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The Carbon Footprint of Acadia National Park

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Abstract

A greenhouse gas emission inventory was conducted at Acadia National Park to explore the impact of park operations, concessionaires, and visitors. Acadia contains fragile ecosystems that are endangered by the effects of climate change from greenhouse gas emission. The purpose of the inventory is to determine Acadia's carbon footprint and provide mitigation strategies for its greatest contributors. With this report, the goal is to help Acadia increase its environmental sustainability and attain the status of a Climate Friendly Park.

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Authorship

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Executive Summary

The 2016 Acadia National Park Carbon Footprint project focused on determining the greenhouse gas (GHG) emission for Acadia National Park (Acadia), identified the largest contributors to the GHG emissions, and suggested practical changes to reduce them. The project also determined the Critical Air Pollutant (CAP) emission for the park.

The importance of this inventory is measuring Acadia's contribution to the greenhouse effect, a major contributor to climate change. When GHGs, such as carbon dioxide, are trapped in the atmosphere, heat is unable to escape into space and warms Earth. Increased temperatures cause rising sea levels and disruption to ecosystems. Acadia is a coastal park and very sensitive to the effects of climate change.

Since GHGs are a leading cause of climate change, people have started to scrutinize the GHG emission by measuring the carbon footprint of people and organizations. The National Park Service (NPS) developed the Climate Leadership in Parks (CLIP) tool to measure the GHG emissions from park operations as well as the visitor and concessionaire contribution.

To complete the GHG emission inventory for the 2015 fiscal year, information was gathered about the different operations within Acadia: park operations, visitors, and concessionaires (National Park Tours, and Oli's Trolley). Park and concessionaire employees were contacted for information about purchased electricity, stationary and mobile combustion, wastewater treatment, solid waste, refrigeration, and employee commuting.

Once the GHG emission was calculated, it was compared to that of Crater Lake National Park, Grand Canyon National Park, Mt. Rainier National Park, Olympic National Park, Petrified Forest National Park, and Redwood National Park. Acadia is a relatively small park -- only

46,299 acres -- with heavy tourism. Therefore, it was unsurprising that Acadia had the highest emission when it was compared per 1,000 acres; almost three times as great as the next highest emission. However, when compared per 1,000 visitors, it was tied for the lowest emission with Olympic National Park.

From the total GHG emission inventory, it was evident that visitors had the largest impact. Since visitor emission is exclusively measured in contribution to mobile combustion, decreasing the number of cars on Park Loop Road would help reduce the overall emissions.

For park operations, purchased electricity and stationary combustion were found to be the largest contributors. These sectors were further analyzed so specific suggestions could be made to reduce their impact on the GHG emission. Purchased electricity use was broken down by square foot for each facility. Cadillac Mountain, headquarter (HQ) garage, and Schoodic had the highest per square foot energy consumption. Energy audits were performed at HQ garage and Schoodic; Cadillac Mountain was excluded because the radio tower was the largest contributor and few suggestions could be made to reduce its consumption. An additional energy audit was completed at the Hulls Cove Visitor Center since it is heavily frequented. From observations during these audits, suggestions were made to turn off lights when not in use, make it possible to have only half the lights on in a room, utilize natural light when available, upgrade light bulbs to high-efficiency models, eliminate phantom load, and replace outdated appliances with energy efficient models. Once electricity use has been reduced, it is suggested that Acadia invest in solar panels to further reduce its reliance on purchased electricity and use a source that does not emit GHGs.

Since stationary combustion, which accounts for fuel used in heaters, boilers, and generators, had the second highest GHG emission, it was examined further. The team noticed that most of the buildings were old and not well sealed. It is suggested that the park re-caulks all the windows/doors, increases insulation, replaces existing windows with energy-efficient models, and installs a vestibule outside of the doors to eliminate heat loss as people enter/exit the building.

CAP emission was calculated as well. The largest contributor to CAP emission is visitor mobile combustion, so reducing the vehicles on Park Loop Road would be the best mitigation strategy.

Moving forward, Acadia should apply to become a Climate Friendly Park, which is an NPS program for parks that are working to become more environmentally sustainable. This would involve annual monitoring of the GHG emission, educational programs to teach staff about climate change, and community outreach.

1. Introduction

Earth is a dynamic planet that responds to human activity. Global industrialization has changed its climate dramatically. Greenhouse gases (GHGs) contribute to the changing climate by trapping heat and raising the global temperature. These rising temperatures affect the entire planet causing changes in the ocean, on land, and in the atmosphere. The cause of these changes has only recently been linked to human activity. Now that scientists have found correlations between greenhouse gas levels in the atmosphere and climate change, steps are being taken worldwide to mitigate GHG emission.

The US federal government is working to reduce its own carbon footprint, especially the National Park Service (NPS). The NPS was established on August 25, 1916 by President Woodrow Wilson under the NPS Organic Act. Its purpose is “to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave they unimpaired for the enjoyment of future generations” (National Park Service Organic Act of 1916). More than 20,000 NPS employees maintain over 400 national parks, sites and monuments (National Park Service 2016 “History”). The NPS is encouraging the nation’s parks to evaluate their individual contributions to climate change by measuring their carbon footprints. Once a park’s footprint is known, initiatives can be taken to reduce its size.

Acadia was established in 1916 to preserve the natural and picturesque beauty as well as the park’s importance to history and scientific research. Today, Acadia National Park encompasses almost 47,000 acres and is operated and protected by the NPS. With the centennial anniversary approaching for both Acadia and the NPS, they have set plans for another hundred years of prosperous preservation. Evaluating and lowering carbon emissions are important to Acadia because the park is directly threatened by global climate change. Rising sea level threatens the shoreline of the park and is changing the habitats of native flora and fauna.

As daunting as it may seem to estimate a carbon footprint on the magnitude of a national park, it was accomplished in 2003 when the NPS collaborated with ICF International - a consulting firm that often works with the government - and developed a program to help quantify the size of a carbon footprint. Acadia's carbon footprint was determined by visiting the various buildings and facilities that make up Acadia, collecting electric bills, and interviewing facility workers. The carbon footprint estimation followed the current industry standard developed by ICF International.

Once the size of the carbon footprint was known, a comprehensive strategy was developed to help reduce the carbon footprint. This strategy focused on practical suggestions including cost-benefit analyses and behavioral changes. The aims of the project were to calculate the overall carbon footprint of the National Park, and suggest methods to reduce it.

2. Background

In order to understand why Acadia's carbon footprint is being determined, it is important to understand why carbon footprinting matters. Global Climate change is endangering the planet and all who inhabit it. Scientists have learned that greenhouse gas (GHG) emissions are contributing to the overall warming of the planet. These GHG emissions come from many different sources including the burning of fossil fuels which is a part of everyday life. Recently steps have been taken to estimate the amount of GHGs emitted by an individual, organization or country. Once a carbon footprint has been found, steps can be taken to decrease the emission of GHG.

2.1 Acadia National Park

The history of Acadia National Park may be dated to 5000 years ago, when Mount Desert Island, the home to Acadia, was inhabited by the Wabanaki people. However, in 1604 the French navigator, Samuel Champlain, rediscovered Mount Desert Island for the western world (National Park Service 2016 “History”). During the next few centuries, settlers came and went. By 1850, the population of Mount Desert Island had learned to make a living by fishing and selling ships - a way of life that is closely linked to the sea. Not long after, Mount Desert Island was discovered by artists, and they unveiled the beauty of this place to the world through their paintings (National Park Service 2016 “History”). Ever since then, Mount Desert Island became a place that people desired to experience, and at the same time, to protect. In 1916, with the great effort of a tireless spokesman for conservation, George B. Dorr, Mount Desert Island finally became a national park, which is now known as Acadia.

2.2 Climate Change

As scientists learn more about the planet, it is evident that humans have expedited global warming. With the continuing industrialization, the emitted GHGs trapped in the atmosphere will warm the planet and cause abnormal weather. Since most of the world’s population lives near the coast, many people will directly be affected by the reshaping of the coastline due to the rise in sea level. Climate change will affect not only the landscape, but the economy and the way of life.

2.2.1 Greenhouse Effect

The major contributor to climate change is the “enhanced greenhouse effect” due to the human induced release of GHGs into the atmosphere. The primary GHGs are water vapor, carbon dioxide, methane, nitrous oxide, and ozone (Pandey, Agrawal, and Pandey 2010). These greenhouse gases form a layer around the planet that causes the overall temperature to rise. Heat passes through both the atmosphere and this layer of gasses to be absorbed by the planet to heat the surface of Earth. Without this layer the heat that is not absorbed by the planet bounces off of the surface and is returned to space. The heat does not have enough energy to traverse through this layer so it gets bounced back toward the Earth. When it reaches the Earth’s surface for a second time the planet absorbs more energy and is heated further. This cycle continues until this energy is depleted. The continual absorption of energy by the Earth’s surface is what heats the overall temperature of the planet (Environmental Protection Agency, 2016).

2.2.2 Contributors to Climate Change

Not all GHGs equally cause climate change. Carbon dioxide has caused most of the climate change and its influence is expected to continue. The spotlight is on carbon dioxide because of its abundance in the atmosphere, the exponential rate by which it is increasing, and its long duration in the atmosphere. Carbon dioxide is emitted from burning fossil fuels to produce electricity, and to run vehicles and machinery (Ekwurzel 2016).

Prevention of carbon emissions would greatly increase sustainability, however carbon is not the only contributor to GHG emissions it is simply the biggest. Other emissions include methane, which comes mostly from agricultural activities and waste management; nitrous oxide (NOX) which comes from agricultural activities and biomass burning; hydrofluorocarbons (HFC) which come primarily from industrial processes and refrigeration; and volatile organic carbons (VOC) which come from the storage of gasoline (Environmental Protection Agency 2016 “Global”). Methane, NOX, HFC, and VOC are also called Criteria Air Pollutants (CAP) due to their harmful effects on humans (Environmental Protection Agency 2016 “Criteria”). In 2010, carbon dioxide, both from forestry use and fossil fuel use contributed to approximately 76% of the global greenhouse gas emissions. Methane, NOX, and fluorinated gases contributed the other 24% of the emissions (16%, 6%, and 2%, respectively) (Environmental Protection Agency 2016 “Global”).

To represent GHGs’ environmental impact (in terms of global warming) alongside carbon dioxide emissions, each other GHG is reported as a carbon emission multiplied by its respective conversion factor, called a Carbon Dioxide Equivalent (CDE) (Wright 2011). For example, one ton of methane has equivalent Global Warming Potential of 25 tons of carbon dioxide, and so, its CDE is 25 (Chameides 2009).

2.2.3 Sources of Greenhouse Gases

There are many different outlets for GHG emissions and they each contribute to the overall problem of GHG emissions. In 2010, electricity and heat production contributed about 25% of the GHG emissions; the reason they are so detrimental to the GHG emissions is that they require the burning of coal, natural gases, and oil. The next leading cause of GHG emissions is agriculture, forestry, and other land use at 24% of the total emissions which come from agriculture and deforestation practices. Industry contributes to about 21% of global GHG emissions, mainly from the burning of fossil fuel on-site for energy. Industry emissions also include chemical, metallurgical, mineral transformations processes, and waste management. Another contributor to GHG emissions is transportation at 14%. Transportation involves the fossil fuels burned for any kind of travel from road travel to air travel. Almost 95% of transportation energy comes from petroleum-based fuels, largely gasoline and diesel. The last specific contributor to GHG emissions is buildings at 6%. The emissions from this sector come from the burning of the fossil fuels that are put toward heating homes and running appliances at the home. The last 10% of global GHG emissions comes from emissions from global energy production that are not directly used in the production of electricity and heat (Environmental Protection Agency 2016 "Global").

2.2.4 Greenhouse Gas Emission Impact on Natural Sequestration

Since Earth is a dynamic planet that responds to the population's actions, its carbon emissions directly affect the welfare of the planet and its inhabitants. Global carbon emissions have increased significantly since the year 1900 with the technological advances that require energy. However, no span of time has been as impactful as 1970 to present. Since 1970, global carbon emissions have increased by 90%. Carbon production currently exceeds the planet's natural carbon sequestration processes, mainly from photosynthesis. Many acres of forests are being cleared every hour by natural causes such as forest fires, and by human causes such as logging. Deforestation expedites the process of climate change, both by the actual process of clear cutting forests and the reduction in carbon sequestration (National Geographic 2016). Maine's forests sequester 0.3 metric tons of carbon dioxide equivalent (MTCE) per acre ("Carbon Sequestration Facts").

Increasing atmospheric carbon concentrations have detrimental effects on the entire planet. Areas that absorb excess carbon in the atmosphere are called natural sinks. These sinks are bodies of water, such as oceans and lakes, the Earth's atmosphere, and the land itself. From 2005 to 2014, 44% of Earth's carbon dioxide emissions have accumulated in the atmosphere, 26% in the ocean, and 30% on land. These sinks naturally require carbon to perform the water cycle (Environmental Protection Agency 2016 “Global”).

For tens of millions of years, Earth’s oceans have maintained a relatively stable acidity level. However, research shows that this trend changed at the beginning of the industrial revolution in the early 1800s, when the use of fossil fuel-powered machines became the mainstream. In the past 200 years the oceans have absorbed approximately half of the carbon dioxide produced by fossil fuel burning and cement production. Once dissolved in oceans, the absorbed carbon dioxide reacts with water to form carbonic acid, which increases the concentration of hydrogen ions in oceans – in other words, the oceans became more acidic. Unfortunately, this damage is essentially irreversible, as it will take tens of thousands of years for oceans to recover to an acidity level that is comparable to that of 200 years ago. Moreover, there is not yet an artificial method that is effective enough to be used on a large scale, and the existing methods that might be effective regionally could potentially damage the marine environment. As homes to thousands of species of organisms, the oceans play a central role in the Earth’s major processes, and the change of chemical conditions in oceans will undoubtedly cause significant consequences. For example, many marine photosynthetic organisms and animals, such as corals, make shells and plates out of calcium carbonate, a substance that decomposes in carbonic acid. Therefore, as the oceans become more acidic, species like corals will gradually lose their abilities to produce their skeletons (Ocean 2005). When shelled organisms are at risk, the entire food web may also be at risk.

2.2.5 Impact of Global Temperature Rise

One of greenhouse effect’s most notable impacts on the planet is the change of temperature. From 1880 to 2012, the average increase in temperature of the land and sea has been 1.53 degrees Fahrenheit (Alexander, Allen, Bindoff, et al. 2013). This temperature increase is growing and will eventually have the potential to destroy ecosystems. Temperature change can disrupt the foundation of an ecosystem and harm some of the species living there. After one or two of the species living in an ecosystem are extirpated, the community can crumble because the food web is disrupted.

The overall increase of the ocean temperature contributes to the rising sea level because water expands as it warms. . Additionally, the rising temperature melts the ice caps which deposit their water into the ocean. Coupled together, this has caused sea levels to rise eight inches since 1880 (National Climate Assessment 2016).

Anthropogenic GHG emission has increased exponentially since the industrial revolution and will accelerate the temperature increase in the future. It is projected that the average rise in global temperature will be 2.7 degrees Fahrenheit, but could be as high as 8.6 degrees Fahrenheit by 2100. Additionally, by 2100, the rise in temperature has yielded a projected increase of sea level by four feet (EPA 2016).

2.2.6 Effects of Greenhouse Gases on National Parks

Evidence within national parks across the US has already demonstrated the impacts of climate change. For instance, in the Cascades and the northern Sierras, the snowpack have diminished at an alarming rate. Carbon emissions must be mitigated due to the belief that GHGs are responsible for climate change. The consequences of climate change in the parks are easily seen by the abnormal weather and receding glaciers (Mayor 2009). National parks can serve as a model to demonstrate the dangers of climate change and as a platform to enact change to reverse the damage it has caused.

With the onset of climate change comes abnormal weather, and a rise in sea level threatening coastlines throughout the world. Acadia, the well-known park in Maine, is a prime example of this dilemma. As one of the most popular national parks in U.S., Acadia welcomes more than two million visitors each year, making it one of the country's most-visited national parks. However, increased tourism brings not only the booming economy, but also the increasingly severe environmental issues, the most significant one being the climate change. The extreme adverse weather is already wearing away at Acadia's iconic granite bedrock, and reducing the populations of native vegetation and wildlife. The National Parks Conservation Association rated Acadia the sixth most endangered park in the country due to climate change (Kennedy 2015). In 2014, the National Climate Assessment reported, that the global sea levels are projected to rise up to four feet by 2100 (Kennedy 2015). The rise in sea level will compromise the infrastructure, agriculture, fisheries, and ecosystem in the Northeast. Acadia National Park is nestled near Bar Harbor, ME and sees over 2.6 million tourists each year. By 2050, Bar Harbor could face a two-foot rise in sea level, which would lead to catastrophic destruction and up to $33 million in damage (Kennedy 2015). Everything that makes Acadia so iconic is in danger and so the future of the national park is at stake.

2.3 Greenhouse Gas Emissions

As a result of industrialization and technological advancements GHG emissions have increased exponentially. The disparity of GHG emissions among the countries around the world is an issue that must be dealt with. It is imperative that the government intervenes to reduce emissions. By focusing on smaller areas, such as national parks, the government can gain insight on how to reduce emissions for future locations.

2.3.1 Global Emissions

It may be surprising to some that the United States (US) is not the leader in global GHG emissions, but rather it is China. China was responsible for 25% of the global carbon emissions in 2012 which is comparable to the emissions from the US and European Union (EU) combined, a value that still holds true to this day. The per capita emissions in China are still significantly lower than that of the US, but have risen to the average level of the EU citizens. The overwhelming majority of carbon emissions (90%) come from the country's burning of fossil fuels. The remaining emissions (10%) come from the production of cement. About 25% of the carbon emissions in China are caused by manufacturing products that are consumed overseas. These types of emissions are called virtual emissions which are connected with their exports and not domestic products. These virtual emissions are what make the emissions associated with China's exports eight times larger than the emissions associated with China's imports (Liu 2015). The magnitude of the growth rate of China's carbon emissions has caused the country to be a critical partner in developing policies that are aimed toward reducing the global carbon dioxide emissions.

A large contributor to GHG emissions that is on a different trajectory than China is the EU. The EU has had a 19.8% decrease in GHG from 1990 to 1999. Between 1999 and 2006 GHG emissions were unchanging but then in 2009 there was a sharp drop in emissions due to the global financial and economic crisis that led to an overall reduction of industrial activity. The EU had an increase in GHG emissions in 2010 which was quickly followed by three consecutive years of GHG reductions with 2013 marking the lowest emissions on record since 1990. In 2013 Germany had the highest GHG emissions for the EU with 21.17% of the EU's total emissions. The United Kingdom was next with 13.1% of the emissions and France contributed 10.98% of the emissions. Fuel consumption (non-transportation), and fugitive emissions (leaks from pressurized fuel containers) were responsible for 57.2% of the EU's GHG emissions in 2013. The second most important source was fuel combustion for transport at 22.2%. The last three were agriculture contribution, industrial processes and product use, and waste management at 9.6%, 7.8%, and 3.3% respectively. Waste management emissions have significantly decreased since the year 1990 (Eurostat 2015).

2.3.2 United States Greenhouse Gas Emissions

The US is the second largest contributor to global greenhouse gas emissions; only China produces more GHGs. Industry and fossil fuel combustion the main contributors to the carbon footprints of large nations such as US and China. The leader in fossil fuel consumption and industrial processes from to 2011 is China, which produced 28% of the global carbon dioxide emissions through these actions. The next largest contributor of global carbon dioxide through these processes is the US with 16% of carbon dioxide produced this way. 26% of the carbon dioxide from fossil fuels and industrial processes comes from Japan, Russia, India, and The European Union. The remaining 30% of the carbon dioxide emissions from these processes in this timeframe come from every other country on the planet. It is quite astonishing that the rest of the world does not produce as much GHGs as The US and China combined (Environmental Protection Agency 2016 "Sources").

From 1990 to 2013 the overall GHG emissions for the US has only increased by 6%. This low increase has been due to changes in the price of fuel, the economy, and technological advancements. The factors that contribute to the production of GHG gasses in the US come from five distinct categories: electricity production, transportation, industry, commercial, residential, and agriculture. The largest contributor to the US GHG emissions is electricity production at

31%. 67% of the electricity produced in the US comes from burning fossil fuels like coal and natural gas. The next leading contributor to the GHG emissions is fossil fuel combustion for transportation at 27%. Over 90% of fuel used for transportation is petroleum based, which includes gasoline and diesel. Another contributor to GHG emissions is industry at 21%. The primary cause of GHG emissions in this sector is from burning fossil fuels for heat, the use of certain products that contain greenhouse gasses, and the handling of waste. The next largest contributor to GHG emissions in the US is energy produced for commercial and residential use at 12%. Lastly, agriculture contributes 9% of total GHG emissions. Another contributor to GHG emissions in the US is land use and forestry. This may be difficult to measure because a land area may be either a sink or a source of GHGs. The percentage of GHG emissions for this sector can range from 0% to 13% annually depending on the type of land usage. Due to the difficulty and variable contribution of this sector, many times this is removed from emissions calculations (Environmental Protection Agency 2016 "Sources").

2.3.3 National Parks' Greenhouse Gas Emissions

The carbon footprints of Mount Rainier, North Cascades and Olympic national park are produced with the help of more than 5 million visitors annually. As a result, these three national parks have an estimated total carbon footprint of 30,820 MTCE. This carbon footprint is comparable to that of over 2,500 average households (Mayor 2009). Meanwhile, Acadia sees over 2.5 million visitors annually and its carbon footprint is to be determined.

2.4 Carbon Footprinting

A carbon footprint is a term used to quantify the total emission of GHGs. Some activities such as the production or consumption of fuels, materials, and manufactured goods will emit

GHGs. Transportation and land clearances are also large contributors of GHGs. It is important to keep in account that the total carbon footprint cannot be calculated because it would not be practical, and so measuring some of the largest contributors of GHGs in terms of CDEs is the industry standard (Pandey, Agrawal, and Pandey 2010).

2.4.1 Carbon Footprint

A carbon footprint is the value of the total carbon emissions (directly and indirectly) produced by an individual or a group that is released into the atmosphere over a period of time, measured in tons of carbon dioxide. The minutia of what is included in this measurement is currently debatable, but some researchers are working towards producing a universal definition of a carbon footprint, which is absolutely necessary for its abatement. One accepted component of measuring carbon footprints is that it includes non-carbon GHGs (Wright 2011).

2.4.2 Climate Leadership in Parks (CLIP) Tool

Since it is difficult to determine a carbon footprint, methods have been created to estimate the carbon footprints of different types; for instance, the footprint of an individual or a business. In 2001, the Environmental Protection Agency and the NPS worked with a consulting firm, ICF International, to develop an instrument to calculate the carbon footprint of the nation's parks. The result of this effort was the Climate Leadership in Parks (CLIP) tool, an Excel-based spreadsheet (Norton 2008). Park data is entered into the spreadsheet, and in turn, it provides a comprehensive carbon footprint. Necessary data include general information about park visitors and staff, and more detailed information about electricity usage and fuel usage in automobiles.

Once the CLIP tool has calculated the carbon emission of the park, it identifies some of the greatest contributors to the overall carbon footprint. It breaks down the carbon footprint by sector: energy, transportation, and visitor. Based on the usage breakdown for the park, suggestions are made for lowering the carbon footprint. Parks can then adapt these suggestions to their specific situation. When used yearly, it is possible to monitor the size of the footprint and see if the changes in the park's operations are helping to abate the carbon footprint.

2.5 Reducing the National Parks' Carbon Footprint

Once scientists discovered the link between climate change and GHG emissions, the NPS decided to take action and reduce its carbon footprint. The NPS published its "Call to Action" which set goals for the domestic national parks to become environmentally sustainable. Many national parks have risen to the challenge and have measured their carbon footprints and made plans to reduce their contribution to global GHG emissions.

2.5.1 A Call to Action

The adversity faced by Acadia and other national parks has raised the public's attention, and some people have begun to realize the need to preserve these natural assets. In 2011, the NPS released a "Call to Action" -- a document that lists four broad themes supported by specific goals and measurable actions. One of these themes is titled "Preserving America's Special Places," in which the NPS describes its ambition to increase the resilience of national parks in the face of climate change and other dangers. To achieve this goal, the NPS has detailed several plans, one of which is to "reduce the NPS carbon footprint and showcase the value of renewable energy to the public" (National Park Service 2016 "A Call"). NPS encourages all national parks to critically examine their operations and how they affect the environment.

2.5.2 Climate Friendly Parks Initiative

"A Call to Action" has also started the Climate Friendly Parks (CFP) program to encourage parks to determine their carbon footprint and create a plan to lower GHG emissions. To become an official member of CFP, a park must submit an application and determine its entire carbon footprint. Then the park must hold a CFP workshop to educate the park staff, volunteers and shareholders about climate change and the impacts on the parks. The final step is to create a plan for moving forward and lessening the park's negative impact on the environment. Parks will continue to monitor the size of the footprint on a yearly basis to see if the proposed changes are effective and decide if additional changes can be made. Parks are encouraged to reach out to communities and educate them about climate change and what they can do to help the environment (National Park Service 2016 "Climate").

2.5.3 Mt. Rainier National Park

Mt. Rainier National Park in Washington State has already created a plan to lessen its greenhouse gas emissions. While calculating its carbon footprint, the park took into account energy usage in the form of stationary combustion and purchased electricity; transportation in the form of mobile combustion; and waste, both solid waste disposal and waste water treatment. In order to reduce emissions, the park has enacted a long-term plan including increased energy efficiency in the park. They will produce and purchase renewable energy, reduce fuel usage by park vehicles, and lessen waste through recycling and composting. Their plan also includes steps to reevaluate their carbon footprint and see which strategies are working. They are also starting community programs to educate the park's visitors about the dangers of climate change and how they can change their lifestyle to lessen their personal carbon footprint (National Park Service 2009).

2.5.4 New River Gorge National River

The New River Gorge National River action plan was founded on three strategies: to reduce GHG emissions resulting from within and by the park, increase climate change education and outreach, and evaluate progress and identify areas for improvement. New River's carbon footprint calculation used a handful of sources, such as: electricity; wastewater treatment; and fuel usage bills (primarily from propane and natural gas heaters); an inventory of cooling units; acreage data on forest types within park boundaries; and records of landscape management practices.

New River, in West Virginia, is a comparable attraction to Acadia. It is of similar size, terrain, and wildlife habitat. However, it is more progressive in sustainability efforts. For example, its Sandstone Visitor Center (erected in 2003) is a LEED certified Green Building (National Park Service 2003). It is made of local recycled materials on a restored landscape. It was built with the intention of minimizing energy consumption (e.g. by using skylights, recycled insulation, and a light-reflecting roof), and energy it does use is partially renewable (e.g. geothermal). Furthermore, it uses irrigation and native landscaping to minimize future maintenance and fertilizer use.

Additionally, as a part of its sustainability program, New River encourages responsible recreational use of its enclosure with the Leave No Trace ethic. This has 7 main contentions. First, it recommends that visitors plan ahead and prepare their excursion to not crowd facilities during peak times and to repackage food items (e.g. in Tupperware) to reduce the amount of waste that is entering the park. Next, it suggests that visitors preserve riverbanks by traveling and camping only 200 or more feet from them, and not disposing of any biodegradable waste closer than that boundary. Further, within this contention, it emphasizes this point by stating that "good campgrounds are found, not made" within the national park. Intuitively, its next contention is the "carry in, carry out" policy of waste disposal (human waste can be buried outside the boundary of the river banks). Next, it advises that natural and historical formations undisturbed aside from viewing. Afterwards, it states that fires be limited to designated areas and wildlife respected. Lastly, it asks that visitors respect other visitors by letting the sounds of nature prevail over their own voices and the space of visitors be respected, because National Parks are large enough so as to make one another uncomfortable while enjoying the outdoors.

3. Methodology

The project began with a greenhouse gas inventory, including the CAP emissions, for the 2015 federal fiscal year: October 1, 2014 to September 30, 2015. Acadia's GHG emission were then compared to six other national parks' emissions on a per acre and per visitor basis to put the results into perspective. Following the evaluation of the results, the electricity use for the park was targeted for reduction. It was further broken down by building allowing for specific suggestions to be made. General suggestions were also made to reduce the overall emissions of the park. These suggestions were then analyzed using a cost-benefit analysis to gauge the potential effectiveness of the proposed changes.

3.1 Greenhouse Gas Emission Inventory

In order to determine the carbon footprint of Acadia, data regarding park operations were entered into the CLIP tool. Key information about electricity purchased, transportation fuel usage, wastewater treatment, solid waste disposal, refrigerants, and employee commuting was gathered. The CLIP tool compiled this information to produce a comprehensive measurement of the carbon footprint in MTCE. This inventory was completed using data from the 2015 fiscal year. Park operations; visitors; and two of the authorized concessionaires, National Park Tours and Oli's Trolley, were considered in the GHG emission inventory. The two other authorized concessionaires, Jordan Pond House and Carriages of Acadia, were not included; it was not possible to obtain the required information about their operations.

3.1.1 CLIP Tool Setup

The CLIP tool first needed to be configured for the 2015 fiscal year GHG emission inventory. Unfortunately, 2012 was the most recent year that could be selected within the CLIP tool, and was therefore selected at the discretion of the team. A note was made within the CLIP tool that this inventory was actually for the 2015 fiscal year.

Park operations, visitors, and concessionaires were chosen as the sectors to be considered. The emission sources to be studied were then chosen: stationary combustion, purchased electricity, mobile combustion, wastewater treatment, municipal solid waste disposal, refrigerant use, and park employee commuting. The decision was made to include CAP -- which consists of stationary sources, mobile sources, and area sources (burning and non-burning).

Additional basic information was required about the park. The information about the employee population was supplied by Kevin Langley, Chief of Administration. The park employee population was divided into full-time (46), and seasonal employees (201). The visitor data, Table 1, were acquired from the NPS Integrated Resource Management Applications (IRMA). The visitor data from the last 30 years were required; the years accounted for on the spreadsheet were from 1982 until 2012. Despite the discrepancy in years, it was decided to input the information from 1985 to 2015. The average length of visitor's stay (4 days) and the peak season (4 months) for Acadia were input into the CLIP tool.

Table 1: Number of Yearly Visitors at Acadia National Park from 1985 to 2015

Year	Number	Year	Number
1985	3,745,570	2001	2,516,551
1986	3,929,054	2002	2,558,572
1987	4,288,154	2003	2,431,062
1988	4,502,283	2004	2,207,847
1989	5,440,952	2005	2,051,484
1990	2,339,591	2006	2,083,588
1991	2,475,857	2007	2,202,228
1992	2,382,113	2008	2,075,857
1993	2,656,034	2009	2,227,698
1994	2,710,749	2010	2,504,208
1995	2,845,378	2011	2,374,645
1996	2,704,831	2012	2,431,052
1997	2,760,306	2013	2,254,922
1998	2,594,497	2014	2,563,129
1999	2,602,227	2015	2,811,184
2000	2,469,238		

3.1.2 Stationary Combustion and Purchased Electricity

Stationary combustion includes fuels used in appliances including boilers, heaters and generators. Diesel usage was taken into account for park operations. Keith Johnston, Chief of Maintenance, provided a spreadsheet listing the total gallons of diesel used for stationary combustion in Acadia for the fiscal year. Dan Rich, Supply Technician, provided gallons of propane used for stationary combustion at three different locations in the park, which were then combined to calculate the total gallons of propane usage in the park. The total amounts of diesel (4,9232.5 gallons) and propane (2,1341.9 gallons) used for stationary combustion were entered into the CLIP tool. Purchased electricity was considered next. This information was gathered by using electricity bills for the 2015 fiscal year provided by Johnston. The total energy use, measured in kilowatt-hours (kWh), was calculated and entered. The electricity provider, Bangor Hydro-Electric Company, was selected.

3.1.3 Mobile Combustion

This section of the CLIP tool includes the fuel usage of gasoline cars, gasoline trucks/SUVS, heavy-duty gasoline vehicles, diesel cars, diesel trucks/SUVs, heavy-duty diesel vehicles, and non-road equipment (lawn mowers, tractors). The volume of gasoline and diesel used by each vehicle was obtained from Program Assistant, Cynthia Stanley. This information was next organized by fuel type and then class of vehicle. The total fuel used in each category, see Table 2, was calculated and entered into the CLIP tool.

Table 2: Mobile Combustion Fuel Use by Category

Fuel	Class	Gallons
Gasoline	Cars	830
	Light Truck/SUV	20,641
	Heavy Duty Vehicle	3.196
Diesel	Light Truck/SUV	1,740
	Heavy Duty Vehicle	5,052
Compressed Natural Gas	Car	32
Ethanol	Car	2,713
	Truck/SUV	4,737
Hybrid Gasoline	Car	1,157

Mobile combustion was also considered for park visitors. Charlie Jacobi, Resource Manager, shared that the park averages three people per car that visits the park. Thus, the total number of visitors for 2015, which was obtained from IRMA, was divided by three to estimate the total number of vehicles (937,061). Next, the average number of miles driven by each car during a visit was calculated. Jacobi supplied the most common path driven by an average visitor; for simplicity, it was assumed that everyone drives the 27-mile trip around Park Loop Road and up to Cadillac Mountain. This value was multiplied by the number of vehicles (937,061) to provide the total number of miles driven by park visitors (25,300,647 miles). The CLIP tool also required the amount of each type of vehicle that visited the park. This was impossible to calculate, so instead the total number of cars was entered, and the CLIP tool broke down the total number of vehicles into the categories based upon the NPS algorithm.

GHG emission for watercraft and non-road equipment was calculated as well. Watercraft GHG emission was calculated based on total fuel usage. Stanley provided the total diesel use in Acadia's boats (216 gallons). Stanley also provided the total amount of gasoline used in the non-road equipment (217 gallons). These two values were entered into the CLIP tool.

Mobile combustion was also considered for two of the concessionaires. Oli's Trolley used diesel and gasoline busses. Denise Morgan, Operations Manager of Oli's Trolley Inc., provided the combined amount of fuel used (5,169 gallons). Since there are six buses total and only one is diesel, it was assumed that one-sixth of the fuel used was diesel (861 gallons); the rest was gasoline (4,307 gallons). National Park Tours uses only diesel vehicles (3,000 gallons).

3.1.4 Wastewater and Solid Waste Disposal

To determine the GHG emission from wastewater treatment, Johnston provided the monthly volume of wastewater that was treated. The monthly amounts were totaled to find the amount of wastewater treated (1,691,097 gallons). The CLIP tool then required the percentage of wastewater treated aerobically (100%) and the amount of methane recovered at the wastewater treatment plant (none). All the wastewater was treated by the plant owned and operated by Acadia.

Solid waste sent to a municipal landfill was the next topic covered. This section required the amount of solid waste generated during the 2015 fiscal year. Thereafter, information about the landfill was required, such as whether it uses methane flaring (no), and how much waste is incinerated each year (235.73 tons). The total amount of waste was provided from Johnston.

3.1.5 Refrigeration and Air Conditioning

The final GHG Emission section was based on hydrofluorocarbon (HFC) usage from refrigerants. This section was broken into two subsections: stationary refrigeration and air conditioning (AC), and then mobile AC. For the stationary section, two types of HFC sources were taken into account for refrigeration: HFC-134a and R-410. Refrigerators and AC units were examined to determine which refrigerant they use. At Schoodic Peninsula, there were residential refrigerators in both the Moore Auditorium and the maintenance building and then 48 in the onsite housing; they used HFC-134a. On the island, there was one residential refrigerator in the Hulls Cove Visitor Center that used HFC-134a. Other refrigerators and air conditioning units used refrigerants not taken into consideration by the CLIP tool.

GHG emission from mobile air conditioning usage was calculated next. The number of vehicles of each aforementioned class used in the park was entered. The CLIP tool broke down the total number of vehicles into four categories: manufactured after 1993, during 1993, during 1992, or before 1992.

3.1.6 Employee Commuting

Employee commuting was the following consideration. A survey provided by the NPS was sent to all full-time employees for this section, Appendix A. It asked employees how many days a week they commute into work and how many days they missed during 2015. Further information was gathered, including but not limited to: the number of miles of their round-trip commute; what type of vehicle; the percentage of the time they drive a personal car; if they carpool or take public transportation to work. The survey data, Appendix B, were transferred to the CLIP tool to calculate the employee GHG emission. The percentage of the full-time respondents (71%) was recorded. This allowed the program to extrapolate the GHG emission of all full-time employees.

A paper copy of the survey was also given to the part-time employees. Since they were part-time, it was not possible to simply have them fill out how many days a week they worked and how many days they missed. Instead, the number of days they missed was extended to include the number of days they would have worked had they been working year-round. It was impossible to enter this on the same version of the CLIP tool because only 21% of the part-time employees responded. The part time employees tended to have shorter commutes so the commutes of the full-time employees were not representative of all of Acadia's employees. The data were entered into another version of the CLIP tool and the values were added to the data analyzed.

Both surveys also had a space for the employees to write down their suggestions for how the park can become greener. These replies are in Appendix C.

3.2 Visitor Impact

The GHG emission savings from reducing the number of vehicles on Park Loop Road by 10%, 25%, 50%, 75% and 100% were calculated, as well as the GHG emission generated by replacing the removed vehicles with buses. Emission savings were calculated by multiplying the total MTCE from visitor's mobile combustion by the percent reduction of vehicles.

To calculate the emissions generated by the buses that would replace the vehicles, it was assumed that every bus had a 45 person occupancy. In this case, adding one bus would be equivalent to removing 15 vehicles from the road. The number of buses needed to replace the number of vehicles removed from Park Loop Road was multiplied by the miles the average visitor drives. The number of miles was inputted into the CLIP tool to calculate the GHG emission for both a gasoline or diesel bus fleet. The net savings for GHG emission were found by subtracting the bus fleet's GHG emission from the GHG emission saved by removing vehicles from the road.

The number of bus routes needed to replace all of the vehicles removed from Park Loop Road per hour was found. It was assumed that the busses would run for the four months of peak season (122 days) for 12 hours a day. The total number of bus routes was divided by the number of days then by the 12 hours a day.

3.3 Comparison of Acadia to Other National Parks

Acadia's GHG emission was compared to other national park emissions as well as the CFP average park. Six parks were chosen for this comparison; selection was based on participation in the CFP Program and the public availability of the data. The list of national parks was narrowed down to Crater Lake National Park, Grand Canyon National Park, Mt. Rainier

National Park, Olympic National Park, Petrified Forest National Park, and Redwood National Park. Data on the park operations and the total GHG emissions were taken from their action plans published on the CFP website (National Park Service 2016 “Climate”). For the comparison, the park operation emissions and the total emissions were calculated on a 1,000 visitor and a 1,000 acre basis. It was on a 1,000 visitor and acre basis instead of a per visitor or acre because of the small magnitude of the values. The visitor statistics were found on IRMA and the acreage was in the *National Parks Index* (United States Department of the Interior). Only the federally-owned acreage was taken into account.

Acadia was also compared to the other parks to look at the percentage of the total GHG emission that was not from park operations. The action plans were used to find the total and the park operations GHG emission. The percent of the total emissions from non-park operations was found by taking the difference of the total and park operations and dividing it by the total emissions.

3.4 Cost-Benefit Analysis of Reducing Purchased Electricity

The cost-benefit analysis weighed the significance of the suggestions made by the research team in an effort to reduce the electricity usage. The cost-benefit analysis determined whether the suggestions were worthwhile. The cost-benefit analysis entailed reviewing all of Acadia’s electricity bills for the 2015 fiscal year. Specifically, the total kWh usage and cost were compiled. Once the savings were measured, research was done on how other national parks managed to reduce their electricity use. After an action plan was compiled, the research team calculated how much the initial investments were. By completing this cost-benefit analysis, potential recommendations were determined if they were feasible in the sense of budget.

3.4.1 Cost-Benefit Analysis of Replacing Light Bulbs

A cost-benefit analysis was done to help determine how long it will take until 100 LED light bulbs pay for themselves in the park and how much money and energy they will save in the long run. This analysis was based on a comparison with four-foot T8 fluorescent bulbs as they are the most common type of light bulbs found in the park. The LED light bulbs were also chosen to be a four-foot T8 type with a luminous flux close to that of the fluorescent bulbs. The operating hours of the lights were assumed to be nine hours per day for five days a week (261 days per year). Unit electricity price ($0.0654/kWh) was provided by Johnston. Additional information, such as prices, lifespans, and power consumption of bulbs were estimated by averaging those of the most common types found online (Home Depot). The electricity cost of a light bulb per year was determined by the following equations:

$$Electricity\ Use\ (kWh/yr) = \frac{Power\ consumption\ of\ the\ bulb\ (Watt) * 9\ (hrs/day) * 365\ (days/year)}{1000}$$

$$Electricity\ Cost\ (\$/yr) = Electricity\ Use\ (kWh/yr) * Unit\ electricity\ price\ (\$/kWh)$$

The total amount of years before a LED light bulb pays for itself was then determined by:

$$Years = \frac{Price\ of\ a\ LED\ bulb\ (\$) - Price\ of\ a\ fluorescent\ bulb\ (\$)}{Electricity\ cost\ of\ a\ fluorescent\ bulb (\$/yr) - Electricity\ cost\ of\ a\ LED\ bulb\ (\$/yr)}$$

3.4.2 Phantom Load

Phantom load occurs when electrical devices are plugged into the power outlet. By being plugged into the power outlet, the devices are continuously drawing power. This phantom load on average accounts for 5-10 % of the annual electricity bill (Energy Vampires 2015). Therefore after determining Acadia’s total purchased electricity usage, it was multiplied by 5% and 10%. The resulting products will be the amount of purchased electricity saved if phantom load were stopped. The amount saved as well as amount of MTCE reduced were be determined by multiplying both the total GHG emission and total electricity bill by 5% and 10%.

3.4.3 Cost-Benefit Analysis of Implementing Solar Energy

Estimates were made to determine the cost of installing a solar energy system that would account for 15% of Acadia's total purchased electricity use. Then, a cost-benefit analysis was performed to determine how long it would take for the solar system to pay for itself and whether it would be feasible to implement solar energy.

To calculate the number of solar systems required, the research team had to calculate the amount of kWh a 5kW system will produce in Maine annually. It was assumed that the total energy delivered by the solar system was 78% and that Maine receives a solar radiance of 1600 W/m^2 (Hahn, 2012). To calculate the kWh that a 5kW system produces, the kW of the system (5) was multiplied by the efficiency (78%) and solar radiance (1600 kWh/kW*year):

$$Amount\ of\ kWh\ per\ 5\ kW\ System = 5kW * 0.78 * 1600\ (kWh/kW * year)$$

Once 15% of the park's purchased electricity use was determined, it was divided by the amount of energy generated by a 5kW system per year, which gave the number of solar systems required:

$$Number\ of\ 5\ kW\ systems = \frac{Park's\ Total\ Purchased\ electricity * 0.15}{Amount\ of\ kWh\ per\ 5\ KW\ System}$$

After the number of solar systems required was determined, it was multiplied by the cost per 5kW solar system, including installation ("Solar Panel Installation Cost" 2012):

$$Cost = \$18{,}749\ per\ 5\ kW\ system * Number\ of\ 5\ kW\ systems$$

The final cost determined was used in the cost-benefit analysis. The solar system investigated was a grid-tied system because it is the most cost effective in terms of installation and use. Energy generated by the system will go towards Acadia's needs and any excess energy is reimbursed through Maine's net metering policy ("Solar Options" 2012). Essentially, this policy allows all of the renewable energy to be consumed ("Net Metering").

Many solar companies, such as ReVision Energy, Assured Solar Energy, Maine Solar Solutions, and Empire Electricity Company were contacted. However, Dr. Miller-Rushing decided he would continue any possible Price Purchase Agreement estimates on his own and wanted the research team to instead consider a rough estimate of the upfront purchase of a solar system that would account for 15% of the park's current purchased electricity use. Unfortunately, this estimation and analysis are flawed insofar as they are founded on uncertain circumstances. Specifically, the calculations the team provided assume:

a) the panels are roof-mounted on the Park HQ building
b) the total cost including installation follow the average nationwide value of $18,749 per 5kW solar system ("Solar Panel Installation Cost" 2012)
c) the total cost does not factor in any government incentives ("Solar Panel Installation Cost" 2012)

3.5 Purchased Electricity Usage Evaluations

Purchased electricity was examined in more detail by reviewing the electricity bills. The electricity use was broken down by building then analyzed. Energy audits of the highest electricity per square foot building were then completed to guide suggestions.

3.5.1 Calculating Adjusted Electricity Consumption

The electricity bills for Acadia for the 2015 fiscal year were sorted by building were given by Johnston. Once that was accomplished, the kWh/ft^2 for each building was calculated by summing its total kWh and dividing the sum by its respective square footage also provided by Johnston. This was completed in order to adjust the electricity usage of each building for comparison. Pinpointing the largest electricity usage helped streamline the process of determining which buildings to further investigate.

3.5.2 Adjusted Electricity Consumption Analysis

The buildings with the largest kWh/ft^2 underwent further examination to see whether anything could be done to reduce the purchased electricity use. Suggestions were then made after visiting them onsite. Specifically, suggestions to help increase efficiency and reduce unnecessary energy use were made from this survey.

3.5.3 Electricity Audit of Selected Buildings

This electricity audit involved determining where, when, why, and how the electricity was used in a building. Once that is determined, opportunities to improve efficiency were identified. For practicality, a Level 1 energy audit was only performed on one of the buildings with the largest kWh/ft^2. A Level 1 audit is considered a site assessment or preliminary audit. A Level 1 audit specifically entailed identifying no-cost and low-cost energy saving opportunities, and simple potential capital improvements (Baechler, Strecker, and Shafer 8). The activities performed included an assessment of energy bills and a brief site inspection of the building.

3.6 Suggestions for Reducing Stationary Combustion

A few suggestions were made to help the park reduce its stationary combustion. This was accomplished by first a brief walkthrough of some buildings in the park in order to identify places where major issues can be found. Along with the walkthrough was a brief interview with site operating personnel, from which some information of the site heating condition in the winter was obtained. After the visits, some suggestions were made aiming at some of the park's major issues regarding stationary combustion. Some other suggestions were adapted from "New River Gorge National River Action Plan."

3.7 Critical Air Pollutants Inventory

The CAP inventory was based on information from the 2015 fiscal year. Taken into consideration were: stationary combustion, gasoline storage tanks, mobile combustion, the burning of wood, and asphalt laid. For the concessionaires National Park Tours and Oil's Trolley only the emissions for mobile combustion were considered. Carriages of Acadia and Jordan Pond House were not considered due to lack of information.

3.7.1 Stationary Sources

It was impossible to obtain information on propane and diesel usage by device, and therefore this information was excluded from the analysis.

The next module asked if on premise gasoline storage tanks were to be included, which they were. The storage tank section required information on both aboveground and underground storage tanks. For aboveground storage tanks, total volumes of four different categories were needed: tanks with volume of 999 gallons and less (13,852 gallons), tanks with volume of 1,000 to 4999 gallons (6,600 gallons), tanks with volume of 5,000 to 9,999 gallons (0 gallons), and tanks with volume of 10,000 gallons and greater (0 gallons). For underground storage tanks, the total volume of all sizes of tanks was required (14,000 gallons). All this information was provided by Johnston and entered into the CLIP tool.

3.7.2 Mobile Combustion

To calculate the CAP emission, information from the mobile combustion section (the number of each class of vehicle) was automatically populated by the CLIP tool based on data entered in the GHG emission inventory. Data for park operations, visitors, and concessionaires were used.

Mobile CAP emissions also wanted the hours of use of the non-road equipment. This was not obtainable and was omitted. Watercraft CAP emission was also based on hours of use along with the horsepower of the boats. This information was obtained from Johnston and entered into the CLIP tool.

3.7.3 Burning

The number of campsites for each campground was divided by 32 (an estimated number of campsites needed to burn a cord of wood, provided by Jacobi). Afterwards, this number for each campground was multiplied by the respective number of days in the summer season that it is open. Campground staff and Jacobi shared that Seawall (299.88 cords/year) and Blackwoods (1582.32 cords/year) campgrounds are at full occupancy during their open seasons. Schoodic Woods (290.84 cords/year) and Duck Harbor (18.24 cords/year) campgrounds were assumed to be at three quarters occupancy during their open seasons. As a conservative estimate, due to lack of data, Wildwood Stables (21.72 cords/year) is assumed to be at half occupancy.

There are fifteen group campsites -- each accommodating up to fifteen people -- spread among the five campgrounds. Each of them is assumed to use as much wood as five regular campsites, since Jacobi speculated regular campsites accommodate an average of three people. Group campsites with an unknown location (340.56 cords/year) are assumed to be at half occupancy for a duration of 132 days (which is the average length of the open season of all of the park campgrounds except Duck Harbor, which is known to have no group campsites).

Next, the amount of planned (173.54 cords/year) and unplanned (5.1 cords/year) burning within the park was calculated. This conversion was performed by using the average live tree density (following a protocol with minimum size requirements) and a rough estimate of tree height (both provided by Miller). Note that the height estimate is the mean of the average codominant and intermediate tree heights, and excludes subcanopy and dominant tree heights.

3.7.4 Asphalt

Another component of the CAP emissions is the amount of asphalt laid. Johnston provided a spreadsheet with the location and size of each road and parking lot in the park. This spreadsheet aided in determining the overall area that is paved within the park. Some of the areas were measured in lane miles so these areas had to be doubled in order to get an accurate measurement of the square footage of the roads.

Once the square footage was found, the next step was to multiply that area by the density of the (2.87 tons/cubic foot) and the thickness of the asphalt laid (2 inches), eventually producing a value in tons. Although the team had the total amount of asphalt laid during the last eight years (2007-2015), it was only relevant to have the amount of asphalt laid in 2015. Therefore, the number was simply divided by eight since the park repaves its roads and parking lots on an eight-year cycle. This value was used in lieu of the asphalt laid in 2015 since the park did not repave that year.

Finally, the last thing to figure out was the percent dilution and what kind of asphalt is laid in the park. The type of asphalt is categorized into three separate groups based on the speed that the asphalt hardens when it is first laid. The three types of asphalt are fast, medium, or slow cure. The higher the percent dilution of the mixture the slower the mixture cures because of the added water. According to Johnston the park used a fast cure asphalt. The last thing to do was contact Lane Construction to determine the percent dilution of the asphalt laid in the park and the cure of said asphalt. Since they were unable to provide an answer, the value of 35% was chosen as suggested by the CLIP tool based on Johnston's information about the curing.

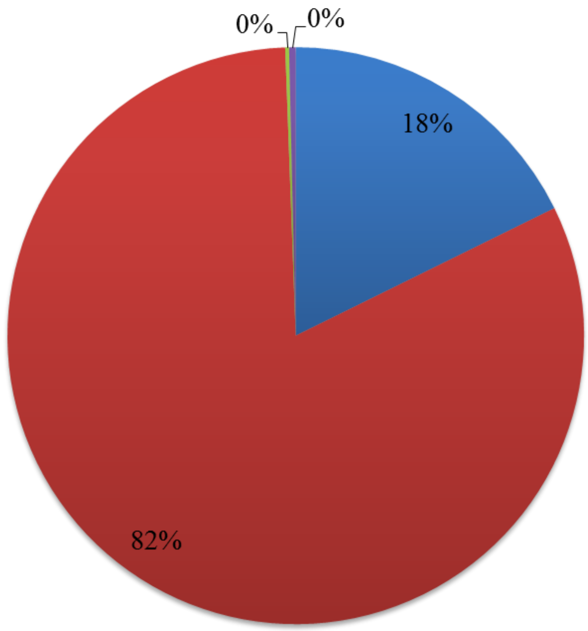
4. Results and Analysis

This chapter discusses the results for GHG emission and CAP emission inventories, along with some mitigation strategies. The results of the GHG emission inventory were presented from two perspectives: emissions broken down by operation, and emissions broken down by sector within the park operation. The results were then analyzed using different strategies, including potential reduction of visitors and making comparisons to other parks. In order to help the park reduce its purchased electricity use, a series of cost-benefit analyses were conducted to determine the feasibility of several suggestions. Suggestions were also made to help reduce the park's second largest GHG emission contributor, stationary combustion. Lastly, the results for CAP inventory were presented, which began with a broad picture of the total emission, followed by a detailed discussion of each pollutant.

4.1 Greenhouse Gas Emission Results

Acadia's total GHG emission is 13,923 MTCE for 2015. Of the total, 2,466 MTCE were from the parks own operations, 11,375 MTCE were from visitors, 30.5 MTCE were from National Park Tours and 51.5 MTCE were from Oli's Trolley, see Figure 1.

As shown in Figure 1, the largest contributor to the park's overall carbon footprint is its visitors. Much of the GHG emission that comes from the visitors is from driving. It is estimated that each visitor drives around Park Loop Road and up to the summit of Cadillac Mountain at least once. This sums to the visitors driving an estimated 25,300,647 miles per year in 937,061 cars. Moving forward, one major action that the park can consider in order to abate its carbon footprint is finding ways to reduce visitor traffic in private vehicles. The carbon footprint of concessionaires was not heavily scrutinized because they collectively produce about 1% of the total GHG emissions of the park.

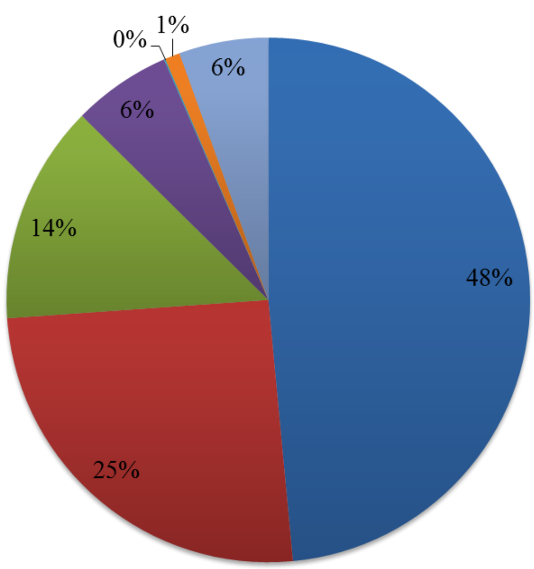


Operation	MTCE
Park Emissions	2,466
Visitors	11,375
National Park Tours	30.5
Oli's Trolley	51.5
Total	13,923

Figure 1: Acadia National Park's Total GHG Emission by Operation

Within Acadia's operations, the emissions were broken down by purchased electricity, stationary combustion, mobile combustion, wastewater treatment, refrigeration and employee commuting. The percentage of the total emissions generated by each sector is shown by Figure 2, as well as the numerical value for each sector's emission.

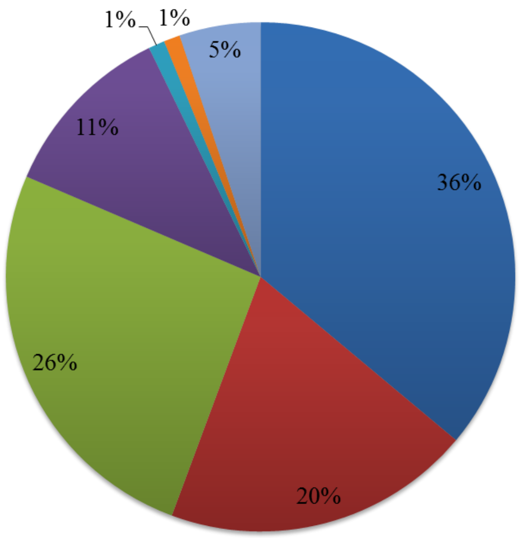
In Figure 2, it is evident that the largest contributor to the park operations' GHG emission is purchased electricity, followed by stationary and mobile combustion. Altogether, these three sectors account for 87% of the park operations' emission. For greatest impact, these should be the sectors that the park focuses on the most. In the future, solid waste, refrigeration, and even employee commuting may be considered for reduction.



Sector	MTCE
Purchased Electricity	1,196
Stationary Combustion	626
Mobile Combustion	333
Solid Waste	150
Wastewater Treatment	2
Refrigeration	23
Employee Commuting	136
Total	2,466

Figure 2: Acadia National Park's GHG Emission by Sector

Acadia's GHG emissions are distributed differently than the average CFP. Figure 3 shows the average breakdown of GHG emission among the 122 CFPs in the US. In most CFPs, the largest contributor to their GHG emission is purchased electricity, followed by mobile combustion, and stationary combustion. Acadia's purchased electricity sector is 12% greater, and stationary combustion is 5% greater, whereas its mobile combustion sector is 12% smaller.



Sector	MTCE
Purchased Electricity	327
Stationary Combustion	177
Mobile Combustion	233
Solid Waste	102
Wastewater Treatment	9
Refrigeration	9
Employee Commuting	46
Other	28
Total	935

Figure 3: Average CFP's Total Emission by Sector

This means that Acadia should prioritize its purchased electricity reduction first and then stationary combustion second while leaving mobile combustion for the future. Acadia has a lower percent from solid waste due to the recycling policies in place already. The last thing that can be taken away from this comparison is that Acadia is just about even with wastewater treatment, refrigeration, and employee commuting so those should be the last considerations.

4.2 Visitor Impact

When the number of visitor vehicles on the road is reduced by 10%, 25%, 50%, 75%, or 100%, there can be drastic reductions in the GHG emission, see Table 3. A 10% reduction would remove 93,706 vehicles from the road. These cars could be replaced with buses, so the visitors can still see the park without emitting as much GHG. Although gasoline or diesel buses emit GHG, it emits less GHG than what the visitor traffic would produce; one bus produces approximately 5% of the emissions from the 15 vehicles replaced. While it may be impractical to remove all visitor vehicles from the road, even a 10% reduction would save around 1,200 MTCE each year for either gasoline or diesel buses. It would only take five additional bus routes an hour, for 12 hours a day, during the peak season to replace the vehicles on Park Loop Road.

Table 3: Emissions Prevented by Replacing Visitor Vehicles with Buses

	MTCE Not Emitted By Visitors	MTCE Emitted by Gasoline Buses	Net MTCE Saved	MTCE Emitted by Diesel Buses	Net MTCE Saved
10% Reduction	1,432	222	1,211	248	1,184
25% Reduction	3,581	554	3,027	621	2,960
50% Reduction	7,162	1,108	6,054	1,241	5,921
75% Reduction	10,743	1,662	9,081	1,862	8,881
100% Reduction	14,324	2216.5	12,108	2,483	11,841

4.3 Comparisons to Other Parks

The GHG emission from Acadia was compared to the emissions from six other parks: Crater Lake National Park, Grand Canyon National Park, Mt. Rainier National Park, Olympic National Park, Petrified Forest National Park, and Redwood National Park.

Figures 4 and 5 compare the emission of Acadia's park operations to the emissions of the other national parks' operations by 1,000 visitors and acres respectively. Figure 4 shows that compared to the other six parks, Acadia is tied for the lowest GHG emission from its park operations per 1,000 visitors with Olympic National Park at 0.88 MTCE. However, Figure 5 shows that compared to the other six parks, Acadia has the highest GHG emission from its park operations per 1,000 acres with 53.26 MTCE, which is more than triple the next highest park, Crater Lake National Park at 16.85 MTCE. The comparison of the two graphs shows that Acadia has a very high number of visitors for its size; this is one of the reasons that Acadia's visitors have such a large impact on its GHG emission.

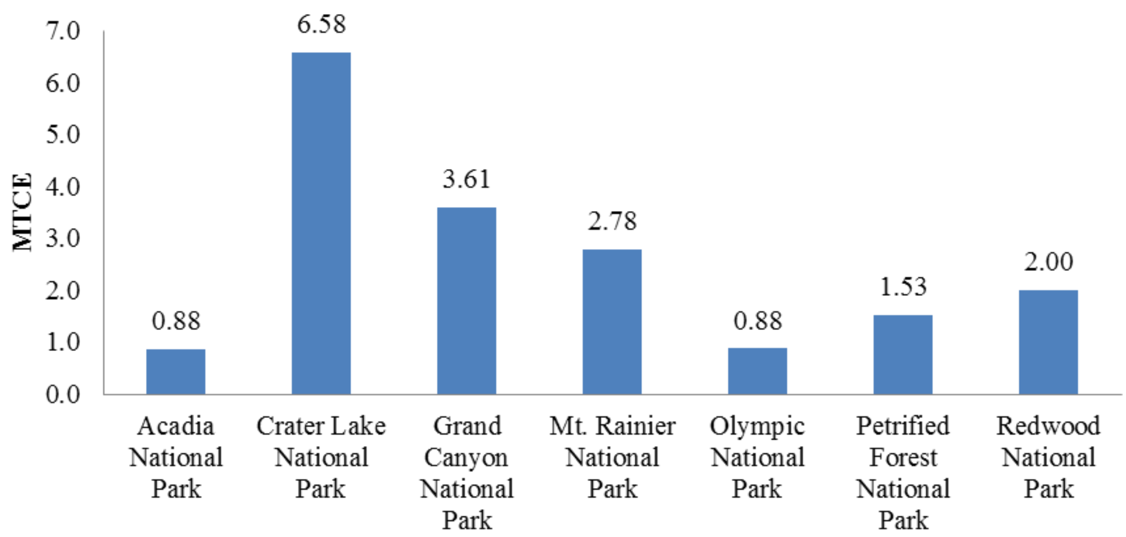


Figure 4: Acadia National Park's GHG Emission Per 1,000 Visitors

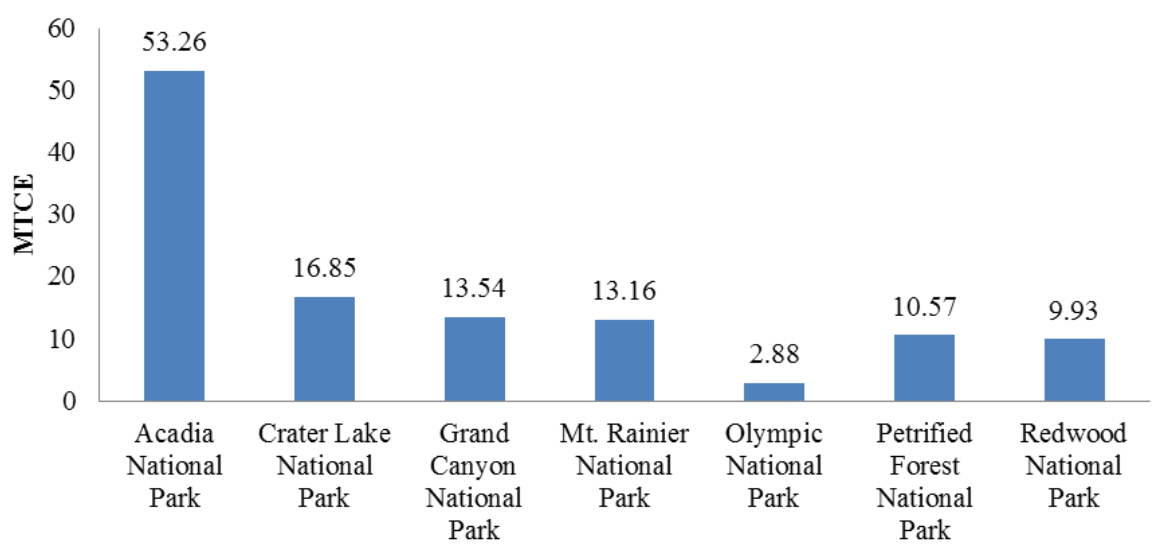


Figure 5: Acadia National Park's GHG Emission Per 1,000 Acres

Figures 6 and 7 compare the total emission from Acadia to the other six parks' total emissions by both 1,000 visitors and 1,000 acres respectively. Looking at Figures 6 and 7, they tell a very similar story to Figures 4 and 5. When compared to the other six parks, Acadia has one of the lowest total GHG emission per 1,000 visitors, however, it has the highest total GHG emission per 1,000 acres. For total GHG emission per 1,000 visitors, Acadia is the third lowest at 6.00 MTCE behind both Olympic and Petrified Forest National Parks. However, when looking at the total GHG emission for 1000 acres, Acadia is unsurpassed with 364.26 MTCE. This comparison reiterates that the main contributor to Acadia's GHG emission is its visitors, and that Acadia should prioritize reducing visitor impact.

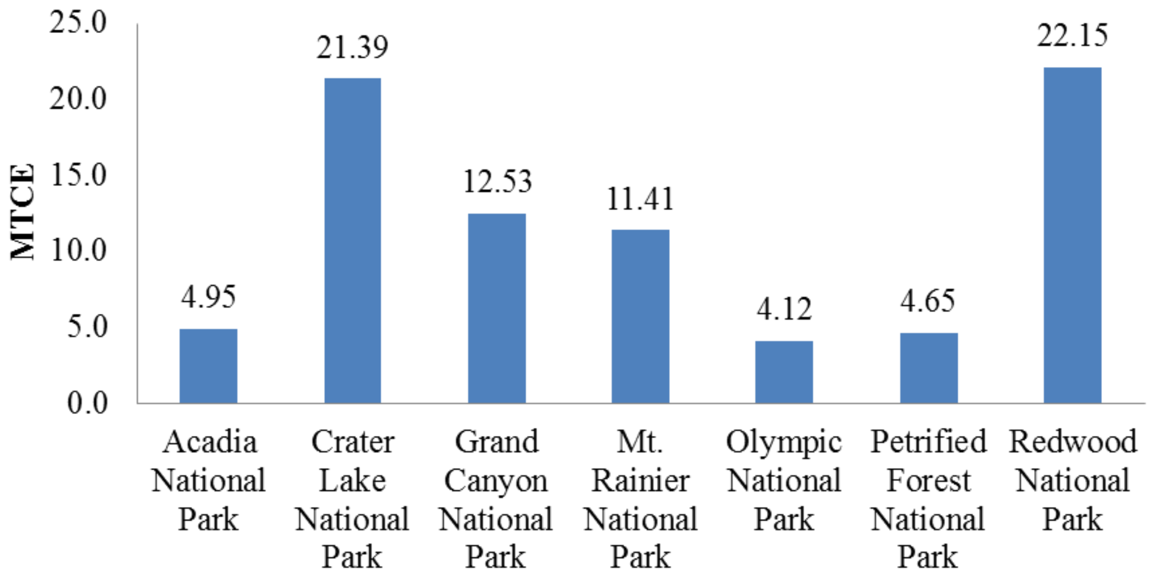


Figure 6: Acadia National Park's Total GHG Emission Per 1,000 Visitors

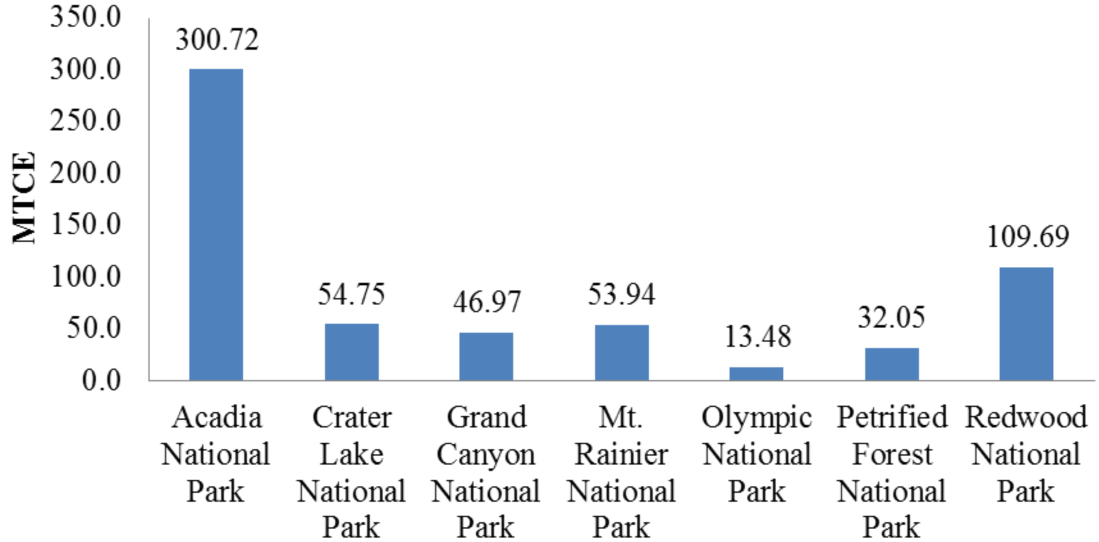


Figure 7: Acadia National Park's Total GHG Emission Per 1,000 Acres

4.4 Cost-Benefit Analysis of Reducing Purchased Electricity

After reviewing all of Acadia's electricity bills for the 2015 fiscal year, it was calculated that the electricity use generated 1,196 MTCE as stated previously. Acadia spent a total of $229,670.10 for the 2015 fiscal year.

The goal is to reduce the park's current electricity usage of 2,674,408 kWh by 15% for its facilities within five years. This means a new annual electricity usage of 2,273,247 kWh. By reducing the electricity usage by 401,161 kWh, Acadia can potentially save $34,450.51 annually, see Table 4. There will also be an annual reduction of 179 MTCE by reaching the goal of 1,017 MTCE.

Table 4: 15% Reduction in Purchased Electricity

	kWh	MTCE	Amount
2015 FY	2,674,408	1,196	$229,670.10
Goal	2,273,247	1,017	$195,219.59
Savings	401,161	179	$34,450.51

Improving energy efficiency and utilizing alternative energy sources will help lower GHG emission, decrease electricity consumption, and have financial benefits for the park. As the inventory results indicated, about 48% of the park's GHG emission results from electricity usage. This is well above the average for most CFPs indicating this is an issue Acadia must address.

In order to reduce the park's purchased electricity usage by 15%, the following suggestions were provided by the team:

- Turn off lights when not in use
- Make it possible to have only half the lights on in a room
- Use Natural Light

- Upgrade light bulbs to high-efficiency models
- Eliminate phantom load
- Replace outdated appliances with energy efficient models

After the park has minimized its electricity use, it should investigate the possibility of utilizing renewable energy sources in its facilities on Mount Desert Island.

4.4.1 Cost-benefit Analysis of Replacing Light Bulbs

Table 5 below shows the energy and economic costs of 100 four ft. T8 LED bulbs in comparison with 100 four ft. T8 fluorescent bulbs and the total savings using LED bulbs over time. It can be seen that although the price of each LED light bulb is $7 more than that of each fluorescent bulb, LED light bulbs will help save money in the long run because of their lower energy consumption and the resulting lower annual electricity cost. After the analysis, it was determined that it will take approximately 3.2 years until a LED bulbs pay for itself. In general, LED light bulbs have longer lifespans than fluorescent light bulbs, however, this factor was not included in this analysis (Home Depot). Therefore, LED bulbs will likely save even more money than indicated in Table 5.

Table 5: Light Bulbs Cost-Benefit Analysis

	LED	Fluorescent
Power Consumption per bulb (Watts)	88	32
Price per bulb ($)	9	2
Lifespan (hrs)	50,000	30,000
Total operating hours (hrs/ yr)	2,349	
	4,228.2	7,516.8
Total Electricity Consumption per 100 bulbs (kWh/ yr)	22	
Total 5-year Electricity Savings per 100 bulbs (kWh)	16,443	
Total 5 -year GHG Emission Reduction per 100 bulbs (MTCE)	7.4	
Total 10-year Electricity Savings per 100 bulbs (kWh)	32,886	
Total 10 -year GHG Emission Reduction per 100 bulbs (MTCE)	14.7	
Unit electricity price ($)	0.06594	
Electricity Cost per 100 bulbs($/ yr)	279	496
Total 5-year Electricity Cost Savings per 100 bulbs ($)	1,085	
Total 10-year Electricity Cost Savings per 100 bulbs ($)	2,170	
Years until pay-off	3.2	
Total 5-year Savings per 100 bulbs ($)	385	
Total 10-year Savings per 100 bulbs ($)	1,470	

4.4.2 Phantom Load

Reducing phantom load will greatly help Acadia reach its goal of reducing electricity use by 15% within five years. Since phantom load accounts for 5-10% of the annual electricity use, the park could save anywhere from 133,720 kWh to 267,441 kWh annually, see Table 6. The savings for Acadia could be from $11,483.50 to $22,967.01 annually, which could be invested back into making Acadia more environmentally friendly. Eliminating phantom load will also reduce anywhere from 60 to 120 MTCE annually.

Table 6: Eliminating Phantom Load

Phantom load 5%	Phantom load 10%
kWh	**kWh**
133,720	267,441
Money Saved	**Money Saved**
$11,483.50	$22,967.01
MTCE Saved	**MTCE Saved**
60	120

Reducing phantom load will be a huge step forward in the right direction for Acadia. Focusing on phantom load was ideal because there was no upfront cost, it simply involves unplugging devices when not in use.

4.4.3 Cost-benefit Analysis of Implementing Solar Energy

To calculate the magnitude of the solar energy system, the research team first determined the average output of a 5kW system in Maine, which was 6,240 kWh. To account for 15% of Acadia's current purchased electricity (401,161 kWh), at least 65 of these 5 kW solar systems are required. The total cost for parts and installation amount to $1,205,347.86 and will take an estimated 35 years to payoff assuming the solar energy saves $34,450.51 each year on purchased electricity. However, this calculation did not include government incentives and may overestimate the cost of the investment ("Solar Panel Installation Cost" 2012).

After determining how long it would take to pay off the solar system, it was evident that switching over to solar energy at this magnitude was not feasible for several reasons. First, the industry standard warranty for most solar panels only lasts 25 years. Having the warranty run out for such a large investment ($1,205,347.86) before it is paid off is an unsafe financial decision. For example, the solar panels may become damaged or require maintenance after the warranty expires. Needless to say, the upfront cost is steep and exceeds the park's budget.

Instead, Acadia could implement solar energy gradually with less upfront cost. This recommendation of implementing solar energy should focus on reducing GHG emission instead of purchased electricity use. However, if Acadia could find a sponsor for the solar panel investment in full, it would be a great way to reduce its purchased electricity consumption.

4.5 Results of Electricity Usage Evaluation

For most CFPs, electricity usage is a large portion of their GHG emission, and Acadia was no exception. Lowering the GHG emission by reducing electricity usage is one of the more feasible actions a park can take. Reducing the emissions can be as simple as changing staff behavior to as complicated as utilizing more efficient technology. In the end, evaluating the electricity usage is beneficial because not only will it reduce GHG emission but save Acadia thousands of dollars annually.

4.5.1 Calculating Adjusted Electricity Consumption

As mentioned, some of the buildings with the largest kWh/ft^2 underwent energy audits. Figure 8 indicates the kWh/ft^2 of some of the well-known buildings owned and operated by Acadia.

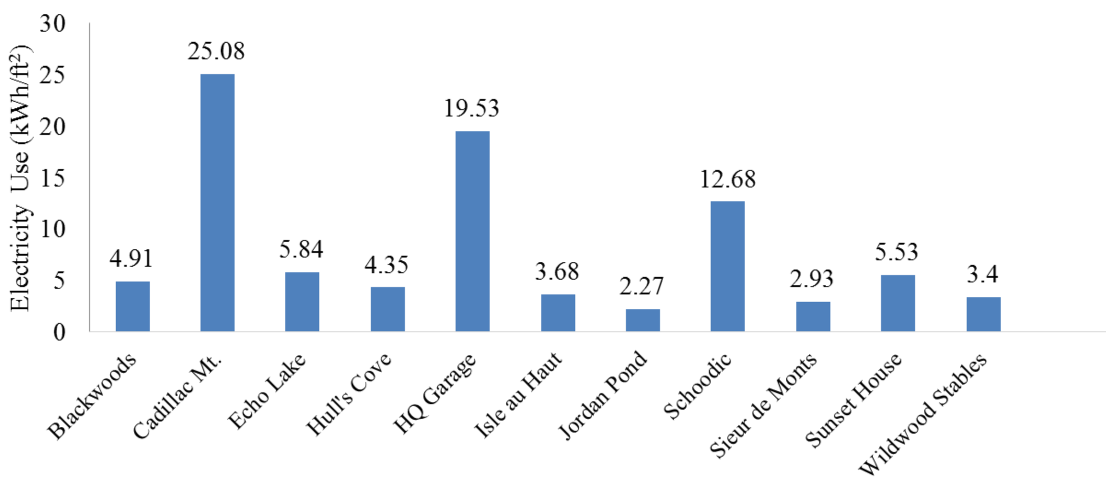


Figure 8: High Energy Use and Well-known Facilities

The three largest contributors were Cadillac Mt at 25.08 kWh/ft^2, headquarters (HQ) garage at 19.53 kWh/ft^2, and Schoodic at 12.68 kWh/ft^2. These three buildings were further examined, however it was found that an audit at Cadillac would not be practical.

4.5.2 Adjusted Electricity Consumption Analysis

After delving deeper into the top three contributing facilities, it was decided that little could be done about Cadillac Mountain because the radio tower was by the far the greatest contributor. The radio tower was not a valid candidate for electricity reduction; it would be a better candidate for having a renewable energy source to compensate for the high energy usage. Instead of Cadillac, Hulls Cove Visitor Center was chosen as an alternative site for an electricity audit since it is heavily frequented. Thus, electricity audits were performed at the HQ garage, Schoodic facilities, and Hulls Cove.

4.5.3 Electricity Audit of Selected Buildings

The team investigated where, when, why, and how the electricity was used at Acadia's HQ garage. As for the abnormally high electricity use, some of its excess is necessary due to on-site maintenance on park vehicles. For instance, there were two car lifts and many electric power tools used regularly. Furthermore, the calculation for its adjusted electricity use (kWh/ft^2) may have been exaggerated due to an underestimate of the area of facilities encompassed in its electricity meter.

One glaring issue was the frequency with which the abundance of lights was unnecessarily left on in the HQ garage. The garage operates four days per week for over 10 hours a day (6 a.m. to 4:30 p.m.). At the time of the audit, the team noticed more than 80% of the 379 lights throughout the garage were left on when it was not necessary, since there was no staff present. The garage could easily use natural lighting for most of the hours of operation. For example, one section of the garage facilities is a repurposed gymnasium, see Figure 9. If transparent windows were installed to replace the covers photographed at the time of the audit, sunlight could illuminate the facility and reduce its need for artificial light.

Figure 9: Converted Gymnasium in HQ Garage

Where natural lighting could not be used, sensors could be installed to ensure lights are only on when staff is present and lighting is required. Another inefficiency that was noted at the HQ garage was the location of an ice maker, Figure 10. It was placed outside in an area that is sometimes in direct sunlight.

Figure 10: Ice Maker at the HQ Garage

With the higher than ideal ambient operating temperature for the ice maker, the ice maker uses excessive energy to produce ice that may melt before it is used. If the ice maker were placed inside a cool and shaded building the ice maker would use significantly less electricity. Furthermore, the label warns that the machine should not be used outside.

Computers, monitors, and various electrical devices were left on in the maintenance office when no staff was present. Shutting off the devices and switching off the power strips will reduce electricity use as well as phantom load. Overall, these changes would be a large step towards efficiency at the HQ garage.

The second audit was done at Schoodic Institute since it used 12.68 kWh/ft^2. After exploring the buildings at Schoodic, it was clear that the staff there had already tried to minimize their electricity use. Lights were on sensors in most of the rooms at Schoodic, so lights were not left on in rooms when staff was not present. The staff also used natural light where it was possible; many buildings were designed to emphasize natural lighting. In rooms where sensors were not present, light switches often had stickers on them reminding the employees to shut them off when not in use. Two buildings at Schoodic were recently renovated to have solar panels installed on their roofs. The unusually high adjusted electricity consumption at Schoodic may be exaggerated due to its radio station. Nonetheless, the efforts at Schoodic to minimize its electricity consumption should serve as a model for other park facilities. The next step for Schoodic may be further investment into renewable energy to reduce its reliance on purchased electricity.

The last facility to have an electricity audit was Hulls Cove. Once again, Hulls Cove was selected for an audit because it is one of the most visited places in Acadia even though its energy consumption was only 4.35 kWh/ft^2. Most of the light bulbs inside were LEDs and the employees were in the process of converting all the lights to energy-efficient LEDs. Since a lot of natural light enters the building, the employees could potentially use half the amount of lights currently used. For example, they could have every other row of lights on. In addition, at the time of one of the team's visits to Hulls Cove, the AC was running while the automatic doors were open during the summer. Thus, the AC had to work harder in a futile attempt to cool the building. The doors were open at this time because the line for one of the service desks extended outside of the building. However, if there were better control over the line, for example, through the use of guidance stanchions, the doors can be shut and the AC may run at a lower power setting. Alternatively, if the line is too long to circle within the building and must extend outside, the AC may be turned off, and a natural breeze or a fan may be used instead. These suggestions could help further reduce the energy consumption at Hulls Cove.

Figure 11: Line at Hulls Cove Visitor Center

Ultimately, a Level 1 audit was performed at these locations in order to find practical solutions to help the park reach its goal of a 15% reduction in electricity use. In the future, locations should have Level 2 or 3 energy audits performed to maximize the efficiency of park facilities.

4.6 Suggestions for Reducing the Stationary Combustion

The GHG emission results of the park showed that stationary combustion is the second largest contributor. As explained previously, stationary combustion includes fuels used in appliances including boilers, heaters and generators. By examining the park's fuel charges for the 2015 fiscal year, #2 heating oil was determined to be the most common fuel used by the park. Heating oil #2 also produces more GHG emission than propane which is also used in the park for stationary combustion. Therefore, most suggestions in this section are geared toward the park's heating systems.

After a walkthrough of the HQ garage along with a brief interview with a shop mechanic, a few places where improvements can be made were observed. Firstly, as the buildings at Acadia have a relatively long history, insulation is a major issue in the winter. The inefficient doors and windows let in not only cold air, but also snow drifts. As reported by the shop mechanic, the snow drifts inside the garage door could be as high as 4 ft tall. Secondly, all the heating systems inside the garages are on one control, and this can be a serious issue. In the winter, some places in the garages can get extremely cold due to either poor insulation or the constant use of the doors, while some other places can be overly warm. The heating system is attempting to warm these extremely cold rooms to the proper temperature. This means they are outputting too much heat into the rooms that have better insulation causing them to be too warm.

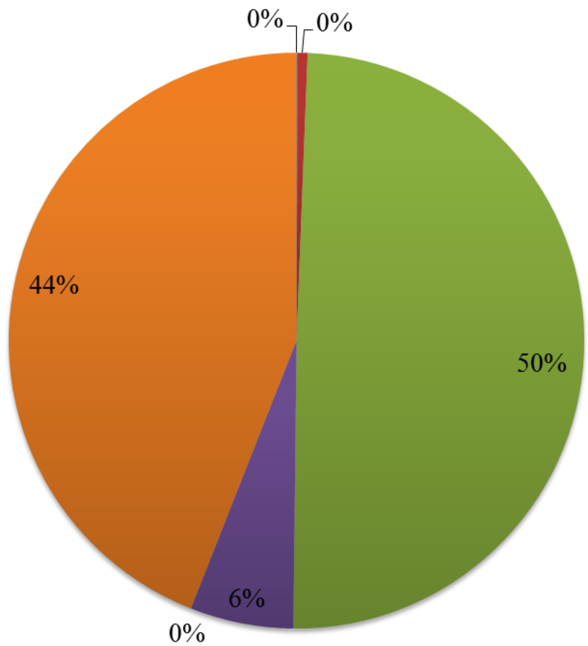
According to Dr. Miller-Rushing, park HQ has many of the same issues with heating. The administration building is constantly cold in the winter. From cursory inspection, the building has single paned windows that are not well sealed. The walls are thin and have inadequate insulation. The exterior doors are loose in the door frames. When they are opened, heat escapes the building making the heaters work unnecessarily hard.

Considering the issues the park currently has, as well as the feasibility of some other things the park can do, the team developed the following suggestions to help reduce the park's stationary combustion:

- Caulk all the windows/doors and increase insulation of the buildings
- Replace park's existing windows with energy-efficient models
- Operate separate heating systems for the garages
- Lower thermostats in winter when possible
- Install a vestibule outside of the doors to eliminate heat loss as people enter/exit the building
- Install solar hot water heaters
- Replace park's existing boiler or furnace with an energy-efficient model

4.7 Critical Air Pollutants Inventory

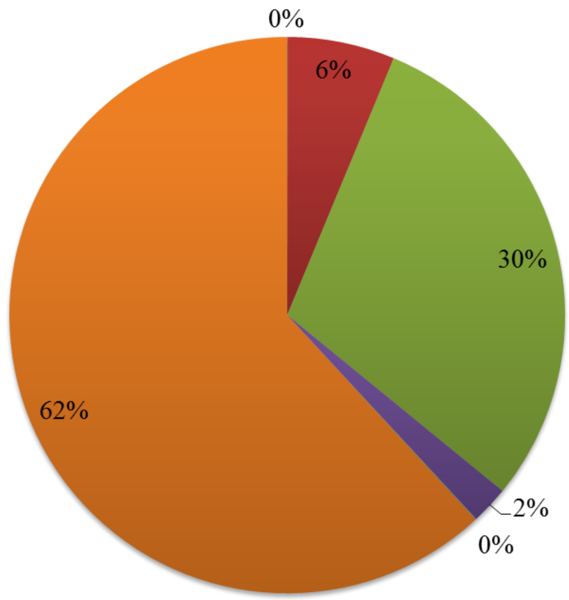
Acadia's CAP emission from park operations is 1,301,428 lbs/year. This can be broken down by the gases: SO_2, NO_X, VOC, $PM_{2.5}$, PM_{10}, and CO, see Figure 12. VOC are the largest contributing CAP constituting 50% of the total annual emission. CO is the next largest contributor with 44% of the total CAP emission, the last 6% is PM_{10}. The other three emission types are less than 1% of the total.



Gas	Pounds per Year
SO_2	874
NO_X	7,140
VOC	645,127
PM_{10}	75,262
$PM_{2.5}$	40
CO	572,985
Total	1,301,428

Figure 12: Park CAP Emission by Gas

The total CAP emission, including visitors and concessionaires, is 3,436,292 pounds per year. This is broken into categories based on what type of gas is being released, see Figure 13. Unlike the breakdown of the park's operations emission, the largest contributor in the total CAP emission is CO. The percent NO_x emission also increased because of the influence of the visitors' mobile combustion.



Gas	Pounds per Year
SO_2	874
NO_X	154,018
VOC	931,264
PM_{10}	75,626
$PM_{2.5}$	1,058
CO	1,647,105
Total	2,809,581

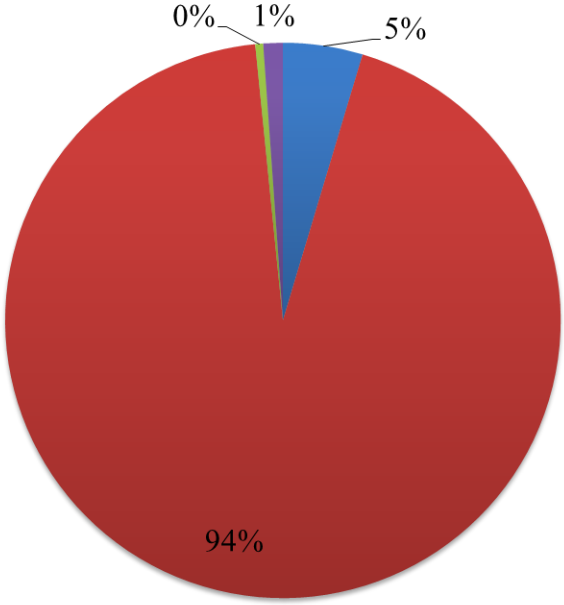
Figure 13: Total CAP Emission by Gas

4.7.1 SO_2 and PM_{10} Emissions

Acadia produces 874 lbs/year of SO_2 and 75,626 lbs/year of PM_{10}. These emissions are from the burning of wood both for clearing the forest and in campfires. These emissions are exclusive to park operations.

4.7.2 NO_x Emissions

Total NO_X emissions are broken down by operation in Figure 14. The total NO_x emissions are 94% from mobile combustion. This means that visitors have the greatest contribution to the NO_x emissions since that operation had the most miles driven. Park operations is the second largest contributor because of their mobile fuel use and also the burning of forests and firewood.

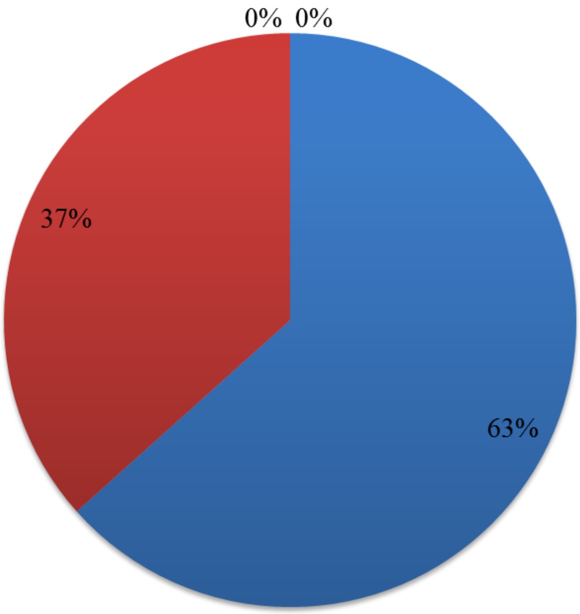


Operation	**Pounds per Year**
Park Operations	7,140
Visitors	144,421
National Park Tours	715
Oli's Trolley	1,742
Total	154,018

Figure 14: Total NO_x Emission by Operation

4.7.3 VOC Emissions

Total VOC emissions are broken down by operation in Figure 15, with the largest contributor being park operations. VOC emissions come primarily from burning wood and laying asphalt, with mobile combustion being a smaller contributor. Half of the total VOC emissions are from burning which is exclusive to park operations; laying asphalt is also a park-only sector. Even though visitors constitute such a large percentage of the total mobile combustion, it is still eclipsed by the other sources of VOC emissions from park operations.

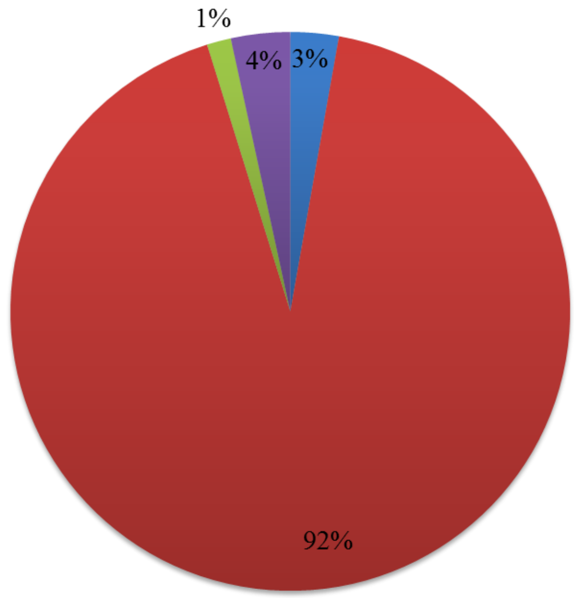


Operation	**Pounds per Year**
Park Emissions	645,127
Visitors	286,062
National Park Tours	22
Oli's Trolley	53
Total	931,264

Figure 15: Total VOC Emissions by Operation

4.7.4 $PM_{2.5}$ Emissions

Total $PM_{2.5}$ emissions are broken down by operation in Figure 16; $PM_{2.5}$ is only emitted through mobile combustion. Since visitors are the largest portion of mobile combustion, their contribution is the greatest. National Park Tours uses one diesel bus and Oli's Trolley exclusively uses diesel buses; diesel buses emit more $PM_{2.5}$ than other types of vehicles. This causes their percent contribution to the $PM_{2.5}$ total to be greater than their vehicles' percent contribution to total fuel use.

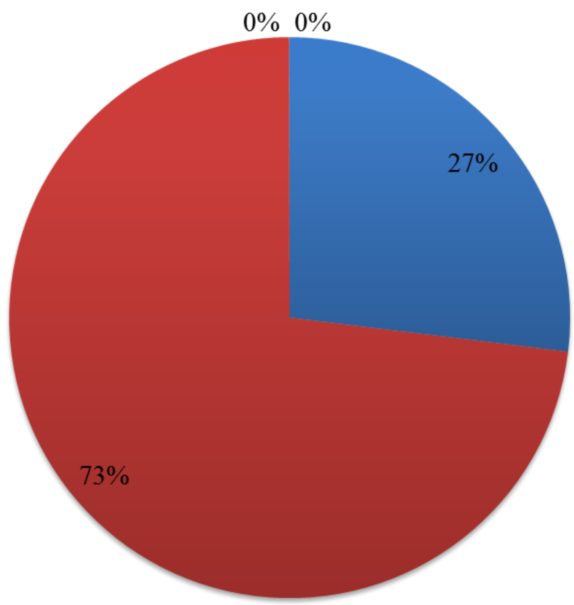


Operation	Pounds per Year
Park Emissions	40
Visitors	494
National Park Tours	20
Oli's Trolley	49
Total	1,058

Figure 16: Total $PM_{2.5}$ Emissions by Operation

4.7.5 CO Emissions

Total CO emissions are broken down by operation in Figure 17; CO is primarily emitted through mobile combustion, although burning wood also emits CO. Since the visitors constitute the majority of mobile combustion, they have the largest contribution to the CO emissions. Park operation's CO emissions are from both the parks mobile combustion and the burning of wood.



Operation	Pounds per Year
Park Emissions	572,985
Visitors	1,073,334
National Park Tours	209
Oli's Trolley	577
Total	1,647,105

Figure 17: Total CO Emissions by Operation

5. Conclusion and Recommendations

When looking at the emission from the park as a whole, it is evident that visitors are the greatest contributor to the park's GHG emission. In consequence, the park should focus on alleviating visitor mobile combustion since it accounts for 82% of the park's overall GHG emission. This can be done by adding more buses to replace visitor vehicles. In order to reduce visitor impact, the park should take steps to broaden its public transportation to replace a number of private vehicles on park roads.

Looking into the other 18% of the park's emission, purchased electricity and stationary combustion are the largest offenders. Suggestions focused on minimizing GHG emission in these two categories.

Since the team only had seven weeks in Acadia, the team had to narrow down the facilities to be audited. To do this, the electricity consumption was adjusted for each of Acadia's facilities. Once the kWh/ft^2 for each facility was determined, the largest contributors were further examined to see if anything could be done to lower the purchased electricity use. As mentioned, Cadillac Mt., Acadia's HQ garage, and Schoodic Facility were the largest contributors. Upon further examination, Cadillac Mt. was deemed not an ideal place for an audit since little could be done about reducing the energy consumption there. Instead, Hulls Cove was chosen since it is often frequented by visitors. The energy audits were only Level 1 but were still extremely insightful. The following recommendations for the buildings will help the Acadia reach its goal of 15% reduction of purchased electricity:

- Turn off lights when not in use
- Make it possible to have only half the lights on in a room
- Use Natural Light
- Upgrade light bulbs to high-efficiency models
- Eliminate phantom load
- Replace outdated appliances with energy efficient models

To further analyze some of these suggestions, a cost-benefit analysis was performed. Replacing the fluorescent light bulbs in the park with the more energy efficient LED can be a useful strategy to help reduce the park's GHG emission. After a cost-benefit analysis, it was determined that it will take approximately 3.2 years until a four ft. T8 LED bulb pays for itself. Calculations also showed that LED bulbs can help save money in the long run when replacing fluorescent bulbs -100 four ft. T8 LED bulbs can save $385 after 5 years and $1470 after 10 years.

Addressing phantom load can immediately help the Acadia reach its goal of 15% reduction of purchased electricity use; phantom load accounts anywhere from 5-10% of the annual electricity bill. This suggestion is one of the more practical ones due to no upfront cost, it simply only involves changing staff behavior, in particular unplugging electrical devices.

Solar energy as a supplement to purchased electricity in park facilities is an advantageous strategy to reduce GHG emission. Renewable energy, such as solar energy, pays for itself over time after the initial capital investment. A cost-benefit analysis of an upfront purchase of solar panels was performed. Herein, the solar panels were assumed to generate for 15% of the current purchased electricity. It would take approximately 35 years for the payoff with an initial investment slightly exceeding one-million dollars. This result is unsatisfactory at face value because the payoff is beyond the typical warranty period, and requires a seemingly unrealistic amount of initial capital. However, it was also noted that there are caveats to this result, such as: variable prices of solar panels and installation, as well as a lack of access of information more recent than 2012. To further investigate, the team recommends examining the solar energy systems at Schoodic Institute in case it would be feasible to expand it to park facilities on Mount Desert Island as well. Solar energy systems may be become feasible with more information on current and competitive total upfront pricing, or through a Price Purchase Agreement.

Suggestions were also made to help reduce the park's second largest GHG emission contributor- stationary combustion. Prior to making suggestions were a walkthrough of the HQ garage and a few brief interviews with the park employees. During the process, it was observed that the inefficient insulation in the park's buildings was a major problem. Additionally, the universal control of all the heating systems inside the garages also resulted in an excessive use of heating fuel. Considering these issues along with the feasibility of some other things the park can do, the following suggestions were made:

- Caulk all the windows/doors and increase insulation of the buildings
- Replace park's existing windows with energy-efficient models
- Operate separate heating systems for the garages
- Lower thermostats in winter when possible
- Install a vestibule outside of the doors to eliminate heat loss as people enter/exit the building
- Install solar hot water heaters
- Replace park's existing boiler or furnace with an energy-efficient model

Compared to other CFPs, Acadia shares the largest contributing sector in purchased electricity. However, Acadia's second highest offender, and its second concern, is stationary combustion whereas mobile combustion is the second largest contributor in other CFPs. When Acadia is compared to other parks such as Redwood National Park and Olympic National Park in terms of GHG emissions per 1000 acres, Acadia has the highest MTCE by triple of the next park. However, when you compare Acadia to these parks in terms of GHG emissions per 1000 visitors it is tied for the lowest with Olympic. This shows that Acadia has an abnormally large amount of visitors for the size of the park.

The progress of CAP emission mitigation cannot be easily outlined in Acadia; however, the emission of NO_x, CO, and $PM_{2.5}$ are overwhelmingly attributable to mobile combustion. VOC is also emitted, in part, by mobile combustion. Therefore, a decrease in CAP emission overall is achievable by reducing visitors' mobile combustion. Strategies to reduce mobile combustion include restricting visitor travel in private vehicles.

Moving forward Acadia should apply for the Climate Friendly Parks program. To qualify, Acadia must:

- Monitor the carbon footprint annually
- Sponsor educational programs for their staff
- Community outreach for environmental sustainability

Acadia should also work to carry out Level 2 or 3 energy audits on the highest electricity use buildings. Acadia should also establish cost-benefit analyses of any change that they are looking to make going forward to budget their money and time so they can alleviate their GHG emission in the most cost effective and efficient manner. Once Acadia has minimized its energy use, it should look into switching to renewable energy sources to help minimize overall GHG emission.

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Appendix A: Commuter Survey

Exit this survey

NEW: Climate Friendly Parks Commuter Survey for CLIP Tool

1. Commuter Survey

100%

* 1. Park Name

* 2. Employee Name

* 3. Inventory Year

* 4. In your normal routine, how many days/week did you commute to work during the inventory year?

- 1
- 2
- 3

◯ 4

◯ 5

◯ 6

◯ 7

*** 5. How many potential commuting days do you think you missed during the inventory year (estimate considering unexpected telecommuting, business travel, sick, vacation)?**

[ ]

*** 6. How far is your commute to and from work (total round-trip in miles)?**

[ ]

*** 7. Many people use multiple modes of travel in a single commute, or different modes on different days. What percentage of your commuting do you do in the following modes? (e.g., 80% Train and 20% Bike would be entered as "80" and "20" for those modes, respectively)**

Automobile (solo)	
Carpool (+1 person)	
Carpool (+2 people)	
Carpool (+3 people)	
Carpool (+4 or more people)	
Commuter Bus	
Train	
Bike/Walk/Run	
Other	

8. If you drive, what kind of vehicle do you drive?

Vehicle Type

Select one: [ ]

*** 9. Do you have the option to take public transportation?**

○ Yes ○ No

10. If applicable, what barriers exist to your using public transportation, carpool, walking, biking, etc. to work?

[ ]

11. How would you like to see your park or NPS become more sustainable? Do you have any project ideas?

[ ]

Done

Appendix B: Commuter Survey Replies

In your normal routine, how many days/week did you commute to work during the inventory year	How many potential commuting days do you think you missed during the inventory year	How far is your commute to and from work (total round-trip in miles)?	Many people use multiple modes of travel in a single commute, or different modes on different days. What percentage of your commuting do you do in the following modes?					If you drive, what kind of vehicle do you drive?
			Automobile solo	Carpool +1 person	Carpool +2 people	Carpool +3 people	Bike/ Walk/ Run	
4	93	10	100%	0%	0%	0%	0%	Gasoline Heavy Truck
4	58	20	100%	0%	0%	0%	0%	Gasoline Heavy Truck
5	30	15	100%	0%	0%	0%	0%	Gasoline Light Truck
5	30	5	100%	0%	0%	0%	0%	Gasoline Light Truck
5	10	14	100%	0%	0%	0%	0%	Gasoline Light Truck
4	107	20	0%	0%	50%	50%	0%	Gasoline Light Truck
4	88	44	0%	100%	0%	0%	0%	Gasoline Light Truck
5	150	10	100%	0%	0%	0%	0%	Gasoline Light Truck
4	5	24	100%	0%	0%	0%	0%	Gasoline Light Truck
4	15	70	100%	0%	0%	0%	0%	Hybrid Car
5	15	16	100%	0%	0%	0%	0%	Hybrid Car
5	10	12	100%	0%	0%	0%	0%	Hybrid Car
4	20	20	100%	0%	0%	0%	0%	Large Gasoline Car
3	0	10	0%	0%	100%	0%	0%	Large Gasoline Car
5	8	8	95%	0%	0%	0%	5%	Large Gasoline Car

In your normal routine, how many days/week did you commute to work during the inventory year	How many potential commuting days do you think you missed during the inventory year	How far is your commute to and from work (total round-trip in miles)?	Many people use multiple modes of travel in a single commute, or different modes on different days. What percentage of your commuting do you do in the following modes?					If you drive, what kind of vehicle do you drive
			Automobile solo	Carpool +1 person	Carpool +2 people	Carpool +3 people	Bike/ Walk/ Run	
4	84	80	0%	0%	0%	100%	0%	Large Gasoline Car
5	190	8	90%	10%	0%	0%	0%	Large Gasoline Car
5	122	8	100%	0%	0%	0%	0%	Large Gasoline Car
2	57	20	0%	0%	0%	50%	0%	Large Gasoline Car
5	1	78	100%	0%	0%	0%	0%	Medium Gasoline Car
5	0	10	0%	100%	0%	0%	0%	Medium Gasoline Car
5	2	6	100%	0%	0%	0%	0%	Medium Gasoline Car
5	20	40	100%	0%	0%	0%	0%	Medium Gasoline Car
5	15	12	100%	0%	0%	0%	0%	Medium Gasoline Car
5	5	14	90%	5%	0%	0%	5%	Medium Gasoline Car
5	35	49	100%	0%	0%	0%	0%	Medium Gasoline Car
5	21	12	85%	15%	0%	0%	0%	Medium Gasoline Car
4	32	80	0%	0%	0%	100%	0%	Medium Gasoline Car
4	80	28	0%	0%	100%	0%	0%	Medium Gasoline Car
4	104	30	100%	0%	0%	0%	0%	Medium Gasoline Car
4	104	9	100%	0%	0%	0%	0%	Medium Gasoline Car
4	16	3	100%	0%	0%	0%	0%	Medium Gasoline Car
4	112	20	100%	0%	0%	0%	0%	Medium Gasoline Car
5	195	12	100%	0%	0%	0%	0%	Medium Gasoline Car
4	80	72	0%	0%	0%	100%	0%	Medium Gasoline Car
5	0	14	100%	0%	0%	0%	0%	Medium Gasoline Car
5	10	6	100%	0%	0%	0%	0%	Motorcycle

In your normal routine, how many days/week did you commute to work during the inventory year	How many potential commuting days do you think you missed during the inventory year	How far is your commute to and from work (total round-trip in miles)?	Many people use multiple modes of travel in a single commute, or different modes on different days. What percentage of your commuting do you do in the following modes?					If you drive, what kind of vehicle do you drive
			Automobile solo	Carpool +1 person	Carpool +2 people	Carpool +3 people	Bike/ Walk/ Run	
1	0	0	0%	0%	0%	0%	100%	N/A
4	0	6	0%	0%	0%	0%	100%	N/A
5	0	0.25	5%	0%	0%	0%	95%	N/A
4	0	8	0%	5%	0%	0%	95%	Small Gasoline Car
5	10	12	15%	5%	0%	0%	80%	Small Gasoline Car
5	32	32	80%	20%	0%	0%	0%	Small Gasoline Car
1	2	4	80%	0%	0%	0%	20%	Small Gasoline Car
5	0	14	40%	40%	20%	0%	0%	Small Gasoline Car
4	4	120	100%	0%	0%	0%	0%	Small Gasoline Car
4	40	6	100%	0%	0%	0%	0%	Small Gasoline Car
5	0	6	80%	0%	20%	0%	0%	Small Gasoline Car
5		25	100%	0%	0%	0%	0%	Small Gasoline Car
5	30	16	100%	0%	0%	0%	0%	Small Gasoline Car
5	2	8	100%	0%	0%	0%	0%	Small Gasoline Car
5	120	90	100%	0%	0%	0%	0%	Small Gasoline Car
4	0	10	100%	0%	0%	0%	0%	Small Gasoline Car
5	0	20	100%	0%	0%	0%	0%	Small Gasoline Car
5	0	42	100%	0%	0%	0%	0%	Small Gasoline Car
4	145	9	100%	0%	0%	0%	0%	Small Gasoline Car
4	113	30	0%	0%	0%	100%	0%	Small Gasoline Car
4	113	16	0%	0%	0%	100%	0%	Small Gasoline Car
4	104	40	100%	0%	0%	0%	0%	Small Gasoline Car

Appendix C: Employee Suggestions

Electric golf carts for loop road
Employee shuttle from Park headquarters that runs at various times throughout the day.
Find a way to cut motor vehicle use down in the park
Free bus for employees from employee housing
I would love to see bike parking areas every place where there is a parking area for cars (including trail heads). I think it is important to view bikes as transportation vehicles, not just recreational.
I'd take a bus that came by my house
Increase the efficiency of the park's vehicle fleet. Provide public transport from a select few locations at optimum commuting times in the morning and afternoon.
Install solar panels on all visitor centers.
Invasive species management/ volunteers/ logging.
Less cars in Park Loop Road
Limit the amount of traffic allowed on loop road
Limit the amount of traffic in the park each day. But there are plans going in for that already.
Limit vehicle traffic on the loop road, switch to bus only; Offer employee's discounts on electric cars; Set up incentives for "green "visitors, entry fees for walkers, cyclists, bus goers; offer ways to bike/ride/ run to work and have a changing room/shower/locker room to promote employee's commuting via "greener" methods.
Love the bus system. But it needs to be added to and opened up farther for it to become a great success in my opinion
Make it more well know that Acadia has public transportation (Island Explorer). Possibly closing the park when a certain amount of vehicles are present. Know this is near impossible considering all the entrances and exits for the park but we are way beyond our carrying capacity.
More buses! Especially buses that run up to Cadillac. Also I would love to see park housing that is in line with our mission. For example LED light bulbs in the housing units, better insulation so we do not need to use as much electricity to regulate the housing and water sustainable toilets so that we could practice what we preach!

More free shuttle use by visitors or more frequent buses running to HQ
More housing / more efficient housing-like one large apt. get rid of SERC- its the most inefficiently operating campus.
More Island Explorer buses!
Newer more efficient park vehicles instead of vehicles that date as far back as the 1990s
No cars on park loop- is too much these days - traffic, etc.
-Not using disposal cutlery and plates at park picnics and other events with food -Not buying food from Walmart, etc. and using the park's purchasing policy for events like the park picnic -Taking advantage of the amazing location of Park HQ and installing solar panels on every and all available rooftops (Administration, Maintenance, Law Enforcement, etc.) -Banning the sale of bottled water within the park and providing more opportunities for filling reusable water bottles within the park -Having more car-free days that actually last for the entire day, as well as education and promotion of alternatives to experiencing Acadia from the seat of a car -Expanded bus schedules that accommodate working people's schedules and not just tourists -Purchasing zero-emission vehicles or "partial" zero-emission vehicles and hybrids.
Outdated administrative buildings that are not efficient. Replacement of aging fleet vehicles.
park a commuter van at the Gateway for early shifts 0600.
Reduce its waste by 30%; better educate its employee on why we work for the NPS and the critical importance of achieving sustainable practices; reduce the fossil fuel! No cars on the loop road!
Replace civilian conservation corps. constructed buildings (Park HQ). Replace with energy efficient buildings and of course incorporate other sustainable practices.
Replace Gov. vehicle fleet with efficient vehicles rather than more "clunkers". Invest in long term sustainable infrastructure projects and discontinue infrastructure which degrades the environment.
Start running the buses earlier so that community members and employees can take the bus to work
This is a huge question. We should model as many sustainable projects as possible, including decreasing or abolishing petroleum use. Wind, solar, thermo-kinetic technology...whatever it takes to decrease our ecological footprint.
Train up Green mountain; No cars on the loop road
Train, buses, no cars; Solar powered carriages
Train, buses. No cars on loop road!!!

Unknown
visitor shuttle bus around the Park Loop Road should run every 15 minutes during July and August, and should start about 7 a.m so more visitors would use it.
Visitor vehicle restrictions coupled with increased shuttle service, especially on weekends sliding some entrance fees.
yes
Yikes this could be pages :)