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Project

Application

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 project must be implemented on campus.
- The person submitting the project must be a NAU student, faculty, or staff member.
- Projects must provide all necessary documents, letters of support, and authorizations prior to submission.
- The Green Fund distributes funding on a **reimbursement basis**. Project teams should partner with an administrative office to provide upfront funding for the project. Once the project has been successfully completed, the Green Fund will reimburse the administrative partner.
- All project applications should be submitted to greenfund@nau.edu for review.

Disclaimer: All applications will go through a comprehensive vetting process. We highly recommend meeting with a Green Fund Committee member prior to submitting the application. The Green Fund Committee member will assist you with every step of writing your project application. If your project is approved, you may be asked to provide more detailed information regarding specific deliverables. The Green Fund is not responsible for acquiring the necessary permits, permissions, or approvals for a project, although we are happy to assist with this process if needed. Additionally, the Green Fund does not provide any ongoing maintenance costs. A sponsoring department must take responsibility for operations and management.

Review Process: Upon project application submission, the Green Fund will review your project within two weeks. At this time, the Green Fund will provide comments on the project. Incomplete applications will not be reviewed until all components are submitted. **Note:** The Green Fund Committee only meets during the academic year. All projects submitted outside of the regular academic year will be reviewed at the start of the next academic session.

Contact Information

Project Leader Name: Logan Yeoman Phone: 702-469-7907 E-mail: lgy5@nau.edu

Project Budget Liaison Name: Sabin Wright Phone: 480-760-5102 E-mail: sjw366@nau.edu

Expected Graduation Date: May 2023

Project Advisor Name: Dr. Jennifer Wade Phone: 928-523-1528 E-mail: Jennifer.Wade@nau.edu

Sponsoring Department: Engineering

Project name: Passive Radiative Cooling

NAU Department/Unit for funding reimbursements (Attach letter of commitment from departmental representative): Engineering

Project Overview

Executive Summary

Please provide a brief overview of your proposal. Please address how this project will support the goals of the Green Fund (student involvement, creating a culture of sustainability, and lessening NAU's impact):

In 2014, Shanhui Fan's research team at Stanford University, published a paper on a new material that can cool surfaces below ambient temperatures by emitting thermal energy to outer space within our planet's atmospheric radiative window. These same materials that enable sub-ambient cooling are now being commercially developed by PARC and 3M into surface paints. Our Mechanical Engineering Capstone team wants to design, build and test a radiative heat exchanger test rig to measure the efficacy of these new coatings alongside reflective paint and blackbody paint to a) explore new cooling applications to lower cooling energy loads – like cooling the return lines of chilled water hydronic loops, and b) demonstrate heat transfer principles and their relation to sustainable building design for our Mountain Campus engineering programs and new engineering programs in our satellite campuses.

We are trying to test the efficacy of passive radiative cooling, which is yet to be commercialized, for cooling building heat loads. An application of this includes heat generated from NAU IT servers. We feel that technologies like this will become even more essential for our southern satellite campuses like NAU Yuma. We would like our rig to be something that can displayed on the NAU Mountain Campus while NAU continues to develop its engineering programs. The rig itself has potential to be utilized in future research projects at NAU.

The ambitions of this project directly reinforce the goals of Green Fund by engaging students in sustainability, supporting a culture of sustainability at NAU, and creating an opportunity to decrease NAU's impact on the environment.

Please answer the following questions detailing the components of your project:

1. Does your project require space or construction on campus? If so, where? Please review the "Space Committee Document" located on our webpage and follow the steps to begin requesting a location.

The passive radiative cooling test stand will occupy a 2'x6' tabletop space when fully assembled for outdoor testing. This can be assembled on a portable table outside in the Mechanical Engineering's Renewable Energy Lab space. When not in use, the apparatus can be disassembled and stored in a 38-gallon tough storage tote, like many other experiments in the mechanical engineering department. The disassembled storage can be kept in the renewable energy lab field house. Approval for use of this space is clarified in the attached letter of support from the Mechanical Engineering Department Chair, Dr. Constantin Ciocanel.

2. Have you obtained all necessary approvals for this project? Please attach all letters of support to this application. Letters of support should include confirmation from the sponsoring department that the sponsoring department will cover all upfront expenses and work with the Green Fund Business Manager to acquire reimbursement after project completion. If any ongoing operations and maintenance

is required of your project, provide a letter of support from the entity that will be covering those costs and/or services.

Yes, please see the attached letter of support for both the use of the ME Capstone account to front the costs prior to reimbursement and the use the NAU Renewable Energy Lab for storage and testing.

3. Will this project provide funding for student wages?

No, it will not.

4. Please list all additional sources of funding you have pursued. Including departments, grants, ASNAU, Graduate Student Government, etc.

PARC Research/Development company will be coating our design with their new passive radiative films for this demonstration project. Their labor hours and material costs are not disclosed, as these materials are still under development, not yet commercial.

The Mechanical Engineering Capstone account will provide an additional $2000 for the project, in addition to providing the data acquisition software that is used to collect the temperature measurements, which is estimated to cost ~$10K annually. If for any reason the department decides to terminate this software license, the data acquisition can be transitioned to low-cost Arduino data acquisition tools and Excel DataStreamer, part of the Microsoft Office 365 suite.

5. Have any of the Green Fund Committee members been involved in this project?
    a. If Yes, please identify all committee members:

        Yes, our capstone team has been in contact with Sophia Swainson. We plan on consulting Sophia with any questions and progression updates we might have.

Project Specifics

Please address the following questions. One or more of these questions may not apply to your particular application. Answer as many questions as are applicable to your project.

Relationship to NAU Climate Action Plan (CAP)

1. How does your project align with one of the seven CAP categories (Energy, Water, Transportation, Waste Minimization, Sustainable Landscaping, Environmental Justice, Communication)?

This project aligns with Energy, Communication and Water because we are exploring new passive cooling technology to lower cooling energy loads, which lowers energy and water demand simultaneously. We will also use this demonstration to communicate conduction, convection, and radiation heat transfer principles in the context of a broader societal problem. The novelty of the project is to explore new systems that take advantage of new radiation emitting coatings.

Community

2. Is there a public outreach plan? How will faculty, staff, and students learn about this?

Currently our capstone team has a website that tracks the progress and results of our project. The results will be presented at the annual UGRADs event at the end of April or early May. The project will continue in a future heat transfer lab developed by ME Faculty (e.g. Prof. Jennifer Wade), and hopefully integrated into extended campus engineering programs.

3. Are you working with other groups on or off campus? If so, describe your partnership.

We are working closely with PARC. Our partnership includes our team designing, constructing, and testing a radiative heat exchanger test rig that would be shipped to PARC where they would coat a heat exchanger panel with a special cutting-edge paint that has been developed by the PARC. Once completed, the rig would be shipped back to us to test the efficacy in cooling simulated hydronic loops responsible for cooling buildings on campus.

Project Parameters

4. What are the environmental costs and benefits associated with your project?

Using passive cooling has the potential to benefit the environment by decreasing heat stored into the atmosphere and lowering the electrical and water loads needed to cool buildings and structures. One potential environmental cost is the life cycle analysis of the passive cooling materials. The details of these materials are not yet revealed because the product is not yet commercial. However, the literature suggests that these films make use of hafnium oxide, a heavy mineral mined throughout the world. Because this material is limited to films and not 3D structures, the volume of this resource is not likely to be large. A bigger question that will need to be understood in the future, if this material is indeed needed to emit energy through the spectral atmospheric wind, is whether it can be recycled and contained outside of solid waste facilities, much like the precious metals found in catalytic converters or lithium in batteries.

5. Provide an economic cost/benefit analysis for your project. Focus on identifying specific cost savings.

Passively cooling an environment/system holds the potential to cut costs in direct cooling methods. A great example of where this could be implemented is in the NAU IT servers. Heat cooling data generated from this experiment (W/m2) will determine how many kWhr can be avoided using existing and future cooling systems. These Cost savings, of course, come at the expense of future passive cooling panels. The cost of the panels is a manufacturing expense that may be estimated by the termination of the project.

6. As this a one-time expense or will you require future funding?

This is a one-time expense. Any future expenses to modify or continue to improve the system will be provided by the courses or student groups using the experiment.

7. When your project members no longer attend NAU, who will be responsible for running the project?

This project will conclude in the Spring 2023. Though Dr. Jennifer Wade may expand on the research we do in the future.

8. How will you monitor the impact of your project after implementation?

If passive cooling methods are eventually implemented into NAU's systems. It would be easy to track the decrease in cost.

Project Budget

Please include a thorough breakdown of all project costs, **as well as a 5% line item for contingency**.

Budget			
Item	**Price**	**Quantity**	**Total**
Pipe Insulation	$2.05	1	$2.05
PEX Pipe	$5.16	1	$5.16
Pump	$249.55	1	$249.55
PEX T fitting	$8.04	2	$16.08
Aluminum sheet	$125.82	2	$251.64
Flat foam insulation sheet	$38.89	3	$116.67
Small bolts	$11.53	1	$11.53

Nuts	$10.29	1	$10.29
Washers	$6.33	1	$6.33
2x4 Wood	$4.31	8	$34.48
5 Gallon Bucket	$5.73	2	$11.46
Black Paint	$55.75	1	$55.75
White Reflective Paint	$57.50	1	$57.50
Thermometer	$164.29	1	$164.29
Thermocouples	$32.80	12	$393.60
Flow Rate Sensors	$95.68	2	$191.36
Valves	$164.15	3	$492.45
Radiation Sensor	$588.92.	1	$588.92
Data Acquisition Device	$2,327.60	1	$2,327.60
Convective Shield Materials	$320.26	1	$320.26
Radiator	$91.99	1	$91.99
Folding Table	$126.50	1	$126.50
Storage Tote	$45.98	1	$45.98
CNC Bits for tooling	$16.78	1	$16.78
PMMA plastics	$47.13	2	$94.26
Mylar film	$26.05	1	$26.05
Brass Connector	$2.84	8	$22.72
Shipping	$584.63	1	$584.63
Data Software	$115	1	$115.00
Contingencies (5%)			$321.53
Total Cost			**$6,752.41**

Note that the total cost of $6752.41 would be partly covered by the Engineering Capstone Account for an amount of $2000. **The total requested amount from the NAU Green Fund is $4752.41.**

Project Timeline

Timeline		
Action	**Parties Involved**	**Month/Year**
Propose project to Green Fund Committee	Project Team, Green Fund Committee	November/2022
Order Materials	Project Team	November/2022
Begin constructing/testing Rig	Project Team	November/2022
Send test Rig to PARC for coating	Project Team/ PARC	January/2023
Receive coated Rig from PARC and being final testing	Project Team/ PARC	February/2023

We are hoping to receive a response regarding approval for this application before the end of November 2022. All dates above are accurate with this assumption.