Green Fund Mission Statement:

"The NAU Green Fund promotes student participation in and provides funding for projects that reduce NAU's negative impact on the environment and create a culture of sustainability on-campus."

Requirements for funding:

> **** The Green Fund distributes funding on a reimbursement basis. Project Teams must partner with an administrative office to provide upfront funding for the project. Once the project has met its agreed upon deliverables, the administrative partner will be reimbursed by the Green Fund.***

Requirements for Application

Abstract

Project Leader Name, Phone, and E-mail:
Mikela Petersen, 520-353-6987, mmp378@nau.edu

Project Advisor Name, Phone, E-mail, Position, and Department :
Jennifer Wade, 928-523-1528, Jennifer.wade@nau.edu
Assistant Lecturer, Mechanical Engineering

Project Name: NAU Campus Dining Energy Audit

Food preparation and service is a significant consumer of natural gas, steam, electricity, and potable water on the NAU mountain campus. Although a number of efficiencies are realized by utilizing central steam and chilled water, the direct consumption costs for cooking, refrigeration, exhaust hoods, and ware washing are extraordinarily high. In 2019, systems related to campus dining consumed over 3.3M KWh of electricity and 7M gallons of water annually. The utility expense associated with these usage levels impacts the final costs of food service to our students and campus community. Any opportunity to reduce these costs is a potential improvement to the overall student experience and our auxiliary services on campus.

There is a growing percentage of commercial foodservice equipment available that is Energy Star labeled or deemed highly efficient by research organizations like the Foodservice Technology Center (FSTC) and the Consortium for Energy Efficiency (CEE). The three organizations, along with equipment manufacturers, are paving the way for mainstream efficiency standards in commercial kitchen equipment. Although NAU strives to purchase equipment that is certified energy efficient for new campus dining projects and remodels, there are hundreds of pieces of equipment that range in age from 10 to over 40 years old that are being used daily in campus dining and are extraordinarily inefficient by today's standards. NAU Campus Dining would like to establish a partnership with a student researcher to establish an approximate energy usage value for each piece of equipment in our inventory and make recommendations for new equipment upgrades based on upfront cost and anticipated energy savings, in short recommendations based on the payback period. Once a matrix of energy usage vs. cost of new equipment is established, the project will deliver a ranked recommendation for new equipment prioritization for future budget requests.

Project Proposal

When thinking of energy-efficient improvements for large energy-intense buildings, it is important to consider what assets are using the most energy per unit service, and how can they be improved or phased out for more efficient equipment. This project will measure the energy use of each dining facility asset as well as quantify the service the asset provides. For example, a kitchen fume hood provides an upward flow rate (e.g., cubic feet per minute, cfm) to remove cooking particulates from the indoor air. The power required to provide a unit of cfm will be either directly measured using the GreenFund power meter, installed on the electric feeder to the fume hood and a flow rate sensor, or estimated from manufacturer specifications. and provide a recommendation of what assets should be replaced or improved on. These recommendations can vary from low-cost to high-cost depending on the circumstance of the asset.

There are many measurement and data collection processes that need to occur to identify the best recommendations for what equipment needs to be improved on or replaced. First, the utility inputs for each piece of equipment within the dining services inventory will be determined by either building site visits or referring to equipment manuals. Estimates on the total energy consumed will first be estimated with the utility stickers on each appliance and asset or measured directly (if electric) using the energy power meter owned by the Green Fund. After analyzing the utility input (electricity, BTU distributed heat, cubic feet of natural gas, gallons of potable water, etc.), the service output (e.g., flow rate, dish cycle load, $\Delta T * \text{Volume}$ of a refrigerator, etc.) will be estimated and recorded in the database. This database will compare the ratio of utility inputs per service output This will help with analyzing what asset is consuming the most energy, thus contributing to the decision of what needs to be replaced or improved.

The recommendations for which dining facility asset should be improved on or replaced is dependent on how much the asset is outputting for the energy input. A similar calculation will be conducted for each recommended replacement to ensure that there is an improvement of emissions, while still improving on the service outputs for each appliance. Each recommended improvement will be based on how much energy will be saved over a period, or the payback period. These recommendations will provide the best results for cost and energy savings while providing the best overall service. They will also be dependent on the overall reduction of emissions caused by the outdated appliances used by the dining services and compared to how much savings the replacement will ensure after a given time period. The recommendations made will be listed prioritizing the most energy-intensive assets.

Literature Review

A variety of articles, journals, and previous college capstone projects informs means to evaluate and recommend energy improvements on a college campus. The technical report, “Energy Analysis of LEED Silver Certified Dining Hall on an Academic Campus— A Revisit Three Years After its Initial Certification” studied the energy use of different HVAC systems. Energy systems were analyzed using an ASHRAE Level 1 and Level 2 Energy Audit by creating a database for the primary functions of Energy Start appliances. Afterward, a function of energy use for a given building metric of heating degree days/floor area was created. This comparison identified which utility assets were consuming the most energy, thus replacing them with energy-efficient appliances, saving roughly $33,000 over a nine-month period [1].

The capstone project, “Chapman University 2016 Environmental Audit: Residence Life Dining Services Equipment” took a similar approach as source one. They collected numerical data from kitchen appliances in the Chapman University dining facilities to provide more information and education on how to improve the appliances used for the kitchen staff. This required the team to estimate the energy consumption of all appliances and assets used in the dining facilities and track it in an energy tracking database. After the data was collected, the team made low, medium, and high-cost recommendations to improve energy use. The low-cost recommendations were using power strips to plug all appliances into, so at the end of the day, each power strip can be turned off to prevent phantom loads from occurring, as adding appliance times to each asset to track and improve energy efficiency. The medium cost recommendations were replacing a variety of old parts, such as gaskets and hinges to improve energy efficiency. Lastly, the high-cost recommendations were replacing the assets that produced the greatest amount of energy with ENERGY STAR-rated equipment to reduce the use of energy on a long-term basis.[2].

The journal, “On the necessity of improving the environmental impacts of furniture and appliances in net-zero energy buildings”, analyzes a variety of components of building and kitchen utilities. They analyze the energy consumed for the production and use of different assets in these two areas. This was done by analyzing the environmental impacts by evaluating the applied International Standardization of Organization (ISO) guidelines ISO14044 and ISO 14040. By doing this, an estimation of how much energy is being used was created. This allowed for the creation of a plot that compares the Global Warning Potential and Nonrenewable energy use. For a building itself, the Global Warning Potential is about 5.7 kg CO2-eq/m^2 for one year, while using approximately 250 MJ/m^2 of nonrenewable energy. The next largest use of energy after the embodied buildings was the embodied appliances, such as heating, cooling, water, refrigerators, ovens, and other appliances that relate to this type of energy use had a Global Warning Potential of about 2.5 kg CO2-eq/m^2 and used roughly 50 MJ/m^2 per year [3].

The article, “(How) Can Appliances be Designed to Support Less Energy-Intensive Use? Insights from a Field Study on Kitchen Appliances” was based on research done on the energy use and quality of a variety of kitchen appliances. The purpose was to determine what was the best appliance in terms of energy use and quality. The team conducted field studies that monitored the energy use of each appliance by using an energy meter and documenting the readings in a database. Afterward, the team had randomly selected volunteers to test the quality over a given time. The conclusions of what was the best appliance were based on the opinions of the randomly selected volunteers [4].

Table 1: Synthesis Matrix

Source	Type	Purpose	Approach	Conclusion
1	Technical Report	To find new ways for conserving energy in energy-intensive buildings, such as research and clean rooms	Conducted an ASHRAE Level 1 and 2 Energy Audit analysis and created a database for Energy star primary functions and their percentage of DDH floor area	Identified assets and buildings using the most energy due to poor operating procedures and overriding the control system to set for changes to the HVAC systems. Able to save energy, saving roughly $33,000 over a period of 9 months
2	Capstone poster	Collect numerical data from kitchen appliances to provide the necessary education on resources for the improvement of specific appliances for kitchen staff	Estimated energy consumption and tracked it in an energy tracking database	Recommendations for low, moderate, and high-cost improvements. Low cost: use power strips for all electrical appliances and turn them off after each day to prevent phantom loads, add appliance timers to improve efficiency. Medium costs: replacing gaskets and hinges on conventional kitchen appliances, install submeters to monitor energy use. The high cost would be replacing appliances with ENERGY STAR rated equipment

3	Journal	Analyzing the energy use from furniture and appliances for high energy efficient buildings	Analyzed the environmental impacts by evaluating the applied guidelines ISO14040 and ISO14044 (International Organization for Standardization), production of appliances, and lifetime analysis of each building furniture and appliance	Implementing NZEB (a solution with very low environmental impacts). Embodied buildings produce the largest global warming potential at about 5.7 kg CO2-eq/m^2 ERA yr and requiring about 250 MJ/m^2 ERA year of nonrenewable energy. The next largest consumption of energy is the appliance, such as refrigerators, stoves, ovens, heating, AC, etc with a Global warning potential of 2.5 kg CO2-eq/m^2 ERA yr, and about 50 MJ/m^2 ERA yr
4	Article	To compare different appliances to see which is the most cost-effective and best energy use for everyday household appliances	Used three different brands of three different appliances to see how effective each appliance is. Each appliance has a different energy use, wattage, and holding capacity. Each product was tested, and results were obtained using energy meters	Conclusions are dependent on how often the appliances were used, how well they worked, and the overall energy usage. Overall, the decision of the best appliance was opinion-based

Scope of work

To start the research project off, the first thing that needs to be established is the utility inputs and service outputs of each dining service asset. To identify the utility inputs, the yellow energy star sticker on each dining service asset needs to be identified. This will give an input in values of energy such as Watts per hour, gallons per use, etc. Once these utility inputs are identified, an analysis of the service output can be determined. This can be determined by estimating the amount of work or product produced given the utility input. For example, how many dishes can be washed per one use of the dishwasher. This process will be used to identify all utility input and service outputs of each dining service asset.

Next, the data given from the utility input and service outputs is the amount of unit input per unit output. This will be done by using a database created from analyzing the utility input and service outputs from the previous step. This allows for an understanding of how much energy is being used per unit output of work or product, that way a cost analysis can be done.

Doing a cost analysis will help with the understanding of what is consuming the greatest amount of energy and/or water and at what price. This will help the researchers create a list that prioritizes important replacements while taking into consideration NAU budgetary constraints and economical constraints.

Finally, the final recommendations will be made to NAU. This will include a cost analysis of each of the recommended replaced assets, and a detailed report of why those assets are recommended for replacement.

Detailed Budget

1. Does this project have any other sources of funding, and/or have you applied for other sources of funding? If so, list all additional sources of funding, both confirmed and potential, outside of the funds being requested from the Green Fund. No.

Line Item Budget:

Item	Justification of Item	Quantity	Price per Unit
Student Salary	Time to analyze energy loads and identify alternative equipment pricing	200 hours	$10.00/hour
Electric Power Meter	Using NAU Green Fund Power Meter to measure electric loads from major dining services equipment	2	$0 (borrowed)
Electrician NAU Trades	For the install of power meter on electric equipment	15 hours	$60/hour
Contingency		5%	$170
TOTAL REQUESTED			**$3070**

Questionnaire

Focus of research project:

This project analyzes NAU's Dining Service equipment energy use and will provide a prioritized list for new equipment upgrades based on both estimated energy reduction and upfront capital cost.

1. How will your research benefit the mission statement of the Green Fund and improve sustainability on NAU's campus?

   This project inventories the energy use of NAU dining services and will create an energy intensity metric for the major equipment used by NAU dining services. This metric will be compared to more energy-efficient technologies to prioritize new equipment for electric, natural gas, and water savings. Based on the inventory and energy intensity metric, recommendations will be made for equipment purchases that will give the biggest payback period and energy saved.

2. Will your research require the utilization of any spaces or infrastructure on campus? If so, identify the specific locations and/or infrastructure, how much of the space you require, and what each space will be used for.

   No.

3. Will other departments on campus (other than your own) be needed to assist in this project (i.e. Facility Services, Campus Transit)? If so, identify department partnerships.

   We will work in collaboration with NAU dining services, specifically TC Eberly. They have already provided some inventory data for us to use, and we will assess the hours of operation, location, and date of installment. If electric, the Green Fund power meter will be needed to analyze the energy load from that device.

Project Timeline

Expected Timeline:

Action	Parties Involved	Month/Year
Identify all utility inputs and service outputs for each dining service asset	M.P, T.C	June/2021
Measure or estimate the amount of input per unit output	M.P, FS, J.W	June- July/ 2021
Identify alternative energy star equipment with pricing for the most energy/water intense assets	M.P	July / 2021
Economic analysis of energy/water-efficient opportunities	M.P	July/ 2021
Final recommendations	M.P	August-September / 2021

Expected Project Completion Date: _November 2021*__
M.P = Mikela Petersen
J.W = Jennifer Wade
TC = TC Eberly
FS = Facility Service Electrician

***NOTE: There is a possibility that the student researcher, Mikela Petersen, will not be able to begin the work over the Summer 2021 due to a potential professional internship. In the event this occurs, Ms. Petersen would begin the scope of work during the Fall 2021 term with expected completion of the project by March 2022.**

Resources

[1] S. Bangerth, M. M. Ohadi, and C. A. Jenkins, “Energy Analysis of LEED Silver Certified Dining Hall on an Academic Campus— A Revisit Three Years After its Initial Certification.”

[2] Alexandra FW. Sidun, Devon T. Bloss, “Chapman University 2016 Environmental Audit: Residence Life Dining Services Equipment’, Chapman University, 2016. [Online] https://digitalcommons.chapman.edu/cgi/viewcontent.cgi?referer=https://scholar.google.com/&httpsredir=1&article=1200&context=cusrd_abstracts

[3] E. Hoxha and T. Jusselmea, “On the necessity of improving the environmental impacts of furniture and appliances in net-zero energy buildings,” *Science of the Total Environment*, vol. 596-597, pp. 405–416.

[4] A. Selvefors, C. Marx, M. A. I. C. Karlsson, and U. Rahe, “(How) Can Appliances be Designed to Support Less Energy-Intensive Use? Insights from a Field Study on Kitchen Appliances.”

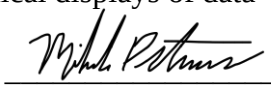
Signed Commitment to Present

Please read and sign the statement below, acknowledging your commitment to present the findings of your research.

If selected as a recipient of the 2020 Green Fund Student Research Grant, regardless of the outcome of my research project, I Mikela Petersen commit to presenting the status of my research described in this application in the form of both an oral presentation to the Green Fund Committee and a poster/exhibit presentation at the Undergraduate of Graduate Symposium, no more than 1 year after receiving notification of funding.

The oral presentation to the Green Fund Committee will consist of an approximately 10-minute-long PowerPoint that includes the following aspects of your project:

- Original goal and purpose of research
- Conflict or changes to the original purpose
- Results/Conclusion
- All relevant graphical displays of data

Project Leader Signature: 

Thank you for your submission. We deeply appreciate your commitment to sustainability at NAU, and we look forward to reviewing your application. Please direct any further questions to ***GreenFund@nau.edu***.

Letter of Recommendation:

3/22/2021
Jennifer Wade
Assistant Professor, Mechanical Engineering
College of Engineering, Informatics, and Applied Sciences
Northern Arizona University

Dear Green Fund,

I am writing this letter in support of Mikela Petersen and the Dining Services Energy Audit project. TC Eberle of dining services is seeking a student to evaluate the energy loads of their equipment assets to recommend future equipment upgrades that minimize the energy demands of their unit, and in turn, lowers their emission and GHG profile while also remaining economically viable. I reached out to a group of engineering students to see if there was interest in the project, and Ms. Petersen eagerly agreed to take up the project within minutes of posting. Further, she has single-handedly taken on this proposal and worked to understand this new project amidst an especially technically heavy part of her engineering degree. I previously had Ms. Petersen as an undergraduate student in my second year Materials Science course where she performed strongly in this highly analytical and abstract course. She is currently learning about engineering economics, net present value, and payback period in her third-year engineering design course. She is eager to apply this new knowledge to real analytical decision-making for our University.

In this project, I will serve as her technical advisor in estimating, and when necessary, measuring electrical loads of the Dining Service equipment. Further, I will guide her in choosing the appropriate technical metrics when comparing service outputs from each of the equipment loads to best inform equipment replacement.

Finally, it was with my recommendation that Ms. Petersen budgets her time at $12.15/hour to match the new Arizona State minimum wage that is law as of January 2021.

Sincerely,

Jennifer Wade