Monitoring and Planning the Reduction of Carbon Emissions at the Institute of American Indian Arts

An Interactive Qualifying Project submitted to the faculty of Worcester Polytechnic Institute

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Abstract

This project developed plans for the Institute of American Indian Arts to further its goal of achieving carbon neutrality by 2050 as established in its Climate Action Plan. The team developed a method for consistently entering data into the Clean Air Cool Planet Carbon Calculator in order to accurately measure the institute's progress. A major step in the IAIA's Climate Action Plan was the reduction of electrical usage. This project developed plans for addressing two aspects of this goal: improving efficiency, particularly in lighting, and providing sources of solar energy. Recommendations were made for future improvements and installations to reduce carbon emissions from electrical usage.

Executive Summary

The 1992 United Nations Conference on Environment and Development identified greenhouse gases, the most prevalent of which is carbon dioxide (CO2), as the main cause of the recent unnatural level of climate change. As this concern continued to grow the American College and University President's Climate Commitment (ACUPCC), founded in 2006, worked with institutions of higher learning to help them reduce their environmental impact by reducing CO2 emissions. The Institute of American Indian Arts (IAIA) recognized the importance of this issue, and joined the ACUPCC in 2010. Within three years of signing the commitment the IAIA had created a Climate Action Plan (CAP) detailing plans to reduce carbon emissions and ultimately reach its goal of carbon neutrality by 2050. Without a sustainability leadership position the IAIA's efforts on carbon reduction have taken a lower priority compared to other projects.

The overall goal of our project was to assist the IAIA in developing plans in order to reduce its carbon emissions. Our project outlined four main objectives for our project, to: (1) create an updatable carbon baseline; (2) perform an inventory of electrical use in buildings; (3) develop plans to reduce electrical consumption; and (4) develop plans to implement solar energy. The first of these objectives was accomplished by using the same Clean Air-Cool Planet Carbon calculator that is endorsed by the ACUPCC and was used by the IAIA in its original carbon baseline. An inventory of the CLE building's electrical usage was performed, and each item identified as "high use" and "low use". For our third objective lighting was identified as the easiest significant source of electrical usage to reduce. For our last objective, we analyzed areas around the IAIA campus to locate sites where solar PV arrays could be installed, including rooftops, parking lots, and the land around the IAIA, for what would be most viable.

The original 2010 carbon baseline calculated that the IAIA emitted 2,474 MTeCO2 (Metric Ton equivalent of Carbon Dioxide). Due to the deviation in severity of environmental impact between different greenhouse gasses, MTeCO2 is used to represent the proportional environmental effect, where each greenhouse gas is scaled in terms of CO_2. The baseline that we performed for 2013 was found to be 2,888 $MTeCO_2$, with approximately the same percent-per-source as the 2010 baseline. We attribute this increase in carbon output to the newly constructed Welcome Center at the IAIA, which began construction in the spring of 2013, and was completed in the spring of 2014.

We performed an inventory of the Center for Lifelong Education building. Prior to performing the inventory, we found that lighting, HVAC, and refrigeration units/kitchen appliances use the most electricity in a commercial building. During our inventory, we discovered that most of the kitchen appliances in the CLE are Energy Star rated, meaning any improvements we recommended would have little impact and would likely not be cost effective. Reducing the electrical consumption of the lighting in the CLE and at MoCNA would provide the greatest cost-to-benefit.

In order to improve on the electrical inventory for buildings we recommend keeping track of any retrofits as they are installed throughout the building. This will allow for progress to easily be monitored, but to also track sources of electrical consumption that have not been replaced. We also recommend using individual building metering to get a more accurate consumption of the electricity being at the CLE building and across campus. Finally we recommend using a Building Information Modeling (BIM) program such as Autodesk Revit to keep track of electrical fixtures. In a BIM program, a 3D model of the entire building can be recreated, including electrical fixtures and appliances. Once this is completed, some BIM programs can perform an energy analysis that calculates a building's electrical consumption as well as carbon output.

In order to reduce electrical usage currently used light bulbs should be replaced with LED light bulbs, which use the fewer watts, wherever cost effective. The currently used bulbs were compared to the top 2 LED replacements in price, watts used, brightness, and life expectancy as seen in Table 1.

Table 1: Light Bulb Comparison Matrix

	Type of Light	Watts	Lumens	Color	Life Expectancy	Cost
Currently used Tube	Fluorescent	32	2800	3500K	14 years	$2.79
Proposed Tube	LED	18	1850	3500K	19 years	$29.96
	LED Easy Fit	22	2200	4100K	19 years	$34.99
Currently used Short Tube	Fluorescent	13	800	2700K	4 years	$1.75
Proposed Short Tube	LED	7	350	3200K	19 years	$105.26
Currently used Track Light	Incandescent Halogen Spot	20				
Proposed Track Light	LED: 20 W equi, spot	4	230	2700K	19 years	$20.93
	LED: 20 W equi, narrow	5	300	2700K	19 years	$25.00
Currently used Flood Light	Incandescent Halogen Indoor	35				
Proposed Flood Light	LED: 30 W equi, flood	6	315	2700K	12 years	$17.11
	LED: 20 W equi, flood	3.5	250	3000K	12 years	$21.05

For each of the light bulbs and their replacements calculations were done. The calculations include the projected savings, in dollars and kilowatts, yearly and over the lifetime of the bulb for both individual bulbs and the entire building. The results of the calculations can be seen in Table 2.

Table 2: Light Bulb Replacement Savings

	Yearly Savings per Bulb		Yearly Savings Total		Lifetime Savings per Bulb		Lifetime Savings Total	
T8 LED	$2.47	47 kW	$1,700.00	20440 kW	$22.46	889 kW	$14,400.00	388360 kW
T8 LED Easy Fit	$1.76	26 kW	$1,200.00	14600 kW	$4.05	494 kW	$1,500.00	277400 kW
GX23 LED	$1.06	16 kW	$207.76	3060 kW	-$76.37	296 kW	-$14,970.00	58140 kW
MR-16 LED Spot	$2.82	42 kW	$423.00	6240 kW	$43.83	798 kW	$6,574.50	119700 kW
MR-16 LED Narrow	$2.64	39 kW	$396.00	5850 kW	$36.34	741 kW	$5,450.00	111150 kW
MR-16 LED Flood 1	$5.11	75 kW	$766.50	11250 kW	$56.36	900 kW	$8,454.00	135000 kW
MR-16 LED Flood 2	$5.55	82 kW	$832.50	12300 kW	$57.70	984 kW	$8,655.00	147600 kW

The calculations for lifetime savings take into account the initial price of the replacement light bulb and the number of currently used light bulbs that would have been used over the course of the LED bulbs life. Replacing the GX23 bulb with the GX23 LED bulb would reduce carbon emissions but would cost more than it would save. We recommend not replacing this bulb until a more affordable LED bulb is available. We recommend replacing the other bulbs based on the greatest lifetime kilowatt savings.

The IAIA would currently need a 1.2 MW PV array system to completely power its current electrical usage, but with the Climate Action Plan's required 25% electrical usage reduction the facility would only need a .9 MW system to fully power itself. We calculated how much electricity could be generated by ground, rooftop, and solar carport PV arrays and found that the arrays could produce 340 kW, 750 kW, and up to 3 MW respectively. We then met with four prospective solar companies to gain estimates on pricing: Current Solar, Positive Energy, Sacred Power and Consolidated Solar Technologies. In order for the IAIA to get the most efficiency and longevity out of its purchase we recommend that it select to buy SunPower solar panels, the only companies that offer these panels are Consolidated Solar Technologies or Positive Energy. The SunPower solar panels create more energy per panel(327 watts compared to 275 watts), degrade at a slower rate(.2% compared to 1%) and their 25 year manufacturer warranty is 15 years longer than SolarWorld, the other proposed panel.

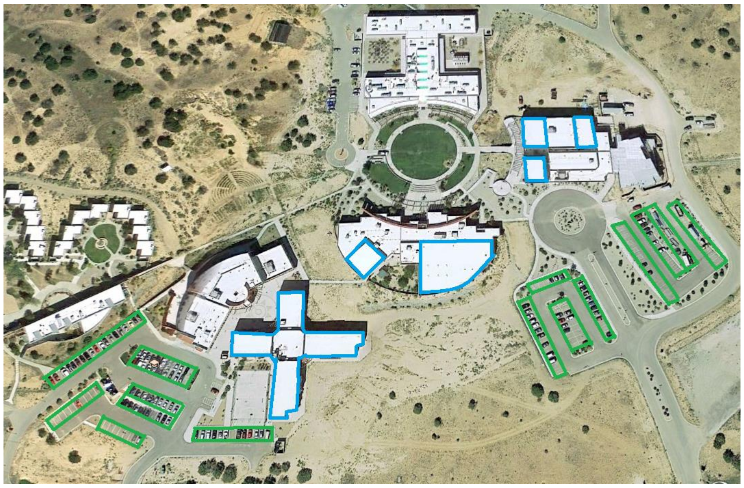

Figure 1: Rooftop Array Area (Blue) and Carport Array Area (Green)

When the IAIA begins installations of solar PV arrays, because of funding issues, should install in phases. It would be most cost effective for the first to be a 105 kW system to begin. This system size will allow the IAIA to receive renewable energy credits, 4.5 cents per kWh produced, from PNM making the return on investment 6.8%. If the IAIA does not want to pay upfront cost for solar energy it has the ability to enter into a Solar Power Purchase Agreement or allow for PNM's Community Solar initiative to be placed on its land.

In conclusion we believe that both the baseline and inventory could be improved to become more accurate. For the baseline we had to use some values obtained from 2010 due to the lack of information we could obtain. Also we were not able to obtain all of the information we needed for inventory which resulted in our major focus for electrical usage. We believe that if our plans our followed in reducing electrical usage through LED light bulbs and implement an efficient HVAC system and appliances that this will produce a significant reduction in electrical consumption. Also using the solar panels and companies we suggested should give the IAIA the most income while obtaining renewable energy. With our recommendations we believe the IAIA can make a large reduction in its carbon emissions.

1.0 Introduction

Recent rises in global temperatures have caused drastic changes in the global climate damaging ecosystems and causing abnormal weather patterns.[1] The 1992 United Nations Conference on Environment and Development identified greenhouse gases, the most prevalent of which is carbon dioxide (CO2), as the main cause of the unnatural level of climate change.[2] In response, organizations around the world have begun to make strides to lower their carbon emissions. On a national level the American College and University President's Climate Commitment (ACUPCC), formed in 2006, works with institutions of higher learning to help them reduce their environmental impact by reducing CO2 emissions.[3] By signing this commitment colleges agree to work towards achieving carbon neutrality, having a net carbon output of zero. Since the ACUPCC's founding 680 universities have signed the commitment[4], approximately 15% of the 4,599 universities in the United States[5].

As concern over the effects of excess greenhouse gas emissions grow, an increasing number of businesses and institutions are working to lower their own emissions. Universities have made a remarkable effort to lead the world in the adoption of carbon reduction goals. Within the United States there are currently three universities that have achieved carbon neutrality[6,7,8] and hundreds more that have pledged to do the same[9]. Dr. Robert Martin, President of the IAIA, demonstrated the institution's dedication to helping the global effort to reduce greenhouse gas emissions by signing the ACUPCC in 2010.[10]

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[1] Earth Science Communications Team, 2007
[2] Agenda 21, 1992
[3] ACUPCC- Mission and History, 2014
[4] ACUPCC - Home, 2014
[5] U.S. Department of Education, 2011
[6] Colby College, 2013
[7] GreenProgress, 2007
[8] Green Mountain College, 2013
[9] ACUPCC - Home, 2014
[10] IAIA, 2010

By signing the ACUPCC, the IAIA has pledged to achieve carbon neutrality by a self-determined date. The steps to reach this goal, mandated by the ACUPCC, include creating a comprehensive inventory of all carbon dioxide emissions, setting a date for achieving carbon neutrality along with intermediate goals, making carbon neutrality a part of its curriculum, and making its plan and progress publically available.[11] Within three years the IAIA had submitted its Climate Action Plan (CAP) detailing the breakdown of its carbon emissions, with a goal of 50% reductions by 2025 and carbon neutrality by 2050, the IAIA has also added classes to its core curriculum that incorporate the effects of climate change on environmental health.[12]

Our goal for this project was to aid in the implementation and monitoring of the IAIA's Climate Action Plan, with a focus on reducing carbon emissions from electrical usage. Our four main project objectives were to: (1) create an updatable carbon emission baseline; (2) inventory significant sources of electrical use in buildings; (3) develop plans of reducing electrical consumption; and (4) develop plans to implement solar energy. The carbon emission baseline was created using carbon sources from the entire campus. The Center for Lifelong Education (CLE) and the Museum of Contemporary Native Arts were focused on and a complete inventory of the buildings electrical use was documented. Using this inventory we developed plans to improve electrical efficiency and reduce usage. The remaining carbon emissions from electrical sources were accounted for by planning the installation of a solar photovoltaic (PV) array. By completing these objectives we have provided the IAIA with means to advance its Climate Action Plan and an updatable baseline to monitor its progress.

[11] IAIA, 2010
[12] Ibid

2.0 Background

Our project focused on helping the IAIA staff to identify sources of carbon emissions on campus and reduce them. Carbon reductions are made to reduce the output of greenhouse gasses that collect in the atmosphere causing climate change. Climate change alters the environment resulting in habitat loss for many organisms, altered seasonality, and abnormal storms in countries and cities throughout the world.

As the severity of climate change increases more individuals, institutions, and countries are making an effort to reduce their carbon emissions, the largest source of greenhouse gas emissions.[13] The desire to change is evident but many lack the will or resources to make any significant improvements. Those who are making an effort to reduce their carbon emissions often create agreements involving others in similar circumstances.

In its Climate Action Plan, the Institute of American Indian Arts identified four overall sources of carbon emissions on campus: electricity, natural gas, transportation, and waste. Our project team considered many carbon reduction methods, especially those successfully used by other colleges, to mitigate the carbon emissions produced by these sources described in the IAIA Climate Action Plan.

2.1 Climate Change and Response

Climate change is a result of increasing levels of greenhouse gasses in the atmosphere trapping solar radiation causing a rise in average temperatures.[14] Awareness and understanding of climate change is continuously increasing throughout the general public. This expansion in awareness has encouraged global and institutional leaders to step up and make an effort to reduce their own carbon emissions.

[13] EPA - Greenhouse Gases, 2011
[14] Ibid

2.1.1 Greenhouse Gas Effect

For the purposes of this proposal, climate change is defined as the alteration of average temperatures and weather patterns throughout the globe beyond the range considered normal, by past climate cycles. Many factors contribute to climate change in particular an increase in greenhouse gas emissions. Greenhouse gases create an invisible blanket in the atmosphere trapping long wave solar radiation which causes global warming shown in Figure 2. Carbon dioxide emissions, which accounts for as much as 78% of greenhouse gas emissions, has increased by 11.1% from 1990 to 2011.[15] As a result, the average mean global temperature increased by 0.7 degrees Celsius (1.3 degrees Fahrenheit) over the last century.[16] Though slight, the increase in temperature has dramatic effects on the environment.

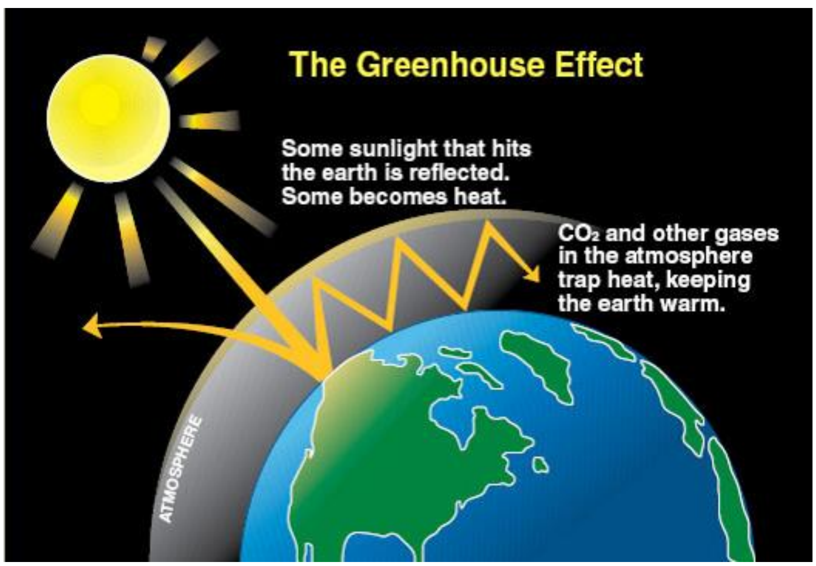

Figure 2: Due to greenhouse gasses, heat from the sun is trapped in the earth's atmosphere, increasing the earth's temperature, and contributing to global warming[17].

Climate change has been linked to various problems throughout the world, from increased storm counts in coastal areas, to decreased rainfall in drought-prone areas.[18] If greenhouse gases, such as carbon dioxide, continue to be emitted at current rates, the

[15] EPA - Trends in Greenhouse Gas, 2011

[16] EPA - Climate Change Science, 2014

[17] Mathematics of Planet Earth, 2012

[18] Earth Science Communications Team, 2007

temperature is expected to increase between 1.4 and 5.8 degrees Celsius (2.5 and 10.4 degrees Fahrenheit).[19] It is this pattern that creates global interest in preventing climate change from continuing and why institutions like the IAIA are reducing their carbon emissions. Figure 3 shows the exponential increase in atmospheric carbon dioxide concentration since 1850 compared to the increase in mean global temperature.

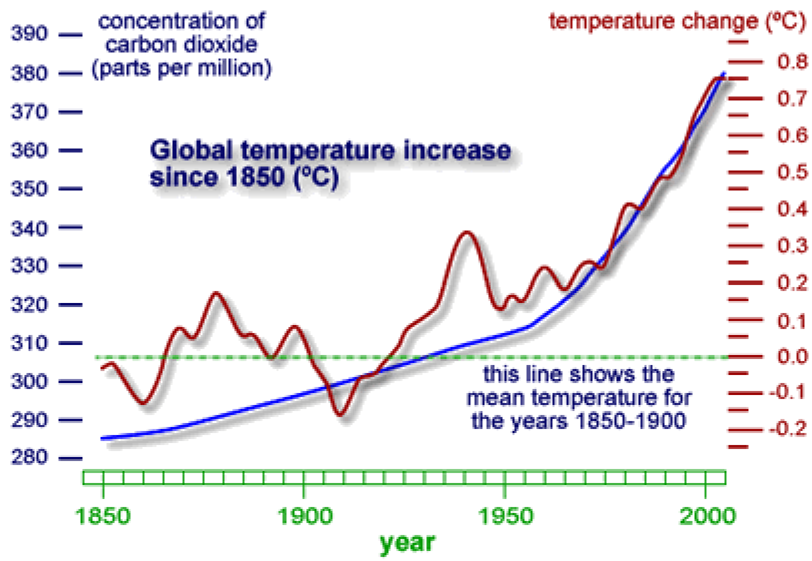

Figure 3: The correlation between atmospheric CO2 concentration and temperature increase. Starting around 1925, temperature change is consistently above the 1850-1900 average, and both levels rapidly increase from 1960 and onwards. [20]

2.1.2 American College & University President's Climate Commitment

The ACUPCC is partnered with the nonprofit organization Second Nature. Founded in 1993, Second Nature's goal is to bring about changes that lead to a sustainable future.[21] A major focus of Second Nature has been universities and students, their program Education for Sustainability, has become a national movement to help students learn how to be sustainable in their lives and careers. As global interest increased and public opinion began to favor the reduction of carbon emissions many businesses and institutions began making efforts to reduce their own emissions. Universities in particular have made a concentrated effort to lead the way

[19] IPCC, 2007
[20] Practical Action, 2013
[21] Second Nature, 2013

in achieving carbon reductions and even neutrality. The ACUPCC was created in 2006 by a group of college and university presidents with the goal of reducing greenhouse gases and becoming more sustainable. As more institutions signed the commitment Second Nature was brought in as its supporting organization to be responsible for the program and to help colleges and universities achieve this goal.[22]

2.2 Carbon Emissions

In the first five years after the introduction of ACUPCC, over 10 million metric tons of carbon dioxide were reduced by colleges and universities across the United States.[23] Removing 10 million metric tons of carbon is equivalent to removing approximately 2.1 million passenger vehicles from the road per year.[24] If this trend in carbon reduction continues significant progress can be made towards slowing climate change. For the IAIA to reduce its carbon footprint most effectively, each of the four major sources of carbon emissions identified by the IAIA's 2010 carbon baseline must be addressed. The sources identified were waste, transportation, heating, and electrical usage.

2.2.1 Waste Disposal

The average American produces 4.38 pounds of solid waste per day of which around 1.51 pounds of this is either recycled or composted.[25] Extrapolating this statistic to the number of students, faculty, and staff at the IAIA campus which is about 405 people comes out to approximately 1,773.9 pounds of solid waste per day. This waste comes from numerous different sources, ranging from food waste to glass, as seen in Figure 4. As the waste decomposes anaerobically in landfills, the greenhouse gas methane is produced and released into the atmosphere.[26] In the United States the way we produce, consume, and dispose of

[22] ACUPCC- Mission and History, 2014
[23] ACUPCC - Five Year Report, 2014
[24] EPA - Calculator, 2014
[25] EPA - Solid Waste, 2014
[26] EcoCycle, 2012

goods and food accounts for approximately 42% of the greenhouse gas emissions.[27]

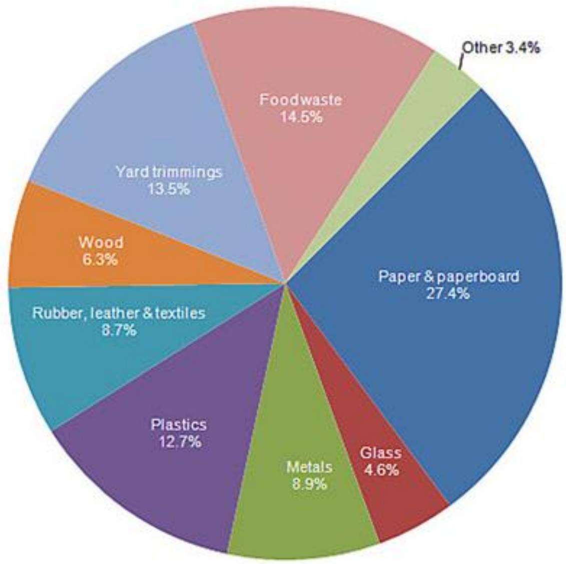

Figure 4: The total municipal solid waste generation in 2012 by category, according to the EPA.[28]

One of the largest contributors of greenhouse gases from waste is food. Food waste across the world is currently the third largest producer of greenhouse gases, directly behind the USA and China, estimated to be at about 3.3 Gigatonnes of CO2 equivalent[29] which can be seen in **Error! Reference source not found.**. Approximately 54% of the waste occurs during production, handling and storage, while 46% occurs during processing, distribution and consumption stages.[30] Approximately 42% of the greenhouse gas emissions produced by the U.S. come from the energy used to produce, process, transport, and dispose of the food we eat.[31] This makes up a large portion of what the U.S. produces in greenhouse gases.

[27] Eco-Cycle, 2012
[28] EPA - Solid Waste, 2014
[29] Food Wastage Footprint, 2013
[30] Climate News Network, 2013
[31] EPA - Climate Change, 2013

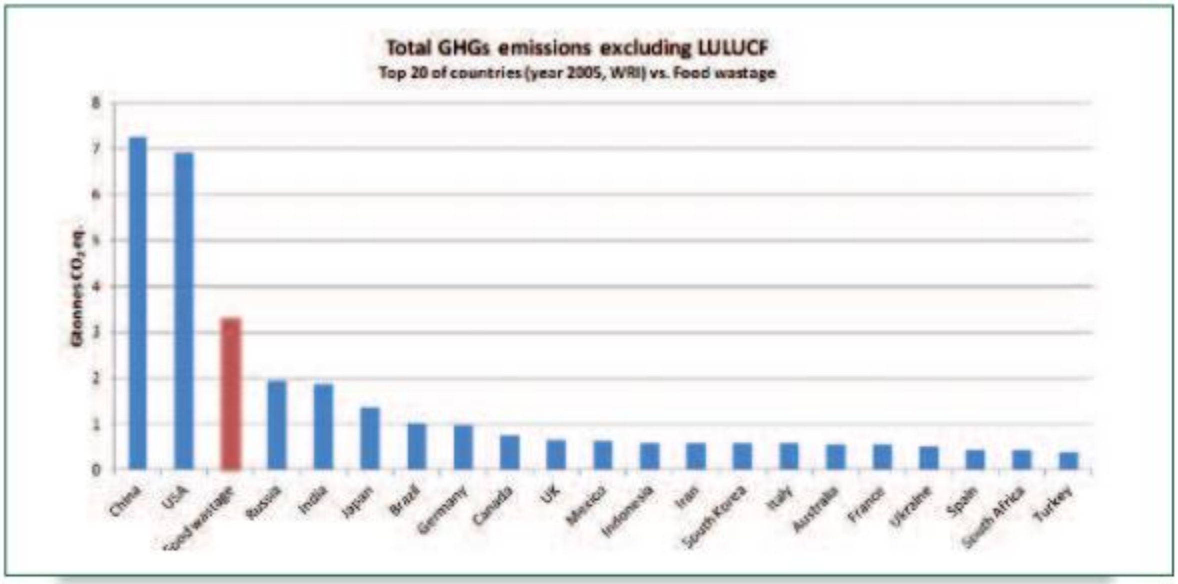

Figure 5: Food waste is the third highest CO2 contributor globally.[32]

2.2.2 Transportation

The United States has been one of the world's prime car culture locations. Transportation produces 28% of all greenhouse gas emissions in the United States.[33] This is due to the burning of gasoline, a fossil fuel, which produces greenhouse gases when combusted. These emissions have increased by 18% and an increase in vehicle miles traveled by 35% since 1990.[34] These factors are mainly due to population growth, economic growth, urban sprawl, and low fuel prices during the beginning of the period.[35] As the demand for fuel continues to grow and the amount of cars on the road increases, the amount of greenhouse gases produced by transportation will continue to increase. Since 1990, emissions produced by transportation represent 48% of the increase of total U.S. greenhouse gases.[36]

This is because the largest producers of greenhouse gases from transportation are typical vehicles including passenger cars and light duty trucks.[37] As can be seen in Figure 6

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32 Food Wastage Footprint, 2013
33 EPA- Sources of Greenhouse Gas, 2012
34 Ibid
35 Ibid
36 U.S. Department of Transportation, 2014
37 EPA - Sources of Greenhouse Gasses - Transportation, 2012

below light duty vehicles account for approximately 63% of all greenhouse gas emissions produced in the U.S. transportation field. Although efforts have been made to reduce fuel consumption in newer vehicles, older less efficient vehicles are still on the road due to the high costs of buying newer vehicles. A typical vehicle on the road produces approximately 5-9 tons of CO2 each year which is approximately 550-1000 gallons of gas consumed in a year.

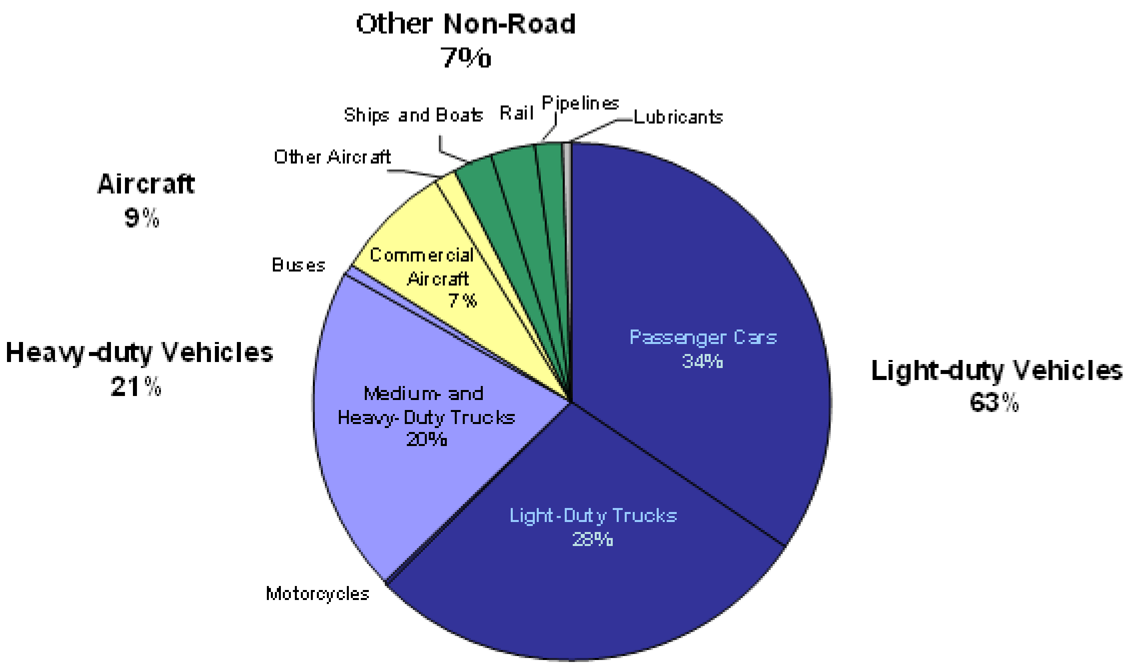

Figure 6: Light-duty Vehicles account for 63% of all transportation emissions[38]

2.2.3 Natural Gas

As a fossil fuel, a non-renewable resource formed from dead plants or animals, natural gas is carbon emitting energy source.[39] This natural gas builds up underground as the dead plants and animals are exposed to intense heat and pressure over thousands of years.[40] To obtain natural gas they drill into reservoirs rich with it. This is then connected to pipelines where it is purified and sent to customers.[41] Natural gas has many different uses, such as heating, electricity generation, cooking, and is starting to be used for vehicles such as cars and buses.

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[38] U.S. Department of Transportation, 2014
[39] EPA, 2013
[40] Ibid
[41] U.S. Department of Energy, 2013

This is primarily because natural gas has many advantages as it gives off less emissions and costs less than the alternatives. Natural gas produces 43% less carbon emissions than coal and 30% fewer emissions than petroleum.[42] This makes natural gas preferable to use but because of cost fluctuations power companies use it when it is cost effective. In 2009 greenhouse gas emissions fell by 6.59% compared to 2008 because the cost of using natural gas was significantly less compared to coal.[43]

2.2.4 Electricity

Power plants produced approximately 2.09 metric tons billion metric tons of greenhouse gases which accounts for 31% of the total greenhouse gases in the United States.[44] As can be seen in Figure 7 sources of electricity including coal and natural gas contribute large amounts of the carbon emissions in the United States. The burning of coal in power plants accounts for about 75% of carbon emissions in the electricity sector.[45] This is also more than one quarter of the of total U.S. greenhouse emissions.[46]

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[42] Martin, Melanie J, 2013
[43] Perry, Caroline, 2012
[44] Barbara Vergetis, Lundin, 2013
[45] EPA- Sources of Greenhouse Gas Emissions, 2012
[46] Union of Concerned Scientists, 2012

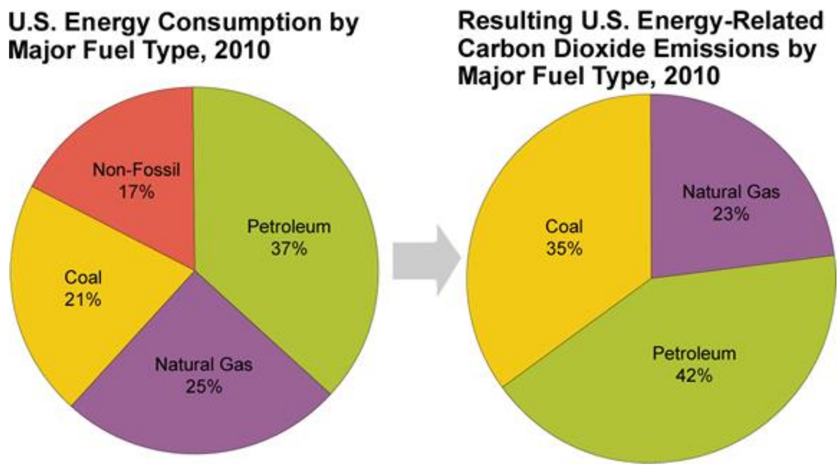

Figure 7: Major Fuels Consumed and Percentage of Carbon Emission related to the Fuel.[47]

The alternatives for going off of the grid are costly and usually not as efficient, such as solar panels or wind turbines in most circumstances. Many power plants cannot use alternative energies because of the inconsistency of the renewable energy, such as solar and wind power which can be interrupted.[48] These interruptions affect the output of the power plants causing issues with the stability of the plant. This causes many power plants to use the alternatives to renewable energy such as coal, natural gas, and oil which produce most of our electricity and are more reliable.[49] Although they are more reliable they produce most of the greenhouse gas emissions across the world.[50]

2.3 Common Carbon Reduction Methods

Many colleges are beginning to look at their carbon emissions and are conducting research into carbon reduction measures. Colleges mainly focus on reducing energy use or using alternative energy as an effective way to reduce their carbon emissions. To determine the best possible methods, specific qualities about a school must be taken into account. These include the university's budget, student body size, campus size, electrical demand, local

[47] EIA, 2013
[48] ABB, 2014
[49] Union of Concerned Scientists, 2012
[50] Ibid

environmental conditions, and politics. These qualities as well as the overall effectiveness of each method, will determine whether it should be implemented.

Every college has a unique set of circumstances making it impossible to generate a generic plan for carbon reductions. Each college must determine for themselves exactly how to reduce their carbon emissions. To decide which methods are best, research has to be done to find ways that may be the most effective for that college. This research should include: the heating/cooling demand, the source of local utilities (coal, nuclear, wind, etc), the local resources (wind, rivers, etc.), and the local limitations (free/usable space, building requirements/laws, etc.).

2.3.1 Reduce, Reuse, Recycle

Landfills are large sources of greenhouse gas emissions because the solid waste sits in landfills releasing emissions as it decomposes.[51] The best ways to reduce landfill waste are to reduce consumption, reuse products and materials whenever possible, and recycle what material is used.[52] Reducing consumption is the most effective method and can be accomplished by converting to electronic documents and using only the minimum required materials.[53] Reusing materials reduces the need for new products and materials. When possible buy non-disposable products and reuse them. Also when a product or material has outlived its primary function think of other ways it could be used, such as shredding old papers to use as packaging material. Reducing and reusing can lower overall consumption but it will never be eliminated. Recycling prevents materials from ending up in a landfill by allowing it to be reused.[54] In order to reduce the amount of solid waste produced, colleges have begun implementing advanced recycling programs.

[51] Grid Arendal, 2013
[52] Ibid
[53] Naseef, Rose, 2012
[54] Ibid

According to the ACUPCC, 413 schools[55] have pledged to minimize waste by joining RecycleMania, a national competition that measures the total trash and recycling output by a school, as well as three associated measures to reduce carbon waste.[56] These include placing more recycling bins and educating students as to what can and cannot be recycled. This encourages people to think more before they throw away recyclables helping to keep the environment clean.

Most food waste can be composted reducing the amount of solid waste in landfills. This also lowers the amount of waste that has to be moved out of the campus reducing the carbon emissions generated by the dumptruck, it also saves the college money if it hires waste removers.[57] Composting, when done correctly, produces little to no emissions of any kind and is beneficial to the environment with nutrients going directly into the soil.[58] Compost can also be used as an environmentally friendly fertilizer replacing standard chemical fertilizers which produce carbon emissions and damage the environment.[59]

2.3.2 Efficient Transportation Methods

Cars are one of the most popular methods of transportation today with approximately 240 million vehicles on the road in the United States.[60] With today's technology cars are much more efficient and are held to a higher standard for their miles per gallon.[61] There has been a strong push in recent years to cut down on gasoline usage and start transferring over to new sources of power. The most recent changes include hybrids which use both gasoline and electricity, fully electric cars, and vehicles which operate on biofuels.[62]

Another easy method to reduce carbon emissions without having to change vehicles or

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[55] ACUPCC – Tangible Actions, 2014
[56] Recyclemania, 2014
[57] EPA – Composting Strategies, 2013
[58] Cornell Waste Management Institute, 2012
[59] Ibid
[60] Tencer, Daniel, 2011
[61] NHTSA, 2014
[62] McManus, Reed, 2014

fuel sources is to carpool, use buses or even bike or walk. Carpooling and buses, although they are not completely carbon neutral, allow for emissions to be shared among numerous people resulting in lower carbon emissions per person.[63] This makes it a more environmentally friendly choice than everyone driving alone. Biking or walking emits no carbon emissions making it the best choice when available.[64] If all students and faculty took public transportation or carpooled there would be a significant decrease in the amount of carbon produced. Figure 8 below compares carbon emissions from public transportation to driving personally owned vehicles.

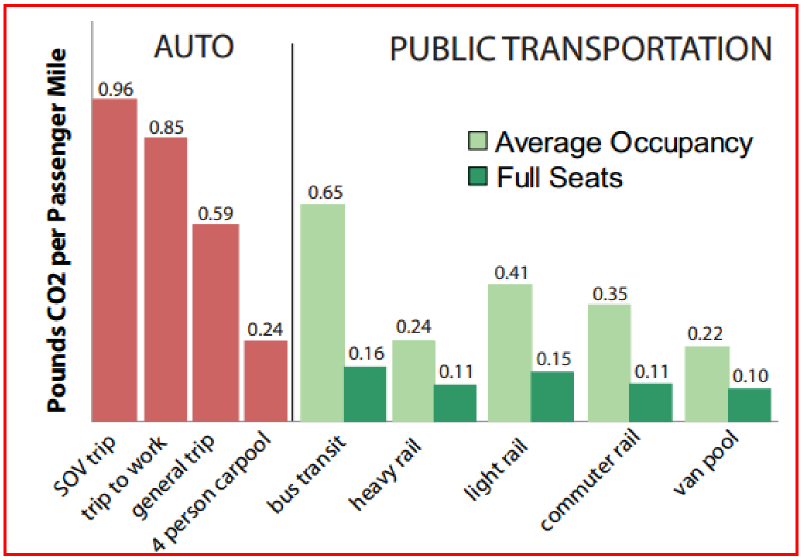

Figure 8: Public Transportation has a much lower environmental impact than personal vehicles. [65]

[63] APTA, 2014
[64] PEA, 2013
[65] FTA, 2013

2.3.3 Natural Gas Reduction

In order to reduce carbon emissions from natural gas more efficient heating and fuels need to be used in order to make it effective. Although natural gas is a cleaner option to more common alternatives such as oil it still produces emissions. According to Figure 9 natural gas produces about a third less of the CO2 emissions compared to coal. In 2012 29% of the electricity was produced by natural gas.[66] These carbon emissions could be reduced if the power plants used renewable energy.

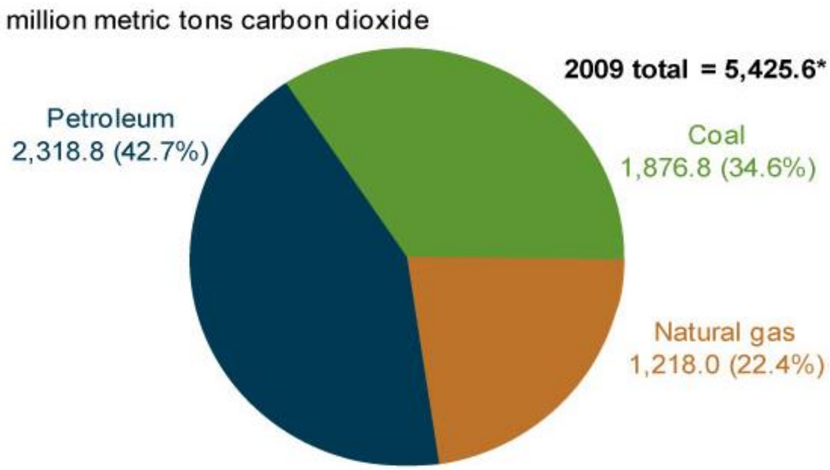

Figure 9: Natural gas has the lowest CO2 output compared to coal and petroleum. [67]

To reduce the usage of natural gas many steps can be taken to accomplish this. One method would be to reduce heating which could include using better insulation in walls, buying better insulated windows, and buying higher efficiency furnaces and water heaters.[68] Reducing hot water usage by taking shorter showers and reducing the temperature of the water will also help in savings. Another method would be to replace natural gas ovens and stoves with electric to reduce consumption.

[66] EIA – Emissions of Greenhouse Gases, 2011
[67] EPA - Electricity Sector Emissions, 2014
[68] API, 2014

2.3.4 Electricity Reduction

In order to reduce the amount of energy used in buildings more energy efficient lighting can be used such as LED's or CFL's which in some cases can save huge amounts of electricity. Also using timers or motion sensors for the lighting can reduce energy as they are only on when needed. Using more energy efficient appliances or other electronics can also help reduce electricity usage. Having items that turn off or enter a sleep mode when not in use will also help reduce the total usage.

Certain appliances will continue to use electricity even when turned off. The electricity is used in power supplies turning AC into DC, the circuits and sensors that receive a remote signal, soft keypads, and displays[69]. The only way to prevent electrical losses through standby power is to unplug the appliance or block the flow of electricity.

2.3.5 Photovoltaic Solar Energy

Solar power converts the sun's solar radiation into electrical energy and is therefore a renewable resource for the public to take advantage of.[70] As of 2013, in the United States, solar power has the capacity to produce 13,000 megawatts of energy, this would be enough to power roughly 2.2 million average American households.[71] However, energy derived from solar power only accounts for 0.1% of the total U.S. production.[72] Solar energy technology is constantly improving in efficiency, and resulting in more affordable solar panels. Since 2011 the cost of solar panels has decreased by 60%, leading to an increase in the amount of solar panels purchased and installed every year.[73] In 2013 4,751 Megawatts of solar energy capacity were installed, the greatest amount installed in a single year.[74]

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[69] Standby Power, 2012
[70] Energy.gov, 2013
[71] SEIA, 2013
[72] Institute for Energy Research, 2014
[73] Ibid
[74] Ibid

Although there are a variety of methods to employ solar energy, our group will be focusing on photovoltaic (PV) cells. Solar PV cells are composed of two layers of semiconductor material, usually silicon crystals. As sunlight enters the cell, electrons are released from the oppositely charged semiconductor layers. An external circuit is used as a pathway for the electrons to travel to their destination, the oppositely charged layer. The flow of electrons in the external circuit creates electricity. These cells are grouped together to form a module or panel, which is then encased in glass or plastic to protect against weather.[75]

Solar PV panels can be installed in three ways: roof mounted, ground mounted or designed into carports. Rooftop solar mounting is installed onto an existing rooftop or integrated in during the construction process of a new building. Installing rooftop PV arrays on existing buildings requires a stress analysis in order to see if the building can handle the weight of the panels and support structures. Ground mounted PV arrays need a flat surface and can be mobile or stationary. Carports are installed in parking lots and serve as a source of shade and car protection along with collecting solar energy. While installing all three of these types of solar installations, the amount of daily sunlight is the major factor when determining the installation site. Areas with shade covering the panels are usually deemed unusable.

Figure 10: An example of a ground-mounted solar array[76]

[75] UCSUSA, 2013
[76] Circular Energy, 2014

Solar panels can be mounted stationary or can be equipped with software to track sunlight for maximum collection. A single axis tracking system allows for a 20% increase in the energy production, while a dual axis tracking system allows for a 35% increase in production[77]. Tracking systems require some maintenance; however, non-tracking solar panels typically require no maintenance for up to 25 years.[78] To obtain maximum efficiency panels, it is recommended that ground panels be angled at 35 degrees and rooftop panels be at an angle between 7-15 degrees in order to collect the greatest amount of sunlight each day over the course of a year.[79]

Figure 11: An example of a rooftop solar array[80]

Figure 12: An example of carport solar arrays[81]

[77] Current Solar, 2014
[78] Sunpower, 2014
[79] Go Solar Energy, 2013
[80] Connect, 2014
[81] Clean Technica, 2014

2.4 Carbon Reduction Measures Utilized by Colleges and Universities

Three universities have achieved the goal of carbon neutrality, the University of the Atlantic, Green Mountain College, and Colby College. All three achieved carbon neutrality with the suggestions and support of the American College and University President's Climate Commitment or ACUPCC, an offshoot of the organization Second Nature.[82] Created in 2006, the ACUPCC is an agreement signed by a university's president pledging that the university will become carbon neutral. The university is also responsible for creating a Climate Action Plan that reports their current carbon emissions and outlines a plan for carbon reductions with intermediate and final goals.[83]

2.4.1 Major Practices of Colleges that have Achieved Carbon Neutrality

In early 2010, Colby College joined the ACUPCC, signifying its commitment to achieve carbon neutrality. However, Colby College's commitment to the environment started long before it joined the ACUPCC. Some examples of this include intuitive heating and cooling systems designed to reduce energy consumption, enhanced recycling capabilities, and a "pest management system" which reduces any chemicals used to the lowest possible limit while maintaining effectiveness[84]. A major part of Colby's initiative is wind power; since 2006, Colby alumni have helped establish 22 wind turbine towers, which are estimated to produce 400 megawatts of wind energy. Large scale wind turbines, like these, are sometimes up to 256 feet tall and boast massive blades that can be over 150 feet long[85]. These blades are designed to catch as much wind as possible and spin about a main rotor head. The rotational energy of the turbine is then converted into usable electricity. This is an excellent example of how Colby utilized its surrounding resources to its fullest potential, by placing wind turbines on nearby

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[82] ACUPCC- Mission and History, 2014
[83] Ibid
[84] Colby College, 2009
[85] Rooks, Douglas, 2010

mountain ranges, which are the ideal place for wind turbines. Colby's utilization of their surroundings shows a sophistication of planning that the IAIA and other colleges would do well to learn from.

Colby College continues to maintain a residual oil fueled steam plant, which supplies much of the school's electricity, while simultaneously being its single largest source of carbon emissions. In 2013 Colby completed building an 11 million dollar biomass boiler plant as an extension of the current steam plant[86]. Biomass plants, like the one installed by Colby, typically burn renewable resources (mainly wood/pellets) to produce steam which is used to generate electricity. It is estimated that this steam plant will offset one million gallons of residual oil each year, and cogenerate 10 percent of the campus electricity needs annually.[87] According to a progress report submitted to the ACUPCC by Colby College May of 2013, the installation of the school's biofuel plant was projected to reduce its 2013 carbon emissions from 11,500 to 3,400 MTeCO2[88] (Metric Tons of Carbon Dioxide – Equivalent, the standard measurement of the atmospheric effects by greenhouse gasses). This is a great example of how effective some carbon reduction methods can be. Further investments in carbon offsets were made in to bring Colby College to carbon neutrality.

In 2009, the College of the Atlantic (COA) was one of the first signatories of the Presidents' Climate Commitment. In its efforts to achieve carbon neutrality, the College of the Atlantic has embraced renewable energy resources, just as Colby College has. According to its 2009 Climate Action Plan, the COA had already eliminated its carbon emissions generated from electricity production. This is achieved through the school's hydropower plant, located on the Androscoggin River, which alone resulted in an approximate 20 percent overall reduction of

[86] Colby College, 2009
[87] Ibid
[88] Ibid

carbon emissions[89]. Hydroelectric power generation is based on the same principle as wind turbines, except that; running water replaces wind to push blades about a turbine to produce electricity.

Another green energy practice by the COA is its newly installed wind turbine, which generates 1.9 Kilowatts of electricity for its [offsite] Beech Hill Farm[90]. This farm offers locally grown meals to the COA's students, faculty, and staff, and is also used as a model for local businesses and residents to learn about the importance of environmentally friendly initiatives (such as carbon neutrality)[91]. This is an excellent example for the IAIA and other colleges and universities, because it exemplifies the possibility of implementing small scale energy efficient practices.

The Green Mountain College (GMC) signed the President's Climate Commitment in the spring of 2007. Since then, GMC has built a $5.8 million, 400 horsepower, combined heat and power (CHP) biomass facility, which offset 85 percent of the schools oil usage. This reduced the fuel oil usage from 230,000 to 40,700 gallons per year. It is estimated that this biomass facility will produce 400,000 kWh per year, roughly 20% of the expected demand, as well as reduce the schools emissions from 1,064 to 878 MTCO2e between 2007 and 2011.[92]

The reason for studying colleges that have achieved carbon neutrality is so that the IAIA can best equip itself to achieve carbon neutrality. Looking beyond the physical accomplishments, there is an underlying theme among these colleges: utilizing the most efficient methods based on local environment and school circumstances, to achieve the best result. For example, the College of the Atlantic utilizes hydropower because its geographic location permits it to easily do so, while Colby College's geographic location is best utilized through wind turbines. Moreover, all three colleges examined have biomass plants to produce a

[89] College of the Atlantic, 2007
[90] Ibid
[91] Beech Hill Farm, 2014
[92] Green Mountain College, 2010

significant portion of their electric requirements. While it would require a large initial investment, its implementation by all three schools is a clear sign that it is an effective carbon reduction method. Finally, all three schools maintain farmland that produces food for their students, faculty, and staff. While growing food eliminates the need for shipping which is a source of carbon emission.

2.4.2 WPI

Although WPI has never signed a specific agreement to reduce carbon emissions or reach carbon neutrality, progress has been made to reduce the amount emissions that are currently produced.[93] The first issue WPI worked on was the power plant. This was identified as a large issue due to the fact that the power plant ran on oil which was expensive and produced large amounts of carbon emissions. This was then upgraded to run on natural gas which after being analyzed turned out to cost less and produced less emissions[94]. WPI then continued to eliminate oil in the other properties it rents out due to the cost and the emissions it produces.

Two buildings on campus that have been identified for using the most energy and resources are the Campus Center and Gateway Park. Major improvements were done to the Campus Center including using more efficient light bulbs and using smart hood fans in the kitchen to only run when smoke needed to be removed rather than all of the time. The institute also upgraded the HVAC system which can now be easily monitored and is energy efficient.[95] Gateway Park is also scheduled for numerous upgrades to both the HVAC system and also to the hood fans in the labs. WPI is also going to be installing cogeneration units at Gateway Park, which generate both heat and electricity. These cogeneration units have roughly around a fuel efficiency of 90% and also reduce environment pollution.[96]

[93] Tomaszewski, Personal Communication
[94] Grudzinski, Personal Communication
[95] Ibid
[96] Nailen, Richard L, 2009

2.4.3 Santa Fe Community College

The Santa Fe Community College, or SFCC, signed onto the ACUPCC in 2007 and adopted its own carbon action plan in 2009 with the intention of achieving carbon neutrality by the year 2035. In order for this to be achieved the college had to end its use of coal as the majority energy source. The burning of coal emits the greatest amount of carbon dioxide into the atmosphere of any energy source. A total of 83% of the energy used in New Mexico is derived from the burning of coal[97], so switching to a new energy source is no easy feat. In order to counter that carbon burden, the SFCC decided to switch to a biomass boiler which provides the campus with 85% of its energy needs.[98]

The SFCC has constructed two buildings with Leadership in Energy and Environmental Design, or LEED, certification since signing up with the ACUPCC. These certifications are proof that the buildings were constructed to certain standards of efficiency. In 2011 their health and sciences center was awarded gold LEED certification for its energy efficiency. The second building constructed was the trades and technologies center in 2012. This building went one step further, receiving platinum LEED certification for its sustainability practices. In a further effort to reduce carbon emissions the SFCC has implemented the latest in lighting systems technologies, as well as improving campus infrastructure to increase energy efficiency even further. Because of the similarities in location the IAIA and Santa Fe Community College share; a lot can be learned from the carbon reduction measures the community college has taken.[99]

2.4.4 The IAIA

The IAIA is a signatory of the ACUPCC and has published a Climate Action Plan detailing their plan to achieve carbon neutrality by 2050. The IAIA's CAP addresses the problem of excessive carbon emissions on three levels: education and curriculum, institutional behaviors

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[97] America's Power, 2013
[98] Combs, Personal Communication
[99] SFCC, 2007

and priorities, and technology.[100] The IAIA's Climate Action Plan includes its carbon emissions baseline, shown in Figure 13, which identifies four major sources of carbon emissions: electricity, natural gas (used by the IAIA for heating), solid waste, and transportation. The first goal in the IAIA's CAP is to achieve a yearly electrical consumption reduction of 5% through 2017. Another part was to implement solar energy on campus to offset the electricity that could not be reduced at the IAIA. The IAIA has yet to develop plans to reduce electrical usage and implement solar energy, and have been looking for recommendations for where to begin these goals.

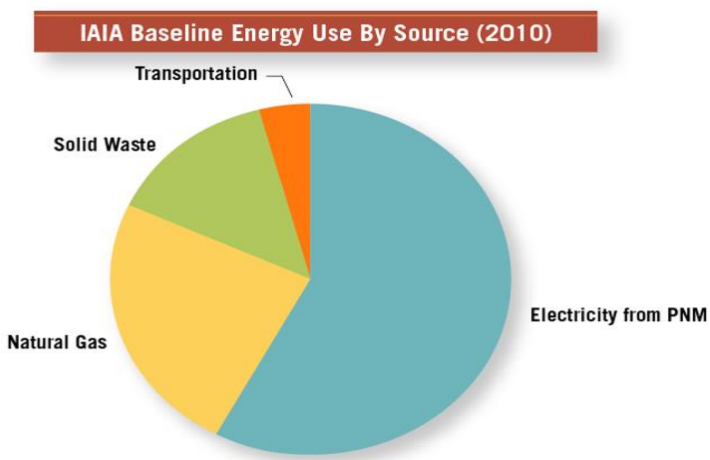

Figure 13: IAIA Carbon Emission Baseline Energy Use By Source[101]

As a multi-tribal college, the IAIA curriculum includes Indigenous Liberal Studies, a course of study that addresses issues of societal and cultural sustainability.[102] Climate change is recognized as an important issue at the IAIA, and as a result, environmental studies courses are a graduation requirement for all majors. These courses raise awareness of the dangers of climate change, the need for carbon reduction, and educate students on ways that they can make a difference.

The IAIA has begun the preliminary steps of carbon reduction. Initial focus has been

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[100] IAIA, 2010
[101] Ibid
[102] Ibid

placed upon the CLE building; any methods that prove successful can then be applied to the other buildings on campus.

New Mexico is ranked as the second highest state in the US for solar gain that is, "the increase in temperature in a space, object, or structure that results from solar radiation."[103] This makes solar energy an ideal alternative energy source in New Mexico. Solar energy is renewable and the creation of electricity creates no carbon emission. However, the current main source of electrical power for New Mexico and therefore the IAIA is coal factories. The use of coal as a power source causes high carbon emissions; the average CO_2 emission rate for coal in the US is 2,249 lbs/MWh (pounds of carbon per megawatt hour of energy).[104] The IAIA currently uses around 1200 kW of electricity; therefore, complete conversion to a non-polluting energy source such as solar power would eliminate approximately 3100 lbs of CO_2 emissions every hour.[105]

Natural gas is another carbon producing energy source currently used by the IAIA to heat water; it accounts for roughly 25% of the IAIA's carbon footprint.[106] Solar thermal technology is being considered as a viable alternative; the company SolarLogic has developed a district-style heating loop that could be used as a replacement for the current natural gas run water heating system.[107] The largest issues encountered when using solar power are the dependence on weather patterns and energy storage limitations (for night time electrical demands). Due to these limitations, the IAIA will never be completely self sufficient using solar power, however, it can reduce its environmental impact to zero by over producing energy during daytime hours to compensate for its night time usage. The IAIA is considering a woodchip boiler

[103] Reference.com, 2008
[104] EPA, 2014
[105] IAIA, 2010
[106] Ibid
[107] SolarLogic, 2014

or methane digester for a backup heating system.[108] The carbon emission of the backup system would depend on the system selected and the frequency of use.

The IAIA owns and operates several vans and trucks that currently have gas powered engines. Currently the IAIA plans to replace these with biofuel vehicles that would produce significantly less carbon emissions compared to gas or diesel engines.[109] As battery technology improves electrical cars that can be plugged into the planned solar power electrical system. If the vehicles are successful the IAIA will reexamine the possibility of purchasing biofuel shuttles for student use. These shuttles would travel to and from the town of Santa Fe, lowering transportation based carbon emissions[110].

Waste is another major source of carbon emission; in order to achieve their goal of carbon neutrality the IAIA has plans to become a zero waste institution. Some of the main features of these plans are using food scraps as compost or fuel for a methane digester, increasing recycling, and replacing paper communication with electronic.[111]

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[108] IAIA, 2010
[109] Ibid
[110] Ibid
[111] Ibid

3.0 Methodology

Our goal was to present the IAIA with a variety of analyzed carbon reduction methods and plans for their implementation, for use either across campus or in the CLE building. In order to accomplish our goal we addressed four major objectives:

1. To create an updateable IAIA campus carbon emission baseline
2. To inventory significant sources of electrical use in buildings
3. To develop plans of reducing electrical usage
4. To develop plans to implement solar energy

In our seven weeks in Santa Fe, from March 19 to May 10, 2014, we worked with the IAIA to complete these objectives. In order to accurately measure the institute's progress towards lowering carbon emissions the baseline has to be updateable using consistent and standardized methods. We developed a carbon baseline "handbook" that simplified the CA-CP and will help the IAIA to measure its progress in the future. The two main carbon reduction methods that our group was responsible for were reducing electrical usage and implementing solar PV arrays. Our sponsors requested that our project's main focus be the CLE building, to serve as an example to the rest of campus for future improvements. The Museum of Contemporary Native Arts also became a focus when its Director, Patsy Phillips, requested our assistance with lighting inefficiencies. We conducted an in depth inventory of all sources of electrical use in the building. For the sources of higher electrical consumption identified in the inventory, methods to reduce the electricity used were considered. Complete electrical reduction is not possible for the IAIA, but replacing inefficiencies can prove to be very beneficial. In order to further reduce carbon emissions we planned the installation of several solar PV arrays to provide renewable energy to the campus. The following sections detail the breakdown of the methods we employed to meet our objectives stated above.

Figure 14: Arial view of the IAIA campus. The CLE building is outlined in blue.

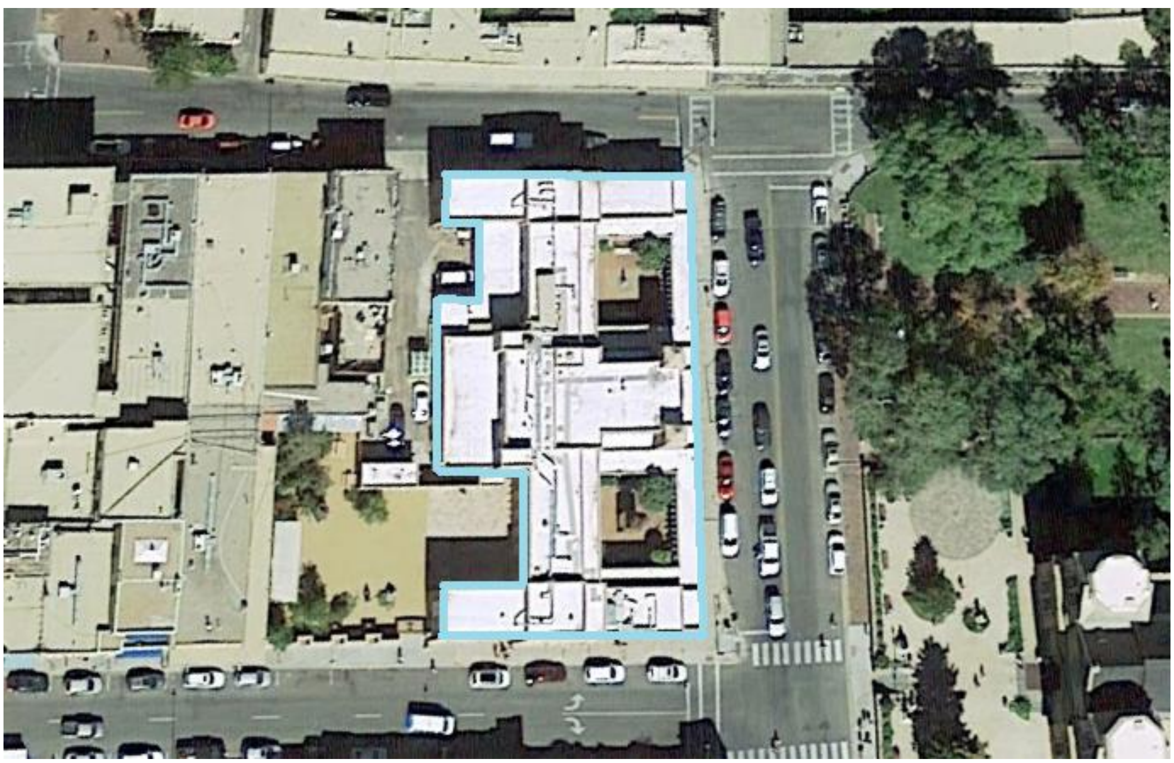


Figure 15: Arial view of the Museum of Contemporary Native Arts outlined in blue.

3.1 Creating an Updatable Carbon Baseline

In its original 2010 carbon baseline, the IAIA identified four main sources of carbon emissions in its Climate Action Plan: electricity, waste, natural gas, and transportation. To produce our baseline, we used the same Clean Air-Cool Planet Campus Carbon Calculator that was used by the IAIA in 2010.[112] It is a comprehensive Microsoft Excel spreadsheet that was specifically designed to measure the total carbon output (among other greenhouse gasses) of higher education campuses, as accurately as possible. Originally created in 2001 for the University of New Hampshire, the CA-CP is now used by "More than 90% of all US colleges and universities that publicly report their greenhouse gas emissions."[113] The CA-CP includes over 100 data field parameters that can be sources of carbon emissions by a campus. For each data field, there is a corresponding tab with predetermined statistics/values that are used to compute the total carbon output. As an example of its thoroughness, the CA-CP includes eight different fuel types for Institution-owned vehicles. Furthermore, a ninth fuel type category exists that is labeled "Other Fleet Fuel" that contains no preset data and is fully customizable. More information about the CA-CP can be found in the CA-CP handbook found in Appendix A – CA-CP Handbook.

To ensure consistency, we input information from the same data fields that were used in the original 2010 baseline into our 2013 baseline. The ACUPCC breaks down campus carbon emissions into three scopes:

> Scope 1 encompasses emissions that are from sources directly owned, such as fossil fuels burned on campus or vehicles used by the school.
> Scope 2 encompasses the generation of electricity off site.
> Scope 3 encompasses emissions that are related to the activities of the school such as commuting or waste disposal which occur off campus.

The original input values for Scope 1 were: MMBTU (Millions of British Thermal Units) of natural gas, gallons of LPG (propane), gallons of gasoline used by fleet, and pounds of HCFH-22 (a common refrigerant). The only original input value for Scope 2 was kWh of purchased electricity. Finally, the original input values for Scope 3 were: faculty/staff automobile commuting mileage, bus commuting mileage, and commuter rail mileage, train mileage that was

[112] IAIA, 2012
[113] Clean Air-Cool Planet, 2014

directly financed outsourced travel, study abroad air mileages, and short tons of CH_4 (methane) recovery. Additionally useful information about the 2010 CA-CP baseline is that it included green power (offset) certificates measured in kWh, and did not include daily student commuting.

Upon request, the IAIA's Facility Manager, James Mason, provided us with the IAIA's electric and natural gas bills. To determine the transportation portion of the 2013 baseline, the IAIA's Director of Business, Entrepreneurship, Academic Technology & Distance Programs, Donna Harrington, sent a survey (Appendix B - Transportation Survey) the faculty and staff of the IAIA. For solid waste production, the only information available was the number and size of dumpster pick-ups per week. We contacted Waste Management of Santa Fe for more accurate tonnage information, but they were unable to provide any further details. Without the tonnage information, our team determined that we could not accurately estimate the solid waste output of the IAIA, and that using the same value from 2010 would be the best estimate. This was also the case for six other data field parameters, including: propane, gasoline, HCFC-22, directly financed outsourced train travel, study abroad air travel, and green power certificates. We determined that those six data fields accounted for less than one percent of the total carbon output of the IAIA. Once we obtained all the necessary information, we inputted the appropriate values into the CA-CP to determine the total carbon emission output of the IAIA for the year 2013.

3.2 Inventorying Significant Sources of Electrical Use

After creating the carbon emission baseline, we narrowed our focus to look at significant sources of electrical use in buildings on the IAIA campus and off campus at the Museum of Contemporary Native Arts (MoCNA). We defined significant as any source that could be replaced with a more efficient option that was cost effective in reducing electrical usage. Through our research we have identified three major sources of electricity consumption: lighting (ceiling lights), HVAC systems, and appliances (refrigerators). This information about the major sources was found from the U.S. Energy Information Administration which submitted a report regarding electrical usage in buildings.[114] Seen in Figure 16, lighting on average uses the most electricity in buildings, followed by cooling and ventilations systems, and finally refrigeration. These total around 66% of the electricity used in commercial buildings, and helped us narrow our focus for these significant sources.[115]

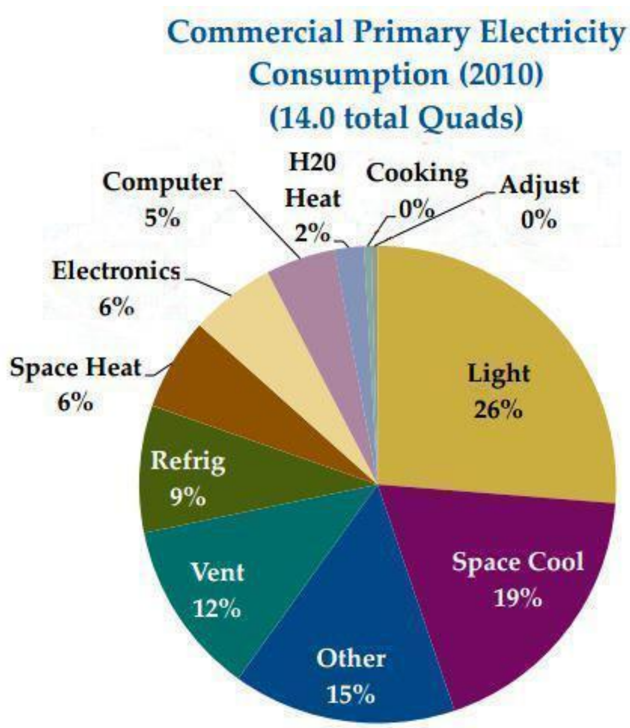


Figure 16: Lighting is the highest contributor of CO_2 in typical commercial buildings.

Our main focus for electrical usage was the Center for Lifelong Education (CLE) building which will serve as an example for the rest of the buildings when the IAIA implements future electrical reduction measures. In order to identify the sources of electrical consumption we went through the CLE building using a survey we created seen below. We inputted as much information we could find about these sources which were wattage, model, and location which an example of the survey can be seen in Appendix C - Lighting Survey. Whenever we were unable to obtain information we contacted James Mason, the facilities manager of the IAIA. Seen in

[114] EIA, 2013
[115] Ibid

Figure 17 and Figure 18, are the floor plans for both floors where we looked at all of the lighting in all rooms.

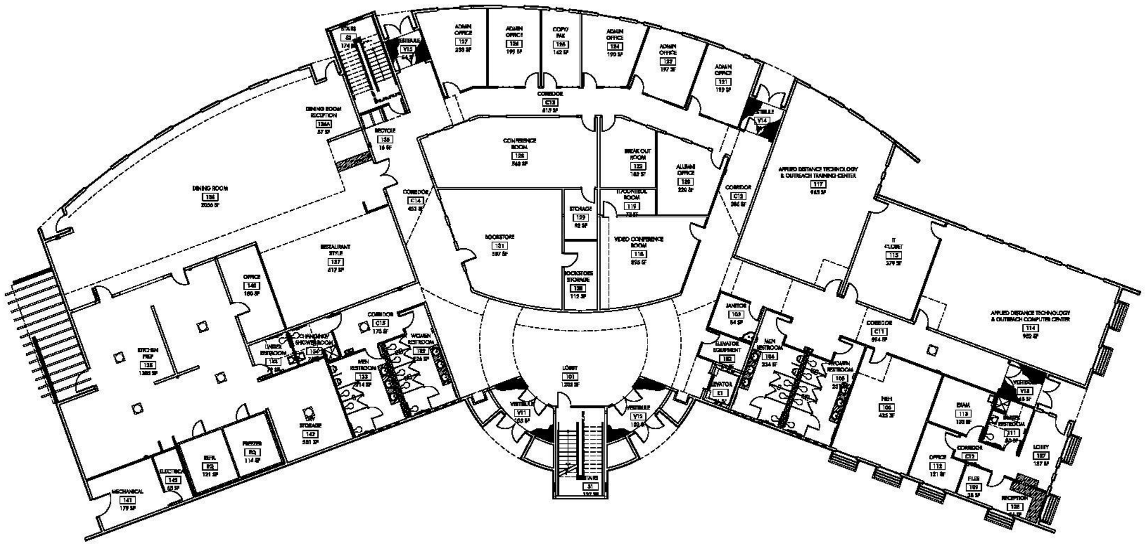


Figure 17: Ground level floor plan of the CLE building.

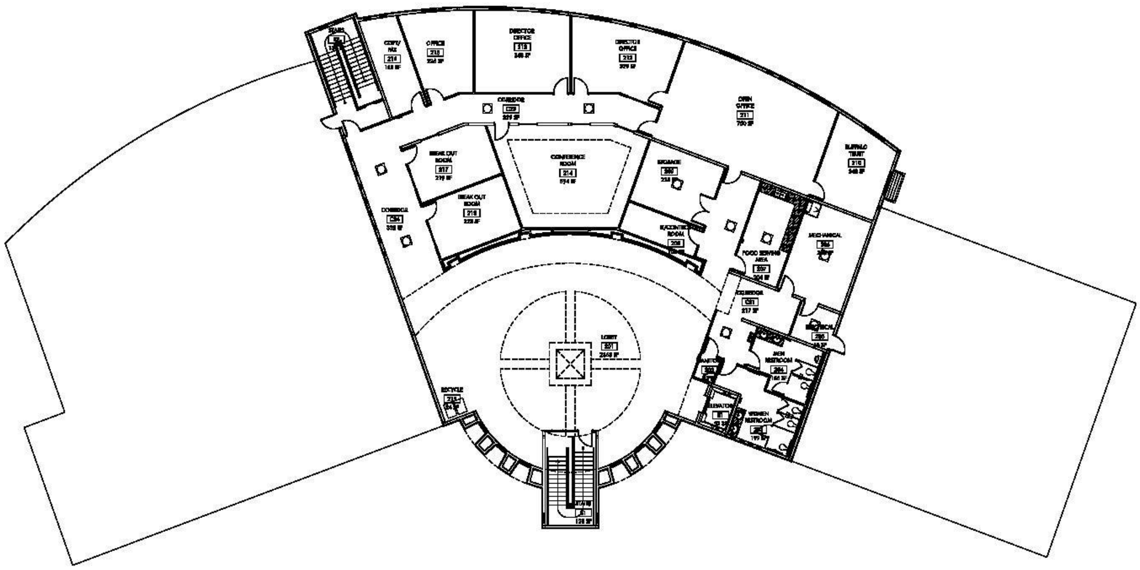


Figure 18: Second level floor plan of the CLE building.

To continue with our inventory, we requested assistance from students, staff, and faculty to help us identify other significant sources of electrical sources. We sent out a form which they would be able to fill out and send back to us through email seen in Appendix D – Electrical Inefficiencies Survey. One of the responses we received which we pursued further was from the Museum of Contemporary Native Arts having inefficient lighting systems. Chris Dixon, the Exhibitions Coordinator at MoCNA, was able to provide us information regarding the lighting at MoCNA. He provided us with how many bulbs there were and the product information. The lighting data Mr. Dixon provided us with was specifically from the galleries; his research found that the gallery lighting used a large portion of the electricity at MoCNA. The lighting information provided only focused on the gallery areas; one large gallery area and two smaller galleries located on the first floor of the IAIA.

After we identified sources of electrical consumption for both the CLE building and MoCNA we quantified the amount of electricity used by these sources. We categorized the hours per day by building. For the CLE building we used regular and irregular traffic which we estimated to be ten and six hours respectively. With the CLE building being open eight hours a day added an hour at the beginning and the end of the day to account for regular traffic. For the irregular traffic we considered that most of the offices, classrooms, and bathrooms tend to be used less and the lights are usually turned off so we estimated under the average day. For MoCNA we considered that it operates on business hours in which it is open seven hours a day and although it is closed on Tuesday's employees are still working and the lights are still on. We estimated that the CLE was open approximately 260 days a year, which was 200 days in the school year in addition to about 60 days during the summer it is open. As for MoCNA employees are in the building approximately 332 days a year which is the total year of 365 days minus 33 days of holidays. Using these numbers we found we were able to calculate the amount of electricity used by these sources using the equations:

kW (Watts/1000) X hours = Kilowatt Hour (kWh)

kW (Watts/1000) * hours per day source on * days in Year = kWh per year

3.3 Developing Plans for Reducing Electrical Usage

In our meetings with PNM, high efficiency lighting was identified as the easiest and most effective way to reduce a building's electrical usage.[116] LED light bulbs are currently the most electrically efficient product.[117] We inventoried the light bulbs currently used in the CLE building and at the Museum of Contemporary Native Arts and found a variety of LED light bulbs that could be used as replacements. We obtained the product information for each type of light bulb

[116] Bueno, Personal Communication
[117] Eartheasy, 2012

used in the CLE building from Mr. Mason and Mr. Dixon provided the information from MoCNA. For each bulb type identified we considered LED replacement fixtures that used the same socket, to prevent the need for rewiring. For each alternative bulb the price, watts used, lumens produced, and expected lifetimes were compared. For each currently used light bulb the top two possible replacements were selected based on watts used and situational effectiveness. For each considered replacement bulb the hourly savings were calculated for on and off peak hours. The yearly savings were calculated based on an assumed 9AM-5PM usage on weekdays throughout the entire year resulting 2600 hours of only peak hours. Energy was priced at $0.844232 during peak hours (8AM to 8PM) and $0.699376 during non-peak hours. The total yearly savings are the yearly savings if every light in the building, CLE or MoCNA, were to be replaced. The necessary formulas are shown following.

Hourly Savings-Peak Hours = [(Wattage of Current Bulb - Wattage of Replacement Bulb)/1000] X $0.844232 per Kilowatt Hour

Hourly Savings-Non-Peak Hours = [(Wattage of Current Bulb - Wattage of Replacement Bulb)/1000] X $0.699376 per Kilowatt Hour

Yearly Savings per Bulb (kW) = [(Wattage of Current Bulb - Wattage of Replacement Bulb)/1000] X Hours in Use

Yearly Savings per Bulb ($) = Yearly Savings per Bulb (kW) X $0.844232 per Kilowatt Hour

Yearly Savings Total (kW) = Yearly Savings per Bulb (kW) X Number of Bulbs in Use

Yearly Savings Total ($) = Yearly Savings per Bulb ($) X Number of Bulbs in Use

In order to determine cost effectiveness the lifetime savings for each recommended replacement bulb was calculated. The calculations account for the initial price of the bulb and the number of currently used bulbs that would be used during the expected lifetime of the LED bulb. The formulas used are shown below.

Lifetime Savings per Bulb ($) = Yearly Savings per Bulb ($) X LED Life Expectancy in Years – Cost of LED Bulb + Cost of Current Bulb X (LED Life Expectancy / Current Life Expectancy)

Lifetime Savings per Bulb (kW) = Yearly Savings per Bulb (kW) X LED Life Expectancy in Years

Lifetime Savings Total ($) = Lifetime Savings per Bulb ($) X Number of Bulbs in Use

Lifetime Savings Total (kW) = Lifetime Savings per Bulb (kW) X Number of Bulbs in Use

3.4 Developing Plans to Implement Solar Energy

The reduction of electrical consumption cannot fully eliminate carbon emissions, in order to move the IAIA towards its goal of carbon neutrality; we focused our efforts on developing plans for the implementation of solar energy to eventually eliminate the need for the IAIA to buy coal-produced energy from the local power company (PNM). We first contacted PNM to determine the benefits of solar panel installation. Since the IAIA expressed interest in photovoltaic arrays, we researched specific solar-power options for the IAIA.

In order to select the appropriate model of solar panel and installation type for the IAIA we, along with Mr. Solimon, met with companies specializing in the implementation of solar energy: Positive Energy Solar, Current Solar, Sacred Power and Consolidated Solar Technologies. After meeting with these companies and discussing specific details about the different types of solar PV arrays such as installation time, tracking or non-tracking, and total cost and average amount of energy produced, we determined the optimum setup for the IAIA. Based on staff and funding concerns, we eliminated tracking systems as an option. We calculated cost of investment vs. yearly savings, from the statistics that were given to us, to supply the IAIA with a timeline on when they would be see return on their investment.

We then developed plans for rooftop, carport and ground level solar paneling. First we calculated the total square footage available on campus building rooftops using Google Earth and then calculated how many solar panels could be installed based on their size to determine the possible energy output available. We eliminated rooftops that had obstacles too dense for efficient production for solar energy. We also used Google Earth to calculate the possible area for carport solar installation in the IAIA paved parking lots. The IAIA has 85 acres of unused land, however, in order to be viable for solar paneling; a slope of less than 5% is needed for installation. During the meeting with PNM they identified the land to the southwest of the main campus as being potentially viable for a ground mounted solar installation. We then calculated the amount of electricity that the designed solar panels would produce for the IAIA and the percentage based on the total energy bill. We then presented our recommendations to the IAIA for future use.

With the length and width of the 327 watt panels researched being 3.5 ft. X 5 ft. we found its area to be 17.5 square feet. We then used this equation to find total wattage available.

Total Area / 17.5 X 327 = Total watts produced

To find estimated cost of each project we used the equation for rooftop and ground mount:

Total wattage produced X 3.50 = Total Cost

For carport solar:

Total wattage produced X 4.50 = Total Cost

4.0 Results

In this section, we detailed our findings for each objective. First we presented a carbon baseline for the year 2013 along with instructions for the IAIA staff to update the baseline for future years. Next we detailed our complete electrical inventory of the CLE building and estimated the total amount of electricity used by each source. Then we outlined plans to reduce electrical consumption at the IAIA by replacing sources of electrical consumption with more efficient alternatives. Lastly we analyzed the area on campus for the installation of solar panels and presented the estimates we were given by the companies we contacted.

4.1 Updatable Campus Carbon Emission Baseline

Our final calculated baseline is shown in Figure 19, with electrical consumption being the highest contributor, followed by natural gas, then solid waste, and finally transportation. We used the Clean Air-Cool Planet Campus Carbon Calculator to measure the total carbon output of the IAIA. According to the PNM electric bill for 2013, the IAIA used 2,250,000 kWh, which accounted for 1,586 MTeCO2. The monthly natural gas bill from the New Mexico Gas Company for 2013 indicated a total of 107,504.5 Therms (or 10,886 MMBtu) which produced 577 MTeCO2. The transportation survey (Appendix B - Transportation Survey) was sent to 110 faculty and staff members, of whom 35 responded. These responses were compiled to determine the yearly miles traveled by automobile, bus, and commuter rail, and then multiplied by 3.14 to account for the remaining 75 unanswered surveys. The yearly commuter results were found to be 760,218 automobile miles, 21,324 bus miles, and 106,200 commuter rail miles, which produced a total 425 MTeCO2. Due to the lack of available information for solid waste, the 2010 baseline value of 290 short tons was input into the CA-CP and found to produce 342 MTeCO2. The total carbon output was found to be 2,946 MTeCO2. A “CA-CP handbook” was created to aid the IAIA in future attempts to create a carbon baseline; it is shown in Appendix A – CA-CP Handbook.

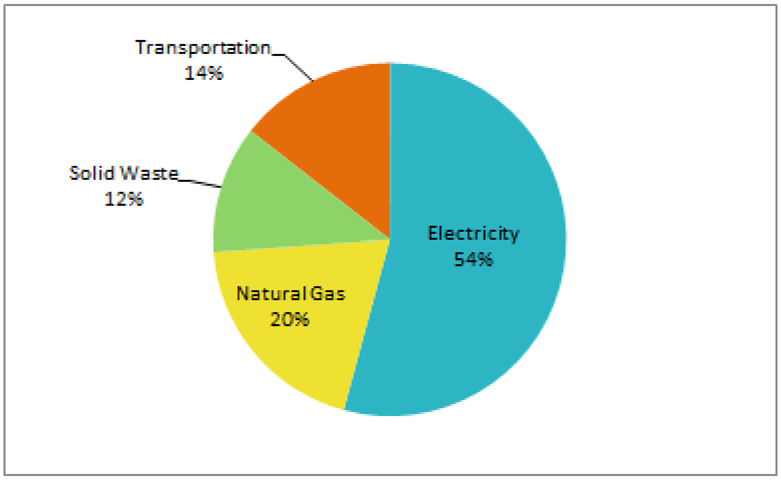


Figure 19: IAIA Carbon Emission Baseline Energy Use By Source

4.2 Inventory of Significant Sources of Electrical Use

After completing our walkthrough we got an initial list which can be seen in Appendix E - Initial Inventory Results. This list was primarily focused on what was in the building to help us narrow our focus to major consumers of electricity. Through our findings we saw that most of the appliances used in the kitchen and throughout the building were Energy Star efficient which we chose not to pursue further. We also were informed by Mr. Mason that the HVAC system had been replaced in the last five years and according to the Public Service of New Mexico (PNM) there would not be much savings through replacing the entire system in both electricity and cost.[118] This left us with smaller devices which did not use much electricity and lighting which according to our research uses the largest amount of electricity in commercial buildings. With this in mind we calculated the amount of electricity used by lighting in the CLE building and in MocNA which can be seen in the Appendix G - Electrical Usage by Lighting in the CLE Building.

Through our findings we determined that the T8 light bulbs used the most electricity

[118] Bueno, Personal Communication

compared to any of the other light bulbs in both buildings. According to our calculations T8 bulbs use ten times more electricity in the than any other bulb in the CLE building. This allowed us to focus Objective 3 primarily on T8 bulbs as they would have the biggest impact on reducing electrical usage. We also found the total quantity of electricity consumed by the lighting at MoCNA was almost 25,000 kWh per year of electricity consumed. This also became a focus as the amount of electricity consumed by the track and flood lights at MoCNA is quite large. A more focused version of our inventory on the highest consumers of electricity in each building can be seen in Table 3.

Table 3: Section of Appendix X, showing the most prominent lights used in the CLE and MoCNA.

Type	Location	Hourly Usage	Quantity	Wattage	Electrical Usage in Year
4' T8 CFL Tube	CLE	10	280	32 Watts	23296 kWh
4' T8 CFL Tube	CLE	6	420	32 Watts	20966 kWh
Track Light Halogen Spot	Museum	9	150	20 Watts	8964 kWh
Flood Light Halogen Indoor	Museum	9	150	35 Watts	15687 kWh

4.3 Plans to Reduce Electrical Use

Light bulbs currently used in the CLE building and at the Museum of Contemporary Native Arts were compared to a variety of LED light bulbs that could be used as replacements. A table of those comparisons is shown in Appendix F - Lighting MatrixAppendix F - Lighting Matrix.

Table 4 shows information for 11 different light bulbs, 4 of which are currently used in the CLE. Table 4 also shows the characteristic of the light bulbs including the watts used; lumens produced (brightness), color of light (warmth), lifetime, and price.

For each currently used light bulb calculations were done to further compare two possible replacement bulbs. The first bulb considered for each type used the least Watts of electricity, the second bulb was chosen based on other particular factors such as quality of light or ease of replacement. The comparisons of the favored replacements can be seen in Table 4

Table 4: Proposed LED replacements.

	Type of Light	Watts	Lumens	Color	Life Expectancy	Cost
Currently used Tube	Fluorescent	32	2800	3500K	14 years	$2.79
Proposed Tube	LED	18	1850	3500K	19 years	$29.96
	LED Easy Fit	22	2200	4100K	19 years	$34.99
Currently used Short Tube	Fluorescent	13	800	2700K	4 years	$1.75
Proposed Short Tube	LED	7	350	3200K	19 years	$105.26
Currently used Track Light	Incandescent Halogen Spot	20	150	2950K	4000 hours	$0.86
Proposed Track Light	LED: 20 W equi, spot	4	230	2700K	19 years	$20.93
	LED: 20 W equi, narrow	5	300	2700K	19 years	$25.00
Currently used Flood Light	Incandescent Halogen Indoor	35	390	2950K	2000 hours	$0.81
Proposed Flood Light	LED: 30 W equi, flood	6	315	2700K	12 years	$17.11
	LED: 20 W equi, flood	3.5	250	3000K	12 years	$21.05

The results of the calculations for yearly savings per bulb and for the entire building can be seen in Table 5. The results of the calculations for lifetime savings per bulb and for the entire building can be seen in Table 6.

Table 5: Yearly savings for LED replacements.

	Yearly Savings per Bulb		Yearly Savings Total	
T8 LED	$3.08	36 kW	$2,160.00	25200 kW
T8 LED Easy Fit	$2.20	26 kW	$1,540.00	18200 kW
GX23 LED	$1.32	16 kW	$260.00	3140 kW
MR-16 LED Spot	$3.52	42 kW	$528.00	6300 kW
MR-16 LED Narrow	$3.30	39 kW	$495.00	5850 kW
MR-16 LED Flood 1	$6.38	75 kW	$957.00	11250 kW
MR-16 LED Flood 2	$6.93	82 kW	$1,040.00	12300 kW

Table 6: Lifetime savings for LED replacements.

	Lifetime Savings per Bulb		Lifetime Savings Total	
T8 LED	$33.40	684 kW	$23,380.00	478800 kW
T8 LED Easy Fit	$11.66	494 kW	$8,160.00	277400 kW
GX23 LED	-$77.73	304 kW	-$15,240.00	59580 kW
MR-16 LED Spot	$82.07	798 kW	$12,310.00	119700 kW
MR-16 LED Narrow	$73.82	741 kW	$11,070.00	111150 kW
MR-16 LED Flood 1	$102.38	900 kW	$15,360.00	135000 kW
MR-16 LED Flood 2	$105.04	984 kW	$15,760.00	147600 kW

The most prevalent light bulb is the T8 tube light. It is a standard commercial light and had the greatest number of possible LED replacements. A graphical representation of the lifetime savings per bulb can be seen in Figure 20

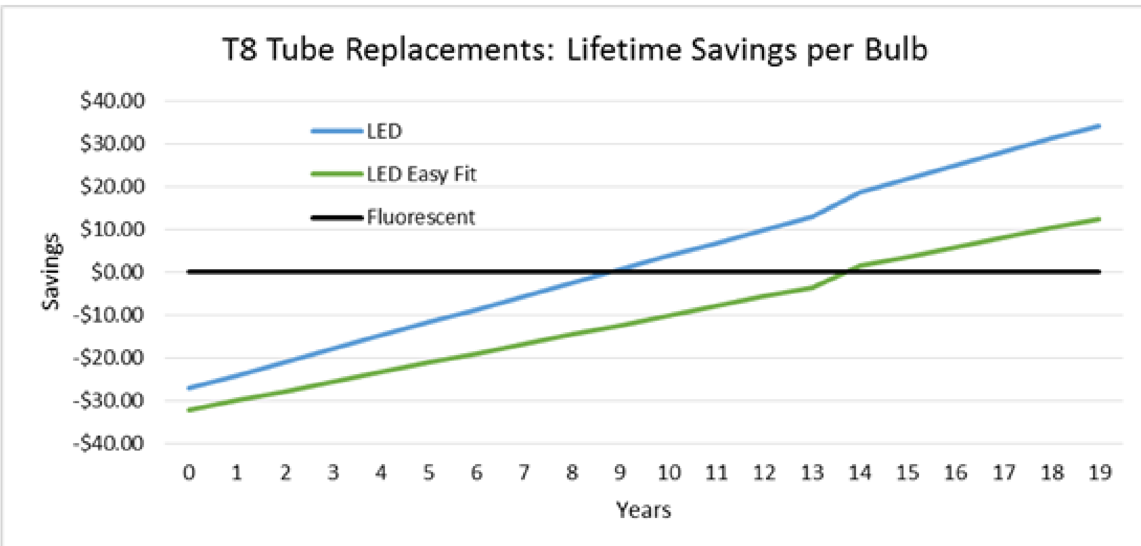


Figure 20: Graphical representation of lifetime savings for T8 LED replacement bulbs.

4.4 Plans for Implementation of Solar Energy

The IAIA currently has an electricity consumption of 2,250,000 kWh per year which would require a 1.2 MW PV array to power the entire system. With the IAIA's Climate Action Plan requiring a 5% electrical consumption reduction annually for 5 years, a 25% total reduction, the projected electrical usage would be 1,687,500 kWh per year reducing the size of a PV array needed to .9 MW. Figure 21 shows the difference in size from before reduction to after.

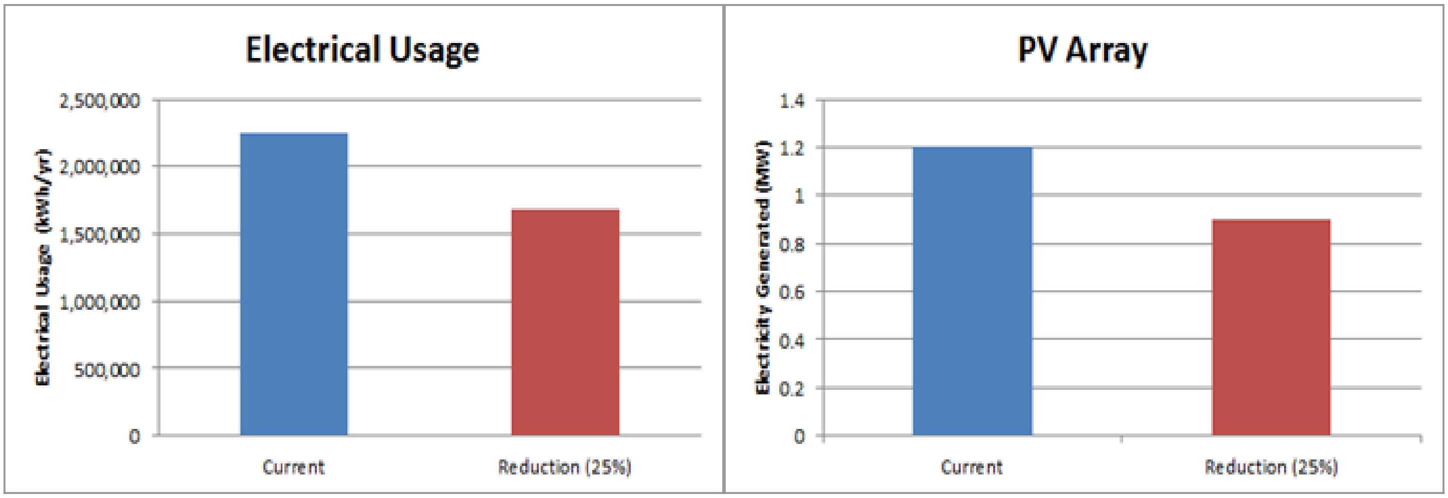


Figure 21: PV array size needed for current use (blue) and post reduction (red).

4.4.1 Rooftop Mounted Solar

Rooftops on the IAIA have many obstructions that will affect productivity and the available locations of installing solar panels. We eliminated buildings with a large density of such obstacles. We then calculated the useable roof area of the IAIA campus to be 36,000 square feet. With the area of a SunPower solar panel being 17.5 square feet, this area could hold a maximum possible system of 680 kW. Because no roofs on campus are free of obstacles (walls, HVACs, etc) that create shade and cut down on usable space, we estimated around 50% of that area would be a realistic area estimation. This will allow for a 340 kW system to be installed creating 25% of the IAIA's current electrical needs, or 38% of the proposed 25% reduced needs. Based on a $3.50 per watt quote from contacted companies the 340 kW system would cost $1,190,000 to install Figure 22 below shows the possible installation areas of rooftop solar PV arrays outlined in blue.

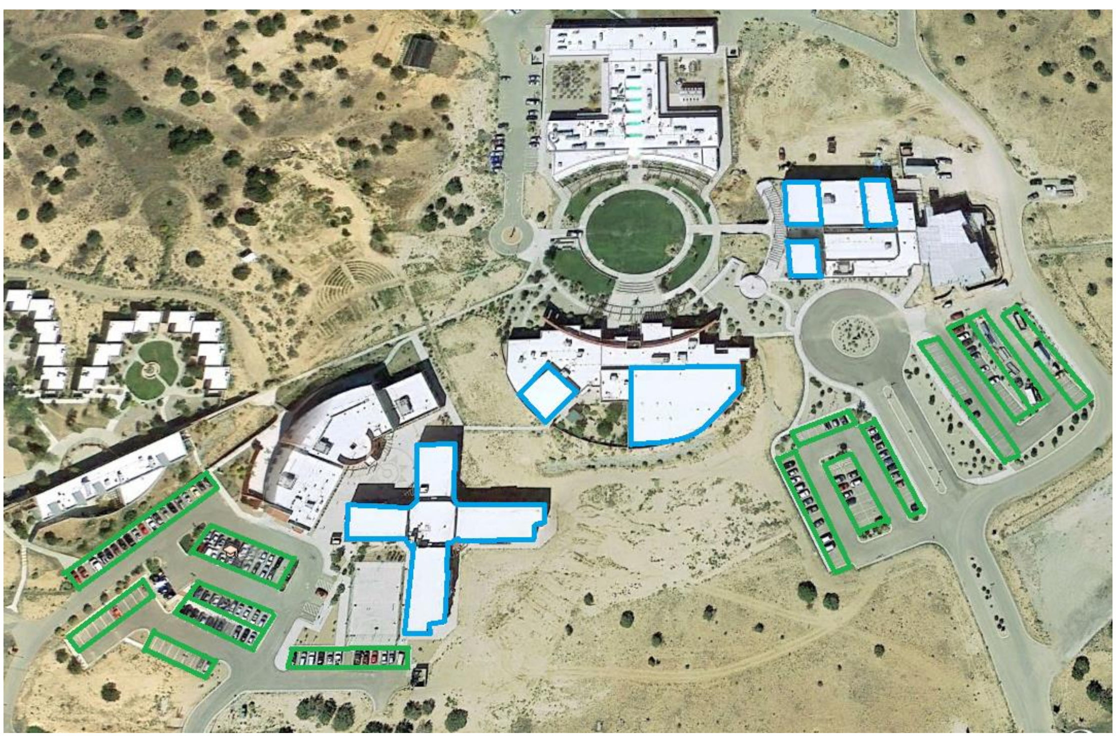


Figure 22: Outlined in green are possible areas for carport solar installations. Outlined in blue are possible rooftop installation areas.

4.4.2 Carport Solar

We estimated the useable area for carport solar using Google Earth to be almost 40,000 square feet of paved parking lot. With the area of a SunPower solar panel being 17.5 square feet, we estimated that the maximum possible PV array size to be 750 kW. With the IAIA needing a 1.2 megawatt system to fully power itself, this would power over half of the institution. With the proposed 25% electrical reduction this system size would power about 84% of the IAIA's needs. Based on an estimate of $4.50 by the contacted companies this system size would cost $3,350,000 to install. Figure 22 shows the possible installation areas of carport solar PV arrays outlined in green.

4.4.3 Ground Mounted Solar

Based on needs for the slope of the land, less than a 5 degree angle, we concluded that the area southwest of the IAIA is the most suitable area for the installation of ground mounted solar panels. Figure 23 outlines the possible area in yellow. Using Google Earth we measured this area to be 22 acres. All four companies provided us with the estimate that six acres of land supports a megawatt of solar PV arrays. This allows for a maximum system of around 3.5 megawatts to be installed. Based on a $3.50 per watt estimate a 1.2 MW system would cost $4,200,000 to install, while a .9 MW system would cost $3,150,000.

Figure 23: Outlined in yellow are possible areas that ground-mounted solar panels can be installed.

4.4.4 Company Comparison

We compared the four companies we talked to by scaling their proposed systems to a 1.2 MW system. Figure 24 displays the total system cost as well as the price per watt of each company.

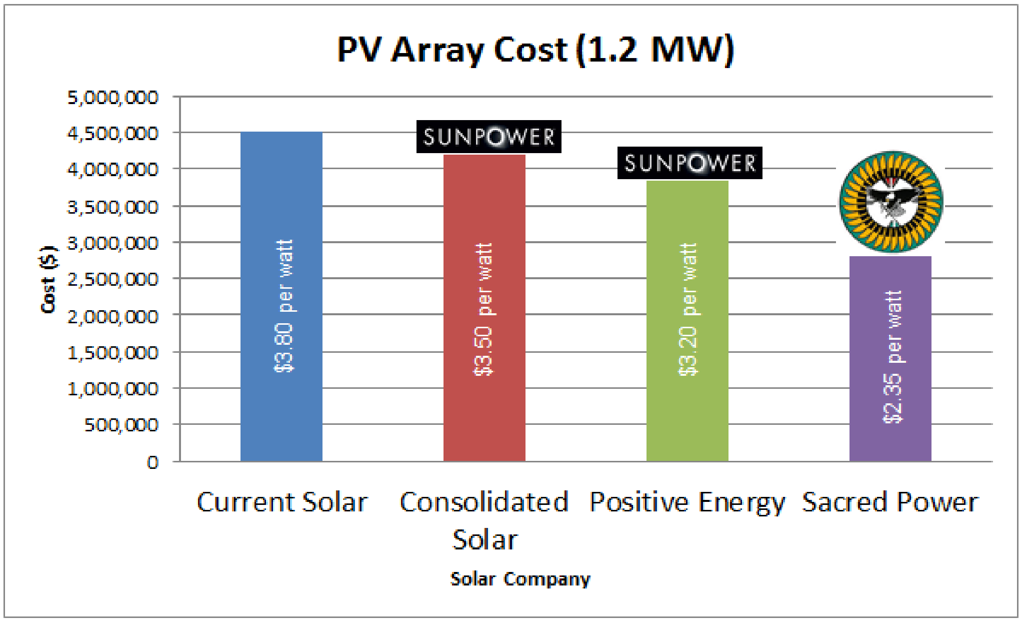


Figure 24: Full PV array cost comparison between companies

Next we compared the proposed solar panels proposed by each company. Sacred Power and Current Solar sell SolarWorld panels while Consolidated Solar Technologies and Positive Energy sell SunPower panels. Table 7 below compares the two proposed panel brands.

Table 7: Solar Panel Comparison.

	SUNPOWER	SOLARWORLD
Solar Panel Model	SunPower E20 - 327 Panel	SolarWorld Plus SW 275 mono
Wattage Capacity Per Panel	327	275
Degradation Rate (Yearly)	0.20%	1.0%
Production Warranty	25 Years	25 Years
Manufacturer Warranty	25 Years	10 Years

4.4.5 Theoretical Installation

As a part of our project we modeled a possible solar PV array installation. The model is based on an eight phase installation with the first phase in 2015 then each additional phase coming online after five years. The first three installations are 100 kW arrays that would cost $350,000 to install and would save approximately $14,400 a year. The fourth and fifth installations are 150 kW arrays that would cost $525,000 to install and would save approximately $21,600 a year. The final three installations are 200 kW arrays that would cost $700,000 to install and would save approximately $28,800 a year. The total installation cost would be $4,200,000 and annual savings after completing the installation would be approximately $158,400. Figure 25 shows the cumulative cost and savings of the installation, it takes until around 2060 for the savings to equal the cost and the installation to pay for itself.

Figure 26 combines the cost and savings to show the total debt or investment over time.

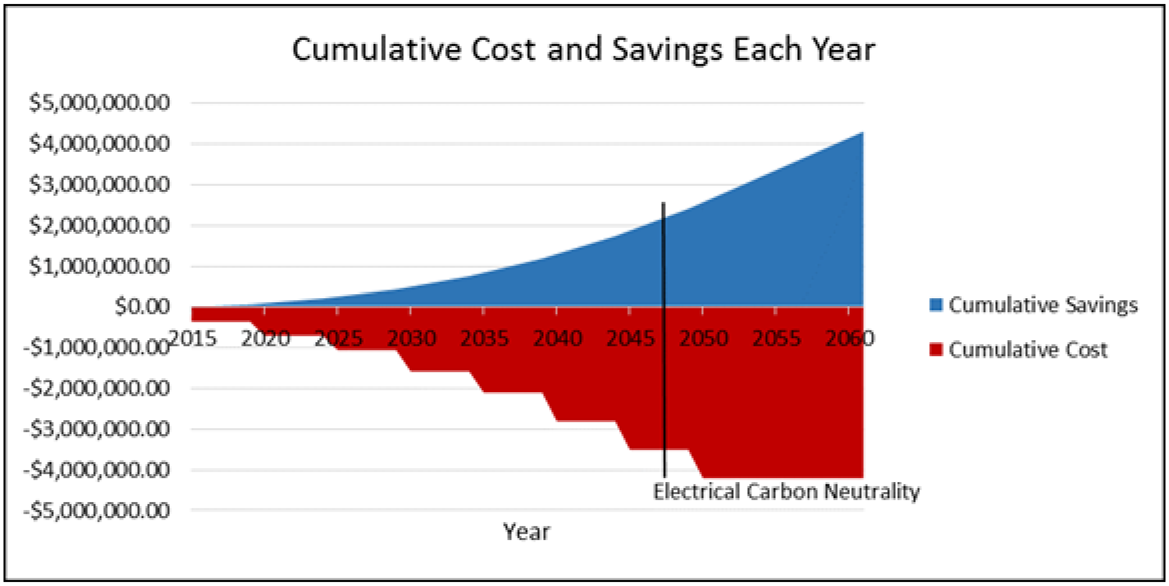


Figure 25: Cumulative cost and savings for eight phase PV array installation.

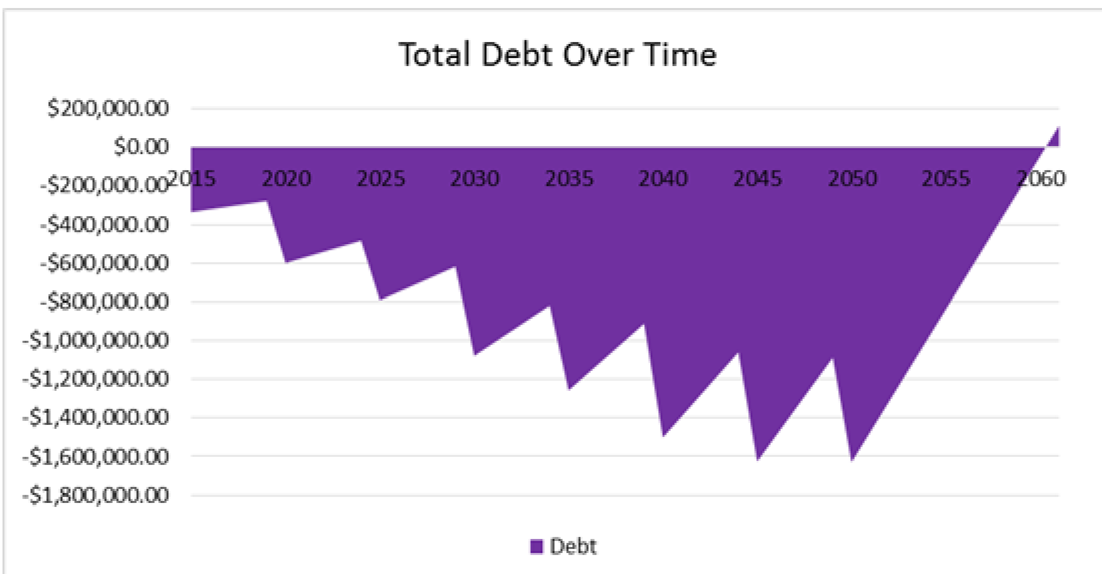


Figure 26: Total debt for eight phase PV array installation.

5.0 Recommendations

The goal of our project for the IAIA was to aid in the implementing and monitoring of its Climate Action Plan to be completed by 2050, when the IAIA is committed to becoming carbon neutral. The purpose of this section is to suggest ideas and plans in order to further what we started here at the IAIA. In order to continue on the path to achieve carbon neutrality, we have suggested steps that can be taken for each of objectives. Our first recommendation is to create a position in charge of sustainability and either hire a new staff member or adjust a current staff member's responsibilities. Currently, there is no strong leadership for sustainability and the staff members who are working on the CAP do so only when their primary responsibilities allow them time. For this reason, we believe that IAIA would greatly benefit from a dedicated sustainability coordinator. For our first objective we looked to improve the accuracy of the carbon baseline and make it easier to update. Next we looked to improve the inventorying of buildings using software and also individually metering buildings. We then suggested plans to reduce electrical usage by replacing both lighting and other sources of electrical consumption that are inefficient. Finally we proposed plans for installing solar panels along with a company we suggested working further with.

5.1 Update Carbon Baseline

1. Include student commuter data in future baselines
2. Contact Waste Management of Santa Fe for solid waste tonnage information
3. Annually update the IAIA's carbon baseline
4. Assign a person or group to annually update the IAIA's carbon baseline
5. Compensation for any faculty member that volunteers to lead this effort

The Carbon Baseline that we created for 2013 was based on the same input data field parameters that were used in 2010. These data fields encompass and account for much of the carbon emissions produced by the IAIA. We recommend expanding the data parameters used in future baselines to include student commuter data. This data can be gathered using a similar survey to the one used to find the faculty and staff commuter data. Additionally, we recommend that the IAIA request tonnage information from Waste Management of Santa Fe, for more accurate solid waste measurements.

Our next recommendation is to assign a person or group of people the task of computing a baseline on a yearly basis, rather than every 3-4 years, as the ACUPCC requires. If followed through, this should increase consistency, as well as save time, as the CA-CP will not have to be relearned every 3-4 years. We also recommend that the yearly baseline results be posted by the IAIA, as a reminder of the schools progress and its commitment to the ACUPCC. Finally, we recommend that the IAIA provides a monetary incentive to any faculty member who volunteers to lead these efforts.

5.2 Improving the Inventory Process

1. Monitor significant sources of electrical use
2. Involve the students and faculty members in tracking electrical consumption
3. Install individual building meters
4. Use a Building Information Modeling (BIM) program

To improve the process to inventory the CLE of electrical sources we would first recommend monitoring the significant sources we have identified in our findings. These would be quantities of each source, model numbers, and how much wattage is used. When a source is replaced this list should be updated to reflect the change. This would include with how many were replaced and any new information added. This will allow the staff to keep track of what is in the building and note what sources have not been replaced with a more efficient option. Expanding to the other buildings on campus will also identify other significant sources of electrical consumption and is necessary for campus wide reductions.

We would also recommend obtaining more accurate electrical consumption data. We had to estimate the hours that electrical devices were left on which leaves room for error. Using a better method such as working with the students and faculty of the IAIA to note when electrical devices are left on will lead to more accurate results. Another way of finding out for individual sources plugged into wall outlets is using meters such as *Kill-A-Watt*. This meter keeps track of how much electricity is used by whatever is plugged into it which can also calculate how much time the device is left on.

To continue with the inventory, we recommend that the IAIA invest in individual electricity meters for all buildings. This will allow for the total amount of electricity used by the CLE building to be recorded, along with other buildings on campus. Currently, the IAIA cannot keep track of how much electricity any individual buildings on campus use. This makes it difficult to prioritize methods of electrical reduction and see how accurate they are. Individual building metering will allow for a better idea as to how much electricity is being consumed by certain sources compared to the entire building. The cost is quite high with building meters costing upwards of $1,000.[119] Across the entire campus this could total up to approximately $9,000.

Our last recommendation to improve the inventorying of the CLE building would be to possibly use a Building Information Modeling (BIM) program such as Autodesk Revit. This program allows for the entire building to be drawn up and all electrical sources can be added. An energy report can also be created to see the amount of electricity being used along with the amount of CO2 being produced. As different sources are replaced the model can be changed to reflect this or simulations can be done to see the impact of replacements. Using Revit allows for an entire visualization for the building which can also be used to locate these sources easily. This could be something a student or staff member could become responsible for as eventually the whole campus would need to be drawn in order to get an accurate estimate of what each building is producing. Currently a free trial is available for students and teachers for three years so they can use it risk free if they choose to opt out of using the program. The IAIA can also use Revit to branch out towards architecture and design programs which the IAIA is interested in

[119] Greentechgrid, 2014

pursuing. In Revit buildings can be designed and modeled in areas across the world and can be bring aspects of both structural engineering and construction into the model.

5.3 Electrical Reduction

1. Replace currently used light bulbs with LED bulbs
2. Install timers and motion sensors on lights in rooms that don't see constant use
3. Turn off lights and appliances when not in use
4. Unplug/cut power for appliances that use standby power when they are not in use
5. Look into building automation systems to improve the efficiency of the HVAC system

Based on the calculations done about the LED replacement bulbs we recommend first replacing all of the T8 bulbs with the T8 LED bulbs, then the MR-16 flood bulbs with the MR-16 LED Flood 2 bulbs, and then the MR-16 Spot bulbs with the MR-16 LED Spot. Replacing the GX23 bulb with the GX23 LED bulb would reduce carbon emissions but would cost more than it would save. We recommend not replacing this bulb until a more affordable LED bulb is available.

The installation of timers and motion sensors to control lights in the CLE building is recommended to reduce electrical consumption. In areas with irregular use install motion sensors. In areas used at specific times install timer controlled lights. Also encourage staff and students to turn off lights whenever they leave a room unoccupied. In rooms with skylights or windows we suggest turning off lights when natural lighting is sufficient.

Several methods were considered to reduce standby power in the CLE building. The simplest method involved unplugging appliances when not in use. We recommend that any irregularly used appliances be positioned so that they can be unplugged and signs be placed near them with a reminder to unplug the appliance after using it.

The current HVAC system is relatively new and not inefficient enough to warrant a replacement. We recommend looking into installing a building automation system that could improve the efficiency of the current system. Companies that install building automation systems include Johnson Controls, Train, Siemens, and Digital Air Control; meet with them to determine options and possible benefits.

5.4 Install Solar PV Arrays

After improving electrical efficiency and therefore reducing electrical consumption, the IAIA should then begin the installation of solar energy to further reduce carbon emission from purchased PNM electricity.

1. Install solar PV arrays in phases beginning with a 105 kW system
2. Continue installations in phases as funding becomes available
3. Install SunPower brand panels because of efficiency and warranty
4. If the IAIA does not want to pay upfront costs a Solar Power Purchase Agreement or Community Solar are options with no initial costs

With a 6.8% yearly return on investment the 105 kW is the most economical starting point because of a 4.5 cent Renewable Energy Credit the IAIA would receive from PNM for every kWh produced. The $367,500 installation will have a 15 year payback period, which means 10 years of warrantied savings.

The next step would be to install greater amounts of paneling in phases as the IAIA receives the money to do so. We have set up a scenario in which the IAIA is never more than $1,600,000 in debt to become completely electrically independent by 2050 as shown in Figure 26, in Section 4.4.5.

We recommend that when purchasing solar panels, the IAIA select SunPower brand panels over the other proposed manufacturer SolarWorld. Although more expensive, SunPower provides a 25 year warranty on energy production as well as a 25 year manufacturer warranty while SolarWorld, with the same production warranty, provides only a 10 year manufacturer warranty. The extra 15 years of no maintenance costs would be beneficial to the IAIA if anything should happen. SunPower panels create more electricity, 327 watts compared to 275 watts, for the same area per panel as the SolarWorld panel. The SunPower panels also converts

21.03%[120] of sunlight into energy compared to 16.4% conversion[121] from SolarWorld Panels. This would supply the IAIA with more electricity for a longer time.

If the IAIA decides it does not want to pay the upfront costs of installing solar paneling, there are two options it can choose: Community Solar or a Solar Power Purchase Agreement. PNM has shown interest in the land the IAIA owns for its Community Solar initiative. With this program PNM would lease around 20 acres of land to PNM in which they would install a 2-3 MW PV array. Our recommendation is that the IAIA use these lease payments to purchase enough electricity directly from the installed PV array to eliminate its coal and natural gas powered electricity purchases from PNM. This would greatly reduce its carbon emissions and assist in its goal of becoming carbon neutral by 2050. Another option to forgo initial costs would be to enter into a Solar Power Purchase Agreement. In this scenario an investor would purchase the entire PV array and sell the IAIA the energy produced based on a negotiated price in the contract.

In order for the IAIA to purchase a PV array system, companies will need to be brought in for on-site quotes. This needs to be done first before any progress can be made because in order to apply for grants or financing, actual price quotes need to be established. Rough estimates are given but all costs cannot be accounted for until a professional scouts the area.

[120] Maehlum, Mathias, 2013
[121] Real Goods, 2014

Appendix A – CA-CP Handbook

To use the CA-CP, first navigate to the "Input" tab, shown in Figure A 1. The year 2010 is highlighted in yellow to show the values that were used in the original 2010 baseline. On the left of Figure A 1, a vertical list can be seen, including the institutional data, and the three scopes. By unchecking specific boxes in that list, the subcategories that do not require input can be "hidden" from view. Each of the three scopes in the input tab of the CA-CP is color-coded; scope one is orange, scope two is yellow, and scope three is beige. Within the three scopes, there are 100 different data fields that can be input to account for a college's carbon output. Of those 100, the IAIA's 2010 baseline accounted for 20. Those 20 data fields are shown in Figure A 1, and outlined in Table A 1 and Table A 2. Note: Figure A 1 is only meant to serve as a visual aid for the CA-CP.

Table A 1: Institutional Data.

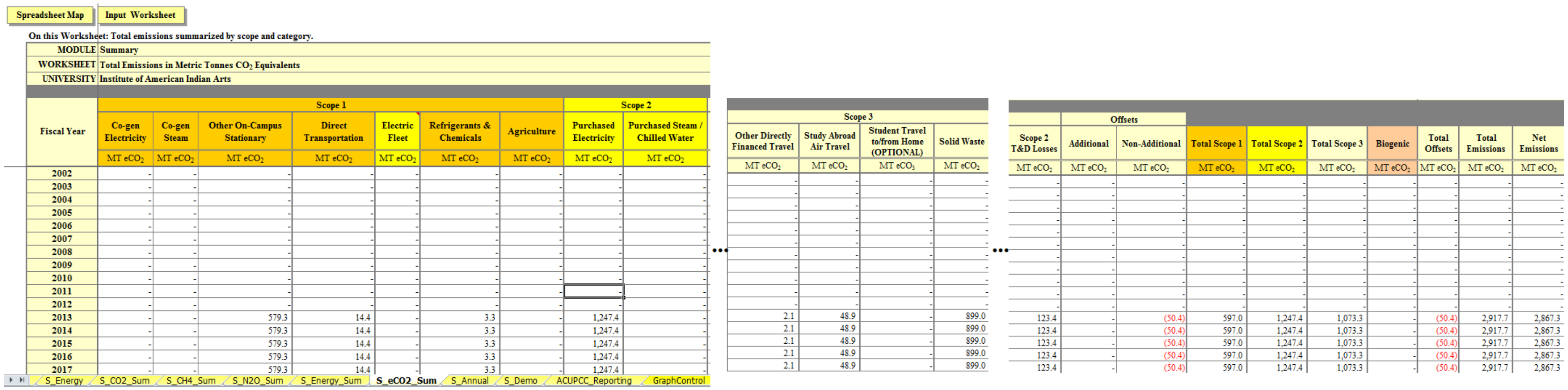
Yearly Operating Budget	Yearly Energy Budget	Full Time Students	Part-Time Students	Summer School Students	Faculty	Staff	Total Building Square Footage

Table A 2: Measured Data Fields.

Natural Gas	LPG (Propane)	HCFC - 22	Electricity Usage	Automobile	Bus	Commuter Rail	Train (directly financed outsourced travel-train)	Air (study abroad)	No CH4 Recovery (methane)	Green Power Certificates
MMBTU	Gallons	Pounds	kWh	Miles	Miles	Miles	Miles	Miles	Short Tons	kWh

Figure A 1: Input tab of CA-CP. Ellipses are used to show a gap in the spreadsheet.

Once all the necessary information is entered into the Input tab, navigate to the “S_eCO2_Sum” tab, shown in Figure A 2. This will show a full breakdown of the data field parameters entered into the input tab, as MTeCO2 output. The S_eCO2_Sum tab also shows the sum of each scope, as well as the gross and net carbon output. Note: Figure A 2 is only meant to serve as a visual aid for the CA-CP.



Spreadsheet Map | Input Worksheet

On this Worksheet: Total emissions summarized by scope and category.

MODULE	Summary
WORKSHEET	Total Emissions in Metric Tonnes CO_2 Equivalents
UNIVERSITY	Institute of American Indian Arts

Fiscal Year	Scope 1							Scope 2	
	Co-gen Electricity	Co-gen Steam	Other On-Campus Stationary	Direct Transportation	Electric Fleet	Refrigerants & Chemicals	Agriculture	Purchased Electricity	Purchased Steam / Chilled Water
	MT eCO_2	MT eCO_2	MT eCO_2	MT eCO_2	MT eCO_2	MT eCO_2	MT eCO_2	MT eCO_2	MT eCO_2
2002	-	-	-	-	-	-	-	-	-
2003	-	-	-	-	-	-	-	-	-
2004	-	-	-	-	-	-	-	-	-
2005	-	-	-	-	-	-	-	-	-
2006	-	-	-	-	-	-	-	-	-
2007	-	-	-	-	-	-	-	-	-
2008	-	-	-	-	-	-	-	-	-
2009	-	-	-	-	-	-	-	-	-
2010	-	-	-	-	-	-	-	-	-
2011	-	-	-	-	-	-	-	-	-
2012	-	-	-	-	-	-	-	-	-
2013	-	-	579.3	14.4	-	3.3	-	1,247.4	-
2014	-	-	579.3	14.4	-	3.3	-	1,247.4	-
2015	-	-	579.3	14.4	-	3.3	-	1,247.4	-
2016	-	-	579.3	14.4	-	3.3	-	1,247.4	-
2017	-	-	579.3	14.4	-	3.3	-	1,247.4	-

…

Scope 3			
Other Directly Financed Travel	Study Abroad Air Travel	Student Travel to/from Home (OPTIONAL)	Solid Waste
MT eCO_2	MT eCO_2	MT eCO_2	MT eCO_2
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
2.1	48.9	-	899.0
2.1	48.9	-	899.0
2.1	48.9	-	899.0
2.1	48.9	-	899.0
2.1	48.9	-	899.0

…

	Offsets								
Scope 2 T&D Losses	Additional	Non-Additional	Total Scope 1	Total Scope 2	Total Scope 3	Biogenic	Total Offsets	Total Emissions	Net Emissions
MT eCO_2	MT eCO_2	MT eCO_2	MT eCO_2	MT eCO_2	MT eCO_2	MT eCO_2	MT eCO_2	MT eCO_2	MT eCO_2
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
123.4	-	(50.4)	597.0	1,247.4	1,073.3	-	(50.4)	2,917.7	2,867.3
123.4	-	(50.4)	597.0	1,247.4	1,073.3	-	(50.4)	2,917.7	2,867.3
123.4	-	(50.4)	597.0	1,247.4	1,073.3	-	(50.4)	2,917.7	2,867.3
123.4	-	(50.4)	597.0	1,247.4	1,073.3	-	(50.4)	2,917.7	2,867.3
123.4	-	(50.4)	597.0	1,247.4	1,073.3	-	(50.4)	2,917.7	2,867.3

S_Energy | S_CO2_Sum | S_CH4_Sum | S_N2O_Sum | S_Energy_Sum | S_eCO2_Sum | S_Annual | S_Demo | ACUPCC_Reporting | GraphControl

Figure A 2: Input tab of CA-CP. Ellipses are used to show a gap in the spreadsheet.

Opening the "G_TotalEmissions" tab, shown in Figure A 3. This tab will give a graphical breakdown of the carbon output of the IAIA.

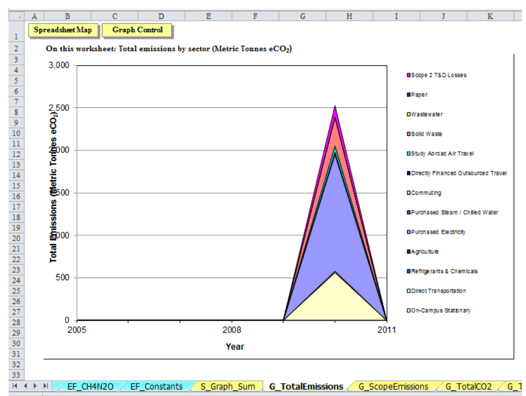


Figure A 3: CA-CP G_TotalEmissions tab

Further information on the Clean Air-Cool Planet Campus Carbon Calculator can be found at http://cleanair-coolplanet.org/campus-carbon-calculator/ where an online and downloadable version of the CA-CP can be found, along with the complete User's Guide.

Appendix B - Transportation Survey

We are a group of students from Worcester Polytechnic Institute (WPI), in Worcester, Massachusetts. We are here conducting a project aimed towards reducing the carbon emissions output of the IAIA. In order to do this, we must produce a carbon baseline that accounts for all of the carbon emissions produced by the IAIA. One of the sources being calculated is the daily commuting by faculty and staff of the IAIA. Please take a few minutes to fill out the below survey as accurately as possible. We thank you for your participation.

1. How do you usually travel to the IAIA?

a. Car/Carpool

b. Bus

c. Commuter rail

d. Combination (please describe)______

e. Other (please describe) _______

2. Typically in the academic year (August-May), how often do you use this means of transportation to commute to the IAIA, including weekends? (fill in which ever is the easiest estimation)

a. ______ days per workweek.

b. ______ days per month.

c. ______ days per year (note: each semester is around 98 days).

3. If possible, estimate the total number of miles traveled (both to and from the IAIA) by this means of transportation. If you use a bus or commuter rail, you can list the route and stops used, if it is easier to do so.

a. _____Car/Carpool miles

b. _____Bus miles

c. _____Commuter rail miles

d. Other (please describe) _______

4. If you carpool with other faculty/staff of the IAIA, how many people do you usually carpool with?

a. _____ people.

5. If you do not always commute to the IAIA by the same means, what is your second most common means of transportation?

a. Car/Carpool

b. Bus

c. Commuter rail

d. Combination (please describe)______

e. Other (please describe) _______

6. Typically in the academic year (August-May), how often do you use this means of transportation to commute to the IAIA, including weekends? (fill in which ever is the easiest estimation)

a. ______ days per workweek.

b. ______ days per month.

c. ______ days per year (note: each semester is around 98 days).

7. If possible, estimate the total number of miles traveled (both to and from the IAIA) by this means of transportation. If you use a bus or commuter rail, you can list the route and stops used, if it is easier to do so.

a. _____Car/Carpool miles

b. _____Bus miles

c. _____Commuter rail miles

d. Other (please describe) _______

8. If you carpool, how many people do you usually carpool with?

a. _____ people.

9. If the above questions did not portray an accurate depiction of your commuting habits, please use the below space to clear up any issues.

a. _____________________________________

Appendix C - Lighting Survey

Lighting Survey

Building Identification_______________ Room Identification__________

Level of Room Use: Regular Irregular

Room Description (i.e. window placement, amount of outdoor lighting received, lighting description):

____
____
____
___

Light Type: LED CFL Fluorescent HID Incandescent

Brand_____________Model_____________Wattage_____Quantity____

Light Type: LED CFL Fluorescent HID Incandescent

Brand_____________Model_____________Wattage_____Quantity____

Light Type: LED CFL Fluorescent HID Incandescent

Brand_____________Model_____________Wattage_____Quantity____

Light Type: LED CFL Fluorescent HID Incandescent

Brand_____________Model_____________Wattage_____Quantity____

Light Type: LED CFL Fluorescent HID Incandescent

Brand_____________Model_____________Wattage_____Quantity____

Appendix D – Electrical Inefficiencies Survey

Dear Faculty and Staff of the Institute of American Indian Arts,

We are a group of engineering students from Worcester Polytechnic Institute in Massachusetts. If you were present at the community gathering on Thursday the 27th of March then you heard our presentation. We are working with the CLE to reduce the carbon footprint of the IAIA. Our projects main focus is electrical usage. At the end of our time here we hope to leave the CLE with a variety of plans that when implemented will reduce electrical consumption. These plans will be focused on the CLE building and significant sources of inefficiency in other buildings throughout campus. In order to make the best use of our time and utilize the resources available to us we are asking you to identify possible sources of inefficiency. You know the campus better than we do and have most likely noticed the major sources of electrical inefficiency, we ask that you identify these sources for us.

If you could email sf14-iaia@wpi.edu and identify the

1. Cause of the Inefficiency
2. Building
3. Room
4. Any Possible Suggestions

Your help is greatly appreciated. Due to time constraints we may not be able to involve ourselves with every source but we will do all that we can and any identified sources will be noted in our final report.

Best Regards,

Adelle Milholland

Blake Cornachini

Jake Nutting

Ian McMullen

Appendix E - Initial Inventory Results

1st Floor:

Walkway
4ft & 6in lights
Vents 1&2
Coffee vending machine
Outlets
Exit sign
Elevator
Camera
Sprinkler
Alarm sensor
Fire alarm
Flood lights
Card Reader
Water Fountain
Router
Handicap door
TV
Speaker
Windows

Conference Room
4ft & 6in lights
Vents 2
Outlet
Projector & Screen
Sprinkler
Alarm sensor

ASG Office
4ft light
Vents 1&2
Sprinkler
Outlet
Computer
Thermostat
Miscellaneous Appliances
Windows

Student Activities Coordinator
4ft light
Vents 1&2
Sprinkler
Outlet
Computer
Thermostat
Miscellaneous Appliances
Windows

Copy Room
4ft light
Vents 1&2
Sprinkler
Outlet
Paper shredder
Thermostat
Microwave
Coffee Pot
Water cooler
Clock
GE mini-fridge
Fax machine - Murate F-520
Copier - Xerox Copycenter C128 (energy star)

Counseling Office
4ft light
Vents 1&2
Sprinkler
Outlet

Breakout Room
4ft light
Vents 1&2
Sprinkler
Outlet

Office Manager
4ft light
Vents 1&2
Sprinkler
Outlet
Computer
Miscellaneous Appliances

Dean of Students
4ft light
Vents 1&2
Sprinkler
Outlet
Computer
Miscellaneous Appliances

Alumni + Constituent Relations Manager
4ft light
Vents 1&2
Sprinkler
Outlet
Computer
Thermostat
Miscellaneous Appliances

Video Conference Room
4ft & 6in light
Vents 1&2
Sprinkler
Outlet
Computer
Video equipment
Miscellaneous Appliances

Janitor
4ft light
Mini-fridge
Vent 1&2
Alarm sensor
Sprinkler
Outlet

Bathroom - Men and Women
4ft & 6in light
Vent 1&2
Sprinkler
alarm Sensor
Toilets
Windows

Bathroom - Men, Women, and either
4ft light
Vent 1&2
Sprinkler
alarm Sensor
Toilets
Windows

Distance Learning 1
4 ft light
Projectors
Vents 1&2
Outlet
Sprinkler
Alarm Sensor

Distance Learning 2
4ft and 6in light
Vent 1&2
Projectors & screens
TV - 2 sizes
Camera
Outlet
Computer
Alarm Sensor
Sprinkler

Server Room
NEH Classroom
4ft and 6in light
Vent 1&2
Outlet
Alarm Sensor
Sprinkler

Elevator Equipment
Bookstore
4ft light
Vent 1&2
Mini-fridge
Outlet
Speaker
Plug lights
Clock
Thermostat
Alarm sensor
Sprinkler
TV
Misc appliances
Computer

Dining Room
4ft and 6in light
Vent 1&2
Sprinkler
Alarm Sensor
Fire Alarm
Heating/cooling food trays
Drink dispensers
Outlets
Microwave
Toaster
Clock
Exit Sign
Router

Kitchen
Stairwell X2
Light?
Sprinkler
Alarm Sensor
Window
Outlet

2nd Floor:				
Hallway 4ft & 6in light Vent 1&2 Outlet Sprinkler SKylight Key Card Reader Alarm Sensor Water Fountain **Kitchenette** 4ft Light Skylight Haier mini- fridge Fridge - Whirlpool ET0MSRXTQ 01 Tea kettle Microwave Water Cooler Coffee Maker - Gemini System 312L Coffee pot Coffee grinder Outlet Phone Thermostat Hot plate Rice Cooker Food Dehydrator Fire Alarm Sprinkler Vent 1	**Presentation Room** 4ft and 6in light Skylight Window Track light Exit Sign Sprinkler Vent 1&2 Outlet Camera Speaker Projector & Screen Clock Thermostat Fire Alarm Flood Light Elevator Alarm Sensor **Breakout 1 and 2** 4ft & 6in light Sprinkler Thermostat Outlet Vent 2 **Office Hallway** 4 ft light Vent 1&2 Outlet Sprinkler Exit Sign Fire Alarm Alarm Sensor Skylight	**Copy Room** 4ft light Sprinkler Outlet Window Vent 1&2 Router Copy Machine - Copyoter CS-C3232 #67755 (energystar) Printer - hp LaserJet 4200tn Printer - hp LaserJet 4600n Copier - Canon image class D760 (energystar) Fax Machine - Canon FaxPhone L170 (energystar) **Commons** 4ft & 6in light Vent 1&2 Projector & Screen Outlet Sprinkler Thermostat**Office X4** 4 ft light Vent 1&2 Outlet Computer Lamp Phone Sprinkler Misc Appliances Windows	**Administration Office** 4 ft light Vent 1&2 Outlet Computer Lamp Sprinkler Misc Appliances Windows Thermostat Clock Phone Alarm sensor Exit sign **Buffalo Trust** 4 ft light Vent 1&2 Outlet Computer Sprinkler Alarm sensor Misc Appliances Windows **Bathroom - Men and Women** 4ft & 6in light Vent 1&2 Sprinkler alarm Sensor Toilets Windows **Janitor** 4ft light Outlet Vent 1&2 Sprinkler Alarm sensor	**IT** 4ft light Vent 1&2 Router Alarm Sensor Sprinkler Outlet Epson Printer (energystar) Sound equipment Video equipment - DSX Access System

Appendix F - Lighting Matrix

		Type of Light	Type of Bulb	Watts	Lumens	Color	Life Expectancy	Cost	Fixture
1	**Currently used Tube**	Florescent	4 ft. T8 - CFL Tube	32	2800	3500K	36000 hours	$2.79	3 bulb inlaid ceiling
2	**Proposed Tube**	LED	4 ft. T8 - LED Tube	18	1800	5000K	25000 hours	$19.99	Rewire
3		LED	4 ft. T8 - LED Tube	18	1620	2900 K	50000 hours	$29.96	Rewire
4		LED	4 ft. T8 - LED Tube	18	1850	3500K	50000 hours	$29.96	Rewire
5		LED	4 ft. T8 - LED Tube	18	1800	4000K	25000 hours	$19.99	Rewire
6		LED	4 ft. T8 - LED Tube	18	1900	4000K	50000 hours	$21.18	Rewire
7		LED	4 ft. T8 - LED Tube	18	1850	4000K	50000 hours	$29.96	Rewire
8		LED Easy Fit	4 ft. T8 - LED Tube	22	2200	5000K	50000 hours	$35.28	Same
9		LED Easy Fit	4 ft. T8 - LED Tube	22	2200	4100K	50000 hours	$34.99	Same
10	**Currently used Track Light**	Incandescent Halogen Spot	MR-16	20	150	2950K	4000 hours	$0.86	GU5.3
11	**Proposed Track Light**	LED: 20 W equi, spot	MR-16	4	230	2700K	50000 hours	$20.93	GU5.3
12		LED: 20 W equi, narrow flood	MR-16	6	295	4000K	25000 hours	$15.79	GU5.3
13	**Currently used Flood Light**	Incandescent Halogen Indoor	MR-16	35	390	2950K	2000 hours	$0.81	GU5.3
14	**Proposed Flood Light**	LED: 30 W equi, flood	MR-16	6	315	2700K	30000 hours	$17.11	twist and lock GU10 base
15		LED: 20 W equi, flood	MR-16	3.5	250	3000K	30000 hours	$21.05	GU5.3
16	**Currently used Short Tube**	Florescent	T4 - CFL 2-Pin	13	800	2700K	10000 hours	$1.75	GX23 (2-Pin)
17	**Proposed Short Tube**	LED	T4 - Florescent PL	7	350	3200K	50000 hours	$105.26	GX23-2

Appendix G - Electrical Usage by Lighting in the CLE Building

Type	Traffic	Quantity	Wattage	Hours	Total Electrical Usage (Per Day)		Total Electrical Usage (Per Year)		Days of the Year
4 ft. T8 CFL Tube	Regular Traffic	280	32	10	89.6	KWh/ day	23296	KWh/ year	School Year (260 Days)
4 ft. T8 CFL Tube	Irregular Traffic	420	32	6	80.64	KWh/ day	20966.4	KWh/ year	School Year (260 Days)
7 in. F26 Light	Regular Traffic	110	13	10	14.3	KWh/ day	3718	KWh/ year	School Year (260 Days)
7 in. F26 Light	Irregular Traffic	54	13	6	4.212	KWh/ day	1095.12	KWh/ year	School Year (260 Days)
Small Recessed Light	Irregular Traffic	6	50	6	1.8	KWh/ day	468	KWh/ year	School Year (260 Days)
Metal Halide Bulb 70W	Regular Traffic	15	70	10	10.5	KWh/ day	2730	KWh/ year	School Year (260 Days)
Metal Halide Bulb 100W	Irregular Traffic	11	100	6	6.6	KWh/ day	1716	KWh/ year	School Year (260 Days)
Interior 13W Bulb	Irregular Traffic	150	13	6	11.7	KWh/ day	3042	KWh/ year	School Year (260 Days)
Exterior H.I.D. Light	Regular Traffic	7	70	10	4.9	KWh/ day	1274	KWh/ year	School Year (260 Days)
Track Light Halogen Spot	Museum	150	20	9	27	KWh/ day	8964	KWh/ year	Work Year (332 Days)
Flood Light Halogen Indoor	Museum	150	35	9	47.25	KWh/ day	15687	KWh/ year	Work Year (332 Days)

Bibliography

ABB. *Connecting renewable energy to the grid*. http://www.abb.com/cawp/seitp326/377dbeff7a3a6aedc12577c20033dbf5.aspx

Agenda 21. *Protection Of The Atmosphere*. http://habitat.igc.org/agenda21/a21-09.htm.

American College and University Presidents Climate Commitment. *ACUPCC Five Year Report.* http://www.presidentsclimatecommitment.org/reporting/annual-report/five-year-report.

American College and University Presidents Climate Commitment. *Home.* http://acupcc.org. March 25, 2014.

American College and University Presidents Climate Commitment. *Mission and History*. http://acupcc.org/about/mission-history.

American College and University Presidents Climate Commitment. *Tangible Actions*. http://rs.acupcc.org/stats/tangible-actions/.

American Petroleum Institute. "Oil & Natural Gas Overview". *What Can You Do to Help Reduce Your Natural Gas Bills?* http://www.api.org/oil-and-natural-gas-overview/exploration-and-production/natural-gas/reduce-bills

American Public Transportation Association. "Public Transportation Use Substantially Reduces Greenhouse Gases

America's Power. *New Mexico. http://www.americaspower.org/according-to-eia-data*

According to New Study". *APTA*. http://www.apta.com/mediacenter/pressreleases/2007/Pages/070926_climate_report.aspx

Bueno, A. (2014, April 1). Personal Communication.

Circular Energy. 2014. *Ground Mounts. http://www.circularenergy.com/circular-energy-ebulletin/the-anatomy-of-a-solar-energy-system-part-ii-mount-systems/*

Clean Air-Cool Planet. *Campus Carbon Calculator*. http://cleanair-coolplanet.org/campus-carbon-calculator/

Clean Technica. 2014. *Solar Power Transforms Parking Lots Into Green Job Generators.* http://cleantechnica.com/2010/08/03/solar-power-transforms-parking-lots-into-green-job-generators/

Climate News Network. *Food waste worsens GHG emissions - FAO*. http://www.climatenewsnetwork.net/2013/09/food-waste-worsens-ghg-emissions-fao/

Colby College. *Carbon Neutral in 2013.* http://www.colby.edu/news_events/carbonneutral/.

Colby College. *Progress Report* Waterville, ME: Sustainability Coordinator, Administration Department, Colby College. http://www.colby.edu/administration_cs/vpadmin/documents/upload/Climate-Action-Plan-July-2010.pdf

College of the Atlantic. *Beech Hill Farm*. Available from https://www.coa.edu/beech-hill-farm-microsite.htm.

College of the Atlantic. *Climate Action Plan* Bar Harbor, ME: Director of Sustainability, President's Office, College of the Atlantic. rs.acupcc.org/site_media/uploads/cap/231-cap.doc

Combs, B. (2014, April 11). Personal Communication

Connect. *Community Solar: Get Renewable Energy without the Panels*. http://connect.xcelenergy.com/minnesota/community-solar-get-renewable-energy-without-the-panels/

Cornell Waste Management Institute. *Composting as a Waste Management Technique*. http://compost.css.cornell.edu/technique.html

Current Solar. *PV System Installation, Maintenance and Longevity*. http://www.gosolarcalifornia.ca.gov/solar_basics/how.php

Eartheasy. *Energy Efficient Lighting*. http://eartheasy.com/live_energyeff_lighting.htm

Earth Science Communications Team. "The current and future consequences of global change." http://climate.nasa.gov/effects.

Eco-Cycle. *Zero Waste & Climate Change*. https://www.ecocycle.org/zerowaste/climate.

EIA. "Analysis and Representation of Miscellaneous Electric Loads in NEMS": *EIA* (2013): Page 5.

EIA. "Emissions of Greenhouse Gases in the U.S." *EIA.* http://www.eia.gov/environment/emissions/ghg_report/ghg_overview.cfm

EIA. "What is the role of coal in the United States?" Available from http://www.eia.gov/energy_in_brief/article/role_coal_us.cfm
ENERGY.GOV. *Solar*. http://www.energy.gov/science-innovation/energy-sources/renewable-energy/solar
Environmental Protection Agency. *2. Trends in Greenhouse Gas Emissions.* http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2013-Chapter-2-Trends.pdf.
Environmental Protection Agency. *Air Emissions*. http://www.epa.gov/cleanenergy/energy-and-you/affect/air-emissions.html
Environmental Protection Agency. *Clean Energy - Natural Gas.* http://www.epa.gov/cleanenergy/energy-and-you/affect/natural-gas.html.
Environmental Protection Agency. *Climate Change and Waste.* http://epa.gov/climatechange/climate-change-waste/.
Environmental Protection Agency. *Climate Change Science Overview*. http://www.epa.gov/climatechange/science/overview.html
Environmental Protection Agency. 2013. *Composting Strategies for Colleges and Universities*. http://www.epa.gov/epawaste/conserve/smm/web-academy/2013/dec05.htm
Environmental Protection Agency. *Electricity Sector Emissions.* http://www.epa.gov/climatechange/ghgemissions/sources/electricity.html
Environmental Protection Agency. *Greenhouse Gas Equivalencies Calculator*. http://www.epa.gov/cleanenergy/energy-resources/calculator.html#results.
Environmental Protection Agency. *Municipal Solid Waste.* http://www.epa.gov/waste/nonhaz/municipal/.
Environmental Protection Agency. "Sources of Greenhouse Gas Emissions -Electricity Sector Emissions". Available from http://www.epa.gov/climatechange/ghgemissions/sources/electricity.html.
Environmental Protection Agency. *Sources of Greenhouse Gas Emissions - Overview. http://www.epa.gov/climatechange/ghgemissions/sources.html.*
Environmental Protection Agency. *Sources of Green*house Gasses - *Transportation Sector Emissions.* http://www.epa.gov/climatechange/ghgemissions/sources/transportation.html.
Federal Transit Administration. "Greenhouse Gas Sources: Vehicles and Carbon Dioxide". *Public Transportation's Role in Responding to Climate Change*. Page 3. http://www.fta.dot.gov/documents/PublicTransportationsRoleInRespondingToClimateChange.pdf
Food Wastage Footprint. *Impacts on Natural Resources Summary Report*. http://www.fao.org/docrep/018/i3347e/i3347e.pdf.
Go Solar Energy. "FAQ" *Will the panels be installed on my roof or the ground?.* http://www.gosolarsantafe.com/learn/faq
Greentechgrid. *Network Infastructure/AMI*. http://www.greentechmedia.com/articles/read/doe-launches-challenge-for-100-electric-submeter
Green Mountain College. *Climate Action Plan* Poultney, VT: Sustainability Office. http://rs.acupcc.org/site_media/uploads/cap/169-cap.pdf
Green Mountain College. *Climate Neutrality*. http://sustainability.greenmtn.edu/climate_neutrality.aspx.
GreenProgress. *College of the Atlantic Becomes First Carbon Neutral Campus.* http://www.greenprogress.com/environment_article.php?id=1451.
Grid Arendal. Climate Change and Waste - Gas emissions from waste disposal. http://www.grida.no/publications/vg/waste/page/2871.aspx
Grudzinski, W. (2014, February 18). Personal Communication.
Institute of American Indian Arts. *Climate Action Plan* Santa Fe, NM: Faculty/chair Essential Studies, Essential Studies Department, Institute of American Indian Arts.
Institute of American Indian Arts. *Greenhouse Gas Report* Santa Fe, NM: Faculty/chair Essential Studies, Essential Studies Department, Institute of American Indian Arts.http://rs.acupcc.org/ghg/2166/

Institute for Energy Research. *Solar.* http://www.instituteforenergyresearch.org/energy-overview/solar/
International Panel on Climate Change. *Climate Change 2007: Synthesis Report*. http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf.
Lundin, Barbara Vergetis. "Power plant Emissions Declining." *FierceMarkets*. Available from http://arizonaenergy.org/News_13/News_June13/AfteryearsofdeclineCO2emissionsontherise.html.
Maehlum, Mathias. *Solar Panel Comparison*. http://energyinformative.org/solar-panel-comparison/
Martin, Melanie J. "Is Natural Gas Cleaner Than Petroleum & Coal." *SFGate*. http://homeguides.sfgate.com/natural-gas-cleaner-petroleum-coal-79371.html.
Mathematics of Planet Earth. *Climate System - Greenhouse Effect.* http://mpe.dimacs.rutgers.edu/images/climate-system-greenhouse-effect-2/.
McManus, Reed. "Rise of the Plug in Hybrids". *Sierra Club*. http://www.sierraclub.org/sierra/201307/electric-vehicle-buyers-guide.aspx
National Center for Education Statistics. *Digest of Education Statistics* Table 5. http://nces.ed.gov/programs/digest/d12/tables/dt12_005.asp.
NHTSA. "Corporate Average Fuel Economy". *NHTSA*. http://www.nhtsa.gov/fuel-economy
Perry, Caroline. "Reduction in U.S. carbon emissions attributed to cheaper natural gas." *R&D*. http://www.rdmag.com/news/2012/02/reduction-us-carbon-emissions-attributed-cheaper-natural-gas.
Piedmont Environmental Alliance. *10 Actions to Radically Reduce Your Carbon Footprint*. http://peanc.org/education/10-actions-radically-reduce-your-carbon-footprint
Practical Action. *Causes of Climate Change.* http://www.climatechoices.org.uk/pages/cchange3.htm.
Real Goods. *SolarWorld Sunmodule Plus SW275 Mono Solar Panel*. http://realgoods.com/solar/solar-panels/solarworld-sunmodule-plus-sw275-275w-mono-solar-panel
RecycleMania. *About*. Available from http://recyclemaniacs.org/about
Reference.com. *Solar Gain*. http://www.reference.com/browse/solar+gain?s=t
Richard, L. N. (2009). Cogeneration (Vol. 62, pp. 14). Chicago: Barks Publications
Rooks, Douglas. Colby Magazine. *Harnessing the Wind*.4. https://www.colby.edu/colby.mag/issues/52/article/1045/harnessing-the-wind/
Santa Fe Community College. *Climate Action Plan* Santa Fe, NM: Sustainability Consultant, POM, Santa Fe Community College. http://rs.acupcc.org/site_media/uploads/cap/86-cap.pdf
Second Nature. *History. http://www.secondnature.org/mission/history.*
SEIA. Solar Industry Data. http://www.seia.org/research-resources/solar-industry-data
SolarLogic. *The New Standard in Green Heating*. http://www.solarlogicllc.com/
Standby Power. *Standby Power. http://standby.lbl.gov/summary-table.html*
SunPower. *SunPower Product Warranty and Manuals. http://us.sunpower.com/support/warranty/*
Tencer, Daniel. "Number of Cars Worldwide Surpasses 1 Billion; Can the World Handle This Many Wheels?." *Huffington Post*. Available from http://www.huffingtonpost.ca/2011/08/23/car-population_n_934291.html
Tomaszewski, E. (2014, February 18). Personal Communication.
UCSUSA. "How Solar Energy Works". *Photovoltaics.* http://www.ucsusa.org/clean_energy/our-energy-choices/renewable-energy/how-solar-energy-works.html
Union of Concerned Scientists. *Our Energy Choices - Coal and Other Fossil Fuels: A Dirty Source of Energy*. Available from http://www.ucsusa.org/clean_energy/our-energy-choices/.
U.S. Department of Energy. *Reduce Climate Change.* http://www.fueleconomy.gov/feg/climate.shtml.
U.S. Department of Energy. *Getting Gas from the Ground…. and the Sea*. http://www.fe.doe.gov/education/energylessons/gas/gas_production.html.
U.S. Department of Transportation. *Transportation's Role in Climate Change*. http://climate.dot.gov/about/transportations-role/overview.html.