

Master's Project Symposium: Spring 2018
Thursday, April 5 and Friday, April 6
Environment Hall
Field Auditorium, Room 2102 and Room 1105

Welcome to the 2018 Spring Master's Project Symposium. All presenters are students in the Master of Environmental Management (MEM) and/or Master of Forestry (MF) or the Duke of Environmental Leadership (DEL) professional degree programs at the Nicholas School of the Environment, Duke University. Presentations are a culmination of theoretical and analytical training acquired by the students to natural resource or environmental problems during their two years of study. The final master's project is the capstone piece for MEM and MF students.

The master's project could take the form of a management plan, handbook and/or educational curriculum. The project is intended to represent the student's major academic focus, and demonstrates the student's competence in that area [as well as integrating] course work, seminars, independent projects, internships, and other experiences in an in-depth study that culminates in a professional quality report and a formal presentation. All students must make a public presentation of their master's project in their final semester of enrollment. Thank you for taking the time to join our students as they present their master's projects to the community as well as their families and friends.

Nicholas School of the Environment Professional Degrees and Program Areas of Study

Master of Environmental Management

- Business and Environment (BE)
- Coastal Environmental Management (CEM)
- Ecosystem Science and Conservation (ESC)
- Ecotoxicology and Environmental Health (EEH)
- Energy and Environment (EE)
- Environmental Economics and Policy (EEP)
- Global Environmental Change (GEC)
- Water Resources Management (WRM)
- Duke Environmental Leadership (DEL)

Master of Forestry

Concurrent/Joint Degrees:

- Master of Environmental Management (MEM) and Master of Forestry (MF)
- Master of Business Administration (MBA)

ABSTRACTS

(In Order by Last Name)

Amalia Alberini (CEM)

Advised by: Patrick Halpin & Daniel Dunn

Assessing the Potential of Important Marine Mammal Areas to Address Connectivity and Promote Marine Mammal Conservation

This study examines the potential of marine mammal scientific data tools, namely the Important Marine Mammal Areas and the Migratory Connectivity in the Ocean system, can have in contributing towards advancing current knowledge on marine mammals. It examines how these tools can significantly improve the synthesis and availability of existing marine mammal data in different ocean regions, using two case studies, the Mediterranean Sea and the Southwest Pacific Ocean. This analysis provides evidence for the first time that these science tools, which have been designed to capture marine mammal data at the maximum possible degree, if combined and fully integrated can attain a more comprehensive view of the dynamic nature of marine mammals, especially in relevance to their migratory habits, providing more robust knowledge on marine biodiversity in data poor areas including in Areas Beyond National Jurisdiction.

Gloria G. Aldana (EEP)

Advised by: Lori Benneer & Lydia Olander

Cost-Benefit Analysis of a Green Infrastructure Project for Water Management in Peru

The purpose of this research is to analyze the costs and benefits of a green infrastructure project in Peru in comparison to a traditional microreservoir. Green infrastructure entails restoring an ecosystem for storm water management. In this case, cattle will be excluded from an overgrazed area in Huamantanga, Peru. Cattle exclusion is expected to allow for soil decompression. Once the begins to decompress, alfalfa can be grown as cattle pasture and reduce erosion. Together, these effects would increase water storage in the wet season and reduce flooding downstream. The water stored may then be used for irrigation of alfalfa in the dry season. The main economic benefit being studied is the additional income from artisanal cheese production in Huamantanga as a result of the augmented water flow in the dry season. This research will contribute information to the sparse existing green infrastructure literature.

Elizabeth C. Arnason (EE/MBA)

Advised by: John Buley

Group Members: Alexandra Cagan

Master Limited Partnerships: Implications for US Energy Infrastructure

Since 1981, Master Limited Partnerships (MLPs) have financed a significant share of United States oil and natural gas transport and processing infrastructure. This paper examines key trends in the midstream MLP space through broad market analysis and focused case studies to explain why the MLP model has been a successful vehicle for aggregating capital and encouraging infrastructure investment. Despite the growing use of MLPs since the 1980s, market capitalization, new IPOs, and number of existing MLPs are down from the peak years of 2013 and 2014. Through an analysis of several recent “roll-ups” and simplification transactions, we identify issues in the MLP model that may affect its success moving forward. Last, this paper considers the recent Hess Midstream IPO to identify in what cases the traditional MLP model may still prove to be successful moving forward.

Danielle Arostegui (EEP)

Advised by: Lori Benneer

Group Members: Rachel Brinks, Ryan Callihan, Leah Louis-Prescott, Lauren Mechak

Recommendations for Implementing a Carbon Tax in Boulder, Colorado

Boulder, Colorado, a small city located approximately 30 minutes outside of Denver, has historically funded its Climate Action Plan through a tax on electricity (“CAP tax”). In addition to generating revenue, the CAP tax serves as a carbon pricing mechanism. With the CAP tax expiring in 2023, this report examines what updates the city could make to the tax so it: 1) continues to generate revenue, 2) incorporates other fuels such as natural gas, and 3) better reflects the societal cost of greenhouse gas emissions. We provide recommendations and next steps to the city based on our analysis of the city’s regulatory authority, research on worldwide carbon pricing systems, and quantitative model results. We find that a charge reflecting the full social cost of carbon (~\$42 in 2020) could greatly increase revenue beyond historical CAP tax levels, and that incorporating the natural gas sector at a lower rate could provide long-term funding stability for the city.

Susana Arredondo (DEL)

Advised by: David Hinton

Public Acceptance of Pure Water Soquel, A Groundwater Replenishment and Seawater Intrusion Prevention Project

WaterReuse (recycled wastewater for drinking) is proven to be safe technology for drinking. However, public acceptance of drinking highly purified wastewater can still be hard to swallow. In California, water providers like Soquel Water District must be forward-thinking and secure drinking water sources. With climate change causing seawater intrusion and over drafting of the groundwater, this is impacting the fresh drinking water to the area. A solution is to replenish the groundwater with recycled wastewater to prevent sea water intrusion and increase water quality. But first, public acceptance must be understood, and more importantly at the community-based level. Soquel Water District operates a Mobile Learning Center Trailer and an on-site Learning Center. Each center is equipped with visual aids but no on-site pilot study. After being toured, this project measured the change in public acceptance. Why is this project valuable? Smaller water reuse projects will be more common and require less funding in the long run. This project answers how effective visual aids are to gain public acceptance of recycled wastewater for drinking and has turned the dial on this new water source. In California, this new paradigm of drinking recycled wastewater is here, and here to stay but only with the help of public acceptance to support sustainable water resources.

Madeline A. Atkins (WRM)

Advised by: Jeff Hughes & Martin Doyle

The State of Water and Wastewater Utility Debt in North Carolina

Over the next 20 years, North Carolina water and wastewater systems will require up to \$26 billion in capital costs to improve degrading infrastructure. Debt financing is a popular option to raise capital to fund these projects, as revenues from water sales alone are not usually sufficient to finance large projects. This study seeks to understand the current state of water and wastewater debt in North Carolina and quantify future financial capacity for issuing debt. Data on all local government debt issuances from 1951 to 2017 was obtained from the North Carolina Department of State Treasurer Local Government Commission. Analyses find that as of the end of fiscal year 2017, local government utilities in North Carolina have a total of \$8.3 billion in outstanding water and wastewater debt. Additional analyses of debt service payments are performed to provide insight into the future capacity of utilities to issue debt.

Roian O. Atwood (DEL)

Advised by: Deborah Gallagher

Examining the Use of Scenario Planning in Corporate Sustainability Strategy

Corporate sustainability practitioners utilize a variety of different tools to engage a company's senior leadership and deliver value back to a business organization through reduced risk or cost, improved operational efficiency, or increased revenue generation. Strategy and planning professionals have used scenario planning to predict global oil crises, rebuild post-apartheid South Africa, and advance military maneuvers. This project evaluated the intersection of corporate sustainability and scenario planning through a literature review of core themes, personal interviews with scenario planners and sustainability professionals, and case study research on how companies were able to utilize scenario planning in corporate sustainability. The two case studies pertained to PepsiCo's use of scenarios to build their Performance with Purpose program, and a multi-company collaboration focused on the future of commerce called Retail Horizons. The results demonstrated that there is an opportunity to use scenario planning to better integrate corporate sustainability into business process, set meaningful goals and engage stakeholders by facilitating a trend-based exercise whereby participants are able to explore the uncertainty of future worlds in which their companies must operate. When the conditions are right for scenario planning, corporate sustainability practitioners potentially have an opportunity to use this strategy tool to embed good corporate citizenship while exploring futures where business thrive in tandem with a well-nourished population and sustain global resources.

Laura L. Bader (ESC)

Advised by: Daniel Richter & Nicolette Cagle

Group Members: Daniel Hickey, Michelle Kaiser, Sarah Sanford

Urban Forest Planning for the Forest History Society in Durham, NC

It is rare to find an urban forest that matches the biological diversity and habitat quality of an untouched, non-urban forest. For this Master's Project, we worked in one of the few remaining patches of untouched forest within the city limits of Durham, North Carolina. We worked with a local nonprofit called the Forest History Society (FHS) to assess how FHS can attain their educational and outreach goals through the creation of a new headquarters site on a 9-acre plot of urban forest in Durham. We conducted three analyses: (1) a forest inventory assessing how vegetation and property characteristics of the site will change over the next 100 years in managed and unmanaged scenarios, (2) a trail feasibility analysis assessing how, where, and with what type of content FHS could build an interpretive trail on the new site, and (3) community outreach assessing how FHS can best connect with the Durham community. Results of the analyses were used to provide recommendations to FHS on management of the property, teaching opportunities, interpretive trail design, and public interface and outreach.

Nicholas C. Becker

Advised by: Grant Murray

Judging Size Limits on Blue Marlin in the Gulf Coast Triple Crown Tournaments

The main event in Gulf Coast Triple Crown tournaments is the weighing of giant Blue Marlin at the weigh scales. Blue Marlin have to be a certain size to be killed in these tournaments, also known as the size limit. The size limits in these tournaments however, allow smaller Blue Marlin to be weighed each tournament that will not win any prize money or place on the leaderboard. Thus, they are wasted. Changing a size limit has implications from a social, economic, and biological standpoint. This project analyzed catch data from the tournaments for the past five years as well as interviews with tournament directors, fishermen, and people of the industry to determine what was the best size limit to reduce waste. The final result is a recommendation for the Gulf Coast Triple Crown Tournament Series on what size limit they should employ in their tournaments going forward that makes sense from an economic, biological, and social aspect.

Jourdan E. Blackwell (CEM)

Advised by: Deborah Gallagher

Group Members: Taylor Brennan, Emily True

Developing Strategic Benchmarking, Innovation, and Communication in the Global Certification Market for Fair Trade USA

FairTrade USA (FTUSA) is a leading third party certification scheme with a focus on triple bottom line benefits of global agricultural commodities. The issue FTUSA wanted to address was how best to effectively communicate their impact to brands and consumers in their annual impact reports. Research was conducted on global retailers, consumer product goods brands, and certification schemes to assess the landscape in order to benchmark FTUSA. The major themes found were as follows: optimizing through partnerships, data as a perspective, human rights and social advancement, removing boundaries, and economic stability. Based on the top performers, a grading methodology was used to create a comprehensive report card. This report card along with internal interviews were used to influence the new, updated "best in class" impact report focusing on coconut as a case study.

Adam M. Blake (WRM/MBA)

Advised by: Deborah Gallagher

Group Members: Devon Bonney, Amanda Duggan, Amanda Gibson, Geoff Luke

Emerging Professional Perspectives on Sustainability

Increasingly, global companies must balance short-term objectives with longer-term opportunities in response to a changing climate. Corporations have a great deal to gain from reframing climate-related risks into opportunities for growth, innovation, and operational efficiency. In turn, business schools have an opportunity to train emerging business leaders in mitigation and response strategies to address environmental and climate-related risk. This multi-faceted research project examines how corporations view non-financial risk, particularly as it relates to climate change and in turn, how MBA students - as a proxy for emerging business leaders - perceive climate-related risks and opportunities. Results indicate that corporations are aligned in their focus on non-financial risks as a category but vary across industries on the importance and relevance of what constitutes 'material.' MBA students place greater value on mitigating environmental and social disruption risk when primed of its importance but do not feel adequately prepared to address emergent social and environmental issues as corporate professionals.

Hannah E. Blondin (CEM)

Advised by: Pat Halpin & Daniel Dunn

Evaluating Electronic Methods of Fisheries Monitoring, Control, and Surveillance

Management of the world's fisheries has become an increasingly important issue over the last several decades, as several stocks have begun to decline - some more rapidly than others. Electronic Technologies encompass a suite of new technologies that can be used to monitor catch, gear usage, reporting, bycatch, and vessel activity. This paper summarizes findings from a three-part study on the evaluation of electronic technologies in fisheries monitoring, control and surveillance (MCS) world-wide. Part I focuses on the various electronic methods that are currently employed within managed fisheries and the distribution of programs that use these methods across the globe, focusing particularly on Remote Electronic Monitoring (REM) and Vessel Monitoring Systems (VMS). Part II is an extensive literature review on the use of REM within fisheries management. Specifically, it analyzes successes and failures of the use of REM in fishery MCS programs. Further, it makes recommendations on the application of the technology to fisheries management worldwide in support of the Environmental Defense Fund (EDF) Fishery Solution Center's Global Electronic Monitoring Project. Part III takes a deeper look into VMS by analyzing VMS data from mid-water trawling vessels in Sierra Leone. A Hidden Markov Model (HMM) is used to spatially distinguish between fishing activity and non-fishing activity to 1) determine the distribution of mid-water trawling effort in Sierra Leone waters and 2) determine if industrial vessels may be fishing illegally in areas that are restricted within these waters.

Devon E. Bonney (EEP/MBA)

Advised by: Deborah Gallagher

Group Members: Adam Blake, Amanda Duggan, Amanda Gibson, Geoff Luke

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as it relates to climate change and in turn, how MBA students - as a proxy for emerging business leaders - perceive climate-related risks and opportunities. Results indicate that corporations are aligned in their focus on non-financial risks as a category but vary across industries on the importance and relevance of what constitutes “material.” MBA students place greater value on mitigating environmental and social disruption risk when primed of its importance but do not feel adequately prepared to address emergent social and environmental issues as corporate professionals.

Tali K. Brennan (CEM)

Advised by: Deborah Gallagher

Group Members: Jourdan Blackwell, Emily True

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Rachel M. Brinks (EEP)

Advised by: Lori Benneer

Group Members: Danielle Arostegui, Ryan Callihan, Leah Louis-Prescott, Lauren Mechak

Recommendations for Implementing a Carbon Tax in Boulder, Colorado

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Samantha A. Burdick (CEM)

Advised by: A. Brad Murray

Effects of Bulkheads on Salt Marsh Erosion: A Multi-decadal Assessment Using Remote Sensing

Salt marshes, and the ecosystem services they provide, are threatened by coastal development and the use of hardened stabilization structures such as bulkheads. This study investigated the effect of bulkheads on marsh erosion using aerial imagery of Bogue, Back, and Core Sounds from 1981-2013. Rates of marsh erosion adjacent to bulkheads ($-0.17 \hat{\pm} 0.02$ m yr⁻¹) were significantly higher than erosion at natural marsh controls when accounting for upland migration ($-0.05 \hat{\pm} 0.02$ m yr⁻¹). Erosion was greatest in high wave energy environments, but bulkheads did not significantly amplify the effect of wave energy on erosion. Shoreline

hardening may increase rates of salt marsh loss by 300% due, in large part, to preventing upland migration as water levels rise (i.e. coastal squeeze) as well as reflection of wave energy. Ultimately, these results may inform shoreline stabilization policy in North Carolina and beyond.

Amanda M. Bushell (EEP/MBA)

Advised by: Martin Smith

A Pricing Model and Environmental Impact Analysis for Manure-based Biochar as a Soil Amendment

Gasification as a manure management practice provides an alternative to land-application that is increasingly regulated for large-scale operations. The output from gasification, manure-based biochar, may be used as a soil amendment to restore degraded soils, capture water, reduce fertilizer application and increase yields. These benefits are realized financially by farmers and environmentally by communities. Current biochar products on the market are made from plant-based feedstocks and are priced with little consistency; the lowest market price is \$50/ton and the highest is \$5000/ton with an average global price of \$2200/ton. In this project, a breakeven floor price of manure-based char is found to be \$383.19/ton. Using value-based pricing methodology comparative to plant-based alternatives, the commodity price could be between \$600-1000/ton and the commodity price of a value-added char-based product would exceed \$1200/ton. Interviews with farmers in California suggest that vineyard producers may be a primary market segment for initial adoption due to long timeframe investments. Almond farmers may also be willing to adopt as a part of a broader water-risk mitigation strategy.

Alexandra C. Cagan (EE/MBA)

Advised by: John Buley

Group Members: Elizabeth Arnason

Master Limited Partnerships: Implications for US Energy Infrastructure

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Ryan Callihan (EEP)

Advised by: Lori Bennear

Group Members: Danielle Arostegui, Rachel Brinks, Leah Louis-Prescott, Lauren Mechak

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Boulder, Colorado, a small city located approximately 30 minutes outside of Denver, has historically funded its Climate Action Plan through a tax on electricity ("CAP tax"). In addition to generating revenue, the CAP tax serves as a carbon pricing mechanism. With the CAP tax expiring in 2023, this report examines what updates the city could make to the tax so it: 1) continues to generate revenue, 2) incorporates other fuels such as natural gas, and 3) better reflects the societal cost of greenhouse gas emissions. We provide recommendations and next steps to the city based on our analysis of the city's regulatory authority, research on worldwide carbon pricing systems, and quantitative model results. We find that a charge reflecting the full social cost of carbon (~\$42 in

2020) could greatly increase revenue beyond historical CAP tax levels, and that incorporating the natural gas sector at a lower rate could provide long-term funding stability for the city.

Ananya Chaurey (EE)

Advised by: Lincoln F. Pratson

Group Members: Ziting Huang, Lina Khan

Energy Storage Pathways to Meet California's 2030 Greenhouse Gas Reduction Goals

In California, due to solar resources coming online during the day, renewable generation often exceeds demand, leading to curtailment. However, during peak evening hours, California is forced to rely on GHG emitting thermal power plants. This will make it difficult for the state to meet its aggressive GHG reduction target of 40% below 1990 levels by 2030. AB 1405 and SB 338 are two proposed bills that call for a clean peak standard, where utilities are required to meet a certain percentage of peak hour electricity from clean resources. The purpose of this study is to evaluate the use of utility scale battery storage to achieve the clean peak standard, and aid California's GHG reduction efforts. The study estimates electricity demand and generation profile in 2030, and uses an Excel-based optimization model to determine an ideal storage capacity and dispatch strategy. Finally, it investigates the total energy storage cost requirements for different scenarios.

Paula A. Chavez Carreno (CEM)

Advised by: Andrew Read

Predicting Cetacean Habitat in the Colombian Pacific EEZ: Challenges and Recommendations

The study of cetaceans in the Colombian Pacific Exclusive Economic Zone (CP-EEZ) has been limited to their distribution and abundance, but little is known about their habitat preferences and ecological processes determining their range. This study establishes a baseline habitat model for cetaceans that occur in this area, using presence-only data for humpback whale (*Megaptera novaeangliae*), bottlenose dolphin (*Tursiops truncatus*), pantropical spotted dolphin (*Stenella attenuata*, coastal and offshore form) and sperm whale (*Physeter macrocephalus*). MaxEnt was used to model habitat suitability using static and dynamic environmental variables. Models for all species except for sperm whales had AUC > 0.7 indicating acceptable model performance. For humpback whale, depth is the main variable that contributes to the modeled distribution, while the distance to shore is a higher contributor for the small cetaceans. Non-directed cetacean surveys with appropriate methodologies prevent the use of better modeling approaches, and therefore, identifying areas of higher priority for conservation and management is difficult. This study provides an initial step to work with the best available data in the country, but it is necessary to improve data collection to understand cetacean ecology as well as to improve management practices.

Megan R. Chery (DEL)

Advised by: Martin Doyle

A Framework for Incorporating Water Efficiency into State-level Climate Change Adaptation Planning

Anticipated climate change impacts such as frequent droughts, snowpack loss and changes in runoff timing may affect water supply availability for municipal uses. Urban water efficiency builds resiliency by improving supply reliability, watershed protection, and flood management. State governments are increasingly conducting climate change adaptation planning and addressing water resource challenges. This study reviews policies and plans across all states and develops case studies on three states to assess the inclusion of water efficiency in state-level adaptation planning. Results show that half of states have addressed water efficiency, with variability in targets, implementation, and enforcement approaches. Going further, semi-structured interviews were conducted to provide recommendations for how states can effectively advance water efficiency for resiliency.

Samantha M. Childress (EE)

Advised by: Timothy Johnson

Microgrids in the Congo: A Utility's Transition from Diesel to Solar Generation

Kivu Green Energy serves 260 commercial and residential electric customers in Beni, a city in the North Kivu region of Democratic Republic of the Congo via two distribution networks. The utility is in the process of transitioning its primary resource from diesel generation assets to solar photovoltaic electricity production paired with battery energy storage. The client, KGE, desires an onsite islanded microgrid, comprised of solar and battery storage, to provide clean and reliable electricity to their office space for business operations. This purpose of this paper is to describe the market influences, data inputs, and components necessary for designing an optimized microgrid solution that meets the financial, environmental, and energy requirements of Kivu Green Energy and to evaluate the potential business growth landscape for the company within the region.

Caitlyn M. Cooper (ESC)

Advised by: Nicolette Cagle

Lemur Species-Habitat Relationships at Multiple Spatial Scales in Ranomafana National Park, Madagascar

Lemur populations are threatened by many factors, but are most impacted by habitat loss, fragmentation, and alteration. Studies have shown that there is a lag time between habitat disturbance and species response. Thus, more data is needed on long-term relationships between forest change and lemur populations to fully understand how anthropogenic disturbances affect lemurs over time. To bridge this data gap, this study evaluates lemur biodiversity and abundance in three levels of forest disturbance (heavily logged, selectively logged, and pristine forest) at multiple spatial scales. This project 1) isolates which specific microhabitat and landscape variables are important for different lemur species 2) evaluates if the habitat is significantly different between the three forest sites, and 3) evaluates if lemur biodiversity is significantly different between recovering and pristine forests. These results will not only help determine species-specific habitat requirements for critically endangered lemurs, but also contribute to previous data sets on recovering forest monitoring.

Barbara C. Cozzens (DEL)

Advised by: Stuart Pimm

Evaluating Interventions to Mitigate Human-Wildlife Conflict: A Rationale for Using Realist Review

Mitigating human-wildlife conflict often involves complex socio-ecological interventions acting on complex socio-ecological systems. As with many social policy problems, interventions are fundamentally dependent on context, circumstances, stakeholders and implementation. As a result, evidence of an intervention's effectiveness is often mixed or conflicting. The aim of this paper is to introduce the realist review, a research synthesis model designed to work with complex social interventions. I argue this explanatory-analysis approach can provide greater support and information utility to conservation practitioners and decision makers managing human-wildlife conflict. Through an evaluation of the use of virtual fencing, I demonstrate how this realist approach to evaluation can provide the conservation community with the kind of rich, thorough and practical understanding of complex human-wildlife conflict interventions that is critical for informed, evidence-based decision making.

Gina N. Daniel (EEH)

Advised by: Jim Zhang

The Effects of Indoor Air Filtration on Peak Expiratory Flow (PEF) in Asthmatic Children: A Cross-Over Trial in Shanghai, China

Air pollution is an international environmental and public health issue. With an estimated 92% of the world's population living in areas exceeding the World Health Organization's air pollution standards many individuals and households turn to environmental control measures like indoor air filtration devices to reduce exposure to

air pollutants and protect health. The health effects of air pollution are universal, but there are susceptible populations which are more sensitive, such as asthmatic children. This study examines the effect of an indoor air filtration intervention on the peak expiratory flow (PEF) of asthmatic children, by conducting a cross-over trial in Shanghai, China. Results show that the use of an air filtration system within a child's bedroom does significantly improve PEF measurements.

Kendall Delyser (ESC/MF)

Advised by: Brian Murray

Group Members: Allison Petro, Alexander Rudee, Leo Wang

Carbon for Conservation

The Nature Conservancy's North Carolina chapter (TNC NC) is exploring opportunities to secure additional financing for their conservation work through the sale of carbon offset credits in regulatory or voluntary markets. This project assesses the prospects for TNC NC to develop carbon offset projects on forest lands and pocosin wetlands in North Carolina for that purpose, including risks associated with project development. We developed a site prioritization model to identify a subset of parcels meeting TNC NC's criteria for establishing a carbon offset project, which we then evaluated for carbon sequestration potential and projected financial performance. Based on this analysis, we will present recommendations on project types and specific properties within the state that may be attractive to TNC NC for a carbon offset project.

Michael J. DeNoia (EE/MBA)

Advised by: Timothy Johnson

Emission and Efficiency Improvements for Duke University's Transportation System

In the United States, the transportation sector accounts for approximately 1/3 of energy consumption and 1/3 of total CO₂ emissions. In fiscal year 2017, the Duke University GHG footprint was 258,582 metric tons of CO₂e, 27% from transportation-related sources, 52% of these further originating from employee commuting. In support of its Climate Action Plan, the university set a goal to reduce the employee single occupancy vehicle (SOV) commute rate from the 2013 baseline of 73% to a rate of 68% in 2018, but increased headcount and average employee commute distance have made attaining this goal difficult. The goal of this project was to consider underlying factors influencing commuter mode choice, to identify hurdles to adoption of alternative modes of transit, and to develop recommendations for innovative solutions for helping to reach the university's climate goals. This analysis first assessed the current employee commuting behavior and metrics used to quantify GHG impact. In doing so, it also considered limitations of our current infrastructure and practices and identified institutional improvements needed to support effective transportation planning. The project then considered potential short-term programs for implementation and provided a sensitivity analysis of the GHG impact, dependent on employee participation in such programs. Finally, it provided next steps for piloting the recommended programs at Duke and projections for achieving short and long-term emissions goals.

Elihu R.M. Dietz (EE)

Advised by: Timothy Johnson

As the Grid Gets Cleaner, Will Microgrids Lower Emissions in New York?

In New York, severe storms such as Superstorm Sandy in 2012, have knocked out power to large areas, raising interest in building microgrids, which provide resiliency. The state has set a goal to produce 50% of its electricity from renewable resources by 2030, and reduce GHG emissions by 40%, also by 2030. As the electric grid adds renewable resources, how will a microgrid need to be designed to help reduce emissions? In this study, electric and thermal demands were simulated using DOE's Commercial Reference Buildings and EQuest for five buildings in Westchester County, New York. The bi-level optimization software HOMER was used to design a microgrid using Combined Heat and Power (CHP) and then simulate hourly performance over 13

years. Electricity emission factors for CO² increase in a CHP microgrid scenario versus a baseline, with no CHP microgrid. In addition to providing resiliency and other distributed resource benefits, microgrids are 25-year assets and may also need to contribute to lowering carbon emissions.

Katherine E. DiPrete (WRM)

Advised by: Michael O'Driscoll

Evaluating the Use of Periphyton as a Biological Indicator of Nutrient Over-Enrichment in North Carolina Wadeable Streams

As primary producers, periphyton play a significant role in aquatic ecosystems. Physical and chemical conditions of waterbodies can be determined by the composition and abundance of assemblages present. They are quick to respond to changes in water quality and can be used as early warning indicators of eutrophication and other deteriorating conditions. The North Carolina Department of Environmental Quality (NCDEQ) is currently working to define nutrient criteria for the State's water bodies. As a component of this project, biomass and taxonomic identification of periphyton were evaluated in the Upper Cape Fear River Basin to assess if periphyton can effectively detect nutrient impairment in wadeable streams. Results show that taxonomic communities identified to the genus level in the laboratory can adequately predict nitrogen and phosphorus concentrations. Specific conductance measured in the field can also be used to predict trends in nutrient concentrations. Land use cover can be used to identify potential nutrient problem areas. More research is needed to adequately determine if patterns exist between periphyton biomass and nutrient concentrations.

Chris Dougher (EE/MBA)

Advised by: Timothy Johnson

Breaking Down the Lithium-Ion Cell Manufacturing Supply Chain in the U.S. to Identify Key Barriers to Growth

While the U.S. government has invested millions in research efforts surrounding energy storage and lithium-ion technology over the past four decades, much of the manufacturing capacity has gone to other countries. This trend is expected to continue with the gap for lithium-ion cell manufacturing between the U.S. and others widening. Potential barriers to this domestic growth were identified and investigated. Findings are presented in an effort to improve visibility of hurdles and generate discussion around possible solutions. Energy storage is the key enabling technology for renewable energy and an electrified transportation market. Manufacturing is critical to reap the benefits of innovation investment and to drive economic independence.

Amanda Duggan (EE/MBA)

Advised by: Deborah Gallagher

Group Members: Adam Blake, Devon Bonney, Amanda Duggan, Amanda Gibson, Geoff Luke

Emerging Professional Perspectives on Sustainability

Increasingly, global companies must balance short-term objectives with longer-term opportunities in response to a changing climate. Corporations have a great deal to gain from reframing climate-related risks into opportunities for growth, innovation, and operational efficiency. In turn, business schools have an opportunity to train emerging business leaders in mitigation and response strategies to address environmental and climate-related risk. This multi-faceted research project examines how corporations view non-financial risk, particularly as it relates to climate change and in turn, how MBA students - as a proxy for emerging business leaders - perceive climate-related risks and opportunities. Results indicate that corporations are aligned in their focus on non-financial risks as a category but vary across industries on the importance and relevance of what constitutes 'material.' MBA students place greater value on mitigating environmental and social disruption risk when primed of its importance but do not feel adequately prepared to address emergent social and environmental issues as corporate professionals.

Eva Drinkhouse (ESC)

Advised by: Randall Kramer

What Hinders the Implementation of Non-Lethal Wolf Deterrents: A Qualitative Analysis of Interviews with Wolf Management Stakeholders

Emotions run high over wolf management, due to fears of their attacks on livestock and concern over intelligent, social animals being lethally removed from public lands. Some conservation organizations tout nonlethal depredation prevention as the solution, yet lethal methods remain the primary means of conflict management. Through semi-structured interviews with stakeholders in Idaho, Montana, and Wyoming, this study aims to reveal what forces underlie the disconnect between popular opinion of nonlethal methods versus the continued reliance on lethal control as well as discover insights on how to encourage more nonlethal implementation. Results show expectations, culture, and poor relationships fuel this conflict. Furthermore, nonlethal control can be effective, but also has considerable limitations, particularly cost-efficiency. Moving forward, better relationships and collaboration are key.

Olivia L. Eskew (BE)

Advised by: Saskia Cornes & Deborah Gallagher

A National Strategy for the Co-location of Solar and Agriculture

Pollinators are crucial to the United States' food supply and agricultural productivity, playing a key role in the size, health, and quality of a wide variety of harvests. Unfortunately, many pollinator species are in decline due to disease, ecosystem destruction, environmental factors, and other issues, hurting thousands of farms across the nation. At the same time, solar energy projects are expanding and agricultural-adjacent land is often a desirable location for solar arrays. Planting native vegetation and managing it in a way that is hospitable to pollinators can expand pollinator populations and improve the aesthetics of solar arrays. Recommendations to authorize the creation of a pollinator standard are provided within this best practice guide to provide a more robust set of site-specific guidelines for pollinator-friendly habitat installation and management. Future research and collaboration is needed within the utility-scale solar industry to expand the current scope of this pilot assessment.

Jianing Fang (BE)

Advised by: John Virdin

Group Members: Vanessa Navarro

Evaluating Ecosystem Services in ETPS Mangrove Systems

Although their total area constitutes only a small percentage of global tropical forests, mangroves supply a wide range of goods and services that benefit people, flora and fauna. They protect coastlines from the impact of storms, provide habitat for numerous fish species, improve water quality and even store carbon, thereby alleviating the effects of global climate change. And yet, despite offering all of these benefits, mangrove systems are rapidly shrinking worldwide. To reverse this trend, many studies have attempted to place economic values on the ecosystem services that mangroves provide. In this report, we focus on the mangrove forests of the Eastern Tropical Pacific Seascape (ETPS), which includes the countries of Ecuador, Panama, Costa Rica and Colombia. Through a meta-regression of mangrove ecosystem service valuation studies and by utilizing the MangroveCarbon toolbox, we aim to determine the monetary values of the mangrove ecosystem services in this region, and to investigate the factors that most influence those values. The hope is that our analyses will better inform future conservation efforts in the ETPS.

Vanessa Ferrero Mendoza (EE)

Advised by: Dalia Patino-Echeverri

Developing Clean Energy in Nigeria: Data-centric Solutions for a Solar-hybrid Company

Nigeria has long suffered from high electricity prices coupled with an unreliable grid. As a result, many Nigerians have turned to generating their own power with diesel generators, using this expensive fuel to make up for their country's unsatisfactory services. My client, Aspire Power Solutions (APS), is a start-up company trying to address these problems by providing citizens with a cleaner, cheaper alternative: solar-hybrid systems. APS has begun selling systems for commercial and residential customers in urban areas, with hopes of expanding into rural and off-grid regions in the future. In order to be successful, APS wants to incorporate the use of data into their business model, to deliver the best and most efficient solutions and outperform their competitors. This project considers how APS can use data in three main aspects of their business: optimizing their solar-hybrid system design, determining which customers are the most financeable, and accessing crowdfunding for their clean energy projects. Through researching a wide variety of sources (from web sites, to journal articles, to videos, to personal communications), recommendations were determined for each of these three focus areas. Finally, the resources and capabilities that APS would need to successfully implement these suggestions are discussed.

Sydney N. Fishman (CEM)

Advised by: Patrick Halpin

Developing a Methodology to Assess Transportation Vulnerability to Recurrent Tidal Flooding

Despite the moniker of "nuisance flooding," the recurrent flooding of coastal cities during high tides poses risks to people and property that extend beyond minor inconveniences. The frequency of this recurrent tidal flooding is expected to increase as sea levels rise. Using publicly available data, this study develops a methodology to assess local vulnerability of coastal cities' transportation infrastructure and residents to tidal flooding. Geospatial analysis methods identify roads, public transit infrastructure, and socially vulnerable populations with potential physical exposure to flooding, while an evaluation of local planning documents suggests a lack of preparedness for coastal flood hazards. Recommendations for improving and expanding upon this exploratory methodology are provided, as are recommendations to local officials and stakeholders for reducing risk in the face of this growing hazard.

Sean J. Flaherty (DEL)

Advised by: Deborah Gallagher

Integrating Internal Sustainability Management Strategies for Gresham, Smith & Partners Corporate Social Responsibility Statement and Sustainability Policy

Gresham, Smith and Partners (GS&P), is one of the largest design firms in the United States. The firm celebrated its 50-year anniversary in 2017 and has a portfolio that reflects the depth of its diverse and broad disciplines with a vision focused on "building value with clients, the firm's professionals, and the world." The company dedicates itself to the practice of social, economic and environmental stewardship for the betterment of staff and our communities; however, GS&P does not currently have an overarching sustainability strategy focused on internal operations. In order to fill this gap, this research strives to capture an understanding of perceptions, attitudes, and priorities of GS&P associates, managers, and executives with regard to sustainable operations. Insights gathered through the creation and distribution of GS&P administrative and office manager surveys, formal interviews with key informants across the firm, along with a survey of current trends within other organizations and formal interviews with practice leaders at leading companies, will be used to develop key components of a long-term internal sustainability management strategy.

Kathryn Gaasch (ESC)

Advised by: Elizabeth Albright & Norman Christensen

Community Perceptions of Wildfire and Controlled Burning

Community backlash following the western North Carolina wildfires in 2016 revealed patterns of miscommunication and distrust regarding forest management practices. To improve messaging in fire-impacted communities, a pilot survey study was conducted in Morganton, NC. The study explored community perceptions of wildfire and controlled burning threats, the variables that might explain them, and whether perceptions of controlled burning can be affected by messaging. Results showed that wildfire threat perceptions were explained by political alignment, gender, perceived wildfire risk to personal residence within ten years, and belief that wildfire is a natural part of the ecosystem. Controlled burning threats were also explained by political alignment and belief that wildfire is a natural part of the ecosystem. Perceptions of controlled burning may also be changed due to effective and targeted messaging.

Peter W. Ganz (EE)

Advised by: Lori Benneer & Rob van Haaren

Solar PV+S and the CAISO Energy Market

The rise of renewable energy generation throughout the United States has been especially impactful in California. Plentiful solar and wind resources combined with pro-renewable energy state policy goals have led to the rapid scaling of renewable generating resources in the state. This rapid penetration has led California's independent system operator, California ISO (CAISO), to introduce methods for financially settling imbalances between day-ahead generation awards and variable, real-time energy production. This study explains how imbalances in the CAISO Energy Market are financially settled for variable energy resources, and investigates the practicality of pairing a utility-scale battery system with a utility-scale solar photovoltaic system to improve the economic performance of the resulting hybrid solar & storage power plant. This study considers both the physical constraints of operating a battery system and the CAISO market rules, seeking to find the battery system size that optimizes the internal rate of return for an energy developer considering a battery project.

Gregory H. Gausewitz (DEL)

Advised by: Daniel Vermeer

Circular Economy in the Outdoor Industry: Assessing Progress, Challenges, and Opportunities in Developing Circular Product Models for Outdoor Hard Goods Products

The term "circular economy" is often used to describe an idealized consumer product model where products at the end of their useful life are recycled as inputs to material manufacturing or returned harmlessly to the biosphere. The transition to a circular economy, however, requires significant action by many parties across the global value chain and is still nascent. While there is an emerging body of research on this topic, hard goods in the outdoor industry is a product category that has not been the subject of much research to date. This report features case studies that assess various such products that represent components of circular product models. The case studies explore the progress made and challenges encountered in deploying circular product models. Finally, the report identifies opportunities to further deploy circular product models across this category and beyond.

Amanda C. Gibson (EEP/MBA)

Advised by: Deborah Gallagher

Group Members: Adam Blake, Devon Bonney, Amanda Duggan, Geoff Luke

Emerging Professional Perspectives on Sustainability

Increasingly, global companies must balance short-term objectives with longer-term opportunities in response to a changing climate. Corporations have a great deal to gain from reframing climate-related risks into

opportunities for growth, innovation, and operational efficiency. In turn, business schools have an opportunity to train emerging business leaders in mitigation and response strategies to address environmental and climate-related risk. This multi-faceted research project examines how corporations view non-financial risk, particularly as it relates to climate change and in turn, how MBA students - as a proxy for emerging business leaders - perceive climate-related risks and opportunities. Results indicate that corporations are aligned in their focus on non-financial risks as a category but vary across industries on the importance and relevance of what constitutes 'material.' MBA students place greater value on mitigating environmental and social disruption risk when primed of its importance but do not feel adequately prepared to address emergent social and environmental issues as corporate professionals.

Amber A. Halstead (CEM)

Advised by: Lisa Campbell

Assessing and Communicating Flood Risk in Currituck County in Partnership with The Nature Conservancy

Flooding is a major threat to communities along the North Carolina coast. Currituck County specifically has seen several major flood events in the last few years. Currently, almost 60% of the county is in a flood zone, a designation that helps mitigate flood risks by ensuring property owners purchase flood insurance. Currently in the process of being adopted, new federal flood maps for the county will remove 64% of the structures from the special flood hazard area. County officials are concerned that these new maps will encourage residents to drop their flood insurance, leaving them more vulnerable to devastating flood events. This project utilized online surveys and participatory mapping meetings to assess the perception of flood risk in the county as well as concerns about flooding and flood insurance. I then used the information gathered to construct a flood communication plan for Currituck County that would help them to better communicate the true risk of flooding to residents.

Jill A. Hamilton (CEM)

Advised by: Xavier Basurto & John Virdin

Supporting Small-scale Fisheries: World Bank Aid, Objectives and Interventions over Time

Coastal, small-scale fisheries account for 46 percent of the total global fish catch and are the ocean's largest employer. Ninety percent of small-scale fisheries (SSF) are found in developing countries, and the proper management of SSF plays a key role in global food security and poverty eradication. The World Bank, a multilateral aid agency focused on reducing poverty and promoting sustainable development globally, provided more than \$475 million in funds explicitly targeted to support SSF from 2000 to 2017. As the biggest individual funder of SSF, analyzing World Bank aid can be a valuable proxy for understanding global aid trends and support strategies for SSF. A review of World Bank projects targeted to support SSF was conducted, and project components, including funding amount, geographic scope, project objective, issue framing, intervention type, project success indicators, project success rating, and lessons learned were identified and analyzed over time. Understanding global efforts to support small-scale fisheries, including the distribution of funding and the types of interventions used for support, can help identify best practices and improve the sustainable management of small-scale fisheries into the future.

Brendan Hannon (EE)

Advised by: Michelle Nowlin

Possible Pathways to Purchasing Pig-Poop Power: A Situation Assessment of Duke University's Proposal to Power a CHP Plant with Renewable Biogas

Swine waste in North Carolina is a wicked problem that impacts human health, water quality, soil health and the global climate. Smithfield Foods, the largest hog producer in North Carolina (and the world) recently announced their intention to capture methane from their hog farms that could be used as a renewable biogas. This comes at a time when Duke University is searching for energy sources that will help it achieve its carbon neutrality goals. This report provides a situation assessment of the plan for Duke University to power a proposed Combined Heat and Power plant using renewable biogas from eastern North Carolina. The analysis considers the nascent biogas market as a part of the Food-Water-Energy nexus to identify necessary research to ensure such a market would be truly sustainable. The report concludes with a proposal that might address issues of nutrient cycling and environmental justice caused by the current system of CAFO hog production in North Carolina in addition to GHG emissions.

Hayley M. Hanway (ESC)

Advised by: Rebecca Vidra

Communicating Science Doesn't Have to Suck

Communications is a critical component of a land trust's success. Since land trusts are mainly private, non-profit organizations, they are heavily dependent on donors and volunteers. A strong communications strategy will attract new donors and volunteers while retaining old ones. This project for the Land Conservancy of West Michigan (LCWM) evaluates different communications platforms and strategies and provides a list of recommendations for an effective communications plan. Research was conducted via a literature review, a survey disseminated to LCWM members, and informational interviews with other environmental organizations. Final recommendations include prioritizing Facebook, Instagram, and Youtube/Vimeo over other forms of social media, investing in an annual (or five-year) professional paper magazine product, strengthening partnerships with local organizations, and holding more events for outreach.

Adam Harms (DEL)

Advised by: Martin Doyle

Feasibility Study: Establishing a Voluntary Blue Carbon Market in the Mississippi River Deltaic Plain

The situation of Louisiana's coastal wetlands, at the output of the U.S.'s largest watershed, threatens the welfare of the region's people and industries, which are experiencing significant effects from climate change and rising sea levels. But the region's geography also presents robust opportunities for solutions - in fact, there are few places as well-suited as the Gulf Coast of the Southeastern U.S., and especially the coastline of Louisiana, for incubating innovative resiliency models that can be replicated and improved upon elsewhere. One significant opportunity could be the implementation of an environmental crediting market that would incentivize preservation of soil carbon levels in the wetlands of the Mississippi River Deltaic Plain - a voluntary "blue carbon" market. Such a market could encourage scaled restorative management practices, maintain the region's high levels of soil-sequestered carbon, and create \$1.6 billion in direct value for stakeholders. This feasibility study explores the major hurdles and levers for implementation, and recommends potential paths forward for funding and implementing a voluntary blue carbon market.

Christine A. Hayes (CEM)

Advised by: Xavier Basurto

Learning from Performance of Small-scale Fishery Development Projects

Small-scale fisheries (SSF) have risen to prominence in the global development agenda to meet the ambitious targets of the 2015 United Nations Sustainable Development Goals to eradicate poverty and ensure food security. As organizations seek to engage with SSF around the globe, it is important to look at characteristics

that contribute to the successful outcomes of SSF development projects. This study analyzes projects providing external financial or technical support to SSF from two levels 1) the local community level utilizing case studies from three Pacific Island countries and 2) at larger spatial scales through a qualitative meta-analysis of the published scientific literature to understand global trends in SSF development projects. By evaluating localized case studies of success, this study identifies and explores some common characteristics of successful initiatives in Pacific Islands small-scale fisheries. The global scan of the published literature hopes to inform understanding of how successful outcomes might change when projects are scaled up to larger spatial extents. Results show that success is most often cited in positive social outcomes, including social cohesion and improvements in participatory management. In a global scan of published literature on SSF development projects, 34 projects deliver support to SSFs at a scale larger than 20 communities. Results of both components of this project were incorporated into internal SSF engagement strategies.

Daniel B. Hickey (MF)

Advised by: Daniel Richter & Nicolette Cagle

Group Members: Laura Bader, Michelle Kaiser, Sarah Sanford

Urban Forest Planning for the Forest History Society in Durham, NC

It is rare to find an urban forest that matches the biological diversity and habitat quality of an untouched, non-urban forest. For this Master's Project, we worked in one of the few remaining patches of untouched forest within the city limits of Durham, North Carolina. We worked with a local nonprofit called the Forest History Society (FHS) to assess how FHS can attain their educational and outreach goals through the creation of a new headquarters site on a 9-acre plot of urban forest in Durham. We conducted three analyses: (1) a forest inventory assessing how vegetation and property characteristics of the site will change over the next 100 years in managed and unmanaged scenarios, (2) a trail feasibility analysis assessing how, where, and with what type of content FHS could build an interpretive trail on the new site, and (3) community outreach assessing how FHS can best connect with the Durham community. Results of the analyses were used to provide recommendations to FHS on management of the property, teaching opportunities, interpretive trail design, and public interface and outreach.

Nicola Hill (WRM)

Advised by: Martin Doyle

Group Members: Oshin Paranjape, Xin Yu

Historical Trends and Projections of U.S. Industrial Water Use: A Case Study of Texas, Indiana, and North Carolina

Chemical, oil & gas, and textile manufacturing industries are the major divers of United States industrial water use, shaping both the economy and water trends in the regions they inhabit. Texas (TX), North Carolina (NC), and Indiana (IN) are dominant examples of states influenced by the fluctuation of these industries and have therefore been selected as case studies. This study analyzes historical, spatial-temporal trends in water use and makes projections for next decade using robust datasets of monthly facility-level water use data. The datasets indicate that spatially, water use and locations of facilities have remained centralized near the coast of TX, while facilities have shifted towards small clusters throughout NC and IN. NC and IN monthly water use follow a seasonal pattern with consistent major users. Additionally, TX industrial water use is estimated to decrease in next decade while the other two states remain stable.

Ziting Huang (EE)

Advised by: Lincoln F. Pratson

Group Members: Ananya Chaurey, Lina Khan

Energy Storage Pathways to Meet California's 2030 Greenhouse Gas Reduction Goals

In California, due to solar resources coming online during the day, renewable generation often exceeds demand, leading to curtailment. However, during peak evening hours, California is forced to rely on GHG emitting thermal power plants. This will make it difficult for the state to meet its aggressive GHG reduction target of 40% below 1990 levels by 2030. AB 1405 and SB 338 are two proposed bills that call for a clean peak standard, where utilities are required to meet a certain percentage of peak hour electricity from clean resources. The purpose of this study is to evaluate the use of utility scale battery storage to achieve the clean peak standard, and aid California's GHG reduction efforts. The study estimates electricity demand and generation profile in 2030, and uses an Excel-based optimization model to determine an ideal storage capacity and dispatch strategy. Finally, it investigates the total energy storage cost requirements for different scenarios.

Sean K. Ireland (ESC)

Advised by: Jennifer Swenson

Group Members: Teagan Rostock

Conservation Beyond Protected Areas

Research in the conservation space has most often focused on traditional protected areas like national parks as being the model places that provide the benefits and values of conserved land like high biodiversity, healthy habitats, and balanced ecosystems. However, other classes of land like sacred groves have the potential to contribute to these same conservation values. We assessed the conservation value of sacred groves by analyzing two specific variables: 1) forest loss that is happening in and around the groves and 2) the groves' contributions to habitat connectivity. A comparison analysis between the amount of forest loss in areas surrounding sacred groves and the district in which the sacred groves are located was performed. This analysis was used to determine if and the extent to which sacred groves help prevent forest loss. Two connectivity analyses were performed: a creation of habitat corridors and an analysis using a set of geoprocessing tools called GeoHAT. These analyses were used to compare what the connectivity of the landscape looks like, both with and without the sacred groves. Results show that despite the historic forest loss in the region, loss in more recent decades is minimal and does not differ with proximity to sacred groves. Results of the connectivity analyses indicate that the sacred groves' contributions to the connectivity of the region is negligible. This is likely due to their extremely small size along with the severity of fragmentation in the region.

John T. Jacobs (ESC/MF)

Advised by: Dean Urban

Prioritizing Land Conservation: Using Geospatial Analysis to Assist a Land Trust's Multi-criteria Decision Making

With increasing development pressures, ever-present funding limitations, and complex stewardship responsibilities, land trusts today place a premium on devoting resources to the most promising conservation projects. Taking advantage of the growing abundance of geospatial data, land trusts are wisely taking steps to integrate geospatial analysis into the decision-making framework. This analysis assists a land trust in the Southeast with developing a robust system for evaluating parcels on their predicted conservation value. It explores tradeoffs in preference for various landscape metrics like scenic value and aquatic resources and how they impact parcel value depending on the focus of partnering agencies and funding opportunities. Ultimately, the priority results assist the land trust in responding to project inquiries as well as developing a proactive conservation strategy.

David M. Johnson (DEL)

Advised by: Chris Wedding

Corporate Procurement of Renewable Energy as a Key Driver in the Decarbonization of the Power Industry

Private companies, motivated by commitments to sustainability, have replaced utilities as the primary buyer of utility scale renewable energy. Positive market fundamentals benefit the new corporate buyer. Renewable energy is competing well against unprecedented and sustained low natural gas prices - - wind and solar costs have declined to where market parity is the norm. System operators are solving the intermittency challenge with advances in digital technology that provide instant feedback and control. Renewable energy is growing against a backdrop of a balkanized regulatory system that confounds a competitive supply of this zero-marginal cost resource. We are starting to see regulated utilities offering new tariffs for offsite renewable energy as an economic development tool. However, corporate renewable energy procurement is reliant on a complex contracting structure. This complexity is wed to limited funding vehicles centered on project finance underwriting. This paper discusses the potential for optimizing the corporate purchase and finance structure, increasing capital markets funding alternatives, and aligning developer's supply requirements.

Kelsey E. Johnson-Sapp (CEM)

Advised by: Thomas Schultz & John Burns (University of Hawaii)

A Tale of Two Reefs: Quantifying the Complexity of Artificial Reefs and Natural Reefs Utilizing Structure-from-Motion 3D Modeling

Coral reefs have experienced severe global decline from compounding pressures like ocean acidification, bleaching, and disease, rendering neighboring coastlines vulnerable to the impacts of shoreline erosion from sea level rise. In lieu of natural defenses, coastal cities like Miami have installed artificial structures to serve as both breakwaters and sites of coral recruitment. However, the degree of manmade structures' success in fulfilling these roles when compared to natural reefs is heavily debated. Structure-from-Motion is a cutting-edge 3D technique that models large-scale areas to millimeters of precision to calculate metrics of complexity. Photogrammetry data of artificial and natural reefs was collected off of the coast of Miami to compare the rugosity and coral coverage of each site as a proxy to suggest which type of habitat performs best in mitigating shoreline erosion. Results reveal that both types of reefs had strengths in different metrics of complexity, but artificial reefs were dominant in overall terrain ruggedness. However, natural reefs were comparable in all other metrics, which is significant considering the area with the highest coral coverage was noticeably low at 30%. Coral coverage on all artificial sites was negligible, demonstrating that coral recruits have a specific preference for settling on existing natural reefs.

Michelle Kaiser (ESC/MF)

Advised by: Daniel Richter & Nicolette Cagle

Group Members: Laura Bader, Daniel Hickey, Sarah Sanford

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Koichi S. Kanaoka (EE)

Advised by: Megan Mullin

State of Recycling in the U.S. and Value of Recyclable Waste Streams in Orlando, Florida

Recycling benefits local economies by recovering the value of wastes and creating jobs. However, the U.S. recycling rate has been stagnating around 34% for the past decade. This study aimed to investigate the drivers and barriers for increasing recycling rates in the U.S. Government reports on recycling rates in the past ten years were compiled and mapped. Then, the values of waste streams in Orlando Metropolitan Area's single-stream recycling system were forecasted for 10 years. The forecasted values were used to conduct a cost-benefit analysis for building a material recovery facility for separating waste in Orlando. Results from the study suggest that values of single-stream waste in Orlando may reach \$100 million in 2027, from \$72 million in 2015. Two materials, cardboard and aluminum cans, accounted for 70-90% of the waste stream's value, while only accounting for 32% of the mass. The study also found that recycling was not a profitable business for waste processors in Orlando due to high costs of processing and low landfilling costs. As a result, support from local government bodies will be vital for improving recycling rates in Orlando.

Lina Khan (EE)

Advised by: Lincoln F. Pratson

Group Members: Ananya Chaurey, Ziting Huang

Energy Storage Pathways to Meet California's 2030 Greenhouse Gas Reduction Goals

In California, due to solar resources coming online during the day, renewable generation often exceeds demand, leading to curtailment. However, during peak evening hours, California is forced to rely on GHG emitting thermal power plants. This will make it difficult for the state to meet its aggressive GHG reduction target of 40% below 1990 levels by 2030. AB 1405 and SB 338 are two proposed bills that call for a clean peak standard, where utilities are required to meet a certain percentage of peak hour electricity from clean resources. The purpose of this study is to evaluate the use of utility scale battery storage to achieve the clean peak standard, and aid California's GHG reduction efforts. The study estimates electricity demand and generation profile in 2030, and uses an Excel-based optimization model to determine an ideal storage capacity and dispatch strategy. Finally, it investigates the total energy storage cost requirements for different scenarios.

Isshu Kikuma (EE)

Advised by: Timothy Johnson

Group Members: Elizabeth Rublev, Xuebei Tan

Siting of Utility-Scale Solar in North Carolina

In 2007, North Carolina passed a Renewable Energy Portfolio Standard (REPS), the first in the Southeast. The REPS mandated that 12.5% of the state's electricity demand be met with renewable energy by 2021. 29 states, Washington D.C., and 3 territories also have Renewable Portfolio Standards (RPS). The REPS, combined with North Carolina's interpretation of the 1978 Public Utility Regulatory Policies Act (PURPA), unleashed a torrent of activity in the state, making it second in the nation for installed solar PV. Our project, using publicly available data and a geographical information system (GIS), creates a screening tool to: (1) identify potential sites for utility-scale solar in North Carolina, given a set of physical constraints; and (2) generate supply curves for those selected sites, given a set of economic considerations. This screening tool can be used by city planning boards, zoning commissions, policy analysts, solar developers, and others to gain a better understanding of utility-scale solar projects and make project development processes smoother, facilitating better environmental outcomes and supporting sustainable economic growth in North Carolina and the U.S.

Group Members: Timothy Swavely

Use of Carbon Footprint Monitoring Application to Modify Human Behavior

Greenhouse gas buildup within the earth's atmosphere has an adverse impact on the Earth. By trapping warmth through the reflection of heat back towards the earth's surface, global temperatures increase. An individual's carbon footprint is described as the total greenhouse gas emissions generated by an individual's everyday activities such as transportation, residential energy usage, and household waste generation. The United States is the second large producer of greenhouse gases behind China. In 2016, the United States emitted 6,546 million Metric Tons of carbon dioxide equivalent greenhouse gases. Of these 6,546 million Metric Tons, 5.4% or 354 million metric tons are emitted by residential economic sector. Through research on behavioral change methodologies combined with smartphone application development surveys this project's objective is to design and develop a smartphone application mock-up that calculates individual carbon emissions and provides positive feedback to users in order to influence behavior change instrumental in reducing residential carbon emissions.

Dominic M. Lee (EE)

Advised by: James Hench & Charlotte Clark

Group Members: Yige Liu, Taylor Price

Developing a Climate Action Plan for the Nicholas School of the Environment and the Duke Marine Lab

It has been nearly 10 years since Duke University's formal commitment to climate action via the creation of the first campus-wide climate action plan, "Growing Green: Becoming a Climate Neutral Campus". As the Duke Office of Sustainability, looks to continue its journey towards carbon neutrality, they are exploring additional avenues to create change. At the same time, the Duke University Marine Lab, based in Beaufort, North Carolina, also has sights set on reducing their campus carbon emission. This study investigates the feasibility of each school creating their own specific Climate Action Plans to supplement the university-wide plan. Furthermore, this study will provide insights into the feasibility of school-specific climate action plans at the university at large as well as provide recommendations for the Nicholas School and the Duke Marine Lab. The results provide an assessment of the greenhouse gas footprint of the Nicholas School and the Duke Marine Lab both long and short recommendations to drive the campus towards carbon neutrality.

Jason Y. Lee (EEP)

Advised by: Xavier Basurto

Group Members: Zoey Z. Xu

How Should the Fundacion Rio Arronte Allocate \$15 million Annually to Address Mexico's Water Problems

The Fundacion Gonzalo Rio Arronte would like to make the best use of around \$15 million a year to improve sanitation and clean water access in Mexico. The challenge is that water resources in Mexico exhibit significant spatial and temporal variation, often in a contradictory pattern to socioeconomic resources. We categorized possible interventions into four categories: technology-based solutions, community outreach and capacity building, microfinancing, and green infrastructure. Through a literature review, a review of NGO reports, and interviews with selected global NGOs, we find the best practices being used around the world in each of these four areas. Our results will assist our client in its future decision making and in forming strategic priorities.

Bobbi E. Lesser (BE)

Advised by: Jesko Von Windheim & Jesse Daystar

An Analysis of CREE's Scope 3 Greenhouse Gas Emissions

Cree is a lighting and semi-conductor company headquartered in Durham, North Carolina. To more-fully understand their environmental footprint, Cree requested the calculation and analysis of their Scope 3 greenhouse gas emissions. This study used data provided by Cree to calculate the company's Scope 3 emissions in four areas: lighting product use; the end-of-life for lighting products; waste generated from direct manufacturing processes; and the transportation and distribution of products. Our analysis determined that the product use phase generated the most Scope 3 emissions in 2016, followed by the transportation and distribution phase. Based on these calculations, the team provided a set of recommendations advising Cree on how they can more easily calculate, track, and reduce their Scope 3 emissions. The methodology and dataset created by the team can be used by Cree for future greenhouse gas analyses.

Brooke A. Levin (EEP/MBA)

Advised by: Jesko von Windheim

Potential for Cryptocurrency to Fund Investment in Sustainable Real Assets

In an era filled with concerns about the preservation of scarce resources, climate change and the environment, investing in and protecting assets related to sustainability and the environment has become an area of greater focus and increased importance to the general population and the investment community. One way of investing in this area is through "sustainable real assets." With the rapidly growing popularity of blockchain, new vehicles for raising capital for investments and projects have developed. These include cryptocurrency and Initial Coin or Initial Token Offerings. These types of offerings enable firms to issue virtual currency, tokens, or coins, also known as cryptocurrency, instead of conventional debt or equity, to raise funds for a given project. This paper looks at the potential for cryptocurrency to fund additional investment in sustainable real assets.

Shuyue Li (ESC)

Advised by: Jennifer Swenson

Seagrass Mapping and Human Impact Evaluation Using Remote Sensing Imagery at Core Banks, North Carolina

Seagrass can provide key ecological service to coastal areas, yet is experiencing significant decline worldwide, mainly due to coastal human population pressures. This project focuses on influence of boating recognized by propeller scars. The goal of this project is to explore the methods for seagrass mapping based on both drone and satellite remote sensing imagery, and evaluate the impact on seagrass from boat propellers using ultrahigh-resolution drone imagery. By analyzing ultrahigh-resolution images surveyed over Core Banks, NC, the results have proved a successful application of Object-Based Classification in classifying drone images of submerged habitats; human activities have lasting effects on seagrass habitat, since seagrass in scar-affected regions has greater rate of both growth and decline. The results also show that propeller scars found in areas with higher density of seagrass are more likely to recover, although this conclusion need further confirmation with on-the-ground species composition data. Based on high-resolution satellite imagery, automated seagrass mapping is feasible through simple thresholding of computed ReGNDVI (Red Edge-Green-NDVI) images. This founding has potential for large-area seagrass mapping, and might be useful for conservation of coastal areas.

Chuwen Liang (EEP)

Advised by: Junjie Zhang

Group Members: Shijie Liu, Xin Pan

Legal Nature of the Emission Allowance in China's National Carbon Trading Scheme

Emission trading scheme (ETS, or Cap-and-Trade Program) is a market-based approach used worldwide to reduce greenhouse gases emissions and mitigate climate change. However, the legal nature of emission allowances in the ETS is controversial and differs across countries, which brings concerns to the operation of the market and the feasibility of cross-region trading. This issue has been raised in China since its national ETS was initiated in 2017, but little relevant literatures can be found. Through literature review and case analysis, this study tries to fill the research gap by examining the regulations of 42 countries and regions with enforced ETS. The study 1) classifies the legal nature of emission allowance into 4 types: property right, compliance instrument, limited property right and depend-on-context, 2) summarizes the features of different classifications, and 3) explores the factors that may influence the choice of legal nature.

Shijie Liu (EEP)

Advised by: Junjie Zhang

Group Members: Chuwen Liang, Xin Pan

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Yige Liu (GEC)

Advised by: James Hench & Charlotte Clark

Group Members: Dominic Lee, Taylor Price

Developing a Climate Action Plan for the Nicholas School of the Environment and the Duke Marine Lab

It has been nearly 10 years since Duke University's formal commitment to climate action via the creation of the first campus-wide climate action plan, "Growing Green: Becoming a Climate Neutral Campus". As the Duke Office of Sustainability, looks to continue its journey towards carbon neutrality, they are exploring additional avenues to create change. At the same time, the Duke University Marine Lab, based in Beaufort, North Carolina, also has sights set on reducing their campus carbon emission. This study investigates the feasibility of each school creating their own specific Climate Action Plans to supplement the university-wide plan. Furthermore, this study will provide insights into the feasibility of school-specific climate action plans at the university at large as well as provide recommendations for the Nicholas School and the Duke Marine Lab. The results provide an assessment of the greenhouse gas footprint of the Nicholas School and the Duke Marine Lab both long and short recommendations to drive the campus towards carbon neutrality.

Adam R. Long (EE)

Advised by: Jesko Von Windheim

Group Members: Colin Walker

Financially Viable Sustainability Solutions for Multifamily Residential Properties

Drucker and Falk is a family-owned real estate company that focuses on third-party fee management of multifamily properties. Through isolated LED retrofit projects, Drucker and Falk realized the environmental and financial benefits of sustainability projects and is now seeking to implement financially viable sustainability solutions for its whole portfolio of more than 350 properties. In order to provide solutions that work for all Drucker and Falk properties, this study created a best practices guide and interactive Excel-based models that Drucker and Falk can use to identify and analyze potential sustainability strategies. This project then conducted case studies, applying the provided tools to three Drucker and Falk properties in order to demonstrate the process and benefits of increased sustainability practices. The case studies revealed potential environmental benefits and cost savings in utility bill management, lighting retrofits, pool pump alterations, and future building design. The tools provided by this project, along with the case study findings, will be used as a foundation for additional analysis and implementation of sustainability projects across the entire Drucker and Falk portfolio.

Leah Louis-Prescott (EE)

Advised by: Lori Bennear

Group Members: Danielle Arostegui, Rachel Brinks, Ryan Callihan, Lauren Mechak

Recommendations for Implementing a Carbon Tax in Boulder, Colorado

Boulder, Colorado, a small city located approximately 30 minutes outside of Denver, has historically funded its Climate Action Plan through a tax on electricity (“CAP tax”). In addition to generating revenue, the CAP tax serves as a carbon pricing mechanism. With the CAP tax expiring in 2023, this report examines what updates the city could make to the tax so it: 1) continues to generate revenue, 2) incorporates other fuels such as natural gas, and 3) better reflects the societal cost of greenhouse gas emissions. We provide recommendations and next steps to the city based on our analysis of the city’s regulatory authority, research on worldwide carbon pricing systems, and quantitative model results. We find that a charge reflecting the full social cost of carbon (~\$42 in 2020) could greatly increase revenue beyond historical CAP tax levels, and that incorporating the natural gas sector at a lower rate could provide long-term funding stability for the city.

Geoff B. Luke (EE/MBA)

Advised by: Deborah Gallagher

Group Members: Adam Blake, Devon Bonney, Amanda Duggan, Amanda Gibson

Emerging Professional Perspectives on Sustainability

Increasingly, global companies must balance short-term objectives with longer-term opportunities in response to a changing climate. Corporations have a great deal to gain from reframing climate-related risks into opportunities for growth, innovation, and operational efficiency. In turn, business schools have an opportunity to train emerging business leaders in mitigation and response strategies to address environmental and climate-related risk. This multi-faceted research project examines how corporations view non-financial risk, particularly as it relates to climate change and in turn, how MBA students - as a proxy for emerging business leaders - perceive climate-related risks and opportunities. Results indicate that corporations are aligned in their focus on non-financial risks as a category but vary across industries on the importance and relevance of what constitutes ‘material.’ MBA students place greater value on mitigating environmental and social disruption risk when primed of its importance but do not feel adequately prepared to address emergent social and environmental issues as corporate professionals.

Impacts of Hunting and Human Disturbance on Wildlife in Gabon

Bushmeat from wild animals is the primary source of protein and income for many rural communities in northeastern Gabon. Using camera traps, we investigated whether hunting and other forms of human disturbance resulting from resource extraction activities like logging alter mammal communities in tropical forests. The results of our study indicate that hunting and human disturbance reduces large mammal abundance close to roads. We found that observations of monkeys increased with distance from Makokou, the largest city in the region. We also found that the abundance of small mammals like squirrels and rats responds positively to the density of logging roads. Our models showed no indication that anthropogenic activities influence species richness. Together, this suggests that the reduction of large mammals in hunted and disturbed areas may benefit small mammal populations by reducing competition for resources.

Group Members: Paige Swofford

Financing Renewable Energy in Cuba

Cuba's recent commitment to generate 24% of the country's electricity with renewable sources by 2030 presents a unique opportunity to explore how a small island nation can lead in decarbonizing their power system. Cuba has a significantly high electrification rate, a very high dependence on imported fossil fuels, and only 4% of electric generation from renewable sources. Several renewable energy projects have been announced to date, but there is still a significant shortfall. In this study, we present an assessment of the challenges and opportunities that Cuba faces to attract the necessary foreign investment to achieve its renewable energy goals. Our main objective is to present information that can be useful both to investors seeking to enter the Cuban market and to officials in Cuban and other island states who are planning for a transition to a more sustainable and resilient electricity system. We provide a review of the status of the physical and institutional infrastructure of the country's electricity sector, a summary of recent laws and regulations governing foreign investments, and a synopsis of the recent efforts by Caribbean island states and their success. Through a lens of project finance and foreign direct investment (FDI) theory, our research assesses how the government can finance the remainder of the projects needed to hit their goals through evaluating the policy and regulatory environment within Cuba and identifying best practices for attracting foreign investment to develop renewable energy projects.

Assessing Decision-making in Shoreline Management Among North Carolina's Waterfront Property Owners

The state of North Carolina is abundant in coastal resources including more than 12,000 miles of estuarine shoreline. Of approximately 600 miles of "modified" shoreline, 86.8% involve a bulkhead. Many coastal states now recommend the use of alternative stabilization methods, such as living shorelines or marsh sills. In comparison to bulkheads, seawalls and other hardened structures, these soft shore stabilization techniques better approximate the natural functions of the estuarine ecosystem while slowing the rate of erosion, often at a lower cost. Despite this, bulkheads remain the preferred method of erosion prevention in North Carolina. This project seeks to understand North Carolina waterfront property owners' perceptions on options for shoreline stabilization and the critical factors in their decision-making. Information gathered from a series of semi-structured interviews is used to make outreach recommendations within the state's permitting framework.

Donal C. O'Brien, Jr. Sanctuary Landscape Environmental and Economic Appraisal

The Audubon Society is in a constant effort of requesting funds to maintain, protect and mitigate high priority areas to strive for their organization's mission. Convincing both private and public parties to contribute to their mission is in need of more accurate economic valuation. Pine Island Sanctuary is home to many migratory birds, rare species and healthy marsh, but what exactly do these species contribute in terms of economic value? This is the purpose of this project, to undergo considerable literature research, geospatial analysis, and ecosystem valuation to provide the Audubon Society with an economic valuation of their marsh. With this information, the Audubon Society hopes to reverse biased market activities from ecosystem degradation and over-exploitation towards conservation and mitigation.

Kristen McKinley (EEH)

Advised by: Avner Vengosh

Scope and Origin of Hexavalent Chromium in North Carolina Groundwater

Potential groundwater contamination from coal ash ponds is a current public health concern in North Carolina. One of the suspected contaminants is chromium, particularly the toxic hexavalent chromium form. A recent study on chromium in groundwater from the Piedmont Aquifers of NC finds that chromium is more prevalent than previously thought due to geogenic sources from water-rock interactions in naturally enriched mafic rock formations. To expand on the prior work, this project generates a dataset of private, domestic, and monitoring wells across the Mountain, Piedmont, and Coastal regions of NC to investigate the scope and origin of hexavalent chromium in groundwater. Geospatial and statistical analyses provide evidence that higher concentrations of hexavalent chromium are associated with rock formations containing major mafic and possible mafic constituents but those containing significant minor mafic constituents. Additionally, correlation tests provide additional evidence that hexavalent chromium is the predominant species of dissolved chromium in groundwater.

Madeleine M. McMillan (ESC)

Advised by: Stuart Pimm

Threats to Big Cats in South East Asia

Southeast Asia is experiencing extensive rates of habitat conversion as biodiverse areas are rapidly being replaced with homogenous oil palm plantations grown to produce vegetable oil. These oil palm plantations have exploded over recent decades, altering the landscape for species such as tigers, leopards, and clouded leopards who depend on large tracts of habitat for survival. To best understand how to protect these big cats and their habitats, I examined 1) the current state of habitat connectivity in Southeast Asia, 2) how oil palm plantation expansion would disrupt habitat, and 3) additional threats challenging big cats such as poaching, forest loss, and human population increase. I identified habitat areas under most threat for each species to inform conservation efforts in the region. Overall, big cats are experiencing greatest threats to their habitats in Malaysia and these habitats should be protected from future anthropogenic influences.

Lauren E. Mechak (EEP)

Advised by: Lori Bennear

Group Members: Danielle Arostegui, Rachel Brinks, Ryan Callihan, Leah Louis-Prescott

Recommendations for Implementing a Carbon Tax in Boulder, Colorado

Boulder, Colorado, a small city located approximately 30 minutes outside of Denver, has historically funded its Climate Action Plan through a tax on electricity (“CAP tax”). In addition to generating revenue, the CAP tax serves as a carbon pricing mechanism. With the CAP tax expiring in 2023, this report examines what updates the city could make to the tax so it: 1) continues to generate revenue, 2) incorporates other fuels such as natural gas, and 3) better reflects the societal cost of greenhouse gas emissions. We provide recommendations and next steps to the city based on our analysis of the city’s regulatory authority, research on worldwide carbon pricing systems, and quantitative model results. We find that a charge reflecting the full social cost of carbon (~\$42 in 2020) could greatly increase revenue beyond historical CAP tax levels, and that incorporating the natural gas sector at a lower rate could provide long-term funding stability for the city.

Roosevelt A. Mesa (CEM)

Advised by: Andrew Read

Interactions Between Short-finned Pilot Whales (*Globicephala macrorhynchus*) and Pelagic Longline Fisheries in the Cape Hatteras Special Research Area (CHSRA)

Short-finned pilot whales have a long history of interactions with Pelagic Longline (PLL) Fisheries along the East Coast of the United States. These interactions present a threat to both the PLL fisheries’ economic interests and the whales themselves due to their overlapping interest in the highly migratory fish found in this region. The establishment of the Cape Hatteras Special Research Area (CHSRA) was one measure enacted in the PLL Take Reduction Plan in response to the negative interactions in the Area. Through satellite-based tracking systems and PLL fisheries data, this study addressed the spatial overlap between fisheries and whales by examining the distribution of the pilot whales, their relation to oceanographic variables, bycatch records, and fishing effort. Results show that pilot whales have recently been reported as bycatch by PLL activities and that both fishing effort and pilot whale presence strongly overlap in a large portion of the CHSRA. This study highlights the importance of the Area and the need for continued protection in the future.

Emily A. Meza (WRM)

Advised by: Elizabeth Albright & Erika Weinthal

Examining Wastewater Treatment Struggles in Lowndes County, AL

Many people in rural Alabama live without access to proper wastewater treatment. My research for the Alabama Center for Rural Enterprise (ACRE) examines the scope and scale of this issue in Lowndes County, Alabama: a rural county of 11,300 residents in Alabama’s Blackbelt located between Selma and Montgomery. In 2011-2012, ACRE went door to door asking people about plumbing, septic, and sewage issues, covering ~60% of all households. Qualitative and quantitative analysis of this data focused on the three main types of wastewater disposal currently used: municipal lagoons, traditional septic systems, and “straight piping” (lack of any treatment). Spatial point pattern analysis and linear regression were used to test hypotheses of key spatial, physical, and economic predictors of seeing raw sewage on the ground. Results from this work provide both input to policymakers as well as findings to share with the community.

Nicole R. Miller (EE)

Advised by: Dalia Patino-Echeverri

Simulating Financial Returns of Arbitrage Opportunities using Lithium-Ion Battery Storage Paired with Photovoltaic Systems in 3 U.S. Wholesale Electricity Markets

Interest in battery storage as a means to support renewable energy integration has recently increased as more developers continue to build utility-scale renewable energy resources. Yet, the ability for large-scale battery projects to be deployed depends on the ability to make the projects financially attractive. This analysis seeks to determine whether a battery energy storage system paired with a 110MW utility-scale solar PV installation can result in net present value (NPV) positive returns when engaging in electricity price arbitrage. The analysis examines the revenues and costs that would be incurred under 12 different scenarios that vary in assumptions regarding the location of the market -focusing on ERCOT, PJM and CAISO, the intra-day variations in electricity prices, the energy storage capacity of the battery, and the length of the battery charge and discharge. Overall, the results show that the financial viability of large battery storage projects receiving revenues exclusively from electricity price arbitrage requires high intra-day price differentials. Therefore, battery storage remains unprofitable without subsidies at current prices and further means of extracting value from batteries (such as ancillary services), and reduction in capital costs are needed before large-scale Lithium-Ion battery operations become widespread in the United States energy market.

Adam D. Mims (DEL)

Advised by: Dalia Patino Echeverri

Beneficial Use Analysis of Alum Sludge from Drinking-water Treatment Plants for Portland Cement Manufacturing in Holly Hill, South Carolina

The Portland Cement Manufacturing process has utilized a variety of natural and industrial byproduct materials to produce cement products at affordable costs. The global demand for cement is increasing and the effort to reduce emissions has placed emphasis on cement manufacturers to reduce their impacts. Emphasis on locating additional alternative raw materials and replacing decreasing industrial byproduct supplies become more important. A case study was conducted analyzing the industrial by product, alum sludge, from a drinking water treatment plant to assess its feasibility for cement production in South Carolina. The sludge was chemically analyzed and trialed as a raw material feed. A cost benefit analysis reviewed the cost savings between waste disposal and beneficial use as well as an environmental review of CO2 impacts from transportation and mining activities. The sludge is promising as a replacement and further trials and analysis will be needed to confirm its viability.

Megan G. Murray (WRM)

Advised by: Megan Mullin

Mapping Rio Grande Water Rights: A Decision Support Tool for Ecosystem Restoration

In Far West Texas water is a precious, limited resource. Matters relating to water resource allocation are highly contested, often leading to a struggle between municipal, agricultural, and industry users. Unfortunately, these debates leave little to no room for environmental considerations. Thus, The Nature Conservancy (TNC) is pursuing efforts to identify and acquire water rights that could be dedicated or in other ways managed for the benefit and protection of environmental flows. This project is intended to help TNC identify those water rights through an online mapping platform that allows users to select for desirable water right attributes like volume, priority year, and watershed. In addition to the map, this project also examines the intricacies of water rights acquisitions to educate TNC on potential opportunities and sources of conflict. With this information, TNC will be better prepared to identify water rights that support their restoration efforts and minimize friction.

Vanessa Navarro (ESC)

Advised by: John Virdin

Group Members: Jianing Fan

Evaluating Ecosystem Services in ETPS Mangrove Systems

Although their total area constitutes only a small percentage of global tropical forests, mangroves supply a wide range of goods and services that benefit people, flora and fauna. They protect coastlines from the impact of storms, provide habitat for numerous fish species, improve water quality and even store carbon, thereby alleviating the effects of global climate change. And yet, despite offering all of these benefits, mangrove systems are rapidly shrinking worldwide. To reverse this trend, many studies have attempted to place economic values on the ecosystem services that mangroves provide. In this report, we focus on the mangrove forests of the Eastern Tropical Pacific Seascape (ETPS), which includes the countries of Ecuador, Panama, Costa Rica and Colombia. Through a meta-regression of mangrove ecosystem service valuation studies and by utilizing the MangroveCarbon toolbox, we aim to determine the monetary values of the mangrove ecosystem services in this region, and to investigate the factors that most influence those values. The hope is that our analyses will better inform future conservation efforts in the ETPS.

Shane F. O'Neal (ESC)

Advised by: Nicolette Cagle & Ron Sutherland

A Comprehensive Assessment of Red Wolf Reintroduction Sites

The current range of red wolves in the wild is limited to Alligator River and Pocosin Lakes National Wildlife Refuges in northeastern North Carolina, but after their population declined in recent years the Fish and Wildlife Service (FWS) announced plans to remove the wild wolves and find another site for reintroduction. I initiated this project with Wildlands Network to identify the best possible sites for FWS to relocate the wolves successfully. Through a literature review, I established the key ecological and social variables that impact wolves. Then, I located data for each of these variables across the historic range of wolves in the East. Next, I surveyed wolf experts to elicit weights for the variables and identified a suite of 21 possible sites to consider. Results from ArcGIS analysis indicated that Croatan National Forest and Okefenokee National Wildlife Refuge may be the best sites for red wolves to be reintroduced, and provided data for more detailed recommendations regarding other sites and further factors to consider.

Xin Pan (EEP)

Advised by: Junjie Zhang

Group Members: Chuwen Liang, Shijie Liu

Legal Nature of the Emission Allowance in China's National Carbon Trading Scheme

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Oshin Paranjape (ESC)

Advised by: Martin Doyle

Group Members: Nicola Hill, Xin Yu

Historical Trends and Projections of U.S. Industrial Water Use: A Case Study of Texas, Indiana, and North Carolina

Chemical, oil & gas, and textile manufacturing industries are the major drivers of United States industrial water use, shaping both the economy and water trends in the regions they inhabit. Texas (TX), North Carolina (NC), and Indiana (IN) are dominant examples of states influenced by the fluctuation of these industries and have therefore been selected as case studies. This study analyzes historical, spatial-temporal trends in water use and makes projections for next decade using robust datasets of monthly facility-level water use data. The datasets indicate that spatially, water use and locations of facilities have remained centralized near the coast of TX, while facilities have shifted towards small clusters throughout NC and IN. NC and IN monthly water use follow a seasonal pattern with consistent major users. Additionally, TX industrial water use is estimated to decrease in next decade while the other two states remain stable.

Devyn R. Parks (BE)

Advised by: Drew Shindell

Group Members: Minchao Xu

Economic Assessment of Extreme Heat Events on Labor Productivity in the US

Extreme Heat Events (EHE) across the U.S. have become more common as climate change continues to progress. There have been numerous studies on the mortality effects of EHEs but relatively little has been done to study the morbidity effects, especially the economic consequences at a national level. We looked at the economic effect of heat on labor in each U.S. state. From previous studies, labor lost was found to be significant in four high risk occupational sectors: farming, construction, installation, and transportation. Looking at 3 representative years (1983, 2014, and 2016) we found that labor lost per state increased, with California, Texas and Arizona taking the majority of the losses. California was especially prevalent in the farming sector, accounting for ~80% of the losses in the occupational category. For the other 3 sectors, California and Texas accounted for ~40% individually, and Arizona ~6%.

Alison E. Petro (ESC/MF)

Advised by: Brian Murray

Group Members: Kendall DeLyser, Alexander Rudee, Leo Wang

Carbon for Conservation

The Nature Conservancy's North Carolina chapter (TNC NC) is exploring opportunities to secure additional financing for their conservation work through the sale of carbon offset credits in regulatory or voluntary markets. This project assesses the prospects for TNC NC to develop carbon offset projects on forest lands and pocosin wetlands in North Carolina for that purpose, including risks associated with project development. We developed a site prioritization model to identify a subset of parcels meeting TNC NC's criteria for establishing a carbon offset project, which we then evaluated for carbon sequestration potential and projected financial performance. Based on this analysis, we will present recommendations on project types and specific properties within the state that may be attractive to TNC NC for a carbon offset project.

Sarah K. Poulin (CEM)

Advised by: Patrick Halpin & Daniel Dunn

Longitudinal Analysis of Historical Seabird Bycatch Data in the North Pacific

Historical ecology is used by researchers to help understand how past interactions between people and their environment have shaped contemporary conditions. Though recent science has responded to the many management challenges of the ocean, the lack of analysis and limited availability of archival data hinders our ability to place current ocean impacts in the historical context of exploitation. All 22 species of albatross and several species of petrels are currently listed as Near Threatened or Threatened by the IUCN with bycatch cited as the main threat. However, there are very few publicly available datasets on the interactions between fisheries and seabirds before the 1990's. The purpose of this project was to explore and analyze historical data collections from the Smithsonian and the USGS. These overlooked records contain seabird band return cards that specify extensive information from as early as the 1940's on seabird bycatch occurrences in the North Pacific. With the inclusion of this new data, more thorough management may be implemented that accounts for the longitudinal gaps of modern day bycatch records through complementing current data sources with archival datasets.

Taylor Price (EEP)

Advised by: James Hench & Charlotte Clark

Group Members: Dominic Lee, Yige Liu

Developing a Climate Action Plan for the Nicholas School of the Environment and the Duke Marine Lab

It has been nearly 10 years since Duke University's formal commitment to climate action via the creation of the first campus-wide climate action plan, "Growing Green: Becoming a Climate Neutral Campus". As the Duke Office of Sustainability, looks to continue its journey towards carbon neutrality, they are exploring additional avenues to create change. At the same time, the Duke University Marine Lab, based in Beaufort, North Carolina, also has sights set on reducing their campus carbon emission. This study investigates the feasibility of each school creating their own specific Climate Action Plans to supplement the university-wide plan. Furthermore, this study will provide insights into the feasibility of school-specific climate action plans at the university at large as well as provide recommendations for the Nicholas School and the Duke Marine Lab. The results provide an assessment of the greenhouse gas footprint of the Nicholas School and the Duke Marine Lab both long and short recommendations to drive the campus towards carbon neutrality.

Delaney M. Reilly (EEH)

Advised by: William Pan

Examining Interactions of Lead and Repeated Rota Virus Infection on Infant Cognitive Development

The negative impacts of low doses of lead on the developing brain are becoming increasingly well understood. Similarly, the field of gastroenterology is increasingly recognizing the importance of gut health on development and cognition. To understand potential interactions between repeated early life gut injury and lead, infants from Bangladesh, India, Pakistan, and Nepal were assessed for cognition at 6 months. This score was evaluated in relation to the child's blood lead level and incidence of Rota Virus infection. No significant relationship was found, suggesting that instead of repeated intestinal injury increasing nutritive absorption and subsequently increasing lead uptake, this injury be decreasing overall absorption allowing the child to excrete lead that may have otherwise caused further injury. Other possible explanations and further research directions are also discussed.

Lisa A. Remlinger (DEL)

Advised by: Mark Borsuk & Rebecca Vidra

An Analysis of Collaboration

Our world's problems are complex, often crossing boundaries between different communities and sectors. To solve these problems more joint evidence-based solutions are needed. As different communities move towards more collaborative approaches to achieve this, success is not a foregone conclusion. Using the newly formed Bridge Collaborative as its foundation, this analysis studies what elements contribute to cross-sector collaboration success. Interviews, a literature review, and studied examples provide insights into the most frequently found elements across successful collaborations. Findings fell into three types of categories: foundational conditions, structure and governance, and outcomes and accountability. The Bridge Collaborative has a majority of these findings in place, but some will need attention if the Collaborative is to succeed long-term. Time is running out to solve our world's most complex problems, but if done correctly cross-sector collaborations can be a key to evidence-based solutions.

Carley C. Reynolds (EEP)

Advised by: Martin Smith & Erika Weinthal

Group Members: Tara Stout, Yuki Wang

Environmental Impacts of Belt and Road Initiative on Pakistan's Energy Sector

In 2013, China announced the Belt and Road Initiative (BRI), which broadly aims to interconnect over 65 countries in Asia, Europe and Africa through infrastructure investment and economic development. A flagship component of BRI, the China Pakistan Economic Corridor (CPEC), has a strong focus on energy infrastructure development. Currently, coal-fired plants constitute half of announced CPEC energy generation projects and 69% of capacity, throwing doubt on the environmentally friendly rhetoric surrounding the BRI initiative. This paper seeks to understand the cost and feasibility of using alternative technologies and a different energy mix as compared to emission-intensive CPEC energy projects. The levelized cost of electricity, CO₂ emissions, and SO₂ emissions were calculated for current CPEC projects using information gathered from Pakistan generation licenses and tariff documents. Generalized plants, based on current projects and other Pakistan power projects, were then used to build an optimization model around LCOE and emissions under different constraints. Model results show that there were more cost-effective and less polluting options than the current CPEC projects. A literature review additionally examines political and economic factors around CPEC energy projects.

Whitney M. Roberts (CEM)

Advised by: Grant Murray

Values and Perceptions of Shellfish Mariculture in Coastal North Carolina

Declining wild fish populations and an upward demand for seafood contribute to a growing interest in marine aquaculture as a source of fresh, local seafood. This study aims to assess the values and perceptions associated with marine shellfish aquaculture in coastal North Carolina and the prospect of its development in key areas of historical conflict. Using stakeholder interviews and analysis of relevant news media sources, I found that news media tended to perceive marine aquaculture development with more optimism and to address consumer well-being more than stakeholders. Both, however, value clean water as the highest environmental priority. From this study, I conclude that language and narrative framing play a key role in shaping perceptions and that conflating news media perceptions with those of stakeholders can be harmful to aquaculture policy development.

Cheryl B. Ross (DEL)

Advised by: Deborah Gallagher

B Corp Certification at R. Riveter

The B Corp certification is a voluntary third-party standard that measures the social and environmental performance of a business. Unlike some other sustainability frameworks, the B Corp certification is suitable for small to medium size businesses (SMEs). This two-part research study examines the overall value of the B Corp certification for SMEs within North Carolina. The researcher assisted an early-stage manufacturing company, R. Riveter, with the initial steps of the B Corp certification process and also studied the benefits and challenges of achieving B Corp certification by interviewing twelve previously certified North Carolina B Corps. This research provides a snapshot of the B Corp movement within North Carolina and the challenges facing SMEs that are prospective B Corps.

Teagan A. Rostock (ESC)

Advised by: Jennifer Swenson

Group Members: Sean Ireland

Conservation Beyond Protected Areas

Research in the conservation space has most often focused on traditional protected areas like national parks as being the model places that provide the benefits and values of conserved land like high biodiversity, healthy habitats, and balanced ecosystems. However, other classes of land like sacred groves have the potential to contribute to these same conservation values. We assessed the conservation value of sacred groves by analyzing two specific variables: 1) forest loss that is happening in and around the groves and 2) the groves' contributions to habitat connectivity. A comparison analysis between the amount of forest loss in areas surrounding sacred groves and the district in which the sacred groves are located was performed. This analysis was used to determine if and the extent to which sacred groves help prevent forest loss. Two connectivity analyses were performed: a creation of habitat corridors and an analysis using a set of geoprocessing tools called GeoHAT. These analyses were used to compare what the connectivity of the landscape looks like, both with and without the sacred groves. Results show that despite the historic forest loss in the region, loss in more recent decades is minimal and does not differ with proximity to sacred groves. Results of the connectivity analyses indicate that the sacred groves' contributions to the connectivity of the region is negligible. This is likely due to their extremely small size along with the severity of fragmentation in the region.

Elizabeth J. Rublev (EE)

Advised by: Timothy Johnson

Group Members: Isshu Kikuma, Xuebei Tan

Siting of Utility-Scale Solar in North Carolina

In 2007, North Carolina passed a Renewable Energy Portfolio Standard (REPS), the first in the Southeast. The REPS mandated that 12.5% of the state's electricity demand be met with renewable energy by 2021. 29 states, Washington D.C., and 3 territories also have Renewable Portfolio Standards (RPS). The REPS, combined with North Carolina's interpretation of the 1978 Public Utility Regulatory Policies Act (PURPA), unleashed a torrent of activity in the state, making it second in the nation for installed solar PV. Our project, using publicly available data and a geographical information system (GIS), creates a screening tool to: (1) identify potential sites for utility-scale solar in North Carolina, given a set of physical constraints; and (2) generate supply curves for those selected sites, given a set of economic considerations. This screening tool can be used by city planning

boards, zoning commissions, policy analysts, solar developers, and others to gain a better understanding of utility-scale solar projects and make project development processes smoother, facilitating better environmental outcomes and supporting sustainable economic growth in North Carolina and the U.S.

Morgan E. Rudd (CEM)

Advised by: Michael O'Driscoll & Grant Murray

An Evaluation of Water Quality Parameters and Flow Dynamics in High Rock Lake, North Carolina to Assist in the Development of Nutrient Criteria for Lakes and Reservoirs in the State

High Rock Dam, located in Rowan and Davidson Counties in North Carolina, was constructed on the Yadkin River in 1927. High Rock Lake (HRL) is primarily fed by the Yadkin River and several smaller tributaries, draining a total area of 3974 square miles. HRL has been on the 303d list of impaired waters since 2004 due to elevated levels of turbidity, chlorophyll-*a*, and pH. The state currently has surface water standards for chlorophyll-*a* (40 ug/l), turbidity (25 NTU- lakes), and pH (<6 or >9), but not for nutrients. NC DEQ chose HRL as a pilot study to help develop nutrient criteria for lakes throughout the state. There is a high degree of spatial variability in water quality in HRL. Turbidity, total nitrogen, and total phosphorus decrease with increasing proximity to the dam, whereas chlorophyll-*a* is most elevated within the mid-section of the lake. Riverine discharge appears to influence chlorophyll-*a* and future studies should aim to identify the impact of discharge of phytoplankton assemblage. An improved understanding of discharge-water quality relationships can help guide nutrient criteria development for the state's reservoirs.

Alexander N. Rudee (EEP)

Advised by: Brian Murray

Group Members: Kendall DeLyser, Allison Petro, Leo Wang

Carbon for Conservation

The Nature Conservancy's North Carolina chapter (TNC NC) is exploring opportunities to secure additional financing for their conservation work through the sale of carbon offset credits in regulatory or voluntary markets. This project assesses the prospects for TNC NC to develop carbon offset projects on forest lands and pocosin wetlands in North Carolina for that purpose, including risks associated with project development. We developed a site prioritization model to identify a subset of parcels meeting TNC NC's criteria for establishing a carbon offset project, which we then evaluated for carbon sequestration potential and projected financial performance. Based on this analysis, we will present recommendations on project types and specific properties within the state that may be attractive to TNC NC for a carbon offset project.

Sarah Sanford (ESC)

Advised by: Daniel Richter & Nicolette Cagle

Group Members: Laura Bader, Daniel Hickey, Michelle Kaiser

Urban Forest Planning for the Forest History Society in Durham, NC

It is rare to find an urban forest that matches the biological diversity and habitat quality of an untouched, non-urban forest. For this Master's Project, we worked in one of the few remaining patches of untouched forest within the city limits of Durham, North Carolina. We worked with a local nonprofit called the Forest History Society (FHS) to assess how FHS can attain their educational and outreach goals through the creation of a new headquarters site on a 9-acre plot of urban forest in Durham. We conducted three analyses: (1) a forest inventory assessing how vegetation and property characteristics of the site will change over the next 100 years in managed and unmanaged scenarios, (2) a trail feasibility analysis assessing how, where, and with what type of content FHS could build an interpretive trail on the new site, and (3) community outreach assessing how FHS can best connect with the Durham community. Results of the analyses were used to provide recommendations

to FHS on management of the property, teaching opportunities, interpretive trail design, and public interface and outreach.

Rajah Saparapa (EEP)

Advised by: Randall Kramer

Local Communities' Perception of Conservation within the National Park of Fazao-Malfakassa in Togo

In 1975, Fazao-Malfakassa National Park of Togo was created. An analysis to understand the value of the land to the local population was not done before dedicating the land as a protected area and the government failed to take into consideration the future land use of the growing local population. As the population increased, land pressure started to become a problem. The rise in conflict, between park managers and local communities, is pushing the conservation community to shift their focus from explaining how important conservation of biodiversity to the ecosystem, to also explaining how important and beneficial it can be to local communities. More in-depth research has been done to understand determinants of local communities' attitudes towards the protected Areas. It is important to understand what drives the attitudes so that effective policies and program can be implemented to either resolve a negative attitude or create a positive one.

Soli Shin (EE)

Advised by: Timothy Johnson

Ancillary Services Participation for Electric Vehicle Fleets

Amid growing concerns of global climate disruption, a diverse set of stakeholders are advocating for deep decarbonization efforts in sectors such as electrical power generation and transportation. This Master's Project (MP) will explore the potential scenarios when these two sectors begin to merge. As the electrification of vehicles becomes commonplace, benefits and limitations will become evident across the U.S. electric grid. The impact of fleet-scale adoption of electric vehicles (EVs) and vehicle-to-grid (V2G) implementation will be discussed. An EV fleet managed by a central entity has the possibility of aggregating their stored power for a grid service through a specialized charger that allows for bi-directional electric flow. The communication software and ability to transfer power from grid to vehicle is called vehicle-to-grid implementation, or V2G. V2G is a broad term with multiple applications. The focus of this MP will be on EV fleets' ability to provide ancillary services. The ancillary services market represents an array of services that provide general grid support, rather than outright electrical power capacity. Ancillary services include services such as frequency regulation and voltage control.

Eric J. Smith (MF/MBA)

Advised by: Jeff Vincent

Multi-Use Valuation Frameworks: Assessing Tradeoffs Among Commercial Timber Production, Conservation Instruments, & Ecosystem Markets

As nascent ecosystem markets continue to develop, the paradigm of traditional forest management is shifting. Land managers are faced with a new set of challenges and opportunities as they assess the potential for managing forest resources for multiple uses. This major transformation is shifting land valuation and management goals towards ecosystem services, resulting in increased opportunities to drive conservation from capital markets. The problem that this client project addressed is to how to accurately value and assess the trade-offs between traditional commercial timber harvesting, the use of conservation instruments such as easements, as well as the development and sale of environmental commodities such as carbon offsets. This project specifically valued the economic options among these competing opportunities on a 40,000-acre bottomland hardwood property in the southeast United States.

Leanne Spaulding (DEL)

Advised by: Elizabeth Shapiro-Garza

Theory versus Practice in Payment for Ecosystem Services in Totonicapán, Guatemala

Payment for Ecosystem Service (PES) initiatives are a popular and wide-spread approach mitigating detrimental impacts of rapid land-use change that threaten vital ecological resources such as water, soil, and timber. The basic premise of PES involves a set of voluntary transactions between the buyers and sellers of a clearly defined ecological service. In theory, sellers – often rural landholders - are incentivized to adopt conservation-based practices to ensure higher quality and quantity of the ecosystem service buyers pay them to provide. Yet in practice, PES initiatives rarely reflect the original market-based model. A debate has surfaced as to why and how this controversial approach to conservation is altered and contested, however few case studies have been documented. To fill this gap, this study documents the history of PES in Totonicapán, Guatemala. The study uses a series of interviews and participant observation to explore how local political, social, environmental and cultural dynamics lead to the contestation and subsequent reshaping of PES programs by local actors. The results of this study provide insight on how PES may be adapted to improve conservation outcomes in rural indigenous communities.

Tara A. Stout (GEC)

Advised by: Martin Smith & Erika Weinthal

Group Members: Carley Reynolds, Yuki Wang

Environmental Impacts of Belt and Road Initiative on Pakistan's Energy Sector

In 2013, China announced the Belt and Road Initiative (BRI), which broadly aims to interconnect over 65 countries in Asia, Europe and Africa through infrastructure investment and economic development. A flagship component of BRI, the China Pakistan Economic Corridor (CPEC), has a strong focus on energy infrastructure development. Currently, coal-fired plants constitute half of announced CPEC energy generation projects and 69% of capacity, throwing doubt on the environmentally friendly rhetoric surrounding the BRI initiative. This paper seeks to understand the cost and feasibility of using alternative technologies and a different energy mix as compared to emission-intensive CPEC energy projects. The levelized cost of electricity, CO₂ emissions, and SO₂ emissions were calculated for current CPEC projects using information gathered from Pakistan generation licenses and tariff documents. Generalized plants, based on current projects and other Pakistan power projects, were then used to build an optimization model around LCOE and emissions under different constraints. Model results show that there were more cost-effective and less polluting options than the current CPEC projects. A literature review additionally examines political and economic factors around CPEC energy projects.

Timothy A. Swavely (DEL)

Advised by: Elizabeth Albright

Group Members: Sara Kitchens

Use of Carbon Footprint Monitoring Application to Modify Human Behavior

Greenhouse gas buildup within the earth's atmosphere has an adverse impact on the Earth. By trapping warmth through the reflection of heat back towards the earth's surface, global temperatures increase. An individual's carbon footprint is described as the total greenhouse gas emissions generated by an individual's everyday activities such as transportation, residential energy usage, and household waste generation. The United States is the second large producer of greenhouse gases behind China. In 2016, the United States emitted 6,546 million Metric Tons of carbon dioxide equivalent greenhouse gases. Of these 6,546 million Metric Tons, 5.4% or 354 million metric tons are emitted by residential economic sector. Through research on behavioral change methodologies combined with smartphone application development surveys this project's objective is to design and develop a smartphone application mock-up that calculates individual carbon emissions and provides

positive feedback to users in order to influence behavior change instrumental in reducing residential carbon emissions.

Paige W. Swofford (EE/MBA)

Advised by: Dalia Patino-Echeverri

Group Members: Harry Masters

Financing Renewable Energy in Cuba

Cuba's recent commitment to generate 24% of the country's electricity with renewable sources by 2030 presents a unique opportunity to explore how a small island nation can lead in decarbonizing their power system. Cuba has a significantly high electrification rate, a very high dependence on imported fossil fuels, and only 4% of electric generation from renewable sources. Several renewable energy projects have been announced to date, but there is still a significant shortfall. In this study, we present an assessment of the challenges and opportunities that Cuba faces to attract the necessary foreign investment to achieve its renewable energy goals. Our main objective is to present information that can be useful both to investors seeking to enter the Cuban market and to officials in Cuban and other island states who are planning for a transition to a more sustainable and resilient electricity system. We provide a review of the status of the physical and institutional infrastructure of the country's electricity sector, a summary of recent laws and regulations governing foreign investments, and a synopsis of the recent efforts by Caribbean island states and their success. Through a lens of project finance and foreign direct investment (FDI) theory, our research assesses how the government can finance the remainder of the projects needed to hit their goals through evaluating the policy and regulatory environment within Cuba and identifying best practices for attracting foreign investment to develop renewable energy projects.

Xuebei Tan (EE)

Advised by: Timothy Johnson

Group Members: Isshu Kikuma, Elizabeth Rublev

Siting of Utility-Scale Solar in North Carolina

In 2007, North Carolina passed a Renewable Energy Portfolio Standard (REPS), the first in the Southeast. The REPS mandated that 12.5% of the state's electricity demand be met with renewable energy by 2021. 29 states, Washington D.C., and 3 territories also have Renewable Portfolio Standards (RPS). The REPS, combined with North Carolina's interpretation of the 1978 Public Utility Regulatory Policies Act (PURPA), unleashed a torrent of activity in the state, making it second in the nation for installed solar PV. Our project, using publicly available data and a geographical information system (GIS), creates a screening tool to: (1) identify potential sites for utility-scale solar in North Carolina, given a set of physical constraints; and (2) generate supply curves for those selected sites, given a set of economic considerations. This screening tool can be used by city planning boards, zoning commissions, policy analysts, solar developers, and others to gain a better understanding of utility-scale solar projects and make project development processes smoother, facilitating better environmental outcomes and supporting sustainable economic growth in North Carolina and the U.S.

Brian D. Taylor (CEM)

Advised by: Daniel Rittschof

Redevelopment Plan for Barrang Lompo, Indonesia

Barrang Lompo, Indonesia is a tiny island located off the coast of Makassar, Indonesia. The island has minimal development, no sanitation system, limited natural resources, and a bleak future. It is home to around 5,000 people, most of whom are fishermen who employ a practice known as "dynamite fishing" that uses explosives to capture fish, but destroys habitats and the fishes' ability to repopulate. The environmental destruction and the

public health problems from the lack of a sanitation system threaten the future viability of the island. To help solve these problems, I performed a public health assessment on Barrang Lompo to gauge the feasibility of installing a bioreactor that converts human waste into usable product, then prepared a proposal to establish a cell phone refurbishment plant on the island. By mitigating the public health problems and providing alternative employment, this project aims to reduce stress on the environment and redevelop Barrang Lompo into a more sustainable community with a promising future.energy projects.

Austin H. Thompson (EEP)

Advised by: Martin Smith

Rising Seas, Falling Funds: An Analysis of Beach Nourishment Finance in Dare County, NC

Climate change presents considerable risk for coastal communities in the southeastern United States, driving adaptive processes, like beach nourishment, with multi-million-dollar price tags. The municipalities of Dare County, NC receive no federal subsidies, but have funded nourishment by establishing Municipal Service Districts (MSD) with additional millage rates for properties that benefit most from project implementation. Despite these municipalities' recent success in completing projects, the relative distribution of costs and benefits was subject to great community protest and debate. This project assesses the drivers of news coverage and public concern for Dare County nourishment, and the distribution of owner-occupied properties within the MSDs of Duck, NC. Results suggest that in Dare County, news coverage and public concern increase two years after particularly damaging storms. In Duck, analysis of properties suggests that successful MSD construction may hinge on satisfying the interests of the voting contingency, rather than reflecting the project's economic benefit.

Emily A. True (BE)

Advised by: Deborah Gallagher

Group Members: Jourdan Blackwell, Taylor Brennan

Developing Strategic Benchmarking, Innovation, and Communication in the Global Certification Market for Fair Trade USA

FairTrade USA (FTUSA) is a leading third party certification scheme with a focus on triple bottom line benefits of global agricultural commodities. The issue FTUSA wanted to address was how best to effectively communicate their impact to brands and consumers in their annual impact reports. Research was conducted on global retailers, consumer product goods brands, and certification schemes to assess the landscape in order to benchmark FTUSA. The major themes found were as follows: optimizing through partnerships, data as a perspective, human rights and social advancement, removing boundaries, and economic stability. Based on the top performers, a grading methodology was used to create a comprehensive report card. This report card along with internal interviews were used to influence the new, updated "best in class" impact report focusing on coconut as a case study.

Lindsay K. Vacek (DEL)

Advised by: Rebecca Vidra

Promoting Prescribed Fire on Private Lands in the Historic Longleaf Range

This project explored impediments to prescribed fire implementation on private lands within the historic longleaf pine range and attempted to identify messaging strategies toward achieving more controlled fire on these lands. Native to the southern United States, longleaf pine thrives in response to prescribed burns. The ecosystem is one of the most biologically diverse in the world and contains multiple threatened and endangered species. Given that 55% of this land currently falls under private ownership, engaging landowners in burning is critical. The researcher's study involved personal interviews with private landowners and forestry consultants in Georgia and Mississippi regarding their experiences and attitudes on prescribed burns. From this group the

researcher chose case studies located in significant geographic areas for longleaf pine restoration that illustrate varied experiences and standpoints on prescribed fire. The researcher began with the hypothesis that liability is the main concern for landowners. Results found that increasing prescribed fire on private lands must also address lack of burning capacity and economic barriers. There is also a great need for experienced practitioners to work with private landowners on a granular level to address individual concerns.

Sarah E. Vogel (DEL)

Advised by: David Hinton

An Analysis of Water Management Strategies in Drought Prone Areas

There is an old adage in the West: “whiskey is for drinking; water is for fighting”. In the West, as well as locales all over the globe, water scarcity is a subject rife with conflicts and emotion. Human beings approach drought in reactionary ways. Rather than plan for the eventuality of drought, societies enact drought policy or regulations well into, and not before experiencing drought conditions. Researchers have predicted that more than half of humanity will live in water-stressed areas in the near future. Understanding the significant role drought plays in water management and the costs of reactionary decision making can help stakeholders create proactive approaches to water allocation. This paper seeks to understand how drought affects water management strategies; how regulation is affected by drought conditions; how local agencies and state authorities interact to manage water resources in California; and how California water management compares to water management strategies employed in other drought prone areas of the globe.

Colin M. Walker (EE)

Advised by: Jesko Von Windheim

Group Members: Adam Long

Financially Viable Sustainability Solutions for Multifamily Residential Properties

Drucker and Falk is a family-owned real estate company that focuses on third-party fee management of multifamily properties. Through isolated LED retrofit projects, Drucker and Falk realized the environmental and financial benefits of sustainability projects and is now seeking to implement financially viable sustainability solutions for its whole portfolio of more than 350 properties. In order to provide solutions that work for all Drucker and Falk properties, this study created a best practices guide and interactive Excel-based models that Drucker and Falk can use to identify and analyze potential sustainability strategies. This project then conducted case studies, applying the provided tools to three Drucker and Falk properties in order to demonstrate the process and benefits of increased sustainability practices. The case studies revealed potential environmental benefits and cost savings in utility bill management, lighting retrofits, pool pump alterations, and future building design. The tools provided by this project, along with the case study findings, will be used as a foundation for additional analysis and implementation of sustainability projects across the entire Drucker and Falk portfolio.

Yuki Wang (EEP)

Advised by: Martin Smith & Erika Weinthal

Group Members: Carley Reynolds, Tara Stout

Environmental Impacts of Belt and Road Initiative on Pakistan’s Energy Sector

In 2013, China announced the Belt and Road Initiative (BRI), which broadly aims to interconnect over 65 countries in Asia, Europe and Africa through infrastructure investment and economic development. A flagship component of BRI, the China Pakistan Economic Corridor (CPEC), has a strong focus on energy infrastructure development. Currently, coal-fired plants constitute half of announced CPEC energy generation projects and 69% of capacity, throwing doubt on the environmentally friendly rhetoric surrounding the BRI initiative. This paper seeks to understand the cost and feasibility of using alternative technologies and a different energy mix as

compared to emission-intensive CPEC energy projects. The levelized cost of electricity, CO₂ emissions, and SO₂ emissions were calculated for current CPEC projects using information gathered from Pakistan generation licenses and tariff documents. Generalized plants, based on current projects and other Pakistan power projects, were then used to build an optimization model around LCOE and emissions under different constraints. Model results show that there were more cost-effective and less polluting options than the current CPEC projects. A literature review additionally examines political and economic factors around CPEC energy projects.

Leo Z. Wang (EEP)

Advised by: Brian Murray

Group Members: Kendall DeLyser, Allison Petro, Alexander Rudee

Carbon for Conservation

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Brian J. Wasserstein (DEL)

Advised by: Elizabeth Albright

Public Water Utilities Objectives Evaluation of Single Family Residence Greywater Systems

Meeting the potable water demand for cities across the world is becoming increasingly difficult considering 54% of the world's population currently live in urban areas. Public water providers have considered a variety of programs to promote potable water conservation including the reuse of greywater, untreated wastewater that is not contaminated by toilet or kitchen discharge. Through interviews with water conservation specialists at public water utilities and analysis of water conservation progress reports, this study evaluates the feasibility and relative success of the most commonly implemented residential water conservation strategies and considers how effective promoting greywater reuse is at reducing potable water consumption. Results show that the ideal combination of water conservation programs supported by a public water utility is influenced by the reliability and source of potable water, as well as the conservation maturity and water use of habits of rate payers.

Celeste L. Whitman (EEP)

Advised by: Erika Weinthal

Tailoring Water Services in Remote and Isolated Indigenous Australian Communities

Freshwater is an essential global resource, but climate change and human development have degraded the quality and quantity of freshwater. A large percentage of the global population is experiencing water stress from water scarcity has led governments and organizations around the globe to re-evaluate their water management plans. However, these plans do not always address the needs and concerns of Indigenous populations who face a variety of challenges stemming from historical disadvantages. Indigenous Australians are one such group whose well-being is impacted by water stress and experiences issues with water services. This study examines if certain water use drivers can be considered when water providers create and implement management plans to offer sustainable services to remote and isolated Indigenous communities. Statistical findings do not show significant overall patterning in drivers for water use, indicating that service providers need to tailor water services with cultural, social, economic, and environmental considerations of individual Indigenous Australian communities.

Anna Windle (CEM)

Advised by: David Johnston

The Use of Autonomous Terrestrial Rovers for High Resolution Light Pollution Sampling in Beach Environments

Nesting sea turtles avoid brightly lit beaches and can turn back to sea prematurely when exposed. However, artificial nighttime light, or light pollution, is challenging to measure accurately for impact assessments. Satellites and light sensors on stationary tripods have proven useful, but the view experienced by nesting females and hatchlings is disregarded. This study assessed nighttime light levels on three different nesting beaches in central North Carolina. Using an autonomous terrestrial rover, high resolution light data was collected at a sea turtle's eye level. Spatial comparisons between light and nesting density at and between beach locations reveal high densities of nests occurring in regions with low light levels, supporting hypotheses that light pollution from coastal development may structure turtle nesting distribution. These results can support ongoing management strategies to mitigate this pressing conservation issue.

Brian Wong (WRM)

Advised by: Patrick Halpin

Automating Offshore Infrastructure & Vessel Identifications using Google Earth Engine & Synthetic Aperture Radar

Global Fishing Watch (GFW) recently published the first worldwide industrial fishing effort data set learned from processing 22 billion Automated Identification System (AIS) observations. Despite quantifying 40 million hours of fishing activity that extended to over 55% of the ocean's surface area in 2016, GFW now aims to quantify fishing effort not captured by current analyses through multimodal remotely-sensed imagery. Such imagery-based vessel identifications are commonly confounded with offshore infrastructure, though, so a global offshore infrastructure data set is first required to disentangle the two. This study first establishes a scalable method for automating offshore infrastructure identification using synthetic aperture radar in the Gulf of Mexico, and then evaluates the feasibility to adopt these methods for vessel identification. Results indicate our model identifies offshore infrastructure with a probability of detection of 94.2%, an overall accuracy of 91.5%, a commission error rate of 3.1%, and an omission error rate 5.8%. Additionally, a cloud-based pipeline was successfully implemented to automate vessel identification globally.

Minchao Xu (GEC)

Advised by: Drew Shindell

Group Members: Devyn Parks

Economic Assessment of Extreme Heat Events on Labor Productivity in the US

Extreme Heat Events (EHE) across the U.S. have become more common as climate change continues to progress. There have been numerous studies on the mortality effects of EHEs but relatively little has been done to study the morbidity effects, especially the economic consequences at a national level. We looked at the economic effect of heat on labor in each U.S. state. From previous studies, labor lost was found to be significant in four high risk occupational sectors: farming, construction, installation, and transportation. Looking at 3 representative years (1983, 2014, and 2016) we found that labor lost per state increased, with California, Texas and Arizona taking the majority of the losses. California was especially prevalent in the farming sector, accounting for >80% of the losses in the occupational category. For the other 3 sectors, California and Texas accounted for >40% individually, and Arizona >6%.

Zoey Z. Xu (EEP)

Advised by: Xavier Basurto

Group Members: Yongwoo "Jason" Lee

How Should the Fundacion Rio Arronte Allocate \$15 million Annually to Address Mexico's Water Problems

The Fundacion Gonzalo Rio Arronte would like to make the best use of around \$15 million a year to improve sanitation and clean water access in Mexico. The challenge is that water resources in Mexico exhibit significant spatial and temporal variation, often in a contradictory pattern to socioeconomic resources. We categorized possible interventions into four categories: technology-based solutions, community outreach and capacity building, microfinancing, and green infrastructure. Through a literature review, a review of NGO reports, and interviews with selected global NGOs, we find the best practices being used around the world in each of these four areas. Our results will assist our client in its future decision making and in forming strategic priorities.

Peijia Yan (EEH)

Advised by: Junfeng (Jim) Zhang

Biomonitoring of Amino-PAHs, Cotinine, and PAH-Hemoglobin adducts in human specimen

Diesel exhaust is a large source of air pollution in urban area due to busy traffic and industrial production. As by-products of incomplete combustion, polycyclic aromatic hydrocarbons (PAHs) and nitro-PAHs are proved cause carcinogenic and mutagenic effects. Particularly, nitro-PAHs is more specific to traffic related exposure, and therefore, amino-PAHs, the metabolites of nitro-PAHs are frequently used as biomarkers of diesel exhaust. This laboratory-based project measured the levels of several amino-PAHs in human urine and red blood cell samples. Also, the smoking status and the level of oxidative stress of objects are assessed by the Cotinine and MDA level in their urine samples, respectively. The aim for this project is to learn the analytical methods for different biomarkers and identify the association between them.

Alaina E. Young (CEM)

Advised by: Andrew Read

Determining the Northern Range of the NNCES Stock of Bottlenose Dolphins (*Tursiops truncatus*) through Photo-identification

Bottlenose dolphins that are seasonally resident to the Roanoke Sound are members of the Northern North Carolina Estuarine System (NNCES) stock. There is considerable uncertainty in the northern range of NNCES, which was formerly thought to only extend as far as the NC/VA border. To better delineate this northern stock boundary, I matched individuals with high capture probabilities (n=59) in the Roanoke Sound with individuals sighted in Virginia, Maryland, and New Jersey through the Mid-Atlantic Bottlenose Dolphin Catalog. Five individuals were matched to the VA catalog but none were matched to either MD or NJ. The results of this study indicate that the NC/VA border is not the northern boundary of the NNCES stock, but instead that the movement of these dolphins extends into the Chesapeake Bay. Thus, the management of this stock of dolphins should consider the threats, including by-catch, that may occur in this extended range.

Xin Yu (WRM)

Advised by: Martin Doyle

Group Members: Nicola Hill, Oshin Paranjape

Historical Trends and Projections of U.S. Industrial Water Use: A Case Study of Texas, Indiana, and North Carolina

Chemical, oil & gas, and textile manufacturing industries are the major divers of United States industrial water use, shaping both the economy and water trends in the regions they inhabit. Texas (TX), North Carolina (NC), and Indiana (IN) are dominant examples of states influenced by the fluctuation of these industries and have therefore been selected as case studies. This study analyzes historical, spatial-temporal trends in water use and makes projections for next decade using robust datasets of monthly facility-level water use data. The datasets indicate that spatially, water use and locations of facilities have remained centralized near the coast of TX, while facilities have shifted towards small clusters throughout NC and IN. NC and IN monthly water use follow a seasonal pattern with consistent major users. Additionally, TX industrial water use is estimated to decrease in next decade while the other two states remain stable.

Ricardo Zaragoza-Castillo (EE)

Advised by: Dalia Patino-Echeverri & Lincoln Pratson

Group Members: Jun Zhang

Increasing the Electricity Generation Capacity from Solar Resources at Duke University

Duke University sets the goal of being carbon neutral by 2024, therefore, this study evaluated the opportunities of developing solar PV by 1) Estimating the technical potential of on-site PV on Duke campus -- up to 51.5 MWdc on rooftops and 14 MWdc atop parking lots, which in most scenarios will reduce the grid carbon-emission rate (tCO₂/MWh) and system cost (\$/MWh), but meanwhile, reduce the grid reliability. 2) Identifying federal regulations' financial incentives when Duke University co-invest in the on-site or off-site solar PV development, while the State regulations limit the options for PV development, as third-party energy providers are not allowed, standard Power Purchase Agreements are available only for ~1 MWdc solar energy facilities, and the RECs market is still a grey area. and 3) Concluding that PV on parking lots is cheaper and easier than on rooftop. Due to economies of scale, attractiveness for tax equity investors, and system size, off-site solar farms are the most cost-effective way to reduce Duke University's carbon emissions by reducing purchased electricity.

Jun Zhang (EE)

Advised by: Dalia Patino-Echeverri & Lincoln Pratson

Group Members: Ricardo Zaragoza Castillo

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farms are the most cost-effective way to reduce Duke University's carbon emissions by reducing purchased electricity.