Climate Risks and Resilience at Dickinson College: Strategies for Infrastructure, Utilities, and Grounds

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February 28, 2025

Prepared for *Building Climate Resilience at Dickinson and in Central Pennsylvania*, an initiative of Dickinson College, the Borough of Carlisle, and Cumberland County, PA, as part of Dickinson's Baird Sustainability Fellows Practicum Course.

1. Introduction

Dickinson College's President, John E. Jones, signed the Resilience Commitment of Second Nature in December of 2022. This commitment underscores the call for the college to assess climate risks and resilience strategies in Carlisle and Cumberland County and develop a plan for action. The purpose for this report is to develop climate resilience strategies for Dickinson college to implement, with a focus on addressing the risks to infrastructure, utility services, and grounds. To assess each strategy, a multi-criteria analysis will be performed to understand how each action will perform within each stated criterion. In conducting a multi-criteria analysis and recommending strategies, the college will better understand the pros and cons, cost-benefit analysis, and overall decision-making within infrastructure, utility services, and grounds. By recommending strategies for implementation, the college can be better informed on what areas are at risk to climate hazards and how they can be potentially addressed.

This report evaluates resilience strategies across two key areas within infrastructure, utility services, and grounds: grounds landscape and infrastructure. Grounds landscape will encompass everything relating to college grounds such as vegetation and stormwater. The focus will be on developing an overall resilient landscape plan for the college. The resilient landscape plan will include recommendations such as tree and vegetation maintenance and replacement, collaboration with the Carlisle Borough, flood risks assessment, and expanding green infrastructure projects. Infrastructure will encompass everything related to the college infrastructure such as transportation systems via roads, sidewalks, etc., and buildings. The focus will be on assessing the condition of existing infrastructure. Assessing infrastructure will include recommendations such as maintenance checks and cool and reflective roofing.

2. Climate Risks

Specific hazards such as flooding, increases in precipitation, and heat waves are expected to increase in Pennsylvania, specifically Carlisle, in the near future, potentially dampening existing infrastructure vulnerabilities and challenging the college's ability to manage and maintain its grounds (PA DEP, 2021 and Leary, 2023). In terms of heat related climate risks, Pennsylvania is expected to experience more extreme heat events in the future, with temperatures affecting areas in human health, built infrastructure, energy, recreation (PA DEP, 2021). Moreover, heat can cause buildings to age more rapidly, and additionally, extreme heat in the near future could cause an increase in cooling costs, concrete degradation, decreased energy functioning, and reduced efficiency overall (CISA, n.d.). Additionally, extreme rainfall events are also expected to become more intense and frequent in Pennsylvania, affecting areas in built infrastructure and agriculture the most (PA DEP, 2021).

The Pennsylvania State Council of the American Society of Civil Engineers has assigned Pennsylvania an overall grade of C in its infrastructure. This means that Pennsylvania infrastructure is granted as “mediocre” and “requires attention” as infrastructure has shown signs of deterioration (Report Card for Pennsylvania’s Infrastructure, 2022). Expected extreme heat conditions are set to face Cumberland County, which can then cause buildings to age more rapidly, and additionally, could cause an increase in the college’s cooling and heating costs. As most infrastructure in Pennsylvania is an overall grade of a C, Dickinson should understand the risks that extreme heat events could pose to their students and overall infrastructure (buildings, sidewalks, roads, etc.).

Further, more intense and frequent rainfall events from climate change are expected to contribute to infrastructural water damage. The risk of water damage includes potential deterioration of building materials, increased mold growth, foundational shifts, and reduced roadway efficiency (US EPA, 2022). Additionally, these intense rain events can contribute to flooding on college grounds. Overwhelmed stormwater management systems can lead to backups, causing more centralized flooding and increased pollutant runoff into local/nearby waterways. As most infrastructure in Pennsylvania is an overall grade of a C, Dickinson should understand the risks that extreme heat events could pose to their students and overall infrastructure.

Together, extreme heat and increased rain events can pose a threat to the college ground’s trees and vegetation. Even the smallest increases in temperature can increase water demands on trees and vegetation surrounding the college grounds (Schieffer, 2024). Therefore, less water is available for trees to function and trees under these heat conditions need extra water (Schieffer, 2024). Moreover, if these conditions are not met, most trees and vegetation in these scenarios will not be able to withstand the climatic forecast. Additionally, increased rain events can have inverse effects on trees and vegetation. For example, flooding can change certain physical and chemical characteristics of trees and vegetation, causing them to weaken, and therefore not be able to withstand the increased rain events (University of Minnesota Extension, 2024).

It is important for Dickinson to therefore address the risks regarding extreme heat events and increased precipitation. The risk of these risks on infrastructure and campus grounds presents a challenge to the campus’s resilience and functionality as climate hazards not only threaten overall infrastructure and grounds, but also the well-being of its students, faculty, and staff. Conducting routine monitoring of these events can aid in mitigating negative health effects from urban heat island and the degradation of trees and vegetation to the college landscape. Trees and vegetation provide shade which, in turn, will help to reduce the urban heat island effect, making outdoor spaces more comfortable for students, faculty, and staff (EPA, 2015).

The risk of infrastructure degradation due to extreme heat events highlights potential vulnerabilities that the College should prepare for as they are not immune to these effects. Moreover, extreme rainfall events threatening stormwater systems on campus can contribute to localized flooding and pollution, affecting campus operations such as access to roads/sidewalks/walkways, and overall grounds. The combination of extreme heat and flooding events negatively affect the college’s vegetation and trees, which are vital for reducing urban heat island, aesthetics, and overall safety. This loss of vegetation on the college campus could thereby worsen health effects and ground management. Therefore, by addressing these risks through climate resilience strategies, Dickinson College can safeguard its campus' functioning and maintain a safe and sustainable environment.

3. Examples of Resilience Strategies

With these risks present, it is important that Dickinson College comes up with strategies to mitigate the effects to the college Infrastructure, Utility Services, and Grounds. To figure out which strategies to focus on, a focus group was conducted for each area of the project, including one for Infrastructure, Utility Services, and Grounds. The focus group consisted of 15 participants, their roles at the college consisted of Director of Projects, Director of Trades, Mechanical Lead, Structural Lead, Director of Grounds and Landscaping, Electrical Lead, Asst. Professor of Environmental Science, Director of The Trout Gallery, Assoc. Dean of Access Services, and Human Resources Coordinator. The purpose of the focus group was to gather data on the types of risks that were considered most "at risk" to the college, while additionally coming up with strategies for these risks. The focus group discussion relating to Infrastructure, Utility Services, and Grounds highlighted risks such as heating and cooling, trees and landscape, and stormwater management. Moreover, participants emphasized concerns such as mold and air quality, ineffective drainage systems, and extreme heat effects. Through the conversations held during the focus groups and subsequent research, here are the strategies that I will be focusing on.

The first strategy that I will be focusing on is developing a plan to create a resilient landscape at Dickinson College. Given the trends of extreme heat events, it is essential to identify trees and vegetation and stormwater management best practices that are suitable for their climatic conditions. I recommend that the college prioritizes tree and vegetation maintenance and replacement, collaborates with the Carlisle Borough, conducts a flood risk assessment, provides course curricula and research opportunities, and maintains and implements green infrastructure projects within this strategy.

Tree and vegetation maintenance and replacement: Tree and vegetation maintenance and replacement includes assessing tree and vegetation suitability for upcoming climate hazards as well as regular maintenance to ensure campus safety. By implementing this action, the college can successfully mitigate increased precipitation and extreme heat as they will be implementing the proper trees that are suitable for the campus, as well as ensuring tree canopy is sustained.

Collaborate with the Carlisle Borough: Collaborating with the Carlisle Borough includes understanding vegetation assessments that are aligned with the Borough's tree canopy policies. By implementing this action, the college can successfully mitigate increased precipitation and extreme heat events as they will be ensuring effective execution of tree canopy.

Flood risk assessment: Flood risk assessment includes understanding impacts on stormwater management from increased precipitation. By implementing this action, the college can reduce risks of flooding as they will be equipped with the knowledge of where the most flooding impacts occur and improve the conditions as needed.

Course curriculum and research opportunities: Course curriculum and research opportunities include involving students and faculty to understand stormwater management and be involved in evaluating best management practices based on research/class findings. By implementing this action, the college can reduce risks from increased precipitation as more students and faculty will have the knowledge to better equip the campus with best management practices in prevention.

Green infrastructure implementation and maintenance: Green infrastructure implementation and maintenance includes maintaining existing green infrastructure as well as implementing new additions to college grounds for effective stormwater management. By implementing this action, the college can prevent stormwater runoff from increased precipitation as green infrastructure has the ability to absorb access water from rainfall, streams, etc.

The second strategy that I will be focusing on is assessing the condition of Dickinson College's infrastructure. Assessing the condition of existing infrastructure at Dickinson College will help the college to assess and monitor the effects of heat on infrastructure integrity with respect to climate hazards and develop a plan to monitor those effects. Increasing temperatures can degrade roofing materials, which in turn, generate increased energy costs and accelerate wear (European Commission. Directorate General for Climate Action, 2023). Therefore, I recommend that the college prioritizes cool and reflective roofing within this strategy.

Cool and reflective roofing: Cool and reflective roofing includes installing white roofs onto new and existing buildings for effective energy efficiency and reduced heating capabilities. By implementing this action, the college can reduce climate risks from extreme heat as white roofs are effective in mitigating extreme heat impacts.

4. Methods for Evaluation Strategies

When evaluating resilience strategies for the Dickinson College campus to implement, I employed a multi-criteria analysis (MCA). A multi-criteria analysis is a decision tool used to compare various approaches with respect to different, stated criteria. The tool then uses a decision matrix to compare the performance of all of the approaches or actions and presents results that rank the actions. In addition to the multi-criteria analysis, I used literature regarding my topic on *infrastructure, utility services, and grounds* to provide a comprehensive evaluation of each action.

The criteria that I used to evaluate each resilience strategy differs based on the topic that I am evaluating (grounds, infrastructure, stormwater management), and include:

- Protection of Structure: How effective would the action be in reducing the risks of adverse impacts on Dickinson's Infrastructure?
- Co-benefits: Would the action generate other benefits in addition to protecting infrastructure?
- Financial Cost: What are the expected financial costs of the action?
- Flexibility: Could the action be modified or scaled up over time to improve performance?
- Proven Strategy: Have others implemented the action successfully?

Each of these five criteria are then assigned a weight to reflect its importance in the evaluation process. The following weights have been assigned:

- Protection of Structure (25%) is assigned a high weight as protecting the college grounds, infrastructure, and stormwater systems from climate hazards is a top priority. The primary goal of resilience strategies and actions is to reduce risks to infrastructure and the environment in the face of climate change. Therefore, ensuring that the strategy effectively mitigates detrimental effects from hazards like increased precipitation, flooding, and extreme temperatures is essential to maintaining the safety and well-being of the Dickinson College campus and its overall infrastructure.
- Co-Benefits (20%) is assigned a moderate weight as while co-benefits such as improved water retention, reduced heat, and energy efficiency are important for the effectiveness of resilience strategies, they are considered secondary to the other evaluation criterion. However, co-benefits help increase the value of a resilience strategy by offering additional advantages to implementation of a main action.
- Financial Cost (25%) is assigned a high weight as it reflects the importance of ensuring that resilience strategies are cost-effective and feasible. This criterion takes into account initial and long-term costs for Dickinson College. As financial resources are often limited, ensuring the financial sustainability of a strategy is important for its implementation.
- Flexibility (10%) is assigned a low weight as it is valuable for resilience strategies to be adaptable and scalable over time, particularly as future risks evolve. However, this criterion is seen as less urgent compared to other criteria being evaluated.
- Proven Strategy (20%) is assigned a moderate weight as it is crucial to consider whether a resilience strategy has been successfully implemented elsewhere, as this provides information regarding its feasibility and effectiveness. Using evidence from previous successful implementations helps to support the rationale for choosing one strategy over another.

Decision Criteria, Weights, and Scoring for Infrastructure, Utility Services, and Grounds:

Criteria		Weight	1 Point	2 Points	3 Points
Protection of Structure	How effective would the action be in reducing risks of adverse impacts on Dickinson's structures?	25%	Action would generate minimal protection of structure.	Action would generate moderate protection of structure.	Action would generate substantial protection of structure.
Co-benefits	Would the action generate other benefits in addition to protecting structures?	20%	Action would generate minimal co-benefits.	Action would generate moderate co-benefits.	Action would generate substantial co-benefits.
Financial costs	What are the expected financial costs of the action?	25%	Action would have substantial financial costs.	Action would have moderate financial costs.	Action would have minimal financial costs.
Flexibility	Could the action easily be modified or scaled up over time to improve performance?	10%	Action could be modified or scaled up over time with substantial effort and additional cost.	Action could be modified or scaled up over time with moderate effort and additional cost.	Action could be modified or scaled up over time with minimal effort and additional cost.
Proven strategy	Have others implemented the action successfully?	20%	Evidence of successful implementation by others is very limited.	Action has been implemented successfully by others.	Action has been implemented successfully by many others.

5. Analysis of Selected Strategies

To assess the feasibility and effectiveness of various strategies for improving infrastructure, utility services, and grounds at Dickinson College, a comprehensive analysis of the strategies is imperative. This analysis will examine each proposed strategy, focusing on its potential implementation, expected outcomes, and anticipated challenges. For each strategy, I will assess its performance based on the five criteria—safety benefits, co-benefits, financial cost, flexibility, and proven strategy—and provide a score for each based on a scale ranging from 1-3. Ultimately, this process will help to guide decision-making at the college and determine the best course of action moving forward to mitigate the effects of growing climate hazards.

	Protection of Structure	Co-Benefits	Financial Costs	Flexibility	Proven Strategy
Resilient landscape plan for the college	2	3	1	1	3
Assess the condition of college infrastructure	3	3	2	2	2

Table 1. Scoring for respective resilience strategies for *Infrastructure, Utility Services, and Grounds*.

<u>1. Develop a Resilient Lanscape Plan for Dickinson College</u>

Given the recent trends of extreme heat affecting Dickinson College and the surrounding areas, it is essential to identify tree species and vegetation that are well-suited to these changing conditions. Therefore, I recommend that the college develops a plan to create a resilient landscape. To do so, first the college should continue to assess current tree canopy and vegetation to understand if they are suitable for an increasingly hotter climate. The college should then identify which of the trees and vegetation on campus grounds should be given increased consideration in the face of climate hazards. Furthermore, in the face of climate hazards it is crucial to continue researching and selecting tree species and vegetation that can thrive on the Dickinson College campus currently, and in the future. Aside from tree canopy implementation and maintenance, I recommend that Dickinson College conducts a flood risk assessment, identifying where stormwater flooding impacts are, and where the most impacts occur. For each area of impact, I recommend the college investigates the right interventions and solutions that the college can implement, such as permeable pavements, rain gardens, etc. Upon evaluation of these buildings, the college can review and improve, as needed, the condition of our buildings and other infrastructure, such as stormwater management.

1.1 Tree and Vegetation maintenance and replacement

Tree and vegetation maintenance and replacement is an important action in ensuring the safety, well-being, and overall structure of the college. I recommend the college continues to have hired arborists inspect trees and trim dead branches to maintain a safe environment on campus grounds, that will help to prevent potential hazards that could pose risks to students, employees, visitors, and infrastructure of the college. I recommend the college be proactive in tree replacement, continuing to replace trees within a year after they have been removed to mitigate urban heat island effects. Additionally, if there is an issue regarding certain trees and vegetation on campus that cannot withstand the increasing climatic conditions, I recommend that the college assesses if the tree or vegetation needs to be replaced, and if so, should take proactive measures. For instance, the college could use the assessment of climate suitability to identify the trees and vegetation most at risk and implement a program/measure to continually monitor their health and appearance. To determine tree suitability, I recommend the college use The US Forest Service's Climate Change Tree Atlas. The Climate Change Atlas provides data on current and projected suitability of Eastern US trees in the face of climate hazards (USDA, n.d.). Additionally, it includes information on specific tree species, such as its traits and life projection.

Moreover, thinking towards the future of what kinds of trees and vegetation would make sense to be replacements is vital. These would include the trees and vegetation that will be more viable in the future impacts of climate change. Examples of specific trees that the college could implement include but are not limited to:

For a climate prone to drought:

- Pin oak
- Black oak
- Shagbark hickory
- Mockernut hickory

For a climate prone to extreme heat:

- Slippery elm
- Black gum

- Shortleaf pine
- Eastern hophornbeam

(DCNR, 2019)

Further, due to changes in weather patterns from the increasing effects of climate change, southernmost plant species are expected to move northward. This is due to there being overall infrequent extreme cold events and increased warmer winters (Osland, 2021). In response to these changes, many tropical freeze-sensitive native plants are expected to move northward (Osland, 2021). Additionally, non-native plant species are expected to move northward and alter ecosystems due to climate change impacts (Osland, 2021). Therefore, I recommend that the college considers implementing southern vegetation on college grounds. By incorporating this vegetation, the college can prepare for these ecological shifts in the face of climate change. However, a challenge to its implementation is the potential for invasives that the college would have to monitor in depth.

<u>1.2 Support and work with the Carlisle Borough</u>

When collaborating with the Carlisle Borough on vegetation assessments, the college should work with and understand the borough's specific policies regarding tree canopy. For instance, to promote healthy trees, the Carlisle Borough removes "dying trees and dead branches and stumps," as well as elevates trees to an 8ft (sidewalk) or 14ft (street) to ensure town safety (*Shade Trees*, 2024). By continuing to cooperate with Carlisle Borough policies, the college will help ensure that tree canopy initiatives around the campus are in alignment with local regulations and best practices for proper implementation. Additionally, it is imperative to consider playing an advocacy role in helping to support Carlisle's efforts in maintaining tree canopy through Shade Tree Ordinance. This collaboration can help ensure long-term health benefits and expansion of green spaces within the college and Carlisle areas.

<u>1.3 Green Infrastructure Implementation and Maintenance</u>

The cause of flooding can be attributed to ineffective stormwater management and impermeable pavement materials at the college. Moreover, permeable pavements can be implemented at the college to help absorb flooding from storms, preventing potential stormwater runoff into other areas of the campus (European Commission. Directorate General for Climate Action., 2023). The college should therefore consider utilizing permeable pavements in areas in and around the Dickinson College campus that are more prone to flooding.

Effective green infrastructure projects are the college have demonstrated effective stormwater management. Currently, Dickinson College green infrastructure projects include a bioswale in front of Kaufman Hall, bioretention basin on West Louther St., flow-through planter on Cherry St., and a green roof on Tome Hall (Ray, 2024). Each form of green infrastructure on the Dickinson College campus has effectively helped to manage stormwater on college grounds. However, I recommend that the college considers adding more green infrastructure projects to areas that are identified as "at risk of flooding," based on the flooding assessment. Additionally, maintenance measures to green infrastructure projects are imperative for them to keep being effective in the future.

To maintain green infrastructure, an understanding of the local climate and vegetation that surrounds the college should be considered. Understanding the local climate's extreme heat and precipitation trends will help to maintain green infrastructure that can handle stormwater effectively, as well as withstand extreme heat conditions. Moreover, by understanding what vegetation will withstand these climate events, the college can ensure that its green infrastructure remains functional, reducing the risk of plant failure, minimizing maintenance needs, and enhancing the overall effectiveness of stormwater management systems. To do this, Dickinson students and employees can take part by helping maintenance to water the plants, etc.

<u>1.4 Course Curriculum and Research Opportunities</u>

Exploring research opportunities within Dickinson College course curriculums - such as Environmental Science and Biology - and research opportunities – independent research and DANA research – can be an insightful for both students and employees to learn more about stormwater management best practices. Involving students and faculty to evaluate these sites in some capacity would provide valuable research experience and education on effective stormwater management. The sites that students and faculty examine are the most impacted, can become a case study or further research opportunity.

Summary Based on Scoring

The development of a plan to create a resilient landscape at Dickinson College is expected to generate high co-benefits in the form of reduced heat, improved public and campus safety, stormwater management, and strong community partnerships for students and employees. According to Kunsch and Parks, the cost of tree planting and removal depends on whether it is publicly or privately planted, as well as the specific area. Private tree planting costs can range from $18-$23, while public tree planting costs can range from $34-$41 (Kunsch and Parks, 2021). Additionally, removal and maintenance costs can range from 18%-60% of a tree's overall annual cost. However, with these costs in mind comes various benefits such as pollutant reduction, energy savings, decreased runoff, etc., (Kunsch and Parks, 2021). The grounds resilience plan would be used to make decisions about wider application to the strategy by providing education to employees, faculty, and students on the types of trees that are suitable for the college. However, it is difficult to implement these strategies in different capacities as it has been proven that there are certain trees that will be suitable for the area and climate (DCNR, 2019). However, the trees and vegetation planted can be planted all throughout the college campus, not just in one area.

Moreover, the cost of green infrastructure that is implemented and upkept depends on the type of infrastructure project. For permeable pavements, the cost per square foot ranges from $.50-$500 depending on if the college implements porous asphalt, concrete, or pavers (Huber, Peace, and Lawson, 2018). Bioretention/rain garden projects can range from $3-$1200 depending on the needs of the rain garden to thrive (Huber, Peace, and Lawson, 2018). However, with these costs in mind come environmental and health benefits for the college such as reduced pollution and cooling. The assessment would direct decision-making about wider applications of effective stormwater management in the form of green infrastructure while providing a unique research experience to students and faculty. However, scaling up or modifying green infrastructure projects takes more effort and costs depending on the issues occurring within existing green infrastructure and where the new additions would be added.

2. Assess the condition of Dickinson College's existing infrastructure

Assessing the condition of existing infrastructure at Dickinson College will help the college to assess and monitor the effects of heat on infrastructure integrity with respect to climate hazards and develop a plan to monitor those effects. Specifically, in routine maintenance checks, the college should emphasize the robustness and resiliency to climate hazards and stresses. Dickinson College should consider bringing in an outside firm to perform an assessment of all campus buildings. The role of the firm would be to do an initial assessment of infrastructure to see which of the college's buildings need to be addressed for climate resiliency. Moreover, if the college does not find this option feasible, I recommend considering an assessment of infrastructure conducted by the college itself and then seeing if additional expertise needs to be hired. Regardless of the option chosen, I recommend the college continues to conduct routine Preventative Maintenance Scheduled inspections and End-of-Year building checks to identify any problems.

2.1 Cool and Reflective Roofing

Cool roofs are made of reflective materials that aid in the cooling of buildings more so than traditional building roofs or buildings covered in darker materials (Huber and Peace, 2018). They are efficient in the transfer of energy due to their high solar reflectance of light (Huber and Peace, 2018). However, in order to prove that white roofs are more efficient than traditional roofs, a case study should be employed. Starkweather Roofing conducted a study to observe whether white roofs are more efficient than traditional roofs (HOBO, n.d.). They installed HOBO data loggers and temperature sensors underneath each roof type to determine their effectiveness (HOBO, n.d.). Overall, three conclusions were found in favor of white roofs: white roofs reduce thermal shock, white roofs increase energy efficiency, and white roofs reduce roof surface temperatures (HOBO, n.d.). Compared to traditional roofing, white roofs were found to be 8.49% cooler during the hottest points of the day and 6.97% cooler during maximum internal temperatures as compared to traditional roofs (HOBO, n.d.).

Therefore, cool and reflective roofing is an element of infrastructure that the college should consider implementing. Currently, the college has implemented white roofing on the Kline Center, Waidner-Spahr Library, Rector, and around 50% of the Holland Union Building (HUB). The reason for the Kline Center white roof that caused this implementation was due to increased heating coming through and around the building. Since then, the Kline Center has effectively managed to mitigate heat. The college is currently investigating a PVC white roof on the HUB. I recommend the college strongly consider this option for the newest HUB renovations, as opposed to all others. When examining the cool roof on the HUB after implementation, the college can assess its impacts and if they are effective in mitigating extreme heat. Depending on what the college learns, they can implement it on more buildings, wherever feasible. For example, as the college works on and replaces roofs in the future, they could consider the new roofs to be a cool roof with every replacement.

Summary of Strategy Based on Scoring

Assessing the condition of Dickinson College's existing infrastructure is expected to generate various benefits and protection of structure in the form of reduced energy use, improved public health, and informed decision-making. In terms of cool roofs, they are estimated to cost around the same as conventional roofing, however, they are around 5-10 cents more per square foot (Huber, Peace, and Lawson, 2018). However, this cost will provide benefits in the form of energy savings in the future, as it has been proven to decrease energy consumption by 10%-40% depending (Huber, Peace, and Lawson, 2018). Additionally, white roof implementations can cost up to 3.3 cents more per square foot compared to traditional black or darker colored roofs (Huber, Peace, and Lawson, 2018). However, white roofs provide increased benefits in the long run such as reduced air temperatures (Huber, Peace, and Lawson, 2018). The assessment would produce outcomes that can be used to make decisions about wider applications to other infrastructure, new and old.

Actions	Criteria Weight (%)	Protection of Structure 25%	Co-benefits 20%	Financial costs 25%	Flexibility 10%	Proven strategy 20%	**TOTAL SCORE** 100%	Rank
Resilient landscape plan for the college	Raw score	2	3	1	1	3		
	Weighted score	0.5	0.6	0.25	0.1	0.3	**1.75**	2
Assess the condition of college infrastructure	Raw score	3	3	2	2	2		
	Weighted score	0.75	0.6	0.5	0.2	0.2	**2.25**	1

Table 2. Weights and Rankings of each action towards climate resiliency at Dickinson College.

Strategy Comparison

The resilient landscape plan for the college ranks second overall, with a total score of 1.75. While it performs well in co-benefits (0.6) and proven strategy (0.3), it struggles in other areas. The plan would score poorly in financial costs (0.25) due to the overall amount of tree and vegetation upkeep. Additionally, it is not as flexible (0.1) as other strategies as there are only certain tree and vegetation species that will be suitable for the future climate conditions.

On the other hand, assessing the condition of college infrastructure is the top-performing strategy, with a total score of 2.25. This strategy performs well in protection of infrastructure (0.75) and provides various co-benefits (0.6). However, it scores moderately in financial costs (0.5) mainly due to the implementation of cool roofing.

When examining each criterion, no single strategy outperformed another.

6. Recommendations

From the multi-criteria analysis, I recommend implementing two key strategies at Dickinson College: assessing the condition of college infrastructure and developing a resilient landscape plan.

The assessment of college infrastructure is a high-priority strategy due to its significant weighted scores in protecting of structure (0.75) and generating various co-benefits (0.75). This assessment should be implemented in the short term, within the next 5-10 years, as it is critical to address infrastructure failures and propose potential solutions in the face of extreme climatic conditions. Bringing in an external firm would be an effective first step to conduct a comprehensive review of all college infrastructure. The focus should be on identifying vulnerable areas, particularly those prone to severe weather events, and prioritizing solutions to ensure the resiliency of the campus.

The resilient landscape plan is a lower-priority strategy but remains important for its strong co-benefits (0.6) and proven strategy (0.3). While financially less advantageous, it addresses crucial climate hazards such as rising heat and flooding due to increased precipitation. This strategy should also be implemented within the next 1-5 years to address increasing heat climate hazards and potential infrastructure damage/functioning as well as address flood management needs. As an initial step, Dickinson College should collaborate with local arborists or other entities that will aid in the process of identifying the right trees and vegetation for the college. Simultaneously, the college should review and improve, as needed, the condition of our buildings and other infrastructure, such as stormwater management. To do so, the college should identify areas of infrastructure that are prone to flooding.

Together, these strategies complement one another by addressing immediate infrastructure and grounds needs while building overall resilience. Assessing infrastructure vulnerabilities will ensure the college can function effectively in the face of climate hazards, while a resilient landscape plan will support the health of trees and vegetation and manage flooding. By taking these steps in the short to mid-term, Dickinson College can strengthen its infrastructure and grounds environment to better prepare for the challenges of a changing climate.

Overall, in the face of increasing climate hazards, Dickinson College should consider the risks and subsequent strategies posed to its infrastructure, utility services, and grounds. By prioritizing an infrastructure assessment alongside and the development of a resilient landscape plan, the college can mitigate vulnerabilities while fostering resiliency in the community. These strategies not only address challenges like extreme heat and increased precipitation but also position the campus as a model for resiliency. Through informed decision-making, the college can ensure its campus remains safe, functional, and aesthetic in the face of climate change. These efforts underscore the institution's commitment to ensuring the campus is socially, economically, and environmentally sustainable and resilient.

7. References

CISA. (n.d.). *Extreme Heat*. Www.cisa.gov. https://www.cisa.gov/topics/critical-infrastructure-security-and-resilience/extreme-weather-and-climate-change/extreme-heat

DCNR. (2019). *Selecting Trees for Pennsylvania's Changing Climate*. Good Natured. https://www.dcnr.pa.gov/GoodNatured/pages/Article.aspx?post=83

EPA. (2015). *Reduce Heat Islands | US EPA*. US EPA. https://www.epa.gov/green-infrastructure/reduce-heat-islands

European Commission. Directorate General for Climate Action. (2023). *EU-level technical guidance on adapting buildings to climate change: Best practice guidance.* Publications Office. https://data.europa.eu/doi/10.2834/585141

HOBO. (n.d.). *Cool Roof Case Study - Are White Roofs Cooler and More Energy Efficient than Non-white Roofs? | Onset's HOBO and InTemp Data Loggers*. Www.onsetcomp.com. https://www.onsetcomp.com/resources/application-stories/cool-roof-case-study-are-white-roofs-cooler-and-more-energy-efficient

Huber, Peace, and Lawson, (2018). Maximizing Benefits: Strategies for Community Resilience [Review of *Maximizing Benefits: Strategies for Community Resilience*]. *The Center for Climate and Energy Solutions*, 1–93. https://www.c2es.org/document/maximizing-benefits-strategies-for-community-resilience/

Kunsch and Parks (2021). *Tree Planting Cost-Benefit Analysis: A Case Study for Urban Forest Equity in Los Angeles*. Y. Chen and M. Gonez (Eds.) TreePeople. https://www.treepeople.org/wp-content/uploads/2021/07/tree-planting-cost-benefit-analysis-a-case-study-for-urban-forest-equity-in-los-angeles.pdf

Leary, N (2023). Changing Climate Hazards in Cumberland County, A Review of the Evidence. Retrieved from https://www.dickinson.edu/download/downloads/id/14784/changing_climate_hazards.pdf

N.A (2022). Report Card for Pennsylvania's Infrastructure [Review of *Report Card for Pennsylvania's Infrastructure*]. In *Infrastructurereportcard.org* (pp. 1–155). PENNSYLVANIA STATE COUNCIL OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS. https://documentcloud.adobe.com/spodintegration/index.html?locale=en-us

Osland. (2021). Tropicalization of temperate ecosystems in North America: The northward range expansion of tropical organisms in response to warming winter temperatures. *Global Change Biology*, *27*(13), 3009–3034. https://doi.org/10.1111/gcb.15563

PA Department of Environmental Protection. (2021). Pennsylvania Climate Impacts Assessment. Retrieved from https://greenport.pa.gov/elibrary//GetDocument?docId=3667348&DocName=PENNSYLVANIA%20CLIMATE%20IMPACTS%20ASSESSMENT%202021.PDF%20%20%3cspan%20style%3D%22color:green%3b%22%3e%3c/span%3e%20%3cspan%20style%3D%22color:blue%3b%22%3e%28NEW%29%3c/span%3e%204/30/2023

Ray, (2024). *Climate Risks and Resilience at Dickinson College: Ecosystem Services, Green Infrastructure, and Stormwater Management* (pp. 1–15) [Review of *Climate Risks and Resilience at Dickinson College: Ecosystem Services, Green Infrastructure, and Stormwater Management*]. Dickinson College. https://www.dickinson.edu/download/downloads/id/15630/dickinson_climate_resilience_ecosystem_services_and_green_infrastructure.pdf

Schieffer, (2024). *Heat Stress in Urban Trees*. Retrieved October 15, 2024, from https://extension.psu.edu/heat-stress-in-urban-trees

Shade Trees. 2024. *Carlislepa.org*. www.carlislepa.org/parks___recreation/shade_trees.php.

University of Minnesota Extension. (2024). *How to Manage Flood Damage to Trees*. Extension.umn.edu. https://extension.umn.edu/planting-and-growing-guides/how-manage-flood-damage-trees

US EPA. (2022). *Climate Change Impacts on the Built Environment*. Www.epa.gov. https://www.epa.gov/climateimpacts/climate-change-impacts-built-environment

USDA Forest Service, (n.d.). *Climate Change Atlas*. US Forest Service Department of Agriculture. Retrieved December 5, 2024, from https://www.fs.usda.gov/nrs/atlas/tree/

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