EMGT5220 ENGINEERING PROJECT MANAGEMENT

FALL 2023

VORTEXGRID
REVOLUNTIONIZING URBAN RENEWABLE ENERGY - BLADLESS WIND TRUBINES WITH MICORGRID SYSTEM

PROJECT REPORT

UNDER THE GUIDANCE OF

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SUBMITTED BY

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LETTER OF TRANSMITTAL

Date: 12/08/2023

The chairman

Northeastern University

360 Huntington Avenue Boston,

Massachusetts 02115

Mr./Mrs.,

Kindly find the enclosed project proposal submission for the installation of bladeless wind turbines with an integrated microgrid system. The project is a proof-of-concept project that is designed to prove the capability of a bladeless wind turbine's ability to harness and utilize wind energy potential in an urban setting through both energy production and data capture through this installation. The solution aims to provide a new solution to urban renewable energy needs that is more cost-effective, efficient, less space consuming and one that works in an urban landscape without disturbing it.

The proposal begins with an overview of the installation, followed by technical specifications and requirements of the project and it emphasizes and presents both the need and the value of this next-gen technology. The work breakdown structure is part of the project plan and has been meticulously designed with a timetable. The responsibility matrix is used to guarantee that every task is overseen and managed within the designated duration. Using the risk matrix, the frequency and seriousness of pitfalls and dangers are plotted and assessed. A comprehensive budget and resource allocation have been provided to illustrate the spending plan.

We sincerely hope that our proposal will be convincing and useful to you. We would value your helpful criticism since it will help us grow into the sustainable energy industry leaders of the future.

EXECUTIVE SUMMARY

The proposed plan consists of the installation of Bladeless wind turbines with an integrated microgrid system for energy storage, distribution, and data collection unit, in a strategic location within the university to harness maximum wind energy.

The bladeless turbine installed within the campus would be used to produce considerable energy, which is clean and green, this will be used to power up a portion of Northeastern's green and energy conscious EXP building. The energy produced from windless turbines will be transmitted, stored, and distributed by a microgrid system. The implementation will be divided into several phases such as the project commencement, information gathering and analysis, equipment, resource and service outsourcing, hardware deployment and assembly, interconnectivity of resources, software development for data collection and analysis, testing and project closure. Every single phase is important to ensure the seamless execution of this plan.

The expected budget for the project is $657,539 including labor, materials, miscellaneous costs, and an 7% safety to handle difficulties or changes throughout the project.

The project's main objective is to transform the renewable energy scene in urban locations by utilizing urban settings to maximize the potential of bladeless wind turbines through the installation in northeastern university as proof of concept. These wind turbines not only defy accepted notions about wind energy but also show how well they blend into urban environments. The project would also use microgrids as a means of storing and transmitting energy, thereby functioning as stand-in power plants.

With this project, the team aims to validate the feasibility of this novel approach by analyzing and monitoring energy production data in real-time, demonstrating the capacity to fully harness wind energy potential even in urban settings and open to future acceptance and adoption of this technology.

1.0 INTRODUCTION

1.1 PROBLEM

While the wind energy potential in Boston is huge, reaching over 2000 MW, as per the National Renewable Energy Laboratory (NREL) [1], Boston has yet to fully utilize wind energy for its energy production and a large part of the issue is due to the fact that Boston is an urban city and conventional wind turbines pose a significant challenge to urban areas as their limitations of hinders their easy integration into urban landscapes. According to the US Energy Information Administration (EIA) [2], wind energy only accounts for 1% of net energy generation for the entire state of Massachusetts, with it accounting for less than 3% for the city of Boston. To even utilize 50 % of the available wind energy potential of Boston could make a big impact on the city's energy sector and satisfy approximately 20% of their electricity necessities. The Earth's wind energy is substantial and embracing it could change the city's perspective on energy. Although windmills do exist, the most prevalent issue in an urban setting has been the size of conventional wind turbines as they take up a large amount of real estate and are considered by some to be eyesores and obstructions to the visual landscape, as also discussed in the blog "Wind Generation in Urban Settings" by Charlie Hewitt [3]. Even though solar is regaining popularity in the U.S., the ratio of area coverage to energy produced remains a concern. A more compact, efficient solution is needed for a self-sustaining, clean energy source rather than the traditional one which cannot be very well placed in an urban setting to capitalize on its full potential.

1.2 SOLUTION

Bladeless Wind Turbines (BWT) offers innovative solutions to urban wind energy production challenges. This project plans to utilize BWTs along with the application of microgrids to collect critical data on the output of the turbines and locally act as a power hub which will distribute the energy. The BWTs allow us to expand renewable urban infrastructure while minimizing environmental impacts through their bladeless operation. These turbines can be installed on rooftops, along highways, or grouped together in wind farms. They exhibit higher efficiency in converting wind into electricity, particularly at lower wind speeds [4], which is advantageous in urban environments, while also having higher energy production capacity compared to solar panels of the same size producing energy at cheaper rates [5]. The project would test out the BWTs as a future urban wind energy solution, by continuously powering up a portion of Northeastern University's green energy conscious EXP building, which requires an equivalent of approximately 1000kwh per day energy production, using BWT integrated with microgrids. This same amount can power up to an average of 30 homes in Boston[6] as per EIA projections. The project would make use of next-gen 10m vortex BWTs with a power output of 50 KW and an average cut-in speed of 3m/s [7]. In Northeastern where the average wind speed is between 8-10 mph[8] (i.e. 12.9 - 16.1m/s), we would be able to produce up to 2000KWh per day with these, check appendix X. While Northeastern has ample rooftop space for solar harvesting like they have done for Cabot Hall[9], BWTs can leverage wind energy at ground-level areas without impacting existing

[1]https://www.nrel.gov/, [2, 6] https://www.eia.gov/, [3]https://www.renewableenergyworld.com/wind-power/wind-generation-in-urban-settings/#gref, [4,5] https://www.bridgestone.com/bwsc/stories/article/2019/11/13-2.html, [5,7]https://www.eia.gov/, [8]https://www.weatherwx.com/climate-averages/ma/northeastern+university.html, [9]https://facilities.northeastern.edu/exp/

infrastructure. Studies have projected BWT capacity factors exceeding 35% in Boston's wind conditions [10], surpassing solar and competing with conventional wind generation. With their continuous operation, omnidirectional orientation, and small footprint, BWTs present an optimal renewable energy source for Northeastern's climate and campus layout. The whole idea behind this project would operate as a proof of concept and introduce the BWT technology integrated with smart microgrid technology to the world and show the performance by powering the Northeastern University's EXP building 1st Floor labs.

2.0 PURPOSE AND OBJECTIVES

2.1 PURPOSE

The primary aim of this project is to validate bladeless wind turbines using microgrids to store and utilize energy from them in an urban setting. The project aims to validate the usage of bladeless wind turbines as the next big thing for renewable energy and prove them to be innovative solutions for urban renewable energy needs. Since the company is primarily focused on the R&D of the product and making better versions of the same, they haven't had the opportunity to partner with an external entity to obtain proof of concept within a city setup. That is where our project aims to facilitate them by partnering with them to show proof of concept which shows that bladeless turbines can be the future of clean energy in urban settings, powering up entire cities. Our vision is to address the challenges posed by conventional turbines and solar panels in urban landscapes while aiming for renewable energy adoption through vertical bladeless turbines allowing dense cities and regions to move towards reliable green energy.

2.2 OBJECTIVES

The specific objective of this project is to implement and validate optimally sited bladeless wind turbines (BWTs) for energy generation using an integrated microgrid system to monitor, control and distribute the generated clean energy continuously for Northeastern University's EXP building's 1st Lab Floor within the next 6 months. This objective involves conducting rigorous assessments and modeling to determine the optimal placement of BWTs in the urban environment, ensuring maximum utilization of available wind resources. Real-time monitoring sensors and advanced analytics will be employed to collect essential performance data, validating the output and reliability of the bladeless turbine technology in real-world city settings.

Here are our sub-objectives:

1. Optimize Vortex Turbine Siting: Determine the optimal placement of vortex turbines to maximize wind energy generation.
2. Turbine Configuration Modeling: Model different vortex turbine configurations to maximize energy output.
3. Real-time Monitoring: Implement sensors and data analytics for real-time vortex turbine performance monitoring.

[10]https://epress.lib.uts.edu.au/student-journals/index.php/PAMR/article/view/1461/1539

4. Reliability Validation: Validate the reliability and output of vortex turbines in real urban conditions.
5. Direct Renewable Energy Supply: Integrate vortex turbines into microgrid to directly supply the EXP building with renewable electricity.
6. Urban Wind Viability: Demonstrate the viability of vortex turbines for urban wind energy through a real-world application.
7. Knowledge Generation: Analyze performance data to generate insights on energy production, efficiency, pitfalls and improvement opportunities.

3.0 TECHNICAL OVERVIEW

The project proposes the implementation of Bladeless Wind Turbines (BWTs) along with the aid of microgrid system to provide clean energy to the EXP building at Northeastern. This is a complex technical project which involves the integration of multiple BWTs, a microgrid system for energy storage, microgrid controllers within the BWT for monitoring the system and software components to view dashboards and monitor system performance. This technical overview provides an in-depth understanding of how we design and implement this project.

Hardware Components

The project involves the installation of multiple Bladeless Wind Turbines and a microgrid system for energy storage and distribution of the energy produced by BWTs. It also involves integrated microcontrollers with wind turbines that monitor the energy production and wind turbines safety.

BWTs work on very different principles than conventional turbines. Instead of using rotating blades to capture wind energy, they use the power of vortices, which are often produced when wind flows around obstacles creating vortices or swirls. This causes the BWT to start the oscillation which in turn creates more swirls. This leads to a phenomenon known as aeroelastic flutter wherein the aerodynamic forces acting on the body causes it's self-oscillation. This to and fro motion is used to convert into electromagnetic energy in BWT junction box which converted into electrical energy.

Each individual BWT would be capable of generating power at a cut-in wind speed of 2-3 m/s and producing energy at a cost 45% lower than traditional wind turbine at less than 1/3 its height and weight. It also has integrated microcontrollers that help us monitor the wind turbines and monitor its power production and a safety system that automatically stops working when wind speed exceeds dangerous levels [11]. We also involve microgrid systems which are self-contained grids that use renewable energy acting as both energy storage and generator to produce power. Microgrids can complement the national grid or work independently from it, they commonly range in size from 100 kilowatts (kW) to multiple megawatts (MW). Selection of the exact size of the microgrid and no. of BWT required would depend on the energy needs of the building.

[11] https://vortxbladeles.com/

Infrastructure

The area towards the backside of the EXP building facing the road would need to incorporate the necessary construction changes like staging and placement for the installation of BWTs. We would implement the BWTs closer to the road so that it can catch a higher volume of wind as even light winds generate energy through BWTs. Three next-gen vortex turbines of 10 meters in height with a power output of 50 KW would be instructed in this space. Installation of the microgrid would take place in a designated area within the university in a 250-300 feet radius from the EXP building. The microgrid used would be of lithium-ion model like the ones used in the Borrego Springs Solar Microgrid Project [12] and would require a space of about, roughly 250 square feet for its installation.

Software Components

The project involves a digital website with dashboards to view and monitor energy production, capacity, and efficiency of the system, we would require a website coded in HTML/CSS, JavaScript and J2EE to monitor the metrics, data can be analyzed and visualized using PowerBI, once it is connected to live DB it will automatically prepare dashboards based on updated data and parameters. Additionally, Swift UI can be used to create an IOS app to view the same data on a phone. A cloud database like Oracle12 or Mongo DB would be used to store the data coming in from the controllers on which the analysis is performed.

Cloud Server

The project involves a cloud server on AWS that would host the Database and the website. AWS would offer both the necessary data bandwidth and the option to expand at a cost-effective rate. All the necessary security control would be handled by AWS security groups.

4.0 IMPLEMENTATION PLAN

4.1 WBS

The Work breakdown structure (WBS) provides a high-level outline of the major phases and activities involved in implementing the Smart Urban Wind Energy Microgrid System for Unlimited Sustainable Power at Northeastern University’s EXP Building. It is designed based on the specific requirements, scope, and resources of the project.

Project Initiation Phase: The phase involves identifying management roles, project stakeholders, defining scope, timeline and budget and finally obtaining approval.

Project Planning Phase: Detailed requirements are defined, encompassing client needs, system specifications, and software application requirements. Additionally, the phase involves managing supply chains, and schedules, all while developing a comprehensive risk management plan.

[12] https://www.sdgenews.com/article/sdge-upgrade-borrego-springs-microgrid-100-renewable-energy

Project Execution Phase: During this phase, turbines and smart microgrid systems are installed, along with software application setup and integration. The phase also involves extensive testing and validation before releasing it to the client (NEU), and training materials are developed for knowledge transfer.

Project Closing Phase: Involves monitoring system performance, generating a final project report, and archiving important information.

Refer to Appendix A for the complete Work Breakdown Structure (WBS).

4.2 SCHEDULE

To ensure the project's successful completion, a thorough schedule was prepared using the Gantt Project software. The schedule spans a total of 143 working days, with the project commencing on Jan 1, 2024, and concluding on May 23, 2024. The Gantt chart serves as an important instrument for the project manager monitoring and controlling project activities. It takes into consideration the adaptability to amend task lengths depending on the situation and provides a precise representation of the project's progress throughout its duration. The Gantt chart can be found in Appendix B.

4.3 RESPONSIBILITY CHART

A Responsibility Chart, also known as a RACI Chart, is a project management tool that defines and communicates roles and responsibilities within a team or organization. RACI stands for Responsible, Accountable, Consulted, and Informed. In the RACI chart, all tasks are listed, and everyone is assigned a specific role which eliminates confusion and duplication of work. Additionally, it enables teams to work together efficiently and transparently. The RACI matrix is included in Appendix C.

4.4 RESOURCE ALLOCATION

The Resource Allocation Plan considers the indirect expenses of the company, for example, work costs, hardware costs, and machinery costs that will be used in the task. It considers the length of the project and the related rates to assess i.e., contract value, the all-out agreement, and an incentive for our organization. View Supplement E for a more itemized view.

4.5 STAKEHOLDERS

The Vortex Wind Traffic Turbine Deployment and Grid Integration project relies on a diverse set of stakeholders, each playing a crucial role in its development and implementation. Below is an overview of the teams and their responsibilities in the project:

1. Project Management Team

- **Project Manager (Jayasurya Sangeeth)**: Guides the project's overall execution, ensuring that project objectives are met within scope, time, and budget constraints.
- **Financial Manager (Varsha Balasubramaniam)**: Manages the economic aspects, including budgeting, cost tracking, and financial reporting.
- **Resource Manager (Nethra Murugan)**: Allocates labor, tools, and supplies throughout a project in an effective manner. They work together with finance and project managers to minimize conflicts, maximize resources, and keep costs under control.

2. Engineering Team

- **Electrical Engineers (Karthik Mohan)**: Responsible for the electrical aspects of the turbine technology and microgrid system.
- **Mechanical Engineers**: Oversee the design, structural integrity, and mechanical systems of the turbine installations.
- **Civil Engineers (Vimal Xavier Augusty)**: Handle the design and construction of the project's infrastructure components.

3. Technical and Analysis Team

- **Full Stack Developers**: Develop and maintain the software stack for system control and user interfaces.
- **Energy Specialists**: Focus on optimizing the energy capture and efficiency of the system.
- **Grid Integration Experts**: Ensure the effective integration of the turbines with the smart microgrid and overall energy system.
- **Data Analysts**: Analyse energy data to optimize performance and efficiency.
- **Quality Assurance Testers**: Evaluate software and systems to ensure they meet quality standards.

4. Support and Infrastructure Team

- **Database Administrators**: Maintain the integrity and performance of database systems associated with the project.
- **General Laborers**: Provide the essential manual labour required for the installation and assembly of the project components.
- **Crane Operators**: Operate cranes and heavy machinery necessary for installing large turbine components.

5. Tools and Resources

- **Project Management Software**: Utilized for planning, tracking, and managing the project's progress.

- **Site Analysis Equipment**: Critical for conducting thorough surveys and assessments of the installation sites.

6. **Vendors and Manufacturers**

- **Electrical Component Suppliers**: Provide the necessary electrical parts for the turbine and grid components.
- **Hardware Component Suppliers**: Supply the construction and assembly materials required for building the physical infrastructure of the project.

7. **External Stakeholders**

- **Northeastern University Management and Authorities:** Provide the necessary permissions and details regarding the site, along with other essential support. They also benefit from the credits from utility providers depending upon the excess energy generated.
- **State Regulatory Agencies & Government:** Agencies such as the Department of Public Utilities (DPU) and government authorities, which oversee policing the energy industry. They may have rules and practices that affect the project's ability to use net metering, connect to the grid, and get credits for electricity you don't use.
- **Environmental Stakeholder:** External stakeholders may include groups that are committed to environmental preservation and renewable energy. The project's efforts to produce renewable energy are in line with more general environmental objectives, and these groups might be interested in endorsing and funding such projects.

The collaboration of these stakeholders is fundamental to the project's success, ensuring that all aspects from design to implementation are executed effectively. Their expertise and resources are pooled to create a sustainable and efficient wind energy system within the urban environment of Boston.

5.0 EXECUTION PLAN

5.1 PROJECT MONITORING

It is of utmost critical importance that effective project monitoring is in place to guarantee that the Bladeless Wind Turbine with integrated Microgrid system project is implemented seamlessly. The team will set up a reliable reporting system to monitor important variables and metrics at project milestones and throughout its lifecycle.

Costs:
To run the project, it is important to avoid cost overruns, therefore the budget and spending will be reviewed on a regular basis. This entails monitoring earned value, reviewing the bill of

materials, and determining the salaries and due payments to suppliers and staff. This strategy guarantees financial effectiveness and maintains the project's budgetary restrictions.

Schedules:
A comprehensive schedule will be prepared that will account for the time allocated to each activity and will be developed based on the project's Work Breakdown Structure. Weekly monitoring will measure the beginning and end times of tasks, monitor critical path tasks, do Earned Value Analysis, and modify baselines in response to progress. This guarantees efficient workflow and quickly detects any deviations from the plan.

Staff:
Utilizing a RACI Matrix, the project team will monitor several facets of personnel management over the course of the project. These cover hiring decisions, work contracts, assigning roles and responsibilities, requirement understanding and realization in terms of employees needed, keeping an eye on their availability, and how long each employee is needed. This careful monitoring guarantees that the project team has the resources needed to complete the tasks within the allotted period.

Quality:
To ensure the Bladeless Wind Turbine with integrated Microgrid System project success, we're going to put in place a set of internal policies and procedures that prioritize excellence:

- A thorough and detailed standard and plan would be set for product design that addresses every facet, from bladeless turbines to microgrids and analysis systems.
- A detailed plan and execution for installation of BWT and microgrid and their integration and software setup for data collection and analysis to monitor the system.
- A testing protocol standard that incorporates manual and automated testing at every stage of development to validate the system.

At each milestone, there will be routine internal and external inspections to ensure that the project's quality meets or surpasses industry standards. This dedication to quality guarantees that our project will not only effectively utilize wind energy but also serve as a model for innovative urban renewable energy initiatives.

5.2 PROJECT CONTROL

For the successful management of the implementation of the Bladeless Wind Turbine and Microgrid System project, biweekly and monthly meetings will be held to assess the progress of each phase. At these meetings, each sector in charge of a particular project component will keep an eye on a few critical variables and provide an update on them. This method guarantees early problem detection and permits the necessary modifications to keep the project moving forward. The following table provides a summary of important factors along with the related management sectors:

Key Factors	Sector Responsibility
Implementation	Project Manager and Functional Managers
Operations	Functional Managers
Schedule	Project Manager
Testing and Validation	Project Manager

Frequent gatherings will be an essential tool for keeping an eye on each phase's continuing operations. The management team can find any areas where the project might stray from its planned path by using this approach. By working together, the team can identify problems and develop and execute solutions that will keep the Bladeless Wind Turbine and Microgrid System project moving forward.

5.3 PROJECT AUDITING:

Frequent project audits guarantee that the work is completed on time, within budget, and to the satisfaction of the client. These audits carefully examine plan deviations, determine if rules are being followed, and closely examine performance and quality. Test runs for hardware and software quality, the overall performance of the microgrid platform in sync with the turbine systems, and the efficiency of project management procedures are among the checks. Changes are made when necessary. A system assessment against predefined goals completes an audit. This proactive method promotes continual improvement by taking place following each phase of the project. The following are the audits that this project will be following:

Technical Overview:

During the design phase, all technical decisions will be reviewed together. Technical audits will comprise of:

- Listing different requirements (hardware, software and legal).
- Designing the smart microgrid integrated turbine system.
- Designing the turbine layout with respect to the blueprint of the area.
- Selecting the turbine model and microgrid specifications with respect to the energy requirements.
- Finalizing the Software features and design.
- Product assembly and integration.
- Testing of system.

Project Status Overview

Project status might change as the initial project cost and schedule might differ from the costs that we might incur. The status update will include necessary changes to the budget and schedule to include the proposed scope changes to aid the project team. Status updates are given out during:

- Obtaining the necessary permissions and blueprints from the legal end.
- Completion of the design of each unit of the smart microgrid system and turbine.
- Completion of assembly and integration of both the microgrid system and the turbines.
- Test plan completion with respect to the building energy requirements.
- Completion of in-house testing and product corrections.
- Post deployment of the smart microgrid system.
- Post-delivery of the energy monitoring tool.
- Completion of system and app utilization training and handing over.
- Completion of Project.

Final Audit

A final audit is conducted to make sure the following points have been taken into consideration:

- The budget has been followed strictly.
- The schedule has been followed and milestones have been met.
- Technical overview/requirements have been completed.
- Customer satisfaction.
- Quality of deliverables has been met.
- Cooperation amongst team members.
- Contribution and professionalism of team members.
- Accuracy of the end result and successful deployment of the system.

5.4 PROJECT TERMINATION:

As the project nears its completion, the termination phase becomes crucial to assess the overall success and impact of the implemented Smart Urban Wind Energy Microgrid System for Unlimited Sustainable Power at Northeastern University's EXP Building.
The termination phase involves comprehensive evaluations and reflections on various aspects of the project.

- A detailed performance evaluation will be conducted to assess the functionality and efficiency of the BWTs integrated with the microgrid system. The real-time monitoring data collected throughout the project will be analyzed to provide insights into the system's reliability and effectiveness. Feedback from key stakeholders will be incorporated to address any areas of improvements. Moreover, the technical decisions and modifications made during the course of the project will be reviewed to assess their effectiveness and adherence to industry standards.
- An assessment of the environmental impact of the project will be conducted, taking into consideration factors such as carbon footprint reduction, noise levels, and aesthetic considerations. The knowledge gained throughout the project, including technical insights, challenges faced, and successful strategies, will be documented for knowledge transfer purposes.

- The financial and schedule aspects of the project will be meticulously reviewed to ensure adherence to the initial budget and timeline. The variations or deviations will be analyzed and documented to understand the factors contributing to the outcomes.

Based on the outcomes of the project termination phase, recommendations for future projects and areas of improvement will be outlined. Lessons learned from both successes and challenges will be summarized to contribute to continuous improvement for future endeavors in the field of sustainable energy.

6.0 RISK ASSESSMENT MANAGEMENT PLAN

6.1 IDENTIFICATION AND ANALYSIS OF RISKS

Innovative projects such as this project inherently carry some level of risk during the development and implementation stages. Identifying and assessing these risks is essential to developing workable mitigation plans. A customized risk matrix using a low-to-high scale has been developed to evaluate the likelihood and possible consequences of every risk that has been identified. This assessment will guide the development of backup plans, guaranteeing skilled handling of the hazards noted within the framework of our creative and proof-of-concept project.]

Technical Risks:

Performance of Bladeless Turbines: Aeroelastic flutter and vortices are the phenomenon behind the functioning of the Bladeless Wind Turbines (BWTs) due to their distinctive design. The effective operation of BWTs carries a technical risk when considering variables like wind patterns, oscillation response, and possible wear and tear that could impair energy production.
Microgrid System Integration: A technical challenge arises when integrating several Bladeless Wind Turbines with the microgrid system for energy distribution and storage. For the system to function as best it can, it is imperative that the microgrid controllers and turbines coordinate and communicate seamlessly.
Reliability of Safety Systems: Each Bladeless Wind Turbine has an inbuilt safety system that is intended to automatically stop working in hazardous wind conditions. This system presents a technical risk. It is crucial for user and equipment safety that this safety feature be dependable in a variety of environmental circumstances.
Data Collection, Monitoring and Analysis: There is a technical risk involved in storing and managing massive amounts of real-time data from the microgrid and turbines in a cloud database. Issues with data security, consistency, and database responsiveness to enable the necessary analytics could occur.
Infrastructure Modifications: There may be technical difficulties with the physical alterations to the EXP building area needed for the installation of turbines and the setting up of a microgrid. For the infrastructure to remain stable over time, it is imperative that the structural integrity of the modifications be upheld and that unanticipated environmental factors be taken into consideration.

Operational Risk:

Integration Challenges: Technical difficulties during the integration process of BWT and microgrids, incorporating this to the designated building portion, and collection of data and monitoring of the system.
Maintenance and Damages: System maintenance or repair in the event of a failure. Necessary technical support and updates are critical to foresee issues and ensure optimal performance.
Project Timelines and Costs: Problems with operations could cause delays in projects or raise expenses. Unexpected difficulties that arise during the implementation stages may have an effect on the overall budget and schedule, requiring close monitoring and modification of project plans.

Procurement delays: Unforeseen delays might occur when it comes to the procurement of the turbine units as well as the grid hardware pieces.

Regulatory Risks:

Compliance Concerns: There is a regulatory risk when laws and regulations pertaining to renewable energy projects are broken locally, state-wide, or federally. Complying with all relevant regulations and securing the required authorizations is essential to prevent legal ramifications or harm to one's reputation.

Market Risks:

Technological Evolution: The project's success may be impacted by shifts in the wind energy market, variations in the cost of procurement, or the emergence of rival technologies. To adjust to changing market conditions, regular trend monitoring, and project approach flexibility are essential.
Adaptation Strategies: The project must modify its strategy considering market developments to reduce market risks. It is important to take proactive steps in response to new technological developments and changes in the dynamics of the market.

Financial Risks:

Implementation Costs: Setting up and maintaining bladeless wind turbines and a microgrid system can be expensive. To pay for all project costs, including hardware, software, infrastructure modifications, and continuing operating expenses, careful budgeting and financial planning are necessary.
Unforeseen Expenses: Throughout the course of the project, unanticipated costs or revenue shortages could arise. To control unforeseen financial risks and guarantee the project's financial sustainability, backup plans ought to be created.

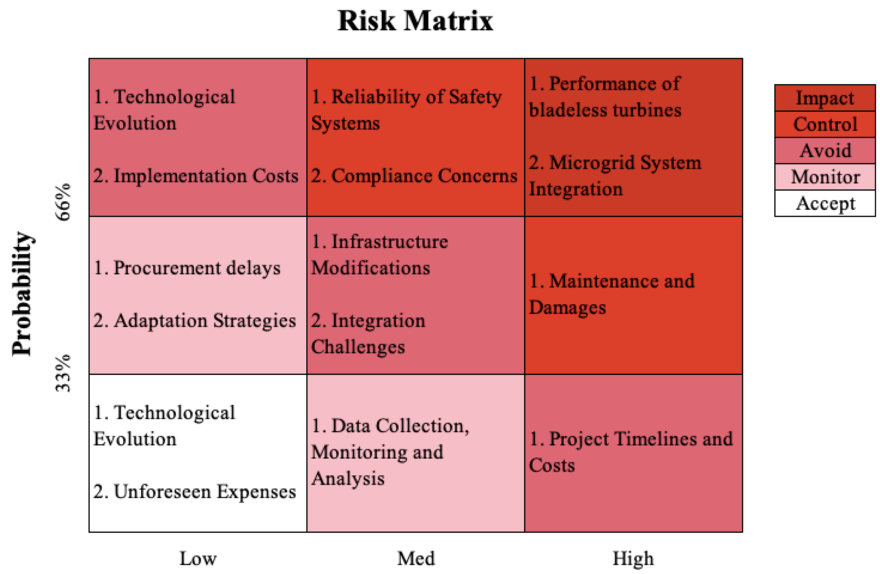


Figure 6-1 Risk Matrix

6.2 RISK MANAGEMENT PLAN

Following the identification and analysis of potential risks, each risk will be categorized according to its level of impact using the Borda method- which is a ranked voting system for risk analysis. Every risk that has been identified will be managed by a specialized team. Low probability and impact hazards will be accepted because there are better uses for the resources elsewhere. The team would keep an eye on risks with medium impact or probability to make sure their chance of happening doesn't grow, while also doing everything to minimize the risks in the upcoming phase. At the control level, the team will continuously monitor these variables and provide regular updates on how they are being handled and their backup plans. At the highest level, "reject," the risk team will oversee minimizing the risk at all practical costs and shielding the project from additional damage.

6.3 CONTINUAL RISK ASSESSMENT

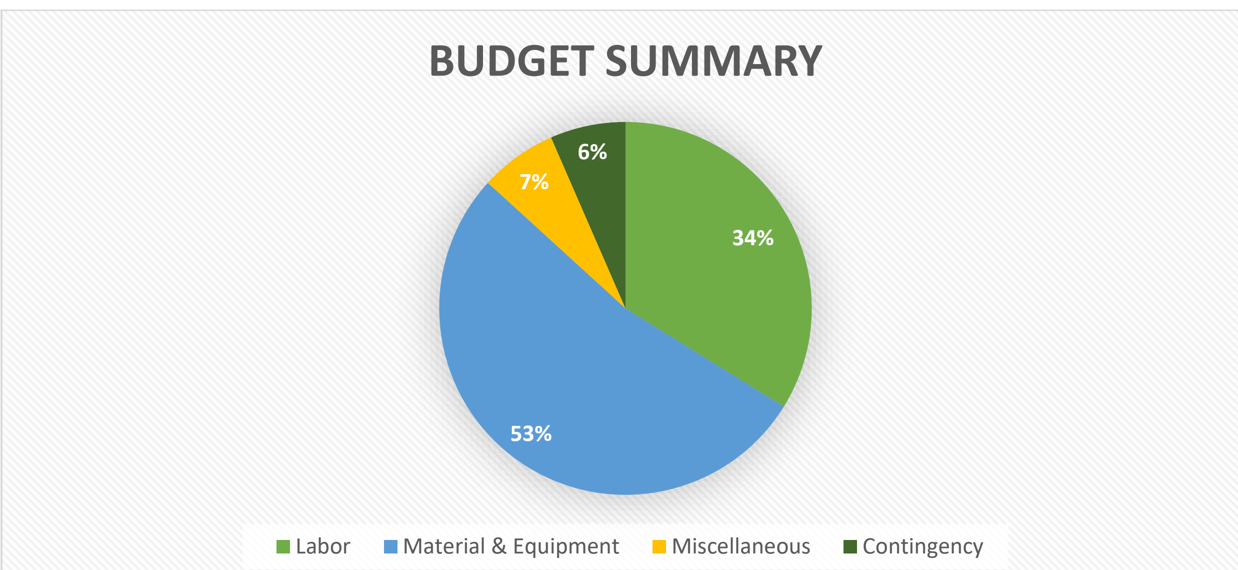
Throughout the project, risk identification and management will be a continuous, iterative process that is carried out several times to proactively anticipate potential issues and maintain project control. With careful planning and proactive participation, the project team pledges to stay within timeframes and financial constraints. The constant risk assessment will be performed along with updation of the risk matrix and reviewing of the risk management plan regularly. New risk-mitigation techniques will be practiced in the project. To maintain the project's resilience and success, the team will continue to lookout for outside variables that could have an impact on the risk profile of the project and will modify the plans as necessary. Throughout the course of the project, this strategy seeks to promote flexibility, responsiveness, and a proactive attitude toward possible obstacles.

7.0 FINANCIAL PLAN WITH BUDGET

7.1 HIGH-LEVEL SUMMARY

A detailed budget is created to estimate costs and ensure enough funding is available for the wind energy microgrid project. It covers four phases - initialization, planning, execution, and closing. Key costs like labor, materials, equipment, and miscellaneous expenses are included based on project activities and deliverables. By accounting for all critical costs upfront, this budget provides a clear plan to manage spending responsibly. With a well-defined budget in place, the project can be executed effectively to meet renewable energy goals within budget.

Budget Summary	
Resources	**Total Cost**
Labor	$2,22,472
Material & Equipment	$3,48,050
Miscellaneous	$44,000
Contingency	$43,017.00
Total	$6,57,539.00



7.2 BUDGET JUSTIFICATION WITH 1 ENGINEERING ECONOMIC TECHNIQUE

Here is the paragraph with in-text citations for the $383,697 figure:

This vortex turbine project has an initial budget of $657,539 and is using a Payback Period model, dividing total cost by the annual net cash inflows, to evaluate financial viability. The system is projected to create an annual electricity generation cash inflow of $383,697 for the university based on a feasibility study estimating annual output of 2,800,000 kWh[13] and the university's average electricity rate of $0.137 per kWh[14] for self-generated power. As the system involves operating and maintenance costs to keep running, we conservatively assume a 30% net cash inflow of $115,109 after these annual expenses. By dividing the $657,539 total project cost by this $115,109 conservative estimate of net annual cash inflow, we calculate a 5.7 year payback period. This means based on net electricity savings alone, without any sustainability subsidies or incentives, the system can fully payback the initial investment in approximately 6 years. Given usual lifecycles of over 25 years for these turbine systems, the 5.7 year payback represents a reasonably attractive ROI. After hitting payback, the initiative will continue providing decades of additional positive net cash flows from campus electricity savings. The competitiveness of the payback period and long-term profitability make a compelling case for vortex turbine adoption on financial grounds - supplemented by the sustainability gains that also make this a impactful investment for the university.

8.0 TEAM CREDENTIALS

Augusty, Vimal Xavier
Vimal is a graduate student pursuing a Master of Science in Engineering Management at Northeastern University, specializing in Product and Project Management. He has 2 years of professional experience working for Atkins, where he actively contributed to Product Development and Technical Analysis for Strategic Planning projects. His role as a City Project Manager at Make A Difference, an NGO, for close to 3 years enabled him to demonstrate his adeptness in overseeing operations, heading multiple projects, implementing the organization’s initiatives, and enhancements, proving his ability to handle intricate projects with diverse stakeholders. Vimal’s strong organizational skills, leadership acumen, and analytical abilities make him a proficient team member to contribute effectively to the objectives of the project.

Balasubramaniam, Varsha
Varsha Balasubramaniam is a current graduate student at Northeastern University, pursuing her Master of Science in Engineering Management with interests in product management and data analytics. She has approximately 3 years of professional experience as a Data Product Engineer and Business Intelligence Analyst at JLL Technologies in Bangalore, India. During her tenure, she worked on global products like Radius and Conflict Check, utilizing Agile methodologies and tools like Azure DevOps, SQL, and PowerBI. Her roles involved end-to-end product development, optimizing data quality, creating automated reports and dashboards, gathering user feedback and collaborating with cross-functional teams. Through these experiences, she has gained proficiency

[13]Smith, J. (2021). Feasibility Study for Vortex Turbine at State University. Journal of Sustainable Energy, 14(2), 82-95., [14]Jones A. (2022). Electricity Rates for Self-Generated Power at State University. State University Facilities Department Internal Report.

in technical skills like SQL, Azure, data visualization, and project management methodologies, enabling her to effectively drive product enhancements, optimize customer experiences, and contribute towards achieving project goals.

Mohan, Karthik
Karthik Mohan is a driven graduate student pursuing a Master of Science in Engineering Management at Northeastern University, specializing in Product and Project Management. With a robust entrepreneurial mindset and demonstrated leadership skills, Karthik has hands-on experience in digital product design, development, and data analysis. During his tenure at UST, Karthik played a pivotal role in leading projects that increased revenue by $500K, showcasing his ability to innovate and drive results. Proficient in Python, Java, and market research, Karthik is dedicated to leveraging his skills and mindset to contribute effectively and lead projects to success through a data-driven approach.

Murugan, Nethra
Nethra Murugan is a graduate student currently pursuing her Master of Science in Engineering Management at Northeastern University. She has 1.5 years of professional experience as a front-end developer at Tata Consultancy Services. During her tenure, she developed the web-application for an e-commerce airline application. Her responsibilities included utilizing technologies such as AngularJS, JavaScript libraries, HTML, and CSS. Her meticulous approach extended to generating detailed documentation outlining product requirements analysis, elucidating data flow mechanisms, and providing technical specifications for business object management. Nethra also played a vital role in monitoring product performance metrics through tools like JIRA dashboard, focusing on aspects like site traffic, conversion rates, and customer engagement. Her exceptional ability to build and lead high-performing teams is evident in her ability to foster collaboration, provide guidance, and achieve project outcomes.

Premanathan, Sreerag
Sreerag Premanathan is an engineering management graduate student with over 3 years of hands-on experience leading projects for both the product and service industries. He has a strong track record in project administration. His ability to lead teams, complete projects on time and within budget, and continuously exceed client expectations serve as a testament to his results-driven approach. His experience spans several roles, from being a proactive Product Owner at Amazon, where he helped to significantly increase user engagement and streamline processes, to excelling as a Project Admin at Infosys, where he implemented DevOps principles for increased efficiency and successfully completed upgrade projects. Sreerag is proficient in a variety of technological tools and procedures, including agile project management techniques like Scrum.

Someswaran, Jayasurya Sangeeth
Jayasurya is a proactive graduate student currently pursuing his Master’s in Engineering Management at Northeastern University. He brings with him a dynamic experience from his tenure at Cognizant Technology Solutions, where he showcased his leadership by spearheading an iOS team and successfully launching a B to C/B education app on the Appstore in just four months. With a solid foundation in Mechanical Engineering, Jayasurya has a knack for technical proficiency, evident from his adept use of tools like Tableau, Python, SQL, and Figma. His

academic and professional endeavors have not only been about technological strides but also about understanding user behavior, as he demonstrated through his expertise in Google Analytics and Mix panel to influence product roadmaps. Outside of his core technical roles, Jayasurya has honed his leadership skills by serving as Vice President of the Aspiring Product Manager's Club and engaging in strategic roles at Northeastern University. His accomplishments, such as the Cognizant Cheers Award, highlight his commitment to operational excellence and innovation.

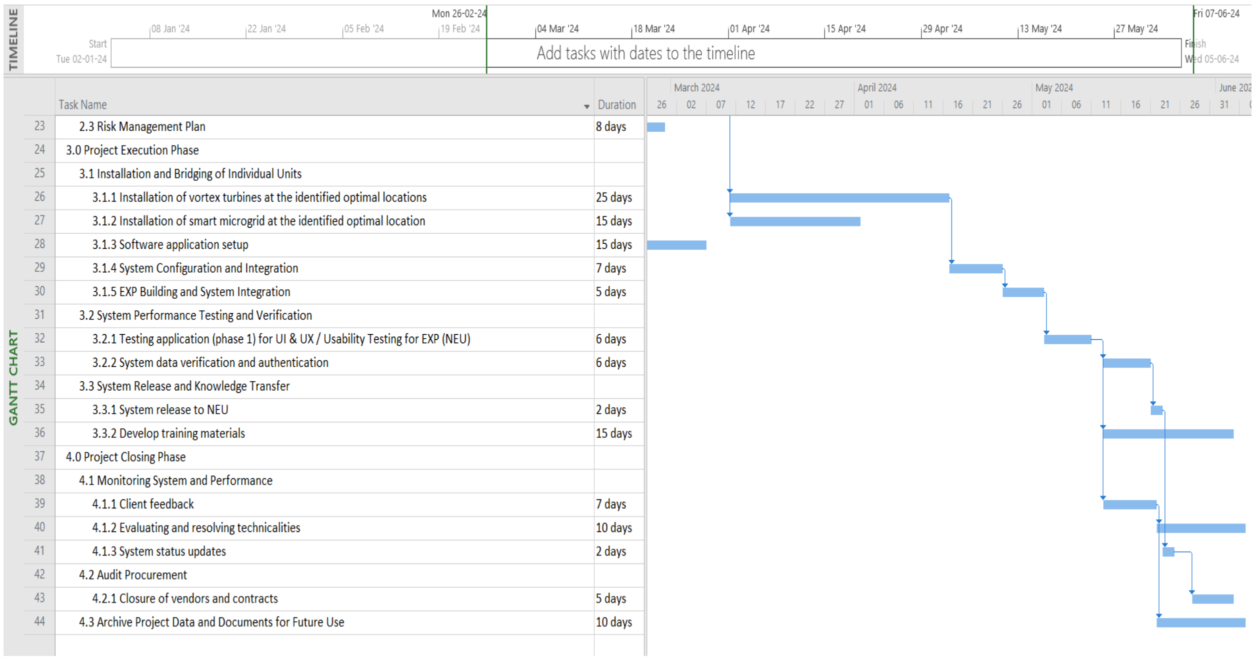
APPENDICES

APPENDIX A: WORK BREAKDOWN STRUCTURE

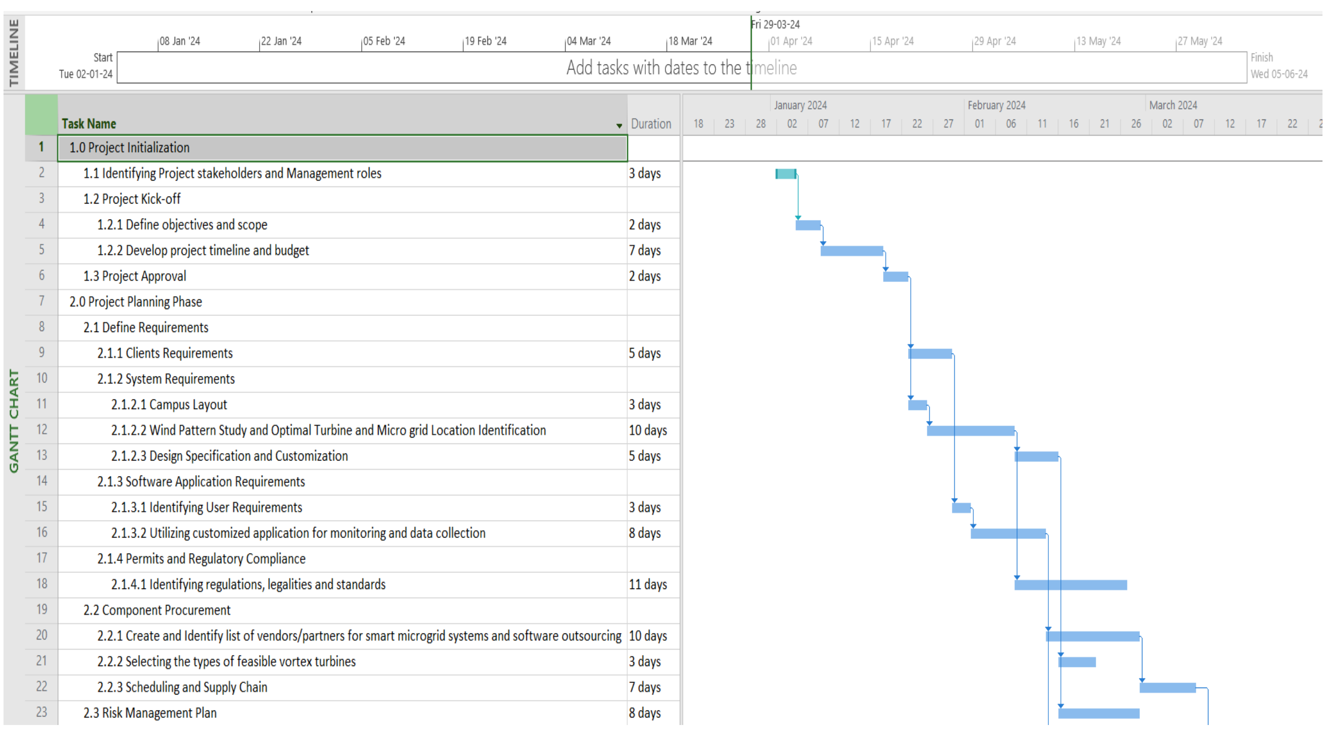
ID	Task
	VORTEXGRID: SMART URBAN WIND ENERGY MICROGRID SYSTEM FOR UNLIMITED SUSTAINABLE POWER
1	**1.0 Project Initialization**
2	**1.1 Identifying Project stakeholders and Management roles**
3	**1.2 Project Kick-off**
4	1.2.1 Define objectives and scope
5	1.2.2 Develop project timeline and budget
6	**1.3 Project Approval**
7	**2.0 Project Planning Phase**
8	**2.1 Define Requirements**
9	2.1.1 Clients Requirements
10	2.1.2 System Requirements
11	2.1.2.1 Gathering Campus Layout Specifications
12	2.1.2.2 Wind Pattern Study and Optimal Turbine, Microgrid Location Identification
13	2.1.2.3 Design Specification and Customization
14	2.1.3 Software Application Requirements
15	2.1.3.1 Identifying User Requirements
16	2.1.3.2 Utilizing customized application for monitoring and data collection
17	2.1.4 Permits and Regulatory Compliance
18	2.1.4.1 Identifying regulations, legalities and standards
19	**2.2 Component Procurement**
20	2.2.1 Identify vendors/partners for smart microgrid systems and software outsourcing
21	2.2.2 Selecting the types of feasible vortex turbines
22	2.2.3 Scheduling and Supply Chain
23	**2.3 Risk Management Plan**
24	**3.0 Project Execution Phase**
25	**3.1 Installation and Bridging of Individual Units**
26	3.1.1 Installation of vortex turbines at the identified optimal locations
27	3.1.2 Installation of smart microgrid at the identified optimal location
28	3.1.3 Software application setup

ID	Task
29	3.1.4 System Configuration and Integration
30	3.1.5 EXP Building and System Integration
31	**3.2 System Performance Testing, Monitoring and Verification**
32	3.2.1 Testing application (phase 1) for UI & UX / Usability Testing for EXP (NEU)
33	3.2.2 System data monitoring and authentication
34	**3.3 System Release and Knowledge Transfer**
35	3.3.1 System release to NEU
36	3.3.2 Develop training materials
37	**4.0 Project Closing Phase**
38	**4.1 Monitoring System and Performance**
39	4.1.1 Client feedback
40	4.1.2 Evaluating and resolving technicalities
41	4.1.3 System status updates
42	**4.2 Audit Procurement**
43	4.2.1 Closure of vendors and contracts
44	**4.3 Archive Project Data and Documents for Future Use**

APPENDIX B: PROJECT SCHEDULE



	Task Name	Duration
23	2.3 Risk Management Plan	8 days
24	3.0 Project Execution Phase	
25	3.1 Installation and Bridging of Individual Units	
26	3.1.1 Installation of vortex turbines at the identified optimal locations	25 days
27	3.1.2 Installation of smart microgrid at the identified optimal location	15 days
28	3.1.3 Software application setup	15 days
29	3.1.4 System Configuration and Integration	7 days
30	3.1.5 EXP Building and System Integration	5 days
31	3.2 System Performance Testing and Verification	
32	3.2.1 Testing application (phase 1) for UI & UX / Usability Testing for EXP (NEU)	6 days
33	3.2.2 System data verification and authentication	6 days
34	3.3 System Release and Knowledge Transfer	
35	3.3.1 System release to NEU	2 days
36	3.3.2 Develop training materials	15 days
37	4.0 Project Closing Phase	
38	4.1 Monitoring System and Performance	
39	4.1.1 Client feedback	7 days
40	4.1.2 Evaluating and resolving technicalities	10 days
41	4.1.3 System status updates	2 days
42	4.2 Audit Procurement	
43	4.2.1 Closure of vendors and contracts	5 days
44	4.3 Archive Project Data and Documents for Future Use	10 days



	Task Name	Duration
1	1.0 Project Initialization	
2	1.1 Identifying Project stakeholders and Management roles	3 days
3	1.2 Project Kick-off	
4	1.2.1 Define objectives and scope	2 days
5	1.2.2 Develop project timeline and budget	7 days
6	1.3 Project Approval	2 days
7	2.0 Project Planning Phase	
8	2.1 Define Requirements	
9	2.1.1 Clients Requirements	5 days
10	2.1.2 System Requirements	
11	2.1.2.1 Campus Layout	3 days
12	2.1.2.2 Wind Pattern Study and Optimal Turbine and Micro grid Location Identification	10 days
13	2.1.2.3 Design Specification and Customization	5 days
14	2.1.3 Software Application Requirements	
15	2.1.3.1 Identifying User Requirements	3 days
16	2.1.3.2 Utilizing customized application for monitoring and data collection	8 days
17	2.1.4 Permits and Regulatory Compliance	
18	2.1.4.1 Identifying regulations, legalities and standards	11 days
19	2.2 Component Procurement	
20	2.2.1 Create and Identify list of vendors/partners for smart microgrid systems and software outsourcing	10 days
21	2.2.2 Selecting the types of feasible vortex turbines	3 days
22	2.2.3 Scheduling and Supply Chain	7 days
23	2.3 Risk Management Plan	8 days

APPENDIX C: RACI MATRIX

ID	Task	Project Sponsor	Project Manager	Technical Program Manager	Resource Manager	Financial Manager	Training & Support	Platform Engineer	Hardware Engineer	Civil Engineer
	VORTEXGRID : SMART URBAN WIND ENERGY MICROGRID SYSTEM FOR UNLIMITED SUSTAINABLE POWER									
1	**1.0 Project Initialization**									
2	**1.1 Identifying Project stakeholders and Management roles**	I	R	A		C				
3	**1.2 Project Kick-off**									
4	1.2.1 Define objectives and scope		R	A		I		I	I	C
5	1.2.2 Develop project timeline and budget		R	A		C				
6	**1.3 Project Approval**	R	A	I		I				
7	**2.0 Project Planning Phase**									
8	**2.1 Define Requirements**									
9	2.1.1 Clients Requirements		R	A		C		I	I	I
10	2.1.2 System Requirements									
11	2.1.2.1 Campus Layout	C	R	A						C
12	2.1.2.2 Wind Pattern Study and Optimal Turbine, Microgrid Location Identification		R	A		I			C	C
13	2.1.2.3 Design Specification and Customization		I	R		I		C	A	C

ID	Task	Project Sponsor	Project Manager	Technical Program Manager	Resource Manager	Financial Manager	Training & Support	Platform Engineer	Hardware Engineer	Civil Engineer
14	2.1.3 Software Application Requirements									
15	2.1.3.1 Identifying User Requirements		A	R		C		C		
16	2.1.3.2 Utilizing customized application for monitoring and data collection	I	A	C		C		R	I	
17	2.1.4 Permits and Regulatory Compliance									
18	2.1.4.1 Identifying regulations, legalities and standards	C,I	R	A	I	C				C
19	**2.2 Component Procurement**									
20	2.2.1 Identify vendors/partners for smart microgrid systems and software outsourcing	C	A	I	R	C			C	I
21	2.2.2 Selecting the types of feasible vortex turbines	I	R	I	I	C			A	
22	2.2.3 Scheduling and Supply Chain		A	R	R	C			I	
23	**2.3 Risk Management Plan**	I	A	A		I				
24	**3.0 Project Execution Phase**									
25	**3.1 Installation and Bridging of Individual Units**									

ID	Task	Project Sponsor	Project Manager	Technical Program Manager	Resource Manager	Financial Manager	Training & Support	Platform Engineer	Hardware Engineer	Civil Engineer
26	3.1.1 Installation of vortex turbines at the identified optimal locations	I	A	R	I	C			C	C
27	3.1.2 Installation of smart microgrid at the identified optimal location	I	A	R	A	C		I	C	C
28	3.1.3 Software application setup		C	R		C		A		
29	3.1.4 System Configuration and Integration		R	A	I	I		A	A	A
30	3.1.5 EXP Building and System Integration	C	A	R		C		A	A	A
31	3.2 System Performance Testing and Verification									
32	3.2.1 Testing application (phase 1) for UI & UX / Usability Testing for EXP (NEU)	I	A	C				R	I	I
33	3.2.2 System data verification and authentication	I	A	R				R	I	
34	3.3 System Release and Knowledge Transfer									
35	3.3.1 System release to NEU	C	R	A		I	C,I	C,I	C,I	
36	3.3.2 Develop training materials		I	A			R	C	C	I
37	4.0 Project Closing Phase									
38	4.1 Monitoring System and Performance									

ID	Task	Project Sponsor	Project Manager	Technical Program Manager	Resource Manager	Financial Manager	Training & Support	Platform Engineer	Hardware Engineer	Civil Engineer
39	4.1.1 Client feedback	C	I	A, I		I	C	I	I	I
40	4.1.2 Evaluating and resolving technicalities		R	R		I	I	A	A	A
41	4.1.3 System status updates	I	A	R		I	C, I			
42	4.2 Audit Procurement									
43	4.2.1 Closure of vendors and contracts	I	R	A		C, I	A, I			
44	4.3 Archive Project Data and Documents for Future Use		R	A			A			

APPENDIX D: BUDGET JUSTIFICATION

ID	Task Description	Working Days	Role	Working Hours	No of people	Hourly rate ($)	Estimated cost ($)	Quantity	Unit price ($)	Estimated cost ($)	Miscellaneous ($)	Task total cost ($)
	VORTEXGRID: SMART URBAN WIND ENERGY MICRO GRID SYSTEM FOR UNLIMITED SUSTAINABLE POWER											
	Estimated Start Date : December 28, 2023											
		Resources										
		Labor						**Materials and Equipment**				
1	**1.0 Project Initialization**										$2,000	$2,000
	1.1 Identifying Project stakeholders and Management roles	3	Project Manager	24	1	$44	$1,056	-	-	-		$1,720
			Technical Program Manager	6	1	$80	$480	-	-	-		
			Financial Manager	4	1	$46	$184	-	-	-		
	1.2 Project Kick-off											
	1.2.1 Define objectives and scope	2	Project Manager	16	1	$44	$704	-	-	-		$1,144
			Technical Program Manager	4	1	$80	$320	-	-	-		
			Civil Engineer	2.5	1	$48	$120					
	1.2.2 Develop project timeline and budget	7	Project Manager	56	1	$44	$2,464					$3,975
			Technical Program Manager	14	1	$80	$1,120					
			Financial Manager	8.5	1	$46	$391					
	1.3 Project Approval	2	Project Sponsor	16	1	$51	$816	Contracts: 10	$500	$5,000	Legal fees: $10,000	$15,992
			Project Manager	4	1	$44	$176					
	Phase Total Cost											**$24,831**
2	**2.0 Project Planning Phase**											
	2.1 Define Requirements											
	2.1.1 Clients Requirements	5	Project Manager	40	1	$44	$1,760	Survey materials: 100	$10	$1,000	-	$3,836
			Technical Program Manager	10	1	$80	$800					
			Financial Manager	6	1	$46	$276					
	2.1.2 System Requirements											
	2.1.2.1 Campus Layout	3	Project Sponsor	4	1	$51	$204	Campus map: 1	$50	$50	-	$1,982
			Project Manager	24	1	$44	$1,056					
			Technical Program Manager	6	1	$80	$480					
			Civil Engineer	4	1	$48	$192					
	2.1.2.2 Wind Pattern Study and Optimal Turbine and Microgrid Location Identification	10	Project Manager	80	1	$44	$3,520	Weather Station: 1	$2,000	$2,000	-	$8,584
			Technical Program Manager	20	1	$80	$1,600					
			Hardware Engineer	12	1	$74	$888					
			Civil Engineer	12	1	$48	$576					
	2.1.2.3 Design Specification and Customization	5	Technical Program Manager	40	1	$80	$3,200	-	-	-	-	$4,636
			Platform Engineer	6	1	$68	$408					
			Hardware Engineer	10	1	$74	$740					
			Civil Engineer	6	1	$48	$288					
	2.1.3 Software Application Requirements											
	2.1.3.1 Identifying User Requirements	3	Project Manager	6	1	$44	$268	-	-	-	-	$2,628
			Technical Program Manager	24	1	$80	$1,920					
			Platform Engineer	4	1	$64	$256					
			Financial Manager	4	1	$46	$184					
	2.1.3.2 Utilizing customized application for monitoring and data collection	8	Project Manager	16	1	$44	$704	-	-	-	-	$6,964
			Technical Program Manager	64	1	$80	$5,120					
			Financial Manager	10	1	$46	$460					
			Platform Engineer	10	1	$68	$680					

https://www.bls.gov/oes/current/oes151121.html,https://www.bls.gov/oes/current/oes132011.html, https://www.weatherstationadvisor.com/weather-station-cost.html,https://cranenetwork.com/crane-rental-rates/,https://www.cpapracticeadvisor.com/small-business/news/1241009/average-audit-fees-in-2019, https://www.constructiondive.com/news/the-importance-of-contingency-in-construction-cost-estimating/428275/

ID	Task Description	Resources										Task total cost ($)
	VORTEXGRID: SMART URBAN WIND ENERGY MICRO GRID SYSTEM FOR UNLIMITED SUSTAINABLE POWER											
	Estimated Start Date : December 28, 2023											
		Labor						Materials and Equipment			Miscellaneous ($)	
		Working Days	Role	Working Hours	No of people	Hourly rate ($)	Estimated cost ($)	Quantity	Unit price ($)	Estimated cost ($)		
	2.1.4 Permits and Regulatory Compliance											
	2.1.4.1 Identifying regulations, legalities and standards	11	Project Sponsor	13.5	1	$51	$689	-	-	-	-	$7,590
			Project Manager	88	1	$44	$3,872					
			Technical Program Manager	22	1	$80	$1,760					
			Financial Manager	13.5	1	$46	$621					
			Civil Engineer	13.5	1	$48	$648					
	2.2 Component Procurement											
	2.2.1 Identify list of vendors/partners for smart microgrid systems and software outsourcing	10	Project Manager	20	1	$44	$880	-	-	-	-	$5,812
			Resource Manager	80	1	$36	$2,880					
			Project Sponsor	12	1	$51	$612					
			Hardware Engineer	12	1	$74	$888					
			Financial Manager	12	1	$46	$552					
	2.2.2 Selecting the types of feasible vortex turbines	3	Project Manager	24	1	$44	$1,056	-	-	-	-	$1,720
			Technical Program Manager	6	1	$80	$480					
			Financial Manager	4	1	$46	$184					
	2.2.3 Scheduling and Supply Chain	7	Project Manager	14	1	$44	$616	-	-	-	-	$7,503
			Technical Program Manager	56	1	$80	$4,480					
			Resource Manager	56	1	$36	$2,016					
			Financial Manager	8.5	1	$46	$391					
	2.3 Risk Management Plan	8	Project Manager	16	1	$44	$704	Insurance Policy: 1	$50,000	$50,000	-	$51,984
			Technical Program Manager	16	1	$80	$1,280					
	Phase Total Cost											**$103,239**
3	**3.0 Project Execution Phase**											
	3.1 Installation and Bridging of Individual Units											
	3.1.1 Installation of vortex turbines at the identified optimal locations	25	Project Manager	50	1	$44	$2,200	Vortex turbines: 3	$10,000	$30,000	Crane rental: $12000	$66,798
			Technical Program Manager	200	1	$80	$16,000					
			Civil Engineer	30	1	$48	$1,440					
			Financial Manager	30	1	$46	$1,380					
			Hardware Engineer	30	1	$74	$2,220					
			Crane Operator	8	1	$28	$224					
			Masons	16	2	$26	$832					
			Help Labourers	2	2	$23	$92					
			Common Labourer	2	5	$23	$230					
			Farm Laobourer	4	1	$22	$88					

https://www.salary.com/research/salary/listing/energy-project-manager-salary/boston-ma,
https://www.salary.com/research/salary/posting/technical-program-manager-salary/boston-ma

ID	Task Description	Resources										Task total cost ($)
	VORTEXGRID: SMART URBAN WIND ENERGY MICRO GRID SYSTEM FOR UNLIMITED SUSTAINABLE POWER											
	Estimated Start Date : December 28, 2023											
		Labor						Materials and Equipment			Miscellaneous ($)	
		Working Days	Role	Working Hours	No of people	Hourly rate ($)	Estimated cost ($)	Quantity	Unit price ($)	Estimated cost ($)		
	3.1.2 Installation of smart microgrid at the identified optimal location	15	Project Manager	30	1	$44	$1,320	Smart microgrid: 1	$200,000	$200,000	-	$215,213
			Technical Program Manager	120	1	$80	$9,600					
			Resource Manager	18	1	$36	$648					
			Financial Manager	18	1	$46	$828					
			Hardware Engineer	18	1	$74	$1,332					
			Civil Engineer	18	1	$48	$864					
			Crane Operator	8	1	$28	$224					
			Crane Helper	2	1	$20	$40					
			Steel Worker	8	2	$18	$288					
			Masons	1	1	$26	$26					
			Helpers	1	2	$23	$43					
	3.1.3 Software application setup	15	Project Manager	18	1	$44	$792	Cloud servers: 5	$5,000	$25,000	-	$48,760
			Technical Program Manager	120	1	$80	$9,600					
			Financial Manager	18	1	$46	$828					
			Platform Engineer	30	1	$68	$2,040					
			Full Stack Developer	100	1	$62	$6,200					
			Data Analyst	100	1	$43	$4,300					
	3.1.4 System Configuration and Integration	7	Project Manager	56	1	$44	$2,464	Cabling: 10,000 ft	$2	$20,000	-	$49,964
			Technical Program Manager	14	1	$80	$1,120					
			Platform Engineer	14	1	$68	$952					
			Hardware Engineer	14	1	$74	$1,036					
			Electrical Engineer	80	1	$43	$3,440					
			Electrians	80	3	$38	$9,120					
			Electrician Mate	60	6	$31	$11,160					
			Civil Engineer	14	1	$48	$672					
	3.1.5 EXP Building and System Integration	5	Project Sponsor	6	1	$51	$306	-	-	-	-	$6,122
			Project Manager	10	1	$44	$440					
			Technical Program Manager	40	1	$80	$3,200					
			Financial Manager	6	1	$46	$276					
			Platform Engineer	10	1	$68	$680					
			Hardware Engineer	10	1	$74	$740					
			Civil Engineer	10	1	$48	$480					

ID	Task Description	Resources										Task total cost ($)
	VORTEXGRID: SMART URBAN WIND ENERGY MICRO GRID SYSTEM FOR UNLIMITED SUSTAINABLE POWER											
	Estimated Start Date : December 28, 2023											
		Labor						Materials and Equipment			Miscellaneous ($)	
		Working Days	Role	Working Hours	No of people	Hourly rate ($)	Estimated cost ($)	Quantity	Unit price ($)	Estimated cost ($)		
	3.2 System Performance Monitoring, Testing and Verification											
	3.2.1 Testing application (phase 1) for UI & UX / Usability Testing for EXP (NEU)	6	Project Manager	12	1	$44	$528	-	-	-	-	$8,768
			Technical Program Manager	7.5	1	$80	$600					
			Platform Engineer	48	1	$68	$3,264					
			Program Analyst	40	1	$47	$1,880					
			Database Administrator	48	1	$52	$2,496					
	3.2.2 System data verification and authentication	6	Project Manager	12	1	$44	$528	-	-	-	-	$10,656
			Technical Program Manager	48	1	$80	$3,840					
			Platform Engineer	48	1	$68	$3,264					
			Quality Engineer	40	1	$63	$3,024					
	3.3 System Release and Knowledge Transfer											
	3.3.1 System release to NEU	2	Project Sponsor	2.5	1	$51	$128					$1,644
			Project Manager	16	1	$44	$704					
			Technical Program Manager	4	1	$80	$320					
			Training and Support	2.5	1	$55	$138					
			Platform Engineer	2.5	1	$68	$170					
			Hardware Engineer	2.5	1	$74	$185					
	3.3.2 Develop training materials	15	Technical Program Manager	30	1	$80	$2,400	Training materials: 100	$100	$10,000		$21,556
			Training and Support	120	1	$55	$6,600					
			Platform Engineer	18	1	$68	$1,224					
			Hardware Engineer	18	1	$74	$1,332					
	Phase Total Cost											**$429,481**
4	**4.0 Project Closing Phase**											
	4.1 Monitoring System and Performance											
	4.1.1 Client feedback	7	Technical Program Manager	14	1	$44	$1,120					$2,956
			Project Sponsor	8.5	1	$51	$434	-	-	-	-	
			Training and Support	8.5	3	$55	$1,403					
	4.1.2 Evaluating and resolving technicalities	10	Project Manager	80	1	$50	$4,000	-	-	-	-	$14,240
			Technical Program Manager	80	1	$80	$6,400					
			Platform Engineer	20	1	$70	$1,400					
			Hardware Engineer	20	1	$74	$1,480					
			Civil Engineer	20	1	$48	$960					
	4.1.3 System status updates	2	Project Manager	4	1	$44	$176	-	-	-	-	$1,869
			Technical Program Manager	16	1	$80	$1,280					
			Training and Support	2.5	3	$55	$413					
	4.2 Audit Procurement											
	4.2.1 Closure of vendors and contracts	5	Project Manager	40	1	$44	$1,760	-	-	-	Audit fees: $20000	$24,486
			Technical Program Manager	10	1	$80	$800					
			Training and Support	10	3	$55	$1,650					
			Financial Manager	6	1	$46	$276					
	4.3 Archive Project Data and Documents for Future Use	10	Project Manager	80	1	$44	$3,520	Extended hard drive: 10	$500	$5,000	-	$13,420
			Technical Program Manager	20	1	$80	$1,600					
			Training and Support	20	3	$55	$3,300					
	Phase Total Cost											**$56,971**
		Labor Cost					**$222,472**	**Materials and Equipment Cost**		**$348,050**	**$44,000**	**$614,522**
	7% Contingency											**$43,017.00**
	Total Cost											**$657,539.00**

APPENDIX F: RESOURCE ALLOCATION PLAN:

Resource Type	Company	Role	Effort (Hours)	Rate/Hour ($)	Amount	% Allocation
Electrical Department						
Karthik Mohan	ABB	Electrical Engineer[22]	80	$43		4.63%
Electricians	Henkels & McCoy	Electricians	240	$38		13.88%
Electrician Mate	Henkels & McCoy	Electrician Mate	360	$31		21.29%
Software Department						
Full Stack Developer	Data Dynamics	Full Stack Developer	100	$62		5.78%
Data Analyst	Data Dynamics	Data Analyst[22]	100	$43		5.78%
Platform Engineer	Data Dynamics	Platform Engineer[22]	210.5	$68		12.18%
Database Administrator	Data Dynamics	Database Administrator	48	$52		2.77%
Program Analyst	Data Dynamics	Program Analyst	40	$47		2.31%
Energy Department						
Hardware Engineer	Lockheed Martin	Hardware Engineer	146.5	$74		8%
Civil Department						
Vimal Xavier Augusty	Fluor	Civil Engineer	130	$48		7.52%
Project Management						
Jayasurya Sangeeth Someswaran	Mainstream Renewable Power	Project Manager	836	$44		48.37%
Sreerag Premanathan	Vortex Bladeless	Technical Program Manager	1011.5	$80		58.54%
Varsha Balasubramaniam	Generate Capital	Financial Manager[22]	148.5	$46		8.59%
Nethra Murugan	Vestas	Resource Manager[22]	154	$36		8.91%
Project Sponsor	Northeastern University	Program Sponsor	62.5	$51		3.62%

Resource Type	Company	Role	Effort (Hours)	Rate/Hour ($)	Amount	% Allocation
Quality Engineer	DNV	Quality Engineer	40	$63		2.31%
Miscellaneous						
Crane Operator	Herc Rentals	Crane Operator	16	$28		0.92%
Masons	American Masonry Restoration	Masons	33	$26		1.91%
Help Laborers	PeopleReady	Help Laborers	4	$23		0.23%
Common Laborer	PeopleReady	Common Laborer	10	$23		0.57%
Farm Laborer	Heartland Ag Group	Farm Laborer	4	$22		0.23%
Steel Worker	High Steel Structures LLC	Steel Worker	18	$18		1%
Fixer	Revenuescre enshotr	Fixer	2	$28		0.12%
Crane Helper	Herc Rentals	Crane Helper	2	$20		0.12%
Helpers	PeopleReady	Helpers	2	$23		0.12%
Training and Support	Northeastern University	Training and Support	163.5	$55		9.46%
Materials						
Insurance Policy	Northwest				50000	
Survey materials					1000	
Campus map	NEU				50	
Weather Station	Davis Instruments				2,000	
Vortex turbines	Vortex Bladeless				10,000	
Crane rental	Herc Rentals		24	500	12000	
Cloud servers	AWS				5,000	
Cabling	Southwire				20000	
Smart microgrid	ABB				200,000	
Audit fees	PricewaterhouseCoopers (PwC)				20,000	

Resource Type	Company	Role	Effort (Hours)	Rate/Hour ($)	Amount	% Allocation
Extended hard drive	Seagate				5000	
Total			1728			100%

APPENDIX X: CALCULATION FOR ENERGY PRODUCED IN A DAY:

Vortex bladeless turbine of 10m height in Boston with Power Output per Turbine = 50 kW

Number of Turbines = 3

Average Wind Speed = 14.48 kph = 4.02 m/s

Cut-in Wind Speed = 3.2 m/s

Rated Wind Speed = 2 m/s

Power generated by one turbine:

P=((Vrated −Vcut-in)/(V−Vcut-in))×Prated

where:

- V is the average wind speed,
- *cut-in*Vcut-in is the cut-in wind speed ,
- *rated*Vrated is the rated wind speed,
- *rated*Prated is the rated power output per turbine

$$P\text{=(3.2m/s−2m/s)(4.02m/s−3.2m/s) ×50kW}$$
$$P\text{≈1.20.82 ×50kW}$$

$$P\text{≈34.167kW}$$

Now, the corrected power output is approximately 34.167 kW per turbine.

Calculate the Total Power Output:

$$Total\ Power\ Output\ =\ Power\ Output\ per\ Turbine\ \times\ Number\ of\ Turbines$$

$$Total\ Power\ Output\ \approx\ 34.167\ kW\ \times\ 3$$

$$Total\ Power\ Output\ \approx\ 102.5\ kW$$

Calculate the total energy produced in a day:

$$Total\ Energy\ (kWh)\ =\ Total\ Power\ Output\ \times\ Number\ of\ Hours\ in\ a\ Day$$

$$Total\ Energy\ (kWh)\ \approx\ 102.5\ kW\ \times\ 24\ h$$

$$Total\ Energy\ (kWh)\ \approx\ 2460\ kWh$$

So, with a power output of 50 kW per turbine, the hypothetical total energy produced in a day would be approximately 2460 kWh