Design Project 1 – Renewable Technology Challenge

ENGINEER 1P13 – Integrated Cornerstone Design Projects in Engineering

Tutorial 2

Team 26

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Submitted: November 2, 2023

Course Instructors: Dr. McDonald, Dr. Doyle, Dr. Ebrahimi, Dr. Fleisig, Dr. Hassan, Dr. Zurob

Table of Contents

Academic Integrity Statement

The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

Mark Atalla 400504087

(Student Signature)

The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

Abdullah Abusalout 400534459

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The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

Syed Khalid Fouwaz Kalam 400504830

(Student Signature)

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Daniel Wen 400478403

(Student Signature)

Finalized Problem Statement

Problem Statement

Our refined problem statement was to design a wind turbine blade for the rural off grid village of Santa Cruz La Laguana in Guatemala to convert wind energy into electrical energy through mechanical means to power small scale electrical devices. Due to the environment of the scenario, the blade must be cost effective, easy to produce and maintain, and have a long lifespan with its constraints being that it must be made with locally available materials, cannot require a high skilled labour floor, and cannot exceed the small budget set out by the village. Additional considerations were also made aside from the main objectives, such as the efficiency of the blades while still retaining its cost effectiveness, and the weight of the blade.

Main Body

Justification of Technical Objectives and Material Performance Indices

Our primary objective was to make a wind turbine for Santa Cruz la Laguna, so the 3 objectives were to make the blade durable, easy to produce, and efficient, along with ensuring that it can be easily assembled and easy to maintain, that villagers that can use materials that are available in the local region, and the efficiency should optimize performance while ensuring maximum energy. Our MPI selection was according to our primary objective which was minimizing production energy and the secondary objective which was minimizing cost. We consolidated individual material rankings by measuring cost strength and stiffness, and production stiffness and strength we ended with carbon steel, bamboo, and wood. During evaluations, we ended up choosing wood because of its effectiveness on the long-term scale due to its easy maintenance and repairability, and since the village is located near forests, the wood will be affordable due to its low cost.

Conceptual Design – Justification of Selected Material

In our research of the material selection in our objective, we came up with a shortlist of three materials ultimately narrowing it down to just one. The three candidates were carbon steel, bamboo, and wood along with typical grain. We studied multiple factors to make our final decision. Each factor had a different weightage depending on its importance in the objective. The first and the highest weighted factor was the fact that the material we chose should be easily available to source to manufacture the blade. We observed that the forestry of Guatemala plays a major role in its economy, so sourcing wood will not be an issue [1]. Our second criterion was the lifespan of the material, in which we observed that steel was the clear winner here due to its ability to withstand under heavy conditions.[2] On our third criteria we focused on repairability. Due to the easy sourcing and replacing of both wood and bamboo, it was clear to be the leaders in the category. On our final basis, we observed the corrosion restraint of the material, in which steel was the leader due to its durability.[3] Ultimately, after considering all the factors and the weightage of each factor, we decided the most sensible material would be that of wood along typical grain.

Table 1 Material Properties

Material	Density (g/cc)	Yield Strength (MPa)
Wood	4.70-6.25	36.3-62.5
Steel	7.8	433-924
Bamboo	6.02-7.97	35.8-44.1

Justification Of Solid (CAD) Modelling

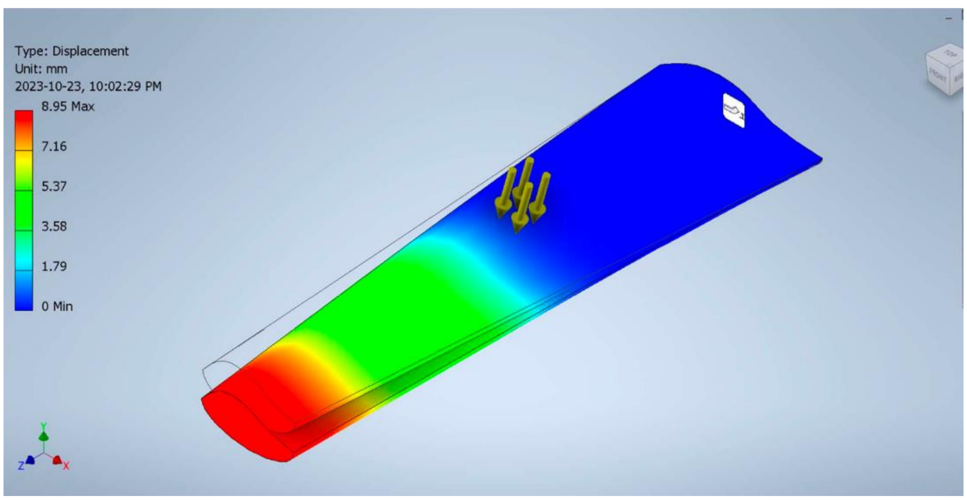

Figure 1. AutoCAD stress simulation using determined thickness. Note the scale on the left.

Through careful testing and refinement, we found our thickness to be 165mm, achieving a deflection of 8.95mm, which was within design constraints of deflection being greater than 8.5mm and less than 10mm. A thick blade was required, particularly due to the density and young's modulus of wood typical along grain. With an average density of 547.5 kg/m^3 and a young's modulus of 11.85 GPa, which is much lower than other materials such as steel and aluminium which have a much higher density and young's modulus. This would result in a blade using wood as its material having a much higher deflection compared a blade using steel or aluminium utilizing the same thickness, so a relatively thick blade was required to satisfy the deflection constraint.

Discussion of Regulations

When designing a wind turbine for Guatemala it is important to consider factors and adhere to rules and regulations. The General Electricity Act and its implementing rules control the electric energy industry in Guatemala. This Act was introduced with the intention of encouraging and growing private sector involvement in the energy sector. To encourage private sector-led growth in this domain, the Guatemalan government deliberately chose to privatize the energy industry. In order to facilitate privately funded development, new legislation was developed in 1994 to start the process of deregulation and privatization within Guatemala's electric energy business. To lessen governmental intervention and encourage private investment in the industry, the Guatemalan government created a legislative and regulatory framework in 1996, two years later. [4] Our wind turbine design prioritizes minimizing impacts reducing noise and minimizing disturbance to the local population, particularly the indigenous communities to comply with these regulations. We also carefully consider protection and land use regulations when selecting locations, for our turbines aiming to minimize disruption while maximizing energy production.

Through the development of blade materials and noise-cancelling technologies like serrated hub vortex generators, we address concerns regarding noise pollution, disturbance of animals and overall environmental impact. [5] Our design differs from wind turbine technology by addressing the unique challenges posed by Guatemala’s terrain and community sensitivities. We place an emphasis, on mitigating impact and complying with local laws more than ever before. The main objective of this method is to improve the integration, with the environment and communities by offering a flexible and situationally aware approach. This is particularly important in Guatemala as the success of energy initiatives relies on the acceptance and adherence to regulations, by the community.

Sustainability

One of the main objectives of designing the wind turbine itself is to provide clean and efficient energy to the people. So, it was crucial to give importance to the factor of sustainability. During our material selection, we noted that wood has a crucial advantage over other materials like steel simply because it is biodegradable in the environment, which eliminates any negative environmental impact in the village.[6] It is highly important for us to note that Guatemala is a country with upwards of 30% of the total land area of the country being forested. This shows the importance of the preservation of forests in the country. [7]

Peer-Learning Interview

In an interview with Mon-25, we were able to review their design for their given scenario, Renewable Energy for a Large Populace. This scenario involved design a large wind turbine blade for a large wind turbine farm on Wolfe Island that would be provide the primary source of power to multiple nearby large cities, along with Kingston itself.

To begin with, their primary objectives were durability, efficiency, and cost effectiveness. They believed that this would best suit the needs of a wind turbine blade design, as the durability and efficiency of the blades would satisfy the need for reliability and effectiveness in the wind farm to supply a large population count, along with cost effectiveness helping to ensure that they did not exceed the constraint of the budget. Considerations were made to the ease of producing and maintaining such blades, along with the availability of materials due to import laws.

The material that they selected to build their blade out of was high carbon steel as during evaluations it had the highest young’s modulus, highest yield strength, highest fracture toughness, and a much higher elasticity which the team valued as they built the blade to bend.

In their design they build a blade that shaped similarly as an air foil or wing. Being 25mm thick, it featured a wing like structure with a deep upper chamber that had a gradually decreasing angle of incidence towards the blade tip to account for different speeds along the blade. The blade was segmented into different parts with interlocking mechanisms to aid in both assembly and transportation costs. On the top of the blade, they had a support beam running lengthwise that was hollowed out to aid in facilitating airflow.

Our team believed that they had made the correct design choices most of the time. We found their design to be well crafted, and praise was given towards the choice of gradually decreasing the angle of attack and the segmentation of the blade as it helped to achieve their design objectives. We also agreed with their chosen material and primary objectives, as they were relevant and pertinent to the design needs of the clients. However, our design team believed that the support beam would disrupt the boundary layer of the blade, moving the transitionary zone between laminar and turbulent flow further up towards the leading edge of the blade, thus reducing the lift generated from the blade [8]. Additionally, our team recommended the use of variable pitch blades so that they could control the angle of incidence of the blades, which would help decrease the wear and tear on the blades and allow it to perform optimally in all conditions. Overall, if our design team was given the same scenario, we would remove the support beam in the design and make use of a variable pitch blades.

Concluding Remarks

The key takeaway is that, considering Guatemala's weather and scarce maintenance resources, it is imperative to design wind turbines with lifetime and low maintenance costs in mind. Important things to think about are choosing durable materials and parts, designing, and sizing the turbine blades to maximize wind speed, and putting efficient energy storage systems in place to ensure a consistent flow of electricity. It would be advantageous for engineering initiatives going forward to concentrate on developments in blade materials and designs that support efficiency and durability.

Summary of Contributions

Member	**Contributions**
Mark Atalla (Manager)	- Preliminary Gantt Chart - Discussion of Regulations - Concluding Remarks - Report Format - Summary of Contributions
Daniel Wen (Subject Matter Expert)	- Problem statement - Justification of CAD - Peer Interview - Source Materials Database
Syed Khalid (Coordinator)	- Justification of selected materials - Discussion of sustainability - Reference List - Logbook Of Additional Meetings
Abdullah Abusalout (Administrator)	- Justification of Technical Objectives - Appendix E - Final Gantt Chart

Reference List

[1] Sutherland, Elizabeth G., David L. Carr, and Siân L. Curtis. "Fertility and the environment in a natural resource dependent economy: Evidence from Petén, Guatemala." *Población y Salud en Mesoamérica* 2.1 (2004):

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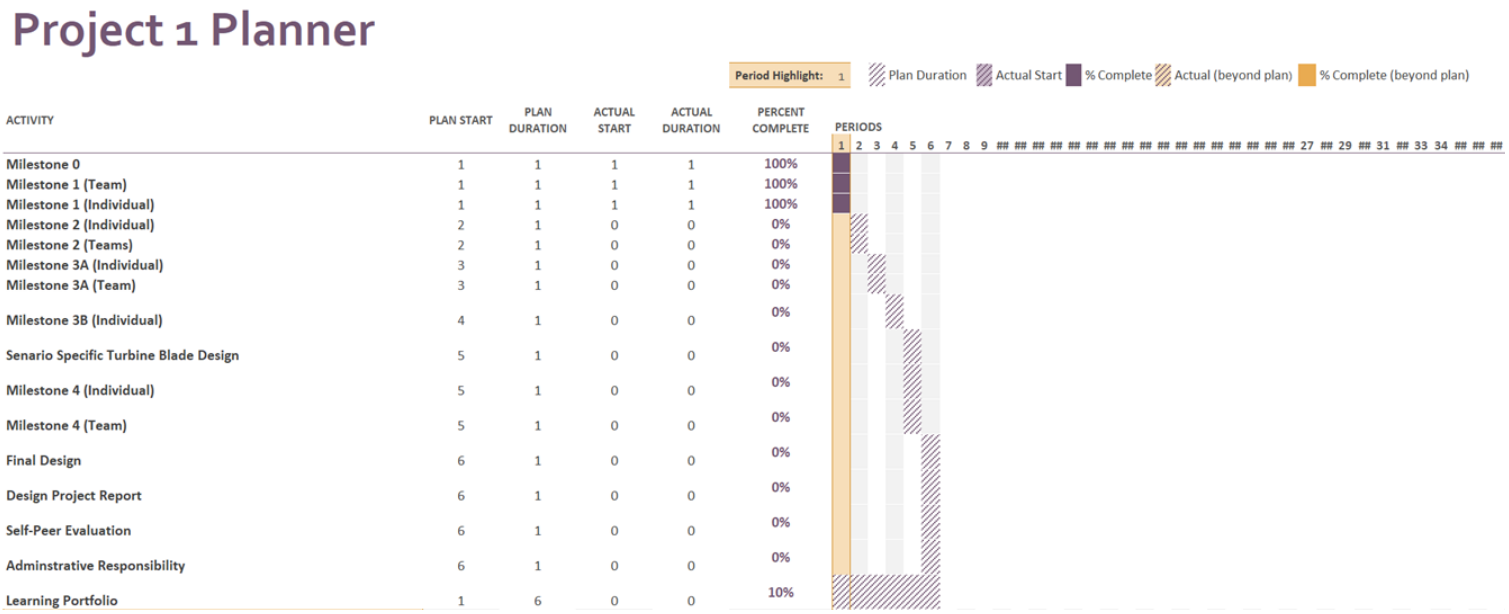
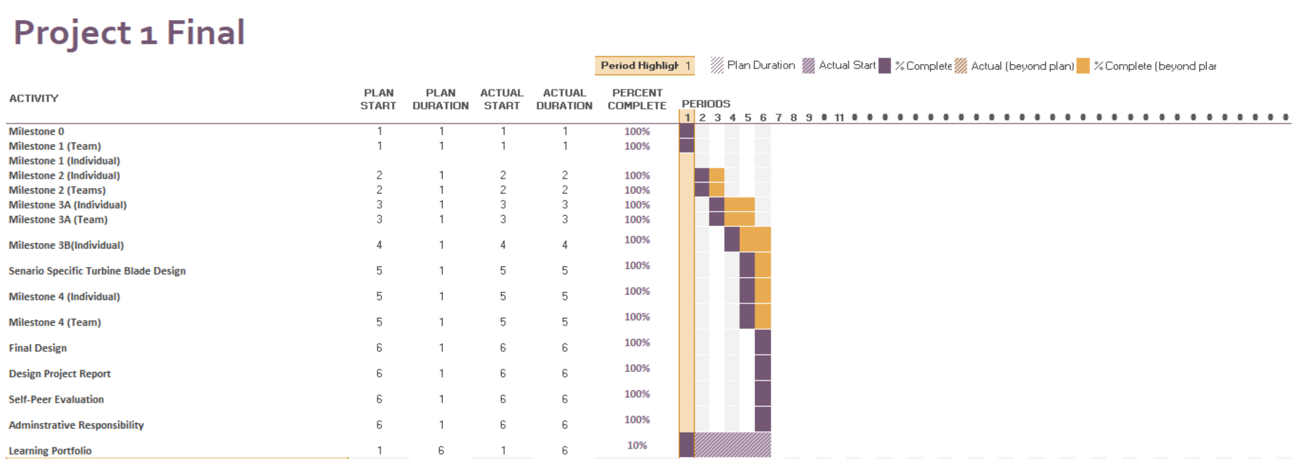
Appendices

Appendix A: Project Schedule



ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Milestone 0	1	1	1	1	100%
Milestone 1 (Team)	1	1	1	1	100%
Milestone 1 (Individual)	1	1	1	1	100%
Milestone 2 (Individual)	2	1	0	0	0%
Milestone 2 (Teams)	2	1	0	0	0%
Milestone 3A (Individual)	3	1	0	0	0%
Milestone 3A (Team)	3	1	0	0	0%
Milestone 3B (Individual)	4	1	0	0	0%
Senario Specific Turbine Blade Design	5	1	0	0	0%
Milestone 4 (Individual)	5	1	0	0	0%
Milestone 4 (Team)	5	1	0	0	0%
Final Design	6	1	0	0	0%
Design Project Report	6	1	0	0	0%
Self-Peer Evaluation	6	1	0	0	0%
Adminstrative Responsibility	6	1	0	0	0%
Learning Portfolio	1	6	0	0	10%

Figure 2. Preliminary Gantt Chart



ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Milestone 0	1	1	1	1	100%
Milestone 1 (Team)	1	1	1	1	100%
Milestone 1 (Individual)					
Milestone 2 (Individual)	2	1	2	2	100%
Milestone 2 (Teams)	2	1	2	2	100%
Milestone 3A (Individual)	3	1	3	3	100%
Milestone 3A (Team)	3	1	3	3	100%
Milestone 3B(Individual)	4	1	4	4	100%
Senario Specific Turbine Blade Design	5	1	5	5	100%
Milestone 4 (Individual)	5	1	5	5	100%
Milestone 4 (Team)	5	1	5	5	100%
Final Design	6	1	6	6	100%
Design Project Report	6	1	6	6	100%
Self-Peer Evaluation	6	1	6	6	100%
Adminstrative Responsibility	6	1	6	6	100%
Learning Portfolio	1	6	1	6	10%

Figure 3. Final Gantt Chart

Logbook of additional meetings

October 20, 2023:

Discussion for Milestone 3B

Preliminary discussion for blade model

Drew rough CAD sketch

October 23, 2023:

Discussion for Milestone 4

Ran multiple simulation for blade deflection.

Refined the thickness to satisfy the deflection constrains.

November 1, 2023:

Final discussion for design project report.

Signed design project report by all group members.

Appendix C: Comprehensive List of Sources

Source Material Database:

[1] K. A. Stol, W. Zhao, and A. D. Wright, "Individual blade pitch control for the controls Advanced Research Turbine (CART)," *Journal of Solar Energy Engineering*, vol. 128, no. 4, pp. 498–505, 2006. doi:10.1115/1.2349542

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Appendix E: Design Studio Worksheets

MILESTONE 0 (TEAM): COVER PAGE

Team ID: Mon-26

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

Full Name:	MacID:
DANIEL WEN	wend8
MARK ATALLA	atallm7
SYEDKHALIDFOUWAZ KALAM	kalams
ABDULLAH ABUSALOUT	abusaloa

Insert your Team Portrait in the dialog box below

MILESTONE 0 – TEAM CHARTER

Team ID: Mon-26

Project Leads:

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

Role:	Team Member Name:	MacID
Manager	Mark Atalla	Atallm7
Administrator	Abdullah Abusalout	abusaloa
Coordinator	Syed Khalid Fouwaz Kalam	kalams
Subject Matter Expert	Daniel Wen	Wend8

MILESTONE 0 – PRELIMINARY GANTT CHART (TEAM MANAGER ONLY)

Team ID: Mon-26

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

Full Name of Team Manager:	MacID:
Mark Atalla	Atallm7

Preliminary Gantt chart

Project 1 Planner

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 (Team)	1	1	1	1	100%
Milestone 1 (Individual)	1	1	1	1	100%
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Milestone 2 (Teams)	2	1	0	0	0%
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Adminstrative Responsibility	6	1	0	0	0%
Learning Portfolio	1	6	0	0	10%

PERIODS

1 2 3 4 5 6 7 8 9 ## ## ## ## ## ## ## ## ## ## ## ## ## ## ## ## ## ## 27 ## 29 ## 31 ## 33 34 ## ##

MILESTONE 1 (TEAM) – COVER PAGE

Team Number: Mon-26

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

Full Name:	**MacID:**
Abdullah Abusalout	abusaloa
Mark Atalla	Atallm7
Daniel Wen	Wend8
Syed Khalid Fouwaz Kalam	kalams

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 1 (STAGE 1) – INITIAL PROBLEM STATEMENT

Team ID: Mon-26

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.**

Design a Wind turbine that can convert potential renewable energy from the winds into electricity through aerodynamically efficient rotor blades.

MILESTONE 1 (STAGE 3) – REFINED OBJECTIVE TREES

Team ID: Mon-26

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.

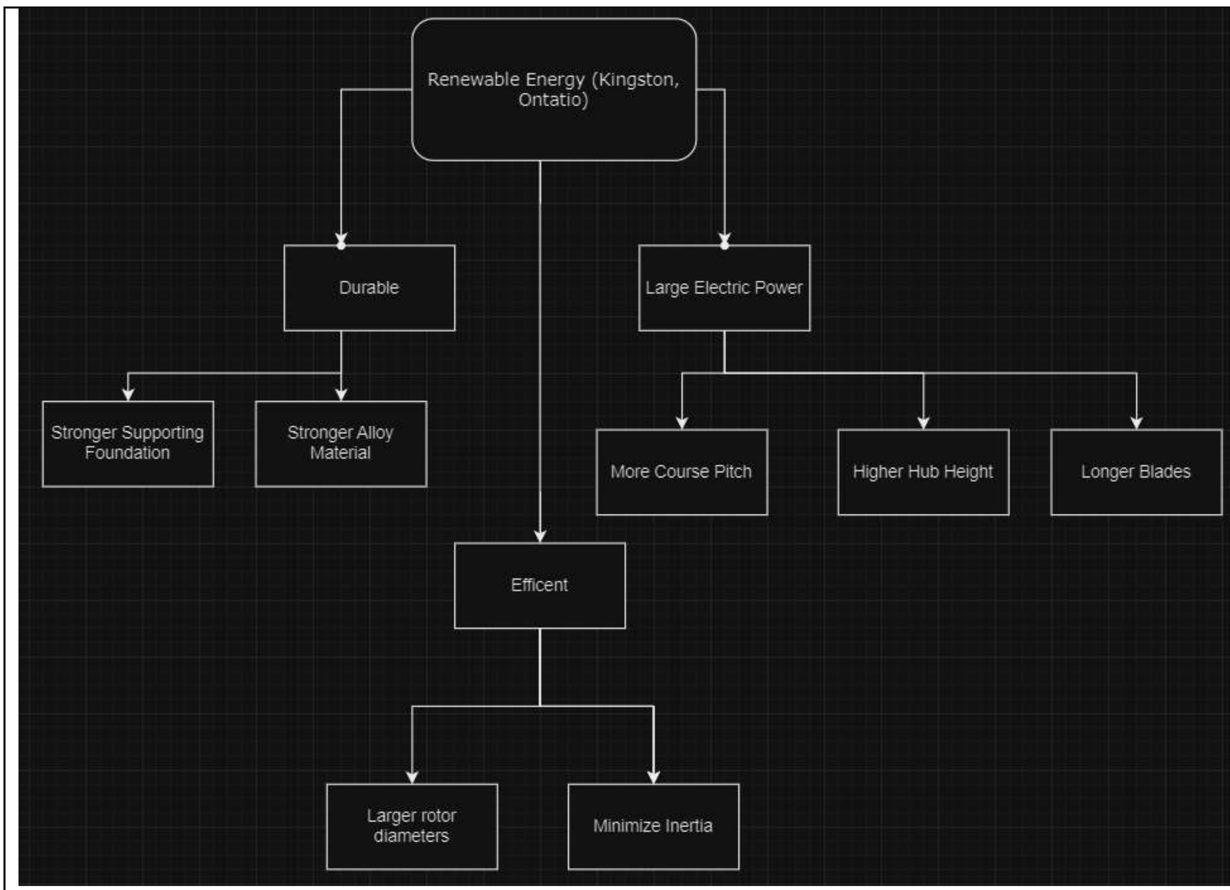
Engineering Scenario #1

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.



Team ID: Day-##

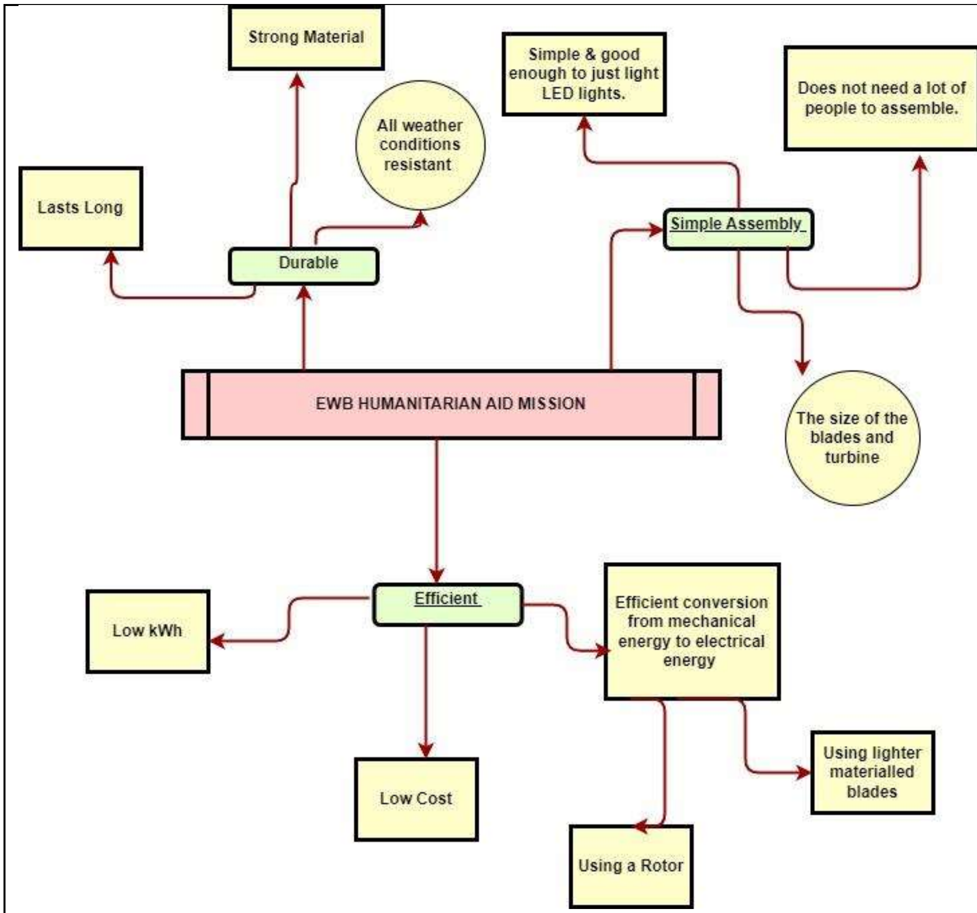
Engineering Scenario #2

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.



Strong Material
Simple & good enough to just light LED lights.
Does not need a lot of people to assemble.
All weather conditions resistant
Lasts Long
Simple Assembly
Durable
EWB HUMANITARIAN AID MISSION
The size of the blades and turbine
Efficient
Low kWh
Efficient conversion from mechanical energy to electrical energy
Using lighter materialled blades
Low Cost
Using a Rotor

Team ID: Day-##

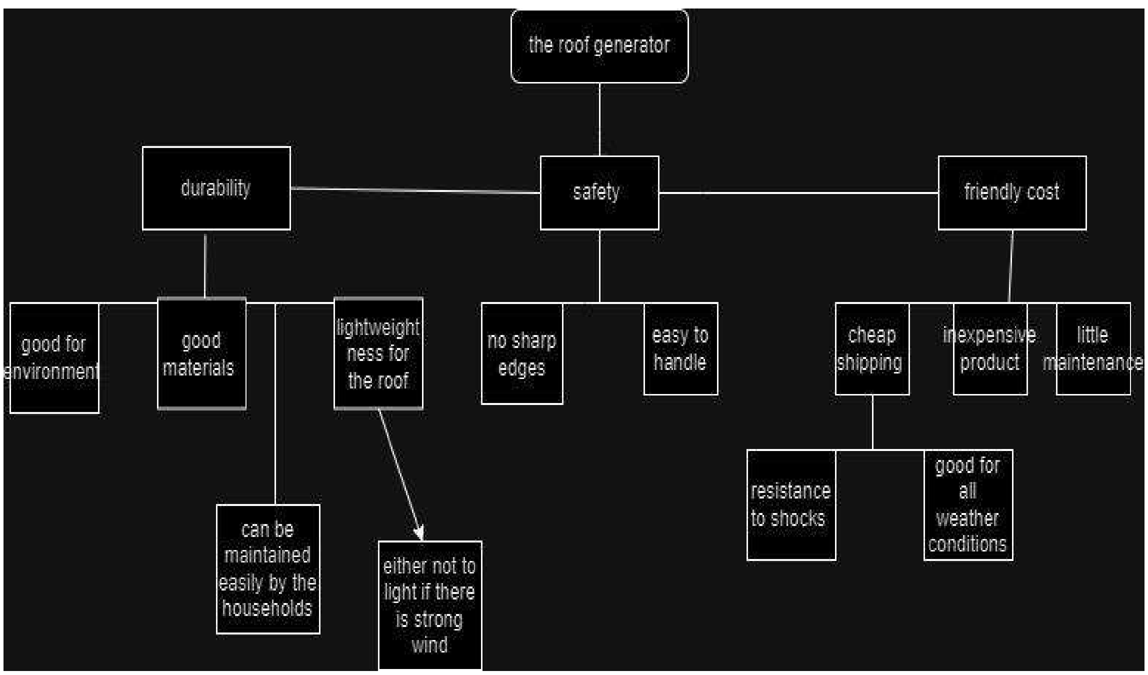
Engineering Scenario #3

The title of the scenario

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: Day-##

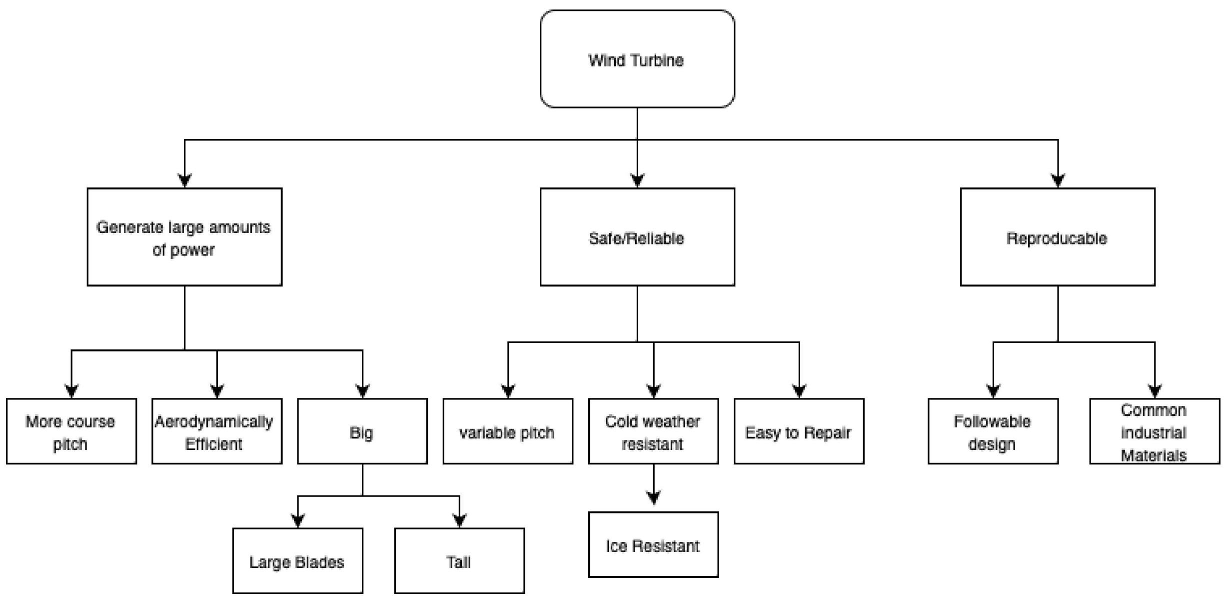
Engineering Scenario #4

The title of the scenario

A 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.



MILESTONE 2 (TEAM) – COVER PAGE

Team Number: Mon-26

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

Full Name:	MacID:
Syed Khalid Fouwaz Kalam	kalams
Abdullah Abusalout	abusaloa
Mark Atalla	Atallm7
Daniel Wen	wend8

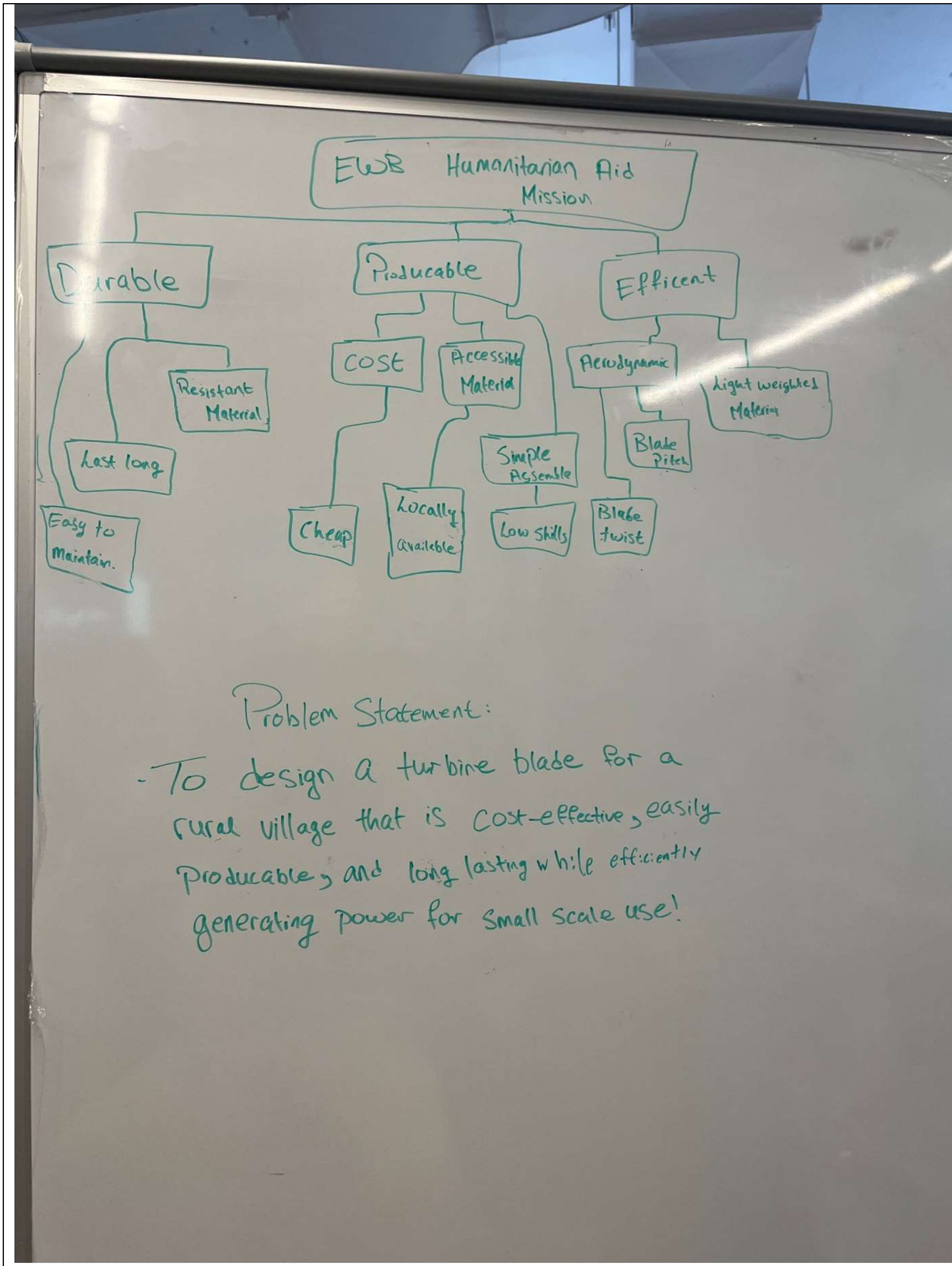
Any student that is ***not*** present for Design Studio will not be given credit for completion of the worksheet and may be subject to a 10% deduction to their P-1 grade.

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

Team ID: Mon-26

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.


EWB Humanitarian Aid Mission
Durable
Producable
Efficent
Resistant Material
Last long
Easy to Maintain.
COST
Accessible Material
Simple Assemble
Cheap
Locally available
Low Skills
Aerodynamic
Light weighted Material
Blade Pitch
Blade twist
Problem Statement:
- To design a turbine blade for a rural village that is cost-effective, easily producable, and long lasting while efficiently generating power for small scale use!

Turbine Blade Problem Statement:

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

Design a turbine blade for a rural village that is cost-effective, easily producible, and long-lasting wile efficiently generation power for small scale use.

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

Team ID:	Mon-26

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

1: Cost-Effective
2: Easily producible
3: Long Lasting

Include a rationale for selecting each of these objectives

→ Write *maximum* 100 words for each objective

Objective 1: Cost-Effective

Rationale: Considering the budget and grant provided by the village to construct such a project, it is important to take account of the cost. The village doesn't really demand a lot of power so it makes sense to compromise on other factors to make the turbine cheaper. By using local and cheaply available parts, the project can be constructed with a lower budget. Opting for a simple and proven turbine design can greatly improve the budget of the project.

Objective 2: Easily Producible

Rationale: It should have fewer parts, accessible material as it is locally available, be simple assemble for low skills, considering that the village doesn't have the ability for high costs, and be simple assemble because most of the people there have low skills and doesn't need a lot of people to assemble

Objective 3: Long Lasting

Rationale: Given the size and scale of the village; it must be able to power the needs of the village while it continues to grow. The villagers will not be able to constantly produce wind turbines and blades due to resources and labour requirements for its needs; therefore, there must be easy ways to maintain and sustain the wind turbine. Additionally, given the rugged conditions of the situation,

it must be reliable, with its longevity being a determining factor.

MILESTONE 2 (STAGE 3) – METRICS

Team ID: Mon-26

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

Objective 1:	Cost Effective
Unit/Metric:	$$ Money

Objective 2:	Easily Producible
Unit/Metric:	Fewer parts

Objective 3:	Long Lasting
Unit/Metric:	Estimated Minimum Mean time between failure

MILESTONE 2 (STAGE 4) – REGULATIONS

Team ID: Mon-26

Insert your group discussion below

There are laws and concepts for regulation of building and zoning, especially in villages because they're rural, so there's limits for height and other structures. Also, it should be good for environments and pollution because they don't have the ability to fight pollution as in modern cities. Also, we should build the wind turbine, which should be placed at least 500 feet (152.4 meters) away from any occupied buildings, including homes. Also, the height of the wind turbine can reach 150 m for large cities, but this is a village, so it can be 30 m to 50 m, and the scale for small residential buildings must be in the range of 5 kW.

Wind turbines consists of complex and specialized components or materials which can be rather challenging to source for rural villages. It is also difficult for these villages to navigate through economic supply to get certain custom clearances or to go through various shipping logistics. An alternative could be to use local sourcing of materials which greatly helps in reducing shipping costs and can additionally help the local economy of the country. But on the downside, it can limit options for the materials of the project. The most important factor to consider is the cost of these projects can be alarmingly high and a village must be incredibly careful of the budgeting of certain materials in such major projects.

As part of a renewable energy incentives laid out in Guatemala's 2013-2027 plan, it called for 80% of its energy to come from renewable sources. In 2003, Guatemala passed the Renewable Energy Incentive Law, which called for VAT taxes to be exempt on imports for renewable energy equipment for up to 10 years. It is possible that future renewable energy projects may see the same benefits and tax breaks that were present in 2003 as it attempts to meets its renewable energy targets set out from before.

References:

building and zoning laws: Computation | Free Full-Text | A Review of Numerical Modelling of Multi-Scale Wind Turbines and Their Environment (mdpi.com)

https://www.epa.gov/sites/default/files/2019-08/documents/wind_turbines_fact_sheet_p100il8k.pdf

Microsoft Word - CSA Guide to Canadian Wind Turbine Codes and Standards November 16 2007 v2.doc (csagroup.org)

Materials: https://www.tandfonline.com/doi/full/10.1080/00220388.2021.2017892

https://www.ewea.org/fileadmin/files/library/publications/reports/Economics_of_Wind_Energy.pdf

Renewable Energy: https://www.iea.org/countries/guatemala

MILESTONE 3A (TEAM) – COVER PAGE

Team Number: Mon-26

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

Full Name:	MacID:
Mark Atalla	Atallm7
Daniel Wen	Wend8
Abdullah Abusalout	abusaloa
Syed Khalid Fouwaz Kalam	kalams

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.

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

Team ID: Mon-26

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

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 Production Energy	$E/\rho H_m$	$\sigma y/\rho Hm$	Given the location and production capabilities of the village, we cannot afford to use materials with a high production cost and must minimize it accordingly.
Secondary	Minimizing Cost	$E/\rho C_m$	$\sigma y/\rho Cm$	Given the budget and economic output of the village, they cannot afford expensive wind turbines, so we must minimize accordingly.

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

Team ID: Mon-26

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: COST STRENGTH	Steel	Wood	Bamboo	Paper & Cardboard	Aluminum Alloy
MPI 2: COST STIFFNESS	Steel	Bamboo	Wood, typical along grain	Aluminum alloys	Paper and cardboard
MPI 3: PRODUCTION ENERGY STIFFNESS	Steel	Bamboo	Wood typical along grain	Zinc Alloy	Copper Alloy
MPI 4 Production Energy Strength	Steel	Wood typical along grain	Bamboo	GFRP	Aluminum Alloy

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:	Carbon Steel
Material Finalist 2:	Bamboo
Material Finalist 3:	Wood typical along grain

Team ID:	Mon-26

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.

Additional Criteria	**Possible question prompt**
Material Accessibility	Is the material easy to source in the country?
Estimated Lifespan	What is the estimated lifespan of the wind turbine blade's material?
Repairability/Ease of Maintenace	Is it possible to repair the blade using such material? Is it easy to maintain the material?

Weather/corrosion resistant	Is it able to resist weather and corrosion?

- 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

→ 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.

Weighted Decision Matrix - Template							
	Weighting	*Material 1: Carbon steel*		*Material 2: Bamboo*		*Material 3: Wood*	
		Score	Total	Score	Total	Score	Total
Material Accessibility	4	4	16	4	16	5	20
Lifespan	2	5	10	3	6	3	6
Repairability /Maintenance	3	2	6	4	12	4	12

Weather/Corrosion Resistant	1	4	4	2	2	3	3
	TOTAL	1	36		36		41

→ State your chosen material and justify your final selection

Justification	
Chosen Material:	Wood
Wood is the most appropriate material to use in this situation. There are numerous factors for this. Since it is a rural area, wood will be very effective due to its cheap cost and the fact that it is very easily accessible, since it is a village there should be no problem in sourcing wood for this as most of the individuals rely on wood as their source for shelter and fuel. This would be also effective in the long-term scale due to its easy maintenance and repairability. Wood is moderately durable as well as it can handle light to medium weather conditions. Additionally, wood is extremely lightweight compared to its other counterpart steel. Furthermore, wood is also biodegradable which eliminates the problem of negative environmental impact in the village.	

Summary of Chosen Material's Properties

Material Name	Average value
Young's modulus E (GPa):	11.85 GPa
Yield strength σ_y (MPa):	49.3 MPa
Tensile strength σ_{UTS} (MPa):	94.8 MPa
Density ρ (kg/m^3):	547.5 kg/m^3
Embodiment energy H_m (MJ/kg)	26.6 MJ/kg
Specific carbon footprint CO_2 (kg/kg)	0.2675 kg/kg

SCENARIO SPECIFIC TURBINE BLADE DESIGN (TEAM) – COVER PAGE

Team Number: Day-##

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

Full Name:	MacID:
Abdullah Abusalout	abusaloa
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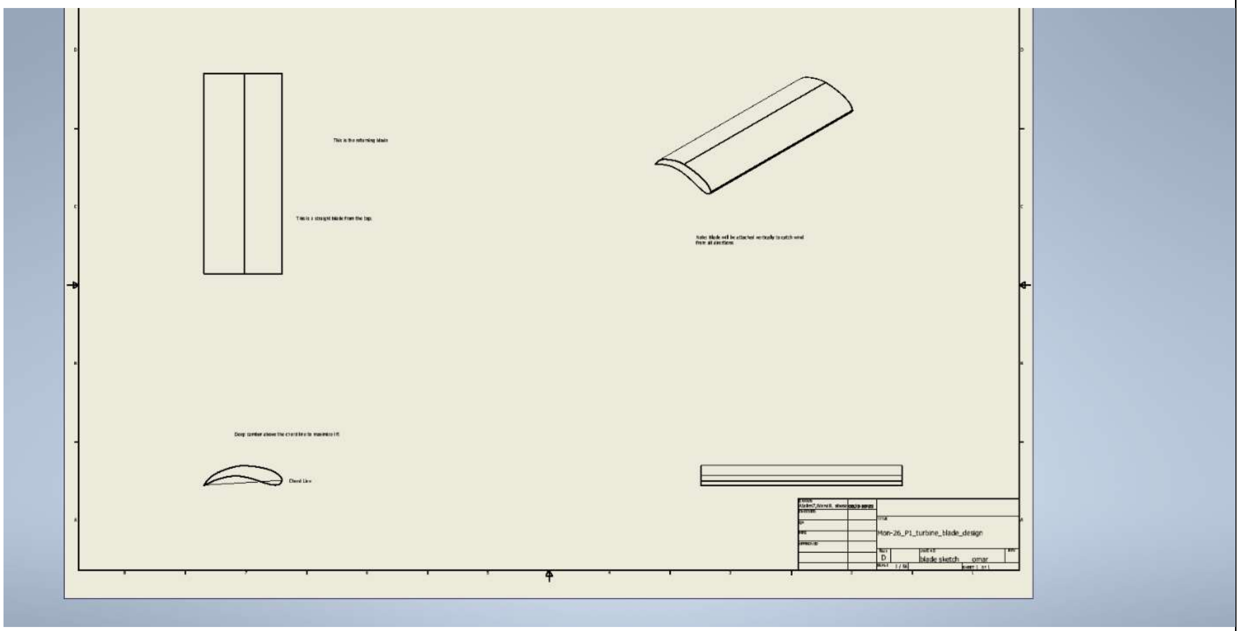
Daniel Wen	Wend8
Sayed Khalid	kalams

MULTIVIEW TURBINE BLADE SKETCH AND JUSTIFICATION

Team ID: MON-26

1. Sketch of Turbine Blade

Insert a multiview sketch of your team's scenario specific turbine design. Multiview sketch must include front, top, and right-side view.



2. Justification of Turbine Blade

The turbine blade possesses a creative vertical design, which is known as a Vertical axis wind turbines or . This possess many advantages compared to the more standard Vertical axis wind turbines.[1] The biggest advantage it serves is the use of omnidirectional wind capture, which mean they can capture wind from any direction, making them suitable for areas with a inconsistent wind patterns.[2] Furthermore this can also be cost effective as it prevents the need of expensive sensors in the turbine which optimizes the power generated from the wind.[3] Another major advantage of a vertical axis is that it can generate power even at lower speeds as compared to its horizontal counterpart.[4] A further advantage of the VAWT is that it uses fewer moving parts as compared to the horizontal axis wind turbines. This helps in extending the durability of the wind turbine which in turn makes the wind turbine suitable for remote or challenging environments where maintenance may be difficult. Since it is also less complex, it simplifies the installation process. The vertical aspect of the wind turbine also makes it effective in supressing the noise which may be a concern in a village and rural areas.[5].

We came to conclusion that H-Darrius wind blade design would be the most suitable for our scenario.

Furthermore, apart from the vertical design the blade also boasts a shape. It is designed in such a way to optimize the flow over the blade surface. This helps in increasing lift which is crucial in a wind turbine. [6] The curved shape is designed to optimize drag by preventing the resistance of motion caused by the fluid's viscosity and turbulence. Reducing drag is crucial in optimizing efficiency, as less energy is wasted. [7] The shape of the blade also enhances the energy transfer process, as it allows to capture more kinetic energy from the moving fluid. The fluid flows over the surface thus increasing acceleration of the blade, which helps spin the turbine. The shape helps increase the structural integrity of the blade as it spreads the load and stress more evenly across the blade reducing the risk of vibration and deformation.[8]

References:

[1] Bhutta, Muhammad Mahmood Aslam, et al. "Vertical axis wind turbine–A review of various configurations and design techniques." Renewable and Sustainable Energy Reviews 16.4 (2012): 1926-1939.

[2] Shahizare, Behzad, et al. "Investigation of the optimal omni-direction-guide-vane design for vertical axis wind turbines based on unsteady flow CFD simulation." Energies 9.3 (2016): 146.

[3] Rolland, S. A., et al. "Benchmark experiments for simulations of a vertical axis wind turbine." Applied energy 111 (2013): 1183-1194.

[4]Korprasertsak, Natapol, and Thananchai Leephakpreeda. "Analysis and optimal design of wind boosters for Vertical Axis Wind Turbines at low wind speed." Journal of Wind Engineering and Industrial Aerodynamics 159 (2016): 9-18.

[5] Ragheb, Magdi. "Vertical axis wind turbines." University of Illinois at Urbana-Champaign 1.40 (2011).

[6]Capuzzi, M., A. Pirrera, and P. M. Weaver. "Structural design of a novel aeroelastically tailored wind turbine blade." Thin-Walled Structures 95 (2015): 7-15.

[7]Li, Ang, et al. "The influence of the bound vortex on the aerodynamics of curved wind turbine blades." Journal of Physics: Conference Series. Vol. 1618. No. 5. IOP Publishing, (2020).

[8]Scheurich, Frank, Timothy Fletcher, and Richard Brown. "The influence of blade curvature and helical blade twist on the performance of a vertical-axis wind turbine." 48th AIAA aerospace sciences meeting including the new horizons forum and aerospace exposition. (2010)

MILESTONE 4 (TEAM) – COVER PAGE

Team Number: Mon-26

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

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Syed Khalid Fouwaz Kalam	kalams
Daniel Wen	Wend8
Mark Atalla	Atallm7

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.

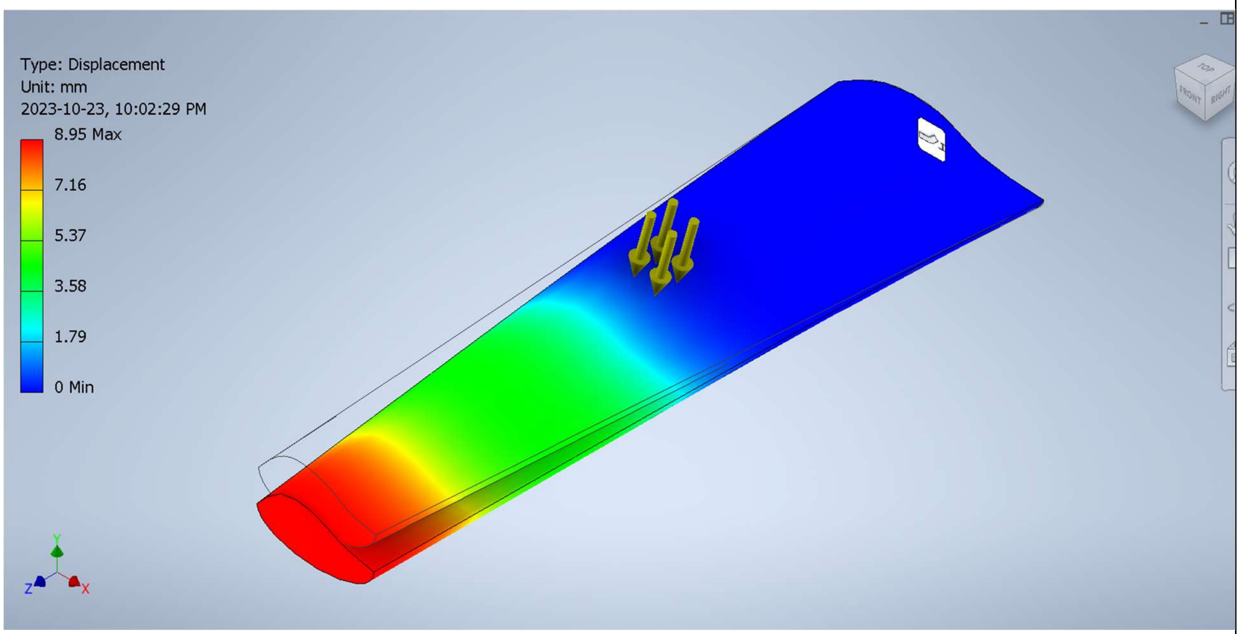
MILESTONE 4 (STAGE 2) – REFINE THICKNESS REQUIREMENT

Team ID: Mon-26

1. Refine Thickness Requirement to Satisfy Deflection Constraint

Refined turbine blade thickness *t* (mm):	165

Insert screen captures of the refined deflection simulation and provide evidence that the deflection satisfies the design constraint. Must show scale that is present on the left side of the screen.



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MILESTONE 4 (STAGE 3) – PEER INTERVIEW

Team ID: Mon-26

→ 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.

Renewable energy for a large populace

The scenario involved making large wind turbines for a wind turbine farm in Kingston on Wolf Island. This farm would provide energy to other nearby cities, and should have a long lifespan, while maintaining efficiency taking advantage of the nearby wind pressures.

The design prioritized the following:

Durability

- Don't have to constantly repair
- Repair costs money
- Kingston does not have the funds to constantly repair, so efforts should be so that maintenance is as easy/cheap as possible

Maximizing Efficiency

- Because the wind farm is providing power to other nearby cities as well, efforts were made to ensure that the design was efficient as possible to take advantage of the wind pressures.

Minimize Cost

- The design team needed to ensure that they stayed well within budget, as one of their constraints was cost.

Ease of Maintenace

- If repairs needed to be done, the team wanted to make sure that it would be easy. They believed that would help maintenance costs low by ensuring that no expensive maintenance would be needed to due to complexity.

Availability

- In comparison to Guatemala, Kingston has better access to materials and skilled labourers due to import laws.
- The design team factor into the availability and shipping costs of sourcing materials from out of reigion

Sustainbility

- While the team did factor in sustainability, it was lowly weighted, as they concluded that Kingston did not care about the environment compared to ensuring efficiency and low cost.

Aesthetics

- Once again, the design team did not weight this objective as highly as others, as it was not as important. The reason why they included this factor was because it would be in a public location, so they wanted to ensure that the public populace would at least approve of its sight.

Ease of manufacturing

- The design team focused on production cost as well to reduce their budgetary needs. If it would be easier to manufacture, then that would lower the costs to produce, and thus reduce budget strain.

Material:

Steel

- Bamboo and wood were ranked highly, but unfortunately not durable enough for needs due to scenario requirements
- High carbon steel had highest young modulus, highest fracture toughness, highest yield strength, and a much higher elasticity compared to others. This was especially important as the team dsigned the blade with the ability to bend.
- In the end, high carbon steel was selected as their material, as it fulfilled the needs of the design.

Design:

- The blade was designed similar to an airfoil of a wing, with a support beam on top
- The blade had a deep upper chamber to maximize the effects of Bernoulli's principle, given the size and circular speed of the turbine.
- Additionally, the blade had a long length in order to maximize efficiency
- Unfortunately, length increased costs.
- One area to note is that they design the blade in segments so that they would be easier to ship and assemble, thus reducing costs associated. They designed with interlocking mechanisms so that they would secure it with the other parts
- The blade also had a varied angle of attack along the length of the blade, with the angle gradually decreasing to account for the different speeds the tip and the root of blade spun at.
- Our team recommended that they use variable pitch blades
- During their research, the design team found that the force would be tangential to the circular motion, so they designed the bl;ade accounting for it.
- They found their thickness to be 25mm

Note: Please be mindful that you are expected to write a short reflection on what you have learned from the other team in your final deliverable. Do not forget to discuss your scenario specific design as well.