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CARBON NEUTRALITY AT THE IAIA

Reducing the Institute of American Indian Arts' Carbon Footprint

An Interactive Qualifying Project Report
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Abstract

In 2010 the IAIA committed to becoming a carbon neutral campus, but since then their carbon emissions have increased. The goal of this project was to help the IAIA move forward on the path towards carbon neutrality. Based on a campus survey and product research and evaluation we identified programs and technologies to help the IAIA make progress towards their goal, by introducing solar power, implementing LED lighting, and improving conservation awareness via metering systems to monitor energy and gas consumption on campus.

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Executive Summary

In 2010, the Institute of American Indian Arts signed the American College and Universities Presidents' Climate Commitment (ACUPCC), committing them to becoming a carbon neutral campus by 2050. However, over the past six years, due to campus expansion, the IAIA's carbon emissions have increased. The school needs to take action and make significant changes in order to reverse this trend. We identified different actions that the school could take to significantly reduce their carbon emissions.

No project done by the IAIA can reach its full potential without the involvement of the whole school's community. After conducting a survey to gauge the community's interest in the IAIA's carbon neutrality efforts, we discovered that the IAIA community is ready and willing to be heavily involved in the school's sustainability initiatives. Therefore, we recommended the IAIA focus on programs that will raise students' interest in the commitment to become carbon neutral so the school can leverage that support to make future projects easier.

To help the IAIA increase their energy conservation efforts, we found an electrical metering system that could monitor and compare the energy consumption of two classrooms—one which used LED fixtures, while the other still employs fluorescent lighting. The meters will be used to demonstrate how much more energy efficient LEDs are and encourage more investment in such energy saving technologies. For this, we recommended the use of 2 Efergy® electrical meters that display the instantaneous power usage, total energy usage over time, the cost of the energy, and the carbon emissions produced.

As part of our efforts regarding community involvement we developed the content for a poster that would be placed near the electric meters to highlight the effects of switching lights from fluorescents to LEDs. This poster will show how much more efficient the updated classroom is than the one with fluorescents, comparing the different values of electricity consumption in layman's terms, money saved, uses for the unused electricity, and how much would be saved if all lights on campus were to be switched to LEDs.

Only a small part of the campus lighting system uses LEDs; the rest of them are fluorescent. Since LED lights have a relatively long lifespan and are much more efficient, switching the entire campus to LED lighting could provide an excellent way for the IAIA to increase their energy conservation on campus, based on the number of lights on campus, we estimate the IAIA would reduce their carbon emissions by 325 tons, or 11% of their 2013 carbon baseline.

The IAIA also knows that improving natural gas conservation is going to be an important part of its journey towards carbon neutrality. In order to improve their natural gas conservation, the IAIA needs to be able to monitor when and where natural gas is consumed on campus for heating and running appliances in the cafeteria kitchen. Based on the technology available, we recommend the Elster RABO family of meters. These meters use a pulse output that is totaled on a remote mounted, easy-to-read LCD screen; it would cost the IAIA around $16,500 plus labor to outfit the entire campus. Because these meters cannot be read automatically, it will be a labor intensive to collect the data from these meters, therefore the IAIA should only invest in these if they are committed to manually collecting data. However, gas monitoring is becoming more popular and gas metering technology is continuing to advance, so if the IAIA is not ready to fully commit to a manual system, they may find less expensive and automated options in the upcoming years. Therefore, our recommendation is that the IAIA should wait to purchase gas meters until an automated system becomes scaled down to fit the IAIA needs.

The next of focus for our research was solar power. As the school will always require electricity, having a source of carbon-free electricity is essential for carbon neutrality. Solar energy is the most cost-effective method to introduce clean energy generation to a school like the IAIA. The IAIA received a proposal for a solar lease in the summer of 2016. We analyzed the proposal and recommended that the IAIA not accept it for its first move into solar generation for two reasons: the proposed system’s equipment efficiency was below market averages, and the terms of the lease would make it more difficult to expand the system to meet the IAIA's growing energy needs.

We determined that the most effective course of action for developing solar at the IAIA was for the school to have a multi-phased approach. We recommend that the IAIA first install a small pilot system because of its reasonable pricing, and would include a roof system—about 24 kW—plus a smaller carport system of 8 kW that could visualize and advertise the school's effort to bring solar generation to campus. The system would cost around $120,000 and could pay for itself in 15 to 20 years. While it was doing so, the IAIA could generate interest in further investments in solar energy.

With this new interest in expanding solar, the school could use either private placements or traditional capital campaigns to fund future, larger projects with a more substantial impact on the IAIA's carbon footprint.

We hope our project can catalyze the IAIA into making significant changes towards achieving their goal of carbon neutrality by combining green energy sources with improved energy conservation.

1 Introduction

Across the United States, many educational institutions are decreasing their energy usage in order to mitigate their carbon footprint and combat climate change. These institutions are realizing the benefits from solar technology, green construction, energy conservation, and more efficient lighting (The Solar Co, 2015). Photovoltaic solar cells, for example, are one of the fastest growing markets in the world (Jawahar, 2016). In 2015, worldwide solar energy production increased by 25% reaching approximately 227 GW. While capturing solar energy is an excellent way to produce carbon free energy, students, faculty, and staff at these institutions also need to be aware of how they use energy, and how they can conserve more energy. Energy prices have steadily increased over the past decade, and they are projected to increase even more in the future.

In 2010, the President of the Institute of American Indian Arts (IAIA) entered the school into an agreement that committed the school to doing its part in fighting climate change by lowering the school's carbon footprint drastically. The school pledged to reduce its carbon footprint to 50% of its 2010 levels by 2025 and to become completely carbon neutral by 2050 (Institute of American Indian Arts, 2013). With the rising costs of electricity—in the past five years alone, the cost of commercial electricity rose by 5.4 percent (US Energy Information Administration, 2016b)—the IAIA has seen the advantages of focusing on lowering the school's reliance on utility provided electricity, which is mostly sourced from burning fossil fuels and is only going to get more expensive. Every bit of energy that the IAIA produces and conserves on site lowers both its energy bill and its carbon footprint. So far the IAIA has not achieved any carbon emission reductions, so they are seeking a better way to reduce emissions and start on the path towards carbon neutrality.

A 2014 WPI research team created a carbon emissions baseline for the IAIA, with instructions on how the IAIA staff could monitor and update it in future years (Cornachini, Mathews, McMullen, Milholland, & Nutting, 2014). This baseline in 2014 showed that the IAIA had not reduced their carbon emissions since 2010, in fact they had actually increased their emissions. In the spring of 2016, another WPI team installed electricity meters in a few buildings on campus in order to facilitate a better understanding of the ways that power is being consumed on campus (DiBiasio, Pilaar, & Rosa, 2016). These meters will help the school develop informed plans on how and where to conserve electricity and increase energy efficiency. While conservation and improved energy efficiency can have a big impact on reducing carbon emissions, they won't be able to bring the IAIA to carbon neutrality by themselves. The biggest impacts in reducing carbon emissions come when an institution can acquire electricity without increasing their carbon footprint. Most often, solar power is used to provide clean energy like this. The first college that achieved carbon neutrality, the College of the Atlantic (2015) in Bar Harbor, ME, used solar generation to provide the power needed by the college.

While past research has identified effective areas for solar arrays on campus and methods for monitoring building-wide energy usage, the IAIA has yet to make any significant steps towards reducing its carbon footprint. As creating awareness of energy sustainability is a significant driver in energy conservation, there was a need for students and staff to be more aware of the efforts that IAIA has taken or could take to achieve energy sustainability. Little research had also been done in identifying how the IAIA can invest in local solar providers. The IAIA did not have information about what size or type of solar array would be the most practical to install, how to fund any investments in solar energy, or how much a solar array would cost to install.

Our overall goal was to help the IAIA advance their commitment to achieving carbon neutrality. To achieve this main goal, we had two sub-goals: conservation and beginning the process of implementing solar energy generation for the campus. For our goal of conservation, we surveyed the campus population in order to establish a baseline of the community's thoughts on sustainability and carbon neutrality. We also researched gas and electrical metering options in order to educate the campus on its utility usage. For implementing solar generation on campus, we analyzed a proposal given to the IAIA by a solar financing company called Re-volv. We also researched other options for solar power in the Santa Fe area that might be more beneficial to the IAIA. Overall, our project will hopefully move the IAIA forward on the path to achieving carbon neutrality by 2050.

2 Background

To provide a context for the IAIA's move toward carbon neutrality, in this chapter we explore and discuss five major topics: climate change and the rise in energy production costs, the effectiveness of solar energy, gas and electricity metering systems, what other educational institutions are doing to become carbon neutral and the IAIA's carbon footprint baseline.

2.1 Climate Change and Rising Energy Costs

Human activity naturally results in the exchange of a multitude of greenhouse gases (GHGs) between the earth and its atmosphere. Around 1950 the concentration of all the GHGs jumped dramatically, especially carbon dioxide. Naturally, the global concentration of carbon dioxide ranges from around 180 - 300 parts per million. In 2005, the concentration of carbon dioxide reached a record high of 379 parts per million, which is well above the natural range (Alley et al, 2007). With carbon dioxide reaching local levels above 400 parts per million in the year 2012, we are soon approaching a time when the measurement of carbon dioxide in ambient air will always above 400 parts per million (Gillis, 2013). If levels continue to rise as they have been and we continue to consume fossil fuels at or above the current rate, the human biosphere will change drastically due to rising temperatures, sea levels, and more extreme weather patterns. Those consequences will affect the rest of the world's ecosystem.

Over the last thirteen years, energy rates, especially those for electricity, have been constantly on the rise (Block, 2013). Figure 2-1 shows that between 2003 and 2015 electricity prices have increased from 8 cents to 13 cents per kilowatt-hour—an increase of about 3.5% per year (U.S. Energy Information Agency, 2016c). The main driver behind the increase in energy costs is the increased cost of fossil fuels. The International Energy Agency has increased its price projections for future oil costs and has expected a barrel of oil to average over $200 by 2030 (Block, 2013). The executive director of the International Energy Agency said, "While market imbalances will feed volatility, the era of cheap oil is over" (¶3). Not only are increased production costs driving the increase in energy prices, supply also has an effect on prices. The current supply of oil and natural gas is expected to last another 40 years at the rate that it is being consumed today. If there were a sudden increase in the rate at which oil and natural gas are consumed, there is a real worry that current supplies will not last 40 years, which would drive prices up even further.

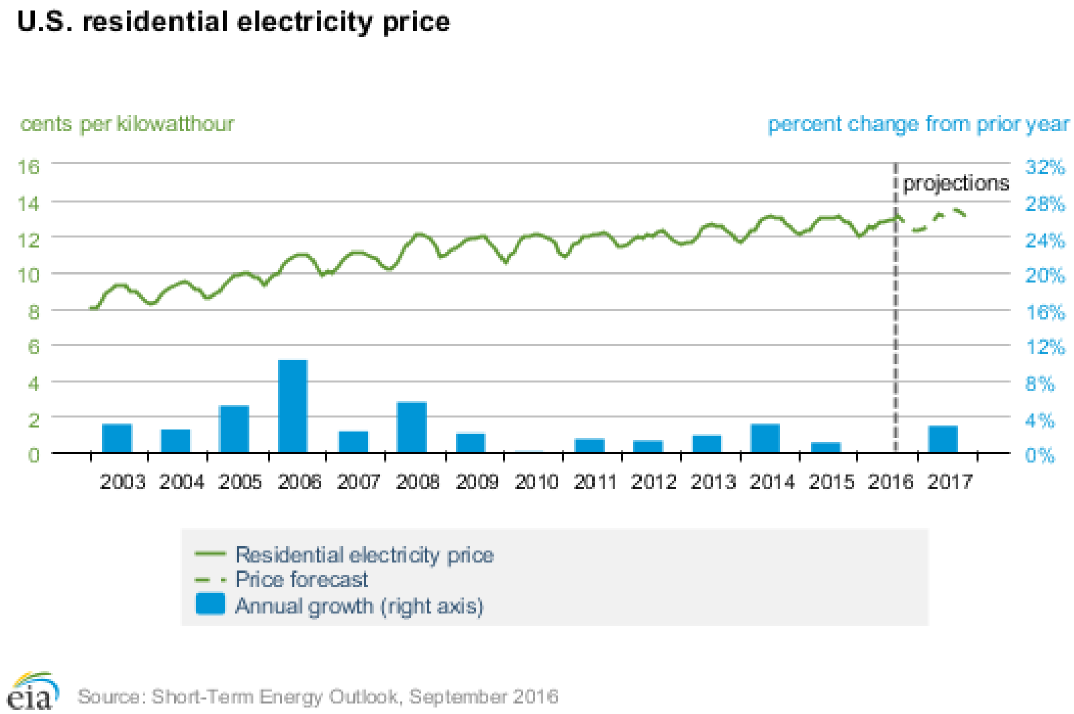


Figure 2-1: The EIA's short-term energy outlook (U.S. Energy Information Administration, 2016b)

Infrastructure is another driver of the rising cost of electricity. Most of the power grid infrastructure is out of date, and as demand increases, more investments in lines, substations, and distribution systems will be required to keep reliability at current levels (Edison Electric Institute, 2006). In the late 1980's and early 1990's, when electricity demands sharply increased, many utility companies did not make the necessary upgrades to their infrastructure to keep up with this increase. Now, as demand steadily increases, companies have to play catch up, investing large amounts of capital into infrastructure to keep up with demand and new technology. This money typically comes from raising the utility rates that consumers pay. As many price caps expire, utility companies can request to raise their rates in order to fund expansion and pay for infrastructure upgrades. A representative of Sunpower, a solar energy company, informed us that if there are too many customers producing more energy than they use, and give this extra energy back to the grid, called co-generation, the New Mexico power supplier will attempt to halt the installation of more energy generation system (D. Baker, personal communication, September 12, 2016). The local technology is out of date, and the statewide energy company, the Public Service Company of NM

(PNM) is extremely worried about too much co-generation that could damage or destroy the local infrastructure. To combat this, when individuals or organizations have their projects halted, PNM has attempted to have that person or group pay for the necessary infrastructure upgrades, even though most power companies have specific funds for infrastructure upgrades.

Finally, the cost of complying with government regulations has also been a significant part of the rising energy costs throughout the United States (Edison Electric Institute, 2006). As worry about the environment due to climate change increases, the federal and state governments have passed laws that utility companies must comply with. There are hundreds of environmental rules created in the wake of the Clean Air and Clean Water Act. These rules have had a great financial impact on utility companies. Between 2002 and 2005, utility companies as a whole spent $24 billion on compliance with federal and state laws. As demand for electricity increases and more fossil fuels are consumed, we expect federal and state governments to continue to pass rules that utility companies must eventually comply with. Two of the relatively newer regulations are the Clean Air Interstate Rule and the Clean Air Mercury Rule. These regulations aim to lower the nitrous oxide, sulfur dioxide and mercury produced by power plants. Between 2007 and 2025, the two regulations are estimated to cost the electricity production industry around $47.8 billion. As more regulations are passed and the cost of compliance and infrastructure upgrades increase, these costs will be passed down to consumers, via higher energy bills, and continue the upward trend.

2.2 The Effectiveness of Solar Energy

For more than a decade, solar co-generation has been expanding rapidly in all markets, from small, two to five kilowatt systems on homes, to multi-Megawatt systems that can power datacenters and industrial complexes. By generating this power on-site, a person or institution can gain a significant amount of power with zero carbon emissions, instead of the thousands of pounds of carbon emitted by a coal-fired, oil, or gas, power plant (U.S. Energy Information Administration, 2016a). Co-generation investments are more expensive than many initiatives to reduce total energy demands might be, but they are more capable of achieving carbon neutrality. Completely eliminating electricity usage is impossible and conservation methods can only eliminate a portion of electrical needs. To neutralize their dependence on energy grids, many people have turned to independent, carbon free energy generation along with conservation methods.

Co-generation is where big strides in carbon neutrality can be made and is the only real option for true carbon neutrality as long as utility companies continue to burn fossil fuels in order to generate power; solar energy is only becoming a more attractive option for co-generation. Every year, advances in technology make the equipment needed for solar electricity generation more efficient and less expensive, making renewables a better option for power generation around the world (Farmer & Lafond, 2016; Lins, Williamson, Leitner, & Teske, 2014). Smaller institutions have begun to invest in enough solar energy to power their entire facilities, often partnering with utility companies and even venture capitalists in order to be able to get the funding to afford such a project (Public Service Company of New Mexico, 2016c; Sunpower, 2016). Solar energy production has reached the point where it is not only lowering carbon emissions but is also able to pay for itself in energy savings in 15 years or less.

There are three popular ways for solar panels to be installed, each with their own advantages and disadvantages (D. Baker, personal communication, September 4, 2016). The least expensive method is to install the solar panels on the roof of an existing building. As this requires the least new infrastructure, its installation costs, over the cost of the panels, is the lowest. However, because they are now limited by the incline and angles of the roof the panels are being installed on, roof-mounted solar panels often can have limited effectiveness if the roof is flat or pointed a direction other than due south. Yet, as roof-mounting is the least expensive option in most cases, it tends to be the most popular choice for residential and commercial systems.

The next most popular choice is to ground-mount the panels (D. Baker, personal communication, September 4, 2016). This system is preferred when considering very large solar arrays. In order to get Megawatt- and Gigawatt-scale generation, so many panels are needed that it is nearly impossible to install all those panels on the roofs of buildings. However, the mounting for such systems is more expensive than when mounting panels on the roof, and the panels take up large tracts of land that could otherwise be developed for other uses. Ground-mount systems tend to be the most efficient, because they can be placed at the exact optimum angle, and sometimes use tracking technology to have the panels follow the sun. However, they also tend to be the least secure, as it is easy to access panels when they are on the ground. Thus vandalism can be a concern so many panel owners choose to fence in the panels, which requires additional costs.

The third option is almost a combination of the two previous ones (D. Baker, personal communication, September 4, 2016). Specially built structures such as carports can become the understructure upon which panels are mounted. Most of the time, these structures are built over parking lots, creating shade for parked cars while generating electricity. These solar carports are the most expensive of the three options due to the large number of support structures required. However, they also can be the most effective. As the angle and location of the carport roofs are up to the designer, they can be built at the optimum angles. Additionally, their structure gives a second purpose to the land it's built on--shade, which doesn't happen with ground-mount systems. Finally, since the carport raises the panels well off the ground, the risks of vandalism are much less. Yet, the panels are fix-mounted on the structures, so they cannot take advantage of the increased efficiency of a tracking system.

2.3 Gas Metering and Importance of Metering

Electricity and gas meters measure the flow of electricity and gas into the systems that they are measuring (U.S. Department of Energy, 2016). Gas meters measure cubic feet simply by using the force of flowing gas to drive the meter. Electrical meters display watts and kilowatt-hours and use electrical current to drive the meter. While electrical meters simply measure a voltage and current to display watts and kilowatt-hours, there are a variety of different options for measuring gas flow. One common type of gas meter is a positive displacement meter, sometimes called a diaphragm meter (Steinberg, 2013). This type of meter requires the gas to displace mechanical components to measure. Another type is a thermal mass flow meter, which use heat transfer from a heated element to measure the mass of the fluid that has passed through the meter. They are very accurate and easy to be installed. Although there are more than two types of meters for gas and other fluids, the last one we will mention is the rotary meter. Rotary meters rely on two rotors that mesh together seamlessly so that no gas can slip by without rotating the meter (Poch, 2015). The amount of times the rotors make a full rotation is directly proportional to the amount of gas that has flowed through the meter. Utility companies use meters to see how much electricity or gas is used by their consumers (U.S. Department of Energy, 2016). Meters allow the utility companies to bill their customers in accordance to the amount of gas or electricity they use. But meters are useful for consumers as well. According a study in Northern Ireland, residential consumers reduced energy usage and bills when given feedback about how much they used through a metering device (Gans, Alberini, and Longo, 2013). This happens because the meters are able to highlight when and where the most resources are expended, providing the consumers with information about where to focus their efforts in conserving electricity or gas, thus reducing their consumption more effectively.

2.4 Other Leaders in Sustainability

Reducing electricity consumption is a powerful tool in lowering an institution's carbon footprint and the IAIA has plenty of places to look for examples on how to do just that. Currently, the largest sources of energy for universities comes from fossil fuels, and therefore energy conservation is one of the biggest ways that colleges and universities can change their climate impact (Uhl & Anderson, 2001). At colleges like the State University of New York at Buffalo, their efforts on conservation has cut energy usage and costs even as the campus has expanded—adding 8 new buildings between 1982 and 1999 while cutting more than 20 million kilowatt-hours of electricity consumption each year. Most of their changes came from updating lighting, adding more and better insulation, and using more energy efficient equipment.

Another major way that colleges have been working on sustainability is through power generation. New buildings at both Oberlin College and Northland College utilize solar photovoltaic arrays and wind turbines in order to supply some or all of the buildings' electricity needs (Uhl & Anderson, 2001). Solar energy production is one of the more popular ways of implementing sustainability improvements. Harvard University is one school that has invested heavily in solar energy and has installed solar panels that generate more than 1,500 kW when running at peak efficiency (Harvard University, 2013). Butte College in California has even developed a solar installation that generates more energy than the school uses, sending their excess energy into the power grid (DPR Construction, 2016). So far these are examples of colleges and universities that have taken steps towards carbon neutrality and energy sustainability, but there are schools out there that have already achieved the goal that the IAIA has committed itself to.

The College of the Atlantic in Bar Harbor, Maine was named *Popular Mechanics* number one among the ten greenest colleges in the United States (Howard, 2008). Although the college is home to only a few hundred students, it managed to be the first U.S. College to be 100% carbon neutral in 2007. The College of the Atlantic (COA) does still produce carbon dioxide emissions, as they are not totally fossil fuel free; however, they take steps to offset what little emissions they do produce. They have invested $25,000 towards a project in Portland, Oregon, to streamline traffic flow, therefore reducing automobile emissions in that city. The parent organization of the project is The Climate Trust, and the project is expected to reduce automobile emissions by 189,000 tons over five years. COA measured everything they do on campus, from the carbon emitted by people traveling to the campus to daily energy use and how that energy is produced. COA used an emissions calculator provided by Clean Air Cool Planet of Portsmouth, NH. Using this calculator, they determined that since October 2006, the college has produced 2,500 tons of carbon dioxide. The school eventually plans to reduce its output to 1,800 tons, while still offsetting this with other green measures. To keep its carbon emissions so low, COA used electricity sourced from hydroelectric generators. It also employed lighting with low energy draw and has encouraged carpooling and biking in and around campus. COA also built a new residential building with wood pellet boilers and composting toilets (Trotter, 2007). It is important to understand that carbon neutral still means the school produces carbon emissions, but it offsets the emissions elsewhere, either on or off campus.

Through energy conservation techniques, carbon offsetting and on-campus power generation, many colleges across the country are working towards sustainability and carbon neutrality. Their methods, technologies, equipment, and experiences can provide a model for the IAIA to move towards carbon neutrality.

2.5 IAIA Carbon Footprint Baseline

The ACUPCC is an organization of colleges and universities that have pledged to make their institutions a carbon emission free environment to combat climate change (Thomashow, 2014, p.177). The Institute of American Indian Arts is one such signatory that has made the commitment to eliminate net carbon emissions. In 2010, the IAIA president, Dr. Robert Martin, signed the ACUPCC. According to the commitment, the IAIA needs to complete carbon neutralization by 2050. In 2013, the Institute of American Indian Arts (2013) reported their baseline energy use, in kilo-watthours, by sources, as shown in Figure 2-2. The IAIA's electricity comes from PNM, the Public Service Company of New Mexico, which provides electricity to most of New Mexico. A significant portion of the IAIA's carbon emissions also comes from burning natural gas, which is provided by the New Mexico Gas Company. The main concern of the IAIA is the dependency of the PNM on carbon based energy sources. One of the Institute's long-term goals is finding a way to be less dependent on the energy provided by the PNM so that they can move towards being a carbon neutral campus.

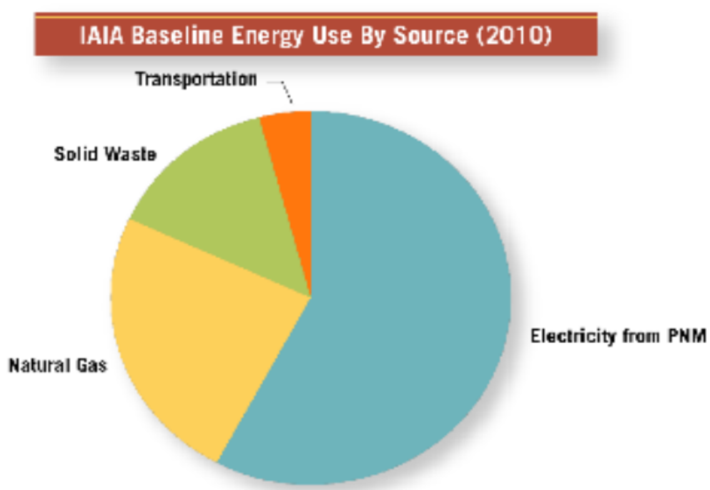


Figure 2-2: IAIA Baseline Energy Sources (Institute of American Arts, 2013)

Since 2013, there has not been much progress made by the Institute of American Indian Arts (2013) to achieve their 2025 midterm goal, which would involve the IAIA switching a large part of their energy demand to renewable energy sources. In their 2013 Climate Action Plan, the IAIA reported an emission quantity of 2,340 metric tons per year of carbon dioxide. In 2014, a WPI research team was tasked with providing an update to the IAIA's carbon emissions and found that the school emitted 2,946 metric tons of carbon dioxide in 2013 (Cornachini, McMullen, Milholland, & Nutting, 2014). This represented a 25.9% increase over the IAIA's emissions in 2010. In 2013, the IAIA had a goal to reduce their carbon emissions by 50% by 2025, and with less than 10 years until this deadline, the IAIA needed to find more efficient solutions to reducing their energy consumption and carbon emissions.

As shown in Figure 2-3, in order to reverse this trend of increasing carbon emissions, the IAIA needed to start reducing their carbon emissions soon, or their goal might be unattainable. In order to reach the goal of zero net emissions by 2050, the IAIA needs to reduce their carbon footprint by an average of nine percent, or 104 tons, a year.

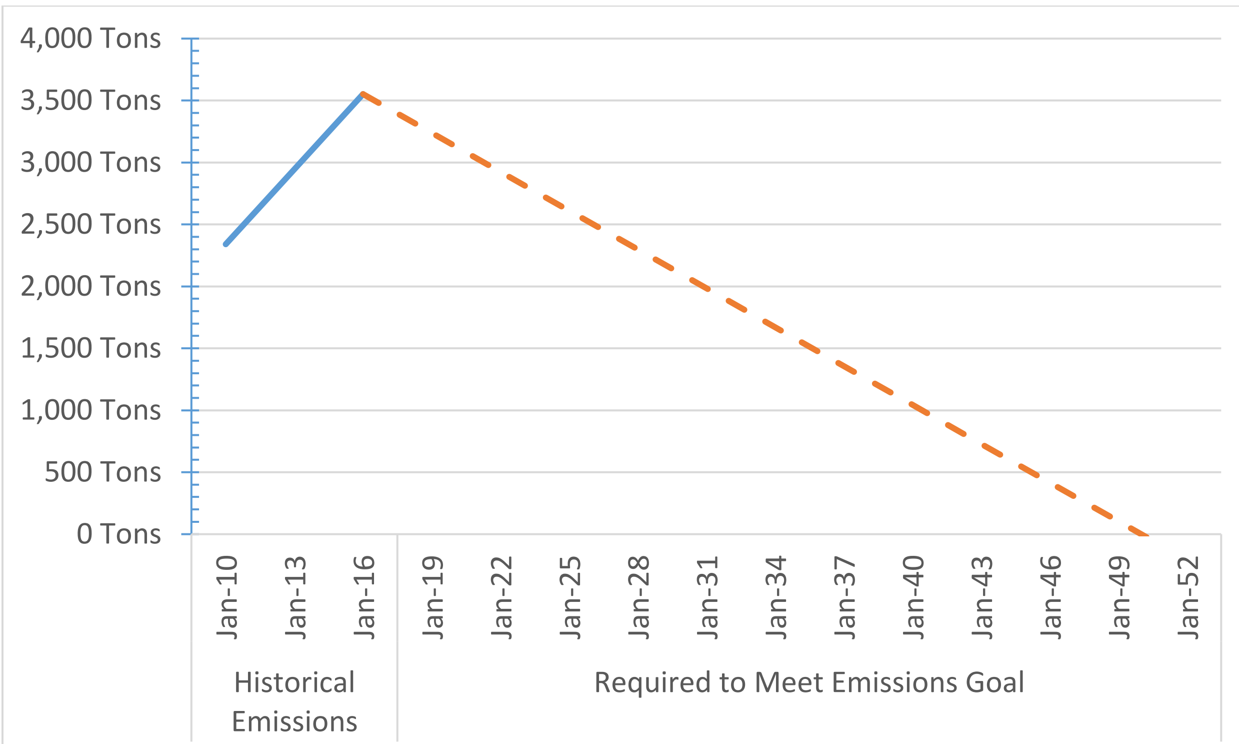


Figure 2-3: Annual Carbon Emissions by the IAIA (2013; Cornachini, McMullen, Milholland, & Nutting, 2014)

Another WPI IQP team undertook the task of starting the IAIA on the right path towards carbon neutrality (Dibiasio, Pilaar and Rosa, 2016). In the spring of 2016, this team recommended and installed electrical meters on the main circuit panels of three buildings on campus, the Main Academic Building, the Center for Lifelong Education and the Foundry. These meters measure the peak power demand of the entire buildings and while this is useful for facilities, it does nothing to show students just how much power the buildings at the IAIA actually use. In addition to the electrical meters, the team also looked into LED lighting for the campus, based on data they gathered from one room that already had LEDs. They took some illuminance measurements, but eventually decided to hold off on recommending that the IAIA purchase LED lights for the entire campus based on the available technologies. The spring 2016 team also came up with a list of recommendation for the IAIA to reduce their carbon output and save on utility bills. One such recommendation was for the IAIA to have an energy audit done of the entire campus, to highlight areas of inefficiency. Another recommendation they made was for the IAIA to come up with a systematic approach for completing future retrofits that align with the IAIA's goal of carbon neutrality. They also recommend that the IAIA look into devices that reduce gas and water usage, but they do not mention the lack of fully functioning natural gas meters for all the campus buildings. It would be difficult for the IAIA to start reducing gas usage if at first they do not know how much each building is using. Overall, it seems that the previous IQP team has made solid recommendations for the IAIA, but there is still work to be done to get them on the path towards carbon neutrality.

2.6 The RE-volv Solar Lease

RE-volv, a solar energy financing company, reached out to the IAIA in the summer of 2016 with a proposal to lease a twenty-five kilowatt solar installation that Sacred Power would install on the roof of the Center for Lifelong Education (CLE) Residence Center (RE-volv & Sacred Power, 2016). RE-volv would own the panels and pay to install and maintain the solar array, while the IAIA would pay RE-volv for the rights to the power generated by the panels. After 20 years of lease payments, the ownership of the system would transfer to the IAIA—at which point the IAIA would assume responsibility for any maintenance of the panels. The array would be composed of a total of 91 CS6k-280M solar panels manufactured by Canadian Solar Inc., and seven Sunny Boy power inverters manufactured by SMA Solar Technology AG. The IAIA was uncertain about whether or not to accept this proposal, but it is the first concrete proposal that the IAIA has considered to install solar power on campus, and it was the first step towards greener sources of energy.

2.7 Summary

In this chapter we reviewed a number of factors that drive many institutions, including the IAIA, to increase their energy efficiency, self-sufficiency and renewable energy sources, especially through using solar energy. We explained how human activities have damaged the environment by producing more CO_2, and what needs to be done to solve these problems. We also reviewed what others have done to achieve the same goal that IAIA has of reaching carbon neutrality. In the next chapter we explain what research methods we used to determine how to help IAIA move to a more carbon neutral future.

3 Methodology

The goal of this project was to identify ways to help the IAIA advance their goal of carbon neutrality on campus. To achieve this goal, we had two main objectives, increasing conservation methods on campus and finding energy generation methods to bring to the IAIA. Under the topic of conservation, we focused on three areas, awareness and community involvement, electrical sustainability, and gas sustainability. For generation, we focused on carbon free power generation systems, starting with a proposed solar system by RE-volv. In this chapter, we discuss the methods we used to achieve our research goals and objectives.

3.1 Conservation

To help the IAIA progress towards their goal of carbon neutrality, the first priority was to determine the attitudes and knowledge about energy and carbon conservation at the IAIA. We first wanted to investigate what the students and staff already knew about energy conservation and carbon neutrality. We then researched various methods that the IAIA could use to provide energy conservation examples such as using meters for comparing LED and fluorescent lighting. In addition, we researched various gas metering systems to help the IAIA determine how to conserve their natural gas usage, thus limiting their carbon emissions from burning natural gas.

3.1.1 Gauging Interest and Knowledge in Carbon Neutrality and Energy Conservation

As community awareness and involvement in sustainability efforts is an important factor in the success of initiatives to conserve energy, we decided to conduct a survey of the IAIA community in order to gauge the level of interest and knowledge in the IAIA's efforts to become carbon neutral. The survey was formatted as a short, informal discussion with several students and faculty where the surveyor discussed the IAIA's current initiatives with the subject, guided by a set of eleven questions, available in Appendix N. We formatted the survey to be more open-ended in order to get a more thorough understanding of students' and faculty members' attitudes towards the IAIA's efforts to combat climate change. A simple online survey would not necessarily get a large number of responses, and the only reliable way to get good information from an online survey is through multiple choice or quantitative questions that don't involve critical thinking. Because we were more interested in opinions and mindsets than quantitative metrics, we believed that we would get a better idea of the mindset and knowledge of the students through a dynamic conversation than through a regimented survey or interview. The survey's questions are arranged by specificity, from more general inquiries about the subjects' awareness of carbon neutrality and the IAIA's Climate Action Plan to more specific questions about their experience with the rooms affected by the switch to LED lights as shown in Appendix N. We also discussed how to make these changes relate to something meaningful enough to them to help provoke interest in the school's efforts towards carbon neutrality.

During each interview, we wrote our notes from the discussion on the Google Form containing the eleven questions we used to guide the survey. Once we had surveyed a total of 15 students and faculty, we collated the responses, available in Appendix N, and analyzed them to gauge the community's interest in sustainability efforts around campus, the student body's willingness to get involved in those efforts, and the sacrifices they are willing to make in order to conserve energy.

3.1.2 Electricity Conservation

The IAIA has been investing in energy conservation methods around their campus, most recently beginning a switchover to LED lighting. In their main academic building, one classroom has received LED lighting fixtures, while the classroom next door still had its original fluorescents. LED's have proven significantly more efficient than fluorescent lights, but the IAIA did not have a system in place to highlight that difference. These two rooms provided an opportunity to demonstrate to everyone on campus the advantages that LED lighting has, in a manner that students, staff, and guests could easily see. The power saved with the LEDs can also provide a model for how the IAIA could save even more energy and reduce carbon emission by expanding LEDs to the entire campus. Our objective was to find an electric metering system that would easily display the effect of LED improvements on energy consumption and carbon emissions, and to use this data to determine the benefit of LED lights for the entire campus.

3.1.2.1 Metering Options

Simply knowing that the LED lit classroom is more efficient did not create the impact desired by the IAIA facilities staff. They required a visual representation that shows anybody walking by that one room uses noticeably less power than its neighbor. Our sponsor at the IAIA suggested that an electrical meter, wired into the lighting circuits of each room, would display the instantaneous power usage in each room

Through discussion with our sponsor, we determined that the meters needed to have readable displays, and the ability to be wired into the hallway outside of the rooms. From there anyone walking by these two rooms could then compare the numeric values shown on the meters to posters that explained what the raw numbers meant. This could highlight exactly how different the two power usages were. In order to recommend a specific meter for this purpose, we needed to ensure the meter could be easily wired into the existing circuitry, have little to no maintenance, be able to output the necessary data in a readable format, and be reasonably priced.

We began by identifying the ranges of power draw that the meters would need to measure. We found the power consumption specifications for the lights in each room by examining each light to find its model number and by looking at the datasheets for each light model. We then developed a spreadsheet, as seen in Appendix D, to enter in the specifications for the meters that we found. This spreadsheet had sections that listed the model of the meter, a link to the product page, the cost, the type of display, the size, the voltage and amperage capacities, the readings it could output, the number of circuits it could monitor, information about the ease of use/maintenance, the manufacturer, and the distributor. Using the features that we had identified as things we should compare, we looked on the websites of well-known suppliers like Grainger, Blackhawk, and Block Lighting, and reputable brands like Leviton, Siemens, and EKM to find the meter that met all of the IAIA’s needs. We entered data on every meter we identified as a possibility on the spreadsheet and compared them based on the criteria we had established in order to find the ones that best fit the IAIA’s needs.

3.1.2.2 LED Benefits

The IAIA uses over 2 million kilowatt-hours of energy a year, which is responsible for the emission of more than 2,000 tons of CO_2, based on the Energy Information Administration’s (2016a) most current estimate of 2 pounds of CO_2 per kWh produced with fossil fuels. Therefore, for the school to get on track with reducing its carbon footprint, they need to make significant changes to their campus with the goal of decreasing their usage of carbon-reliant electricity. As lighting is one of the single largest users of electricity on many institutional campuses (E Source Companies LLC, 2013) we focused a portion of our research on determining if the effect that changing over all existing lighting to LEDs from the current fluorescents would be worth the expense.

The first step was to develop an estimate for the number of lights that were in use around campus and how much electricity they consumed. We measured the lighting density—how many lightbulbs were in use per square foot of campus by counting the bulbs in several different locations where we could accurately measure the rooms' areas. The Southwest classroom was our main baseline. Using the total area of campus buildings provided by the facilities department at the IAIA, we extrapolated the lighting density to make an estimate of the total number of bulbs on campus. With that number in hand, we examined the lights themselves to determine the exact consumption of each lightbulb when it was on. Then we estimated the balance of lights between two categories, regular and irregular traffic.

In the spring of 2014, a WPI IQP team did a lighting survey in the Center for Lifelong Education. They divided all of the lights' locations into two categories, regular and irregular traffic (Cornachini, Mathews, McMullen, Milholland, & Nutting, 2014). They described irregular traffic as offices, classrooms and bathrooms and regular traffic as hallways, meeting areas and all other spaces in the building. Using the schedules posted outside classrooms and with input from Mr. Mason, we were able to estimate the weekly runtime for each category of location

By searching retailers like Amazon and the Home Depot, we found drop-in replacement LED bulbs for the fluorescent lightbulbs already installed. Using the specifications available for the consumption of the new LED bulbs, we estimated the total weekly consumption of the lights on campus if they all were switched to these LEDs. With the two consumption numbers (with and without LEDs), we then calculated the approximate savings that would show up on the school's electricity bill and the approximate amount that IAIA's carbon footprint would be reduced by.

3.1.3 Gas Conservation

The IAIA also lacks a system that measures how much natural gas each individual building on campus uses, the gas being mainly used for heating and hot water. Similar to the electrical meters identified by the previous WPI team, we identified metering systems that the IAIA could install on each building's gas inlet so they could measure gas usage across campus with more granularity than was available from the utility company. For these gas meters, our objective was to find a system or family of meters that could be fitted to each building, and that would provide simple and understandable measurements to help the IAIA better understand their gas usage and develop gas saving strategies, all in the hopes of reducing their carbon emissions.

3.1.3.1 Metering Options

There are ten main buildings on the IAIA campus, each consuming gas to provide hot water and central heating. For the most part, the IAIA only knows how much natural gas the entire campus uses, not how much each individual building uses. While seven of the buildings do have individual gas meters installed on their gas lines, those meters are bulky and difficult to read and in some cases, bypassed. The ability to monitor each individual building's gas usage could help the IAIA identify usage patterns and inefficiencies, which will eventually help them reduce their natural gas usage and become more energy efficient.

We began our research on what new meters to install by identifying the current meters already installed on campus and examining the gas inlets for each building. We communicated with the IAIA's natural gas provider to discuss if the conclusions we made from our observations were valid and could be used to choose compatible metering options. We had an informal phone interview with an HVAC contractor for Arden Engineering, who had some experience installing gas meters, in order to identify the criteria that would help us choose an appropriate gas meter; our interview protocol for this conversation is available in Appendix M. We estimated the amount of gas each building would consume by recording what equipment was in each building that could burn natural gas. We went to each building's mechanical rooms and recorded the technical specifications of all of the equipment attached to the main gas line, such as furnaces, water heaters, HVAC units, ovens, ranges, and other kitchen equipment. At a maximum, a building could use the sum of each piece of equipment's maximum consumption of natural gas, so we used those numbers to determine which meters would be compatible based on the natural gas demands of each building.

We also observed the existing meters and gas lines leading into buildings at the IAIA in order to better understand how much space was available on the gas main for a metering system and what the shortcomings of the existing meters were. Using that information, we searched manufacturer and supplier websites for meters that provided a simple and clear display, were capable of measuring the amount of gas flowing to each of the buildings, and were reliable and credible metering systems, trusted by consumers and reviewing agencies. From there, we called suppliers and manufacturers for quotes and further information about the preferred models in order to see if there was anything we had overlooked. We narrowed our recommendations by determining what an acceptable price range was to the IAIA and ranked the meters based on their prices and the features that each meter provided. We provided our final list of recommendations to our sponsor, so that the IAIA could choose one to install.

3.1.3.2 Data Collection

Installing gas meters at the IAIA will only provide them with a means to visualize their gas usage, it will be equally important for the IAIA to collect and monitor their gas usage. This data could highlight the times or areas were gas efficiency could be improved. We investigated the important times of day for data to be collected, and the necessary information that could benefit the IAIA. An important factor in our investigation into a data collection methods was the effort required for data collection. If a data collection method is simple enough and records the necessary data, the IAIA will have another tool to use to decide how to reduce their carbon emissions by conserving their natural gas usage.

3.2 Generation

Upon arriving at the IAIA, we were immediately presented with RE-volv's proposal for a rooftop solar array and asked to evaluate it. We first looked at the history and effectiveness of both of the companies involved in the proposal and the equipment that they wished to use. We considered whether the system would produce long term savings by generating enough energy to offset the costs. After researching the option presented to the IAIA, we investigated the options available to the IAIA in the Santa Fe area. Our objective was to provide the IAIA with the best solar implementation plan in order to start the IAIA down the path to carbon neutrality.

3.2.1 Analyzing RE-volv's Proposal

We began investigating RE-volv's proposal by examining the companies that would be completing the project and the equipment they planned to install. When researching RE-volv, we identified past projects from the company's website and considered the sizes of those projects, their outcomes, and the costs of the projects in comparison to what the site owners had to pay RE-volv. For Sacred Power, we identified the company's certifications as listed on the company website and looked for their experience as far as installing solar arrays of similar size. We also looked for what kind of history they had with solar installations and their maintenance by looking at reviews and comments by organizations that have partnered with RE-volv and Sacred Power in the past. We found a list of previous projects on the Sacred Power website and, by searching the local newspaper archives for the locations of those projects, determined how successful or not Sacred Power has been with their past projects.

Besides evaluating the capability of the two companies, we also determined the quality, durability and reliability of the equipment they would install on the CLE Residence Center roof. RE-volv proposed putting up Canadian Solar CS6K panels with SMA Sunny Boy string inverters. We used manufacturer datasheets on the hardware, experts' reviews from equipment review blogs and review aggregation websites, and data on similar configurations quoted by other solar energy companies. We could only recommend RE-volv's proposed system if all the hardware were trusted and tested models or technologies that came highly recommended from other consumers, and if the systems came with good warranty packages. If the IAIA was going to invest in this project, we needed to be certain that the equipment would be effective and reliable, and that the manufacturers guaranteed them against suboptimal performance. If this were not the case, then the system would be a waste of time, effort and money for the IAIA.

For the solar panels, we determined which photovoltaic technology was used in the CS6K panels from the manufacturer's datasheets. We then compared the efficiency numbers on the datasheet to those on datasheets for recent panels produced by other manufacturers such as Sunpower, First Solar, and Trina Solar to see if the panels were up to industry standards. We also confirmed that the manufacturers' warranties on the system were sufficient for the IAIA and that, if the hardware were to fail, the manufacturer would replace the system at no extra cost in most cases. Finally, we compared different types of solar panels and inverters from different manufacturers, in a similar price range, to see if they produced a comparable amount of energy by researching solar panel aggregation sites and comparing technical datasheets for the different technologies. We also compared the different warrantee packages as described by the marketing material provided by other manufacturers, and made note of any hardware that significantly outperformed the specific panels proposed by RE-volv.

Similarly, with the Sunny Boy string inverters, we checked the datasheets provided on the SMA company website and reviews for basic information about the system, to see if they came up as highly recommended and would perform as expected for the life of the system. We also compared them with other systems, such as those manufactured by Enphase, General Electric, SolarEdge, and LG, to see if there were better choices from other companies or by using other models. Our comparisons, similar to those with the panels themselves, relied on comparing the datasheets and reviews of the SMA inverters to those produced by their competitors, as mentioned above. Additionally, we compared the costs and benefits of switching from string inverters to micro-inverters, such as the ones produced by Enphase and Sunpower. We looked at the comparative costs and benefits of each to determine the scenarios where switching technologies could benefit the IAIA.

Once we had determined the quality of the equipment mentioned in the proposal, and once we had determined whether the IAIA could trust RE-volv and Sacred Power to install and maintain the equipment properly, we turned to a financial analysis of the proposal. One of the biggest factors in our analysis of RE-volv's proposal for this rooftop solar array was the projected costs and savings that the system would provide. While RE-volv provided their own statistics and tables with information on how much they believed the IAIA could save by implementing their proposal, it was important that we perform our own financial analysis to determine the accuracy of RE-volv's calculations and assumptions.

To begin our financial review, we extrapolated the future increases in grid energy costs based on historical data drawn from PNM's records. Using that information, we developed a model, available in Appendix F, which would show how much money the IAIA would spend on electricity throughout the life of the solar array.

We also modelled how much power the solar array could generate, using historical data for solar irradiance in the Santa Fe area provided by the National Renewable Energy Laboratory (2010), and formulas compiled by John Duffie and William Beckman (1980), to confirm that the system would generate the amount of electricity claimed by RE-volv. These calculations also relied on the efficiency specifications of the Canadian Solar panels so that we could properly determine the amount of energy that would be converted from the available radiation. We used these calculations to determine whether the prediction provided in RE-volv's proposal was reasonable and accurate.

Once we knew how the panels would perform and had our own financial predictions for how much the IAIA could expect to spend or save over the twenty-year lease period, we formulated our final recommendation on whether or not this project would provide a financial benefit to the IAIA. No matter what our recommendation on the RE-volv proposal ended up being, the IAIA would also need to know what the possible alternatives were if the IAIA was to look into other companies for their first move into solar generation.

3.2.2 Other Solar Options

In addition to determining the efficiency of RE-volv's proposed system, we also began to look at local solar providers. We looked to see if the IAIA could get a better deal by working with other companies to install a rooftop system on the CLE Residence Center, instead of RE-volv. We contacted GoSolar, Sunpower, and Amenergy, three solar companies that serve the Santa Fe area, and inquired about their costs for a similar 25 kW system and ways to save money over the long term by changing certain parameters. We also discussed the option of having solar carports as a part of the overall system. We then set up meetings with sales representatives in order to determine whether changing the size of the system could be better for the IAIA, or if switching types of panels, inverter technology, or mounting technology would be cheaper or more efficient with a focus on increasing overall savings for the IAIA.

Our sponsor highlighted the flexibilities in the IAIA's budget, and the fact that their budget sometimes allows for the spending of a large sum of money at the end of the fiscal year. This led us to research smaller systems that the IAIA could potentially fund within their own yearly budget. Since the IAIA does not have room in their yearly budget for a large solar installation, we researched local grants and funding options other solar providers recommend. After learning about popular methods to fund solar projects, we researched local laws and implementation methods for forming an LLC at the IAIA.

This information gave us a better perspective on the RE-volv proposal and allowed us to determine if an alternative supplier would provide a better option. We have included information from these companies or systems that could provide a better return-on-investment, as calculated using the same methods we used for the RE-volv proposal.

3.3 Summary

In this chapter we explained how we went about our research in order to determine the advisability of accepting the solar proposal given to the IAIA by RE-volv, to identify alternative solar options and to determine the best metering solutions for both gas and electricity. We present the results and findings of our research in the next chapter.

4 Results & Analysis

This chapter presents the results of our research into helping the IAIA achieve their goal of carbon neutrality. To improve the IAIA's conservation, we discuss the results of our student survey, ways to improve electricity conservation on campus, and a metering and data collection method to help improve the IAIA's gas usage. We then discuss our results on ways to bring solar energy generation to the IAIA, based on our review of the RE-volv solar proposal and the other options we located in the Santa Fe area.

4.1 Improving Conservation

On the road to carbon neutrality, one step is to reduce energy usage through conservation. We conducted a survey to gauge the campus' opinion on sustainability, carbon neutrality and willingness to help the IAIA towards their goal. We also researched metering systems for both natural gas and electricity. To begin the process of conservation, the IAIA must first know the amount of resources they are using.

4.1.1 Gauging Interest and Knowledge in Carbon Neutrality and Energy Conservation

The survey we conducted of students and faculty at the IAIA uncovered many interesting and useful information regarding current knowledge about carbon neutrality, sustainability, LED lighting, and attitudes towards carbon saving and sustainability. From our data, recorded in Appendix M, only 42% of students interviewed knew what carbon neutrality meant, and only 33% of the students knew that the IAIA had signed a carbon neutrality commitment. However, on a very positive note, 93% of students are interested in sustainability efforts at the IAIA as shown in Figure 4-1. There is a lot of room for improving the awareness on the campus about the IAIA's efforts to achieve carbon neutrality.

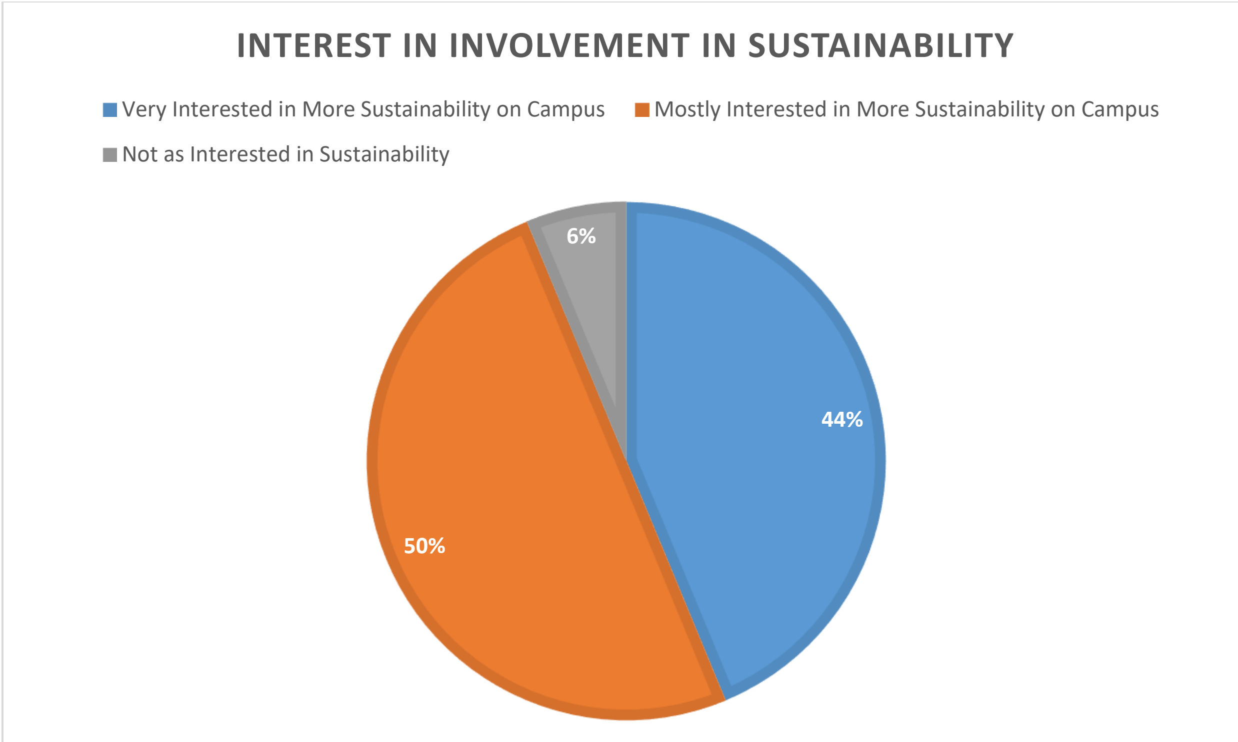


Figure 4-1: Interest in Sustainability Efforts on Campus

The lighting of the Northwest and Southwest classrooms in the main academic building was also an important topic of interest. Of eight students who said they currently had classes in either or both rooms, only 3 students actually noticed a difference in the light quality. But, of all the students surveyed, 15 of the 16 students said they would be interested in seeing real-time data about how much energy is saved with the LED lighting, as shown in Figure 4-2. Some interviewees stated that the fluorescent room light was “too harsh” and the LED lights were “nice and calming.” The students and faculty who use the rooms on a regular basis have a preference for the LED lights, and have no issues with the level of brightness in the rooms.

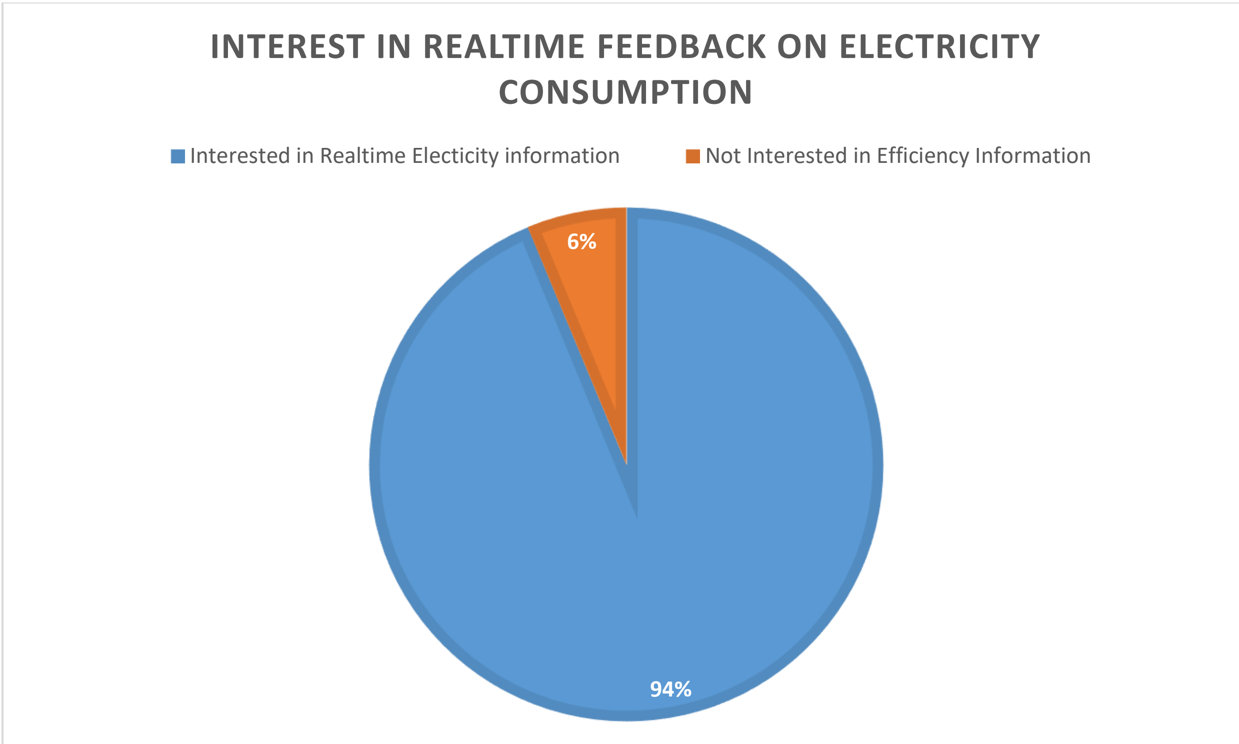


Figure 4-2: Interest in Seeing Electrical Consumption Data

The ability to see more sustainability and carbon neutrality projects was also an interest of students and faculty. All but one interviewee supported seeing more projects or more project advertising to show how the IAIA is trying to limit carbon emissions and be more sustainable. One person specifically stated that they wanted the IAIA to "make the projects more visible to the whole campus." All but two interviewees stated that seeing more changes would lead them to make more sustainable and carbon emission reducing changes, especially if the IAIA could "better educate members on how they can affect real change." Students and faculty had lots of suggestions for the IAIA to support sustainability. Students wanted to see changes like: bottle filling stations on water fountains to reduce plastic bottle waste, more recycling instructions, better heating and AC monitoring in buildings, and bringing solar technology, as well as other renewable energy to campus.

The students at the IAIA are not as informed as they would like to be, and there is a great interest among both students and faculty to learn about carbon neutrality, sustainability, and how the IAIA is progressing towards these goals.

4.1.2 Electricity Conservation

Electrical sustainability is an important factor to the IAIA's goal of becoming carbon neutral. Our research into options for electrical sustainability found two metering devices that could be used to educate the students and staff at the school about the benefits that LED lights can bring to their campus. We also explain our calculations for determining the power saved by switching to LED's, and how this information was conveyed to increase interest in sustainability and carbon neutrality.

4.1.2.1 Metering Options

After studying the fixtures and lighting circuits for each room, we calculated the max amperage that both the LED and fluorescent systems drew, in order to size possible meters. These limiting points allowed us to select meters that would be able to read the minimum and maximum draws between the rooms.

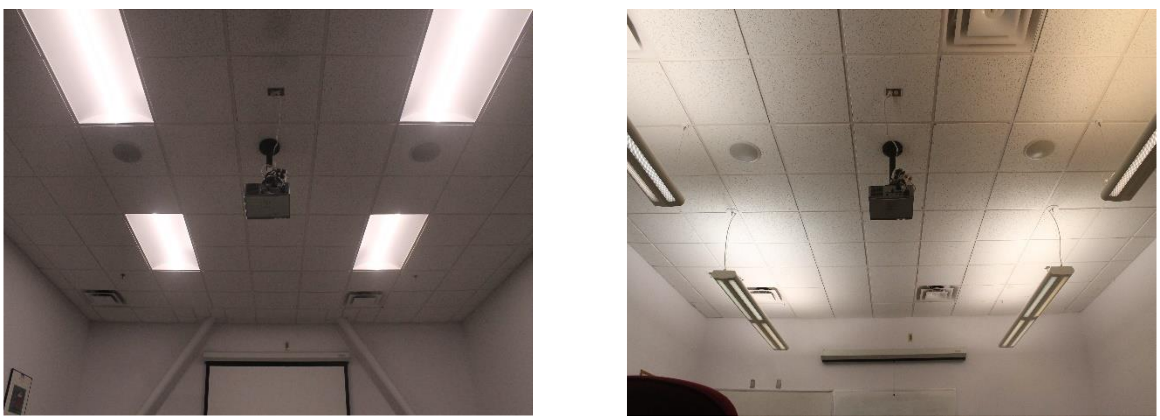


Figure 4-3: Comparison of lighting between two classrooms. LED classroom on left. (Camera Settings: Shutter: 1/320; ISO 1600; f-stop: 5.6, 18mm, WB: 4000k)

For the LED-lit room, there are four individual LED lights, one LED strip per fixture, shown on the left in Figure 4-3. These LEDs use 43 Watts of power, according to their datasheet, and are all connected in parallel (Eaton Corporation, PLC, 2016). This means that each light uses the same voltage. If one light uses 43 Watts, with a 277 Volt system, the light draws 0.16 Amperes. Since they are connected in parallel, the total Amperage of the circuit is the amperage of each light added together. Four LED strips, at 0.16 Amperes each, draw a total of 0.64 Amperes.

There are four fixtures of fluorescents, with six bulbs per fixture. As with the LEDs, each fluorescent fixture is connected in parallel, and the bulbs are also connected parallel with each other. These 48-inch fluorescents use 32 Watts each, and since the entire system is in parallel, each uses 277 Volts (General Electric, 2013). This means that each bulb draws around 0.16 Amperes. At this amperage, each of the four fixtures draws 0.96 Amperes for all six bulbs. This means that all four fixtures draw a total of 3.84 Amperes.

With the “max draw” value found for each room, we knew that any meter must be able to detect a draw as little as 0.64 Amperes, and detect a max draw of 3.84 Amperes. With these limits we came up with a list of possible metering solutions, which can be seen in Appendix D. We then narrowed our choices down to two main options. The first solution was a non-invasive, wireless display that required no changes to the room’s wiring or exterior walls. The second choice was a less expensive multi-meter that would be housed inside the wall, and would require the electrical wiring to be rerouted. The two meter choices were the Efergy® Elite Classic Wireless Electricity Monitor and the DROK 20A AC Digital Monitor respectively. We compared the features and specifications of the two meters in Table 4-1, below. This comparison highlights the significant price difference between the two models, with the DROK meter being 86% less expensive. Its trade-offs for the low price are a smaller screen and information range (though it can handle power draws far beyond our needs), and that it needs to be installed directly in the wiring, as opposed to the Efergy meter, where the measurement device can just be secured on the positive (hot) wire without a lot of labor.

Table 4-1: Comparison of Electrical Metering Systems (DROK, 2016; Efergy, 2016)

	Efergy® Elite Classic Wireless Electricity Monitor	**DROK 20A AC Digital Multimeter**
Price	$119.95	$15
Installation Method	Put sensors on wires in ceiling, place wireless monitor in convenient location.	Installed in wall, with circuit wired through meter
Display Type	Segmented LCD display: 4-inches.	Segmented LCD-display, backlit, 2-inches.
Output	Power, Total Consumption, Energy Costs, Carbon Emissions, Tariffs.	Voltage, Current, Power, Total Consumption (All simultaneous)
Capacity/Display Range	0-200A; 0W-24kW; 0Wh-9999kWh	0W-4.5kW; 0Wh-9999kWh; 0-20A; 80-260 VAC

After compiling the technical information for each of the systems, we presented these two options to our sponsor. While the DROK meter was the initial preference due to its lower price, it had to be eliminated as an option for these two rooms. While the meter would work for most rooms on campus, the Northwest and Southwest classrooms both run on 277 Volts, which is outside of the 260 Volt limit for the DROK. This left the more expensive Efergy meter as the top choice. We think the higher price of the Efergy meter could be worth the extra display information that can provide a real-time comparison for how much the energy for each room costs, and how much carbon is emitted by the power used.

While the meters were purchased we developed calculations, phrasing and graphics to highlight information about the power difference in the rooms, presented in Appendix O. This information would be displayed on a poster, presenting qualitative information describing the power usage in non-technical terminology.

Our poster described electrical terms and calculations in a simple manor, and related the theoretical power difference between the rooms in terms that are applicable to common devices. These examples will need to be refined once the meters are installed and the true difference can be determined. If the LED room draws 0.64 Amps at 277 Volts, it uses approximately 172 Watts, while the fluorescent room, at 3.84 Amps and 277 Volts, uses approximately 768 Watts. We then explained the 596 Watt difference in common terms for presentation. We began by explaining what a Watt means, and how energy in kilowatt-hours (kWh) is calculated from Watts (W). We based all of our calculations on the lights running 66 hours a week, this assumption is explained in further detail in the next section. After finding the difference in kilowatt-hour usage per year which is 2,045, we listed examples of how many kilowatt-hours common appliances use. For example, an iPhone battery holds a charge of 5.45 Watt-hours (Helman, 2013). This means a student could charge their iPhone 375,316 times with the energy saved by the LEDs. Some other examples included: the number of years a LCD television could be left running, how many years a computer could be left on, how much capital the school saves a year, and what people can save in their own homes with this energy difference. Using the base figure where approximately two pounds of CO_2 are emitted per kWh that is produced by burning fossil fuels (U.S. Energy Information Administration, 2016a), the IAIA saves 4,090 pounds of CO_2 from being emitted into the atmosphere a year. This is almost 4,100 pounds of CO_2 that the IAIA has eliminated from their carbon footprint by just changing one room to LED lights.

A limitation for our electrical meter recommendations is the size of systems that the electrical meters are meant to read. These meters were intended for an entire household electrical system, but we recommended using them for individual circuits. While this will not cause any problems, the meters will only be functional for comparison if both of the rooms have the lights on at the same time. Along with this, any totaling features that measure the cumulative energy usage, in kWh, of each classroom will provide an inaccurate comparison. If one room is used more than the other, it will have a higher kWh reading as it has been used more than the other circuit. Therefore, the IAIA will need to make sure the meters are set to the instantaneous power reading in kW.

4.1.2.2 LED Benefits

LED light, compared to fluorescent light, would undoubtedly save a lot of energy. We did some calculations to confirm the benefits of replacing fluorescent lighting with LED lighting. We did not look with detail into specific models of lights; this is only a general calculation. Hopefully this section can provide constructive advice for future work at the IAIA.

LED lights have a lot of advantages compared to normal fluorescent light. LEDs typically produce the same number of lumens, using half of the power of fluorescent lights (Eco Revolution, 2016). Although LED lightbulbs are usually 2-4 times more expensive than fluorescent lightbulbs, the long lifetime of LEDs can counteract this difference over time.

We began our projection by estimating the number of fluorescents lights per square foot for the entire campus. Using the 24 lights in the 400 square foot Southwest classroom, there is approximately 0.06 lights per square foot. With a campus of 208,885 square feet, there are approximately 12,500 fluorescents on campus. Assuming all the lights are 32 Watt (W) bulbs, 400,000 Watts, or 400 kilowatts of power is used to light the campus. In the CLE there are 700 fluorescent bulbs, 420 bulbs are categorized as being in an area of irregular traffic and the other 280 bulbs are in areas described as regular traffic (Cornachini, Mathews, McMullen, Milholland, & Nutting, 2014). This means that 60% of the bulbs are in offices, classrooms and bathrooms, which are in the category of irregular traffic, and the other 40% are in hallways and other areas. We extrapolated these percentages to the entire campus, then we assumed 60% of the lights would be on for 66 hours per week, and the other 40% of lights would be on for 20 hours per week. We assumed the lights in hallways and other areas were only on for 20 hours per week due to the large amounts of skylights built into the buildings on campus. With 52 weeks in a year, this means each light is on for an average of 2475 hours each year. This means that the IAIA uses approximately 990,000 kWh per year.

If each fluorescent bulb was switched to a 17-18 W LED replacement bulb, the IAIA would draw approximately 225,000 W, or 225 kW. Using the same estimates for how many hours each light would be on, with LEDs the IAIA would only use approximately 556,875 kWh a year.

This means the IAIA would save approximately 433,125 kWh a year by switching to LED lights. At the IAIA's current average energy cost per kilowatt-hour, provided by PNM's (2016a) recent data, of $0.086/kWh, the IAIA could save $37,252 a year. The IAIA also stands to save carbon emissions by switching to LEDs. According to PNM (2016b), 75% of their power produced in New Mexico is from fossil fuel fired power plants. Additionally, the U.S. Energy Information Administration (2016a) said that fossil fuels produce around 2 pounds of carbon dioxide (CO_2) per kWh. If 75% of the energy saved, 324,844 kWh, generates CO_2 emissions at 2 pounds per kWh, the IAIA would prevent 649,687 pounds of CO_2 from being emitted, equivalent to about 325 tons of CO_2. This is 11% of the IAIA's carbon baseline in 2013 of 2946 tons. Since the IAIA needs to cut 104 tons a year to reach their goal of carbon neutrality by 2050, 325 tons provides three years' worth of emissions reductions. The switch to LED lighting is an easy retrofit that would kick-start the IAIA in the direction of carbon neutrality.

Current drop-in replacements can be found for approximately $6 for residential users, and possibly less from bulk suppliers (The Home Depot, 2016). We did a very simple return on investment calculation assuming a $6 LED bulb. Using our assumption that there are 12,500 bulbs on campus, the IAIA would spend approximately $75,000 on purchasing LEDs. Since these are simple drop-in tubes, there is no additional cost for installation as anyone should be able to replace these bulbs. With the difference in power usage between the bulbs, as stated previously, the IAIA would save approximately $37,252 on energy savings a year. This means that in two years the LED bulbs would return the IAIA's investment in the form of energy savings. This is one excellent way for the IAIA to not only conserve energy costs, but an easy retrofit to start the campus on the path to carbon neutrality.

The limitations for our LED benefits are a simple estimation for the number of fluorescent lights, and the source for LED replacements. There are certainly rooms that do not use fluorescent tube lights, and some rooms might have more lights than our prediction counts for. For our simple return on investment, our limitation is that we did not account for a bulk price of the bulbs. A company that supplies thousands of bulbs at a time will probably sell each bulb at a lower price, which would decrease how long it would take the LED lights to provide a return on investment.

4.1.3 Gas Conservation

In order set up a system for the IAIA to get a thorough understanding of their natural gas consumption patterns and have a baseline from which to launch conservation efforts, we developed a plan for the IAIA to upgrade their gas meters to Elster RABO pulse meters and to collect the data those meters produced on a rigorous schedule.

4.1.3.1 Metering Options

From discussions with our sponsor, we determined that the most important requirements for natural gas meters were that they were easy to read, which meant that the meters needed to display the recorded flow on a digital screen instead of a dial or odometer style display, and that the meters needed to be sized correctly so as not to disrupt the flow of gas into the buildings, while still being able to measure low-flow situations. For buildings that did not already have existing meters, we calculated the maximum amount of gas that could be consumed if all of their gas-burning appliances were running at 100% demand. For buildings that did already have meters installed, we trusted that they were sized correctly for the building. Figure 4-4 shows which buildings already had gas meters installed and which buildings did not have a meter at all, more detailed information about the preexisting gas meters is available in Appendix B.

Figure 4-4: Map of Gas Meter Locations (Institute of American Indian Arts, 2016c)

All the existing meters had capacities of 5,000 or less cubic feet per hour (CFH) of flow. Our calculations of the requirements of the buildings without existing meters--the Main Academic Building (building 3 on the map in Figure 4-4), the Fitness and Wellness Center (building 8), and the Family Housing Complex (building 2)—show that the main academic building requires a meter capable of handling more than 7,000 CFH and that the Fitness and Wellness Center and Family

Housing Complex require meters that can support 3,000 CFH each, the full table of calculations can be seen in Appendix C.

We found three different systems that seemed to fit our requirements. The first metering system was a family of ultrasonic meters manufactured by Sensus, the Sonix. These meters could handle the rates of flow of all of the buildings, but are completely different from the existing meters, and would require that each meter be replaced, regardless of its condition. The second system was a pulse meter system manufactured by Elster, the RABO family of rotary meters, with pulse counters, which output an electrical pulse as natural gas passes through the meter, the technical documentation for these meters is available in Appendix Q (Elster Gas Depot, 2014). These also require the replacement of all existing meters. Our third option didn't require replacing meters, but required purchasing add-on equipment for the buildings with existing meters. This was the Encoder Receiver Transmitter [ERT] system manufactured by Itron.

After contacting suppliers of each meter, we developed estimates for the costs. The information provided by each supplier is displayed in Table 4-2, below.

Table 4-2: Cost Comparison of Different Gas Metering Systems (P. Malone, personal communication, September 23, 2016; Flow Factor, 2016; Mountain State Pipe & Supply, personal communication, September 23, 2016; Elster Gas Depot, 2016a; Elster Gas Depot, 2016b)

Option	What Needs to be Purchased	Costs
Install & replace all meters (Sensus Sonix Ultrasonic with LCD display)	10 Sensus Sonix Ultrasonic Meters	10 meters × $2170 = $21,700
Replace All Meters with Elster RABO Rotary Meter w/ Pulse counter	8 Elster RABO 3.5M, 1 5.5M, 1 9.5M, and 10 CTR30 Pulse counters	$16,545
Install meters for buildings without meter, replaced broken meter and install ERT module for all of them.	Roots rotary meter 5M175*1 2M175*1 3M175*1 Diaphragm Meter AC630*1 ERT module*10	$6910 (reading device and software not included)

Our quotes showed that the ERT metering system would be the least expensive one to implement. However, after further research, we found that the handheld meter reading device, the server it required, and the software licenses to make it all run would be prohibitively expensive for the IAIA. Therefore, the RABO metering system with the pulse counters is the least expensive way to achieve the IAIA's requirements. A more detailed breakdown of the costs for the IAIA is shown in Table 4-3.

Table 4-3: Elster RABO Pulse Metering System Price Breakdown (Flow Factor, 2016; Elster Gas Depot, 2016a; Elster Gas Depot, 2016b; D. Cunningham, Personal Communication, October 12, 2016)

Building	***Meter Model***	***Price***	***Required Accessories***	***Accessory Price***	***Total Price***
[4] CLE	RABO 5.5M	$1,845	T210 Pulse Counter and Pulser Kit	$210	$2,055
[7] Res	RABO 3.5M	$1,260	T210 Pulse Counter and Pulser Kit	$210	$1,470
[5] Lib	RABO 3.5M	$1,260	T210 Pulse Counter and Pulser Kit	$210	$1,470
[3] Academic	RABO 9M	$2,520	T210 Pulse Counter and Pulser Kit	$210	$2,730
[9] Science	RABO 3.5M	$1,260	T210 Pulse Counter and Pulser Kit	$210	$1,470
[10] Foundry	RABO 3.5M	$1,260	T210 Pulse Counter and Pulser Kit	$210	$1,470
[14] Welcome	RABO 3.5M	$1,260	T210 Pulse Counter and Pulser Kit	$210	$1,470
[2] Family	RABO 3.5M	$1,260	T210 Pulse Counter and Pulser Kit	$210	$1,470
[6] Facilities	RABO 3.5M	$1,260	T210 Pulse Counter and Pulser Kit	$210	$1,470
[8] Fitness	RABO 3.5M	$1,260	T210 Pulse Counter and Pulser Kit	$210	$1,470
	Labor Estimate	*~$24,800*		***Parts Costs***	*$16,545*

This system is the best option for the IAIA if they were to install the meters in the near future. The total parts cost for the system would be around $16, 500, with an installation cost of approximately $24,800. This labor estimate came from a quote given to us by Roadrunner Plumbing, displayed in Appendix S.

4.1.3.2 Data Collection

Installing gas meters would not provide any benefits to the IAIA on its own. In order for the IAIA to be able to use the measurements that these meters generate, someone would have to record how much gas has been consumed at each meter quite regularly. The meters will only be as useful as the data one can collect from them. Therefore, we developed a measurement schedule that provides consumption figures for the night, the morning, and the afternoons. This schedule requires measurement of each meter three times each day. The first measurement time should start relatively early in the morning, before classes would begin. The second measurement of the day would occur around the lunch hour and the final measurement would start after most of the day's classes have finished. As it only would take a few moments to write down the value displayed on the meter, most of the time taken would be from moving between the different buildings to perform the measurements. Table 4-4 shows an example of what data to collect and how to record it.

Table 4-4: Example Data Recorded for Gas Meters

Date	Time of Day	Outdoor Temp	Indoor Temperature	Building	Building Occupied?	Meter Reading
	AM/PM	°F	°F		Yes/No	CFH
10/4/2016	8:00 AM	61	69	Academic	Yes	6789
10/4/2016	8:04 AM	61	65	CLE	Yes	2901
10/4/2016	1:00 PM	67	72	Academic	Yes	9799
10/4/2016	1:08 PM	67	68	CLE	Yes	3988
10/4/2016	7:00 PM	56	73	Academic	No	12835
10/4/2016	7:06 PM	54	66	CLE	No	5231

The data collected here could be used to develop recommendations for where to focus the IAIA's efforts on conserving natural gas for the greatest effect in carbon footprint.

Our gas meter recommendation is limited by the currently available technology. Gas meter reading technology is rapidly evolving and is an emerging market. If the IAIA purchases and installs the RABO system and commits to collecting the necessary data, a simpler, more cost effective, technology could become available. For instance, there is a real possibility that ERT style systems with automatic data collection will become a huge market for homes and small businesses, driving down the complexity and price. This would be a much simpler, cost effective, and less time consuming retrofit for the IAIA.

4.2 Solar Energy Generation

Starting with Re-volv's proposed solar array, our research showed that in order to create the dramatic changes the school needs to meaningfully reduce carbon emissions, solar was the best way forward. While the RE-volv proposal had a number of limitations that made it difficult to use as a starting point for more significant investments into solar (with more impressive reductions in carbon emissions), we found several other possibilities for the IAIA that would perform better.

4.2.1 Analyzing RE-volv's Proposal

Our research regarding RE-volv's proposal initially focused on confirming or refuting the claims laid out in their proposal documentation. The most appealing part of those claims was that, over the 25-year life of the panels, the system would generate around $100,000 in savings beyond the costs of the system. However, we believed it to be far more useful to understand how much savings the array could generate over the length of the 20-year lease since the school may want to update the system with new technologies at that point.

Therefore, according to the proposal, the IAIA could expect to save $38,000 over that 20-year period (RE-volv & Sacred Power, 2016). However, when we analyzed the equipment that RE-volv had proposed using—91 Canadian Solar CS6K panels and 7 Sunny Boy string inverters manufactured by SMA Technology Group AG—we questioned the ability of the panels to perform as well as predicted. Canadian Solar panels have a very high degradation rate—2.5% of its production is lost after the first year of the panels' life and a further 0.5% is lost each year thereafter, based on Canadian Solar's data on the panel's performance (Canadian Solar, 2016). Therefore, in our model, we used a more conservative estimate for power generation by the array. RE-volv guarantees that the array will produce 90% of their optimistic estimate of 43,000 kilowatt-hours each year or 38,183 kWh of generation for the first year, degrading the guaranteed performance by 0.5% each year. If the system generates power at the 90% guaranteed rate, then the savings would be quite lower than RE-volv's predictions. Additionally, the life of most string inverters is only about ten years, so we had concerns about how those would be replaced once before the end of the lease, and the proposal did not clearly state how that requirement would be dealt with.

We also had questions about the rate of inflation of electricity prices quoted by RE-volv. The energy market is a volatile one, and we wanted to see if historical trends matched the figures provided in the proposal. Therefore, we analyzed the short- and long-term trends of historical data for commercial electricity prices provided by the U.S. Energy Information Administration (2016c). From this data, visualized in Figure 4-5 below, we found that the average rate of increase in energy prices over the past five years was 5.4% annually, a little higher than the 5.0% presented by RE-volv. However, a longer-term trend including the last 15 years indicated a lower rate of inflation, with prices rising by 3.2% yearly.

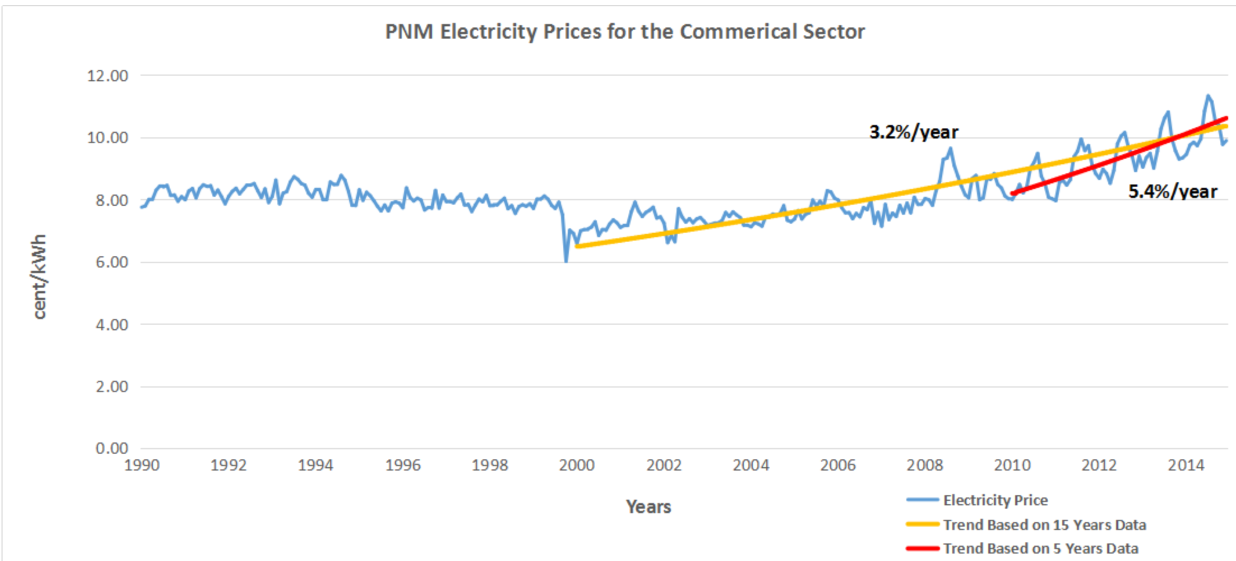


Figure 4-5: Historical Electricity Prices for the Commercial Sector

Then we extrapolated both of those rates of electricity price inflation out over the length of the lease. The solar array would provide energy offsetting the costs of purchasing electricity from the utility at those rates. For the starting point of the cost of electricity, we used the average cost of electricity during peak hours (8 AM—8 PM) for the General Power (3B) rate from the Public Service Company of New Mexico over the past year, which is $0.096/kWh. The only expense for the IAIA regarding this system during the life of the lease is the lease payments paid to RE-volv monthly. In the first year, these monthly payments would sum to $3756, and increased by 2.9% every twelve months. Combining that information produces the following cash flow, displayed in Table 4-5.

Table 4-5: Cash Flow Analysis

Year	Electricity Costs at 5.4% Inflation	Cost of Lease	High Inflation Cash Flow
1	$3,757.25	$3,760.56	-$3.31
2	$3,940.34	$3,869.62	$70.72
3	$4,132.25	$3,981.84	$150.41
4	$4,333.39	$4,097.31	$236.08
5	$4,544.21	$4,216.13	$328.08
6	$4,765.16	$4,338.40	$426.76
7	$4,996.72	$4,464.21	$532.51
8	$5,239.40	$4,593.67	$645.73
9	$5,493.71	$4,726.89	$766.82
10	$5,760.22	$4,863.97	$896.25
11	$6,039.48	$5,005.03	$1,034.46
12	$6,332.11	$5,150.17	$1,181.94
13	$6,638.73	$5,299.53	$1,339.20
14	$6,960.00	$5,453.21	$1,506.79
15	$7,296.61	$5,611.36	$1,685.26
16	$7,649.28	$5,774.08	$1,875.20
17	$8,018.76	$5,941.53	$2,077.23
18	$8,405.84	$6,113.84	$2,292.01
19	$8,811.35	$6,291.14	$2,520.21
20	$9,236.13	$6,473.58	$2,762.55
Total	**$122,350.95**	**$100,026.06**	**$22,324.89**

We performed this calculation for the two different electricity inflation rates and the two estimates for the performance of the solar array. These estimates for the savings generated by the proposal lease are in Table 4-6, below.

Table 4-6: Quadrant Diagram Illustrating the Boundary Cases for the Net Savings or Loss of the Array

	Optimistic Power	Guaranteed Power
Avg. 5-Year/ 5.4%	$35,919.44	$22,324.89
Avg. 15-Year/ 3.2%	$8,426.79	-$2,418.50

As this table shows in the worst case the school would lose approximately $2,400 dollars over the twenty years of the lease. This was achieved when using the conservative guarantee for solar generation figures combined with the lower, long-term, trend for electricity price inflation. When using the more optimistic figures, the IAIA could hope to see more savings than predicted by RE-volv. The actual performance of the array would likely lie within this range. However, despite the likely economic success of the proposal there are serious drawbacks to the system that make us feel that RE-volv's proposal would not be a good investment for the IAIA.

Our primary reservations about this system stem from the fact that for the first twenty years of the system's life, the IAIA would be leasing the array and not have ownership of it. Once the lease ends and the IAIA owns the system, solar energy technology will likely have advanced so significantly that the IAIA will want to use the roof-space taken up by the array for newer technology. In fact, it is likely that these panels, already out-of-date, will be completely obsolete long before the lease is up. Thus the IAIA may be stuck operating and paying for a solar array that is comparatively useless when they could alternatively use that roof-space for the much more effective technologies.

Additionally, not owning the panels would make it more difficult for the IAIA to expand their investment into solar with other projects and arrays. Different manufacturers for solar panels often use different hardware to connect the system to the power grid, and they are often incompatible. This makes it difficult to tie in multiple systems at a later date, especially since Canadian Solar panels are much less effective than panels from different manufacturers and any future projects would probably use those better systems. Since the IAIA could not make changes to the RE-volv array while leasing it, future expansion would be quite difficult. Since it is important to use solar as a big portion of their efforts in reducing carbon emissions, the ability to expand solar to the sizes necessary to reduce carbon output significantly is essential and RE-volv's proposal limits that ability.

Because of the disadvantages to RE-volv's solar lease, it was not a good plan for the IAIA. Our full report can be seen in Appendix E.

4.2.2 Other Solar Options

In the last section, we mentioned that the effectiveness of the Canadian Solar panels was subpar. We found three companies that install solar arrays in the Santa Fe area and use panels of much better quality than those recommended by RE-volv. These companies are Positive Energy Solar, a local partner with the nationally recognized brand Sunpower, Go Solar, a small, locally owned installer that uses panels produced by LG, and AmEnergy, another local company that uses LG panels.

These panels both would generate significantly more electricity over their lifetimes than the Canadian Solar panels. Because of their increased initial efficiency and a lower degradation rate overall, panels manufactured by LG and Sunpower are both more than 10% better than Canadian Solar in terms of generation. Therefore, these systems are more suitable to be used by the IAIA as they will have a longer lifespan before obsolescence. That is, these systems are less likely to be so quickly outpaced by technology that they will become essentially useless before they produce enough electricity to have paid for themselves. In Table 4-7, we compared the specifications of each of the manufacturer's panels.

Table 4-7: Comparison of Panels from Different Manufacturers, Roof-mounted, 10-degree elevation (Canadian Solar, 2016; Sunpower, 2016; LG, 2016).

	Canadian Solar Panels	**Sunpower Panels**	**LG Panels**
Rated Wattage	280 W	327 W	320 W
Panel Area	1.62 m^2	1.62 m^2	1.62 m^2
Efficiency	Approx. 17%	Approx. 21%	Approx. 19%
Degradation	Guaranteed 2.5% the first year, 0.5 % of initial production thereafter.	Guaranteed less than 0.4% of initial production per year.	Guaranteed less than 0.6% of initial production per year.
Manufacturer's Warranty	25-year parts and labor warranty	25-year parts and labor warranty	12-year parts and labor warranty
Generation Per Year	478 kWh per panel	653 kWh per panel	577 kWh per panel
Guaranteed Lifetime	25 years	25 Years	25 years
Generation over Life	11,000 kWh per panel	15,500 kWh per panel	13,400 kWh per Panel

The main difference between the Sunpower panels and LG panels are their degradation rates. Both panels are around 20% efficiency, but the Sunpower panels degrade 17% slower, at 0.4% per year rather than the 0.6% degradation of the LG panels. Therefore, because the difference in prices between these panels is less than their difference in production, the Sunpower panels are a better value. Thus, it would be more economical for the IAIA to use Sunpower technology.

The IAIA consumes about 2.5 million kWh of electricity a year (Public Service Company of New Mexico, 2016a). According to our model in Appendix P, to generate all of their needed electricity, the IAIA would need to install a 1.3 Megawatt solar array. An array of this size, in the commercial sector, would cost more than $2.5 million (Chung, Davidson, Fu, Ardani, & Margolis, 2015). While that is an option for the school, its large expense would make it difficult to fund. Additionally, since the IAIA would prefer to save ground space for the construction of future buildings, rather than dedicating land to solar generation, and it would be very difficult to set up a Megawatt-scale solar array without resorting to ground mounts, quickly ramping up to this size of system is not the best plan for the IAIA. Therefore, we focused on creating a proposal for smaller systems that would still make an impact on the IAIA's energy usage.

Because ground-mounted solar panels would take up land that the IAIA would prefer to save for other uses, we examined the main two other methods for installing solar arrays, roof-mounting and solar carports. As discussed in the Background chapter of this report, the roof-mounted arrays are the least expensive, while solar carports are a bit more efficient, yet cost more. The carport solar systems also are the most visible, providing a greater impact for the casual passersby, and do a better job of showing the IAIA community that the school is making efforts towards carbon neutrality. If the funding is there, there are numerous benefits to installing solar on carports over rooftop installations as large carports will draw attention to the IAIA's goals for expansion and commitment to carbon neutrality. We set up three different systems, with varying focuses on solar carports. The least expensive option would be to forgo carports and put all the solar power on the roof. Then we compared that option with using carports alone. Finally, we looked at using a hybrid of small, modular carports, and having the bulk of the panels roof-mounted. In Table 4-8, below, we compared the costs and features of those three different designs.

Table 4-8: Comparison of Mounting Methods for Solar Array (D Baker, personal Communication, September 18, 2016)

	Roof-Mounted Only	**Pilot-size system, with both roof and carport**	**Carport-Mounted Only**
Cost	Least Expensive option: ~$4.10/Watt	Slightly less Expensive. ~$3.90/Watt	Most Expensive Option: $4.80-$5.30/Watt
Visibility	Sign Presenting Solar Array, panels barely visible from ground	Some carport system with visible solar panels. Other roof panels are barely visible.	12 or more spots of shaded parking with visible solar panels, will have attached sign presenting array.
Total Cost for 35 kW	$143,500	$135,500	$168,000 – $185,500

The middle option in the above table, using the modular single-car carports and leaving the remainder of the panels to be roof-mounted, is a flexible one. The modular units are prefabricated and installing two or three of them would be just as easy as installing only one. Each carport contains 3 kW of panels so that number of panels could be removed from the roof system to keep the same production and minimize costs. However, it would be more economical to switch to a single, larger, carport if the IAIA were to increase the number of cars covered to more than 10.

The more expensive a project, the more difficult it would be for the IAIA to find funding. Therefore, we designed systems of various sizes, so the IAIA could choose the one that makes the most sense when they start fundraising. The smaller systems could be constructed as part of any new buildings to help offset the increased energy usage that those buildings would require. We created proposals for system sizes of 31 kilowatts, 70 kW, and 150 kW. The 31 kW system would be a good initial project. It would cost around $120,000, provide a good starting point to expand for future projects, would be visible enough to create interest in solar energy, and could make future funding efforts easier. Specifically, in its first year, the array could be expected to generate about 55,000 kWh, or about 2.5% of their current electrical demands. That energy would reduce carbon emissions around campus by about 42 tons of CO_2. A larger system would have the same effects, but would make the economic barrier to entry into solar power that much higher. In Figure 4-6, below, we compare the relative sizes and costs of these different systems.

Figure 4-6: Comparison of Costs and Footprints for Various Solar Options (Google, 2016)

There are a number of solutions open to the IAIA for funding solar projects. The most economically beneficial solution would be for the IAIA to create a Limited Liability Company, or LLC, funded by "friendly investors" (D. Baker, Personal Communication, September 13, 2016). For our purposes, a "friendly investor" is closer to a donor than a traditional investor, in that they aren't really funding the project purely for economic gain, but rather to help the school. However, unlike traditional donors, they could expect to receive all of their investment back through tax credits and lease payments. A second option for the school would be to follow the pattern they used when constructing many of their buildings, soliciting donations in a capital campaign for the construction. However, if the IAIA did not want to pressure investors or donors into another project or if they had the necessary funds ready to spend, the IAIA could simply purchase the system outright.

An LLC provides the most savings and benefits for the IAIA, as many of the tax-related benefits that come from investing in renewable energy would not be available to the IAIA given their tax status. The company would be created by the school and shares would be offered to "friendly investors" in a private placement. These investors would purchase the shares, and the capital raised from those purchases would be used to fund the purchase of a solar array at the IAIA. The investors could then use the Federal Renewable Energy Tax Credits to help offset some of the costs of the system. The IAIA would then pay a below-market lease payment for the system to the LLC, which would be split among the investors to continue to offset their investments. Finally, when the lease had paid for most of the value of the system, the LLC would donate the array, and could take advantage of the tax credits which come with making a valuable donation to a charitable entity.

Thus the IAIA would end up paying less than if they had leased a similar system from a traditional solar financier. The investors would have made back all of the money they invested, through tax credits and the lease payments. Additionally, the IAIA would have far more control over the system than through a traditional lease, as they would be able to set the terms of the project in the funding documents for the LLC and through the private placement.

As with any project, we faced certain limitations in completing our research and recommendations. The biggest limitation we faced was the IAIA's plans for expansion. No matter what recommendations we make for reducing the IAIA's carbon footprint, their carbon reductions need to reduce their output at a greater rate than the school plans to expand. With each new building comes new electrical and gas needs, which adds to their total carbon emissions. To combat this, our gas metering and lighting retrofits would need to be included to each expansion, and each phase of solar installations would need to offset the new building, and a portion of the existing usage to advance the IAIA's goal.

The decreasing price of solar energy also limits our ability to make accurate predictions. Technology is constantly being improved, which lowers the cost of installing solar generation on campus. This means that any estimates of system cost, and system size could change over the course of a few months. For instance, if the IAIA waits until next year to install solar, the price of the system could change based on the available technologies from Sunpower. Or, the cost of energy could drop dramatically based on new generation methods that would make the savings from the system minimal. When we calculated the savings projections from solar generation on campus, we made a few assumptions. We assumed that energy prices increased at a fixed rate, when our research proved this is not the case. We needed to assume a constant increase as it is very difficult to provide an accurate model of an inconsistent change.

4.3 Summary

The results of our survey showed that the students at the IAIA really want to see more visible sustainability projects at the school. We determined that the best option for the IAIA in terms of solar is not the system proposed by RE-volv, but rather a series of solar arrays installed as the IAIA can get funding using equipment manufactured by Sunpower. We also found that the IAIA would create significant carbon savings by switching campus lights over to LEDs from fluorescent bulbs and that the Elster RABO meters would be the best option for gas metering at the IAIA at this time.

5 Conclusions & Recommendations

The IAIA signed the ACUPCC in 2010, realizing that their campus needed to drastically reduce its carbon footprint and become a more energy sustainable campus. The goal of our project was to set the IAIA on the path towards achieving carbon neutrality by 2050, as they are not currently on that path. In order to reverse their current trend of increased emissions, we gave the following recommendations for the how the IAIA should proceed in the fields of electricity and natural gas conservation, as well as with solar energy implementation and expansion on campus. We also recommend different areas for the IAIA to conduct future research, in order to further reduce carbon emissions.

5.1 Energy Conservation

Conservation is very important to the community at the IAIA and we recommend that the IAIA capitalize on this and leverage student interest to make future efforts smoother. Along with student interest, we recommend that the IAIA use the educational value of the metering systems to interest even more student and provide more examples of where opportunities for energy conservation exists. To further electricity conservation on campus, we also recommend that the IAIA should switch their lighting systems to LEDs for both the carbon reduction and electricity savings. Lastly we recommend that the IAIA only use a gas metering system at this time if the IAIA is fully committed to the rigorous data collection method necessary to get full value out of the system.

5.1.1 Progressing Interest in Energy and Carbon Conservation

One of the biggest takeaways from the results of our survey was that the student body of the IAIA was unsatisfied with the visibility of the IAIA's current and past efforts in promoting carbon neutrality on campus. Therefore, the IAIA needs to focus on student awareness and involvement in these efforts. This topic was out of the scope of our main research on this project, but possible areas of focus for the IAIA's efforts in creating student investment in carbon reduction around campus are renewing student involvement in the community garden on campus, improving the information available for recycling on campus, having presentations about the various sustainability efforts the IAIA will take, and forming student groups that could provide their own ideas for achieving carbon neutrality that the IAIA. We recommend that the IAIA do their own research on what the most effective methods for stimulating community involvement might be and then implement the methods that they identify as having the greatest potential for their community.

5.1.2 Electricity Conservation

One of the IAIA's largest expenses and sources of carbon emissions on campus is the school's electricity usage. With the installation of electricity meters on the two classrooms discussed in previous sections, the IAIA can monitor their electricity consumption and highlight the benefits of switching from fluorescent lighting to LED lights. The next step is to educate the students about electricity usage on campus and to find out exactly how much the lighting changes would benefit the IAIA.

Just having electrical meters installed on the Northwest and Southwest classrooms of the Main Academic Building is not enough to show the students the energy efficiency benefits of using LED lights in classrooms on campus. We created various phrasings to put the difference in energy usage created by LEDs into terms that have more impact, than the raw electrical figures, on the community at the IAIA. We recommend that the school utilize the student's interest in seeing more information about the sustainability efforts on campus to develop posters and infographics to highlight the data that the meters produce. These graphics should be visually pleasing and could provide another marketing tool to develop interest in the investment that LED lights require. We also recommend that the same metering solutions also be used in different classrooms, art studios, or galleries to provide other examples of where LEDs can benefit the IAIA.

With the information for the graphics developed, our survey complete, and our predictions on LED lighting benefits, we recommend that the IAIA begin replacing all of the fluorescent lights on campus with their drop-in ready LED counterparts. This process can be done all at once, on a floor-by-floor basis, or building-by-building. It is up to the IAIA administration to choose which method of replacing all the fluorescent lights on campus would be the best for the school, as well as finding the specific models of LED lights that will be the most economically effective.

5.1.3 Gas Conservation

Based on the metering technologies currently available, our recommendation regarding gas metering at the IAIA is that, unless the school is ready to fully commit to the labor intensive task of gathering data on their natural gas usage, they delay purchasing a system until more automated options are available.

If the IAIA is committed to fully utilizing any new metering technologies to help reduce their gas usage—including ensuring that they are collecting data with enough regularity that the school can judge when and where efficiencies in usage appear—our recommendation is to purchase the Elster RABO rotary meters, along with an electronic pulse output and pulse totalizer for each meter. Unlike the electrical meters, where the same meter model will work for any size room, gas meters are sized for each specific building. The IAIA will need to purchase:

- A 9M model for the Main Academic Building.
- A 5.5M model for the Center for Lifelong Education.
- A 3.5M model for each of the 7 remaining buildings on campus.
- 9 IN-S10 pulse output attachments—one for each meter.
- 9 T210 pulse counters—one for each meter.

The total cost for the entire system would be $41,344 (including $16,545 for the meters themselves and $24,799 for the labor to install them (D. Cunningham, Personal Communication, October 12, 2016).

If the IAIA decides to use other gas meters, they should support the same flow capacity as the meters currently installed on each building, or the meters that we are recommending.

It should be noted that the IAIA must be seriously committed to acquiring the data produced by these meters in the manner developed within the Results Chapter before they make the investment. Since remote gas metering systems are currently not available at a scale that is affordable for the IAIA, they will be required to send someone to walk by each meter and record the necessary data. We recommend that the IAIA record this data at each meter multiple times each day. This will highlight the times of day that use the most natural gas and will point out opportunities for efficiency improvement. However, having a staff member record these data for each building so often will be a time consuming task, and that time could be used on other projects. Therefore, the IAIA may prefer to not commit so many resources to collecting these data. However, without collecting that information as recommended, the gas meters will not be able to inform the IAIA of opportunities to save energy and therefore, not be worth the investment.

Thus, we recommend that the IAIA waits until newer and better technologies are available to the IAIA within their technical constraints and are affordable to outfit and install. There is a high possibility that automated metering technologies, like the ERT modules, which can record measurements with minimal human interaction, will become less expensive and useful at a scale more applicable to the IAIA.

5.2 Power Generation

The IAIA has been interested in solar energy production since its singing of the ACUPCC. Solar energy is one way the IAIA hopes to reduce its carbon footprint. Our research into the proposed RE-volv system led to our recommendation that the IAIA not enter into the agreement. We then focused on finding other solar options available to the IAIA, ultimately recommending an installation company and solar implementation plan to maximize the IAIA's solar potential. As we discussed in the Results chapter, RE-volv's proposal for a solar array has serious drawbacks regarding its long term benefits for the IAIA. So, we recommend that the IAIA reject the proposal and search for solar energy from other sources.

Because we recommended that the IAIA choose not to accept the solar lease proposal from RE-volv, we came up with an alternative for the IAIA to bring solar generation to campus. Our research revealed two options for solar power in the Santa Fe area, Go Solar and Positive Energy Solar, the local affiliate of Sunpower, a national solar energy company. We concluded that, based on estimated prices and equipment performance data, the best option for the IAIA is to use Positive Energy Solar as a provider for a solar generation system. We recommend that the IAIA continue work together with Sunpower and develop a mutually beneficial set of terms that will allow the IAIA to use their equipment for introducing solar generation on campus.

Since the IAIA has already set aside funds to build solar panels on their next construction project, the Recreation and Performing Arts Center, we also recommend that they specify

Sunpower as a preferred subcontractor during their Request for Proposal process. That way, the IAIA can be sure of getting the most generation and best equipment for the value.

We also recommend that the IAIA begin the process of bringing solar generation to the campus by installing a 31 kW pilot system that would be funded by the school. This pilot system would consist of 24 Sunpower 327 Watt panels installed on a prefabricated two-car solar carport and 72 roof-mounted panels. According to Dan Baker, at a rough estimate, this system would cost the IAIA approximately $120,000 (Personal Communication, October 7, 2016). If the IAIA decides to choose Sunpower as their preferred installer, they will be able to tie together their first two projects on campus, the new Recreation and Performing Arts Center and our recommended pilot system.

In the future, we recommend the IAIA continue to expand their investments in solar energy as the campus expands. The school should install future solar arrays in phases where each phase is large enough to more than offset any new energy demands and lower the IAIA's total carbon output. These phases could be funded by donors, in the same fashion as many of the campus' expansions have been, or purchased through LLC investments.

5.3 Future Impact

There are certain aspects of our project that will create a lasting impact for the IAIA. The first is the explanations that will accompany the electrical meters. We hope that the displays—which can even be student designed—will explain the power differences in terms that will help the IAIA community understand energy usage and conservation. We also hope that they will continue to promote and build community interest in helping the IAIA become carbon neutral. This understanding of energy usage can be applied anywhere, in the dorms, in classrooms, and even places outside of the school, even if it as simple as turning off the lights when they are not needed.

We also hope our recommendation for a solar project can open up new pathways for the IAIA to receive funding for future expansion. If the IAIA goes through with installing a small solar carport as a part of its pilot system, we believe they can use it as an advertising tool to interest investors and donors. More donors mean that the IAIA will be able to increase its donor pool to those who are interested in solar energy expansion which will help the IAIA achieve carbon neutrality. As for the future, there is still a lot that the IAIA needs to do before they will be able to reach zero net carbon emissions by 2050.

In order to make their path towards carbon neutrality easier, there is research that we believe the IAIA should complete in order to follow up on our research. The first project would be to develop a more concrete plan for how solar energy expansion should tie into the campus' expansion as a whole. If the IAIA begins with a pilot system like the 31 kW design that we recommended, they will need to expand that system to really have a significant effect on their carbon emissions. Therefore, we recommend that the future research develop a year-by-year timeline for the IAIA so they know when to expand the initial system, how much solar to install each time, and where to install that equipment. This would give the IAIA a plan to work towards.

If the IAIA does choose to install gas meters on campus they will need to be manually read, we recommend that future research develop an explicit schedule for reading all of the gas meters the IAIA may decide to install. If they are read randomly, they will not provide information that is useful towards reducing gas usage on campus. If a schedule is adhered to, then the IAIA will be able to determine usage patterns and find opportunities to reduce gas usage and therefore carbon emissions.

While we did a basic calculation for how much energy the IAIA could save if the lights on campus were switched to LEDs, more research should be done to refine the estimates and assumptions that we made for those calculations before the IAIA can retrofit the entire campus. This research should be focused on the different LED lights available for replacement, and should determine which specific products would best serve the IAIA to achieve the most energy, monetary, and carbon emission reductions.

The IAIA should also look into alternative methods of transport for their students. While the school is in a fairly remote location, with students from various parts of the country, there are many opportunities to save carbon emissions by lowering the amount of driving by the school community to and around campus. Future research in this field will determine which solutions will work for the IAIA's specific situation in this area. The combination of all of these possible projects and the dedication and commitment of the IAIA campus and staff will lead the IAIA to meet their 2050 goal of carbon neutrality.

References

Alley, R., Berntsen, T., Bindoff, N., Chen, Z., Chidthaisong, A., Friedlingstein, P., … Wratt, D. (2007). Climate change 2007: the physical science basis. *Agenda*, *6*(7), 333.

American Indian Higher Education Consortium (2016a). *AIHEC: What We Do*. Retrieved from http://www.aihec.org/what-we-do/index.htm

American Indian Higher Education Consortium (2016b). *AIHEC: Who We Are and Membership*. Retrieved from http://www.aihec.org/who-we-are/board.htm

Block, B. (2013). Energy Agency Predicts High Prices in Future. *Worldwatch Institute*. Retrieved from http://www.worldwatch.org/node/5936

Canadian Solar. (2016). CS6K-270|275|280M. Retrieved from http://www.canadiansolar.com/fileadmin/user_upload/downloads/datasheets/v5.4/Canadian_Solar-Datasheet-CS6KM_v5.4C1en.pdf

Chung, D., Davidson, C., Fu, R., Ardani, K., Margolis, R. (2015). U.S Photovoltaic Prices and Cost Breakdowns. Golden, CO: National Renewable Energy Laboratory. Retrieved from http://www.nrel.gov/docs/fy15osti/64746.pdf

Clover, I. (2016). US solar system prices fell 17% in 2015, finds GTM. *PV Magazine*. Retrieved from http://www.pv-magazine.com/news/details/beitrag/us-solar-system-prices-fell-17-in-2015--finds-gtm_100023743/#axzz4LwgqRJnp

College of the Atlantic. (2015). Energy. Retrieved from https://www.coa.edu/about/environmental-commitment/energy/

Cornachini B. J. C., Nutting J. T., McMullen I. T., & Milholland A. C. (2014). *Monitoring and reducing the carbon emissions of the Institute of American Indian Arts* (Undergraduate Interactive Qualifying Project No. E-project-050914-211427). Retrieved from Worcester Polytechnic Institute Electronic Projects Collection: https://web.wpi.edu/Pubs/E-project/Available/E-project-050914-211427/

DiBiasio, A., Pilaar, E., & Rosa, K. (2016). *An Implementation Guide for the Institute of American Indian Arts' Climate Action Plan* (Undergraduate Interactive Qualifying Project No. E-project-050116-174650). Retrieved from Worcester Polytechnic Institute Electronic Projects Collection: https://web.wpi.edu/Pubs/E-project/Available/E-project-050116-174650/

DPR Construction. (2016). Butte College Phase 3 Solar Grid. Retrieved from http://www.dpr.com/projects/butte-college-phase-3-solar-grid

DROK. (2016). Digital AC/DC Multimeter 4 Data Display Voltage Current Power Energy. Retrieved from http://www.droking.com/digital-acdc-multimeter-4-data-display-voltage-current-power-energy/

Duffie, J. A., & Beckman, W. A. (1980). *Solar engineering of thermal processes* (Vol. 3). New York: Wiley.

E Source Companies LLC. (2013). Managing Energy Costs in Colleges and Universities. National Grid. Retrieved from https://www9.nationalgridus.com/non_html/shared_energyeff_college.pdf.

Eaton Corporation, PLC. (2016). Metalux Encounter 24EN 2'x4' Specification Grade LED Troffer Spec Sheet. Dublin, Ireland. Retrieved from http://www.cooperindustries.com/content/dam/public/lighting/products/documents/metalux/spec_sheets/PS519063EN-24EN-2x4-LED-SSS.pdf

Eco-Revolution. (2016). Lumens and Light Output. Tampa, FL: Eco-Revolution. Retrieved from: http://www.eco-revolution.com/lumens-and-light-output/

Edison Electric Institute. (2006). Rising Electricity Costs: A Challenge For Consumers, Regulators, And Utilities. Washington, DC: *Edison Electric Institute.* Retrieved from: http://www.eei.org/whatwedo/PublicPolicyAdvocacy/StateRegulation/Documents/rising_electricity_costs.pdf

Efergy. (2016). Elite Classic Power Meter. Sheffield, UK. Retrieved from http://efergy.com/media/download/datasheets/usa/eliteclassicv3_us&ca_datasheet_web2011.pdf

EKM Metering Inc. (2016). EKM-25IDS-N v.2 Spec Sheet. Retrieved from http://documents.ekmmetering.com/EKM-25IDS-N-Spec-Sheet.pdf

Elster Gas Depot. (2014). RABO® Rotary Gas Meter. Retrieved from http://www.elster-americanmeter.com/assets/products/products_elster_files/EAMTB5900.pdf

Elster Gas Depot. (2016a). IN-S10 Pulser Kit. Retrieved from http://www.elstergasdepot.com/in-s10-pulser-kit-rabo.html

Elster Gas Depot. (2016b). T210 Remote Display / Cubic Foot x 100 – Unit of measure. Retrieved from http://www.elstergasdepot.com/accessories/rvp-t210/t210-remote-display-3593.html

Farmer, J.D., & Lafond. F. (2016). How Predictable is Technological Progress? *Research Policy*, *45*(3). 647-665.

Flow Factor. (2016). Elster American Meter RPM Rotary Gas Meters. Retrieved from http://www.flowfactor.com/Merchant2/merchant.mvc?Screen=CTGY&Store_Code=FF&Category_Code=AMMETR

Gallo, A. (2014). A Refresher on Net Present Value. *Harvard Business Review.* Retrieved from: https://hbr.org/2014/11/a-refresher-on-net-present-value

Gans, W., Alberini, A., & Longo, A. (2013). Smart meter devices and the effect of feedback on residential electricity consumption: Evidence from a natural experiment in Northern Ireland. *Energy Economics, 36*, 729–743. http://doi.org/http://dx.doi.org/10.1016/j.eneco.2012.11.022

General Electric. (2013). 4' T8 Sarcoat® Ecolux® XL: Extra-Life F32T8 Lamps. Retrieved from http://www.gelighting.com/LightingWeb/na/images/64404_LFL_4_T8_Starcoat_Ecolux_XL_F32T8_tcm201-21070.pdf

Gillis, J. (2013). Carbon Dioxide Level Passes Long-Feared Milestone. Retrieved from http://www.nytimes.com/2013/05/11/science/earth/carbon-dioxide-level-passes-long-feared-milestone.html?pagewanted=all

Harvard University. (2013). Renewable Energy. Cambridge, MA: Harvard. Retrieved from: https://green.harvard.edu/topics/climate-energy/renewable-energy

Helman, C. (2013). How Much Electricity Do Your Gadgets Really Use? *Forbes.* Retrieved from: http://www.forbes.com/sites/christopherhelman/2013/09/07/how-much-energy-does-your-iphone-and-other-devices-use-and-what-to-do-about-it/#77b6b082228e

The Home Depot. (2016). Phillips 4ft. T8 17-Watt Daylight Linear LED Light Bulb. Retrieved from: http://www.homedepot.com/p/Philips-4-ft-T8-17-Watt-Daylight-Linear-LED-Light-Bulb-456608/206278132

Howard, B. C. (2008). 10 Greenest Colleges. *Popular Mechanics.* Retrieved from http://www.popularmechanics.com/science/environment/green-energy/10-greenest-colleges-460708

Hughes, J. (2014). RE-volv Inaugurates Second Crowdfunded Project at Kehilla Community Synagogue. *PV Solar Report*. Retrieved from: http://pvsolarreport.com/re-volv-inaugurates-crowdfunded-kehilla-community-synagogue-project/

Institute of American Indian Arts (IAIA). (2013). *The IAIA Climate Action Plan Spring 2013*. Santa Fe, NM: Institute of American Indian Arts. Retrieved from http://reporting.secondnature.org/cap/1119/

Institute of American Indian Arts (2016a). About. Retrieved from https://iaia.edu/about/

Institute of American Indian Arts (2016b). Board of Trustees. Retrieved from https://iaia.edu/about/board-of-trustees/

Institute of American Indian Arts (2016c). Campus. Retrieved from https://iaia.edu/about/campus/

Institute of American Indian Arts (2016d). History. Retrieved from https://iaia.edu/about/history/

Institute of American Indian Arts (2016e). Key Facts and Public Documents. Retrieved from https://iaia.edu/about/key-facts-and-public-documents/

Institute of American Indian Arts (2016f). Mission. Retrieved from https://iaia.edu/about/mission/

Jawahar, R. (2016). *Renewables 2016 Global Status Report*. Paris, France: REN21 Publications. Retrieved from http://www.ren21.net/wp-content/uploads/2016/06/GSR_2016_Full_Report.pdf

Jordan, D. C., & Kurtz, S. R. (2013). Photovoltaic degradation rates: an analytical review. *Progress in Photovoltaics*: *Research and Applications, 21*(1), 12–29.

Leviton. (2016). 1K240-1SW. Retrieved from http://www.leviton.com/OA_HTML/LevitonCreateSingleSpecPdf.jsp?item=1049325&productFamily=

LG Electronics. (2016). LG NeON™2. Retrieved from: http://www.lg.com/us/commercial/documents/lg-commercial-solar-spec-neon2-g4-320-060116.pdf

Lins, C., Williamson, L. E., Leitner, S., Teske, S. (2014). *REN21 10 Year* Report. Paris, France: REN21 Publications. Retrieved from: http://www.ren21.net/Portals/0/documents/activities/Topical%20Reports/REN21_10yr.pdf

Lumel. (2016). DIGITAL PANEL METER N30P TYPE USER'S MANUAL. Retrieved from http://www.wpa.ie/Portals/0/Lumel/Digital%20Meters/1%20phase/N30P/n30p07_en.pdf

Nation Renewable Energy Laboratory. (2010, January). Santa Fe, NM: National Solar Radiation Database. Retrieved from http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2010/hourly/siteonthefly.cgi?id=723656

Newkirk, M. (2015). Best solar inverters review. *Clean Energy Reviews*. Retrieved from http://www.cleanenergyreviews.info/blog/inverters

Poch, J. (2015). Types of Gas Meters. Callmepower. Retrieved from: http://callmepower.com/about-us

Public Service Company of New Mexico. (2016a). Usage History. Unpublished. Available from Public Resource Company of New Mexico.

Public Service Company of New Mexico. (2016b). System. Retrieved from https://www.pnm.com/systems

Public Service Company of New Mexico. (2016c). Requests for Proposals. Retrieved from: https://www.pnm.com/rfp

Public Service Company of New Mexico. (2016d). 19th Revised Rate NO. 1A Canceling 18th Revised Rate NO. 1A. Retrieved from https://www.pnm.com/documents/396023/396197/schedule_1_a.pdf/d9cfda9e-61a1-4008-ba3c-4152c9dbe7f1

RE-volv. (2016). About Us. Retrieved from https://re-volv.org/about-us/

RE-volv & Sacred Power. (2016). Institute of American Indian Arts Solar Lease. San Francisco, CA. Unpublished proposal delivered to the IAIA

Robinson-Avila, K. (2013). Sacred Power. *Albuquerque Journal, 133(186).* Retrieved from: http://www.pressreader.com/usa/albuquerque-journal/20130708/281547993483736

Sibelga. (2016). How much energy do my household appliances use? Retrieved from: http://www.energuide.be/en/questions-answers/how-much-energy-do-my-household-appliances-use/71

Sacred Power. (2014). "Home". Albuquerque, New Mexico. Retrieved from http://robert-martin-ydzw.squarespace.com.

SMA Solar Technology AF. (2016a). About SMA. Retrieved from http://www.sma-america.com/products/solarinverters/sunny-boy-3000tl-us-3800tl-us-4000tl-us-5000tl-us-6000tl-us-7000tl-us-7700tl-us.html#Downloads-137455

SMA Solar Technology AG. (2016b). SUNNY BOY 3000TL-US / 3800TL-US / 4000TL-US / 5000TL-US / 6000TL-US / 7000TL-US / 7700TL-US. Retrieved from http://www.sma-america.com/products/solarinverters/sunny-boy-3000tl-us-3800tl-us-4000tl-us-5000tl-us-6000tl-us-7000tl-us-7700tl-us.html#Downloads-137455

The Solar Co. (2015). Schools and Colleges Going Solar? *The Solar Co.* Retrieved from http://www.thesolarco.com/schools-and-colleges-going-solar/

Steinberg, B. (2013). Gas Meter Types for Flow Measurement. Sage Metering. Retrieved from http://sagemetering.com/back-to-basics/gas-meter-types-for-flow-measurement/#.V_gc0egrJPa

Sunpower. (2016). Sunpower E-series Residential Solar Panels. Retrieved from https://us.sunpower.com/sites/sunpower/files/media-library/data-sheets/ds-e20-series-327-residential-solar-panels.pdf

Thomashow, M. (2014). The 2014 ACUPCC climate leadership summit: Why it matters. *Sustainability: The Journal of Record,* 7(4), 177-179.

Trotter, B. (2007, December 20). COA first school to become carbon-neutral. *Bangor Daily News.* Retrieved from http://archive.bangordailynews.com/2007/12/20/coa-first-school-to-become-carbon-neutral/

Tucker, B. (2015). Re-volv(ing) Around Solar. Retrieved from http://www.forbes.com/sites/billtucker/2015/07/09/re-volv-ing-around-solar/#5a9f06a161ff

Uhl, C., & Anderson, A. (2001). Green Destiny: Universities Leading the Way to a Sustainable Future. Retrieved from: http://doi.org/10.1641/0006-3568(2001)051[0036:GDULTW]2.0.CO;2

U.S. Department of Energy. (2016). How to Read Residential Electric and Natural Gas Meters. Washington, D.C.: U.S. Department of Energy. Retrieved from: http://energy.gov/energysaver/how-read-residential-electric-and-natural-gas-meters

U.S. Energy Information Administration (EIA). (2016a). How much carbon dioxide is produced per kilowatthour when generating electricity with fossil fuels? Retrieved from https://www.eia.gov/tools/faqs/faq.cfm?id=74&t=11

U.S. Energy Information Administration (EIA). (2016b). Short-Term Energy Outlook - U.S. Energy Information Administration (EIA). Retrieved from http://www.eia.gov/forecasts/steo/report/electricity.cfm

U.S. Energy Information Administration (EIA). (2016c). Sales Revenue. Retrieved from http://www.eia.gov

Veris Industries. (2006). Veris Industries H8100 Series Commercial Energy Consumption Meters Catalog. Retrieved from http://cgproducts.johnsoncontrols.com/cat_pdf/H8100.PDF

The Wall Street Journal. (2016). London Interbank Offered Rates. New York, NY: *The Wall Street Journal.* Retrieved from http://www.wsj.com/mdc/public/page/2_3020-libor.html

Wesoff, Erik. (2016). Sunpower Holds World Record for Most Efficient Rooftop Solar Panel, Again. *Greentech Media.* Retrieved from: http://www.greentechmedia.com/articles/read/SunPower-Again-Holds-Record-For-Worlds-Most-Efficient-Rooftop-Solar-Panel

Appendix A: Sponsor Description

The Institute of American Indian Arts (2016a) is a private, fine arts college located in the outskirts of Santa Fe, New Mexico. Unlike many colleges that cater to a wide variety of majors and educational paths, the Institute of American Indian Arts has a much narrower focus:

> At [the] IAIA, the spirit and vision of Native American and Alaska Native people is a first priority. Founded in 1962, the Institute of American Indian Arts offers academic excellence to both Native and non-Native populations. Our goal is empowerment through education, economic self-sufficiency and expression and enhancement of artistic and cultural traditions. (¶3)

The mission of the Institute of American Indian Arts (2016f) is "to empower creativity and leadership in Native Arts and cultures through higher education, lifelong learning and outreach."

During the presidency of John F. Kennedy, the Institute of American Indian Arts was established (2016d).

It was first a high school but offered post-graduate art classes before switching to an accredited degree-awarding institution in 1979, offering associates degrees. The Institute's main area of focus was the "study, preservation and dissemination of traditional and contemporary expressions of the Native American language, literature, history, oral traditions and the visual and performing arts" (Institute of American Indian Arts, 2016f). The IAIA has been constantly expanding since then, by adding new buildings and expanded course offerings. The school reached a milestone in 2013 when it began offering its first graduate program.

Currently, the campus consists of more than a dozen buildings situated on a 140-acre campus (Institute of American Indian Arts, 2016c). There is one traditional dormitory of 77 double suites, along with 24 "family housing" two-bedroom apartments housing more than 154 of the 610 students enrolled at the IAIA. The 610 students of the IAIA (2016e) represent 71 federal American Indian tribes, with 39 of 50 US states represented.

In addition to the 610 students at the school, the faculty and staff of the IAIA (2016e), (not including the museum) consist of around 103 active workers. The largest group of the faculty and staff consists of the 24 professors that teach the classes needed to obtain a degree from the school. The possible areas to obtain a degree in are creative writing, studio arts, museum studies, media arts, new media arts, art history, business/entrepreneurship, indigenous liberal studies, and Native American studies. The IAIA also offers general education classes, like math, science and English. Each department has its own department head. Another large portion of staff is for facilities maintenance and conference service, our sponsor, Mr. James Mason, is the director of facilities maintenance operations.

Being a federally appropriated college, the IAIA (2016e) must submit a budget request to the federal government. It outlines all the expected expenses in each department for the upcoming school year. Compared to the budget for the 2014, the 2015 budget request went up by $2.1 million dollars. One hundred thousand dollars was for wage compensation due to a slight increase in the cost of living. The other $2 million was due to a forward funding request. The IAIA made this request due to the recent government shutdown; it is essentially a safety net for the institute in the event of another shutdown. This would provide peace of mind for faculty and students. Overall, the projected budget for the IAIA in 2015 is around $11.469 million, of which, $1.715 million is allocated for facilities operations.

Everyday operations and the future of the institute are the primary responsibilities of the President of the Institute and the Board of Trustees, appointed by the President of the United States, with consent from the United States Senate (Institute of American Indian Arts, 2016b). The board of trustees has the power to approve and create policies for the Institute, and appoint the President of the Institute. The current President of the Institute is Dr. Robert Martin, who is associated with the Cherokee Nation (Institute of American Indian Arts, 2016b)

Although the IAIA does not currently list any sponsoring organizations on its website, it is a member of the American Indian Higher Education Consortium (American Indian Higher Education Consortium, 2016b). The consortium is a group of thirty-seven tribal colleges and universities located throughout the Southwestern United States. The main purpose of the group is to “help ensure the principle of tribal sovereignty is recognized and respected and that the tribal colleges and universities are equitably included in this nation’s higher education system” (American Indian Higher Education Consortium, 2016a).

Appendix B: Existing Gas Meters

Table B-1: Natural Gas Meters on Campus

Building	Existing Meter?	Meter Type	Meter Sizing	Required Meter Capacity (max. CFH)
Academic Building	No	N/A	N/A	7360
Center for Lifelong Education	Yes	Dresser Roots 5M175	5000 CFH max	5000
CLE Residence Center	Yes	Dresser Roots 3M175	3000 CFH max	3000
Facilities	Yes	Itron Metris 250	250 CFH max	250
Family Housing	No	N/A	N/A	2040
Fitness and Wellness	No	N/A	N/A	1780
Foundry	Yes	Dresser Roots 3M175	3000 CFH max	3000
Library	Yes	Dresser Roots 3M175	3000 CFH max	3000
Science and Tech Building	Yes	Itron 1000A/800A	890 CFH max	890
Welcome Center	Yes	Itron 1000A/800A	890 CFH max	890

Appendix C: Gas Meter Sizing

Table C-1: Gas-burning Appliances in Main Academic Building

Equipment	Use	Max BTU/hr	Quantity	Max Total Use (BTU/hr)
A.O. Smith BTR 154 106	Hot Water Heater	154,000	1	154000
Reznor RGB-H250	HVAC unit	108,400	2	216800
Reznor RGBL-1200	HVAC unit	1,170,500	1	1170500
Reznor RGBL-1050	HVAC unit	917,900	1	917900
Reznor RGB-H350	HVAC unit	144,500	1	144500
Reznor RGB-H125	HVAC unit	102,600	1	102600
Reznor RGBL-500	HVAC unit	484,200	1	484200
Reznor RGB-225	HVAC unit	204,000	1	204000
Reznor RGBL-400	HVAC unit	176,900	1	176900
Reznor RGB-H250	HVAC unit	110,300	1	110300
Reznor RGB-H250	HVAC unit	112,500	1	112500
Reznor RGBL-400	HVAC unit	202,200	1	202200
Reznor RGBL-400	HVAC unit	277,400	1	277400
Reznor RGBL-1200	HVAC unit	1,243,700	1	1243700
Reznor RGBL-400	HVAC unit	396,600	1	396600
Reznor RGB-H75	HVAC unit	73,900	2	147800
Reznor RGB-H150	HVAC unit	98,700	2	197400
Reznor RGB-H150	HVAC unit	135,000	1	135000
Reznor RGB-H150	HVAC unit	101,100	1	101100

Equipment	Use	Max BTU/hr	Quantity	Max Total Use (BTU/hr)
Reznor RGB-H150	HVAC unit	138,100	1	138100
Reznor RGB-H75	HVAC unit	46,600	2	93200
Reznor RGBL-800	HVAC unit	780,300	1	780300

Max Building Total (BTU/hr)	7507000
Max Building Total (CFH)	7360

Table C-2: Gas-burning Appliances in Family Housing Units

Equipment	Use	Max BTU/hr	Quantity	Max Total Use (BTU/hr)
Carrier 58 MCA 040-12	Furnace	40,000	26	1040000
A.O. Smith PGCG 40 246	Hot Water Heater	40,000	26	1040000

Max Building Total (BTU/hr)	2080000
Max Building Total (CFH)	2039

Table C-3: Gas-burning Appliances in Fitness and Wellness Center

Equipment	Use	Max BTU/hr	Quantity	Max Total Use (BTU/hr)
A.O. Smith BTR 275A 104	Hot Water Heater	275,000	1	275000
A.O. Smith PGCG 40 246	Hot Water Heater	40,000	1	40000
Reznor RGB-250	HVAC unit	250,000	1	250000
Reznor RGBL-600	HVAC unit	600,000	1	600000
Reznor RGB-H350	HVAC unit	350,000	1	350000
Reznor RGB-300	HVAC unit	300,000	1	300000

Max Building Total (BTU/hr)	1815000
Max Building Total (CFH)	1779

Once all the gas consumption data was compiled, we totaled the maximum use of each building in BTU/hr, highlighted in the first row in each of the green boxes. Since all of the gas meters we were considering were sized in cubic feet per hour (CFH), we thought it would be relevant to convert BTU/hr to CFH. Since there is about 1020 BTUs in a cubic foot, the conversion is straightforward. The maximum usage rate in CFH is highlighted in the second row of each of the green boxes.

Appendix D: Electrical metering options

Table D-1: Electrical Metering Options (EKM Metering Inc, 2016; Veris Industries, 2006; Leviton, 2016; Lumel, 2016; Efergy, 2016; DROK, 2016)

Meter	Cost	Display	Voltage	Amperage	Reading	Manufacturer
EKM - 25IDS	$90.00	LCD	120/240VAC	100	kWh	EKM
Veris H8150-0200-1-1	$313.90	LCD	120/240VAC	200	kWh	Veris
Leviton 1K240-1SW	$347.20	LCD	120/240VAC	100	kWh, demand, kW	Leviton
PCE-N30P	$147.90	LED	0-480V	6	16 different readings	Lumel
Efergy Elite Classic	$119.95	LCD	100-600V	N/A	kW/$	Efergy
Drok Digital	$15.00	LCD	80-260VAC	20	V/A/W/Wh	DROK

Appendix E: The IAIA's Solar Future: A Report on RE-volv's Solar Lease Proposal.

Our research regarding RE-volv's proposal focused mainly on confirming or refuting the claims laid out in their proposal document. The most appealing part of their proposal's claims were that, over the course of the 25-year life of the panels, the system would generate around $100,000 in savings. We found that RE-volv has funded a number of similar lease agreements across the country. Each project seems to have been successful and has been completed to the satisfaction of the leasing entities. Sacred Power, a New Mexico solar contractor, has also completed many solar installations of various sizes. Both of these companies have extensive histories and experience with similar projects, and there is no reason they would not succeed in delivering the IAIA's proposed system.

The RE-volv proposed solar array would consist of 91 Canadian Solar CS6K panels and 7 SMA Sunny Boy string inverters. The CS6K panels are a monocrystalline cell panel, with an efficiency rating of 17% and a 25-year warranty (Canadian Solar, 2016). While 17% is not a bad efficiency for a panel, there are more efficient panels on the market that are above 20% efficiency (Wesoff, 2016). This means that fewer panels can create the same level of energy. While efficiency can be fixed with adjusting the number of panels, the Canadian Solar panels also have a relatively high degradation rate of 0.5% per year, after a 2.5% loss in the first year. The degradation rate is how quickly the silicon loses the ability to convert solar radiation to electricity. Half a percent a year is quite high compared to the national average for monocrystalline panels, which is 0.36% (Jordan & Kurtz, 2013). A lower degradation rate leads to more solar energy produced each year, increasing the yearly savings the arrays generate.

While the solar panels could be more efficient, or degrade slower, the SMA Sunny Boy inverters are top of the line. RE-volv claims the inverters come with a 25-year warranty, whereas SMA only provides a 10-year warranty, with an option to increase it to 20 years (SMA Solar Technology AG, 2016b). These inverters are highly rated by solar magazines and suppliers (Newkirk, 2015). These string inverters will serve the IAIA well, and are an excellent product to use with any solar system.

In RE-volv's proposal, they estimated the IAIA would save $38,735 over the lease period. We completed our own calculations based on the IAIA's energy price history and operating limits for the equipment. RE-volv guarantees the solar arrays will operate above or at 90% efficiency, and anything below that is credited to the IAIA. We assumed the solar panels would operate at 90% efficiency for the lease period, as 100% cannot be guaranteed. We then based our model on the IAIA's past payments to PNM, and average energy usage. The energy produced by the solar arrays each year, including the loss each year due to degradation, was then calculated and used to determine how much the IAIA would save each year on energy bills. The total savings were then calculated, and subtracted from the total amount the IAIA would spend on the lease. Assuming the two best case scenarios, of optimistic power generation and a higher percent increase for the price of electricity, the IAIA could save up to $36,000. Assuming the opposite scenarios of low power generation and a lower percent increase for the price of electricity, the IAIA could lose up to $2,400 after their total lease payments.

While this RE-volv proposal has the potential to return a net financial benefit, and would bring solar energy to the IAIA, we believe there are much better technologies and companies in Santa Fe that can provide the IAIA with better service. We also believe that by using a different solar installer the IAIA can save more on energy costs and create a more appealing system that can be advertised to future investors or donors of the school. In conclusion, we do not think that the IAIA should agree to RE-volv's proposal and that better options exist for expanding the IAIA's solar energy.

Section 1: The Introduction

For the past six years, the IAIA has committed to green energy reform and carbon savings. In the past two years the IAIA has retrofitted lighting systems, installed electrical meters, and planned new buildings with green technology. In 2010, the IAIA signed an agreement and set forth a plan to make the school carbon neutral by 2050. Installing solar energy solar technologies is important to achieving this goal, and the IAIA could begin realizing the benefits from solar projects today.

In the summer of 2016, RE-volv, a solar financing company, presented a proposal to the IAIA to install a solar energy system on the roof of the Center for Lifelong Education Residence Center. RE-volv would provide the upfront capital to purchase and install the necessary equipment and lease the system back to the IAIA over twenty years. The IAIA asked us to evaluate the merits of the proposal and make a recommendation on whether they should proceed with this proposal. To evaluate this proposal, we examined the capability, experience and viability of the companies, the quality and performance of the proposed technologies, and the overall economic benefits for the IAIA.

Section 2: The Companies

Two companies working in partnership, RE-volv and Sacred Power, proposed this solar project. To install the solar arrays, RE-volv would provide the capital to buy the necessary materials for the system and pay Sacred Power to install it. We were initially concerned with RE-volv's and Sacred Power's ability and experience to complete this project.

RE-volv is a non-profit organization founded in 2011, and is exempt from taxation under section 501(c)(3) of the Internal Revenue Code (Tucker, 2015). RE-volv's slogan is "people-funded renewable energy" (RE-volv, 2016, ¶8). Since 2011, most of their projects have been located in San Francisco but recently have expanded to other states, including Wisconsin, Ohio and, Pennsylvania. Once RE-volv crowdfunds the capital, they purchase the panels and associated hardware, then a local solar contractor installs the equipment; RE-volv then owns the arrays and all associated hardware. RE-volv then leases the panels to the organizations that they are working with, and over the course of twenty years, RE-volv assumes the maintenance and operational costs (Tucker, 2015). RE-volv recently completed funding a 22 kilowatt array at the Kehilla Community Synagogue in San Francisco (Hughes, 2014). Sunwork, another San Francisco based company, installed the system. RE-volv estimated that the synagogue would save $130,000 over the next twenty years. RE-volv reinvested the lease payments from Kehilla to finance three new solar projects: systems built at The Serenity House, a community outreach center in North Philadelphia, The Riverwest Co-op Grocery & Cafe in Milwaukee, and the Isla Vista Food Cooperative in Isla Vista, California. RE-volv has had a number of successful projects of similar size and scale and we could find no reasons to believe that they would be less successful serving the IAIA.

Sacred Power (2014), a New Mexico solar energy contractor, would install the solar arrays, and would be responsible for maintaining the system during the twenty-year lease. The company was established in 2001, is located in Albuquerque, and is the largest Native American owned and operated renewable energy systems integration and manufacturing firm in the U.S. Sacred Power is a North American Board of Certified Energy Practitioners certified installer of solar photovoltaic and solar hot water systems, proving that they are qualified to install photovoltaic systems on most buildings and in most areas. Sacred Power has an extensive project history, working with numerous government and public facilities nationwide including the US Navy, the DOD, NASA, and the National Guard. The 21 kilowatt, grid-tied, solar photovoltaic system consisting of nearly two dozen carports at Fort Bliss in El Paso, Texas, is one of Sacred Power’s most well-known projects (Sacred Power, 2014; Robinson-Avila, 2013). Sacred Power also has a foothold in the private sector. In 2013, the company reached a deal with The Home Depot to begin selling its patented portable solar systems in stores in New Mexico, with plans to sell them nationwide (Robinson-Avila, 2013). Sacred Power has installed many solar projects of similar size, type, and scale, and we could find no reason to believe they would be unable to install the proposed system.

Section 3: The Equipment

To create the 25 kilowatt system Sacred Power would install 91 Canadian Solar CS6K-280M panels along with seven SMA Sunny Boy 4000TL AC/DC inverters. Specific datasheet about these two models can be found in Appendix H and Appendix I respectively.

Canadian Solar (2016) is a well-known and trusted solar panel manufacturer that produces a variety of panels and home solar options. The CS6K panels are a monocrystalline solar cell that are 17 percent efficient at converting solar energy into usable electricity. RE-volv and Sacred Power plan to install the solar array in seven strings of thirteen panels each. An SMA inverter would tie each string into the IAIA’s power grid.

SMA is a German based company that has been in the electrical inverter manufacturing business since 1985 (SMA Solar Technology AF, 2016a). The Sunny Boy inverters have been in production for the past six years and are at the top of “premium” lists of string inverters. The inverters get high ratings for quality and product service (Newkirk, 2015). The inverters that RE-volv plans to use would support converting up to four thousand watts each from the DC power emitted by the panels to usable AC energy. This power would then be able to enter the IAIA’s energy grid where it can be consumed.

All of the equipment Re-volv and Sacred Power plan to install is high quality and durable. The Canadian Solar (2016) panels have a 25-year performance warranty and a 10-year product warranty. The SMA inverters come with a 10-year warranty that can be extended to 20 years, which is much greater than most inverter warranties (SMA Solar Technology AG, 2016b).

While the CS6K panels are not the most efficient panels on the market, they would work well in this system and would provide the expected energy to the system. The SMA Inverters are top of the line, and highly rated. They also carry a much longer warranty than other similar inverter choices.

Section 4: Specifications and Costs

The proposal from Re-volv briefly introduced their plans and the benefit for IAIA. The planned PV system would have 25.48 kW of power and would produce 43,487 kWh in the first year. RE-volv claimed a 0.5% degradation of the solar panels each year. Degradation is the rate at which the silicon in the panels lose the ability to generate electricity. However, we found different values for the degradation of the solar panels. According the National Renewable Energy Laboratory (NREL) (Jordan & Kurtz, 2013), monocrystalline solar panels like the Canadian Solar panels, degrade at a national average of about 0.36% each year. However, based on test data provided by Canadian Solar (2016), the panels actually degrade 2.5% in the first year, and 0.5% every year thereafter. The Canadian Solar panels underperform compared to other panels in a similar price and technology range. A lower degradation rate is recommended as more energy can be produced each year, decreasing the rate of return, increasing the future value, and the energy credits of the system.

Once the system is installed, RE-volv's lease would begin. Under the leasing conditions, the IAIA would pay a monthly lease, totaling $3,761 a year. The lease payments will increase by 2.9% each year, for 20 years. Projecting these costs over the 20-year lease, the IAIA would pay RE-volv a total of $100,026.06. One way to gauge whether or not the project would be worthwhile to the IAIA is to calculate the Net Present Value of the investment. The net present value (NPV) of a cash flow is a way to find the present value of a future sum of money (Gallo, 2014). In Appendix J, we created a table to outline the cash flow of the lease period. For our interest rate, we used the 12 month libor, from October 1st, 2016, plus 2%, which gives us an interest rate of 3.55% (The Wall Street Journal, 2016). Using the NPV formula in excel, we were able to discount each year's cash flow back to the value of money at year zero. When totaling the present value of each year's cash flow, you get the total NPV. In the case of the lease proposal, if the IAIA opts to accept the lease instead of spending $100,000 out of pocket, they, in theory, have the ability to invest it instead. If the IAIA invested at 3.55%, they would generate $31,566 in addition to the savings from the electricity produced by the solar array. This means that if the IAIA was going to purchase a $100,000 solar array on their own, the real cost would be $131,566.

Since a 25 kW system is larger than a residential project, it will cost more upfront for equipment and labor, but the system is much smaller than commercial projects, meaning this in-between project cannot benefit from the lower cost per Watt installed that larger systems provide. A 10 kW residential system can cost as little as $3.50 per Watt, and commercial systems cost even less (Clover, 2016). The turnkey cost per installed Watt for this project is about $4 per Watt, which is reasonable for an installation that is in between typical residential and commercial projects in size. When we asked Sunpower, the most prominent solar installer in Santa Fe, what a similar sized system would cost, they estimated about $4 per Watt (Dan Baker, personal communication, September 13, 2016), which also aligns with RE-volv's proposal. Since a system of this size would cost approximately $100,000 without RE-volv, the financial benefit of this proposal comes from the fact that the costs of the project are spread out over 20 years.

RE-volv provided calculations on the projected savings for the IAIA. They calculated these savings by assuming the cost of electricity starts at $0.096/kWh, and increases at an annual rate of five percent. Using these values, RE-volv projects that the IAIA would save approximately $38,735 over the 20-year lease period and $100,259 over 25 years. Twenty-five years is the warranty period for all the equipment that Sacred Power would install. To check the accuracy of RE-volv's calculations we researched the actual cost of energy and the actual yearly rate of increase of the cost of electricity per kilowatt-hour.

Using historical data for the past 25 years, for electricity rates from the Public Service Company of New Mexico (PNM), we were able to determine a percent increase for different lengths of time. RE-volv estimated that energy costs would increase yearly at a five percent rate. When looking at the past five years, the cost of energy increased at a rate of 5.4%. Table E-1, below, shows the results of our calculations. A full set of these calculations can be found in Appendix F.

Table E-1: Calculated Rates of Energy Cost Increases by Percentage over 25 years

Time Period	Start Year	End year	Percent
5	2010	2014	5.4
10	2005	2014	4.2
15	2000	2014	3.2
20	1995	2014	2.2
25	1990	2014	1.6

As shown in Table D-, the farther back the period reaches, the rate of increase becomes lower. The first three data sets are the most usable for any financial calculations, as the data before the year 2000 do not follow a similar trend compared to the next fifteen years, as depicted in Figure E-1, below.

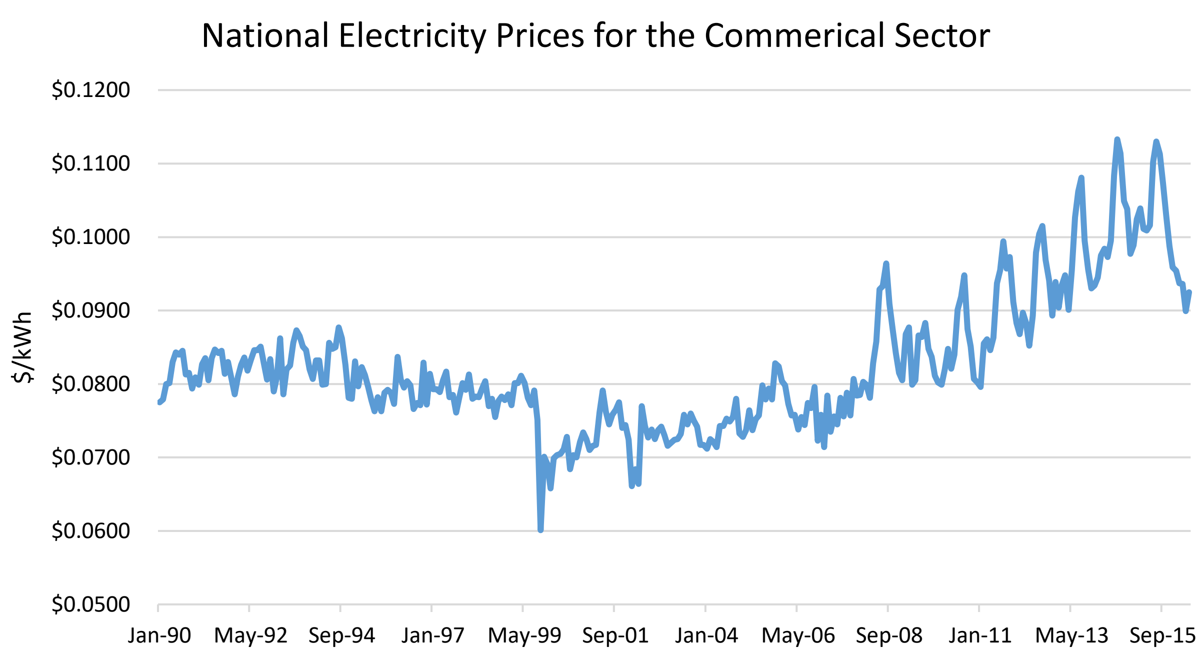


Figure E-1: Commercial/Institutional Electricity Prices Over Twenty-Five Years (U.S. Energy Information Administration, 2016c)

After eliminating the first ten years' worth of data, we took the remaining percentages, and calculated the expected costs vs. savings for each percentage at the expected degradation pattern. These final costs or savings over the twenty-year lease, after paying RE-volv the total lease payment, are displayed in Table E-2. Our full calculations can be found in Appendix G.

Table E-2: 20-year Savings/Losses after Lease Payments

	Optimistic Power	Guaranteed Power
Avg. 5-Year/ 5.4%	$35,919.44	$22,324.89
Avg. 15-Year/ 3.2%	$8,426.79	-$2,418.50

The optimistic and guaranteed power variables are taken from RE-volv's proposal. Their system is expected to produce 43,487 kWh (RE-volv & Sacred Power, 2016). With the variability in weather and system functions, RE-volv set a guaranteed production value at 90% efficiency, or 39,138 kWh for the first year. This means that if the solar arrays operate at less than 90% efficiency, RE-volv will repay for the electricity the IAIA had to spend while the system was below that threshold. This efficiency difference, 4,349 kWh, at $0.096/kWh, is $417 of possible savings that is lost. If the panels operate closer to 90% for the lease period, the IAIA will spend roughly $8,340 on purchasing power from PNM that the solar arrays could have produced instead.

With the highest rate increase for energy costs, and the system operating at 100% efficiency, the IAIA can expect to save around $36,000. But using all worst case scenarios the IAIA would lose up to $2,418. Both of these assumptions predict that the cost of energy would linearly increase for the next twenty years, whereas the data in Figure 5.1 shows that the cost of energy is anything but linear.

After identifying the potential outcomes, we then attempted to determine the percent increase in energy costs that would cause this project to have not net cost or savings for the IAIA. After testing various percent increases in electricity rates, we managed to find the rate of increase that allowed the total savings or costs to be under one dollar. With a 90% effective system, the IAIA will have a net zero gain on this project if energy costs increase at approximately 3.44% a year. If the system operates close to 100% for its lifetime, a 2.38% will return no savings or costs.

PNM is currently attempting to increase electricity rates by 3.73% for the IAIA's rate plan next year. If local energy costs follow this trend every year, and the panels operate above the lower limit of 90%, the IAIA can expect to generate a positive return on investment.

Summing up all the financial calculations, it is very possible that this project would save the IAIA more money than they would spend. Since it is unlikely the solar panels would greatly underperform, and it is very likely, given recent data, that energy prices would continue to increase at a percentage above the zero limit we calculated, we expect to see a positive net gain after the twenty-year lease.

Section 5: The Verdict

As discussed in the previous sections, RE-volv's proposal is likely to be a beneficial deal for the IAIA. The equipment, while not uniformly top of the line, is quite good for the price and is considered quite reliable. The companies involved, RE-volv and Sacred Power, both have experience with projects of this size or larger. According to our calculations and the ones done by RE-volv in the proposal document, the solar system is likely to produce a positive return on investment over the lease period. In comparison to doing nothing, this proposal would bring solar technology to the IAIA and could save the IAIA several thousand dollars in energy bills, even while paying off the lease.

However, our research has indicated that the IAIA could find additional savings by going elsewhere to install solar panels on the roof of the CLE Residence Center. There are various technologies that could lower the costs of installing, such as using micro-inverters, a different mounting system, or even expanding the size of the system. The proposed twenty-five kilowatt system would cost approximately $4 per installed Watt, not only for RE-volv, but for the IAIA as well since they would pay off the system over twenty years. A 25kW system is much larger than residential scaled systems, which are about 5 to 10 kW. It is also much smaller than any commercial installations, which are above 100kW. Most large commercial systems cost around or less than $3 per Watt, because of the fixed labor cost for balancing any sized solar system (Chung, Davidson, Fu, Ardani, &Margolis, 2015). A large system has fewer "soft costs," or costs that are not directly hardware but have a fixed value. This includes balancing the system, interconnecting the system, and having the system inspected. On larger systems, these relatively fixed costs matter less in terms of costs per Watt, but on smaller systems, including a 25kW system, these costs can be very high.

We feel the IAIA has much more solar potential for their campus, and this RE-volv deal would limit the solar future of the IAIA. If the IAIA leases this system, they will have no control over it for 20 years. The IAIA cannot upgrade the technologies or build upon the existing system to increase their solar capacity, which is important for the IAIA to save even more on energy costs, and limit their carbon emission baseline. If the IAIA uses up other available lands and attempts to install more solar technology in Re-volv's system area, they will run into a problem trying to tie any new installation in with the existing solar system, because during that 20-year lease period, the IAIA does not own the panels or any associated equipment. Any new solar technology that the IAIA wants to install on the same roof would require the IAIA to try to seek permission from RE-volv to expand the system.

Any other system installed by the IAIA has more flexibility and potential for increased energy generation for two reasons, the array can be larger than the 25kW system proposed by RE-volv, and it could incorporate carports. Solar carports are an excellent way of generating solar energy, while also providing an advertising tool. Investors to a solar carport project will have a tangible product to look at and can peak interest in solar to fund expanding solar on campus. These carports could even hold student art on the outside, to provide students with more ways of presenting their art, while attempting to keep with the aesthetic on campus. While carports provide a good advertising tool, rooftop solar remains the most cost efficient solar option. We recommend the IAIA invest in their solar potential through phases. These phases are made up of solar installations, of similar size to the RE-volv deal, or smaller, that can generate interest in solar and fund other phases. The first phase should be a “pilot project” to highlight the solar future of the IAIA and peak investor interest. This pilot project could be relatively small, a simple carport or a small rooftop system. Then, the IAIA could market where it wants to go with its solar future to interested donors and investors who can help fund an even larger project to install more carports, or make the roof of one or more buildings completely solar the possibilities at the IAIA are endless.

Appendix F: Economic Model for Electricity Prices

In Re-volv's proposal, they assumed that the price of electricity would rise by 5% annually. Initially this seemed like a very large rate of increase for energy prices, so we decided to look into its accuracy. In order to get an idea of a more realistic rate, we downloaded the commercial/institutional electricity prices recorded in New Mexico over the last 25 years and analyzed them.

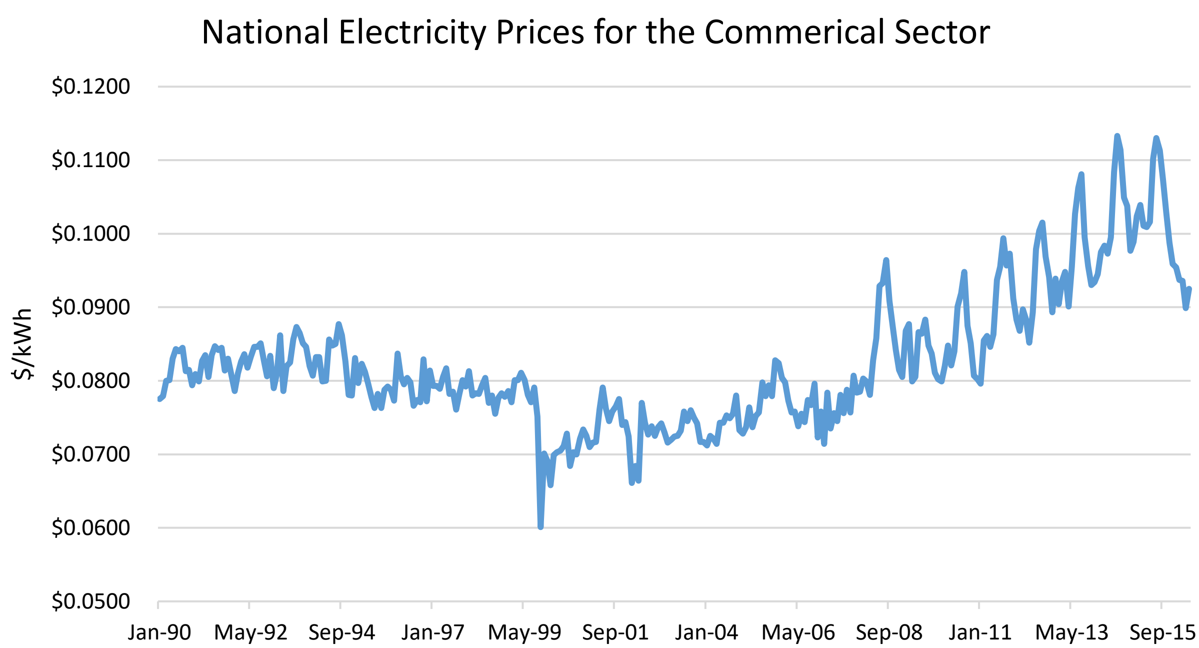


Figure F-1: Commercial/Institutional Electricity Prices Over Twenty-Five Years (U.S. Energy Information Administration, 2016c)

The graph above shows the energy prices over that last 25 years, starting from 1990, going until 2016. Between 1990 and 2000, the price for energy remained relatively constant, hovering around $0.08 per kilowatt-hour. Around 2000, energy prices began to rise. Because of the irregularities of the rate at which the energy prices rise, we decided not to use the average rate of increase over the whole 25 years because it is considerably lower due the segment of relatively constant prices for the first ten years. Instead, we thought it would be it would be more relevant to look at the data from 2000 forward, since RE-volv had assumed that energy prices would increase at a rate of 5% over the twenty-year lease period. If you look at the 15-year data, you find that the average annual rate of energy price increase is 3.2%. If you look at the ten-year data, the average annual rate of energy price increase is 4.2% and finally, if you look at the 5-year data, the average annual rate of energy price increase is 5.4%, which is closest to what RE-volv assumed.

Appendix G: Savings Calculations

Appendix F develops our own economic model for predicting how electricity prices will increase over the life of the solar array. With that in hand, we can now recalculate how much the solar array would save the IAIA over the life of the lease.

Before the real calculation starts, the performance rate of solar panels need to be referred. In Re-volv's proposal, the promised performance rate starts at 39,138 kWh in the first year, with the amount reducing by 0.5% of the initial value each year, which means if the whole system produces less this prediction, Re-volv will compensate the value of the energy lost. RE-volv also predicted a more optimistic rate of energy production starting at 43486 kWh in the first year.

The timespan of our savings calculations is for the 20-year lease period. After the lease payments is when the solar array with generate the most savings, as the IAIA is no longer paying RE-volv. But after 20 years, it is highly possible this solar system will be severely outdated, and technology in energy creation may have advanced to the point to make this system obsolete, especially the 17% efficient panels. Therefore, we assumed the system would need replacing at year 20.

Using the percent increase of energy cost, and a starting cost of energy of $0.096/kWh, we predicted how the cost of energy would increase over the 20 years.

Model equations:

Year 2 Solar Energy = $(39138\ kWh) - (0.05 \times 39138\ kWh) = 38942\ kWh$

Year 3 Solar Energy = $(38160\ kWh) - (0.05 \times 39138\ kWh) = 38747\ kWh$

Table G-1: Assumptions for Calculating Economic Savings

Assumptions	Value	Units
Percent Increase of energy costs	5.4	%
Starting cost of energy	0.096	$/kWh
Starting energy produced by solar	39138	kWh
Degradation rate (RE-volv Guarantee)	0.5	%
Interest rate (annually)	2.9	%

Table G-2: Table of Savings Calculations

Year	Cost of energy (annual avg)	Solar Energy Produced per year	Value of energy saved	Payments to RE-volv	Savings	
	$/kWh	kWh	$	$	$	
0 (2016)	0.0960	0	$0.00	$0.00	$0.00	
1	$0.096	39,138	$3,757.25	$3,761	-$3.31	
2	$0.101	38,942	$3,940.34	$3,870	$70.72	
3	$0.107	38,747	$4,132.25	$3,982	$150.41	
4	$0.112	38,551	$4,333.39	$4,097	$236.08	
5	$0.118	38,355	$4,544.21	$4,216	$328.08	
6	$0.125	38,160	$4,765.16	$4,338	$426.76	
7	$0.132	37,964	$4,996.72	$4,464	$532.51	
8	$0.139	37,768	$5,239.40	$4,594	$645.73	
9	$0.146	37,572	$5,493.71	$4,727	$766.82	
10	$0.154	37,377	$5,760.22	$4,864	$896.25	
11	$0.162	37,181	$6,039.48	$5,005	$1,034.46	
12	$0.171	36,985	$6,332.11	$5,150	$1,181.94	
13	$0.180	36,790	$6,638.73	$5,300	$1,339.20	
14	$0.190	36,594	$6,960.00	$5,453	$1,506.79	
15	$0.200	36,398	$7,296.61	$5,611	$1,685.26	
16	$0.211	36,203	$7,649.28	$5,774	$1,875.20	
17	$0.223	36,007	$8,018.76	$5,942	$2,077.23	
18	$0.235	35,811	$8,405.84	$6,114	$2,292.01	
19	$0.247	35,616	$8,811.35	$6,291	$2,520.21	
20	$0.261	35,420	$9,236.13	$6,474	$2,762.55	
					$22,324.89	Total Savings

Appendix H: Canadian Solar CS6K Solar Panel Data Sheet

Available from: http://www.canadiansolar.com/fileadmin/user_upload/downloads/datasheets/v5.4/Canadian_Solar-Datasheet-CS6KM_v5.4C1en.pdf

CanadianSolar

CS6K-270|275|280M

The high quality and reliability of Canadian Solar's modules is ensured by 15 years of experience in module manufacturing, well-engineered module design, stringent BOM quality testing, an automated manufacturing process and 100% EL testing.

*Black frame product can be provided upon request.

KEY FEATURES

- Excellent module efficiency of up to 17.11 %
- Outstanding low irradiance performance: 96.5 %
- +5Wp Positive power tolerance of up to 5 W
- High PTC High PTC rating of up to 90.93 %
- IP67 junction box for long-term weather endurance
- Heavy snow load up to 5400 Pa, wind load up to 2400 Pa
- Salt mist, and ammonia resistance, for seaside, and farm environments*

25 years linear power output warranty

10 years product warranty on materials and workmanship

MANAGEMENT SYSTEM CERTIFICATES*

ISO 9001:2008 / Quality management system
ISO/TS 16949:2009 / The automotive industry quality management system
ISO 14001:2004 / Standards for environmental management system
OHSAS 18001:2007 / International standards for occupational health & safety

PRODUCT CERTIFICATES*

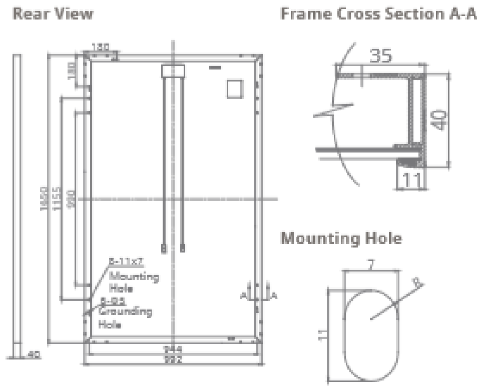
IEC 61215 / IEC 61730: VDE / CE / MCS / CEC AU
UL 1703 / IEC 61215 performance: CEC listed (US)
UL 1703: CSA / IEC 61701 ED2: VDE / IEC 62716: VDE / Take-e-way

* As there are different certification requirements in different markets, please contact your local Canadian Solar sales representative for the specific certificates applicable to the products in the region in which the products are to be used.

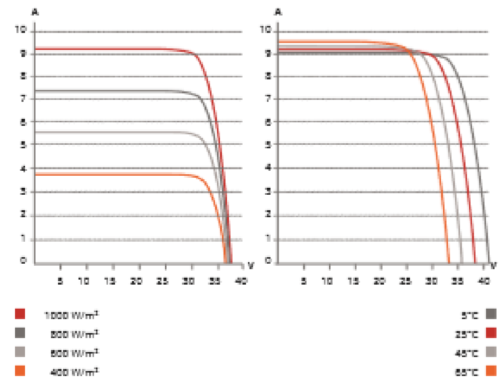
CANADIAN SOLAR INC. is committed to providing high quality solar products, solar system solutions and services to customers around the world. As a leading manufacturer of solar modules and PV project developer with over 14 GW of premium quality modules deployed around the world since 2001, Canadian Solar Inc. (NASDAQ: CSIQ) is one of the most bankable solar companies worldwide.

CANADIAN SOLAR INC.
545 Speedvale Avenue West, Guelph, Ontario N1K 1E6, Canada, www.canadiansolar.com, support@canadiansolar.com

ENGINEERING DRAWING (mm)



CS6K-270M / I-V CURVES



ELECTRICAL DATA / STC*

CS6K	270M	275M	280M
Nominal Max. Power (Pmax)	270 W	275 W	280 W
Opt. Operating Voltage (Vmp)	31.1 V	31.3 V	31.5 V
Opt. Operating Current (Imp)	8.67 A	8.80 A	8.89 A
Open Circuit Voltage (Voc)	38.2 V	38.3 V	38.5 V
Short Circuit Current (Isc)	9.19 A	9.31 A	9.43 A
Module Efficiency	16.50 %	16.80 %	17.11 %
Operating Temperature	-40°C ~ +85°C		
Max. System Voltage	1000 V (IEC) or 1000 V (UL)		
Module Fire Performance	TYPE 1 (UL 1703) or CLASS C (IEC 61730)		
Max. Series Fuse Rating	15 A		
Application Classification	Class A		
Power Tolerance	0 ~ + 5 W		

* Under Standard Test Conditions (STC) of irradiance of 1000 W/m², spectrum AM 1.5 and cell temperature of 25°C.

ELECTRICAL DATA / NOCT*

CS6K	270M	275M	280M
Nominal Max. Power (Pmax)	195 W	199 W	202 W
Opt. Operating Voltage (Vmp)	28.4 V	28.5 V	28.7 V
Opt. Operating Current (Imp)	6.87 A	6.95 A	7.04 A
Open Circuit Voltage (Voc)	35.0 V	35.1 V	35.3 V
Short Circuit Current (Isc)	7.44 A	7.54 A	7.63 A

* Under Nominal Operating Cell Temperature (NOCT), irradiance of 800 W/m², spectrum AM 1.5, ambient temperature 20°C, wind speed 1 m/s.

PERFORMANCE AT LOW IRRADIANCE

Industry leading performance at low irradiance, average relative efficiency of 96.5 % from an irradiance of 1000 W/m² to 200 W/m² (AM 1.5, 25°C).

The specification and key features described in this datasheet may deviate slightly and are not guaranteed. Due to on-going innovation, research and product enhancement, Canadian Solar Inc. reserves the right to make any adjustment to the information described herein at any time without notice. Please always obtain the most recent version of the datasheet which shall be duly incorporated into the binding contract made by the parties governing all transactions related to the purchase and sale of the products described herein.
Caution: For professional use only. The installation and handling of PV modules requires professional skills and should only be performed by qualified professionals. Please read the safety and installation instructions before using the modules.

MECHANICAL DATA

Specification	Data
Cell Type	Mono-crystalline, 6 inch
Cell Arrangement	60 (6×10)
Dimensions	1650×992×40 mm (65.0×39.1×1.57 in)
Weight	18.2 kg (40.1 lbs)
Front Cover	3.2 mm tempered glass
Frame Material	Anodized aluminium alloy
J-Box	IP67, 3 diodes
Cable	4 mm² (IEC) or 4 mm² & 12 AWG 1000 V (UL), 1000 mm (39.4 in)
Connectors	Friends PV2a (IEC), Friends PV2b (IEC / UL)
Standard Packaging	26 pieces, 520 kg (1146.4 lbs) (quantity & weight per pallet)
Module Pieces per Container	728 pieces (40' HQ)

TEMPERATURE CHARACTERISTICS

Specification	Data
Temperature Coefficient (Pmax)	-0.41 % / °C
Temperature Coefficient (Voc)	-0.31 % / °C
Temperature Coefficient (Isc)	0.053 % / °C
Nominal Operating Cell Temperature	45±2 °C

PARTNER SECTION

Appendix I: SMA Sunny Boy Inverter Datasheet

Available from: http://files.sma.de/dl/18726/SB5000TL-US-DUS163951W.pdf

SUNNY BOY 3000TL-US / 3800TL-US /4000TL-US /
5000TL-US / 6000TL-US / 7000TL-US / 7700TL-US

Certified
- UL 1741 and 1699B compliant
- Integrated AFCI meets the requirements of NEC 2011 690.11

Innovative
- Secure Power Supply provides daytime power during grid outages

Powerful
- 97.6% maximum efficiency
- Wide input voltage range
- Shade management with OptiTrac Global Peak MPP tracking

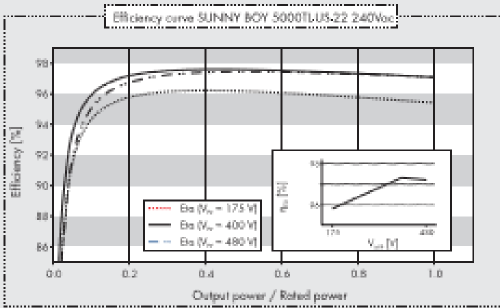
Flexible
- Two MPP trackers provide numerous design options
- Extended operating temperature range

SUNNY BOY 3000TL-US / 3800TL-US /4000TL-US / 5000TL-US / 6000TL-US / 7000TL-US / 7700TL-US

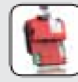
Setting new heights in residential inverter performance

The Sunny Boy 3000TL-US/3800TL-US/4000TL-US/5000TL-US/6000TL-US/7000TL-US/7700TL-US represents the next step in performance for UL certified inverters. Its transformerless design means high efficiency and reduced weight. Maximum power production is derived from wide input voltage and operating temperature ranges. Multiple MPP trackers and OptiTrac™ Global Peak mitigate the effect of shade and allow for installation at challenging sites. The unique Secure Power Supply feature provides daytime power in the event of a grid outage. High performance, flexible design and innovative features make the Sunny Boy TL-US series the first choice among solar professionals.

Technical data	Sunny Boy 3000TL-US		Sunny Boy 3800TL-US		Sunny Boy 4000TL-US	
	208 V AC	**240 V AC**	**208 V AC**	**240 V AC**	**208 V AC**	**240 V AC**
Input (DC)						
Max. usable DC power (@ cos φ = 1)	3200 W		4200 W		4200 W	
Max. DC voltage	600 V		600 V		600 V	
Rated MPPT voltage range	175 – 480 V		175 – 480 V		175 – 480 V	
MPPT operating voltage range	125 – 500 V		125 – 500 V		125 – 500 V	
Min. DC voltage / start voltage	125 V / 150 V		125 V / 150 V		125 V / 150 V	
Max. operating input current / per MPP tracker	18 A / 15 A		24 A / 15 A		24 A / 15 A	
Number of MPP trackers / strings per MPP tracker	2 / 2					
Output (AC)						
AC nominal power	3000 W		3330 W	3840 W	4000 W	
Max. AC apparent power	3000 VA		3330 VA	3840 VA	4000 VA	
Nominal AC voltage / adjustable	208 V / ●	240 V / ●	208 V / ●	240 V / ●	208 V / ●	240 V / ●
AC voltage range	183 – 229 V	211 – 264 V	183 – 229 V	211 – 264 V	183 – 229 V	211 – 264 V
AC grid frequency; range	60 Hz / 59.3 – 60.5 Hz		60 Hz / 59.3 – 60.5 Hz		60 Hz / 59.3 – 60.5 Hz	
Max. output current	15 A		16 A		20 A	
Power factor (cos φ)	1		1		1	
Output phases / line connections	1 / 2		1 / 2		1 / 2	
Harmonics	< 4%		< 4%		< 4%	
Efficiency						
Max. efficiency	97.2%	97.6%	97.2%	97.5%	97.2%	97.5%
CEC efficiency	96.5%	96.5%	96.5%	97.0%	96.5%	97.0%
Protection devices						
DC disconnection device	●					
DC reverse-polarity protection	●					
Ground fault monitoring / Grid monitoring	● / ●					
AC short circuit protection	●					
All-pole sensitive residual current monitoring unit	●					
Arc fault circuit interrupter (AFCI) compliant to UL 1699B	●					
Protection class / overvoltage category	I / IV					
General data						
Dimensions (W / H / D) in mm (in)	490 / 519 / 185 (19.3 / 20.5 / 7.3)					
DC Disconnect dimensions (W / H / D) in mm (in)	187 / 297 / 190 (7.4 / 11.7 / 7.5)					
Packing dimensions (W / H / D) in mm (in)	617 / 597 / 266 (24.3 / 23.5 / 10.5)					
DC Disconnect packing dimensions (W / H / D) in mm (in)	370 / 240 / 280 (14.6 / 9.4 / 11.0)					
Weight / DC Disconnect weight	24 kg (53 lb) / 3.5 kg (8 lb)					
Packing weight / DC Disconnect packing weight	27 kg (60 lb) / 3.5 kg (8 lb)					
Operating temperature range	–40 °C ... +60 °C (–40 °F ... +140 °F)					
Noise emission (typical)	≤ 25 dB(A)		< 25 dB(A)		< 25 dB(A)	
Internal consumption at night	< 1 W		< 1 W		< 1 W	
Topology	Transformerless		Transformerless		Transformerless	
Cooling	Convection		Convection		Convection	
Electronics protection rating	NEMA 3R		NEMA 3R		NEMA 3R	
Features						
Secure Power Supply	●		●		●	
Display: graphic	●		●		●	
Interfaces: RS485 / Speedwire/Webconnect	○/○		○/○		○/○	
Warranty: 10 / 15 / 20 years	●/○/○		●/○/○		●/○/○	
Certificates and permits (more available on request)	UL 1741, UL 1998, UL 1699B, IEEE1547, FCC Part 15 (Class A & B), CAN/CSA C22.2 107.1-1					
NOTE: US inverters ship with gray lids						
Type designation	SB 3000TL-US-22		SB 3800TL-US-22		SB 4000TL-US-22	



Accessories



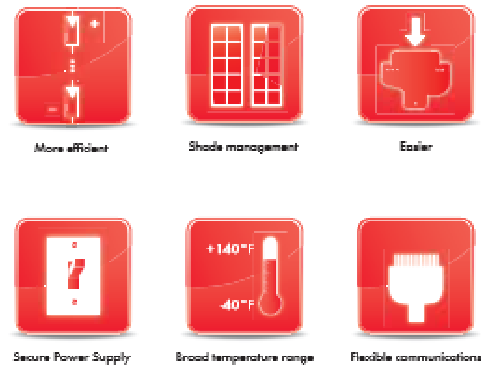
Speedwire/Webconnect Interface SWDM-US-10

RS485 interface DM-485CB-US-10

Fan kit for SB 3000/3800/4000/5000TL-US-22 FANKIT02-10

● Standard feature ○ Optional feature – Not available
Data at nominal conditions

Sunny Boy 5000TL-US		Sunny Boy 6000TL-US		Sunny Boy 7000TL-US		Sunny Boy 7700TL-US	
208 V AC	240 V AC	208 V AC	240 V AC	208 V AC	240 V AC	208 V AC	240 V AC
5300 W		6300 W		7300 W		8000 W	
600 V		600 V		600 V		600 V	
175 - 480 V		210 - 480 V		245 - 480 V		270 - 480 V	
125 - 500 V		125 - 500 V		125 - 500 V		125 - 500 V	
125 V / 150 V		125 V / 150 V		125 V / 150 V		125 V / 150 V	
30 A / 15 A		30 A / 15 A		30 A / 18 A		30 A / 18 A	
2 / 2							
4550 W	5000 W	5200 W	6000 W	6000 W	7000 W	6650 W	7680 W
4550 VA	5000 VA	5200 VA	6000 VA	6000 VA	7000 VA	6650 VA	7680 VA
208 V / ●	240 V / ●	208 V / ●	240 V / ●	208 V / ●	240 V / ●	208 V / ●	240 V / ●
183 - 229 V	211 - 264 V	183 - 229 V	211 - 264 V	183 - 229 V	211 - 264 V	183 - 229 V	211 - 264 V
60 Hz / 59.3 - 60.5 Hz		60 Hz / 59.3 - 60.5 Hz		60 Hz / 59.3 - 60.5 Hz		60 Hz / 59.3 - 60.5 Hz	
22 A		25 A		29.2 A		32 A	
1		1		1		1	
1 / 2		1 / 2		1 / 2		1 / 2	
< 4%		< 4%		< 4%		< 4%	
97.2%	97.6%	97.0%	97.4%	96.8%	96.8%	96.8%	97.3%
96.5%	97.0%	96.5%	97.0%	96.5%	96.5%	96.5%	96.5%
●							
●							
● / ●							
●							
●							
●							
I / IV							
490 / 519 / 185 (19.3 / 20.5 / 7.3)							
187 / 297 / 190 (7.4 / 11.7 / 7.5)							
617 / 597 / 266 (24.3 / 23.5 / 10.5)							
370 / 240 / 280 (14.6 / 9.4 / 11.0)							
24 kg (53 lb) / 3.5 kg (8 lb)							
27 kg (60 lb) / 3.5 kg (8 lb)							
-40 °C ... +60 °C (-40 °F ... +140 °F)							
< 29 dB(A)		< 29 dB(A)		< 29 dB(A)		< 29 dB(A)	
< 1 W		< 1 W		< 1 W		< 1 W	
Transformerless		Transformerless		Transformerless		Transformerless	
Convection		Fan		Fan		Fan	
NEMA 3R		NEMA 3R		NEMA 3R		NEMA 3R	
●		●		●		●	
●		●		●		●	
○/○		○/○		○/○		○/○	
●/○/○		●/○/○		●/○/○		●/○/○	
UL 1741, UL 1998, UL 1699B, IEEE1547, FCC Part 15 (Class A & B), CAN/CSA C22.2 107.1-1							
SB 5000TL-US-22		SB 6000TL-US-22		SB 7000TL-US-22		SB 7700TL-US-22	



A NEW GENERATION OF INNOVATION

THE SUNNY BOY TL-US RESIDENTIAL SERIES HAS YET AGAIN REDEFINED THE CATEGORY.

Transformerless design

The Sunny Boy 3000TL-US / 3800TL-US / 4000TL-US / 5000TL-US / 6000TL-US / 7000TL-US / 7700TL-US are transformerless inverters, which means owners and installers benefit from high efficiency and lower weight. A wide input voltage range also means the inverters will produce high amounts of power under a number of conditions.

Additionally, transformerless inverters have been shown to be among the safest string inverters on the market. An industry first, the TL-US series has been tested to UL 1741 and UL 1699B and is in compliance with the arc fault requirements of NEC 2011.

Increased energy production

OptiTrac™ Global Peak, SMA's shade-tolerant MPP tracking algorithm, quickly adjusts to changes in solar irradiation, which mitigates the effects of shade and results in higher total power output. And, with two MPP trackers, the TL-US series can ably handle complex roofs with multiple orientations or string lengths.

An extended operating temperature range of -40 °F to +140 °F ensures power is produced in all types of climates and for longer periods of time than with most traditional string inverters.

Secure Power Supply

One of many unique features of the TL-US residential series is its innovative Secure Power Supply. With most grid-tied inverters, when the grid goes down, so does the solar-powered home. SMA's solution provides daytime energy to a dedicated power outlet during prolonged grid outages, providing homeowners with access to power as long as the sun shines.

Simple installation

As a transformerless inverter, the TL-US residential series is lighter in weight than its transformer-based counterparts, making it easier to lift and transport. A new wall mounting plate features anti-theft security and makes hanging the inverter quick and easy. A simplified DC wiring concept allows the DC disconnect to be used as a wire raceway, saving labor and materials.

The 3800TL-US and 7700TL-US models allow installers to maximize system size and energy production for customers with 100 A and 200 A service panels.

Leading monitoring and control solutions

The new TL-US residential line features more than high performance and a large graphic display. The monitoring and control options provide users with an outstanding degree of flexibility. Multiple communication options allow for a highly controllable inverter and one that can be monitored on Sunny Portal from anywhere on the planet via an Internet connection. Whether communicating through RS485, or SMA's new plug-and-play WebConnect, installers can find an optimal solution to their monitoring needs.

Wide Power Class Range

Whether you're looking for a model to maximize a 100 A service panel or trying to meet the needs of a larger residential PV system, the Sunny Boy TL-US with Secure Power Supply has you covered. Its wide range of power classes—from 3 to 7.7 kW—offers customers the right size for virtually any residential application. The TL-US series is not only the smartest inverter on the planet, it's also the most flexible.

Toll Free +1 888 4 SMA USA
www.SMA-America.com

SMA America, LLC

Appendix J: Net Present Value

Table J-2: Net Present Value Calculations

Interest:	3.55%

Year	Cash Flow	Present Value
0	$100,026.00	$100,026.00
1	-$3,761	-$3,632
2	-$3,870	-$3,609
3	-$3,982	-$3,586
4	-$4,097	-$3,564
5	-$4,216	-$3,541
6	-$4,338	-$3,519
7	-$4,464	-$3,497
8	-$4,594	-$3,475
9	-$4,727	-$3,453
10	-$4,864	-$3,432
11	-$5,005	-$3,410
12	-$5,150	-$3,389
13	-$5,300	-$3,367
14	-$5,453	-$3,346
15	-$5,611	-$3,325
16	-$5,774	-$3,304
17	-$5,942	-$3,284
18	-$6,114	-$3,263
19	-$6,291	-$3,242
20	-$6,474	-$3,222

$31,566	NPV

Appendix K: Interview Protocol: Solar Companies

Interview Protocol: Solar Companies

Use for contacting solar providers to gather quotes or estimates about various systems

Methods: Phone calls, emails

Contacts:

Solarcity NM
(888) 765-2489

GOSolar
505-250-9602

Sunpower (Dan Baker)
(505) 424-1112

Amenergy
(505) 424-1131

Key Points:
- 25 - 50 kW system
- Roof or carport only

Questions:

- We are looking to purchase a 25 to 50 kW solar system, what can your company offer in terms of meeting that size?
- What are the configuration options? (ie. part carport, part roof mount?)
- What would the cost/kW be for each of these options?
- What racking equipment is used for racking
  - Ballasted or roof piercing
- What solar panels will be used
- What inverters are used
- Is there a warranty besides the manufacturer's warranty?

Appendix L: Interview Protocol: Gas Meter Suppliers

Interview Protocol: Gas Meter Suppliers

Use for contacting suppliers and manufacturers for quotes, estimates, and technical inquiries about metering systems.

Methods: Phone calls, emails

Contacts:

Mountain State Pipe and Supply
1 (719) 634-5555

Elster American Meter
1 (714) 835 0995

Key Points:

- High Flow turndown range:
  Meters need to be able to measure low flow as well as high flow
- LCD or ERT/AMR
  LCD's are easy to read, or the alternative is systems with compatibility for Automated Meter Reading and a walk-by measurement device.

Questions:

- What is the turndown ratio for the meter? We have flow that can sometimes exceed 3000 CFH and might only be 11 CFH at points over a year as well. Is the meter capable of reading both of these extremes?
- Do the meters fit in the available area (Pictures attached)?
- For ERT/AMR Systems--Is the system compatible with the meters in place (Pictures/Model Numbers attached)? Which ones are not compatible?
- What are the unit costs/soft costs of the systems?
- How much labor is required to install the system?
- For ERT/AMR systems--Does the system require gas flow to be shut off while installing the meter?

Appendix M: Interview Protocol: Arden Engineering

Interview Protocol: Arden Engineering

Used for contacting an employee who works for Arden Engineering, a mechanical contractor based in Rhode Island, installs and repairs HVAC systems

Method: Phone call

Contact:

John Deneault
401-230-8432
jdeneault@msn.com

Key Points

- General information regarding natural gas meters

Questions

- What is the benefit of having gas meters installed on individual buildings?
- What information is needed to size a meter correctly for a building?
- What is the best meter type for the money?
    - Rotary?
    - Turbine?
    - Diaphragm?
    - Vortex?
    - Thermal mass flow?
    - Other?
- Any brand or meter type recommendations
- Can gas meters restrict flow if not sized correctly?

Appendix N: Survey Data

Survey Questions:

1. Do you know what achieving carbon neutrality means?
   a. Yes
   b. No
2. Are you aware that the IAIA signed a commitment to be a carbon neutral campus by 2050?
   a. Yes
   b. No
3. How interested are you in seeing the IAIA invest in sustainability efforts that will lead towards carbon neutrality? (1 = not at all, 2= not very interested, 3 = neither interested or disinterested, 4 = somewhat interested, 5= very interested)

   1 2 3 4 5
4. Have you ever had class in either the Northwest or Southwest classrooms in the Main Academic Building?
   a. Yes
   b. No
5. Do you know about the different types of lighting in each classroom?
   a. Yes
   b. No
6. Have you ever noticed any difference in the light quality between the Northwest and Southwest classroom?
   a. Yes, Northwest is brighter
   b. Yes, Southwest is brighter
   c. I have not noticed a difference
7. Would you be interested in seeing real-time data about the differences in the classrooms' electricity consumption?
   a. Yes
   b. No

8. Would seeing more energy sustainability projects around campus inspire you to think more about your carbon footprint and your effect on the environment?
    a. Yes
    b. No
    c. Maybe
    d. Other:
9. Would that lead you to make any changes in behavior towards conserving energy on campus?
    a. Yes
    b. No
    c. Maybe
    d. Other:
10. In which ways would you like to see the IAIA make improvements to help lower its carbon footprint?
11. What would you personally like to do to help promote sustainability on campus to help achieve the IAIA's goal of carbon neutrality?

Table N-1: Survey Result

Question	1	2	3	4	5	6	7	8	9	10	11
Entry											
1	No	Yes	3		Yes	Never noticed	Yes	Yes	Yes	Bottle Stations	Eliminate continuous copies as they are wasted a lot of times
2	No	No	5		No	Never noticed	Yes	Yes	Yes	Not really	Follow through with turning off lights
3	Yes	Yes	5	Yes	No	Never noticed	Yes	Maybe	No	Renewable Energy	Work on understanding the recycling rule on campus
4	Yes	No	5	Yes	No	Yes, NW	Yes	Yes	More Educated	Recycling, Gardens, Temperature Monitoring	
5	No	No	4	Yes	No	Never noticed	Yes	Yes	Maybe	Not sure	Turning off lights when leaving
6	No	No	4	Yes	No	Never noticed	Yes	Yes	Yes	All of the above	Wearing a t shirt to promote sustainability
7	Yes	Yes	4	Yes	Yes	Never noticed	Yes	Yes	Yes	Solar panels	Compost and gardens
8	No	Yes	4	Yes	Yes	Yes, SW	Yes	No	No	Wind and other renewable energy	Not really
9	Yes	No	4				Yes	yes			
10	No	No	4	Yes	Yes	Yes, SW	Yes	yes	Wants to see tangible results	Not have funding from Exxon Mobil;	
11	Yes	No	5	Yes	Yes	Never noticed	Yes	Yes	Yes	Solar and recycling oil	Paper recycling and art that involves recycling
12	No	No	5	No	No	Never noticed	No	Yes	Yes	Apply dorm changes to CLE	Motion sensors in the dorm hallways
13	No	No	4	No	No	Never noticed	Yes	Yes	Yes	Promote awareness	
14	Yes	No	5	Yes	Yes	Yes, Nw	Yes	Yes	Yes	Renewable energy	
15	Yes	Yes	5	Yes	Yes	Never noticed	Yes	Yes	Yes	Renewable energy	
16	No	No	4	Yes	No	Never noticed	Yes	Yes	Maybe	Not really	Willing to help

Appendix O: LED Poster Information

**Please note, these numbers do not represent the displayed values from the metering system. Once the meters are installed, simply find the difference in the power usage, and apply that difference to each topic to generate the correct values.

- Have you noticed the new LED Lights? Why is switching to LED's good?
  - In 2016, all the fluorescents in the NW Classroom were replaced with energy saving LED lights.
- The SW Classroom still has 24 standard fluorescent lights that's use 32 Watts of power.
  - The whole room uses 768 Watts of power
- Whereas the NW Classroom has 4 LED lighting fixtures that use 43 Watts of power.
  - The whole room uses 172 Watts of power.
- This is a savings of 596 Watts!
- What is a Watt?
  - Watt is the rate that work is done to move electrons from positive to negative charged areas.
- What can a 596 Watts do?
  - 596 Watts is equal to 2,045,472 Watt-hours (Wh) a year, or 2,045 kilowatt-hours (kWh) a year. This is how energy is measured in homes and every day devices.
    - Based on our assumption of 66 hours of run time per week.
  - If an iPhone 6 uses 5.45 Watt-hours to fully charge itself, you could charge your iPhone 375,316 times!
  - A standard LCD television, turned on, uses 241 kWh a year. You could keep 8 TVs turned on with your favorite channel playing for 1 year, or keep 1 TV on your favorite channel for 8 years!
  - A standard computer with a flat screen uses about 72 kWh, while turned on, a year, meaning you could power your computer for 28 years straight!
- If the IAIA currently spends an average of $0.086/kWh, the school saves $176 year!
- How much would you save at home?
  - If electricity currently costs $0.16/kWh during the day in your own home, you would save $327 in a year!
- If approximately 2 pounds of carbon emissions are created for each kWh produced by PNM, the IAIA saves 4,090 pounds of carbon from being emitted into the atmosphere each year!

Sources

Helman, C. (2016). How Much Electricity Do Your Gadgets Really Use? *Forbes*. Jersey City, NJ. Retrieved from http://www.forbes.com/sites/christopherhelman/2013/09/07/how-much-energy-does-your-iphone-and-other-devices-use-and-what-to-do-about-it/#29520666228e

Sibelga. (2016). How much energy do my household appliances use? Retrieved from: http://www.energuide.be/en/questions-answers/how-much-energy-do-my-household-appliances-use/71

Public Service Company of New Mexico. (2016). 19th Revised Rate NO. 1A Canceling 18th Revised Rate NO. 1A. Retrieved from https://www.pnm.com/documents/396023/396197/schedule_1_a.pdf/d9cfda9e-61a1-4008-ba3c-4152c9dbe7f1

Appendix P: Solar Production Model

Using historical solar radiance data for the Santa Fe area provided by the National Renewable Energy Laboratory (NREL), we were able to estimate the amount of solar energy that might be generated by a solar panels installed at the IAIA.

The NREL provided the following fields of information (National Renewable Energy Laboratory, 2010).

- **Date/Time**: The dataset includes hourly data from January 1, 1991 through December 31, 2005. Each entry is recorded along with the date and time the measurement is taken.
- **Direct Normal Irradiance (DNI)**: This is the amount of energy that is delivered to a surface presenting the maximum area towards the Sun as shown by the panel in Figure P-1 below. This presents a reasonable approximation of the total portion of solar radiation that can be classified as Direct Beam Radiation.

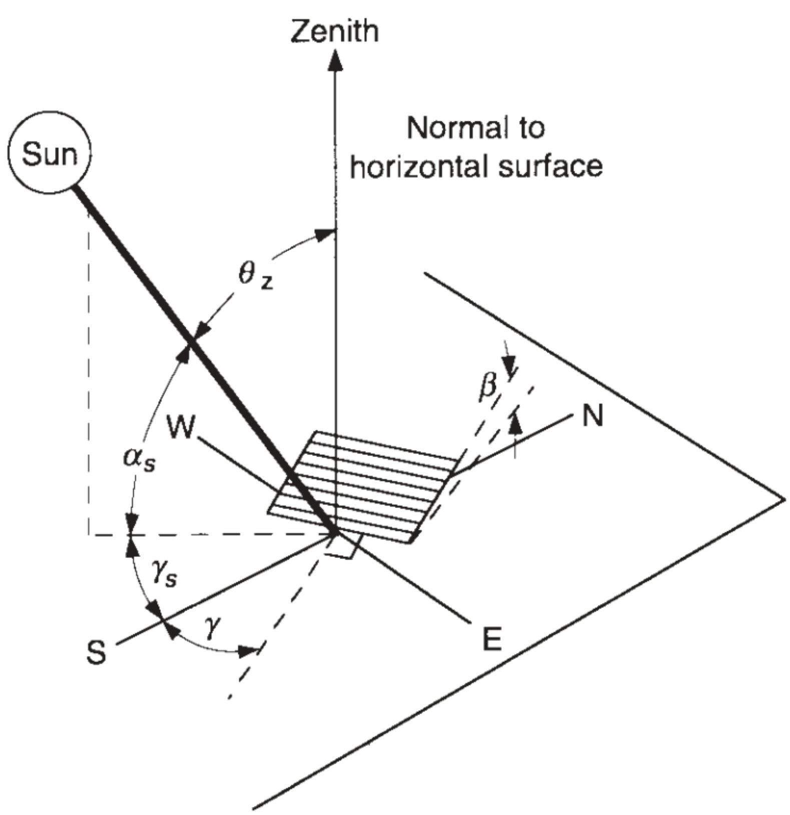


Figure P-1: Diagram of Normal Irradiance (Duffie & Beckman, 1980, p 13)

- **Direct Horizontal Irradiance (DHI)**: This is the amount of energy that is delivered to a surface lying horizontally on the ground. This provides a reasonable approximation of the uniform amount of diffuse radiation in an isotropic model of the sky.
- **Solar Altitude (Zenith) Angle:** This is the angle θ_z in Figure P-1, the angle between the incident angle of the Sun and a vertical line extending from the ground. At Sunrise and Sunset, this angle would be 90°.
- **Solar Azimuth Angle**: This is the angle γ in Figure P-1, the angle between the Sun and due South. At noon, this angle would be very close to 0°.

An example of the data recorded and provided by the NREL follows in Table P-3:

Table P-3: Solar Irradiance Data from January 1, 1991 (NREL, 2010)

Date/Time	DHI	DNI	Zenith	Azimuth
1/1/1991 7:00	$7\frac{W}{m^2}$	$397\frac{W}{m^2}$	86.4°	58.4°
1/1/1991 8:00	$19\frac{W}{m^2}$	$822\frac{W}{m^2}$	78.0°	49.9°
1/1/1991 9:00	$28\frac{W}{m^2}$	$946\frac{W}{m^2}$	69.5°	38.6°
1/1/1991 10:00	$40\frac{W}{m^2}$	$851\frac{W}{m^2}$	63.1°	25.3°
1/1/1991 11:00	$39\frac{W}{m^2}$	$933\frac{W}{m^2}$	59.4°	10.1°
1/1/1991 12:00	$44\frac{W}{m^2}$	$869\frac{W}{m^2}$	58.9°	5.9°
1/1/1991 13:00	$41\frac{W}{m^2}$	$863\frac{W}{m^2}$	61.8°	21.4°
1/1/1991 14:00	$55\frac{W}{m^2}$	$790\frac{W}{m^2}$	67.6°	35.3°
1/1/1991 15:00	$26\frac{W}{m^2}$	$687\frac{W}{m^2}$	75.6°	47.1°
1/1/1991 16:00	$16\frac{W}{m^2}$	$446\frac{W}{m^2}$	85°	57.2°

With all of these parameters we were able to develop a model for estimating how much solar energy a specific panel would be able to generate every hour. The equations we used to develop this model are provided in *Solar Engineering and Thermal Processes,* an engineering textbook written by J.A. Duffie and W.A Beckman.

The beam radiation available on tilted surface is shown by the following equation (Duffie & Beckman, 1980, p24):

$$I_b = I_{DNI}\cos(\theta_z - \theta_t)\cos(\gamma)$$

Where I_{DNI} is the Direct Normal Irradiance for the given hourly period, θ_z is the average zenith angle during that hourly period, θ_t is the tilt angle of the surface, and γ is average absolute azimuth angle for the hourly period (that is, that regardless if the angle is towards the East or West, γ will be positive).

Then, since we assumed an isotropic model of the sky—that is, that the amount of diffuse radiation will be the same regardless where the panels are pointed, we add the Direct Horizontal Irradiance to the beam radiation value. Therefore, the total radiation a solar panel receives during an hour is equal to:

$$I_{total} = I_{DNI}\cos(\theta_z - \theta_t)\cos(\gamma) + I_{DHI}$$

However, panels do not convert 100% of incident radiation to electricity, so that will be multiplied by the efficiency of the equipment, and then multiplied by the area of a single panel.

$$Energy = I_{total} \times Efficiency \times Panel\ Area$$

To develop an estimate for the amount of energy generated in a year, the hourly radiations for the entire 14-year period of recorded data are added together, and then averaged out to develop a more robust estimate for yearly production.

An example of the calculations is shown below, for January 1, 1991, for the 11:00 AM hour and a 1.62 square meter panel that is mounted due south at a 10-degree tilt, with 17% efficiency.

$$Energy = I_{total} \times Efficiency \times Panel\ Area$$
$$Energy = (I_{DNI}\cos(\theta_z - \theta_t)\cos(\gamma) + I_{DHI}) \times 17\% \times 1.62\ m^2$$
$$Energy = \left(397\frac{Wh}{m^2}\cos(86.4° - 10°)\cos(58.4°) + 7\frac{Wh}{m^2}\right) \times 17\% \times 1.62m^2$$
$$Energy = (55.8\ Wh) \times 17\% \times 1.62m^2$$
$$Energy = 15.4\ Wh$$

We used this information to run estimates for each of the different models of solar panels we examined.

We also used this model to develop an estimate of how much solar generation would be needed to offset all of the IAIA's energy usage. As the IAIA uses about 2,500,000 kilowatt-hours of electricity each year, which would require 3,900 solar panels with the technical specifications of Sunpower panels (PNM, 2016a; Sunpower, 2016). These panels total about 1.3 Megawatts of generation, and will provide 2.5 million kilowatt-hours of energy each year.

Appendix Q: RABO Rotary Meter Datasheet

RABO® Rotary Gas Meter

elster Instromet

Elster Instromet has combined tried and tested product features of their RVG and IRM rotary meter product lines with new developments into a single product. The new RABO offers a feature set that meets virtually all market applications in one simple design. Rotary-All-By-One, simply, all-in-one!

Features

- 4 meter sizes
- 3,500 to 14,000 acfh Maximum Capacity
- 2", 3" and 4" ANSI 125/150 flanged connections
- High rangeability across the flow range
- Low pressure drop
- Differential pressure taps on inlet and outlet with Pete's Plugs®
- Non-lubricated and non-resettable index
- End view, rotatable index
- Heavy duty, compact design
- High impact-resistant, ultraviolet stabilized index cover
- Anodized extruded aluminum body and impellers
- Anodized forged aluminum case covers
- Permanently lubricated bearings
- 10ft³ output on all meter sizes

General Information

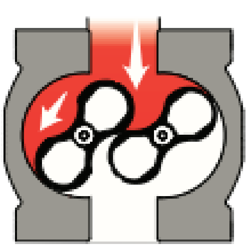
- MAOP 290 psig
- Temperature range -40 F to +140 F
- Meets ANSI B109.3 (pending)
- Approvals pursuant to MID/PED/ATEX directives
- Media: dry natural gas, noncorrosive industrial gases

Options

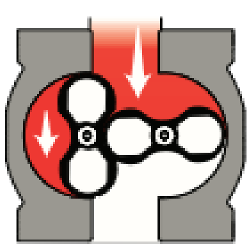
- Pulse outputs
- Thermowell
- Index masking
- Gasket strainers
- Flange bolts and gaskets
- AMR mounting
- Differential pressure gauge kit

Operating Principle

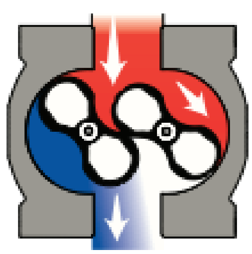
The RABO meter utilizes the rotary-type positive displacement principle of operation which makes volumetric measurements by displacing finite volumes of gas. The positive displacement occurs within a cavity formed between the meter's internal housing and its rotating impellers. The counter-rotating "figure-8" impellers turn as a result of pressure drop across the meter's inlet and outlet created as downstream gas is consumed. The rotating impellers separate the flowing gas into small, finite, volumes and are counted using a mechanical index.



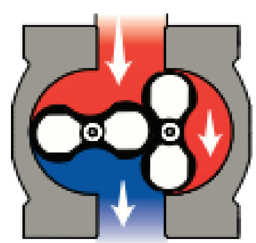
As the left impeller rotates toward the vertical position, gas enters the cavity created between the impeller and the housing.



When the left impeller reaches the vertical position, a finite volume of gas is captured in the left cavity.

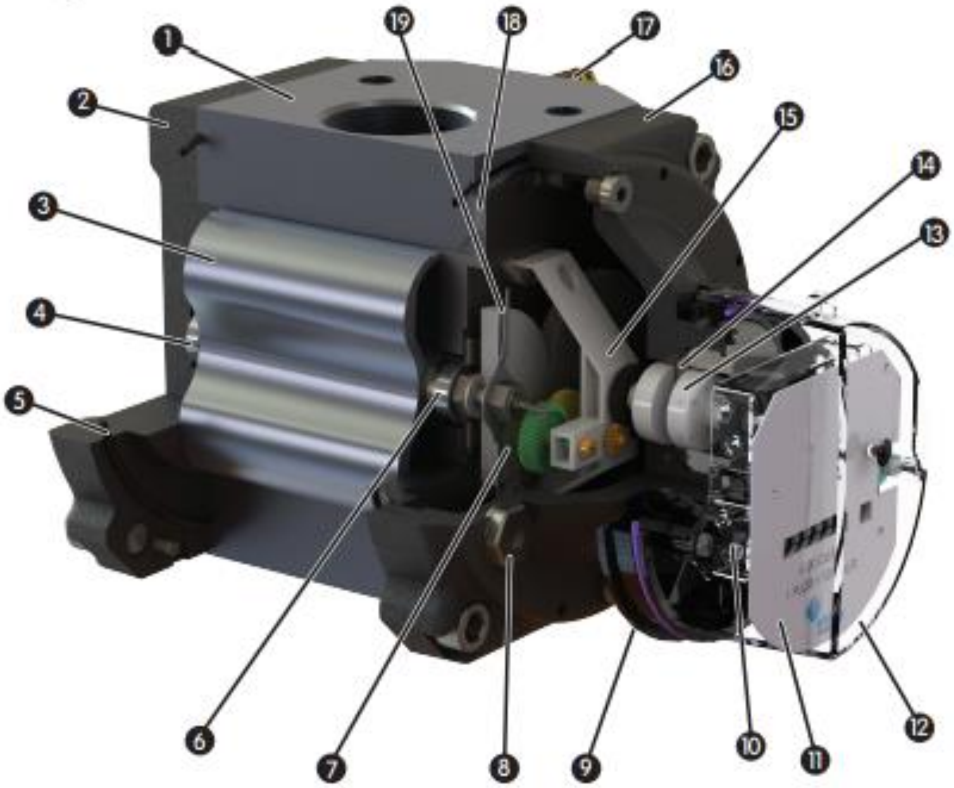


As the impellers continue to turn, the volume of gas in the left cavity is discharged. Simultaneously, gas is entering the space between the right impeller and housing.



After further rotation, the right impeller becomes vertical and a finite volume of gas is captured in the right cavity.

RABO Rotary Meter Construction



	Part Name	Material
1	Case	Extruded Aluminum, Hard-coat Anodized
2	Back Case Cover	Forged Aluminum, Hard-coat Anodized
3	Impellers	Extruded Aluminum, Hard-coat Anodized
4	Back Bearing	Stainless Steel, Permanently Lubricated, Shielded
5	O-Ring	Buna-N
6	Front Bearing	Stainless Steel, Lubricated, Shielded
7	Timing Gears	Carbon Steel
8	Oil Sight Glasses	Aluminum Housing
9	Index Base	High Performance Polyamide (Nylon)
10	Index	Polycarbonate
11	Index Masking Plate	Aluminum
12	Index Cover	Polycarbonate, UV Resistant
13	Index Drive	Magnet
14	Pressure Plate	Stainless Steel
15	Gear Box	Polyoxymethylene
16	Front Case Cover	Forged Aluminum, Hard-coat Anodized
17	Pete's Plugs	Brass Housing
18	Front Bearing Plate	Aluminum, Hard-coat Anodized
19	Oil Slinger	Steel
	Lubricating Oil	Shell Morlina

Pulse Outputs

Elster RABO flow meters come equipped with a drive magnet as standard equipment for easy adaptability of a low frequency pulse generator. The pulse generators are attachable to the exterior of the index cover, and can be retrofitted or changed without opening the index. They also have sealing capability to visually detect tampering.

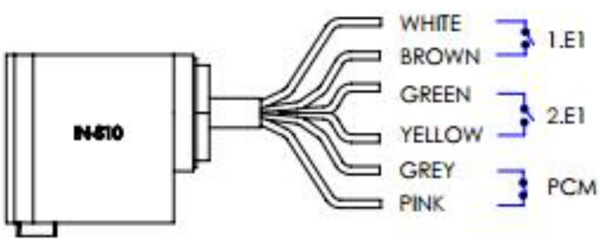
Model	Description
IN-S10	8' cable
IN-S11	1 connector
IN-S12	2 connectors

All models include 2 independent switches and a tamper circuit.
Pulse value is 10 acf (0.28 x am^3) for all meter sizes.
IN-S11 and IN-S12 come with mating connector, no cable included.

Technical Specifications

Description	Min.	Typ.	Max.	Unit
Voltage (U)			24	V
Current (I)			76	mA
Power (P)			1,1	mW
Static Contact Resistance			200	mΩ
Insulation Resistance	10^9			Ω
Breakdown Voltage	100		100	VDC
Switching Time Including Bounce		0.5		ms
Release Time		0.1		ms

Temperature range: -40°C ... +70°C
IP-Class: IP67
Explosion protection: Ⓔx II 2 G EEx ia 2C T4



Pulser Pin-Out Connections			
Connector	1.E1	2.E1	PCM
IN-S11	1 + 2	5 + 6	3 + 4
IN-S12	1 + 2 (Back)	1 + 2 (Front)	3 + 4 (Front)

Thermowell

316 SS, 0.25" Bore

Model
¼" NPT with gland

Index Masking

Mask
4 X 1,000 CF
5 X 100 CF (Std)
5 X 1,000 CF
6 X 10 CF
6 X 100 CF
Blank

Gaskets, Strainers, Bolts

Gaskets and bolts are necessary for mounting a meter in the gas line. Gaskets and strainers are high quality Garlock® BLUE-GARD® Style 3000, and Grade 5 bolts are Xylan® coated for increased corrosion resistance and reduced friction. Gasket strainers are an effective way to to protect the meter and downstream equipment from weld slag and other debris in the gas system.

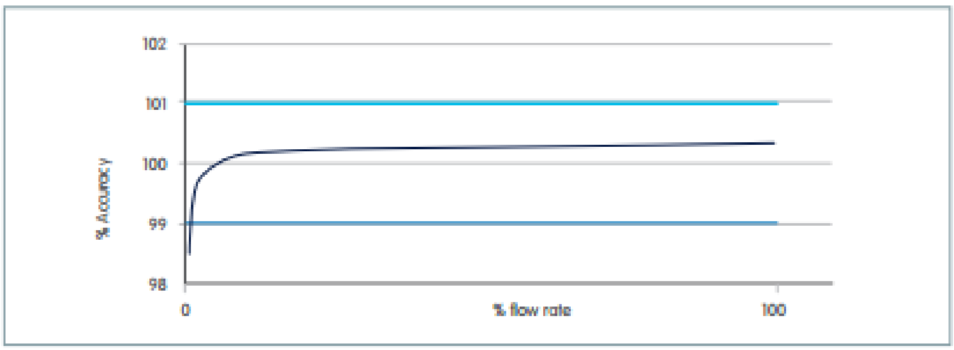
Description	Size	Type	Mesh
Gasket Strainer	2" ANSI 125/150	Full Face *	80
Gasket Strainer	3" ANSI 125/150	Full Face *	80
Gasket Strainer	4" ANSI 125/150	Full Face *	80
Gasket Strainer	2" ANSI 125/150	Ring	40
Gasket Strainer	3" ANSI 125/150	Ring	40
Gasket Strainer	4" ANSI 125/150	Ring	40
Gasket Strainer	2" ANSI 125/150	Ring	20
Gasket Strainer	3" ANSI 125/150	Ring	20
Gasket Strainer	4" ANSI 125/150	Ring	20
Gasket Strainer	2" ANSI 125/150	Full Face *	20
Gasket Strainer	3" ANSI 125/150	Full Face *	20
Gasket Strainer	4" ANSI 125/150	Full Face *	20
Gasket & Bolts	2" ANSI 125/150	Ring	N/A
Gasket & Bolts	3" ANSI 125/150	Ring	N/A
Gasket & Bolts	4" ANSI 125/150	Ring	N/A

*Not rated for full MAOP of the meter.

Performance

	Units	3.5M/G65		5.5M/G100		9M/G160		14M/G250	
Rangeability		90:1		160:1		160:1		160:1	
Start Rate	acfh (am³/h)	1.3	(0.04)	0.9	(0.03)	2.5	(0.07)	2.5	(0.07)
Stop Rate	acfh (am³/h)	1.1	(0.03)	0.8	(0.02)	1.9	(0.05)	2.3	(0.07)
Flow Rate at ½" w.c. DP	acfh (am³/h)	2,715	(77)	4,074	(115)	5,722	(162)	6,740	(191)
Differential Pressure at 100% Flow Rate	in. w.c. (mBar)	1.46	(3.64)	1.23	(3.06)	1.70	(4.23)	2.65	(6.60)

Accuracy Curve



Sizing Chart

Using the chart below, select the appropriate meter by using the Maximum Instantaneous Flow Rate (scfh) and the Minimum Operating Pressure (psig) at any given point in time.

Example: A flow rate of 25,000 scfh and an operating pressure range of 75–100 psig would require a 5.5M meter based on a 75 psig minimum inlet pressure.

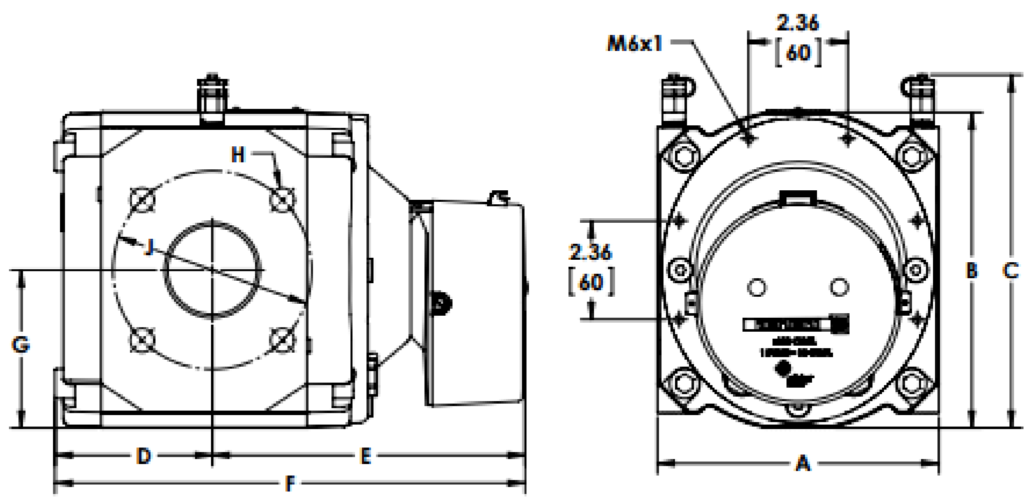
Model		3.5M/G65		5.5M/G100		9M/G160		14M/G250	
psig	(Barg)	Corrected Capacity in scfh (sm³/h)							
0.25	(0.0)	3,500	(100)	5,500	(160)	9,000	(250)	14,000	(400)
2	(0.1)	3,900	(110)	6,100	(170)	10,000	(280)	15,600	(440)
5	(0.3)	4,600	(130)	7,200	(200)	11,900	(340)	18,400	(520)
10	(0.7)	5,800	(160)	9,100	(260)	14,900	(420)	23,200	(660)
20	(1.4)	8,200	(230)	12,800	(360)	21,000	(590)	32,700	(930)
30	(2.1)	10,500	(300)	16,600	(470)	27,100	(770)	42,200	(1,190)
40	(2.8)	12,900	(370)	20,300	(570)	33,200	(940)	51,700	(1,460)
50	(3.4)	15,300	(430)	24,000	(680)	39,300	(1,110)	61,200	(1,730)
60	(4.1)	17,700	(500)	27,800	(790)	45,500	(1,290)	70,700	(2,000)
75	(5.2)	21,200	(600)	33,400	(950)	54,600	(1,550)	85,000	(2,410)
100	(6.9)	27,200	(770)	42,700	(1,210)	69,900	(1,980)	108,700	(3,080)
150	(10.3)	39,100	(1,110)	61,400	(1,740)	100,400	(2,840)	156,300	(4,430)
175	(12.1)	45,000	(1,270)	70,700	(2,000)	115,700	(3,280)	180,000	(5,100)
250	(17.2)	62,800	(1,780)	98,700	(2,790)	161,500	(4,570)	251,300	(7,120)
290	(20.0)	72,300	(2,050)	113,700	(3,220)	186,000	(5,270)	289,300	(8,190)

Note: All capacities are based on 14.4 psia atmospheric pressure, 14.73 psia base pressure, and 60° F base temperature.

Dimensions and Weights

	Units	3.5M/G65		5.5M/G100		9M/G160		14M/G250	
A	in. [mm]	6.75	[171]	6.75	[171]	9.5	[241]	9.5	[241]
B	in. [mm]	7.56	[192]	7.56	[192]	10.08	[256]	10.08	[256]
C	in. [mm]	8.63	[219]	8.63	[219]	10.75	[273]	10.75	[273]
D	in. [mm]	3.78	[96]	5.43	[138]	5.16	[131]	6.14	[156]
E	in. [mm]	7.52	[191]	9.17	[233]	10.67	[271]	11.65	[296]
F	in. [mm]	11.26	[286]	14.61	[371]	15.83	[402]	17.76	[451]
G	in. [mm]	3.78	[96]	3.78	[96]	5.04	[128]	5.04	[128]
Nom. Pipe Size*	in. [mm]	2		3		3		4	
Bolt Size, H		5/8" - 11		5/8" - 11		5/8" - 11		5/8" - 11	
# Bolts / Flange		4		4		4		8	
Bolt Circle, J	in. [mm]	4.75	[121]	6.00	[152]	6.00	[152]	7.50	[191]
Shipping Weight	lbs. [kg]	29.8	[14]	37.7	[17]	73.9	[34]	82.3	[37]
Carton Size	in.	18.3L x 1.6W x 12.6H				23.6L x 13.0W x 13.4H			
	[mm]	465L x 270W x 320H				600L x 330W x 340H			

*ANSI Class 125/150 flat face flange connection



Ordering Information

- Meter Model
- Index Masking
- AMR Mounting
  - Horizontal or Vertical Flow
- Special Badge
- Options
  - Thermowell
  - Pulser
  - Gasket Strainer
  - Gasket and Bolt Installation Kit

About Elster Gas

Elster provides best-in-class measurement and regulation products, systems and solutions for the safe control and delivery of natural gas across the globe.

Trusted Brands

- Elster American Meter Company, LLC
- Elster Perfection Corporation
- Elster Instromet
- Elster Canadian Meter Company, LLC
- Elster Gas Depot
- Elster Meter Services

Certified System™

ISO 9001
QMI-SAI Global

Elster American Meter Company, LLC
2221 Industrial Road
Nebraska City, NE 68410
USA

T +1 402 873 8200
F +1 402 873 7616

www.elster.com/gas

EAM-TB5900 8/14

Appendix R: Efergy Electrical Meter Datasheet

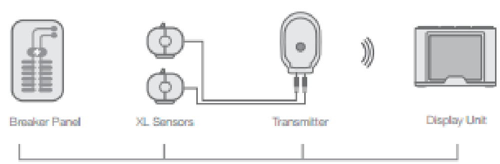
ELITE CLASSIC

WIRELESS ENERGY MONITOR

efergy

ENERGY MONITORS - HOW THEY WORK

Our **elite classic** electricity monitor is simple to install and easy to use. Two small sensors are clipped on to the supply cables of your breaker panel. A lead from the sensors is plugged into the energy transmitter, which then wirelessly sends real time data to the energy monitor. The monitor converts the data and displays the demand in kilowatts of energy being consumed at any given time. The **elite classic** display may be programmed for various rates, ensuring that the cost of your energy is accurate.



INSTANT SAVINGS

The **elite classic** updates every 10, 15 or 20 seconds. The display then shows how much energy is consumed at that given moment and how much it will cost if the 'energy now' load is maintained for a period of one hour.

AVERAGE DATA

The **elite classic** displays your average energy usage per hour, week and month. See the impact of your energy efficient efforts, and then watch your average energy usage reduce.

MEMORY FUNCTION

The **elite classic** memory function allows you to view your energy usage by the hour, week or month. The elite helps you understand your energy usage and how it changes over time.

EASY TO INSTALL

- Clip the sensors around the cables of your breaker panel
- Plug the sensors into the transmitter
- Press **link** on the back of the **elite classic** display unit
- Signal symbol will flash - press **learn** on the transmitter
- Signal symbol becomes solid when your monitor is working
- Use the **elite classic** to review energy usage instantly

TECHNICAL INFORMATION

Model Name	**elite classic**
Model Number	**EF003**
Frequency	**433MHz**
Transmission Time	**10, 15 or 20 Sec**
Transmission Range	**230 - 328ft**
Voltage Range	**100 - 600V**
Measuring Current	**50mA - 200A (max)**
Memory	**64K**
Testing Standards	**CSA - UL - FCC**

4000228

Industry Canada / Industrie Canada

Canada

1 x Customer Information Display
1 x Transmitter
2 x XL Sensor

MONITOR REDUCE SAVE

Appendix S: Gas Meter Installation Labor Quote

ROADRUNNER

AIR CONDITIONING, HEATING & REFRIGERATION, INC.

Derek Cunningham, President

3200 Calle Marie, Santa Fe, NM 87507

www.roadrunnerair.com

d@roadrunnerair.com

Licensed, Insured and Bonded #367021

505-473-9000 Fax: 505-424-4402

To: I.A.I.A.

83A Van Nu Po

Santa Fe N.M. 87508

Attn: Peter

Email: **psmith2@wpi.edu**

Project Name: 9 Gas Meter Install.

I. Remove existing meters at 9 buildings so as to install owner provided meters.

a. Install by-passes with valves where there are no by-passes.
b. Pressure test for leaks & functionality.
c. Bleed lines and relight all pilots to gas fired equipment

Extras

All extra work will require a written request (by owner) as well as a change order with price of extra work & material provided by RAHR. Change order must be signed prior to any extra work or services rendered.

Warranty

All materials (purchased by Roadrunner) & workmanship will include a one (1) year warranty.

Materials not purchased by Roadrunner will not be warrantied.

Workmanship

All workmanship will be performed in a professional manner & will meet or exceed local/state codes.

Inclusions:

All Labor, materials and permits required to complete above project.

Exclusions:

Any, and or all existing piping or equipment.

Terms:

This proposal is valid for 30 days from date above. All payments for work completed not made after 30 days of invoice being issued shall be considered overdue (unless permission is given for late payment). All overdue invoices past 30 days for work completed will receive an interest charge rate of 1.5% per month to remaining balance until invoice or contract matter is paid or resolved (not to exceed 24.99% per year). In addition, any legal action necessary (including all court costs and attorney fees) to receive payment for work completed shall be the responsibility of the customer until payment is received or issue is resolved. RAHR shall reserve the right to recover any equipment and supplies installed by RAHR if payment is not received for work rendered to recover some expenses already paid out to suppliers for equipment. Any installation delays beyond our control by owner longer than six months from date of acceptance of job contract to complete work shall constitute a change in price and contract due to parts and/or labor increasing in price or the necessity to renew permits otherwise completion of work may or shall be canceled and current price portion of work completed shall be due.

Term Specifics:

Terms of sale shall be 50% upon execution of this contract and balance due at successful completion of above described work.

Total investment: $22,896.00 + Tax of $1,903.23 = $24,799.23

John A. Vigil

Service Manager: ___________________________________ Date: ____________

Client's Approval: __________________________________ Date: ____________