Design Project 1 – Renewable Technology Challenge

Mechanical Design of an EWB Humanitarian Aid Wind Turbine Blade Project

ENGINEER 1P13 – Integrated Cornerstone Design Projects in Engineering

Tutorial 7

Team 14

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Submitted: November 1, 2023

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Yahya Zaher 400507826

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Finalized Problem Statement

This assigned scenario requires a group of volunteers from Engineers Without Borders to build and design a simple, off-grid wind turbine units in the Guatemalan village of Santa Cruz La Laguna [1, p.11]. This turbine should provide them with enough electricity to power basic devices, such as LED lights, while still remaining efficient enough to power all units in the village. The finalized problem statement is to create an efficient wind turbine that is very simple and aims to design both a two-foot and a three-foot tall turbine, with a deflection value of less than 10mm, as the project seeks to minimize maintenance for the wind turbine [1, p. 11]. It is because the villagers will be assembling the units themselves that the product must be of a simple design, as this ensures the smooth installation and operating of the turbines. Additionally, the materials must be affordable, easy to maintain, and long-lasting to minimize overall costs, as it is for a small village that is off the grid [1, p. 11].

Main Body

Justification of Technical Objectives and Material Performance Indices:

The objective tree, as seen in Figure 1, for the project "EWB Humanitarian Aid Mission" is characterized by the objectives of low-cost, efficiency, accessibility, and durability. Culminating these objectives will help in building strong and long-lasting wind turbine units for the village, with accessibility leading to sub-objectives like a minimized mass and cost. With these overarching objectives, the sub-objectives of optimal energy harnessing, portability, and inexpensive production arises. Thus, the primary objective was selected as minimizing the mass, as it was important to consider the simplicity of the overall design as well as creating a lightweight and portable turbine blade, and the secondary objective was decided on as minimizing the cost, as the EWB volunteer group is designing this project rather than an established firm or company. Thus, the MPIs for our strength design were yield strength by density and yield strength by cost times density respectively, and the MPIs for our stiffness design were Young's Modulus by density and Young's Modulus by density times price respectively [2]. One of the constraints for this design was that the turbines must require little maintenance, such as once or twice a year. As for the decision matrix that guided our material selection, some of the considerations included ease of access to materials, corrosion resistance, ease of maintenance, and wear-resistance.

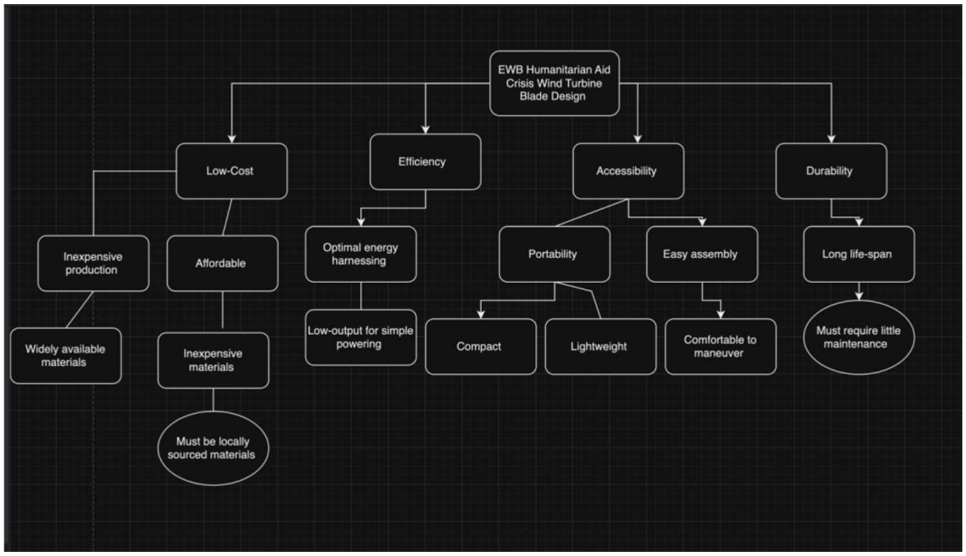

Figure 1. Finalized Objective Tree

Conceptual Design: Justification of Selected Material

As seen in Figure 2, which plots Young's Modulus against the product of density times price, CFRP, epoxy was chosen from the material property chart because it integrates various important considerations for designing the EWB Humanitarian Aid Mission wind turbine into our approach [2]. While low-carbon steel, as seen in the material property chart of Figure 3, was a finalist for the decision matrix, it was ultimately its susceptibility to corrosion that ruled it out. Particular to this scenario, in which low-maintenance is ideal in terms of considering the turbine's off-grid location, having to invest more resources in a further finishing to extend its lifespan serves as a major disadvantage [3]. As for the other finalist, aluminum alloy, its fatigue as displayed in the Figure 4 decision matrix make it less ideal of a material, as it is susceptible to wear with its lower machinability and weldability [4]. However, CFRP, epoxy seems to be the most optimal material for our design scenario. For one, it's lightweight enough that it is easy to transport, operate, and install, which is a major consideration for this scenario as local workers oversee and facilitate the assembly. Directly compared to the other two finalists, CFRP, epoxy is up to five times more lightweight than steel and has only 60 percent of aluminum's weight [5]. It is also highly durable and resistant to the dynamics and stresses associated with the weather, meaning there will be little maintenance required [5]. Additionally, this material is highly corrosion-resistant, adding to its low-maintenance amid harsh weathers that expose the turbine to things like salt or moisture which may be of issue in its off-grid location [5]. Because there is also an overall reduction in the mass, there is a lower waste production that makes this material more environmentally friendly. Ultimately, the trade-off when using this material serves as the most optimal for our design scenario. Despite the having a comprehensive manufacturing process, the availability, accessibility, and readiness of this trailblazing material allows it to serve as a bountiful, worthwhile investment for the EWB even, all while maintaining a standard of quality for the Guatemalan village itself.

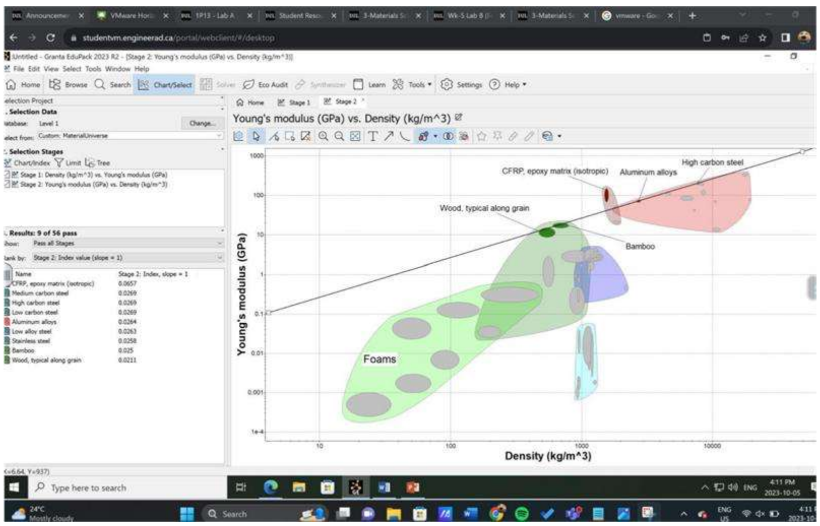

Figure 2. Material Properties Chart Stiffness Testing the Minimized Cost

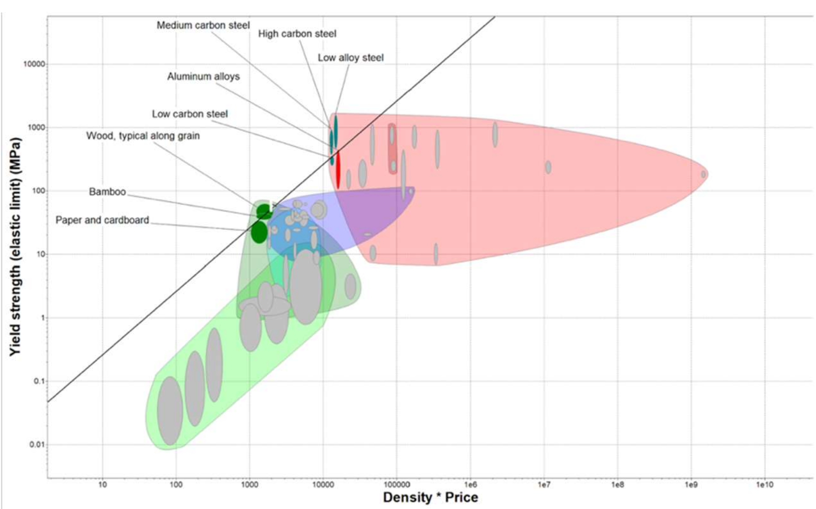

Figure 3. Material Properties Chart For Strength Testing the Minimized Cost

Table 1. Simple Decision Matrix

Simple Decision Matrix - Template			
	Material 1: CFRP, epoxy	*Material 2:* Low-carbon steel	*Material 3:]* Aluminum alloys
Ease of access to material	5	5	5
Chemical, weather and/or corrosion resistance	5	1	4
Ease of maintenance	4	5	3
Locally Sourced Materials	4	2	4
Wear-resistant	5	4	3
Low-cost production	5	1	4
Low-waste sourcing	3	4	2
TOTAL	31	22	25

Table 2 . Material Properties of CFRP, epoxy

Young's modulus E (GPa):	109.5 GPa
Yield strength σ_y (MPa):	800 MPa
Tensile strength σ_{UTS} (MPa):	800 MPa
Density ρ (kg/m^3):	1325 kg/m^3
Embodiment energy H_m (MJ/kg)	728.5 MJ/kg
Specific carbon footprint CO_2 (kg/kg)	50.9 MJ/kg

Design Embodiment: Justification of Solid (CAD) Modelling

Our target maximum displacement in terms of the CFRP epoxy blade's deflection was just under 10mm, which we achieved after calculating the blade thickness of 53.33mm. To determine this optimized value, four sample values were tested for the chosen material of CFRP in order to gauge the range of thickness that produces the closest value. The four tests of 15mm, 30mm, 50mm, and 150mm thicknesses yielded the respective deflections of 27.56mm, 15.49mm, 11.9mm and 72.44 [6]. Given the value of 11.9 for the 50mm thickness test, running further simulations with varied values slightly greater than 50mm determined the optimal thickness to be 53.33 mm for a 9.956 mm deflection, as seen in Figure 5 [6]. Thus, the stiffness-limited design constraint of a maximum 10 mm deflection is satisfied, as our thickness corresponds with the deflection of 9.956 mm [1, p. 40].

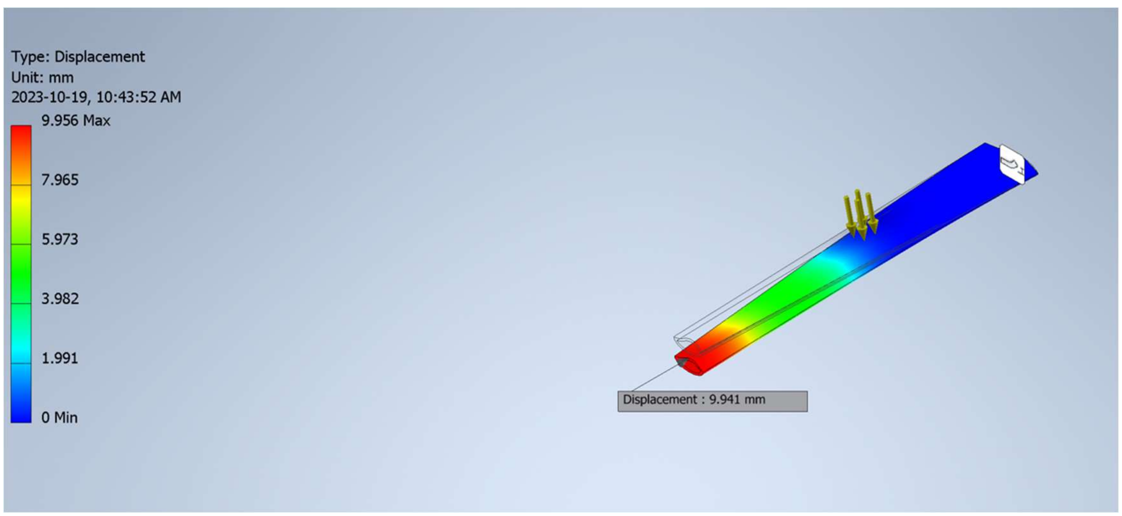

Figure 5. Blade Deflection Within Stress Analysis Environment

Discussion of Regulations

According to the "Comisión Nacional de Energía Eléctrica (CNEE), the power law relating to off-grid initiatives for creating power only requires a permit [7]. For the permit, it would only restrict the area of the project. Thus, the main policy we emphasized was adhering to the given allotted area, however, we also emphasized safety regulations of the blade. We approached these constraints by focusing on the actual size of the turbine blade. Our design has vertical blades which use less volume and allow the blade to be out of harm's way for villagers, as opposed to horizontal blades that take up more volume and therefore a higher chance of injury. Also, due to the blade being more compact, it is easier to condense the turbines in the small area in the village. This allows us to produce large quantities of these turbines and allows us to work in the allotted area without compromising safety.

There were two main socio-cultural concerns for this project, which are the cost of the turbine blade and maintaining a standard of environmental consciousnesses. To combat these concerns, we integrated the careful considerations they posed into our approach of choosing the material CFRP epoxy for our blade. Due to CFRP being rust-proof and extremely durable, this would minimize the needed maintenance required for the blade [5]. Minimizing the maintenance required for the blade will ultimately reduce the cost in the long term. We also approached the safety concern for the environment by using dull edges in our design. Due to the blades being exposed having dull edges prevents extreme injury to the wildlife as opposed to sharp edges. The similarity of the present design to ours is the use of vertical blades. However, the current turbine blade uses semi-circle blades [2] in contrast to our curved long rectangular blade. The current design does a better job in safety as the blade reduces impacts more effectively due to the larger curved surface area. If we were to change the design, we might consider changing the blade to a more semi-circle design for better performance in safety.

Discussion of Sustainable Choices:

Our careful selection of the primary material, CFRP (Carbon Fiber Reinforced Polymer) with epoxy, for our wind turbine project in Santa Cruz La Laguna, Guatemala, is driven by a series of compelling reasons. This choice is pivotal to the success and sustainability of our project. CFRP, a material known for its strength and durability, is readily accessible on a global scale. This accessibility ensures that we can efficiently procure the material without encountering logistical challenges, a crucial practicality for our project.

The coastal setting of Santa Cruz La Laguna demands materials with exceptional resistance to corrosion and environmental factors. CFRP, epoxy precisely exhibits these qualities, guaranteeing the long-term durability of our wind turbines even in the face of harsh coastal conditions. Moreover, its low maintenance requirements and resistance to wear align perfectly with our project's goal of keeping maintenance efforts to a minimum, a vital consideration in a remote location like Santa Cruz La Laguna.

Although CFRP isn't locally sourced in Guatemala, its global availability and the material's inherent durability effectively address concerns about the origin of materials. While the initial costs may be somewhat higher than alternative materials, the long-term cost savings and reduced need for replacements and repairs make CFRP, epoxy a highly sustainable choice that minimizes environmental impact.

In addition to material selection, we've thoughtfully considered the end-of-life scenario for our wind turbines. We plan to explore recycling and reusability options for the components, promoting a sustainable approach to the life cycle of our turbines. Importantly, we intend to involve the local community in these processes, creating economic opportunities and closely aligning with our commitment to environmental sustainability and community engagement. For example, EWB can invest in a local manufacturer of the chosen material, CFRP, epoxy, to reinforce even the strength of the local economy. This holistic approach ensures that our wind turbine project will not only provide much-needed electricity to Santa Cruz La Laguna but also contribute to the long-term well-being of the community and the environment.

Peer-Learning Interview

During Milestone 4, we interviewed with Team 12 and explored their approach to engineering a turbine blade for the Roof Generator Scenario. Given how their product would be located on the rooftops of homes in Calgary, their major considerations were in terms of keeping the turbine blade lightweight and reducing the noise. Their primary objective was minimizing the volume, as per the rooftop location, while their secondary objective was minimizing the cost. This was an approach that we really recognized and would have certainly employed as well had this been our own scenario. Keeping the production cost to a minimum for mass-produced, residentially purposed wind turbines keep the product both accessible and affordable. Additionally, making clean, renewable energy affordable would not only incentivise the product itself, which supports the project, but takes a greater step in the grand scheme of promoting a philosophy of sustainability, which is a message we would’ve honed in on as well had this been our scenario.

The material chosen by this group was low-alloy steel for its jack-of-all-trades-esque presence in the design. Considering how well it scored in the decision matrix, with a 4/5 or 5/5 in all categories, this seemed like their best choice. However, we would have opted for a different material had this been our scenario. To reinforce the success and loyalty to our product, it would have been a major consideration for us to choose a material that is highly durable, as this is what will create an air of reliability and positive review for our product. Low-alloy steel tends to have a lower, inferior corrosion resistance as compared to that of materials like CFRP, epoxy or even stainless steels [4]. Thus, it is the materials selection that perhaps we would have approached differently.

As for the scenario specific turbine blade design, we were highly impressed with the design choices made by this group. As aforementioned, noise was a major consideration for this group due to its commercial purposing, so they took inspiration from the "Savonius" Blade Design which works to reduce noise through the dull-edged barrel shape. Even if the turbine isn't installed in the most optimal environment for the wind, the shape and vertical blade axis ensures that even in weaker wind conditions, enough energy can and will be harnessed. The idea of a vertical blade axis is something that we would reinforce in our own approach of this scenario and is already something we did with our own, especially because we investigated exactly how a vertical axis reduces the size of the turbine, which is a major consideration in this scenario. The only real changes that perhaps we would've made is in terms of the shape simply for aesthetic purposes. Knowing how this product must be highly marketable for its residential purposes, we would've considered a visual appeal to give more reason for people to invest in it, which the barrel design could've perhaps stepped up. For instance, we would've curled the blade slightly more to give it a stronger, more enticing look, rather than the minimalistic barrel design.

Concluding Remarks

From running stress-analysis tests for blade deflections in Autodesk Inventor to utilizing GRANTA to produce scenario-specific material properties charts that created a comprehensive path to our decisions, Project 1 served as the first gust of wind for our engineering minds to harness and hone-in on for a higher, more integrated approach to design. We were given several opportunities to think widely and critically about our scenario and then apply it to areas of technical testing. For example, coming to the logical decisions of our primary and secondary objectives is what allowed us to leverage off of the MPIs, which were then fused with the GRANTA software to produce our charts. This pattern of logical-leading-to-technical thought is highly applicable to future engineering opportunities, as it placed emphasis on the importance of planning and process, rather than solution-based thinking. With all of the discussions and justification we collectively produced, this project taught the importance of careful consideration and research as the foundation for technical skills. It was only after we had discussed our objectives, functions, and constraints that we were able to select a material and then perform deflection-testing simulations, which may be of great importance independently in future engineering projects. Perhaps in future projects, there may be greater considerations of the logistics and structural design itself, taking a step up and away from the approach of a theoretical design. For example, more analysis could even be performed in terms of exploring other aspects of the design project, such as running cost-benefit analysis for a given prototype.

Name	Summary of Contributions
Ayesha Dogar	Final Report - Justification of Solid (CAD) Modelling - Justification of Material Selection - Peer-Learning Interview - Concluding Remarks - Revising of Finalized Problem Statement and Justification of Technical Objectives and MPI - Report-wide editing - Logbook of Additional Meetings - Organization of Tables and Figures
A*aron Van*	- Created Source material database - Helped edit and revise the overall report - Discussion of regulations
Anushka	– Spell check – Format data tables – Double checking numbers accuracy – Aiding in refined problem statement – Table of contents

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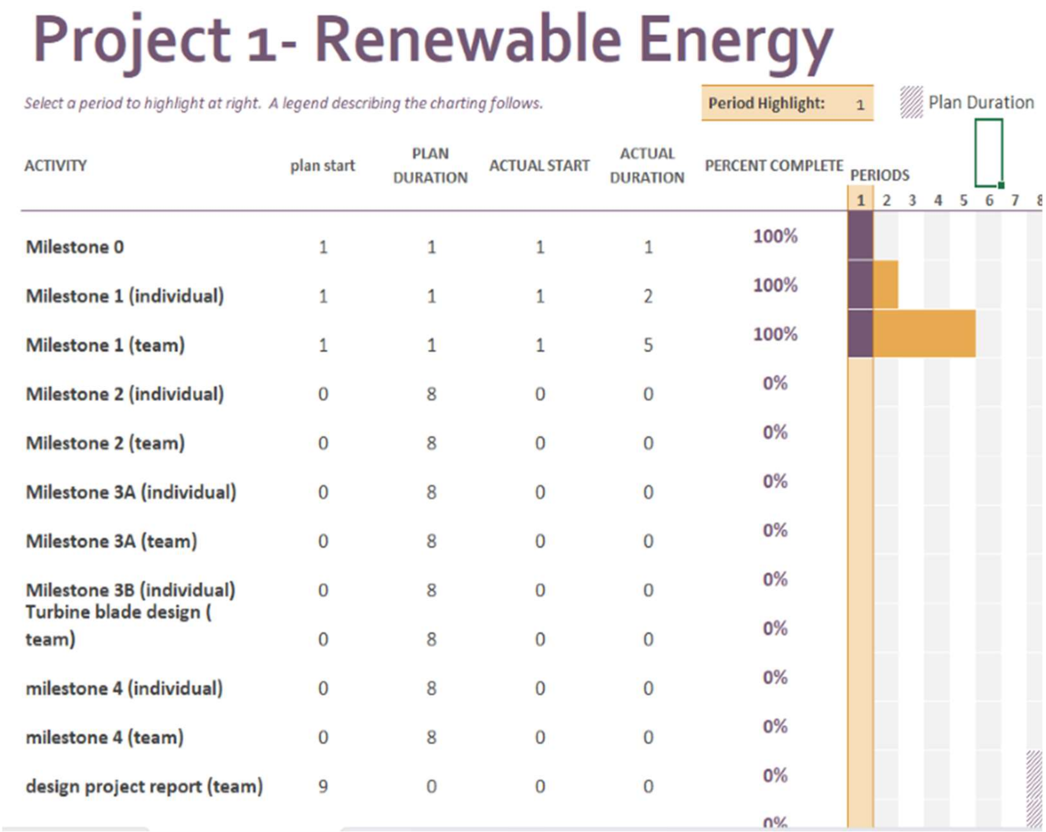
Appendix A: Project Schedule

Figure 1. Preliminary Gannt Chart



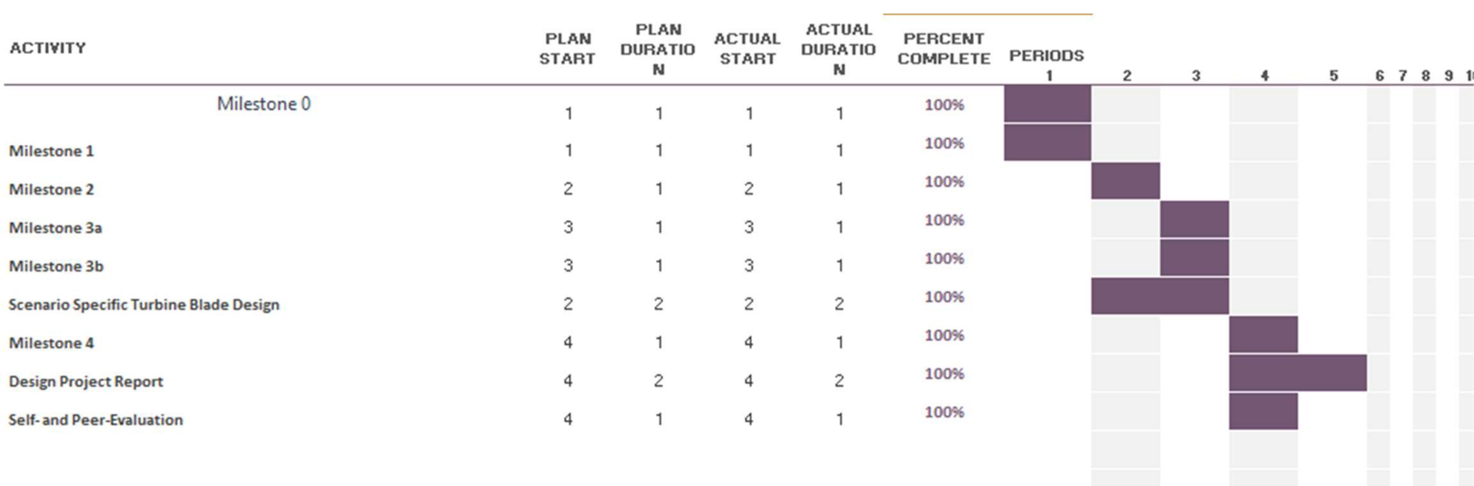
Project 1- Renewable Energy

Select a period to highlight at right. A legend describing the charting follows.

Period Highlight: 1 Plan Duration

ACTIVITY	plan start	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Milestone 0	1	1	1	1	100%
Milestone 1 (individual)	1	1	1	2	100%
Milestone 1 (team)	1	1	1	5	100%
Milestone 2 (individual)	0	8	0	0	0%
Milestone 2 (team)	0	8	0	0	0%
Milestone 3A (individual)	0	8	0	0	0%
Milestone 3A (team)	0	8	0	0	0%
Milestone 3B (individual)	0	8	0	0	0%
Turbine blade design (team)	0	8	0	0	0%
milestone 4 (individual)	0	8	0	0	0%
milestone 4 (team)	0	8	0	0	0%
design project report (team)	9	0	0	0	0%
					0%

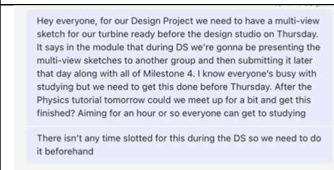
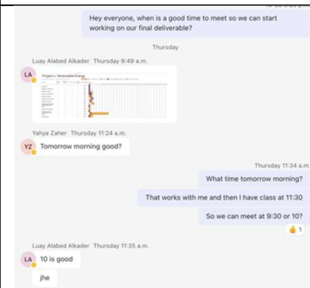
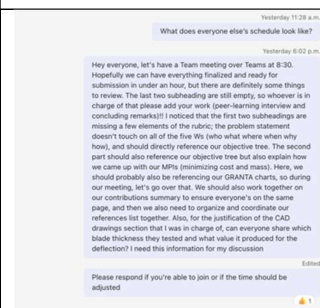
Figure 2. Final Gannt Chart



ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Milestone 0	1	1	1	1	100%
Milestone 1	1	1	1	1	100%
Milestone 2	2	1	2	1	100%
Milestone 3a	3	1	3	1	100%
Milestone 3b	3	1	3	1	100%
Scenario Specific Turbine Blade Design	2	2	2	2	100%
Milestone 4	4	1	4	1	100%
Design Project Report	4	2	4	2	100%
Self- and Peer-Evaluation	4	1	4	1	100%

Appendix B: Scheduled Weekly Meetings

Figure 3. Logbook of Additional Meetings and Discussions – Coordinator

Meeting Date	*Meeting Ojective*	*Meeting Discussion*	*Meeting Media*
October 18, 2023	*Scenario-Specific Turbine Blade Design*	- *Reviewed all shared resources for turbine blade design inspiration* - *Selected two pre-existing designs to choose from; the Nemoi S wind turbine and the SkyWind NG micro wind turbine* - *Meeting started at approximately 5:30 pm, ended at pm, took place in Thode Library* - *Aaron sketched the Multiview, Ayesha gathered information to base the discussion around.* -	 - *Text initiating meeting*
October 26, 2023	*Progress on the Final Deliverable*	- *Discussed vision for the final product* - *Divided up the work so that each group member was working on a particular section* - *Cleared up confusion so that each group member understood the objective of the question and how to understand it clearly* - *Set a soft deadline of Monday, October 30 for completing the first draft of the final deliverable*	 *ROUGH brainstorm document for SSTBD*
November 1, 2023	*Revising the Final Deliverable*	- *Reviewed all completed sections, sharing pointers and ideas that would increase the quality of the work* - *Worked on consolidating references and figures throughout the document, labelling all of them correctly and accordingly.* -	

Appendix C: Comprehensive List of Sources

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Appendix D: Design Studio Worksheets

ENGINEER 1P13 – Project 1: *Renewable technology challenge*

MILESTONE 0 (TEAM): COVER PAGE

Team ID:
Thurs-14

Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Ayesha Dogar	dogara1
Yahya Zaher	zahery
Aaron Van	Vanc3
Luay alkader	Alabedal

Insert your Team Portrait in the dialog box below

2

ENGINEER 1P13 – Project 1: *Renewable technology challenge*

MILESTONE 0 – TEAM CHARTER

Team ID: Thurs-14

Project Leads:

Identify team member details (Name and MacID) in the space below.

Role:	Team Member Name:	MacID
Manager	Luay alkader	alabedal
Administrator	Yahya Zaher	zahery
Coordinator	Ayesha Dogar	dogara1
Subject Matter Expert	Aaron Van	Vanc3

3

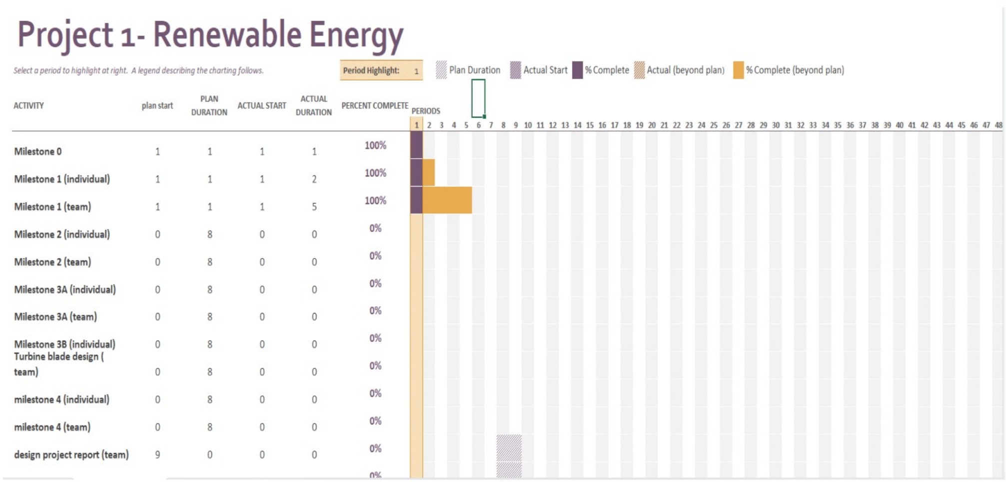
ENGINEER 1P13 – Project 1: *Renewable technology challenge*

MILESTONE 0 – PRELIMINARY GANTT CHART (TEAM MANAGER ONLY)

Team ID: Thur-14

Only the **Project Manager** is completing this section!

Full Name of Team Manager:	MacID:
Luay Alabed Alkader	Alabedal



Project 1- Renewable Energy

Select a period to highlight at right. A legend describing the charting follows.

Period Highlight: 1 — Plan Duration, Actual Start, % Complete, Actual (beyond plan), % Complete (beyond plan)

ACTIVITY	plan start	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Milestone 0	1	1	1	1	100%
Milestone 1 (individual)	1	1	1	2	100%
Milestone 1 (team)	1	1	1	5	100%
Milestone 2 (individual)	0	8	0	0	0%
Milestone 2 (team)	0	8	0	0	0%
Milestone 3A (individual)	0	8	0	0	0%
Milestone 3A (team)	0	8	0	0	0%
Milestone 3B (individual)	0	8	0	0	0%
Turbine blade design (team)	0	8	0	0	0%
milestone 4 (individual)	0	8	0	0	0%
milestone 4 (team)	0	8	0	0	0%
design project report (team)	9	0	0	0	0%
					0%

PERIODS 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48

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ENGINEER 1P13 – Project 1: ***Renewable technology challenge***

MILESTONE 1 (TEAM) – COVER PAGE

Team Number: Thur-14

Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Ayesha Dogar	dogara1
Aaron Van	Vanc3
Yahya Zaher	zahery
Luay Alkader	alabedal

Any student that is ***not*** present for Design Studio will not be given credit for completion of the worksheet and may be subject to a 10% deduction to their P-1 grade.

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ENGINEER 1P13 – Project 1: ***Renewable technology challenge***

MILESTONE 1 (STAGE 1) – INITIAL PROBLEM STATEMENT

Team ID: Thurs-14

Stage 1: Initial Problem Statement:

What is your first draft of the problem statement? Keep it brief and to the point. One or two sentences should be enough. **For this initial problem statement, you should be focusing on the main function(s) of the wind turbine.**

- Transform kinetic energy of the wind into electricity - Make use of clean wind power - Low Maintenance - more efficient than any other sources.
- Designing a wind turbine that transforms the kinetic energy of the wind into electricity in a mechanically stable, non-disruptive manner.

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ENGINEER 1P13 – Project 1: *Renewable technology challenge*

MILESTONE 1 (STAGE 3) – REFINED OBJECTIVE TREES

Team ID: Thurs-14

For each engineering scenario, you will be submitting a modified/revised objective tree agreed upon by the group. Each branch of objective trees should have a minimum of 3 layers. This can be hand-drawn or done on a computer.

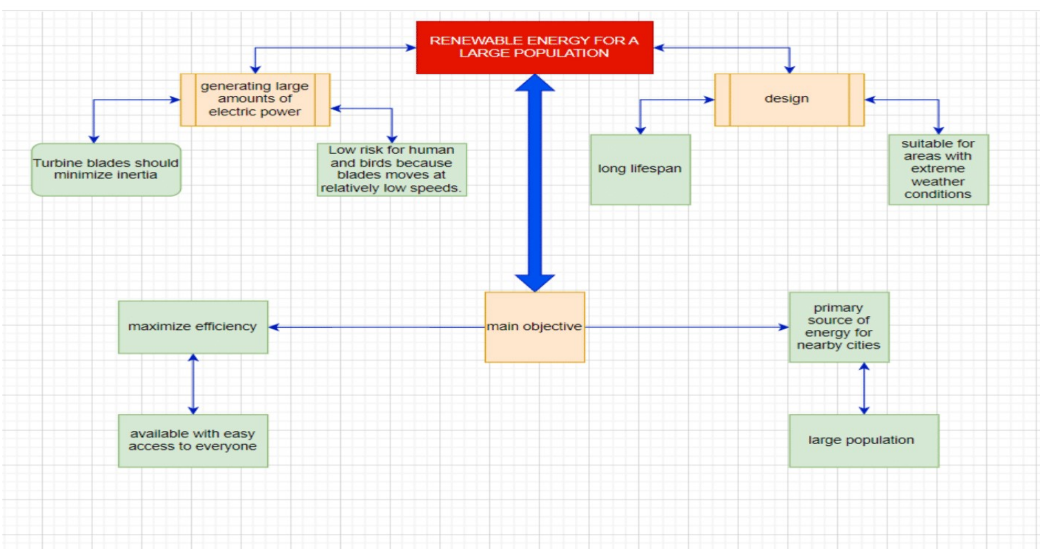
Engineering Scenario #1

The title of the scenario

RENEWABLE ENERGY FOR A LARGE POPULATION

Team objective tree diagram for scenario #1

Please insert a copy of the refined and finalized team objective tree for scenario #1.



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ENGINEER 1P13 – Project 1: ***Renewable technology challenge***

Team ID: Thur-14

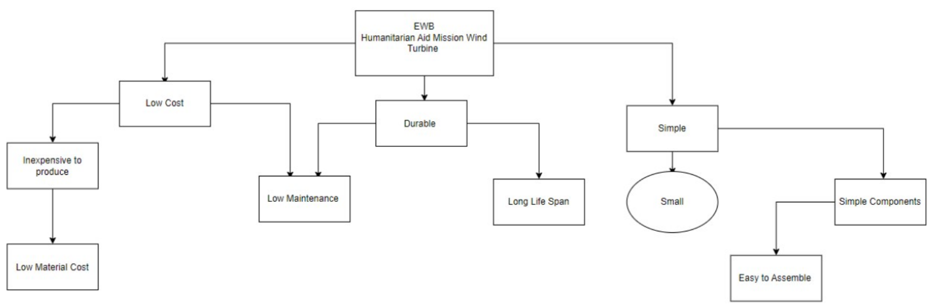
Engineering Scenario #2

The title of the scenario

EWB Humanitarian Aid Mission

Team objective tree diagram for scenario #2

Please insert a copy of the refined and finalized team objective tree for scenario #2.



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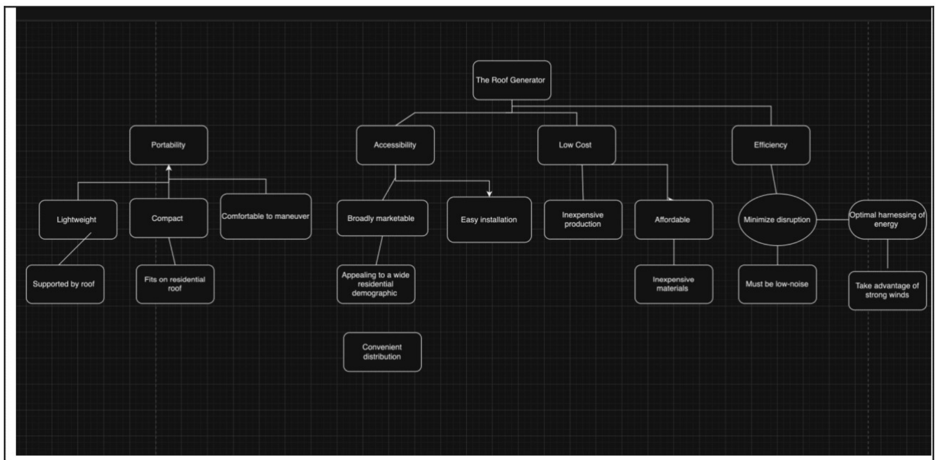
ENGINEER 1P13 – Project 1: *Renewable technology challenge*

Team ID: Thur-14

Engineering Scenario #3

The Roof Generator



Team objective tree diagram for scenario #3

Please insert a copy of the refined and finalized team objective tree for scenario #3.

Team ID: Thurs-14

Engineering Scenario #4

The title of the scenario

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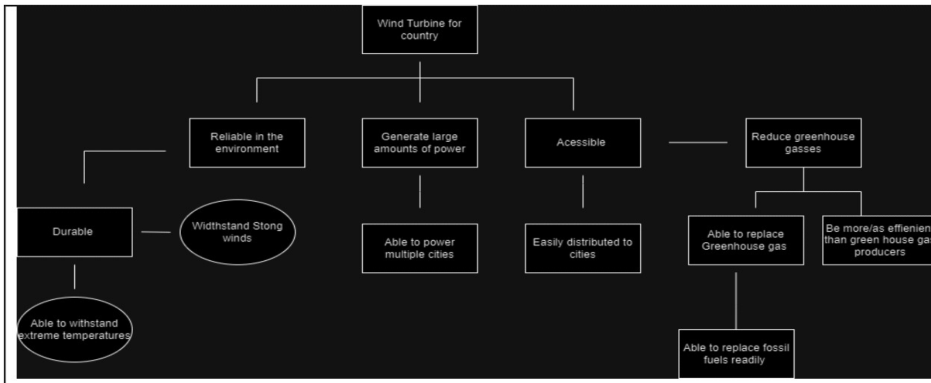
ENGINEER 1P13 – Project 1: *Renewable technology challenge*

Pioneer In Clean Energy

Team objective tree diagram for scenario #4

Please insert a copy of the refined and finalized team objective tree for scenario #4.



ENGINEER 1P13 – Project 1: *Renewable technology challenge*

MILESTONE 2 (TEAM) – COVER PAGE

Team Number: Thurs-14

Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Yahya Zaher	zahery
Anushka Datta	dattaa17
Aaron Van	vanc3
Luay Alkader	Alabedal
Ayesha Dogar	dogara1

Any student that is ***not*** preset for Design Studio will not be given credit for completion of the worksheet and may be subject to a 10% deduction to their P-1 grade.

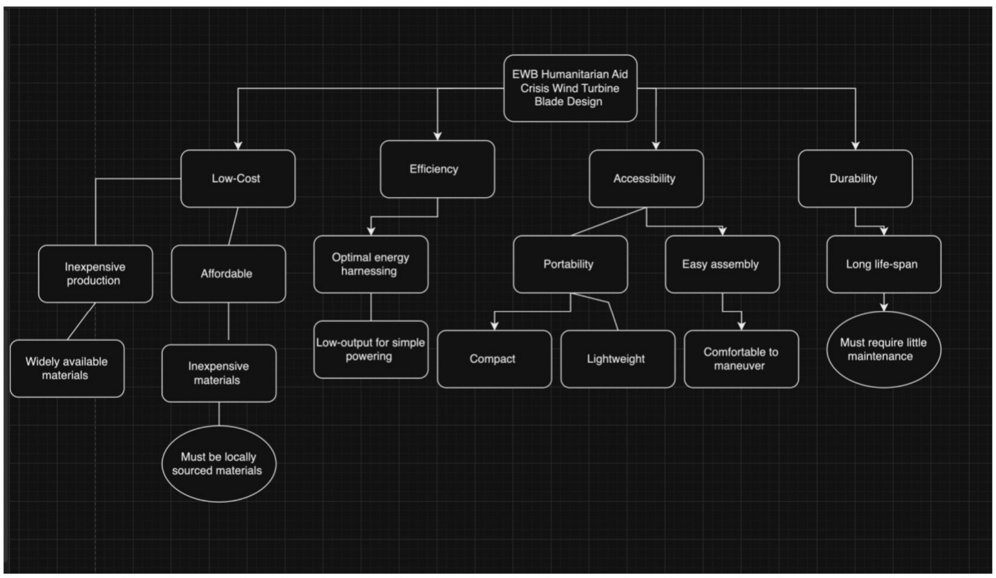
ENGINEER 1P13 – Project 1: *Renewable technology challenge*

MILESTONE 2 (STAGE 1) – DESIGN REQUIREMENTS FOR A TURBINE BLADE

Team ID: Thurs-14

Objective Tree of turbine blade for assigned engineering Scenario

→ Please insert a copy of your team objective tree for the design of a turbine blade based on your assigned engineering scenario.



Turbine Blade Problem Statement:

→ Write a complete problem statement for the design of a turbine *blade* based on your assigned engineering scenario.

Designing a simplistic wind turbine that transforms the kinetic energy of the wind into electricity in a highly efficient, durable, cost efficient, environmentally friendly manner.

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ENGINEER 1P13 – Project 1: ***Renewable technology challenge***

MILESTONE 2 (STAGE 2) – SELECTION OF TOP OBJECTIVES FOR A TURBINE BLADE

Team ID: Thurs-14

List the top three objectives of a turbine blade for your assigned engineering scenario

1: Simple
2: Low Maintenance
3: Cost Efficient

Include a rationale for selecting each of these objectives
→ Write *maximum* 100 words for each objective

Objective 1: Simple

Rationale:

The wind turbine must have a simple design since the people of the Guatemalan village in Santa Cruz La Laguna will be the ones assembling the two-foot wide and three-foot-tall wind turbine. An uncomplicated design means faster and more efficient assemblies, minimal chances of part breakages, and avoided confusion on part assembling.

Objective 2: Minimal maintenance

Rationale:

The wind turbine must be minimal maintenance since the village is off grid. Since it is off gird there will be less professional help to maintain the wind turbine units. Due it being minimal maintenance it correlates to the other objectives such as being durable and long lifespan. Durable means less repairs, thus long lifespan, thus minimal maintenance.

Objective 3: Cost efficient

Rationale:

The wind turbine must be cost efficient since the village is building multiple wind turbines across the village. The Village is off the grid so Minimizing initial cost is important to building a wind turbine. Also, the materials must be affordable, easy to maintain, and long-lasting minimizing costs overall.

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MILESTONE 2 (STAGE 3) – METRICS

Team ID: Thurs-14

For your selected top three objectives fill out the table below with associated metrics (including units) for each objective.

Objective 1:	Simple
Unit/Metric:	Mass (Kilograms)

Objective 2:	Low Maintenance
Unit/Metric:	Dollars ($)

Objective 3:	Low Cost
Unit/Metric:	Dollars ($)

MILESTONE 2 (STAGE 4) – REGULATIONS

Team ID:	Thurs-14

Insert your group discussion below

As a team we have examined and given careful thought to the fundamental concepts that will guide the development of this turbine for the benefit of the villagers, realizing that a high-power turbine is unnecessary for their needs. Our group has come to terms with the importance of two key goals: reducing the need for maintenance and using money-saving items wisely. This strategy not only fits with the small scale of the hamlet but also actively lowers greenhouse gas emissions in their neighborhood. Our conversations have also included the issues related to the village's installation of the turbine. We are dedicated to making sure that the deployment is both ecologically responsible and carbon neutral. Additionally, we recognized that minimal maintenance and cost-efficiency are interconnected objectives. By designing a turbine that requires less maintenance and is durable, we can ensure a longer lifespan for the turbines. This, in turn, reduces long-term costs for the village as they do not require frequent repairs or replacements. Therefore, to achieve these objectives, we discussed the need for careful material selection. It's crucial to choose materials that are both affordable and long-lasting, taking into consideration the local availability of resources. We should also explore options for sourcing materials locally to further minimize costs and support the local economy.

MILESTONE 3A (TEAM) – COVER PAGE

Team Number: Thurs-14

Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Yahya Zaher	zahery
Aaron Van	vanc3
Anushka Datta	Dattaa17
Ayesha Dogar	dogara1
Luay Alkader	Alabedal

Any student that is ***not*** present for their scheduled Lab-B session will not be given credit for completion of the worksheet and may be subject to a 10% deduction to their P-1 grade.

ENGINEER 1P13 – Project 1: *Renewable technology challenge*

MILESTONE 3A (STAGE 1) – MATERIAL SELECTION: PROBLEM DEFINITION

Team ID: Thurs-14

1. Copy-and-paste the title of your *assigned* scenario in the space below.

SCENARIO 2: EWB HUMANITARIAN AID MISSION

2. MPI selection
   → List one primary objective and one secondary objective in the table below
   → For each objective, list the MPI
   → Write a short justification for your selected objectives

	Objective	MPI-stiffness	MPI-strength	Justification for this objective
Primary	Minimizing mass	E/ρ	σ_y/ρ	With villagers themselves being the ones to assemble these wind turbines, it is important to consider the simplicity of the overall design. By minimizing mass, we are creating a blade that is not lonely lightweight and portable due to the minimized density, but also small and compact as needed.
Secondary	Minimizing cost	$E/\rho C_m$	$\sigma_y/\rho C_m$	Because the EWB volunteer group is designing this project, rather than an established firm or company, there is expectedly a greater consideration in keeping the project low-cost. We want to minimize the cost since the volunteer group only has access to fixed funds and cannot afford to pay for expensive equipment since they are trying to get quantity over quality

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MILESTONE 3A (STAGE 3) – MATERIAL SELECTION: MATERIAL ALTERNATIVES AND FINAL SELECTION

Team ID: Thurs-14

Document results of each team member's materials selection and ranking on the table below.

- All different types of steel (carbon steels, alloy steels, stainless steels) have very similar Young's moduli. **For this stage in Project 1, please group all variations of steels into one family as "steel"**. Please put **steel** in your material ranking list only once and indicate in a bracket which steels made the top ranks.

Consolidation of Individual Material Rankings					
	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5
MPI 1: E/ρ	CFRP, epoxy matrix	Steels	Aluminum Alloys	Magnesium alloys	Titanium Alloys
MPI 2:	CFRP, epoxy	Titanium Alloys	GFRP,epoxy matrix	Low alloy steel	Aluminum alloys
MPI 3: $E/\rho C_m$	CFRP Epoxy Matrix (medium carbon steels, High carbon steel, low carbon steels, low alloy steel, stainless steel	Steels	Aluminum alloys	Bamboo	Wood, typical along grain
MPI 4: $\sigma_y/\rho C_m$	Steel (Low alloy steel, High carbon steel, medium carbon steel, low carbon steel)	Wood, typical along grain	Bamboo	Paper and cardboard	Aluminum alloys

ENGINEER 1P13 – Project 1: *Renewable technology challenge*

As a team, fill out the table below and narrow down the possible materials for your assigned scenario by choosing the 3 materials which showed up the most across all MPI rankings in the table above.

- For this stage in Project 1, if **"steel"** is one of your three material finalists, please specify which steel your team chose to continue with, based on which showed up the most in your team's consolidated table.
- Remember to save the datasheets of all 3 material finalists

Narrowing Material Candidate List to 3 Finalists	
Material Finalist 1:	CFRP, epoxy
Material Finalist 2:	Low-carbon steel
Material Finalist 3:	Aluminum alloys

Team ID: 14 Thurs-14

As a team, compare material alternatives and make a final selection based on either a simple decision matrix or a weighted decision matrix (up to your team to decide)

→ As a team, consider *at least* 3 additional criteria that are relevant to your assigned scenario and discuss your 3 materials finalists for each criterion
  - Feel free to pause at this stage and do some quick research on the materials finalists
  - You may refer to the material finalists' datasheets for any relevant information that will enable your discussion.

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- To help you come up with your additional criteria, below are some question prompts that you may consider. Please note that you are not limited to these suggestions, and they may or may not be relevant to your assigned scenario

Additional Criteria	Possible question prompt
Ease of access to material	Is the material easy to source in the country, are there tariffs due to international trade policy?
Chemical, weather and/or corrosion resistance	Will the material degrade over time (e.g. due to chemical resistance, corrosion resistance, fatigue resistance)?
Ease of maintenance	Consider maintenance if the part got damaged. Based on the material, is it easy to fix or will the entire part need replacement?

→ Remember that:
- Your MPI ranking takes into consideration both material and mechanical properties relevant to the objectives of your assigned scenario.
- Your additional considerations should not include previously evaluated objectives e.g. If minimizing the carbon footprint was either your primary or secondary objective, then it should not be an additional criterion

→ Compare the material alternatives and make a final selection based on either a simple decision matrix or a weighted decision matrix (up to your team to decide)
- *Applies to a weighted decision matrix only:* choose a range for the weighting (e.g., 1 to 5) for each criterion. The higher the number on the weighting, the more important that criterion is.
- Choose a range for the score (e.g., 1 to 5) for each material on each criterion. Give each material a score based on how successfully it meets each criterion. The higher the score, the better the material is for that criterion.
- Add additional rows as needed.
- Add up the total score for each material alternative.

Fill one of the following templates only:

Simple Decision Matrix - Template			
	Material 1: CFRP, epoxy	*Material 2:* Low-carbon steel	*Material 3:]* Aluminum alloys
Ease of access to material	5	5	5
Chemical, weather and/or corrosion resistance	5	1	4
Ease of maintenance	4	5	3
Locally Sourced Materials	4	2	4
Wear-resistant	5	4	3
Low-cost production	5	1	4
Low-waste sourcing	3	4	2
TOTAL	31	22	25

→ State your chosen material and justify your final selection

Justification	
Chosen Material:	CFRP, epoxy

Discuss and justify your final selection in the space below (based on the decision matrix results and any other relevant considerations).

We chose CFRP, epoxy because it integrates a variety of important considerations for designing the EWB Humanitarian Crisis wind turbine into our design, as demonstrated through the decision matrix. While low-carbon steel was a finalist for the decision matrix, it was ultimately the high density that created heavier blades and the susceptibility to corrosion that ruled it out. As for the aluminum alloy, its high density and fatigue resistance make it less ideal of a material, as it is susceptible to wear after repeated bending and flexing.

However, CFRP, epoxy seems to be the most optimal material for our design scenario. For one, this material is lightweight enough that it is easy to transport, operate, and install, which is a major consideration for this scenario as local workers oversee and facilitate the assembly. While maintaining lightweight, it is also highly durable and resistant to the dynamics and stresses associated with the weather, meaning there will be little maintenance required. Additionally, this material is highly corrosion-resistant, adding to its low-maintenance amid harsh weathers that expose the turbine to things like salt or moisture. Because there is also an overall reduction in the mass, there is a lower waste production that makes this material more environmentally friendly. Ultimately, the trade-off when using this material serves as the most optimal for our design scenario, as it maintains the most important considerations for the EWB Humanitarian Crisis wind turbine project.

Summary of Chosen Material's Properties

Material Name	Average value
Young's modulus E (GPa):	109.5
Yield strength σ_y (MPa):	800
Tensile strength σ_{UTS} (MPa):	800
Density ρ (kg/m^3):	1325
Embodiment energy H_m (MJ/kg)	728.5
Specific carbon footprint CO_2 (kg/kg)	50.9

ENGINEER 1P13 – Project 1: *Renewable technology challenge*

SCENARIO SPECIFIC TURBINE BLADE DESIGN (TEAM) – COVER PAGE

Team Number: Thurs-14

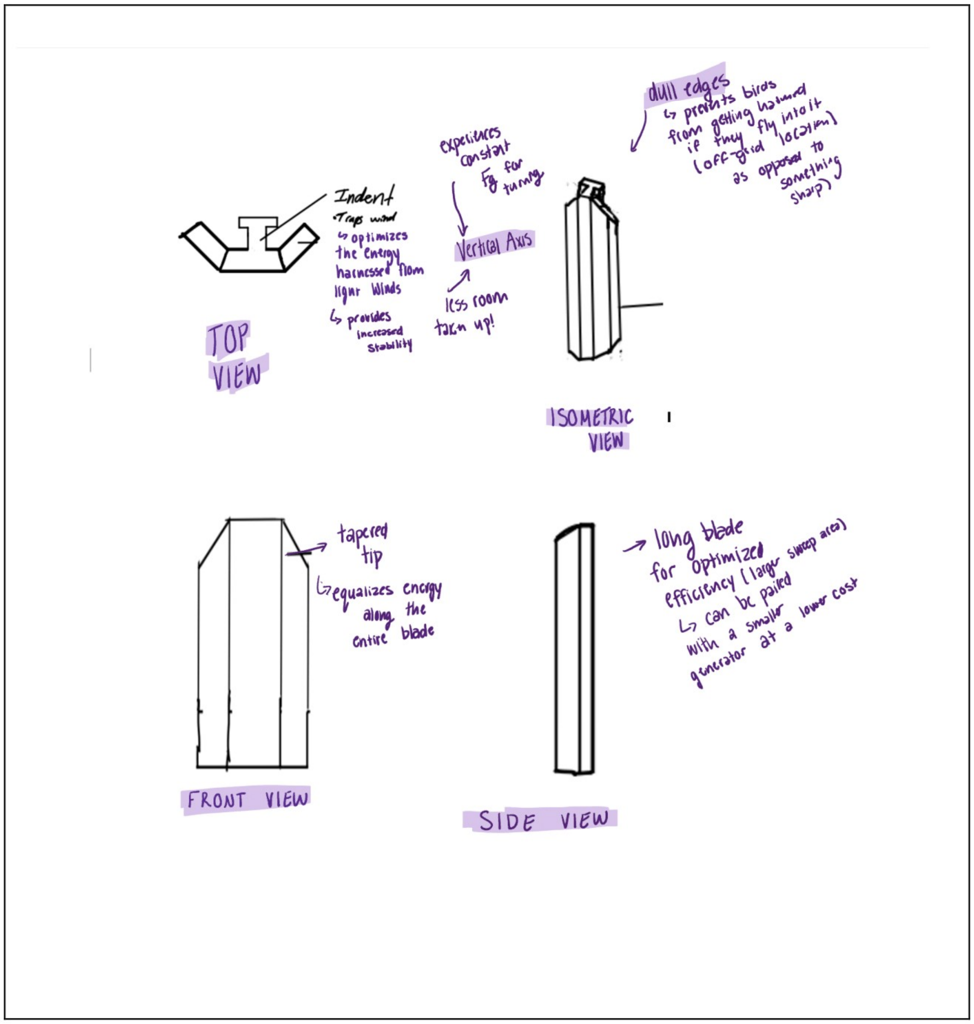
Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Yahya Zaher	zahery
Luay alabed alkader	alabedal
Aaron Van	vanc3
Ayesha Dogar	dogara1
Luay Alkader	Alabedal

MULTIVIEW TURBINE BLADE SKETCH AND JUSTIFICATION

Team ID: Thurs-14

1. Sketch of Turbine Blade



2. Justification of Turbine Blade

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ENGINEER 1P13 – Project 1: *Renewable technology challenge*

Include an explanation on how your turbine blade design meets your assigned scenario. Be sure to discuss the creative elements behind your design and provide justification for them.
This turbine blade design takes into account the specific factors that make up the Engineers Without Boarders Humanitarian Aid scenario, as it is important to consider the scale, limitations, and considerations of this project. The primary objectives for this design included a minimized mass and minimized cost, as multiple units of this design are to be assembled and installed by visitors and then placed in close vicinity. Thus, we were heavily inspired by the Nemoi S turbine blade design, characterized by its vertical axis, easy assembly, and optimized harnessing of energy for low-consumption applications [2]. Our design features the vertical-axis blade design that experiences a constant gravitational force, making it highly efficient as this contributes to the rotations [2]. While conventional turbine blades may be more efficient in high winds, as they also tend to be larger in size, this also makes them more difficult to install as well as maintain. Additionally, energy may be lost for a conventional blade from the point of generation to the storage and transportation required for it's operation. However, the Nemoi S turbines can operate off-grid once they are set-up while producing the same amount of energy that is being used, keeping the mechanism optimized [2]. Keeping in mind that multiple units are to be assembled, the vertical-axis design also allows for several turbines to be placed close together, as they take up less space. Thus, with more wind turbines in the area and less wind required to make them turn, the energy produced is ultimately more affordable for the village. As for the narrow shape of the blade, the smaller blade area prevents energy from being lost to drag. Rather, the blade is just wide enough that the required torque is produced to keep the hub turning without the interference of drag at higher speeds [1]. Additionally, another consideration was tapering the top of the blade to reduce turbulence and drag, which also works to improve the structural integrity of the design to ultimately enhance its durability. With the structural stress being distributed more evenly along the blade, there is a reduced risk of structural failures and thus, a reduced need for maintenance [1]. Moreover, with a tapered tip, the energy generation is equalized along the entire blade, whereas no tapering would cause more energy to be extracted at the tip than the root, ultimately leading to a reduced total rotational energy produced by the wind [1]. Additionally, the taper reduces the blade's bend as there is less of a wind force at the top, along with general failure and fatigue [1].
References [1] "Article 5: The Single Wind Turbine: From the Wind to the Blades," *Andlinger Center for Energy and the Environment.* Available: https://acee.princeton.edu/wp-content/uploads/2019/04/AndlingerDistillate_Article5.pdf [2] V.B Ramirez, "This Mini Wind Turbine Can Power Your Home in a Gentle Breeze," *SingularityHub,* Jul. 9, 2017. [Online]. Available: https://singularityhub.com/2017/07/09/this-mini-wind-turbine-can-power-your-home-in-a-gentle-breeze/. [Accessed Oct. 17. 2023].

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MILESTONE 4 (TEAM) – COVER PAGE

Team Number: Thurs-14

Please list full names and MacID's of all *present* Team Members

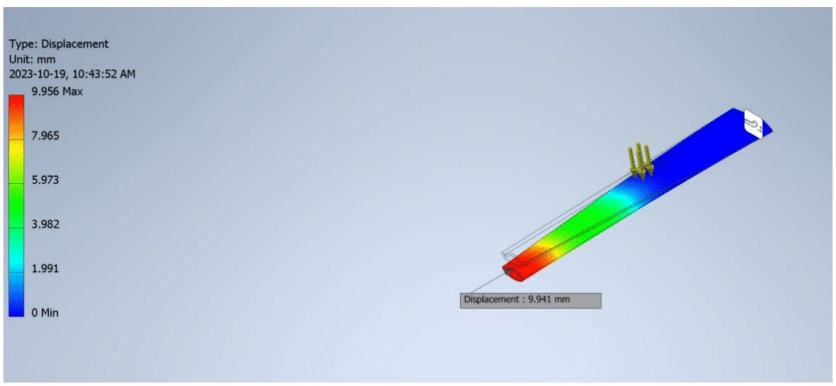
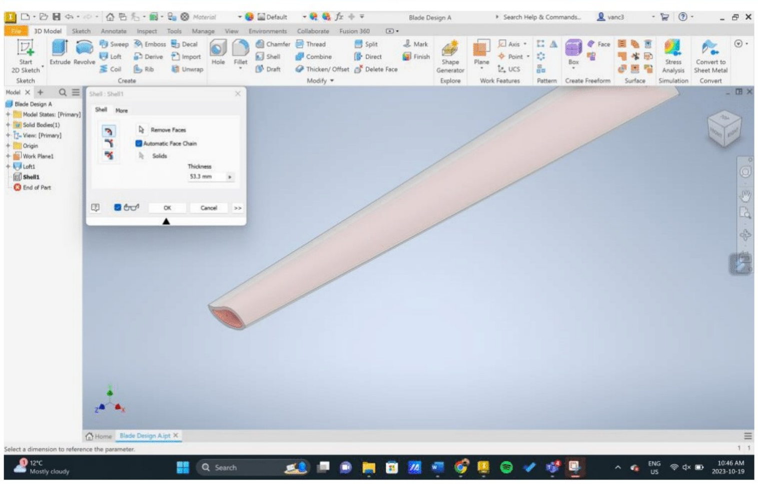
Full Name:	MacID:
Ayesha Dogar	dogara1
Luay Alabed Alkader	alabedal
Aaron Van	vanc3
Yahya Zaher	zahery

Any student that is ***not*** present for Design Studio will not be given credit for completion of the worksheet and may be subject to a 10% deduction to their P-1 grade.

MILESTONE 4 (STAGE 2) – REFINE THICKNESS REQUIREMENT

Team ID: Thurs-14

1. Refine Thickness Requirement to Satisfy Deflection Constraint

Refined turbine blade thickness *t* (mm):	53.3mm
 	

ENGINEER 1P13 – Project 1: *Renewable technology challenge*

MILESTONE 4 (STAGE 3) – PEER INTERVIEW

Team ID: Thurs-14

→ Meet another team with a different scenario
- Discuss differences in your design process
- Compare:
  - Primary/secondary objectives
  - Chosen materials, thickness, etc.
- Discuss the relevance of your scenario-specific turbine blade design to your assigned scenario and any design challenges you have encountered.

1. Peer Interview Notes

Discuss what you have learned from another group.

Ayesha Notes:

Group: Thurs-11

Scenario: The Roof Generator

- This is located in Calgary, on the rooftops
- As a result, some major considerations were keeping it lightweight and reducing the noise

PRIMARY OBJECTIVE: Minimizing Volume

- Because it's on a rooftop, the more compact and lightweight, the better

SECONDARY OBJECTIVE: Minimizing Cost

- Because these are going to be mass-produced for residential purposes, the production cost should be minimized to keep them accessible and affordable
- Ultimately, this incentivises clean and renewable energy

CHOSEN MATERIAL: Low-alloy Steel

- jack of all trades; it's not amazing in everything, but it is highly well-rounded for this scenario!
- Decent volume, cost, durability, weight, melting point. Scored a 4/5 for all categories in the descision matrix (5/5 for volume!), so they chose it.

THICKNESS: 23 mm

Scenario-Specific Design:

ENGINEER 1P13 – Project 1: ***Renewable technology challenge***

“Savonius” Turbine Blade: - Noise is a very important consideration - Not sharp blades, half of a cylinder, which reduces lots of noise - Not always installing in most optimal environment for the wind - Regardless of the direction of the wind, it will still generate energy - It doesn’t need to spin very fast, no matter the wind speed, it still produces enough energy - Vertical axis: considering lots of different laws and regulations, this keeps it small enough to go on the roof - Dull blades keep it safe for animals (I.e birds wont be hurt if they fly into it) Aaron notes: Challenge -light weight, rooftops -Primary Objective: minimizing size -Secondary Objective: minimizing cost Material chosen: Low alloy steel Well balanced for all objectives Two scoops turbine: They chose the blade because noise is an important objective because the sharp blade would reduce the noise. Vertical blade- because of laws and regulations that involve space. Thus, the vertical blade makes it easier to pass regulations and to produce many. Simple design: easy to mass produce and save money for every house. Challenges: Regulations of laws to implement in the design.