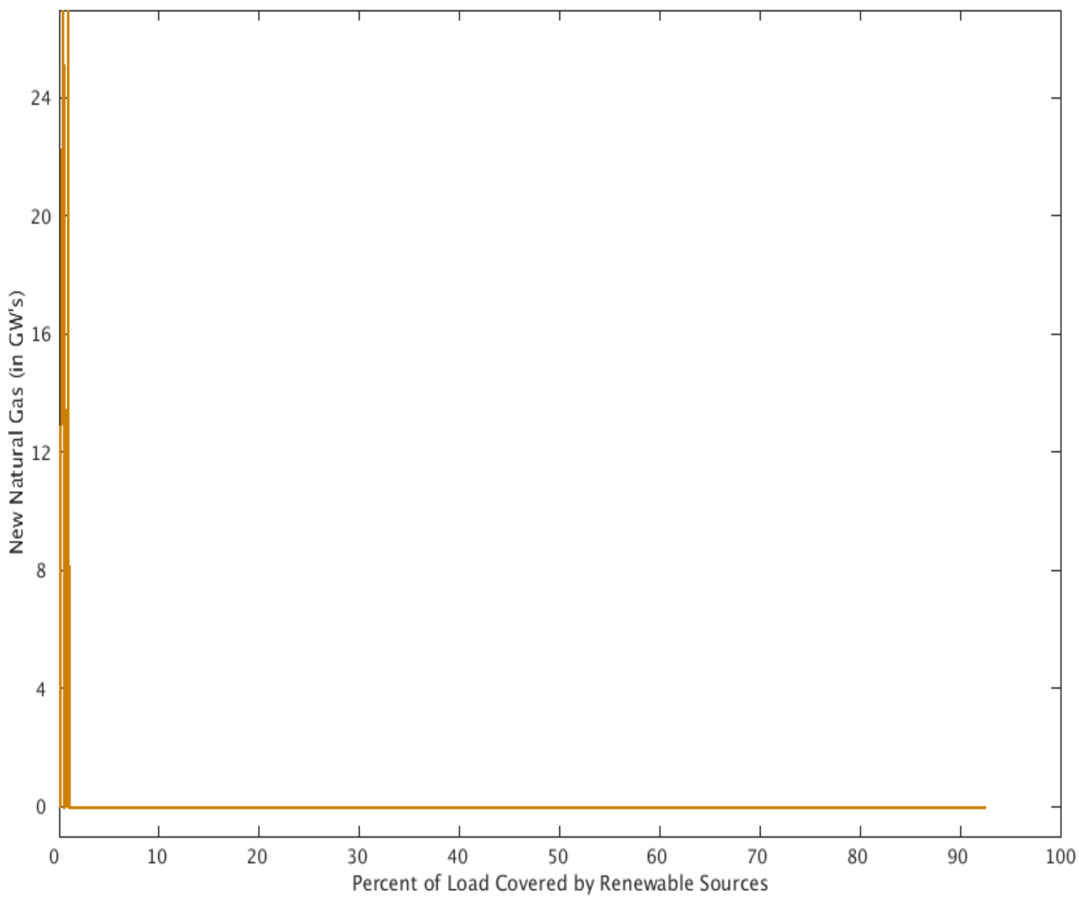
c) Power Capacity Mix For Each The Cost Minimized Energy Systems

Figure 4.5. Comparing Renewable Share of Load to Total Net Present Cost for All and Minimized Energy Systems, and Associated Power Capacity Maxes

Next, Figure 4.6 shows the amount of new natural gas capacity that would be needed in order to meet load in comparison to the amount of load that is met by renewable sources, for (a) all energy systems, and (b) cost minimized energy systems only.   For the minimum cost energy systems, no new natural gas is built as renewable percentages of load increases above a few percent. This finding is counter to the popular idea that building renewable electricity would require substantial amounts of new natural gas.   Instead, this analysis implies that substantial amounts of renewables can be integrated into the current energy system by using existing nuclear and natural gas plants, as well as constructing a substantial amount of storage.



a) All Energy Systems



b) Cost Minimized Energy Systems

Figure 4.6. Required Construction of New Natural Gas for All Grids as Renewable Share of Load Increases

Figure 4.7 shows the minimized energy systems that implement a single type of renewable electricity technology (i.e., only solar or only land-based wind), and their relative impact on renewable share of load and cost. Other than a few reversals in the first few percentages of each source, land-based wind is the largest and cheapest renewable electricity source. Other than the first few percent, offshore wind is less expensive and considerably larger in resource than solar. In comparison of the maximum renewable share of load, land-based wind can provide up to 65%, offshore wind 38% and solar just can provide 15%. This implies that land-based wind should be the primary short-term focus of renewable electricity development.

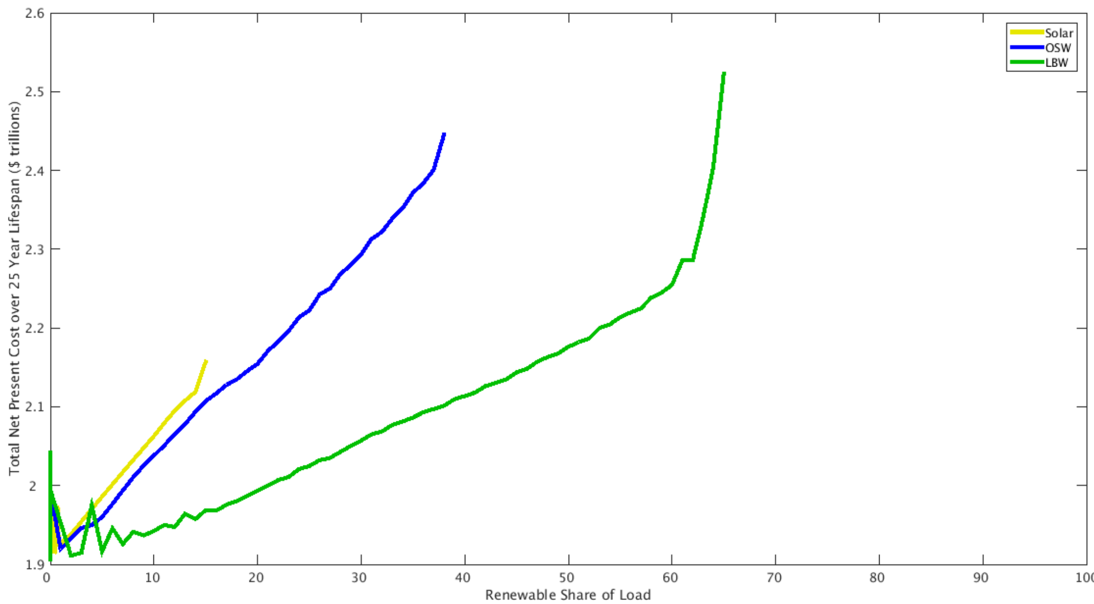


Figure 4.7. Minimum Cost of Building a Single Type of Renewable Electricity to Reach a Certain Share of Load

Figure 4.9 compares the interaction of total renewable electricity and total storage capacity on total cost for all energy systems under the H+SCC1 cost scenario. The lower-cost mixes, in darker blue, under this cost scenario, includes a substantial amount of renewable electricity (200-350 GW), but relatively modest amounts of storage (1,000-4,000 GWh). Indeed, it is cheaper to overbuild renewable electricity in comparison to today's PJM capacity with medium amounts of storage than to build higher levels of storage and not overbuild capacity. Moreover, we find the role of storage, to be of lesser importance than earlier work [2]. While the minimized energy systems do require storage, they rely more on using the current PJM capacity to fill in the lulls of renewable electricity generation.

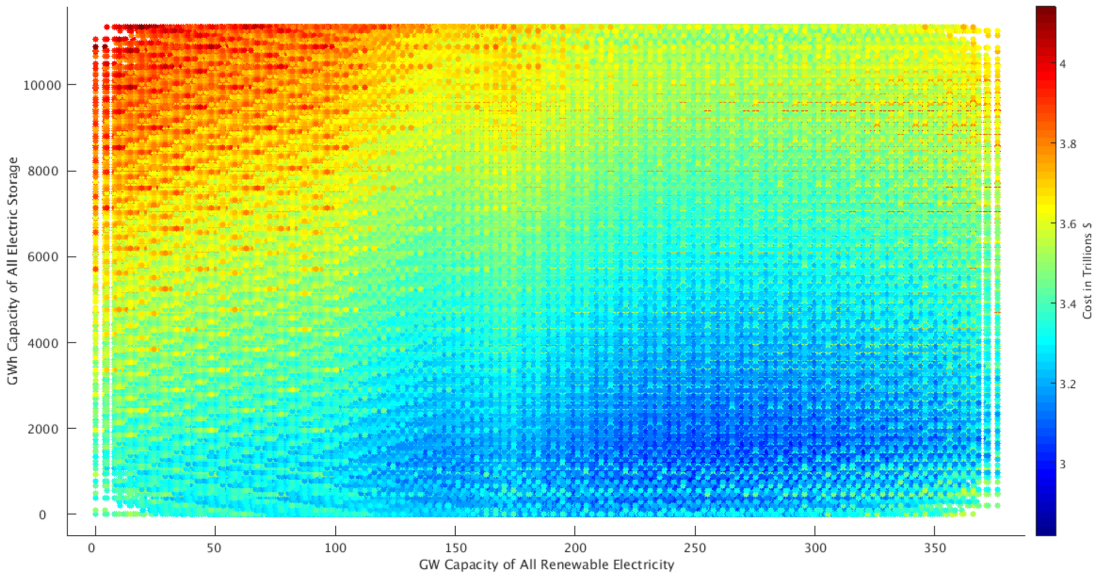
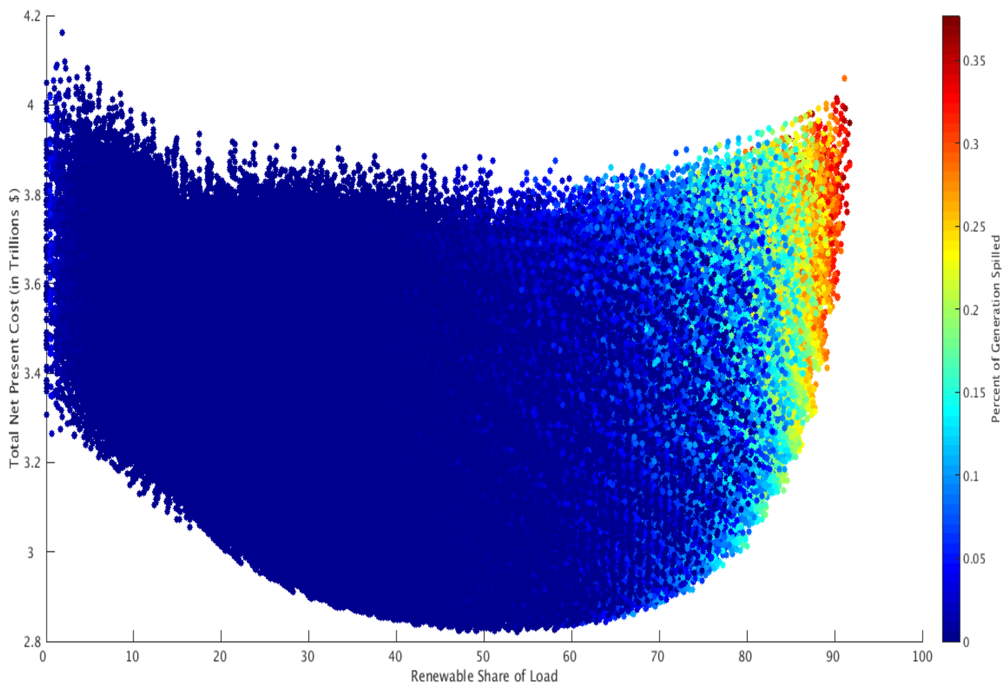


Figure 4.8. Comparing the Cost of Increasing Renewables versus Increasing Storage in the H+SCC1 scenario

Figure 4.10 shows the renewable share of load, the total system cost, and the percentage of renewable energy that is excess generation and accordingly spilled, for both all energy systems and for minimum cost energy systems. The most any energy system spills is 38% of its renewable generation, and these energy systems are among the most expensive, but also have the highest renewable share of load. Though the minimized energy system in the H+SCC1 cost scenario does not spill any generation because of substantial amounts of both electrochemical and heat storage, spilling renewable generation would not be significantly more expensive.

While increasing the renewable share of load to 60% very marginally increases the total cost of the system, the energy system would spill over 15% of its generation. While losing 15% of generation would cause individual renewable energy developers to suffer, as they would lose 15% of their potential revenue, in these energy systems, society would benefit. In another perspective, Figure 4.10 also shows that at and over 60% of renewable share of load, the marginal benefit of adding additional renewables is not cost-effective, as higher portions of renewable generation are spilled.

a) All Energy Systems



b) Cost Minimized Energy Systems

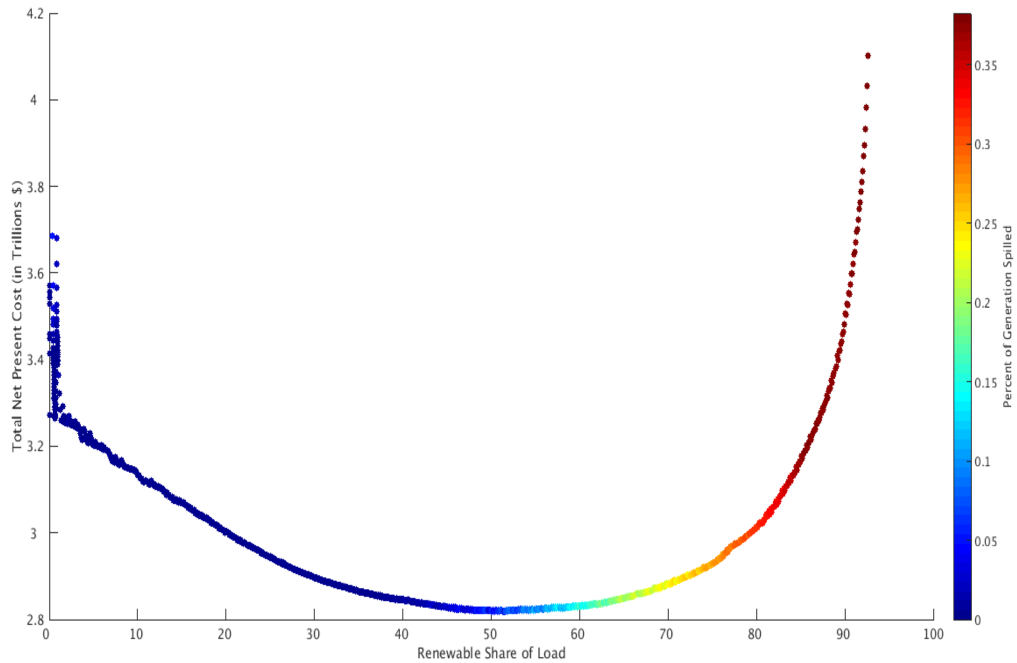


Figure 4.9. Comparing Spilled Generation to Renewable Share of Load in the H+SCC1 Scenario

4.5 Sensitivity Analyses

Beyond the central results, several alternative cost calculations were conducted to test how certain inputs affected the results, and thus the optimal development of renewable energy. A total of seven different alternative cost calculations were conducted to contextualize the main results. Table 4.5 summarizes the optimal power capacity mixes for all the different sensitivity analysis, under both the No Externality and the H+SCC1 cost scenarios.

The first sensitivity analysis conducted was to test how changing the discount rate from a social discount rate (3%) to a discount rate more attuned to the borrowing decisions made by private developers (7%). In comparison to the central results, using a higher discount rate makes a significant difference in the amount of renewable energy developed. While neither develops any renewable electricity when not including externalities, using a 7% discount rate in H+SCC1 cost scenario leads to a minimized energy system with 120 GW less renewable electricity, as well as several hundred less GW worth of V2G. Thus the choices that would be made from a societal perspective rather than a private, financial perspective would elicit substantially more renewable energy. An implication of this result is that governments should focus on policies to reduce interest rates on borrowing related to renewable energy closer to values that are socially optimal.

Next, another alternative cost calculation was done with 2030 capital cost for renewable energy. This was done by using the mean of several estimates for the future capital costs of solar [56] [57] [58] [10] [59] [60], land-based wind [56] [57] [61] [10] [62], offshore wind [56] [63] [61] [10], and EV lithium ion batteries [64] [65] [66] [67].[749] Based on these references the mean 2030 capital cost would be $1.4 million per MW for solar, $1.53 million per MW for land-based wind, $3.4 million per MW for offshore wind, and finally, $240 per kWh energy capacity for

[749] As the purpose of this sensitivity analysis was to test whether future reductions in the cost of renewable energy would lead to similar implementation as the central results, future fuel prices of conventional energy were not estimated.

batteries.[750] Using these 2030 capital costs, the only change in the minimized energy system without consideration of externalities is that there is substantially more EVs. In contrast, in comparison to the central results H+SCC1 cost scenario, using 2030 capital costs would result in the construction of 300 GWs of renewable electricity, highlighting the effect of monetizing externalities. The substantial amounts of EVs that would be implemented assuming 2030 costs imply that reduction in battery costs will lead to large-scale utilization of EVs. These results imply that the barrier to EV implementation in the near future will not be cost but rather willingness to drive EVs, and consequently, it should be a focus of government-funded research. Conversely, more research dollars should be invested into reducing the costs of renewable electricity sources, because projected costs will not lead to large-scale implementation of neither wind nor solar, absent policy incentives.

Another argument is that the Production Tax Credit (PTC) and the Investment Tax Credit (ITC), the two major subsidies to encourage renewable electricity development, are enough to properly incentivize renewable electricity. Even with renewable electricity subsidies, the deployment of renewable electricity is still more dependent on the monetization of externalities than on the subsidies. The minimized energy system including the PTC and ITC but without externalities is the first to include any renewable electricity when only considering market costs. However, this energy system would only implement 20 GW total of renewable electricity. In contrast, the H+SCC1 minimized energy system would construct 14 times the amount

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[750] Note that the capital cost for offshore wind increases the further an offshore wind farm is constructed from shore, and that the capital cost of batteries were converted to the cost to incentivize the purchase of an EV. See Appendix B.

of renewable electricity as the energy system without externalities. Thus, while the PTC and ITC would encourage some renewable electricity without the monetization of externalities, like 2030 capital costs, it is not enough to encourage similar amounts of renewable electricity as the central results inclusive of externalities would.

Moreover, the combination of future reductions in capital cost and implementing the two subsidies for renewable electricity, but without externalities, still do not provide the same incentive as current unsubsidized costs with the consideration of externalities. In fact, even with 2030 capital costs and the PTC and ITC, the minimized energy system in the No Externality scenario would still only construct 20 GW worth of renewable electricity. Again, adding externalities makes the most substantial difference, increasing the amount of renewable electricity 15 times over, to just over 300 GW.

The next three sensitivity analyses were conducted on how the model dispatched the hourly requisite conventional generation. Of these three, the first sensitivity analysis conducted was removing the legacy conventional generation from the existing PJM electric grid. Instead, any conventional electricity would come from the construction of new natural gas plants. This analysis was done in order to directly compare the efficacy of using either new natural gas or new renewable electricity to power the PJM territory from “scratch”. Despite increased capital costs, the No Externality cost scenario would utilize exclusively new natural gas power plants, and would not construct any renewable electricity. Conversely, monetizing externalities incentivizes similar amounts of renewable electricity as in the central results. Essentially, the optimal generation mix is entirely dependent on the monetization of externalities, even with natural gas’s lesser pollution in comparison to coal generation.

The next two sensitivity analyses were conducted on the model's dispatching of coal power. The first analysis assumed that there was no coal power in the PJM system to model the substantial retirements of coal capacity [14]. In the No Externality cost scenario, the decrease in coal capacity would be entirely replaced by new natural gas plants. On the other hand, the H+SCC1 cost scenario would construct substantial amounts of renewable electricity, but not to directly replace coal generation. In fact, even with 215 GW of renewable electricity constructed, the H+SCC1 minimized energy system would still build nearly 73 GW of new natural gas to replace coal power, but namely to fill the valleys of renewable electricity production. Because substantial amounts of new natural gas power capacity is required to meet load, the H+SCC1 cost minimized energy system builds less solar energy than the central results, though it does build 10 GW more of land-based wind. Indeed it is cheaper to use new natural gas to fill the gaps of land-based wind generation than to construct solar, as these new natural gas plants would have to be built either way. In fact, increasing the solar capacity of this energy system by 5 GW would increase the cost of the energy system by $86 million, and only decreases the required amount of new natural gas power capacity by only 1 GW. Thus, as coal plants are retired, these results suggest that, under the H+SCC1 cost scenario, the capacity will be replaced by both renewable electricity sources and new natural gas, but the majority of the generation will be replaced renewable sources.

The last sensitivity analysis conducted was done to reflect the discrepancy that the conventional dispatch model utilized in the central results underestimated the amount coal power used in the No Externality cost scenario, 24% of annual generation, in comparison to current share of load that coal provides in today's grid, which was 43% of annual generation in 2014 [14].[751] Thus a sensitivity analysis was conducted assuming that conventional generation was dispatched in a way similar to today's grid, that is, with higher penetrations of coal. However, even with higher penetrations of coal, the power capacity mixes under both cost scenarios remain somewhat similar to the central results. The high coal use No Externality minimized energy system is slightly cheaper- by 2% - than the central results No Externality minimized energy system. On the other, the high coal use H+SCC1 minimized energy system is 3.5% more costly than the central results H+SCC1 minimized energy system. In fact, other than the high coal use No Externalities minimized energy system, none of the other sensitivity analyses conducted on the dispatching of conventional generation were less costly than the central results.

Across all the sensitivity and policy analysis, several things become apparent. First and foremost, the monetization of externalities is a more important driver of renewable electricity development than any of the assumptions tested in the sensitivity analysis. Without externalities, practically none of these sensitivity analyses would develop any renewable electricity, while with externalities, high amounts of renewable electricity are implemented. However, in many of the H+SCC1 cost scenarios, the maximum amount of land-based wind is built, implying that the PJM territory is wind resource limited. Future work should explore the effects of importing land-based wind from Great Plains states beyond PJM's western borders. Lastly, under all scenarios, a substantial amount of conventional power capacity is required.

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751 In our simplistic dispatch model of conventional generation, we dispatch natural gas and nuclear before coal, because they have a smaller VOM costs. However, we do not consider other costs that may make natural gas cheaper than coal, such as unpaid capital costs, that may cause coal to be dispatched before natural gas in practice.

Table 4.5. Summary of Cost Minimized Energy System Power Capacity Mixes under Various Different Assumptions (in GW)

	Solar	Offshore Wind	Land-based Wind	V2G	Hydrogen	Total Conventional (New Natural Gas)	Electric Heat
Maximum Resource Capacity	**97**	**77.5**	**201**	**521**	**2,000**	**165 + (∞)**	**180**
Central Results No Ext H+SCC1	 0 33.9	 0 0	 0 191	 235 365	 0 0	 180 (17) 153.5 (0)	 180 126
7% Discount Rate No Ext H+SCC1	0 0	0 0	0 101	104 156.5	0 0	162 (0) 148 (0)	0 36
2030 Capital Costs No Ext H+SCC1	0 53	0 19	0 201	496 496	0 0	191 (26) 154 (0)	180 144
With PTC/ITC No Ext H+SCC1	 0 77	 0 0	 20 201	 231 365	 0 0	 171 (6) 153 (0)	 180 153
2030 Cap & PTC No Ext H+SCC1	0 72.5	0 27	20 201	496 496	0 0	180 (15) 165 (0)	180 180
No Legacy CG No Ext H+SCC1	 0 53	 0 0	 0 201	 235 365	 0 0	 171 (171) 144 (144)	 144 0
No Coal Use No Ext H+SCC1	 0 14.5	 0 0	 0 201	 235 365	 0 0	 170 (85) 159 (73)	 144 171
High Coal Use No Ext H+SCC1	 0 58	 0 0	 0 201	 235 365	 0 0	 182 (17) 145 (0)	 180 45

4.6 Discussion

There are three main energy policy conclusions from this paper. First, we find that, using today's costs of renewable electricity and estimates of externalities, it is cost effective to implement 240 GW of renewable electricity that meets 50% of total electric load. This implies that if energy policy had used a common metric to compare the tradeoffs between the mitigation of climate change and public health damages, and the increased costs of renewable energy deployment, as opposed to developing policies from a "warring agency" perspective, our energy system today *would* have had large scale deployment of renewable electricity and EVs. As policies regarding the implementation of renewable energy are developed, they should be cognizant of the full societal costs and benefits that high penetrations of renewable energy would entail. Indeed, the energy policies in place today, and ones currently being considered, are vastly underestimating the optimal levels of near-term renewable electricity. For example, across the states covered in the PJM territory, the average RPS goal is 18% renewable electricity by the average year of 2023 [68]. In the absence of a Pigouvian tax or other equivalent policy mechanism, these RPS goals sizably under-implement renewable electricity compared to the social optimal found in the central results of this modeling effort. This study supports far more ambitious RPS targets in a shorter time frame for these states. In fact, implementation of an RPS from a PJM-wide scale rather than a state-by-state may be easier to undertake, as some states within PJM territory have no RPS goals [68] and given the regional characteristics of renewable electricity development. Likewise, the results from our sensitivity analysis show that when considering the reduction in renewable energy capital costs, long-term renewable energy policies should be substantially more ambitious as well.

Secondly, the results find that there is limited need to construct new natural gas power plants. When developing large-scale renewable electricity, it is not necessary to develop new capacity of natural gas power plants to fill in the gaps of renewable electricity generation. Instead, it is substantially cheaper to use the current PJM legacy conventional electricity and storage to fill in these generation lulls. While new natural gas may play a local, supplementary role in PJM's future, such as decreasing transmission congestion, our results conflict with implementing the 41 GW of new natural gas plants that are in fact now in PJM's generation queue [14]. Indeed, the focus of new generation should not include this magnitude of new natural gas, but rather, should be planning large-scale development of land-based wind and solar energy.

Thirdly, we find that existing coal plants in the PJM territory can still be useful to the energy system. While coal plants do not provide substantial amounts of generation in the central results, their existing power capacity may be useful to provide generation occasionally – much like the role that oil plants play currently on the PJM grid. Thus, PJM should not retire these coals plants, PJM should, but instead repurpose them. PJM is currently planning the retirement of over 20 GW of coal through 2019 [14], which will likely rise in the ensuing decades. However, as PJM implements large-scale renewable electricity, it would be highly valuable to instead retain this coal capacity to fill the gaps of renewable generation. As coal power plant operators consider retirement in the face of further pollution regulations, PJM should recognize the potential benefits of maintaining this capacity as a reserve.

Beyond these three energy policy implications, this study has also shown that throughout the sensitivity analyses and central results, the monetization of externalities has a substantial impact on the amount of renewable energy. These results highlight the importance of monetizing externalities and the role that a hypothetical Pigouvian tax would have on energy systems. However, to properly apply a Pigouvian tax, the damages need to be estimated appropriately, and there is significant uncertainty in both the health damages from fossil fuel combustion and the economic damages associated with climate change. Namely, health damages are highly regionally dependent, and for example, are dependent on the type of fuel burnt, the population downwind of the plant, and the background $PM_{2.5}$ levels [35] [29]. Though this model attempts to fit other's work to the PJM area, this number is an estimate, and could be improved by a separate regionally-specific health study, a substantial additional project. Nevertheless, given that the PJM territory has higher SO_2 emission levels and potentially higher $PM_{2.5}$ background levels [35], and given that a significant portion of the power plants are near large population centers, the health damages used as inputs to this study may be likely to underestimate the true damages caused by fossil fuels. In addition, the monetization of health damages used in this study do not include the damages associated with individual morbidity (Cameron 2014), nor the larger benefits of mitigation $PM_{2.5}$ pollution to society and labor productivity (Isen, Rossin-Slater and Walker 2014).

The monetization of the damages due to climate change is more uncertain. Though the Interagency Work Group (IWG) on the Social Cost of Carbon conducted a thorough analysis of the damages associated with climate change, its central estimate of about $40 per metric ton of CO_2 [37] [22] is based on several assumptions. Even relatively minor changes in some of these assumptions, such as policymaker's risk aversion [69], the fat tail probabilities of climate change catastrophe [70], or climate change's impact on economic growth [71] can lead to much higher social costs of carbon.

For example, Moyer et al. [71] concludes that changing the assumption of how climate change affects economic growth as well as the assumed discount rate would increase the SCC to between $360 and $4,270 per ton of CO_2, far above the $40 used here. Howarth et al. [69] finds that changing the assumed risk aversion of society, and given no major climate change policy, can increase the SCC up to $30,700 per metric ton of CO_2. At the very worst, Weitzman proposes that it is possible that due to the fat tail probabilities of catastrophic climate change disaster, the social cost of carbon could be infinite, known as the "Dismal Theory" [80]. While all of the estimates described here are of extreme values of low probability, they highlight the difficulty of precisely monetizing the damages of climate change. Howarth [69] concludes that climate change mitigation presents a "diamond-water" paradox – the idea that the *marginal* utility of removing a ton of CO_2 is highly non-linear, and the SCC is entirely dependent on the amount of climate change mitigation action is taken. Essentially the main benefit of mitigating climate change is avoiding the worst catastrophic consequences of climate change rather than avoiding an individual ton of CO_2. As a result, Howarth [69] suggests that policymakers move away from cost-benefit analyses using a SCC when determining the scope and substance of climate change mitigation action. The results in this paper show that even "average" estimates of the SCC, with its uncertainties, plausibly support the mitigation policies and justify the large-scale construction of renewable energy facilities. While both the health damages and the social cost of carbon are imprecise, each is more likely to be a low estimate than the converse.

4.7 Conclusion

This work has modeled and calculated the cost of 86 million different combinations of wind, solar, electric vehicles, hydrogen storage and electric heat under four different externality assumptions. The results of the modelling effort show that the monetization of externalities leads to the large-scale implementation of the renewable electricity. When externalities are monetized, the cost minimized energy systems would develop substantial amounts of renewable electricity, transportation and heat. On the other hand, these cost minimum energy systems would still rely considerably on conventional sources of electricity to fill in the gaps of renewable electricity, rather than storage, which compared to previous work [2], plays a much lesser role. In addition, the central results suggest that new natural gas is only cost effective at a more local level, as opposed to system-wide implementation. The results show that PJM's current planning of large-scale new natural gas power plants and comparatively limited renewable electricity conflict with the social optimal renewable electricity mix found in the central results, even in the uncertainty of properly pricing externalities.

This paper invites revisiting renewable energy goals of the states that comprise the PJM territory. Indeed, the central results of this paper imply that the cost minimized energy systems with externalities would require substantial amounts of renewable electricity, electric vehicles and electric heat. In that thread, this paper calls for the transition to the electrification and integration of the transportation and heating sector, and for transportation and heating planning and policy to be connected to electricity planning and policy. While there were several assumptions made that warrant future studies, the results show that our current short-term goals do not fully account for the health and climate change damages caused by fossil fuel consumption. In sum, the monetization of externalities associated with fossil fuel combustion in the electricity, transportation, and heating sectors would incentivize renewable energy development much more than current stated renewable energy goals.

REFERENCES

[1] Arent, D., Pless, J., Mai, T., Wiser, R., Hand, M., Baldwin, S., . . . Denholm, P. (2014, January 4). Implications of high renewable electricity penetration. *Applied Energy*, In Press. doi:10.1016/j.bbr.2011.03.031

[2] Budischak, C., Sewell, D., Thomson, H., Mach, L., Veron, D. E., & Kempton, W. (2013). Cost-minimized combinations of wind power, solar power and electrochemical storage, powwer up to 99.9% of the time. *Journal of Power Sources, 225*, 60-74.

[3] Pensini, A., Rasmussen, C. N., & Kempton, W. (2014, June 23). Economic analysis of using excess renewable electricity to displace heating fuels. *Applied Energy, 131*, 530-543. doi:10.1016/j.apenergy.2014.04.111

[4] EPA. (2015). *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013.* Washington, DC: U.S. Environmental Protection Agency. Retrieved from http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html

[5] PJM. (2014 , August). *Hourly Load Data*. Retrieved August 2014, from PJM Web Site: http://www.pjm.com/markets-and-operations/energy/real-time/loadhryr.aspx

[6] Monitoring Analytics, LLC. (2014). *State of the Market Report for PJM: 2013.* Monitoring Analytics. Retrieved from http://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2013.shtml

[7] U.S. Department of Transportation. (2014, January). *State Motor Vehicle Registrations*. Retrieved from Highway Statisitics 2012: http://www.fhwa.dot.gov/policyinformation/statistics/2012/mv1.cfm

[8] Jacobson, M. Z., & Delucchi, M. A. (2011). Providing all global energy with wind water and solar power, Part 1: Technologies, energy resources, quantities and reas of infrastructure and materials. *Energy Policy, 39*, 1154-1169. doi:10.1016/j.enpol.2010.11.040

[9] Jacobson, M. Z., Howarth, R. W., De lucchi, M. A., R., S. S., Barth, J. M., Dvorak, M. J., . . . Ingraffea, A. R. (2013). Examining the feasibility of converting New York State's all-purpose energy infrastructure to one using

wind, water and sunlight. *Energy Policy, 57*, 585-601. doi:10.1016/j.enpol.2013.02.036

[10] Mai, T., Mulcahy, D., Hand, M. M., & Baldwin, S. F. (2014). Envisioning a renwable electricity future for the United States. *Energy, 65*, 374-386. doi:10.1016/j.energy.2013.11.029

[11] Mileva, A., Nelson, J. H., Johnston, J., & Kammen, D. M. (2013, July 19). SunShot Solar Power Reduces Costs and Uncertainty in Future Low-Carbon Electricity Systems. *Environmental Science & Technology, 47*, 9053-9060. doi:10.1021/es401898f

[12] Nikolakakis, T., & Fthenakis, V. (2011, May 29). The optimum mix of electricity from wind- and solar-sources in conventional power systems: Evaluating the case for New York State. *Energy Policy*(39), 6972-6980. doi:10.1016/j.enpol.2011.05.052

[13] EIA. (2013). *Updated Capital Cost Estimates for Utility Scale Electricity Generating Plants.* Washington, DC: US Department of Energy.

[14] Monitoring Analytics, LLC. (2015). *State of the Market Report for PJM 2014.* Monitoring Analytics. Retrieved July 24, 2015, from http://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2014.shtml

[15] World Energy Council. (2013). *World Energy Perspective: Cost of Energy Technologies.* London: World Energy Counil.

[16] EIA. (2014). *Electricty Data Browser*. Retrieved April 3, 2014, from EIA: http://www.eia.gov/electricity/data/browser/#/topic/15?agg=2

[17] EIA. (2013). *Electric Power Annual 2012.* Washington, DC: U.S. Department of Energy. Retrieved from http://www.eia.gov/electricity/annual/pdf/epa.pdf

[18] Epstein, P. R., Buonocore, J. J., Erckerle, K., Hendryx, M., Stout, B. M., Heinberg, R., . . . Glustrom, L. (2011). Full cost accounting for the life cycle of coal. *Annals of the New York Academy of Sciences, 1219*(Ecological Economics Reviews), 73-98.

[19] McCubbin, D., & Sovacool, B. K. (2013). Quantifying the health and environmental benefits of wind power to natural gas. *Energy Policy, 53*, 429-441. Retrieved from http://dx.doi.org/10.1016/j.enpol.2012.11.004

[20] Sundqvist. (2004). What causes the disparity of electricity externality estimates? *Energy Policy, 32*, 1753-1766.

[21] Moomaw, W., Burgherr, P., Heath, G., Lenzen, M., Nyboer, J., & Verbruggen, A. (2011). Annex II: Methodology. In O. P.-M. Edenhofer, Y. Sokonoa, K. Seyboth, P. Matchoss, S. Kadner, T. Zwickel, . . . C. von Stechow, *IPCC Special Report on Renwable Energy and Climate Change Mitigation.* Cambridge, UK: Cambridge University Press.

[22] Interagency Working Group on Social Cost of Carbon. (2013). *Technical Support Doccument: Technical Update of the Social Cost of Carbon for Regulatory Impact Anlaysis Under Executive Order 12866.* Washington, D.C.: United States Government.

[23] Schoenung, S. (2011). *Economic Analysis of Large-Scale Hydrogen Storage for Renewable Utility Applications.* Livermore, California: Sandia National Laboratories.

[24] Hidrue, M. K., Parsons, G. R., Kempton, W., & Gardner, M. P. (2011). Willingness to pay for electric vehicles and their attributes. *Resource and Energy Economics, 33*, 686-705. doi:10.1016/j.reseneeco.2011.02.002

[25] U.S. Bureau of Economic Analysis. (2014, November 26). *Table 7.2.5S Auto and Truck Unit Sales, Production, Expenditures, and Price.* Retrieved December 9, 2014, from U.S. Department of Commerce, Bureau of Economic Analysis: http://www.bea.gov/iTable/iTable.cfm?ReqID=12&step=1#reqid=12&step=3&isuri=1&1203=55

[26] Steward, D., Saur, G., Penev, M., & Ramsden, T. (2009). *Lifecycle Cost Analysis of Hydrogen Versus Other Technologies for Electrical Energy Storage.* NREL. Golden, Colorado: NREL.

[27] U.S. Department of Transportation, Federal Highway Administration. (2014, January). *Annual Vehicle Distance Traveled in Miles and Related Data*. Retrieved from Highway Statisitics 2011: http://www.fhwa.dot.gov/policyinformation/statistics/2012/vm1.cfm

[28] EIA. (2014, May). *Table EN1. Federal and State Motor Fuels Taxes*. Retrieved August 14, 2014, from Petroleum Marketing Monthly May 2014: Explanatory Notes: http://www.eia.gov/petroleum/marketing/monthly/pdf/mgt.pdf

[29] von Stackelberg, K., Buonocore, J., Bhave, P. V., & Schwartz, J. A. (2013). Public health impacts of secondary particulate formation from aromatic hydrocarbons in gasoline. *Environmental Health, 12*(19), 1-13. doi:10.1186/1476-069X-12-19

[30] EPA. (2005). *Average Carbone Dioxide Emissions Resulting from Gasoline and Diesel Fuel.* Washington, DC. Retrieved from http://www.epa.gov/nscep/index.html

[31] Heide, D., Greiner, M., von Bremen, L., & Hoffman, C. (2011, March 17). Reduced storage and balancing needs in a fully renewable European power system with excess wind and solar power generation. *Renewable Energy, 36*, 2515-2523.

[32] EIA. (2013, May 6). *2009 RECS Survey Data.* Retrieved August 14, 2014, from Residential Energy Consumption Survey: http://www.eia.gov/consumption/residential/data/2009/

[33] EIA. (2014, July 31). *Natural Gas Prices*. Retrieved August 15, 2014, from U.S. Energy Information Administration: Natural Gas: http://www.eia.gov/dnav/ng/ng_pri_sum_dcu_nus_m.htm

[34] EPA. (2014, February 19). *Emissions Factors & AP 42, Compilation of Air Pollutant Emission Factors*. Retrieved August 31, 2014, from U.S. Environmental Protection: Technology Transfer Network Clearinghouse for Inventories & Emissions Factors:

[35] Levy, J. I., Baxter, L. K., & Schwartz, J. (2009). Uncertainty and Variability in Health-Related Damages from Coal-Fired Power Plants in the United States. *Risk Analysis, 29*(7), 1000-1015. doi:10.1111/j.1539-6924.2009.01227.

[36] EIA. (2013, Febraury 14). *Carbon Dioxide Emissions Coefficients*. Retrieved August 15, 2014, from U.S. Energy Information Administration: Environment: http://www.eia.gov/environment/emissions/co2_vol_mass.cfm

[37] Interagency Working Group on Social Cost of Carbon. (2010). *echnical Support Doccument: Social Cost of Carbon for Regulatory Impact Anlaysis Under Executive Order 12866.* Washington, DC: United States Government.

[38] US Department of Energy. (2014). *EV Everywhere: Grand Challenge.* Energy Efficiency and Renewable Energy, Washington, DC. Retrieved from http://energy.gov/sites/prod/files/2014/02/f8/eveverywhere_road_to_success.pdf

[39] Kempton, W., & Tomic, J. (2005). Vehicle-to-grid power fundamentals: Calculating capacity and net revenue. *Journal of Power Sources, 144: 268-279.*

[40] EIA. (2014, July 31). *Natural Gas Consumption by End Use*. Retrieved August 15, 2014, from U.S. Energy Information Administration: Natural Gas: http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_m.htm

[41] EIA. (2014, March 27). *U.S. States: State Profiles and Energy Estimates.* Retrieved from U.S. Energy Infoamtion Administration: http://www.eia.gov/state/

[42] U.S. Census Bureau. (2014, March 27). *State & County QuickFacts.* Retrieved from United States Census Bureau: http://quickfacts.census.gov/qfd/index.html

[43] U.S. Department of Energy. (2011, April 13). *Wind Resource Potential*. Retrieved March 2014, from Office of Energy Efficiency & Renewable Energy: http://www.windpoweringamerica.gov/windmaps/resource_potential.asp

[44] NREL. (2014, February 6). *Wind Maps*. Retrieved March 2014, from Dynamic Maps, GIS Data & Analysis Tools: http://www.nrel.gov/gis/wind.html

[45] Business Solutions Department, PJM Interconnection (2014, April 21) Personal Communication.

[46] AWEA. (2013). AWEA Market Database Pro. Retrieved June 17, 2014, from AWEA Resources: http://www.awea.org/Resources/Content.aspx?ItemNumber=5728&navItemNumber=5776

[47] Wiser, R., & Bolinger, M. (2014). *2013 Wind Technologies Market Report.* Lawrence Berkeley National Laboratory. Washington, DC: U.S. Department of Energy. Retrieved from http://eetd.lbl.gov/sites/all/files/lbnl-6809e.pdf

[48] Lopez, A., Roberts, B., Heimiller, D., Blair, N., & Porro, G. (2012). *U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis.* Golden, CO: NREL. Retrieved from http://www.osti.gov/scitech/

[49] U.S. Census Bureau. (2014, March 20). *TIGER/Line Shapefiles Pre-joined with Demographic Data*. Retrieved from Geography: https://www.census.gov/geo/maps-data/data/tiger-data.html

[50] NREL. (2014, March 27). *Solar Data*. Retrieved April 2014, from Dynamic Maps, GIS Data, & Analysis Tools: http://www.nrel.gov/gis/data_solar.html

[51] NREL. (2010). *National Solar Radiation Data Base 1991-2010 Update*. Retrieved from National Solar Radiation Data Base: http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2010/

[52] Simao, H. P., Powell, W. B., Archer, C. L., & Kempton, W. (2015). The challenge of integrating offshore wind power in the U.S. electric grid. Part II: Simulation of electricity market operations. *Submitted to Renewable Energy*.

[53] Samoteskul, K., Firestone, J., Corbett, J., & Callahan, J. (2014). Changing vessel routes could significantly reduce the cost of future offshore wind projects. *Journal of Environmental Management, 141*, 146-154. doi:10.1016/j.jenvman.2014.03.026

[54] Pearre, N. S., Kempton, W., Guensler, R. L., & Elango, V. V. (2011). Electric vehicles: How much range is required for a day's driving? *Transportation Research Part C, 19*, 1171-1184.

[55] Veron, D., Brodie, J., Shirazi, Y., & Gilchrist, J. (2015). An examination of the costs of wind forecasting inaccuracies for Delaware offshore wind power. *Working Paper for Wind Energy*.

[56] Schröder, A., Kunz, F., Meiss, J., Mendelevitch, R., & von Hirschhausen, C. (2013). *Current and Prsopetive Costs of Electricity Generation until 2050.* Berlin: Deutches Institut für Wirtschaftsforschung.

[57] Elliston, B., MacGill, I., & Diesendorf, M. (2013, April 20). Least cost 100% renewable electricity scenarios in the Australian National Electricity Market. *Energy Policy, 59*, 270-282. doi:10.1016/j.enpol.2013.03.038

[58] Feldman, D., Barbose, G., Margolis, R., James, T., Weaver, S., Darghouth, N., . . . Wiser, R. (2014). *Photovoltaic System Pricing Trends.* NREL. doi:http://www.nrel.gov/docs/fy14osti/62558.pdf

[59] Bosetti, V., Catenacci, M., Fiorese, G., & Verdolini, E. (2012, July 11). The future prsopet of PV and CSP solar technologies: An expert elicitation survey. *Energy Policy, 49*, 308-317. doi:10.1016/j.enpol.2012.06.024

[60] Hernández-Moro, J., & Martínez-Duart, J. (2012, December 27). Analytical model for solar PV and CSP electricity costs: Present LCOE values and their future evolution. *Renewable and Sustainable Energy Reviews, 20*, 119-132. doi:10.1016/j.rser.2012.11.082

[61] IEA. (2013). *Technology Roadmap: Wind Energy.* Paris.

[62] Wiser, R. (2012). WREF 2012: The Past and Future Cost of Wind Energy. *World Renewable Energy Forum.* Denver: LBNL. Retrieved from http://escholarship.org/uc/item/9161j61q

[63] Valpy, B., & English, P. (2014). *Future renewable energy costs: offshore wind.* KIC InnoEnergy.

[64] Cluzel, C., & Douglas, C. (2012). *Cost and performance of EV batteries.* Cambridge: ElementEnergy.

[65] Catenacci, M., Verdolini, E., Bosetti, V., & Fiorese, G. (2013, July 23). Going for electric: Expert survey on the future of battery technologies for electric vehicles. *Energy Policy, 61*, 403-413. doi:10.1016/j.enpol.2013.06.078

[66] Liosel, R., Pasaoglu, G., & Thiel, C. (2014, November 6). Large-scale deployment of electric vehicles in Germany by 2030: An analysis of grid-to-vehicle and vehicle-to-grid concepts. *Energy Policy, 65*, 432-443. doi:10.1016/j.enpol.2013.10.0290

[67] BNEF. (2012, April 16). *Electric Vehicle Battery Prices Down 14% Year on Year*. Retrieved July 22, 2015, from Bloomberg New Energy Finance:

http://about.bnef.com/press-releases/electric-vehicle-battery-prices-down-14-year-on-year/

[68] DSIRE. (2015). Summary Maps: Programs. Raleigh, North Carolina. Retrieved from http://programs.dsireusa.org/system/program/maps

[69] Howarth, R. B., Gerst, M. D., & Borsuk, M. E. (2014). Risk mitigation and the social cost of carbon. *GLobal Environmental Change*, *24*, 123-131. doi:10.1016/j.gloenvcha.2013.11.012

[70] Weitzman, M. L. (2014). Fat Tails and the Social Cost of Carbon. *American Economic Review, 104*(5), 544-546. doi:10.1257/aer.104.5.544

[71] Moyer, E. J., Woolley, M. D., Matteson, N. J., & J., G. M. (2014, June). Climate Impacts on Economic Groth as Drivers of Uncertainty in the Social Cost of Carbon. *The Journal of Legal Studies, 43*(2), 401-425. doi:10.1086/678140

[72] PJM EIS. (2014, March 3). *PJM System Mix - System Mix By Fuel.* Retrieved from PJM EIS: https://gats.pjm-eis.com/gats2/PublicReports/PJMSystemMix/Filter

[73] U.S. Bureau of Labor Statistics. (2014, November). *Consumer Price Index - All Urban Customers.* Retrieved December 8, 2014, from Databases, Tables & Calculators by Subject: http://data.bls.gov/cgi-bin/surveymost?cu

[74] Pearce, D. (1990). The Role of Carbon Taxes in Adjusting to Global Warming. *The Economic Journal*, 938-948.

[75] Stern, N. (2007). *The Economics of Climate Change: The Stern Review.* Cambridge and New York: Cambridge University Press.

[76] Nordhaus, W. D. (2007). A Review of the Stern Review on the Economics of Climate Change. *Journal of Economic Literature*, 686-702.

[77] Dasgupta, P. (2008, December). Discounting climate change. *Journal of Risk and Uncertainty, 37*(2/3), 141-169. doi:10.1 007/s 111 66-008-9049-6

[78] Kempton, W., & Tomic, J. (2005, April 11). Vehicle-to-grid power implementation: From stabilizing the grid to supporting large-scale renewable energy. *Journal of Power Sources, 144*, 280-294.

[79] EIA. (2015, March 26). *Gasoline and Diesel Fuel Update*. Retrieved from Petroleum & Other Liquids: http://www.eia.gov/petroleum/gasdiesel/

[80] Monitoring Analytics, LLC. (2011). *State of the Market Report for PJM: 2010.* Monitoring Analytics. Retrieved from http://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2010.shtml

[81] Monitoring Analytics, LLC. (2012). *State of the Market Report for PJM: 2011*. Monitoring Analytics, LLC. Retrieved from http://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2011.shtml

[82] Monitoring Analytics, LLC. (2013). *State of the Market Report for PJM: 2012*. Monitoring Analytics. Retrieved from http://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2012.shtml

[83] Archer, C. L., & Jacobson, M. Z. (2003). Spatial and temporal distributions of U.S. winds and wind power at 80 m derived from measurements. *Journal of Geophysical Research*, 108(D9).

CONCLUSION

The complexity of climate change mitigation requires robust and detailed policy analysis to ensure that mitigation is implemented in a societally beneficial manner and is cognizant of the potential costs of implementation. With this in mind, the dissertation has focused on the economic, legal, and policy implication of climate change through three papers, each with a distinct but correlated subject matter. These three papers have each bred novel conclusions that contribute to the literature and provide guidance to energy policy-makers. The synthesis of these three papers show that renewable energy implementation is cost effective today and policies should be put in place to encourage renewable energy.

The first paper found that fleet vehicles, such as school buses, are optimal candidates for electrification and implementation of V2G technology. Given their limited and predictable daily range, fleet vehicles avoid many of the barriers that private individuals encounter in regards to electric vehicles, such as range anxiety and the lack of public charging infrastructure. Additionally, their limited and regular use allows for ample time for these vehicles to provide ancillary services to the grid. Likewise, this paper concluded that V2G revenues are essential to the cost efficacy of the electric vehicle, and without V2G revenues, the electric school bus would not be cost effective. The implication of this paper shows that V2G technology must be a key part in incentivizing electric vehicle adoption in general.

Next, the second paper has shown that the public trust doctrine can serve four purposes. First, citizens can use the public trust doctrine to compel states to develop renewable electricity and lessen impacts to trust resources. Second, the states can cite their duties under the public trust doctrine as a legal defense to potentially controversial actions encouraging renewable energy. Third, state agencies can use the normative standards of the public trust doctrine to supplement and buttress imperfect energy and wildlife laws. Finally, the procedural nature of the public trust doctrine can revitalize the judiciary in the realm of environmental law. Advancing these four objectives can help facilitate the reasonable development of renewable electricity.

Lastly, the third paper found that policymakers have vastly underestimate the societal benefits of renewable energy in setting renewable energy quotas within the PJM territory. Indeed, while on average, a state in the PJM territory has a renewable portfolio standard of 18% in 2023 (DSIRE 2015), the central results found that even given sunk costs of the existing fossil fuel dominated grid, the monetization of health and climate change externalities would imply a renewable portfolio standard of more than 50% in the near-term.   The modeling effort also found that the least cost energy systems did not construct any new natural gas, implying that the construction of renewable electricity does not require similar amounts of new natural gas to ensure reliability, at least from a system-wide perspective. Instead, it is less expensive for society to use the current PJM electricity system and storage to fill in the gaps of renewable electricity generation. Thus, this chapter concludes that coal plants need not be retired en masse, but instead should be repurposed to providing renewable support.

These papers complement one another. For example, while the cost-benefit analysis of school buses provided a local economic perspective of renewable energy implementation, the analysis of the public trust doctrine provided a state's perspective on the legal implications of renewable electricity.   Given its complexity, climate change mitigation will require analyzing renewable energy policies from many disciplinary perspectives and at different scales (local, state, regional, etc.).

Beyond the conclusions specific to each of the three papers, the dissertation also contributes to the literature by developing tools that can be implemented in other study areas.. The methodologies of cost-benefit analysis, legal analysis and cost minimization modeling can be readily replicated and applied to other studies of the efficacy renewable energy policies and done so in other jurisdictions and at other scales. These tools provide a framework in which to analyze the specifics of the local, state, or regional implementation of renewable energy.

However, as these tools are applied further, they should be built upon to provide higher resolution and more accurate recommendations for climate change policy. For example, the cost minimization model can be further developed to include local marginal pricing. Adding this detail will increase the thoroughness of the modeling effort and increase its value for policy. Likewise the cost-benefit analysis can be considered from a wider fleet perspective, instead of an individual bus, in order to include additional costs, such as upgrades to the local distribution grid.

United States climate change emissions have increased over the decades, and will likely continue to increase, despite the growing probability of worsening climate change impacts. Troublingly, there is currently no major or comprehensive climate change mitigation policies that are being planned, especially at the level of the federal government. The results of this dissertation imply that more focus should be put on state and local actions that mitigate climate change. The tools presented in this dissertation will continue to be helpful as society wrestles with the behavioral and economic barriers to implementing renewable energy.

Appendix A

A COST BENEFIT ANALYSIS OF A V2G-CAPABLE ELECTRIC SCHOOL BUS COMPARED TO A TRADITIONAL DIESEL SCHOOL BUS: EQUATIONS

Refer to Nomenclature section for definitions of variables.

Equation A.1. Annual V2G revenue calculation.

$$R_{V2G} = \frac{P_R \times (1 + i_e)^y}{1000} \times H_{V2G} \times E_{CAP}$$

R_{V2G}	$15,274/Year
P_R	$28/MWh
i_e	1.9%
Y	N/A
$H_{V2G/Y}$	7,647.8
E_{CAP}	70 kW

Equation A.2. Annual electricity cost calculation.

$$E_C = \frac{P_E \times (1 + i_e)^y}{1000} \times \mu_e \times d$$

E_C	$714/Year
P_E	$0.106/kWh
i_e	1.9%
Y	N/A
μ_e	747 Wh/mile
D	8,850

Equation A.3. Annual electric bus maintenance calculation.

$$M_E = m_{er} \times d(+B_R)$$

M_E	$1,770 ($25,770)

m_{er}	\$0.20
D	8,850
B_R	\$300/kWh

Equation A.4. Annual electricity externalities calculation.

$$E_E = h_{er} \times d + E_D \times \ C_{er} \times SCC$$

E_E	\$280
h_{er}	\$0.015
D	8,850
E_D	6,613 kWh
C_{er}	1.18 lbs/kWg
SCC	\$36/MTCO_2e

Equation A.5. Annual diesel fuel cost calculation.

$$D_C = \frac{d}{\mu_d} \times P_D \times (1 + i_d)^y$$

D_C	\$6,351
D	8,850
μ_d	6.35 mpg
P_D	\$4.20/gal
i_d	8.5%
Y	N/A

Equation A.6. Annual diesel bus maintenance cost calculation.

$$M_D = m_{dr} * d + L_r$$

M_D	\$9,075
m_{dr}	\$1
D	8,850
L_r	\$225

Equation A.7. Annual diesel fuel externalities calculation.

$$E_D = h_{dr} \times d + D_D \times C_{dr} \times SCC$$

E_D	\$1,214
h_{dr}	\$0.08
D	8,850
D_D	1,393 gal
C_{dr}	22.2 lbs/kWh
SCC	\$36/MTCO$_2$e

Appendix B

COST MINIMIZATION SUPPLEMENTAL METHODOLOGY SECTION

B.1 Costs

B.1.1 Electricity

As discussed previously, electricity generation was broken into six generation types; offshore wind, land-based wind, solar, nuclear, natural gas, and coal. Offshore wind, land-based wind, solar, and natural gas were modeled as potential installations. It was assumed that when load was not met by renewable electricity or backup storage, conventional electricity sources would be used to meet load by the current PJM system. Currently, both capacity and generation in PJM are nearly entirely coal, natural gas and nuclear, making up 89% of capacity [6] and nearly 96% of generation [72], see

B-1.

Table B-1. PJM Capacity and Generation by Fuel Type

Fuel Type	PJM Capacity (%)[1]	PJM Generation (%)[2]
Coal	42	44.4
Natural Gas	29	16.4
Nuclear	18	35.1
Wind	1	1.8
Oil	6	2

[1]Monitoring Analytics, LLC 2014
[2]PJM EIS 2014

B.1.1.1 Capital Costs

For the purposes of the model, conventional electricity was assumed to be the current PJM generation mix, and thus did not have any capital costs. On the other hand, offshore wind, onshore wind and solar would all require significant capital investments for installation. The cost inputs of renewable sources were based on World Energy Council estimates of current capital costs specific to the United States, with the exception of offshore wind, which was based off European cost estimates (since offshore wind does not currently exist in the United States) [15]. While various sources offer estimated capital cost prices, the World Energy Council estimates were used to in order to have consistent estimates across all renewable energy technologies. Also, it is important to note that the model increases the cost of installed offshore wind depending on the depth of the ocean and distance from shore. The existing current generation has no capital costs, which is a conservative assumption given pollution controls and other regulations to which existing power plants will have to adhere. The model also includes the possibility of building more conventional types of generation, including natural gas. The capital costs of natural gas were included as estimated by the EIA [13]. The capital costs are summarized in Table B-2.

In addition to overnight capital costs of the generator itself, all types of generation require construction of transmission cables to connect to the grid. This will increase the relative costs of wind, since wind may be located in more remote regions. The generalized cost of transmission was added to the capital cost of land based wind, based on the EIA's estimate of average transmission upgrade and construction cost

$125,000/MW [13].[752] Offshore wind transmission costs were calculated at approximately $775,000/MW. This estimate includes the costs of offshore submarine cables, offshore converter platforms, onshore underground cables, and the onshore substation (Personal Communication, Deniz Ozkan, August 6, 2014).[753] Lastly, natural gas requires an average transmission upgrade and construction cost of $150,000/MW [13]. Transmission costs were included as part of the capital costs inputs of the model.

Table B-2. Capital Cost per Generation Type

Generation Type	Capital Costs ($/MW)	Transmission Costs ($/MW)	Total Capital Costs ($/MW)[1]
Land Based Wind	1,830,000	125,000	1,955,000
Solar PV	1,770,000	-	1,770,000
Offshore Wind	4,200,000 to 6,080,000	775,000	4,975,000 to 6,855,000
Natural Gas	985,000	150,000	1,135,000

752 All dollars have been converted into 2013 dollars, using the Consumer Price Index of All Urban Customers and All Items [73].

753 Deniz Ozkan is the Project Coordinator for the Atlantic Wind Connection.

B.1.1.2 Operation and Maintenance

In addition to capital costs, all electricity generation has costs due to operation and maintenance. Operation and maintenance costs were broken into two different categories: fixed operation and maintenance (FOM), and variable operation and maintenance (VOM). FOM is the cost of operating and maintaining the power plant, regardless of actual production, in $/MW per year. This cost includes the maintenance of the structures and grounds, routine preventative maintenance, among other costs [13]. On the other hand, VOM is the cost dependent on the amount of generation a power plant produces, expressed in $/MWh, and generally includes the cost of water, catalysts, and other consumable materials [13]. Lastly, conventional electricity requires fuel, and average fuel costs dependent on generation type were calculated. Coal and natural gas fuel costs were calculated by using assumed heat rates per unit of generation, in Btu/kWh [13], and multiplying those by the 2013 average price of fuel, in $/MMBtu [16]. Nuclear fuel prices are not available on the EIA website per ton of uranium; however, the data was already expressed in $/MWh [17]. These fuel costs were incorporated into the VOM cost. Since renewable energy technologies do not require fuel, they have a VOM cost of $0/MWh.[754] See Table B-3 for FOM and VOM summarized per generation type.

Table B-3. Electric Generation FOM and VOM

Generation Type	FOM ($/MW/yr)	VOM ($/MWh)
Land Based Wind	39,550	0

[754] It should be noted that operation and maintenance for wind, to a degree, increases as generation increases, but this is averaged across the annual FOM.

Offshore Wind	74,000	0
Solar PV	25,000	0
Coal	31,180	25.13
Natural Gas	9,960	35.02
Nuclear	93,280	9.22

B.1.1.3 Externalities

Externalities were included in the model to solve for the optimal energy system from the perspective of the costs and benefits to society. Damages to public health and/or the social cost of carbon were included as externalities in three scenarios. The first scenario run did not include any externalities. This reflects the fact that many decisions made by local electricity planners will not include considerations of benefits to society as a whole (or to ratepayers outside of the bill costs), but rather only internalized market prices, or so-called ratepayer impact. The second scenario included the health externalities of energy combustion, a scenario that might describe electricity planners who are considering local impacts or local effects in addition to the ratepayer impact. Lastly, the third scenario included both the health and climate change externalities, and thus would consider the costs to society at large. Comparisons among these different scenarios will help illuminate differences in optimal electricity mixes under various policy assumptions.

B.1.1.3.1 Health Externalities

Health externalities were determined for each fuel type based on values in the literature. The health cost associated with coal was calculated to be $103.80/MWh [18], based on monetization of particulate matter impacts on public health. Natural gas health externalities were based on a study by McCubbin and Sovacool [19] that focused on the increased mortality due to particulate matter ($PM_{2.5}$) emissions from natural gas combustion. Since $PM_{2.5}$ impacts are directly correlated with population density, the monetized health externality took into consideration natural gas plant location and size in PJM (EIA 2014) and the county population density in which those natural gas plants were located [42] in comparison to the counties used in the study [19]. The average calculated natural gas health externality in PJM was $58.70/MWh. Unlike other conventional electricity production types, nuclear power does not directly emit any air pollutants via combustion. However, it still has health externalities since direct human radiation and other health consequences occur during its lifecycle outside the generation stage. There has been a lack of recent health externality studies of nuclear power. In the most recent literature review of nuclear externalities Sundqvist [20] found a mean of $123.30/MWh with a standard deviation of $266.10/MWh, and a median of $14.30/MWh. Since the standard deviation was more than double the mean, implying a significant range in the distribution, the median health externality of $14.30/MWh was used in the model, to be conservative and to not penalize nuclear based on extreme values. The risk in doing so is that the societal cost of nuclear may be underestimated, by not including any cost for proliferation risk or catastrophic disaster risk. Lastly, we included no monetized health externalities associated with offshore wind, land based wind, or solar electricity production.

B.1.1.3.2 Social Cost of Carbon

The social cost of carbon (SCC) has been a recent focus of policy makers, and has implications for the electricity market given that it is the highest CO_2 emitter in the United States [4]. However, finding a correct societal cost per metric ton of carbon dioxide is difficult [74] [75] [76]. The model used a social cost of carbon based on the estimate of the federal Interagency Working Group on Social Cost of Carbon [22]. The Interagency Working Group determined the cost of carbon to society through various models, and averaged across the models. However, since much of the damages occur in the future, the discount rate impacts the net present cost, and thus, the computed carbon price, significantly. Here we choose the mid-range 3% discount rate rather than 5% or 2.5%, consistent with economics literature on social discount rates and with OMB Circular A-4 [37].[755] This produces a SCC of $40 per metric ton of carbon dioxide ($MTCO_2$) [22]. Below we call this the "mid-range" SCC. The Interagency Working Group also calculated the 95th percentile for the 3% discount rate of all model runs, as a way of valuing the worst-case climate effects, yielding a social cost of $112 per $MTCO_2$. We label this value as the "realistic worst-case SCC". We do not run a "best case" SCC, since two of our scenarios assume a SCC of $0 per $MTCO_2$.

To find the average cost per MWh of electricity generated, the cost of carbon was then multiplied by lifecycle emission rates of each generation type [21]. In addition, it should be noted that the social cost of carbon increases over time, and this was included in the model as well. Externalities by generation type are summarized in B-4.

[755] It should be noted that this discount rate does not include the intergenerational concerns that are included in prescriptive discount rates proposed by economists and policymakers [37] [77].

Table B-4. Cost of Electricity Externalities

Generation Type	Health Externality ($/MWh)	Mid-range SCC ($/MWh)	Realistic Worst Case SCC ($/MWh)
Land Based Wind	0	0.48	1.36
Offshore Wind	0	0.49	1.38
Solar PV	0	1.86	5.20
Coal	103.80	40.49	108.63
Natural Gas	58.43	19.00	53.00
Nuclear	14.30	0.63	1.74

B.1.2 Storage

Storage becomes more valuable as the scale of implementation of renewable energy increases [31]. In this model, two types of storage were included: vehicle-to-grid (V2G) capable electric vehicles and hydrogen storage (H_2). While the costs of hydrogen storage are relatively straightforward to determine, incorporating the potential for V2G capable electric vehicles in the model requires other considerations, such that the model must include a simplified model of light vehicles. This is because while H_2 storage is built with the sole purpose of storage of modeled generation needs, V2G storage's primary use is transportation, and achieves major capital cost savings as a result. But for this same reason, V2G storage capacity is dependent on EV purchases and availability of the batteries when the cars are not in use.

B.1.2.1 Capital Costs

The capital costs of storage include both the cost for energy storage capacity (in MWh) and capacity to move energy in and out of storage, or power capacity (in MW). Hydrogen power costs include the costs of a solid oxide fuel cell (SOFC) and an electrolyzer, which together cost $870,000/MW [23]. The energy storage of hydrogen is the cost of hydrogen gas and the cost of the steel tank, totaling $15,535/MWh of storage capacity [23].

The capital costs of V2G storage are more complex. The capital cost of V2G storage is the cost of the electric vehicle supply equipment (EVSE, in MW) and the cost of the electric vehicle and its battery (in MWh). It was assumed that each car would, on average, require one EVSE to charge the car, with an average capacity of 10 kW. 10 kW was assumed, as some chargers would likely be 15kW while others would be lower capacity, such as 6kW. A cost of $150,000/MW was used for EVSEs, an estimate based on the literature [78] [2]. The total capital cost of V2G storage is also more difficult to properly value, because it also depends on the willingness of the public to drive electric vehicles. The previous iteration of this model assumed that 100% of the public would be willing to drive electric vehicles, and 45% of those would be V2G capable, at no capital cost, including only the cost of V2G on the battery's life and the aforementioned capital cost for the EVSE [2]. However, 100% EV penetration is unrealistic given that such a large scale implementation of electric vehicles would come at significant cost to society. There are several limitations to large-scale implementation of electric vehicles, including range anxiety, lack of public charger infrastructure, and higher initial costs, in comparison to gasoline vehicles. Switching to electric vehicles would require significant behavioral change, due to limited range, or require a significantly higher investment for electric vehicles with driving ranges similar to gasoline vehicles. Furthermore, the willingness to change behavior or pay more for an electric vehicle is heterogeneous across the population.

Based on a recent stated preference survey, a range of willingness-to-pay (WTP) values were calculated and estimated for various types of hypothetical electric vehicles [24]. WTP varied based on the size of the battery in the hypothetical cars in comparison to the proportion of today's electric vehicle market suggest retail price (MSRP), and assumes a current average battery cost of $325/kWh of usable energy [38]. The average price paid for a gasoline car in 2013, $25,600 [25], was then subtracted from the estimated cost of each type of hypothetical electric car.[756] The stated WTP for each of the hypothetical car, as reported in Hidrue et al [24], was then subtracted from this additional cost, and the result then divided by the battery capacity of each car (See the Appendix C). See Equation B-1. The result can be considered the additional cost required for people to change their behavior to drive a V2G-capable electric vehicle, or from the perspective of the model, the cost to society to purchase an additional MWh of V2G storage. Added to societal cost was the potential cost of V2G on the life of the battery, estimated to reduce the battery life by 10% (Saxena 2014), adding a cost of $32.5/kWh [2] (Kempton and Tomic 2005). See Figure 4.1 for the cost of V2G per kWh and how it increases over the population, ranging from $110/kWh up to $947/kWh. See also the Appendix C.

Equation B-1. Estimated Cost of V2G-Capable Electric Vehicle j for person i as Based on Hidrue et al. (2011).

$$V2G_{ij} = \frac{\left((k * BC * S_j) - ICE\right) - WTP_{i,j}}{S_j}$$

Where	V2G	*equals*	Capital Cost to Incentivize Person i to Purchase V2G-Capable EV_j (in $/MWh)
	k		Estimated Proportion of Battery of Total Electric Vehicle Cost

[756] In reality, the amount paid for a gasoline car is heterogeneous across the population, however, this data is unavailable, especially as it relates to EV-purchasers. As a result we use only the average gasoline car in our estimates, and the difference between the cost of an EV and a gasoline vehicle would vary more based on individual's preference.

BC	Cost of Battery (in $/kWh)
ICE	Average Gasoline Vehicle Cost (in $)
WTP	Stated WTP (in $)
S	Size of Battery (in kWh)

For electric vehicle type j for person i (as found in Hidrue et al. [24])

B.1.2.2 Operation and Maintenance

Storage operation and maintenance cost, like electricity generation, was separated into FOM and VOM. For hydrogen storage, it was assumed that there would be no VOM (and no fuel) cost, only FOM costs of $29,318/MW/year [26]. On the other hand, the FOM and VOM costs of V2G needs to be compared to the FOM and VOM costs of displaced internal combustion engines. While it is expected that maintenance of electric vehicles will be significantly less than gasoline vehicles, this remains uncertain, and thus, the model assumes there would be no benefit. However, a major benefit of electric vehicles is the reduction of gasoline consumption. To capture the costs of both fuel sources, electric vehicle charging was added to the hourly load of the model, and the cost of gasoline fuel consumption was calculated for vehicles still powered by gasoline.

Required charging was estimated by converting the average distance travelled per year - 11,705 miles [27] - into the required kWh. Assuming an average efficiency of 4 miles per kWh, it is estimated that each car would require nearly 3 MWh of charging per year. If all cars were electric, as was assumed in Budischak et al. [2], this would add approximately 16 GW of load to each hour, increasing the average PJM load by almost 20% (PJM 2014). As a simple first model, we assume that charging would occur “blindly”- meaning that cars would constantly charge throughout the day, not charge when electricity prices were low.

While electric vehicles would add electricity load, they would also displace the consumption of gasoline fuel. To calculate this reduction of gasoline consumption, the model took the miles driven per year per car and divide it by the average estimated actual engine efficiency, 21.6 miles per gallon [27]. Using this methodology, it is estimated that the vehicles in PJM consume 27.2 billion gallons of gasoline per year. This was then multiplied by the average retail price of gasoline per gallon within the PJM area [79], but with federal and state taxes removed [28]. This results in a total market cost of gasoline for PJM of $63 billion per year. This cost was reduced by each percentage of V2G-capable electric vehicle penetration (e.g., 0% EV penetration would have a gasoline fuel cost of $63 billion per year, 50% EV penetration would have a gasoline fuel cost of $31.5 billion per year, and 100% EV penetration would have gasoline fuel cost of $0/year).

B.1.2.3 Externalities

While neither hydrogen nor V2G storage technology directly cause substantial externalities, there are two indirect externalities associated with storage. First, before the electricity is stored, there are externalities associated with the generation, and these costs have been previously discussed and accounted for. However, increased V2G storage capacity necessarily means that gasoline consumption is displaced, and thus, would also reduce the health and climate change externalities caused by gasoline. The transportation sector, is next largest emitter of greenhouse gases after the electricity sector, accounting for 28% of emissions in the United States [4]. On the other hand, hydrogen storage would not affect the transportation sector, and other than the externalities associated with the stored electricity would have no other monetized health or climate change externality.

B.1.2.3.1 Health Externalities

Gasoline, being a fossil fuel, is a major source of particulate matter in the United States when combusted. If electric vehicles were implemented, they would reduce the health impacts from gasoline consumption. This was monetized based on a recent study that calculated the health damages from gasoline within each state [29]. Based on these numbers, it is estimated vehicles within PJM cause $9.8 billion in health damages per year.

B.1.2.3.2 Social Cost of Carbon

Transportation is also a major source of carbon emissions. To estimate the social cost of carbon associated with vehicle use, total gallons used by vehicles in the PJM area was estimated by dividing the total calculated miles driven in the PJM area by the average miles traveled per gallon of fuel consumed [27]. The total gallons used by vehicles in PJM, approximately 11.8 billion gallons per year, was then multiplied by an emission rate due to combustion of gasoline [30] and converted into metric tons. This was then multiplied by the two different levels of the SCC to find the overall yearly cost in the PJM area; the “average” cost being $8.6 billion per year, and the realistic worst-case cost being $24 billion per year.

The cost of fuel, VOM, health externalities and SCC of gasoline vehicles were all included in the model as a yearly cost dependent on the amount of EV penetration. For every MWh of V2G storage added, this would correlate to a certain amount of electric vehicles, and thus a certain savings through displacement. For this purpose, B-5 shows the costs in both total PJM system savings, and savings per MWh of V2G storage.

Table B-5. VOM and Externality Savings Displacement from V2G EV

	VOM (Fuel Costs)	Health Externality	Mid-Range SCC	Realistic Worst Case SCC
Total PJM Cost ($ billion per year)	62.9	9.8	8.6	14.4
Cost savings per V2G capacity ($/MWh/year)	32,151	4,990	4,406	12,483

B.1.3 Heat

Large scale renewable penetration often implies that generation will exceed load during certain hours [2] [31]. It has been proposed that this excess generation could be used for heat, because the largest amount of excess generation of wind occurs in the winter [2] [3]. This excess generation could provide a very cheap source of heating while also displacing natural gas consumption. However, to use excess renewable generation for heating, capital investments into electric heating systems would be required. The model uses a hybrid electric heating system, using both a heat pump (HP) and resistive heating with thermal energy storage (RHTS), each with their own benefit. A HP is beneficial in that it has a very high efficiency of 300% while RHTS allows for storage of heat over long periods of time [3]. Similar to V2G storage, increased penetration of electric heat would displace natural gas boilers (NGH), which comprise about 75% of all non-electric heaters in PJM (EIA 2013).

B.1.3.1 Capital Cost

The capital cost of a hybrid electric heating system was derived from Pensini et al. [3]. The combined cost of electric heating power used in the model is $1.1 million per MW, and includes both the HP and TES [3]. Similar to current electricity generation, it was assumed that there would be no capital costs associated with NGHs, as they have already been installed.

B.1.3.2 Operation and Maintenance

The FOM cost of the electric heat is comprised of the FOM cost of the HP and the FOM cost of the RHTS, which is then compared to the the FOM cost of the NGH. Based on Pensini et al. [3], the combined FOM cost of electric heat, $7,300/MW/year, is less than the average FOM cost of NGHs, $10,600/MW/year. Therefore, the FOM cost included per year for electric heating would reduce the FOM of heating by $3,300 per MW of electric heat capacity installed per year.

The sole component of VOM for heating is fuel costs. While electric heating systems will add to load, they will also displace residential and commercial natural gas consumption. Currently, it is estimated that the PJM system consumes approximately 2.1 trillion cubic feet of natural gas per year [40], and costs $21 billion per year, based on monthly residential and commercial natural gas prices [33].

B.1.3.3 Externalities

Residential and commercial energy consumption that is used primarily for space and water heating [32] accounts for about 10% of U.S. greenhouse gas emissions (GHGs) [4]. In addition, combustion of natural gas for heating emits particulate matter that causes public health damages.

B.1.3.3.1 Health Externalities

The health externalities of natural gas boilers were estimated using average primary and secondary particulate matter emission rates [34] and the societal costs of particulate matter per ton [35]. Based on PJM total annual average natural gas consumption, it is estimated that heating causes a health externality of approximately $0.41 billion per year.

B.1.3.3.2 Social Cost of Carbon

According to the EIA, natural gas emits 53.1 kilograms of CO_2 per thousand cubic feet [36]. Converting this into metric tons, and multiplying it by the PJM annual residential and commercial consumption rate of natural gas (EIA 2014), the PJM territory emits around 110 million tons of CO_2 per year due to heating requirements. Using the mid-range and realistic worst-case SCC, this equates to an annual SCC of $4.5 billion and $12.5 billion, respectively. Similar to V2G storage and EVs, each percent of penetration of electric heating was assumed to displace VOM, health and SCC costs associated with natural gas. See Table B-6.

Table B-6. VOM and Externality Cost of Heating

	VOM	Health Externality	Mid-range SCC	Realistic Worst Case SCC
Total PJM Cost ($ billions per year)	21	0.4	4.5	12.5
Cost Savings per MWh of Electric Heat Generation ($/MWh)	48.25	0.90	9.75	27.30

B.2 Resource Assessment

In addition to the costs of the system, the model depends on accurate resource assessment of renewable energy sources. There are two important aspects of resource assessment: maximum potential capacity and hourly fluctuation of generation. The maximum potential capacity is the most MW of any renewable generation one can build in the PJM system, as limited by the resource. Secondly, an implication of implementation of renewable generation is that those sources are variable, and may not match up with load. To address the variable nature of renewable energy generation, it is necessary to incorporate accurate information on hourly fluctuations of generation. It should be noted that conventional energy sources such as new natural gas and NGHs were not limited by hourly fluctuations nor maximum capacity in this model, so resource assessment did not apply to these sources.

B.2.1 Electricity

B.2.1.1 Land-Based Wind

The maximum capacity of onshore wind per state was determined based on areas where wind could be developed without conflicting with other land uses, which for all states in PJM, was 654 GW [43]. However, since not all of Illinois, Indiana, and Kentucky[757] is included in PJM, a portion of each state's wind capacity was excluded from the overall analysis, as only wind farms, and their associated capacity, that were built inside the PJM area would be included in this analysis.[758] The proportion of wind resources in each of these states that would be included was determined by using wind resource GIS data [44] in comparisons to maps of PJM. This significantly reduces the maximum PJM wind potential down from 654 GW to 201 GW.

Furthermore, not all 201 GW are equally windy. The overall maximum capacity was separated into three annual average capacity factor ranges; 0.3 to 0.349, 0.35 to 0.399, and 0.40 and above [43], which corresponds to maximum capacities of 128 GW, 57 GW, and 16 GW, respectively. While actual construction of wind energy would depend on various factors, such as locational marginal pricing (LMP), it was assumed that wind would be built in the windiest areas first. The model incorporates these diminishing returns by scaling down the hourly fluctuation of generation (or hourly capacity factor). The highest wind range would generate 100%

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757 North Carolina and Michigan are also partially included in PJM, however these were not considered in the capacity analyses because both the wind and solar resources of the PJM territory in each state is insignificant. On the other hand, the model does include both the hourly load and the current PJM capacity from these territories.

758 It should be noted that this ignores all imported wind, and thus conservatively underestimates the total amount of land-based wind that could provide energy to the PJM territory.

of the hourly capacity factor, but the middle wind range would be scaled down to 93.75% (0.375/0.40) of the each of the hour's capacity factor, and the lowest wind range would scaled down to 81.25% (0.325/0.40) of the each of the hour's capacity factor.

To determine the hourly fluctuation of wind generation, actual wind production data from 2010 to 2013 within PJM was obtained from PJM Interconnection (Business Solutions Department, PJM Interconnection April 21, 2014). This hourly generation of wind data was then converted into an hourly capacity factor, based on monthly wind capacity in PJM, which grew from around 3.5 GW to 6 GW over the four years of this data [80] [81] [82] [82] [6]. Using this methodology, the average capacity factor over the four years was 0.258. Nevertheless, using the current hourly wind generation data may significantly underestimate the capacity factor. In the last several years, hub height and rotor diameter area have increased significantly (Wiser and Bolinger, 2013 Wind Technologies Market Report 2014), causing land-based wind capacity factors to rise dramatically. Thus, if society were to develop large-scale renewable penetration of land based wind, it is likely that the average capacity would be greater than 0.258.

To determine how newer technology would affect the hourly wind production, we compared the power curves of the current wind turbines in PJM to the power curves of a present generation turbine, the Siemens SWT-2.3-113.[759] There are two reasons that higher capacity wind turbines were not considered in this model: first,

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[759] It is recognized that other turbine models also will be utilized, but they would have similar power curves to the SWT-2.3-113 and thus would not differ significantly for purposes of the model.

wind turbines designed for lower wind speed sites are utilized not only in medium and low average wind speed areas but also in high average wind speed areas [47]; and second, the wind sites in PJM consists almost entirely of medium and low wind speed [43] [47]. While actual turbine selection would be highly dependent on the site, this is outside of the scope of this paper, and we expect the results to only change slightly. The current wind turbine mix was determined for each year within PJM using the AWEA Market Database [46]. The rotor diameters of top 10 wind turbines of each year, comprising over 75% of the PJM capacity are set forth in Table B-7.

Table B-7. Percent Penetration of Wind Turbines Models in PJM over Four Years

Turbine	Rotor Diameter (m)	2010	2011	2012	2013
GE 1.5-77	77	33.2%	32.1%	26.4%	26.7%
Vestas V82	82	27.7%	26.8%	22.0%	18.1%
Gamesa G87	87	19.2%	18.6%	15.3%	15.5%
Gamesa G90	90	0.1%	1.0%	13.4%	13.6%
Suzlon S88	88	4.4%	4.2%	8.5%	6.5%
Gamesa G80	80	7.0%	6.7%	5.5%	5.6%
GE 1.5-82.5	82.5	5.7%	5.5%	4.6%	4.6%
GE 1.6-100	100	0.0%	0.0%	0.0%	4.2%
AW 82/1500	82	2.7%	5.1%	4.2%	2.1%
GE 1.6-82.5	82.5	0.0%	0.0%	0.1%	3.1%
Overall Percent of PJM	**N/A**	**86.0%**	**81.2%**	**76.1%**	**75.2%**

As seen in Table B-7, the overwhelming majority of the turbines in PJM had a rotor diameter less than 90 meters, whereas currently, over 75% of turbines installed have a rotor diameter over 100 meters [47]. The model turbine, in comparison, has a rotor diameter of 113 meters, over 20 meters larger. As a result, future installation of the model Siemens turbine or similar turbine from other OEMs with its higher rotor swept area would have a significantly increased capacity factor at average wind speeds, as seen in Figure B-1. This increase in capacity factor was included in the model by transforming the actual hourly capacity factor to a new hourly capacity factor, based on difference between the model turbine power curve and that year's aggregate power curve. After adjusting the hourly data, the new average capacity factor over the four years would have been 0.351, 36% higher than the capacity factor using older turbine models. Lastly, this likely underestimates hourly capacity factors because it does not account for the difference in hub heights between the model turbine, 99.5 meters, and the current PJM wind turbine fleet, close to 80 meters or below. Due to the complexities of the relationship between surface roughness, hub height, and site selection [83], we opted to take a conservative approach and ignore any benefit from increased wind speed as the average hub height increases.

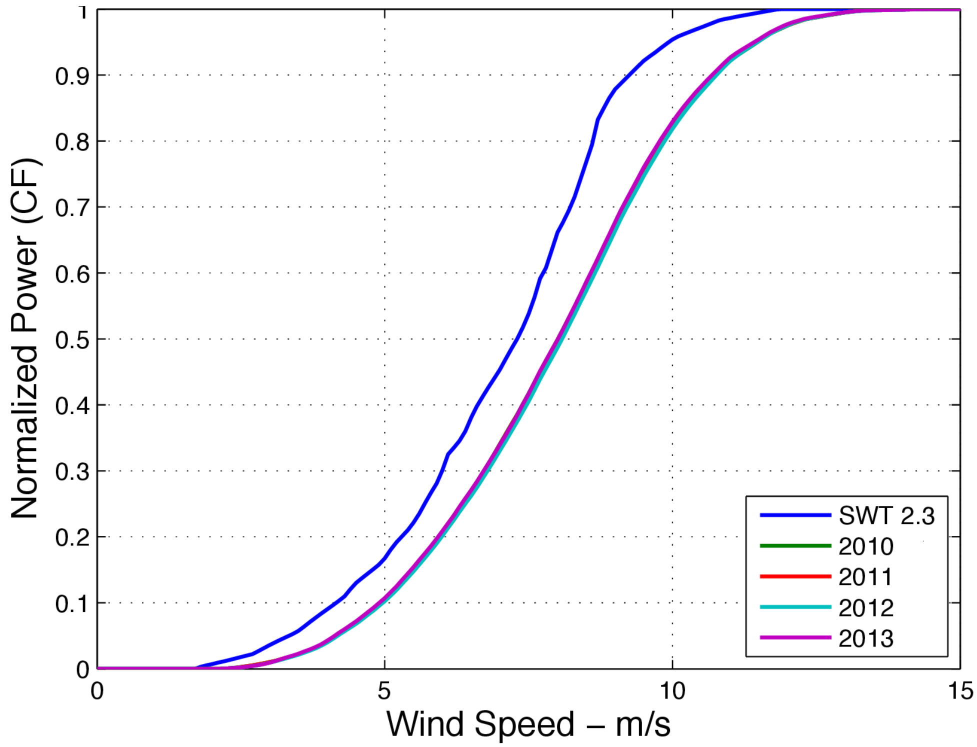

Figure B-1. Aggregate Power Curve in Comparison to Model Wind Turbine Power Curve

B.2.1.2 Solar

Solar energy in PJM differs from some other regions of the United States, since the PJM region has no concentrated solar potential [48]. Thus, the model focused exclusively on rooftop PV solar capacity and generation. Utility-scale rural solar was not considered because it is very uncommon in PJM and the likelihood it would create land use conflicts with land based wind. Rooftop solar capacity was determined by state potential rooftop solar resource. Unlike onshore wind, where siting of utility scale turbines depends heavily on the location, the implementation of rooftops was assumed to be equally distributed across each state. As mentioned previously, only portions of the states of Illinois, Indiana, and Kentucky, would be within the PJM grid. To determine the proportion of the solar capacity within each of these states, GIS data was used to find the relative household density within the PJM service are of each of these states [49], which was overlaid with the GIS data of solar capacity[50] [48]. Using this methodology, the total capacity of solar is 96 GW.

Hourly solar data was gathered from all the locations within NREL's National Solar Radiation Data Base that would fall under PJM jurisdiction. At each location, the solar radiance was modeled in watt-hours per square meter (Wh/m^2) based on the METSTAT model [51].[760] This was converted into an hourly capacity factor by dividing modeled radiance by 1,000 Wh/m^2, the ideal solar radiance for maximum capacity, and then multiplied by 0.80 to account for losses. This resulted in an average hourly capacity factor of 0.134 over the four years. Unlike land-based wind, locations across the PJM territory have roughly the same radiation, so there were no diminishing returns included [48] [50].

B.2.1.3 Offshore Wind

The maximum capacity of offshore wind in the region was based on areas that were available for offshore wind development from Virginia to New Jersey, with exclusion areas removed [52]. Based on this work, 78 GW of offshore wind could be developed and connected to the PJM area. However, further development of offshore wind would increase both the distance offshore, and the water depth. To accurately understand the tradeoffs of complete development of offshore wind, a higher cost was

[760] Hourly solar data was only available up until 2010, thus the hourly solar of the four years from 2007 to 2010 were used in this model.

used for the areas that had a water depth greater than 35 meters and required a jacket structure. Of the 78 GW of offshore wind capacity, 43 GW are in shallow water and close to shore, and 35 GW are in deeper waters, farther offshore. While there is significant potential for cost-savings by redirecting vessel traffic and bringing wind turbines closer to shore in shallower waters [53], given uncertainty of implementation of a policy that would do so, the model assumes that deeper waters would need to be developed, at a costlier rate. Thus, the 43 GW were assumed to be the lower cost range ($4.975 million/MW), and the 35 GW of offshore would have the higher cost range ($6.8 million/MW).

As discussed previously, hourly generation of offshore wind over the four years was determined using the Weather Research & Forecasting (WRF) model by using a model turbine, the REpower 5MW turbine, and includes losses. [761] Based on this modelling effort, the average capacity factor of offshore wind in this region, over the four years, is 0.424.

B.2.2 Storage

Maximum storage capacity is markedly different from renewable generation, because it does not depend on meteorological resource availability. Instead, hydrogen storage depends on the availability of materials, such as catalysts and steel. Since these would not be limiting in the scope of this analysis, it was assumed that as much hydrogen storage could be built as society desired. Likewise, hydrogen storage is not limited on an hourly basis as renewable electricity sources are. On the other hand,

[761] Modelling was done by Mike Dvorak of Sailor’s Energy for the MAOWIT project (W. Kempton, PI) funded by US DOE grant DE-EE000537.

V2G depends on the amount of light vehicles in the PJM territory, and the battery capacity per car, both of which are considered to be the “resource constraints” on V2G capacity. Overall vehicle registration, by state, was used to determine potential capacity of V2G vehicles [7]. Again, only a proportion of these cars in the states of Illinois, Indiana and Kentucky would be in the PJM service area, and that proportion was estimated by using the population density of people 18 and over in the states within in PJM [49]. It was assumed that adult population would be roughly proportional to vehicle ownership. Excluding non-PJM areas, we estimate the count of light vehicles in PJM at 52 million.

The second aspect of overall maximum potential V2G capacity is the battery capacity per car. This was determined based on the average range of the cars as reported in Hidrue et al [24], which was converted into equivalent kWh battery capacity. Assuming equal distribution of the six hypothetical cars in Hidrue et al [24], the average car would have a 37.5 kWh battery. Thus, the total maximum potential V2G capacity of PJM is 1,950 GWh.

From the perspective of the model, the total capacity of V2G is treated as one single aggregated battery. While V2G storage does not fluctuate hourly dependent on meteorology, as renewable energy does, V2G storage is constrained by other factors. First, since these vehicles are also being used for driving, the model does not allow the battery to be discharged below 20% state-of-charge (SoC). This would ensure that at any given time, the average modeled electric vehicle would be able to drive around 30 miles without planning.[762] In addition, the model restricts the availability of battery

[762] Some vehicles may have a higher minimum SoC to always have 30 miles range, whereas other vehicles will have a significantly lower minimum SoC to have the same 30 mile range.

capacity based on the number of vehicles driven. On an average day, between 86% and 99.9% (average 93%) of vehicles are parked at any given time, and thus available for V2G storage [54]. As previously mentioned, driving electric vehicles was included in the model, which would drain energy from the aggregate battery. Given that the maximum capacity of the aggregate battery is 1,950 GWh, and the maximum vehicle load to recharge from driving (i.e., maximum meaning 100% of cars are electric) is 16 GW per hour, the aggregate battery in the model would lose 0.86% of its maximum capacity each hour from driving. Moreover, it was assumed that EVs would charge blindly, meaning they would charge each and every hour, regardless of cost, though "smart" charging, i.e. charging EVs when electricity prices are low, would substantially decrease the burden on the grid and the cost.

B.2.3 Heat

The maximum capacity of electric heat employed in the model is based on the maximum heat load for the PJM system over the four years, which is 180 GW based on Pensini, Rasmussen, & Kempton [3]. Thus, the maximum capacity of the RHTS is 180 GW; because the HP has an efficiency of 300%, its maximum capacity is 60 GW. Based on an average RHTS system, it was assumed that each electric heating system would have 180 kWh of thermal storage [3], which equates to an aggregate maximum capacity of 1,350 GWh. As heating systems are neither dependent on meteorology nor have a secondary use, it was assumed there was no hourly fluctuations limiting capacity.

Appendix C

COST MINIMIZATION ELECTRIC VEHICLE CAPITAL COST

Table C-1. WTP per Car, converted into 2013$ from Hidrue et al [24]

Hypothetical Car	Min WTP	Q1 WTP	Median WTP	Q3 WTP	Max WTP
A	-20874.6	-15956.7	-13459.2	-11120.3	-7513.06
B	-13678.6	-10542.6	-8950.74	-7464.2	-5170.86
C	-10827.1	-7682.45	-6087.33	-4597.53	-2298.76
D	-5118.74	-567.904	1741.718	3906.922	7243.767
E	-2143.49	3764.674	6769.247	9580.537	13920.72
F	571.162	7118.894	9365.537	13569.98	17797.23

Table C-2. Estimated Proportion of Battery Cost of Overall MSRP (assuming battery cost of $325/kWh)

Model	Battery size (kWh)	Estimated Battery Cost ($)	MSRP ($)	Battery Proportion of MSRP
Nissan Leaf	24	11,400	29,010	0.392968
Tesla 60	60	28,500	69,500	0.410072
Tesla 85	85	40,375	79,900	0.505319
Rav4EV	41.8	19,855	49,800	0.398695
Fit EV	20	9,500	36,625	0.259386
Chevy Spark EV	21.3	10,117.5	26,685	0.379146
Fiat 500e	24	11,400	31,800	0.358491
I-MIEV	16	7,600	22,995	0.330507
Focus EV	23	10,925	35,170	0.310634
Average	**35**	**16,630.28**	**42,387**	**0.371691**

Table C-3. Estimated Additional Cost per Car (2013$) (assuming battery cost of $325/kWh)

Hypothetical Car	Range (mi)	Estimated size of the Battery (kWh)	Estimated cost of battery ($)	Estimated cost of equivalent EV (using Table C-2) ($)	Additional cost to the "average" gas car ($)
A	75	18.75	8906.25	26755.54	-3244.46
B	75	18.75	8906.25	26755.54	-3244.46
C	100	25	11875	34074.61	4074.605
D	150	37.5	17812.5	46905.86	16905.86
E	200	50	23750	57785.89	27785.89
F	300	75	35625	75237.59	45237.59

Table C-4. Estimated Additional Cost Minus the WTP per Car (or the Cost of subsidy required to get people to switch) (2013$)

Hypothetical Car	Min	Q1	Median	Q3	Max
A	17,630.1	12,712.24	10,214.77	7,875.824	4,268.599
B	10,434.11	7,298.147	5,706.277	4,219.736	1,926.401
C	14,901.71	11,757.06	10,161.93	8,672.134	6,373.37
D	22,024.6	17,473.76	15,164.14	12,998.94	9,662.092
E	29,929.37	24,021.21	21,016.64	18,205.35	13,865.17
F	44,666.43	38,118.7	35,872.06	31,667.61	27,440.36

Table C-5. Estimated Societal Cost (2013$ per kWh)

Hypothetical Car	Min	Q1	Median	Q3	Max
A	940.2719	677.9862	544.7875	420.044	227.6586
B	556.4858	389.2345	304.3348	225.0526	102.7414

C	596.0683	470.2824	406.4773	346.8854	254.9348
D	587.3227	465.967	404.3771	346.6383	257.6558
E	598.5875	480.4243	420.3328	364.107	277.3034
F	595.5524	508.2493	478.2941	422.2348	365.8714