Bass Connections Energy and Environment Design: Solar Umbrella Team Report

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Executive Summary

The Solar Umbrella project is designed to provide sustainable energy for outdoor spaces through a solar-powered charging station. The system features an umbrella-like solar canopy fitted with a backup battery, offering convenient device charging while promoting renewable energy use. This initiative aligns with Duke University's ongoing efforts to reduce carbon emissions and enhance environmental awareness on campus. Additionally, user surveys and data tracking will assess the real-world impact of the system on student behavior and energy usage.

(Insert image of the prototype concept here, labeled as Figure 1)

I. Introduction (Motivation & Mission Statement)

Motivation

Duke University has been a global leader in achieving carbon neutrality for institutions and universities alike. In 2007, Duke University committed to being carbon neutral by 2024 and has since achieved that goal. In this time, Duke has heavily relied on external investing to offset their own carbon emissions.

They have invested hundreds of millions of dollars in infrastructure improvements, reducing energy costs, renewable energy investments, and purchasing over $4 million of high-quality carbon offsets. Since 2007, Duke's GHG has only decreased by 31%. Duke does have a 101-megawatt solar energy project that will come online to provide nearly half of the campus' electricity in mid-2025.

Alongside institutional changes, Duke also fosters several student-driven initiatives to fight the climate crisis including the Duke Smart Home, Duke Climate Coalition, Energy Week at Duke, and Duke Energy Club. In the spirit of student-driven initiatives, our team sought to reduce energy while enriching our community. Decentralized solar microgrids on campus can further decarbonize Duke's energy usage and enhance environmental awareness. We sought to create a microgrid that reduces electricity usage on campus while encouraging community engagement, providing shaded charging areas, and increasing the visibility of renewable energy technologies.

(Insert Duke sustainability efforts visual, labeled as Figure 2)

Statement of Problem

Current outdoor study and gathering spaces on campus lack reliable access to charging stations powered by renewable energy. Students and faculty require accessible, sustainable power sources for their devices. We aim to develop a scalable solar-powered umbrella system that integrates seamlessly with campus infrastructure, providing shade and energy solutions while quantifying energy consumption through solar power meters.

II. Technical Design (Methodology, System Overview, Prototype)

Approach and Methodology

Once we established the general concept of the solar umbrella, we conducted site analysis to determine optimal locations for installation. Second, we designed the frame and mounting structures for the four solar panels. Additionally we created a mechanism to open and close the umbrella using a 3-bar linkage. To record data and track energy harnessed and deployed, we developed an online dashboard and installed a solar power meter to monitor real-time energy consumption. We also implemented electronic waterproofing to ensure durability. Lastly, to focus on the consumer experience, we conducted user surveys to assess behavior changes and system usage.

System Overview

- Charging Capacity: 300 W (supports multiple laptops and phones)
- Storage Capacity: 1,280 Wh (allows extended charging hours)
- Solar Panels: 400 W total (four 100W panels for shade and energy generation)
- Charge Controller: 40 A (regulates voltage and current)
- Current Inverter: 750 W (converts DC power to AC)

(Insert system diagram, labeled as Figure 3)

- *Include information on expected solar panel efficiency and potential degradation over time.*
- *Include battery lifespan data, mention how often replacements might be needed.*

Prototype

- Structural schematics of the umbrella frame
- Electrical system layout
- Battery and inverter integration

(Insert CAD drawings, labeled as Figures 4-6)

III. Analysis

Analysis

- Structural stress testing under wind loads
- Thermal effects on battery storage and efficiency
- Energy output variations under different weather conditions
- Material selection for frame durability
- Energy efficiency calculations
- Safety assessments for public use
- Weather resistance evaluation (protection against wind, rain, and debris)

Testing, Evaluation, and Results

(*Current testing is ongoing; results will be incorporated in the future draft.*)

(Include data table from solar panel testing, labeled as Table 1)

- Load testing of the charging system
- Weather resistance trials
- Feedback from user surveys
- Field tests with potential deployment
- Evaluating charging reliability under varying loads
- The team needs to figure out how charging reliability will be tested. Potentially measuring performance under different loads (e.g., a single laptop vs. multiple devices)?

IV. Benefit Analysis (Environmental and Social Benefit)

Environmental Benefit Analysis

- Quantify kilowatt-hours saved per unit annually

- Compare to conventional outdoor electrical outlets' carbon footprint

This product offers the following environmental benefits:

1. XXX energy saved
2. XXX worth of carbon offsets
3. XXX contribution to Duke's decarbonization efforts
4. An impact on outdoor energy accessibility
5. A reduce of XXX indoor energy demand by encouraging the use of outdoor study areas

(Insert energy savings projection graph, labeled as Figure 7)

Social Benefit Analysis

This product also offers several social benefits outlined by the 2030 Sustainable Development Goals.

1. Health benefits: this product provides shade and protection from sunlight to reduce heat exposure
2. Community engagement: this product heavily encourages outdoor social interactions
3. Education: this product serves as a hands-on-education for renewable energy technology

V. Market Opportunity (Target Market & Business Plan)

Target Market

1. Primary Users: Duke University students, faculty, and visitors
2. Potential Expansion: Other university campuses, parks, and public spaces
3. Stakeholders: Duke administration, environmental organizations, student groups, Duke Facilities

Campus Interviews and Results

We conducted campus interviews of some friends and randomly sampled Duke students to gauge overall interest, and understanding about placement. Interview questions include:

1. Do you study or hang out outside?

2. What’s most important to you in an outdoor study/hang-out spot?
3. Where on campus would you be most likely to use the solar spot?
4. How important is reliability v. sustainability? (being able to charge devices 24/7 v. that the table only uses solar power)?
5. How likely would you be to use an outdoor study spot?

Once interviews are finalized, I will detail the results here and link to a table in the appendix with individual results.

(Insert survey data table, labeled as Table 2)

Basic Business Plan

The estimated production cost is ~$1,500 per unit in the prototype phase. Before finalizing a potential consumer price, we are running our model based on volume, deployment costs, ROI, and phasing in cost reduction through a data-driven optimization model.

Phase	Milestone	Timing
Phase 1	Prototype Development	Q1 2025
Phase 2	Pilot Testing at Duke	Q2 2025
Phase 3	Fundraising & Deployment Strategy	Q3 2025
Phase 4	Commercialization to Consumer & Regulatory Compliance	Q1 2026

Our funding goals are to support a prototype, testing, and the first commercialization pilot phase. Potential sources include Duke’s Office of Climate and Sustainability, SCALE grants, alumni donations, energy resilience & green tech grants, and corporate sponsors (renewable energy firms, and edtech companies). Our path to commercialization would rely on partnership with facilities and other universities’ sustainability offices. Our primary regulatory issues revolve around energy standards and safety regulations.

Maybe we can consider adding potential pricing models for long-term maintenance and scaling?

Other Considerations

- Location & Facilities: Identifying suitable locations and ensuring Duke's facilities can maintain the system
- Weather: Protecting solar panels from debris and optimizing performance on cloudy days
- Demand: Ensuring sufficient power generation for user needs
- Aesthetics: Designing an appealing structure that fits campus architecture
- Safety: Ensuring structural stability and electrical safety for users

VI. Conclusion

Principal Findings

- The Solar Umbrella is a viable solution for decentralized renewable energy on campus
- Further testing is required for performance optimization

Suggested Improvements & Recommendations

- Enhance the umbrella mechanism for easier deployment
- Reduce umbrella weight for easier transport
- Improve weatherproofing for long-term outdoor use
- Expand integration with smart monitoring systems
- Scale up implementation across campus
- Explore commercialization opportunities
- Investigate potential partnerships with sustainability initiatives
- Establish criteria for project success, including usability, accessibility, and data collection

VII. References

(Citations in MLA format)