Design Project 1 – Renewable Technology Challenge

ENGINEER 1P13 – Integrated Cornerstone Design Projects in Engineering

Tutorial T03

Team Mon-44

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Submitted: November 2, 2023

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

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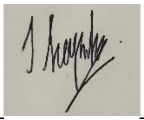
Academic Integrity Statement

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.

Theepika Piramenthiratheesan 400519417



(Student Signature) *

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Albert Membere 400496830

(Student Signature) *

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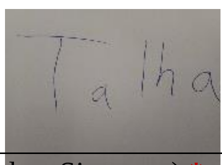
Talha Ahmad 400517273



(Student Signature) *

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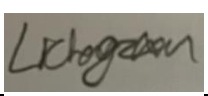
Licheng Zhou 400509160



(Student Signature) *

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Hailey Chegus 400530379

(Student Signature) *

Finalized Problem Statement

Our task involved the development of an environmentally sustainable wind turbine blade intended for use in a new Swedish wind farm. The primary challenge is to create a blade that surpasses the sustainability and power generation capabilities of the current turbines, contributing to Sweden's goal of achieving zero greenhouse gas emissions by 2045 in collaboration with the Swedish Wind Energy Association (SWEA). The turbine's main function is to efficiently harness wind energy and convert it into usable electrical power, while adhering to Swedish building and safety regulations. Additional engineering constraints include limiting the blade deflection to less than 10mm and ensuring the blade can withstand substantial pressure loads without yielding. Some additional considerations to consider are the overall sustainability of the energy production process and the efficiency in mass manufacturing the multiple blades required for the wind farm.

Main Body

Justification of Technical Objectives and Material Performance Indices

In our project, our objective tree outlined four main objectives: sustainability, energy generation, durability, and scalability. Our full objective tree is shown in Figure 1. Sustainability, specifically referring to reducing greenhouse gas emissions, takes priority as it directly contributes to Sweden's aim to lower its emissions. With the help of the objective matrix, we narrowed our objectives to sustainability, energy generation, and durability. As mentioned before, sustainability is our primary goal, which aligns with Sweden's goal to reduce greenhouse gas emissions. Energy generation ensures the blades can power Swedish cities, and durability reduces the material usage and being able to last long in harsh weather conditions. For the relevant material performance indices (MPIs), we prioritized minimizing the carbon footprint, as it directly supports the emission reduction objective, and minimizing mass, which supports the energy output, as it also another important objective to fulfill for our project.

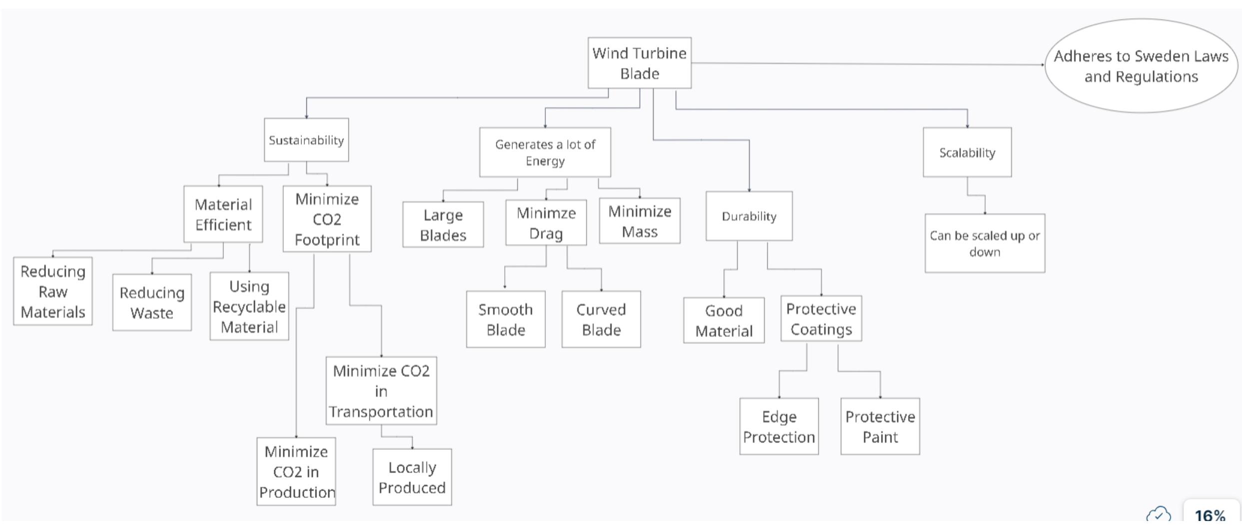


Figure 1. Objective Tree

Conceptual Design – Justification of Selected Material

In our material selection process, we began by narrowing our objectives, ultimately focusing on two key criteria: minimizing the carbon footprint and minimizing mass. Using Granta Edupack, we applied our specific equations for these objectives in the Material Performance Indices (MPIs) stiffness and strength categories. The Granta software generated the plots on the horizontal and vertical axes based on our equations, which helped us find the top five materials for each objective. From this list, we selected three materials that appeared most frequently: high carbon steel, bamboo, and wood (typical, along the grain). To make a well-informed choice, we created a weighted decision matrix considering eco-friendliness, durability, and mass. High-carbon steel turned out to be our chosen material. This material selection aligns with our project objectives as it combines recyclability, and exceptional mechanical properties, such as high tensile strength, a high melting point, excellent fracture toughness, and fatigue strength [1]. As shown in Table 1, we can clearly see how high carbon steel surpasses bamboo and wood (typical along the grain) in these categories. Although it is relatively heavy compared to bamboo and wood, its overall properties outweigh this disadvantage, making it a suitable choice for our wind turbine blade design [1].

Table 1. Material Properties[1]

Material	Recyclability	Specific Carbon Footprint CO2 (kg/kg)	Tensile strength σ_{UTS} (MPa)	Melting Point (°C)	Fracture Toughness (MPa.m^0.5)	Fatigue Strength (MPa)	Density (kg/m^3)
High Carbon Steel	✓	16.25	1055.5	1350	54.3	440	7800
Bamboo	X	0.328	239.5	-	6.35	34.35	1000.5
Wood (typical, along the grain)	X	0.2675	94.8	-	5.03	31	547.5

Design Embodiment – Justification of Solid (CAD) Modelling

Our chosen turbine blade thickness of 15mm meets the stiffness-limited design constraint as it has a maximum deflection of 9.744mm, which is below the 10mm limit. The analytical calculations and

[1] This table of values obtained from Granta EduPack compares the general, mechanical and eco properties of our top three materials to show why we decided to choose high carbon steel.

deflection simulations were performed in Autodesk Inventor, and Figure 2 serves as proof that our blade satisfies this constraint.

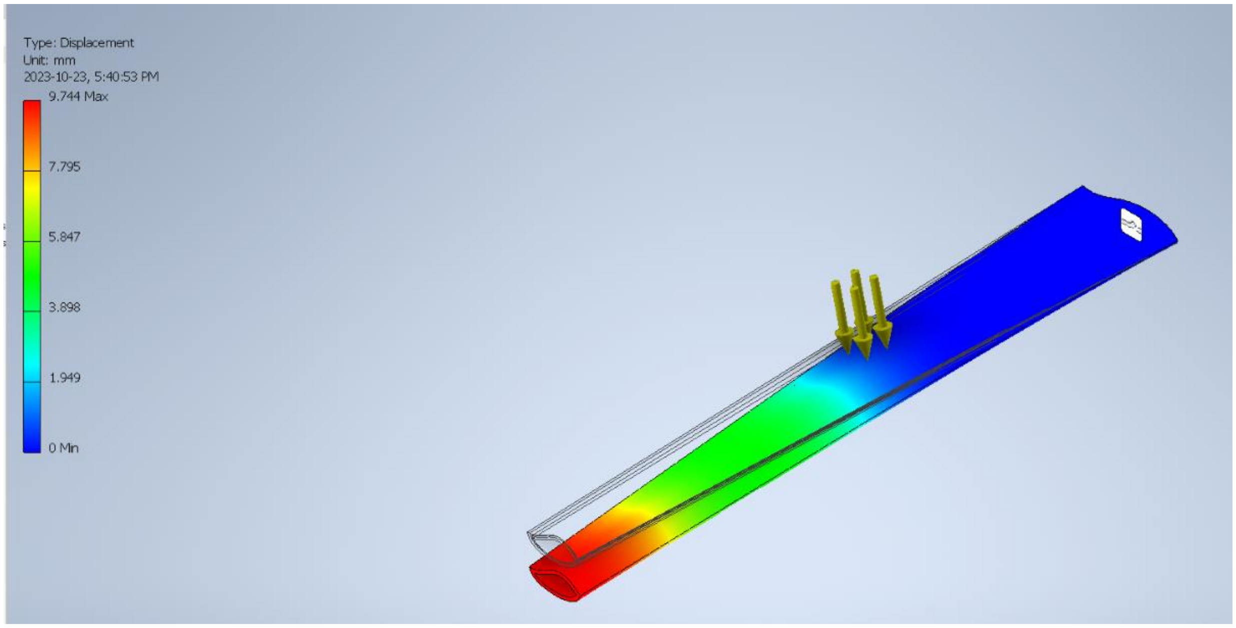


Figure 2. CAD Drawing

Discussion of Regulations

Our wind turbine design takes into consideration the essential regulations, policies, and socio-cultural concerns specific to Sweden. The main design regulations for wind turbines are related to location and height. According to Swedish law, buildings cannot be located close to the shoreline, with a minimum distance of 100 meters and a maximum distance of 300m [2]. As our design envisions a wind turbine farm, we've accounted for the necessary space while making sure it follows these regulations. With respect to Swedish building laws, our turbines are designed to be below 120 meters in height, satisfying the height restrictions [3].

To enhance the practicality of our design, a potential change that could be made is changing the blades to be more vertical, so that it takes up less space and allows for more turbines to be built. Additionally, adding protective tape and coatings in our design sets it apart from the of current wind turbines in the world. While some traditional turbines lack these protective features, we believe that they are essential as they will make the wind turbine last longer and will reduce the amount of maintenance required. Our wind turbine design is different in comparison to the current technology that already exists in terms of compliance with environmental regulations as it focuses on long-term sustainability. Not only does our wind turbine blade meet the legal requirements, but it places a strong focus on reducing its environmental impact and contributing to Sweden's goal of achieving zero net greenhouse gas emissions by 2045. The turbine's eco-friendly features, include recyclable materials and a low carbon footprint, which align with Sweden's environmental policies. Moreover, our emphasis on material efficiency, energy efficiency and power generation efficiency emphasise long-term sustainability.

Discussion of Sustainable Choices

The long-term goal that this wind turbine aims to accomplish is reducing the net greenhouse gas emissions in Sweden to 0 by 2045. This accomplishment would greatly improve the environment in Sweden as it would benefit both the wildlife and individuals living there. Our chosen material, which is high carbon steel, is extremely durable and long-lasting [1]. Near the end of its life, which will most likely be after countless decades, newer synthetic materials will be created that would be far better for the environment. Regardless, carbon steel is recyclable and reusable, meaning that when it does reach the end of its life, it can be recycled and put to other uses which would reduce the negative impact it might have on the environment. As for the location of the turbine, due to Swedish regulations, it would need to be a good distance away from the shoreline [2]. Moreover, it should be relatively close to major cities so the amount of wildlife impact from electric lines can be minimized. Also, it should be a flat piece of land, allowing large scale wind turbines to be stable. This makes prairies the ideal biome for building a large-scale wind farm. Prairies do not have any forests, which would allow us to build it while minimizing habitat loss for the indigenous wildlife. Moreover, as stated earlier, the flat nature of prairies would allow large scale buildings such as wind turbines to be stable.

Peer-Learning Interview

The other team we interviewed was tasked with the responsibility of creating wind turbines which could be placed on the roofs of houses in Calgary, to generate electricity to power up their homes. From their blade design, we learned that vertical wind turbine blades are known to generate less noise during operation, and since the wind turbines are being installed in housing communities, we thought that this was a very good idea. Although they had many excellent ideas for their project, what we would have done differently was that we would have used high carbon steel rather than CFRP, Epoxy Matrix (Isotropic), which was the material they chose, because high carbon steel is more cost effective [1]. CFRP is known to be more expensive than other materials. [1] If these wind turbines are being sold, then the selling price must match or exceed the cost of production or else there will be a loss. Since many people buy wind turbines to reduce their electricity bills, we feel it is better to make it out of a more cost-effective material to ensure that the prices for production and sales do not get too high. This wouldn't have changed the approach for the overall scenario, but only minimized the cost of production.

Concluding Remarks – Reality Check Subsection

This project was a great introduction to engineering design for us. The main take-home message would be the importance of everyone's individual role in a project. Most high school level projects usually have blurred lines between different roles. With this project, however, each member's role had clear instructions with minimal crossover with other roles. For this project going forward, additional engineering considerations that are worth exploring would be cost, since there is a limit to how much money can be spent on a single project, and practicality, since a project that may work in theory but is impossible to create in a current day setting is not very helpful for this problem. The nature of our project required environmental impact to be the primary design consideration, so if this project were to be continued, cost and practicality would be two important considerations.

Summary of Contributions

Finalized Problem Statement: Theepika Piramenthiratheesan & Hailey Chegus

Justification of Technical Objectives and Material Performance Indices: Theepika Piramenthiratheesan

Conceptual Design – Justification of Selected Material: Theepika Piramenthiratheesan

Design Embodiment – Justification of Solid (CAD) Modelling: Hailey Chegus

Discussion of Regulations: Licheng Zhou

Discussion of Sustainable Choices: Talha Ahmad

Peer-Learning Interview: Albert Membere

Concluding Remarks – Reality Check Subsection: Talha Ahmad

Comprehensive List of Sources: Licheng Zhou

Reference List

[1] Ansys Granta EduPack software, ANSYS, Inc., Cambridge, UK, 2023(www.ansys.com/materials)

[2] Core concepts related to building permits et al., "Permits and processes," Building Sweden, https://buildingsweden.com/permission-to-build (accessed Oct. 2, 2023).

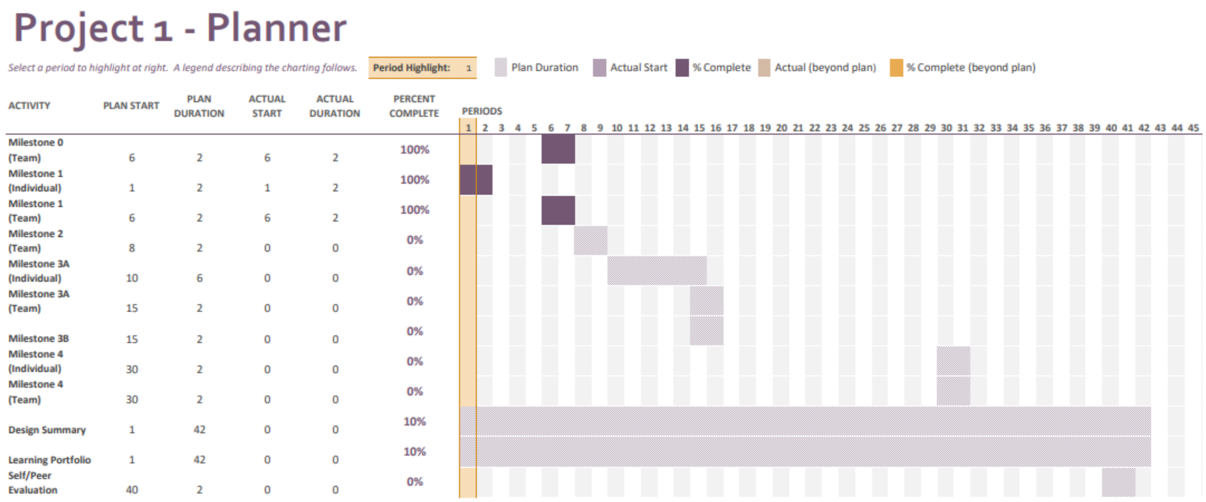
[3] M. Alanko et al., "Onshore wind power development in Sweden and Finland: Practical law," Thomson Reuters Practical Law,

https://content.next.westlaw.com/practical law/document/I8417d5c51cb111e38578f7ccc38dcbee/Onshore-wind-power-development-in Sweden-and Finland?viewType=FullText&transitionType=Default&contextData=%28sc.Default%29#co_anchor_a1059000 (accessed Oct. 2, 2023).

Appendices

Appendix A: Project Schedule

PRELIMINARY GANTT CHART

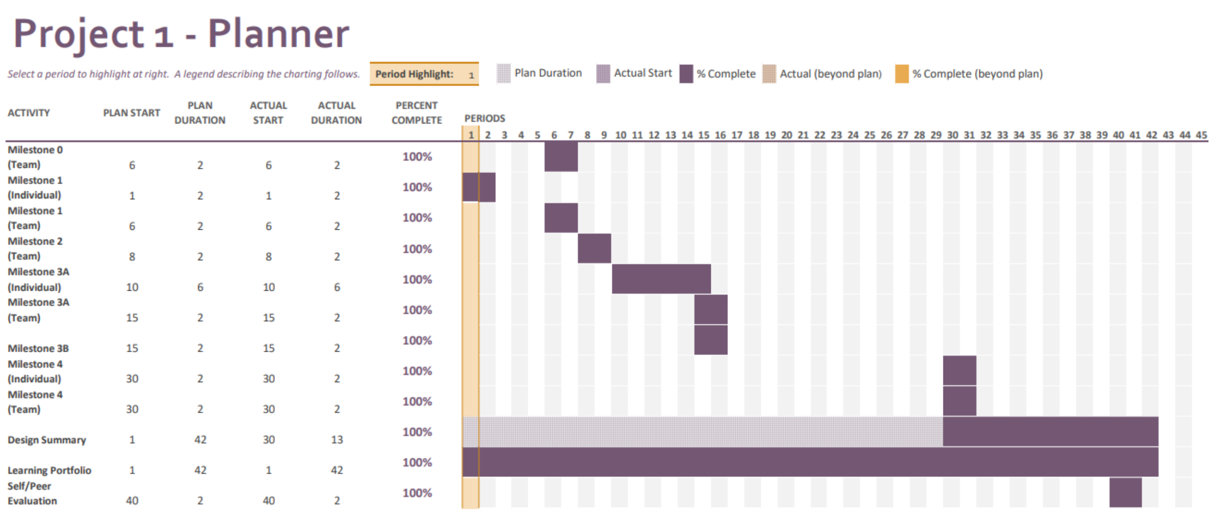


Project 1 - Planner

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 (Team)	6	2	6	2	100%
Milestone 1 (Individual)	1	2	1	2	100%
Milestone 1 (Team)	6	2	6	2	100%
Milestone 2 (Team)	8	2	0	0	0%
Milestone 3A (Individual)	10	6	0	0	0%
Milestone 3A (Team)	15	2	0	0	0%
Milestone 3B	15	2	0	0	0%
Milestone 4 (Individual)	30	2	0	0	0%
Milestone 4 (Team)	30	2	0	0	0%
Design Summary	1	42	0	0	10%
Learning Portfolio	1	42	0	0	10%
Self/Peer Evaluation	40	2	0	0	0%

FINAL GANTT CHART



Project 1 - Planner

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Milestone 1 (Individual)	1	2	1	2	100%
Milestone 1 (Team)	6	2	6	2	100%
Milestone 2 (Team)	8	2	8	2	100%
Milestone 3A (Individual)	10	6	10	6	100%
Milestone 3A (Team)	15	2	15	2	100%
Milestone 3B	15	2	15	2	100%
Milestone 4 (Individual)	30	2	30	2	100%
Milestone 4 (Team)	30	2	30	2	100%
Design Summary	1	42	30	13	100%
Learning Portfolio	1	42	1	42	100%
Self/Peer Evaluation	40	2	40	2	100%

ENGINEER 1P13

MEETING WITH TEAM 44 - FRIDAY, OCT. 6, 2023

ATTENDENCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	Theepika Piramenthiratheesan	pirament	**Yes**
Administrator	Hailey Chegus	chegush	**Yes**
Coordinator	Albert Membere	memberea	**Yes**
Subject Matter Expert	Talha Ahmad	ahmadt20	**Yes**
Subject Matter Expert	Licheng Zhou	zhoul103	**Yes**

AGENDA ITEMS

1. Attendance & Updates
2. Resolution of blade material
3. Design of blade
4. Final Notes

MEETING MINUTES

1. . Attendance & Updates
   a. How is everybody doing?
   b. Anything we can help each other out with?
   c. How did the Physics midterm go?
2. Issues from past week
   a. We could not conclude for our blade material
      i. We decided to create a weighted decision matrix to decide.

3. Discuss changes from last week's blade design model
   a. Add wind blade protective coatings

   b. Add wind protection tape
4. Action Items for next meeting
   a. Finish blade design
   b. Fill out worksheets
   c. Fill out Gantt chart
5. Final Notes
   a. It’s reading week next week!
   b. Check your action items

POST-MEETING ACTION ITEMS

1. *Finish blade design [Whole team]*
2. *Fill out worksheets [Hailey Chegus]*
3. *Fill out Gantt chart [*Theepika Piramenthiratheesan*]*

Appendix C: Comprehensive List of Sources

[1] K. Grogg, "Harvesting the wind: The physics of wind turbines," large.stanford.edu, http://large.stanford.edu/courses/2017/ph240/perry2/docs/grogg-13apr05.pdf (accessed Sep. 30, 2023).

[2] F. Porté-Agel, M. Bastankhah, and S. Shamsoddin, "Wind-turbine and wind-farm flows: A review - boundary-layer meteorology," SpringerLink, https://link.springer.com/article/10.1007/s10546-019-00473-0/ (accessed Sep. 30, 2023).

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[8] "Electricity Generation From Wind." https://www.eia.gov/energyexplained/wind/electricity-generation-from-wind.php (accessed October 2, 2023).

[9] "Energy Education: Efficiency." https://energyeducation.ca/encyclopedia/Efficiency (accessed October 2, 2023).

[10] "Energy Education: Betz limit." https://energyeducation.ca/encyclopedia/Betz_limit (accessed October 2, 2023).

[11] "Vertical Axis Wind Turbines vs Horizontal Axis Wind Turbines." https://www.windpowerengineering.com/vertical-axis-wind-turbines-vs-horizontal-axis-wind-turbines/ (accessed October 2, 2023).

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[14] M. Alanko et al., “Onshore wind power development in Sweden and Finland: Practical law,” Thomson ReutersPracticalLaw, https://content.next.westlaw.com/practical-law/document/I8417d5c51cb111e38578f7ccc38dcbee/Onshore-wind-power-development-in-Sweden-and-Finland viewType=FullText&transitionType=Default&contextData=%28sc.Default%29#co_anchor_a1059000 (accessed Oct. 2, 2023).

[15] Essentra Components, “What are the differences between carbon steel and stainless steel?” Essentra Components US, https://www.essentracomponents.com/en-us/news/solutions/access-hardware/what-are-the-differences-between-carbon-steel-and-stainless-steel#:~:text=Yes.,threat%20to%20oxidation%20and%20corrosion. (accessed Oct. 22, 2023).

[16] “Home,” Thomas Cook Tours and Travels: Flights, Hotels, Forex & Holidays Packages, https://www.thomascook.in/international-tourism/best-time-to-visit-sweden#:~:text=Weather%3A%20Winters%20in%20Sweden%20can,of%20the%20insanely%20cold%20weather! (accessed Oct. 23, 2023).

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[21] Ansys Granta EduPack software, ANSYS, Inc., Cambridge, UK,

Appendix E: Design Studio Worksheets

Project One Milestone (Team) Worksheets

MILESTONE 0 (TEAM): COVER PAGE

Team ID: Mon-44

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

Hailey Chegus	Chegush
Theepika Piramenthiratheesan	pirament
Talha Ahmad	ahmadt20
Licheng zhou	Zhoul103
Albert Membere	Memberea

fullname ↑ macID ↑

Insert your Team Portrait in the dialog box below

MILESTONE 0 – TEAM CHARTER

Team ID: Mon-44

Project Leads:

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

Role:	Team Member Name:	MacID
Manager	Theepika Piramenthiratheesan	pirament
Administrator	Hailey Chegus	Chegush
Coordinator	Albert Membere	Memberea
Subject Matter Expert	Talha Ahmad	ahmadt20
Subject Matter Expert	Licheng Zhou	Zhoul103

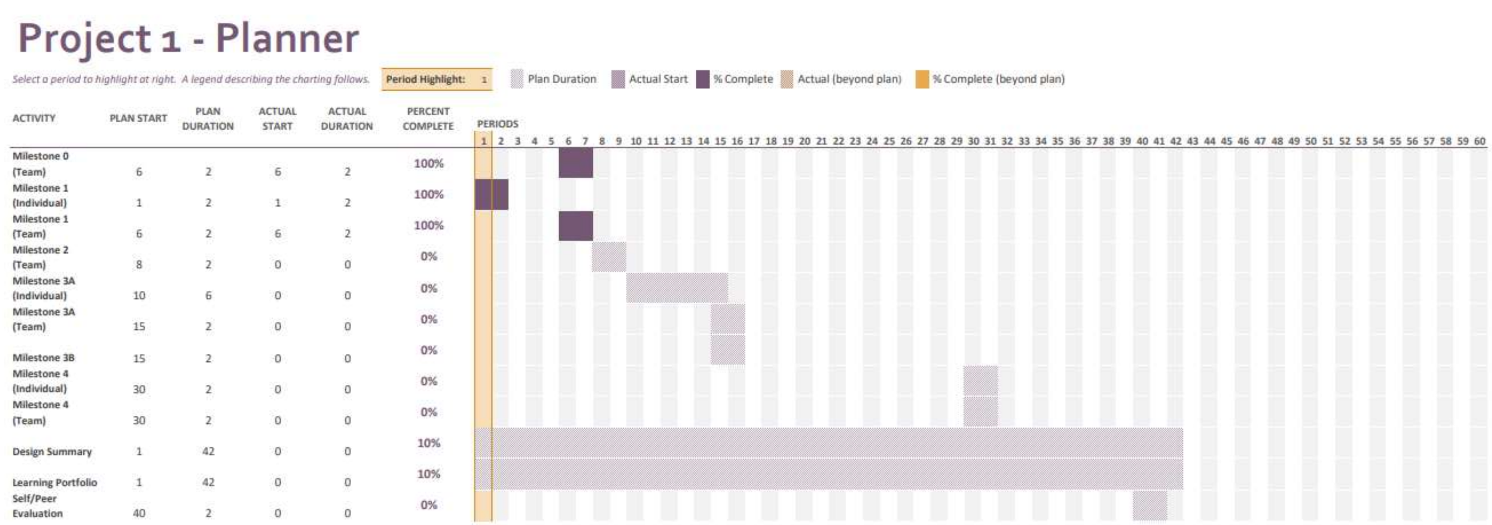
MILESTONE 0 – PRELIMINARY GANTT CHART (TEAM MANAGER ONLY)

Team ID: Mon-44

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

Full Name of Team Manager:	MacID:
Theepika Piramenthiratheesan	pirament

Preliminary Gantt chart



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Milestone 1 (Individual)	1	2	1	2	100%
Milestone 1 (Team)	6	2	6	2	100%
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Milestone 4 (Team)	30	2	0	0	0%
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Learning Portfolio	1	42	0	0	10%
Self/Peer Evaluation	40	2	0	0	0%

MILESTONE 1 (TEAM) – COVER PAGE

Team Number: Mon-44

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

Full Name:	MacID:
Theepika Piramenthiratheesan	pirament
Talha Ahmad	ahmadt20
Hailey Chegus	chegush
Licheng Zhou	zhoul103
Albert Membere	memberea

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-44

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.**

Create a wind turbine that can efficiently convert kinetic energy into usable electrical energy, so one has the option of using an eco-friendly source of energy. As well, for the turbine to be made with sustainable, durable materials that are able to withstand extreme weather conditions.

Brainstorming:

Wind Turbine

durable materials

efficent

reusable energy

rotates

speed of blades

blade

generate wind to energy

MILESTONE 1 (STAGE 3) – REFINED OBJECTIVE TREES

Team ID: Mon-44

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.

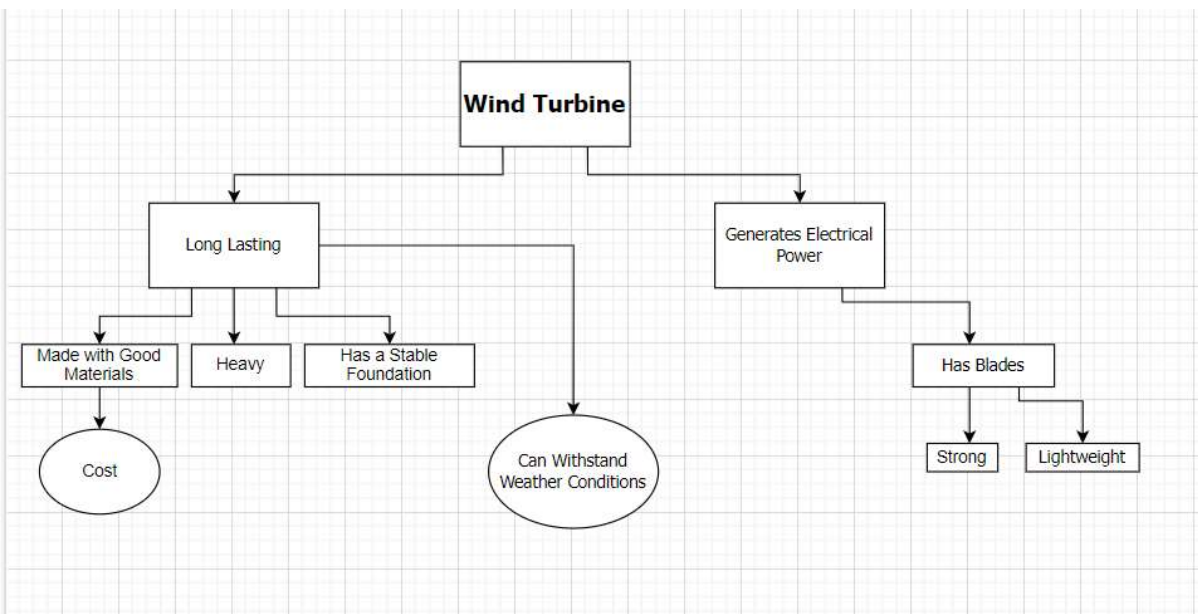
Engineering Scenario #1

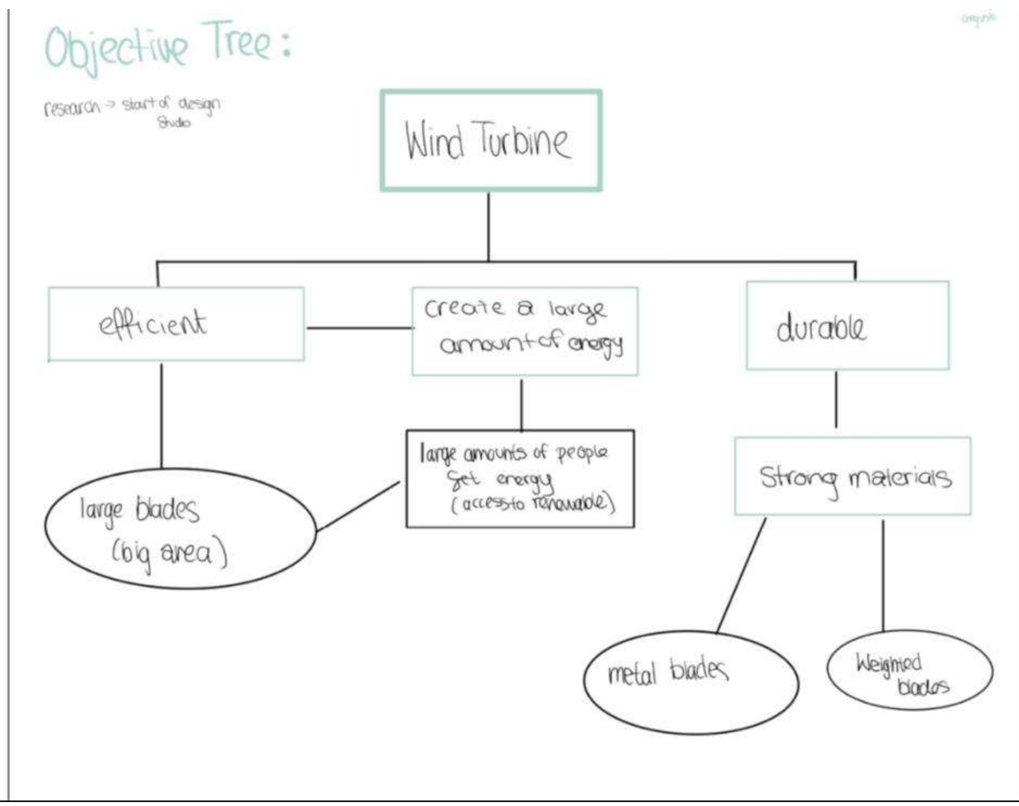
The title of the scenario

Renewable Energy for a large population 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: Mon-44

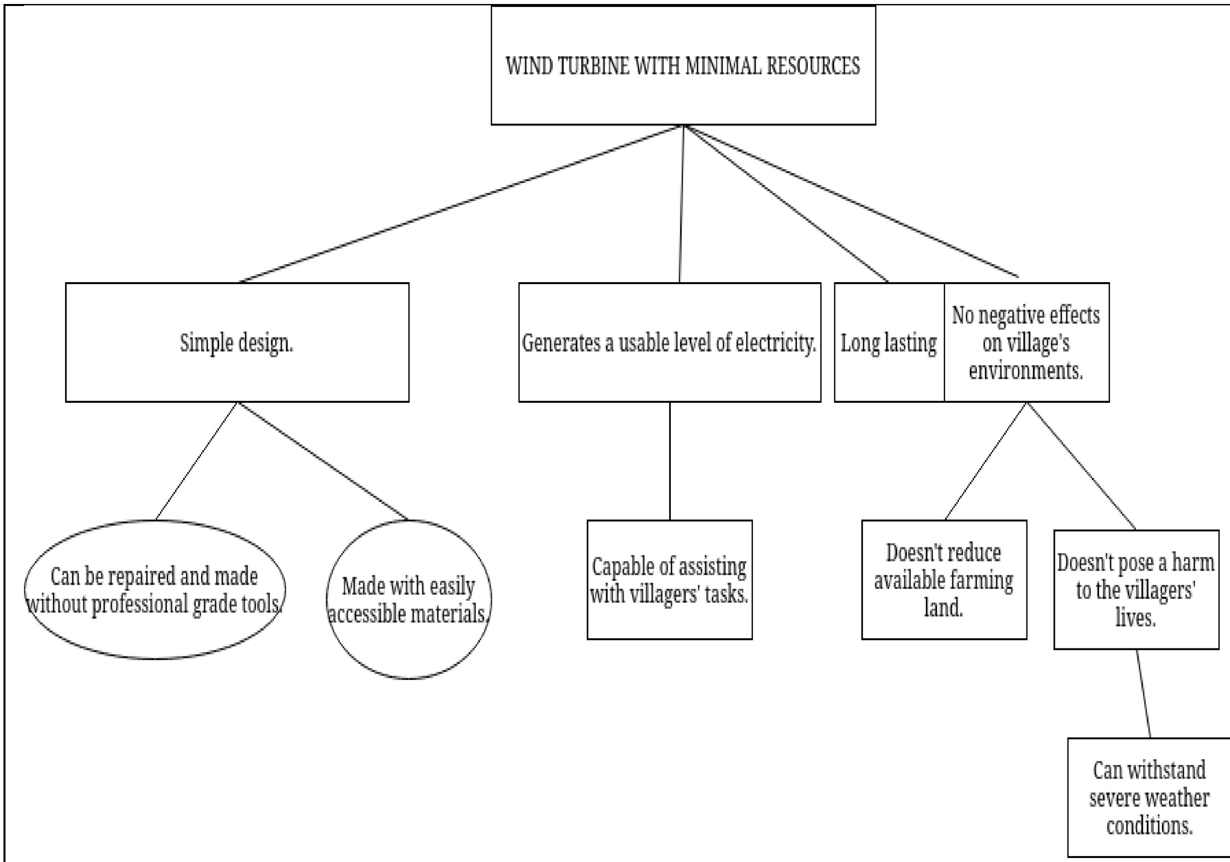
Engineering Scenario #2

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.


WIND TURBINE WITH MINIMAL RESOURCES
Simple design.
Generates a usable level of electricity.
Long lasting
No negative effects on village's environments.
Can be repaired and made without professional grade tools.
Made with easily accessible materials.
Capable of assisting with villagers' tasks.
Doesn't reduce available farming land.
Doesn't pose a harm to the villagers' lives.
Can withstand severe weather conditions.

Team ID: Mon-44

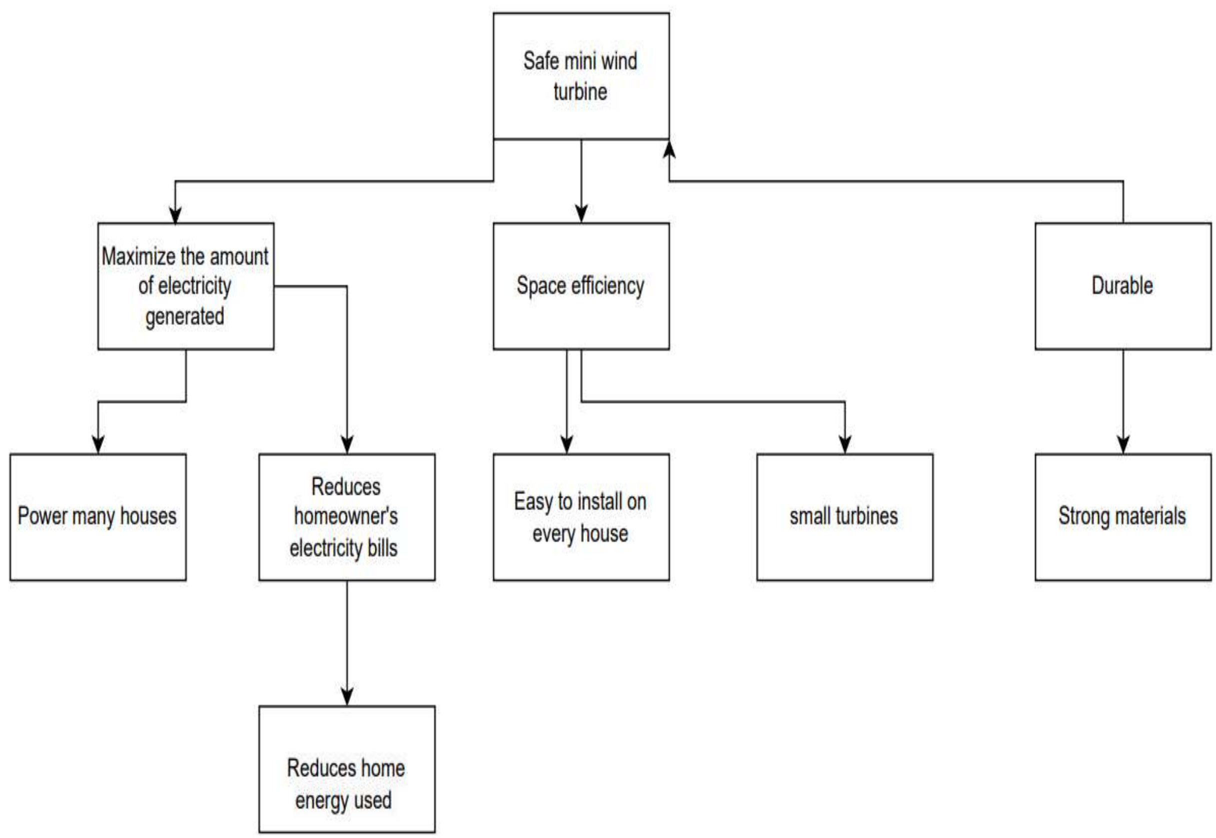
Engineering Scenario #3

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: MON-44

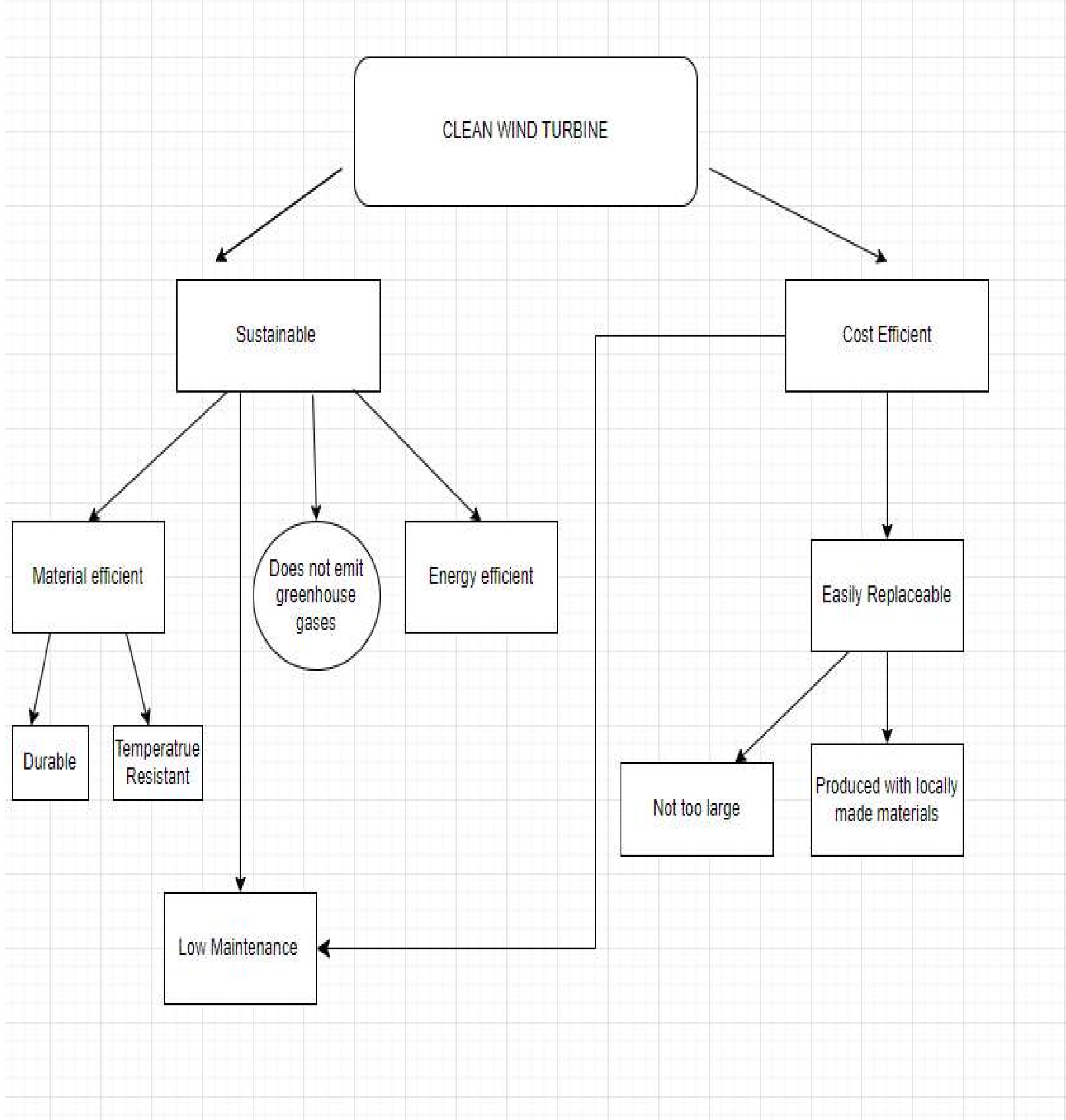
Engineering Scenario #4

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.


CLEAN WIND TURBINE
Sustainable
Cost Efficient
Material efficient
Does not emit greenhouse gases
Energy efficient
Easily Replaceable
Durable
Temperatrue Resistant
Not too large
Produced with locally made materials
Low Maintenance

MILESTONE 2 (TEAM) – COVER PAGE

Team Number: Mon-44

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

Full Name:	MacID:
Theepika Piramenthiratheesan	pirament
Talha Ahmad	ahmadt20
Hailey Chegus	chegush
Licheng Zhou	zhoul103
Albert Membere	memberea

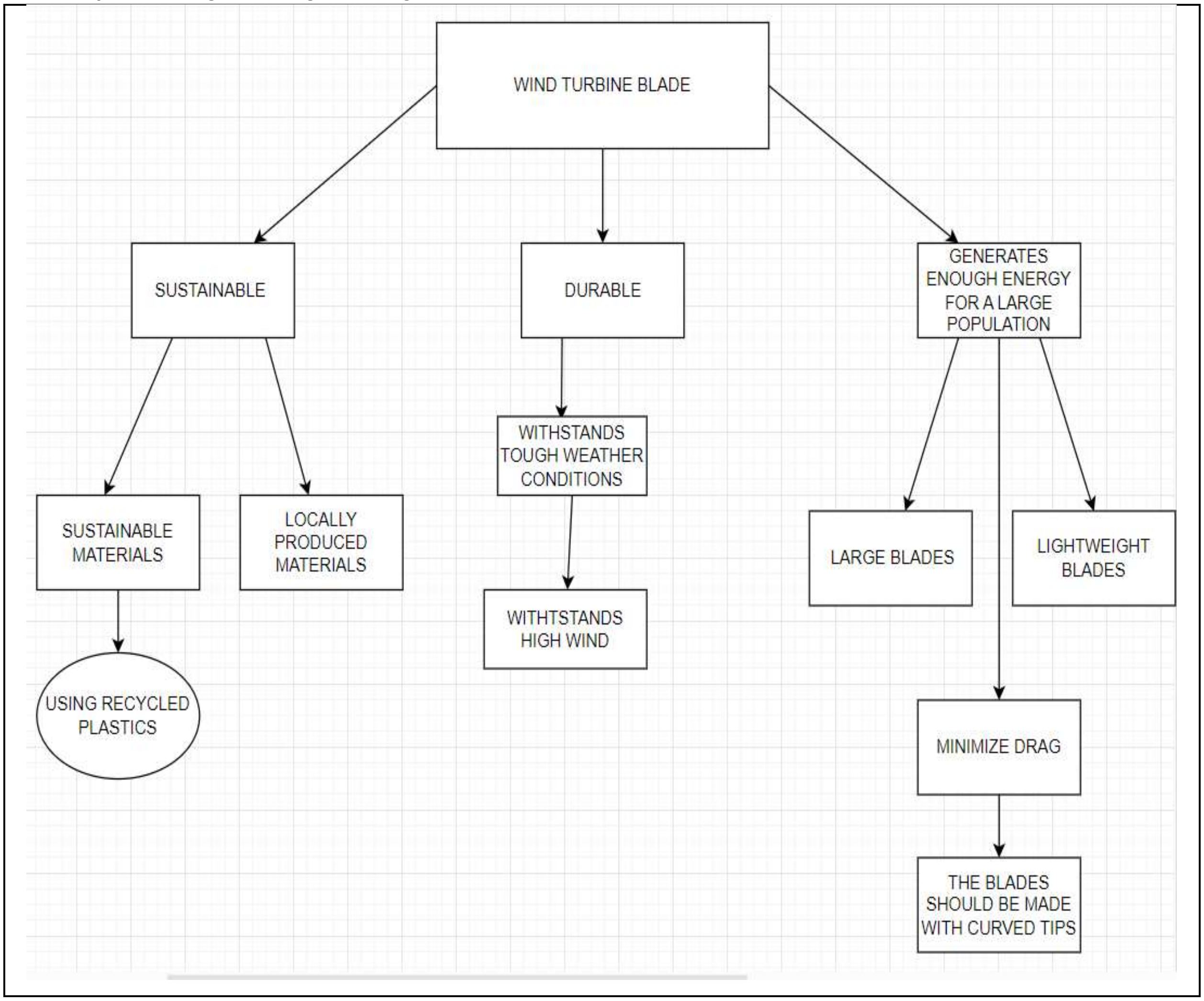
Any student that is ***not*** present for Design Studio will not be given credit for completion of the worksheet and may be subject to a 10% deduction to their P-1 grade.

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

Team ID: Mon-44

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.

To design a wind turbine blade in conjunction with the Swedish Wind Energy of Association

(SWEA) that can effectively convert wind into usable electrical energy for the residents in Swedish cities to cut down on the net greenhouse gas emissions.

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

Team ID: MON-44

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

1: Sustainable

2: Generates large amounts of energy

3: Durable

Include a rationale for selecting each of these objectives

→ Write *maximum* 100 words for each objective.

Objective 1: Sustainable

Rationale: The primary goal of the blade is to be sustainable, such that it lowers the net greenhouse gas emissions. Since sustainability is the main objective to consider, we must consider this objective from the beginning to the end of the process while designing the blades. This is because if the design processes and the material selections do not consider the environment, then it negates the initial objective of producing renewable energy. So, producing this wind turbine in a sustainable manner enables Sweden to achieve its goal of reducing its net greenhouse gas emissions to zero.

Objective 2: Generates large amounts of energy.

Rationale: The secondary objective of the wind turbine blade is that it has the capacity to produce large amounts of energy. The blades should be designed to be able to generate enough energy to support the amount of people living in Swedish cities.

Objective 3: Durable

Rationale: The third objective of the blade is it should be durable. Durability speaks for itself for the most part; we need this turbine to last a long time. Not having to keep replacing the same thing repeatedly will reduce the number of materials used in manufacturing thus, reducing the amount of greenhouse gases released in the process. Also, since so many people will rely on these wind turbines to produce electrical energy for them, it must be able to withstand harsh weather conditions.

MILESTONE 2 (STAGE 3) – METRICS

Team ID: Mon-44

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

Objective 1:	Sustainability
Unit/Metric:	Amount of greenhouse gases released (i.e. Tonnes of C02 released)

Objective 2:	Produces Large Amounts of Energy
Unit/Metric:	Amount of energy produced (i.e. Joules)

Objective 3:	Durability
Unit/Metric:	Amount of time the turbine lasts (i.e. Years)

MILESTONE 2 (STAGE 4) – REGULATIONS

Team ID: MON-44

Insert your group discussion below

In Sweden, no buildings can exist close to the shoreline [1]. At minimum, a 100m distance must exist between the building and the shoreline, and in some places, this limit increases to 300m [1]. Before a large-scale wind farm's construction can start, which according to Swedish law consists of at least 2 wind turbines at 150m high or at least 7 wind turbines at 120m high, an application must be submitted to the local municipal for them to assess any problems or complications that may arise because of that wind farm [2]. After the project has been approved and notable permits have been acquired, then the construction of the wind turbines can commence [2].

[1] Core concepts related to building permits et al., "Permits and processes," Building Sweden, https://buildingsweden.com/permission-to-build (accessed Oct. 2, 2023).

[12 M. Alanko et al., "Onshore wind power development in Sweden and Finland: Practical law," Thomson Reuters Practical Law, https://content.next.westlaw.com/practical-law/document/I8417d5c51cb111e38578f7ccc38dcbee/Onshore-wind-power-development-in-Sweden-and-Finland?viewType=FullText&transitionType=Default&contextData=%28sc.Default%29#co_anchor_a1059000 (accessed Oct. 2, 2023).

MILESTONE 3A (TEAM) – COVER PAGE

Team Number: Mon-44

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

Full Name:	MacID:
Theepika Piramenthiratheesan	pirament
Talha Ahmad	ahmadt20
Hailey Chegus	chegush
Licheng Zhou	zhoul103
Albert Membere	memberea

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-44

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

Scenario 4: A Pioneer in Clean Energy

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	Minimize Carbon Footprint	$\frac{E}{\rho CO2}$	$\frac{\sigma_y}{\rho CO_2}$	The primary goal of creating this wind turbine blade is to minimize the amount of greenhouse gasses that Sweden produces. This means that we should aim to minimize the carbon footprint.
Secondary	Minimize Mass	$\frac{E}{\rho}$	$\frac{\sigma_y}{\rho}$	Acceleration is inversely proportional to mass, velocity is proportional to acceleration, and kinetic energy is proportional to velocity. This means that kinetic energy is inversely proportional to mass. So, reducing the mass increases the energy produced.

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

Team ID: Mon-44

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:	Wood (typical along grain)	Bamboo	Steel (medium carbon, high carbon, low carbon, low alloy, stainless)	Wood (typical across grain)	Cork
MPI 2:	Cork	Wood (typical along the grain)	Bamboo	Paper and cardboard	Steel (high carbon, medium carbon, low alloy, low carbon, stainless)
MPI 3:	CFRP, epoxy matrix (isotropic)	Steel (High Carbon, Medium Carbon and Low Carbon)	Aluminum Alloys	Bamboo	Wood, (typical along grain)
MPI 4:	CFRP, epoxy matrix (isotropic)	Titanium alloys	GFRP, epoxy matrix (isotropic)	Steel (low alloy)	Aluminum alloys

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

Team ID: Mon-44

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.

Weighted Decision Matrix - Template

	Weighting	*Material 1: High Carbon Steel*		*Material 2: Wood (typical along the grain)*		*Material 3: Bamboo*	
		Score	Total	Score	Total	Score	Total
Eco-friendly production	5	5	25	3	15	3	15
Durability (includes chemical, weather and/or corrosion resistance)	3	4	12	1	3	2	6
Low Mass	3	1	3	3	9	4	12
…							
	TOTAL	10	**40**	7	**27**	9	**33**

→ State your chosen material and justify your final selection

Justification	
Chosen Material:	High Carbon Steel

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

For our scenario, high carbon steel would be an excellent material choice for constructing the wind turbine blades, because of its eco, mechanical and general properties.

Firstly, our main objective is to minimize the carbon footprint, which makes the eco-properties of the chosen material a very important factor to consider. High carbon steel stands out as an eco-friendly choice, as it is not only recyclable but also has a very low CO2 footprint of just 1.05. Additionally, its embodied energy is merely 15 MJ/kg, which is much lower than the other materials.

Secondly, in terms of mechanical properties, high carbon steel surpasses both wood and bamboo. This is because of its high tensile strength, high melting point, great fracture toughness, and outstanding fatigue strength. These properties will make the blades last long even in tough weather conditions.

Lastly, when considering general properties, high carbon steel is cheaper than wood and bamboo. Since it is more cost-efficient, more material can be produced, allowing for larger blades and a bigger blade radius, which ultimately results in more electrical energy being produced.

In conclusion, in our case high carbon steel is an optimal choice for building the wind turbine blades, as it is eco-friendliness, has good mechanical properties and is cost effective.

Summary of Chosen Material's Properties

Material Name	Average value

Young's modulus E (GPa):	210
Yield strength σ_y (MPa):	678.5
Tensile strength σ_{UTS} (MPa):	1055.5
Density ρ (kg/m^3):	7800
Embodiment energy H_m (MJ/kg)	16.25
Specific carbon footprint CO_2 (kg/kg)	1.125

SCENARIO SPECIFIC TURBINE BLADE DESIGN (TEAM) – COVER PAGE

Team Number: Mon-44

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

Full Name:	MacID:
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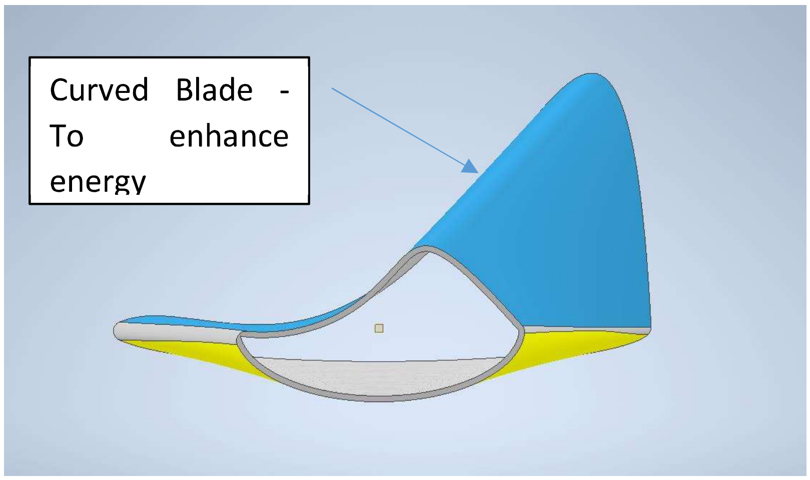
Talha Ahmad	ahmadt20
Hailey Chegus	chegush
Licheng Zhou	zhoul103
Albert Membere	memberea

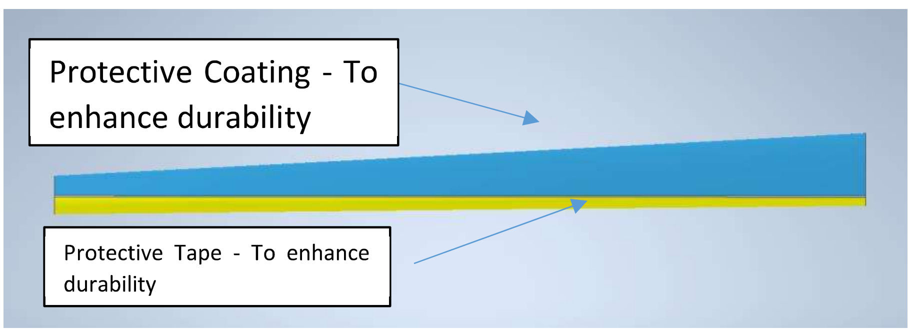
MULTIVIEW TURBINE BLADE SKETCH AND JUSTIFICATION

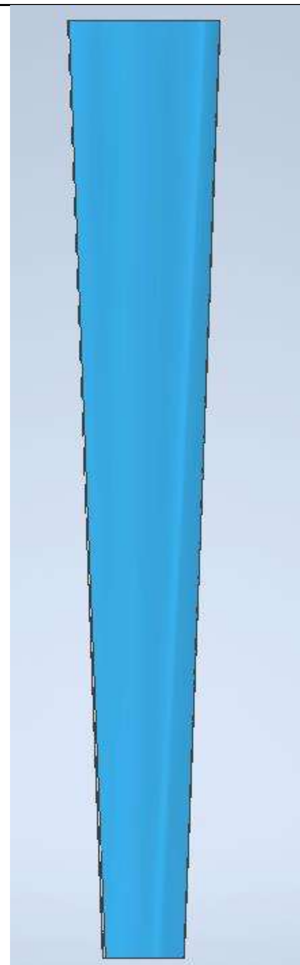
Team ID: Mon-44

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

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.

Design Justifications:

1) Material Selection

One important design factor of our turbine blade is the material that we have chosen. After careful consideration, we agreed that High Carbon Steel would be the best material for our scenario. High carbon steel fits our scenario because it is a sustainable material. It is a sustainable material because it can be recycled, and it has a low CO2 footprint. High carbon steel also has the mechanical and strength properties to ensure our wind turbine can generate a lot of power. Additionally, due to the harsh weather conditions that are often experienced in could be experienced all year round (with Sweden known to have temperatures ranging from –5 degrees Celsius to 23 degrees Celsius) [2], we picked high carbon steel as last in rough weather conditions. Moreover, high carbon steel is generally more corrosion resistant than other forms of steel, although it could still be slightly prone to it. [1]

2) Blade Thickness

The two aerodynamic forces present in a wind turbine that contribute to the conversion of wind kinetic energy to electrical energy are lift and drag [3]. For a wind turbine blade to work as efficiently as possible, it needs to maximize the power coefficient, which is used to figure out how efficient a wind turbine is at converting wind energy into electricity [4]. As the thickness is increased, the lift coefficient is decreased, and the drag is increased [3]. The ratio between these two coefficients determines the power coefficient, and according to an article published in the International Journal of Innovative Technology and Exploring Engineering, the ideal thickness of a wind turbine blade that maximizes the power coefficient is around 20mm [3]. For this reason, we have chosen 15mm as our blade thickness.

3) Protective Tape for Edge of Blade

The wind turbine's blade must be protected to maximize efficiency when generating energy. Overtime in harsh weather conditions, the blade surface erodes due to high-velocity impact at the edge such as rain, sand, or hail. In fact, damaged wind-turbine blades account for 41% of maintenance cases. [5] Protective tape on the blades is important as they shield the blade from erosion, weathering, and water damage. This will help make the wind turbine more durable as the tape can reduce the amount of erosion on the rotor blades. Acrylic foam tapes are ideal tapes due to their durability and ease of application. They can withstand severe weather conditions such as wind and rain, protecting the wind turbine's blade's surfaces. [6]

4) Wind Blade Protective Coating

Applying protective coatings to the blades of wind turbines is vital for both environmental conservation and the overall design efficiency of these renewable energy generators. [5] First and foremost, these coatings act as a shield against the harsh environmental elements, such as ultraviolet radiation, moisture, and airborne particles, which can cause corrosion and erosion over time. By safeguarding the blades from such damage, we extend their operational lifespan, reducing the need for frequent replacements or repairs. [5] This, in turn, minimizes the energy and raw material inputs required for blade production and disposal, contributing to a reduction in the environmental footprint of wind energy systems. Furthermore, the aerodynamic efficiency of wind turbines largely depends on the smoothness of the blade surfaces. [6] Protective coatings act as a repair for wind turbine blades and ensures that the blades maintain their optimal shape and performance, thus maximizing energy production. In conclusion, the use of protective coatings on wind turbine blades not only protects the environment by extending their life and reducing waste but also enhances the design's operational efficiency, promoting the growth of sustainable wind energy solutions.

5) Curvature of Blade

Lastly, we modified the curvature of the blade, so that the blade would be more curved. By making the blade more curved, it reduces the drag the blade will experience and in turn will result in more energy being produced.

Citations:

[1] Essentra Components, “What are the differences between carbon steel and stainless steel?” Essentra Components US, https://www.essentracomponents.com/en-us/news/solutions/access-hardware/what-are-the-differences-between-carbon-steel-and-stainless-steel#:~:text=Yes.,threat%20to%20oxidation%20and%20corrosion. (accessed Oct. 22, 2023).

[2] “Home,” Thomas Cook Tours and Travels: Flights, Hotels, Forex & Holidays Packages, https://www.thomascook.in/international-tourism/best-time-to-visit-sweden#:~:text=Weather%3A%20Winters%20in%20Sweden%20can,of%20the%20insanely%20cold%20weather! (accessed Oct. 23, 2023).

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[3] F. Wikantyoso et al, “The Effect of Blade Thickness and Number of Blade to Crossflow Wind Turbine Performance using 2D CFD Simulation “- IJITEE, https://www.ijitee.org/wp-content/uploads/papers/v8i6s3/F10040486S319.pdf (accessed Oct. 23, 2023).

[4] D. Watson, “Wind Turbine Power Coefficient (Cp),” Ftexploring.com, https://www.ftexploring.com/wind-energy/wind-power-coefficient.htm (accessed Oct. 23, 2023).

[5] D. Major, J. Palacios, M. Maughmer, and S. Schmitz, “Aerodynamics of leading-edge protection tapes for wind turbine blades,” *Wind Engineering*, p. 0309524X2097544, Dec. 2020, doi: https://doi.org/10.1177/0309524x20975446. (accessed Oct. 23, 2023)

[6] S. Chandrabalan, “Protecting the Blades | Wind Systems Magazine,” Oct. 17, 2016. https://www.windsystemsmag.com/protecting-the-blades/#:~:text=Wind%20Protection%20Tape&text=After%20installation%20on%20a%20blade (accessed Oct. 23, 2023).

MILESTONE 4 (TEAM) – COVER PAGE

Team Number: Mon-44

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

Full Name:	MacID:
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Talha Ahmad	ahmadt20
Hailey Chegus	chegush
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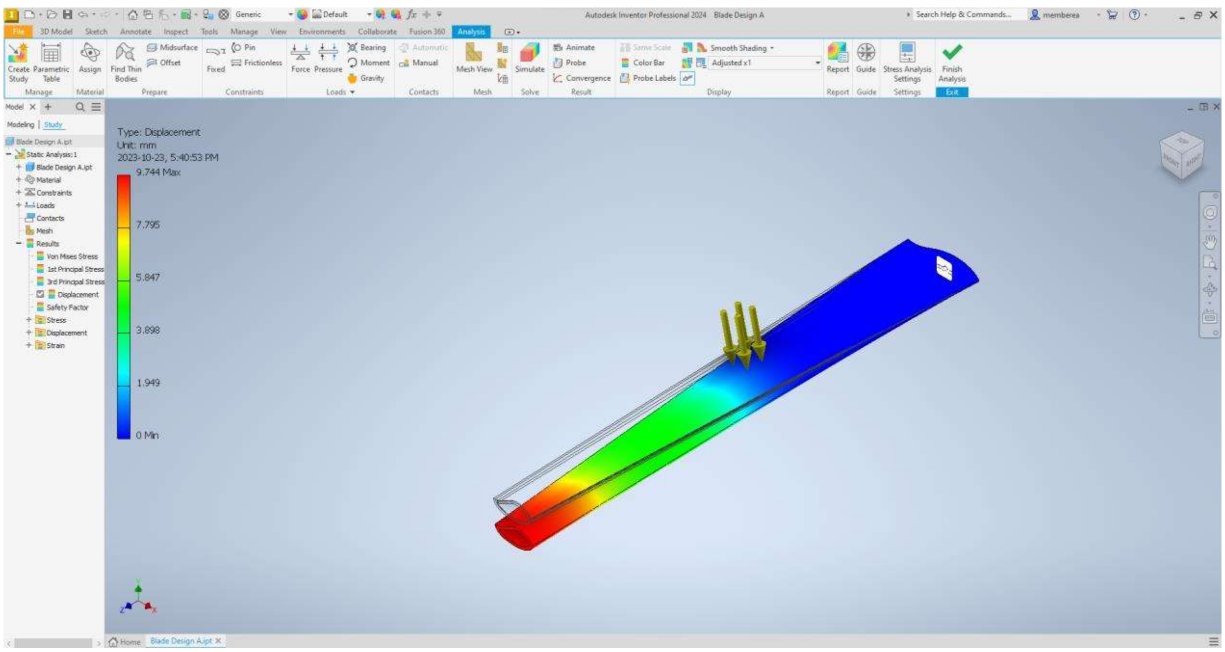
MILESTONE 4 (STAGE 2) – REFINE THICKNESS REQUIREMENT

Team ID:	Mon-44

1. Refine Thickness Requirement to Satisfy Deflection Constraint

<table>
<tr><td>Refined turbine blade thickness t (mm):</td><td>15mm</td></tr>
<tr><td colspan="2">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.

</td></tr>
</table>

MILESTONE 4 (STAGE 3) – PEER INTERVIEW

Team ID: Mon-44

→ 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.

This group had scenario three; which was to create wind turbines for roofs of houses.

Unlike our design, they had to worry about the size and compactness of their turbine. The goal was to create a small enough turbine so multiple could be places in a small area.

For their material they chose CFRP Epoxy and for their thickness they chose 15mm.

Some design challenges that we encountered was the creative aspect of the blade. We had a hard time of thinking of things to include for it.

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.