# 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 |
| --- | --- | --- |
| **M**anager | Luay alkader | alabedal |
| **A**dministrator | Yahya Zaher | zahery |
| **C**oordinator | Ayesha Dogar | dogara1 |
| **S**ubject Matter Expert | Aaron Van | Vanc3 |
| | | |

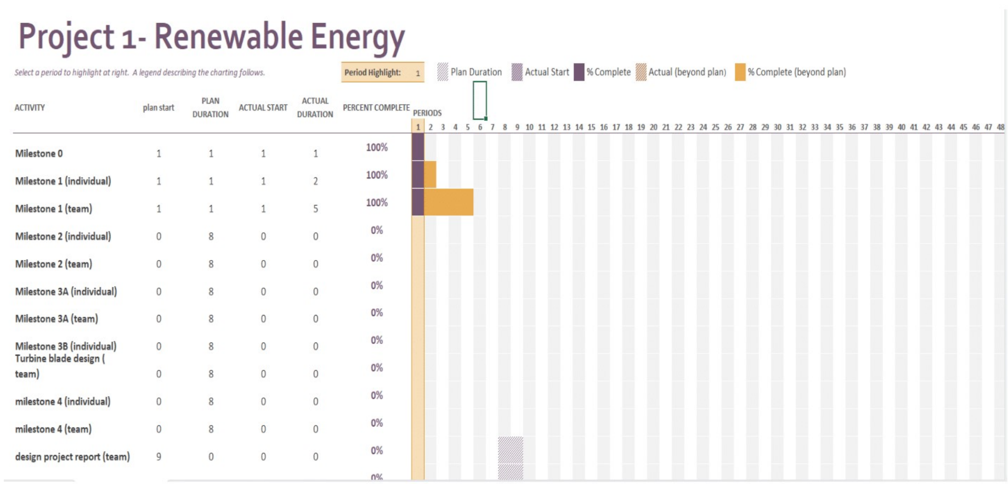
ENGINEER 1P13 – Project 1: *Renewable technology challenge*

# 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 |




| 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% |

4

**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.

# 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.

**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.**

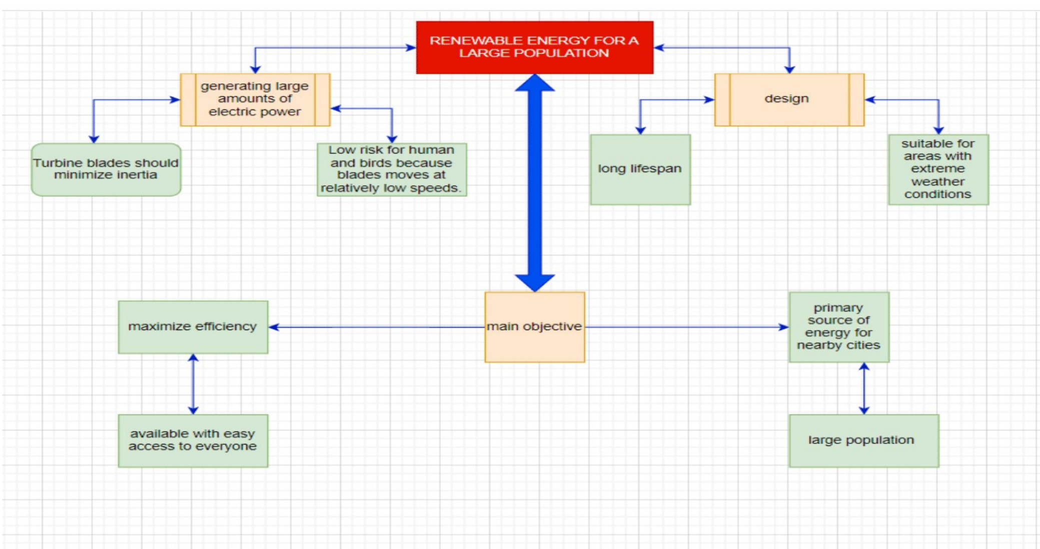
**Engineering Scenario #1**

**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.**



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

Team ID: Thur-14

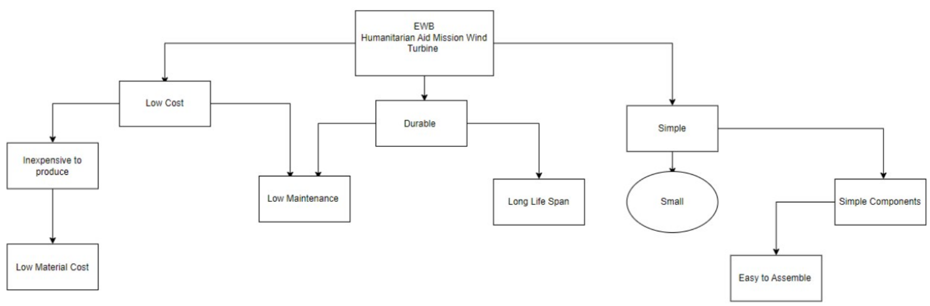
Engineering Scenario #2

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.



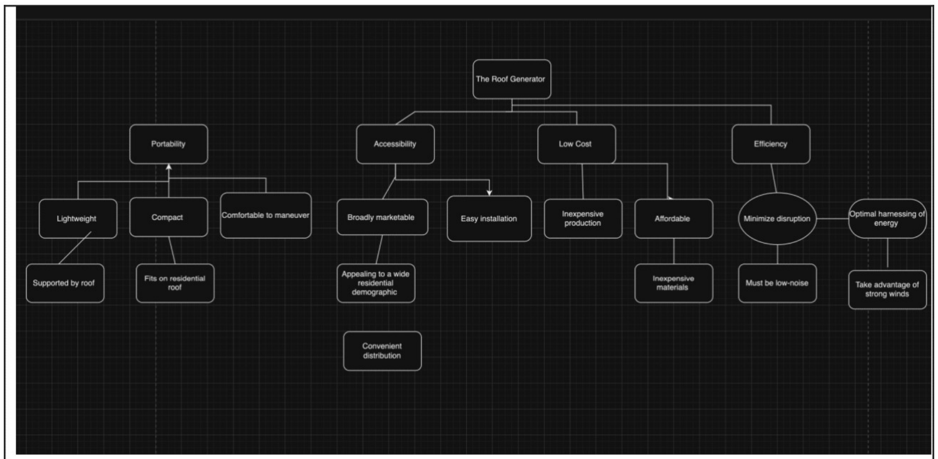

9

**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

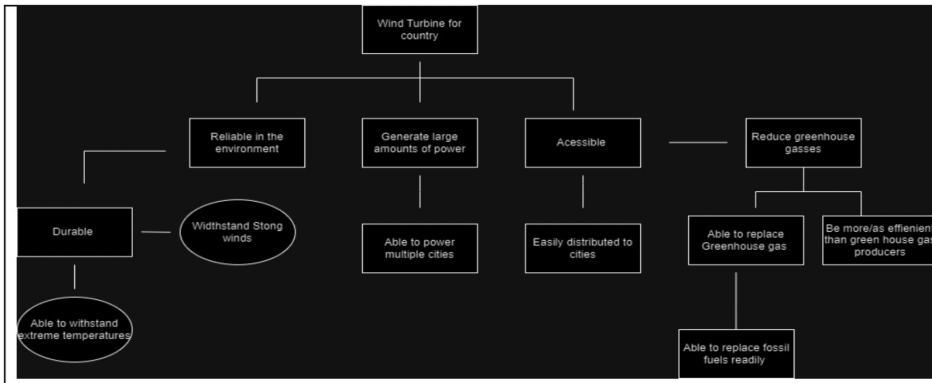
10

**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.




11

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.

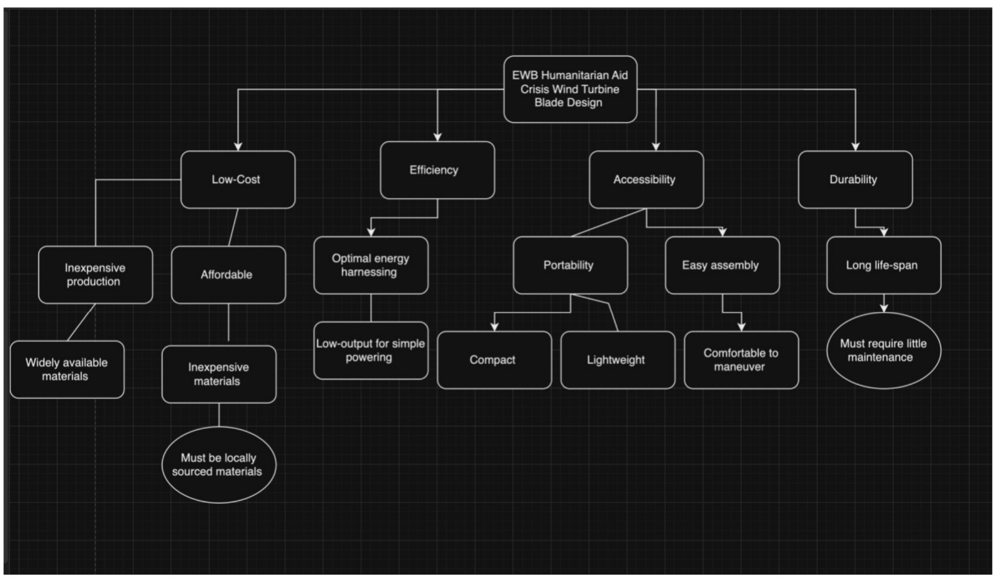
ENGINEER 1P13 – Project 1: *Renewable technology challenge*

# 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.

13

**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.

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

## 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 ($) |

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

# 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 | $E/\rho$ | $\sigma_y/\rho$ | 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.<br>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 |

18

# 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*: $E/\rho$ | 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.

- 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:

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

| 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 $\sigma_y$ (MPa): | 800 |
| Tensile strength $\sigma_{UTS}$ (MPa): | 800 |
| Density $\rho$ (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

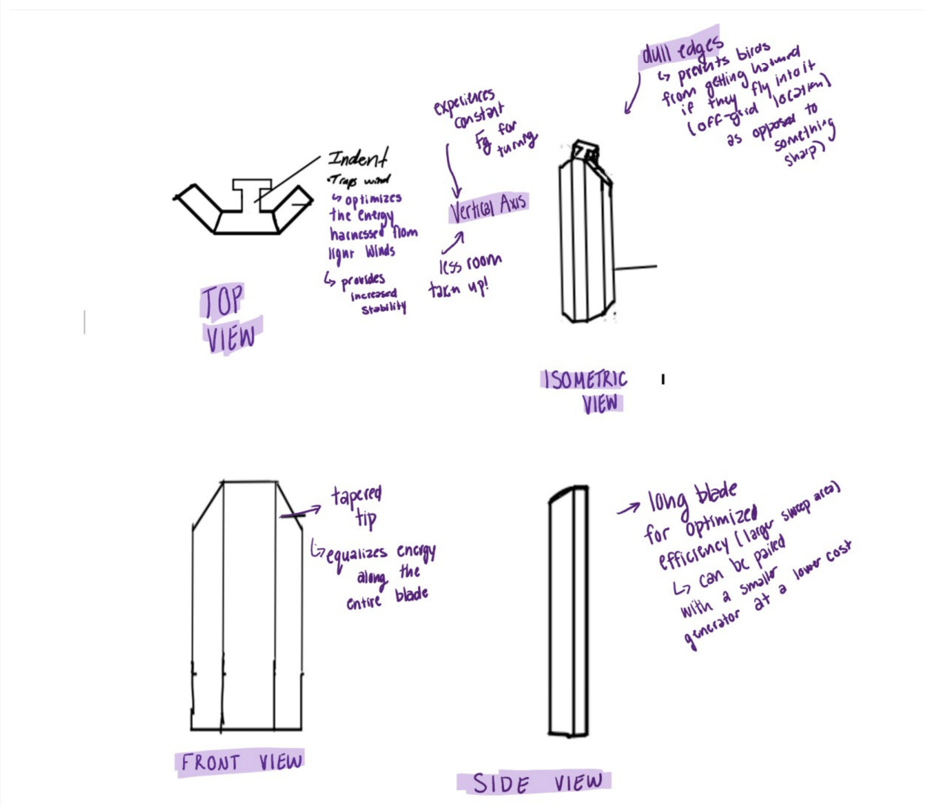
Please list full names and MacID's of all *present* Team Members

| 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

25

**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].<br><br>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].<br><br>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.<br><br>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<br><br>[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<br><br>[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]. |

26

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

## 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 |
| | |

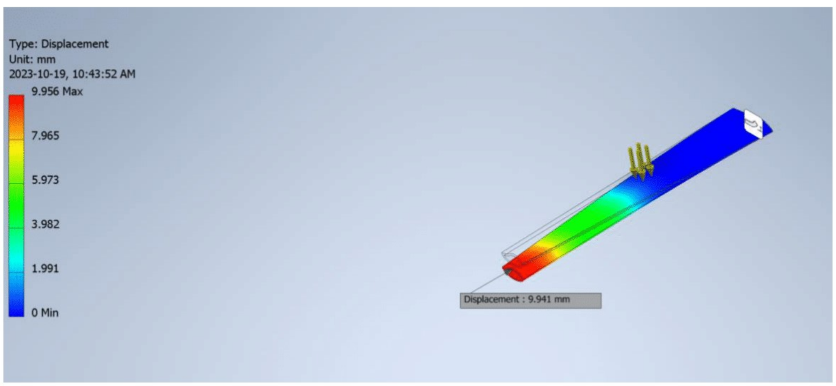
Any student that is ***not*** present for Design Studio will not be given credit for completion of the worksheet and may be subject to a 10% deduction to their P-1 grade.

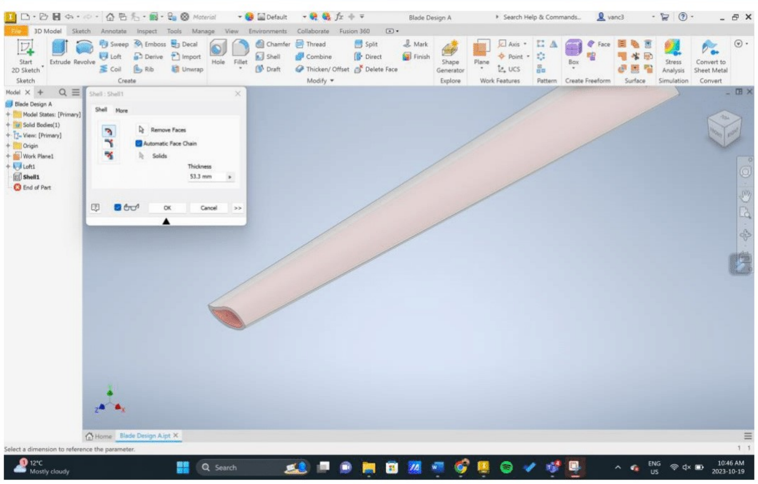
# MILESTONE 4 (STAGE 2) – REFINE THICKNESS REQUIREMENT

Team ID: Thurs-14

1. Refine Thickness Requirement to Satisfy Deflection Constraint

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



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