RPROJECT ONE: MILESTONE 1 – COVER PAGE

Team Number: Tues-36

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

Full Name:	MacID:
Luigi Quattrociocchi	quattrl
Tuong Minh Doan	doant6
Rahul Mahesh	maheshr
Brian Tang	tangb17
Michael Shadoff	shadoffm

MILESTONE 1 (STAGE 0) – PRE-PROJECT RESEARCH MEMO

Team Number: Tues-36

You should have already completed this task individually prior to Design Studio 3.

1. Copy-and-paste each team member's pre-project research memo on the following pages (1 team member per page)
   → Be sure to indicate each team member's Name and MacID

We are asking that you submit your work on both worksheets. It does seem redundant, but there are valid reasons for this:

- Each team member needs to submit their Pre-Project Research Memo with the **Milestone One Individual Worksheets** document so that it can be ***graded***
- Compiling your individual work into this **Milestone One Team Worksheets** document allows you to readily access your team member's work
  - This will be especially helpful when completing ***Stage 1*** of the milestone

Team Number: Tues-36

Please list Team Member that is submitting the memo.

Full Name: Michael Shadoff	MacID: shadoffm

Introduction:

Modern wind turbines are currently faced with the monumental task of competing with fossil fuels and nuclear power generation [1]. This struggle for dominance has forced companies to increase the economic practicality of wind turbines. This means both increasing the efficiency of systems like the turbines and rotors, and decreasing the costs of all components involved in constructing a wind turbine [1].

Design Factors:

Rotors are a crucial design element to wind turbines as they use the principals of lift force to turn the kinetic energy of wind into mechanical energy [2]. The optimal material for rotors should be light and strong, as larger lighter rotors will capture more of the wind's energy [2]. Therefore, industries are shifting towards composite materials, like carbon fibre reinforced epoxy, as theses materials are around half the weight of aluminum [2]. Additionally, composite materials have 1.5 to 2 times the breaking strength of aluminum, which is the length at which the material will begin to collapse in on itself [2]. Carbon fibre reinforced epoxy even boasts the highest fatigue strength of any industry standard material, which will lower repair and maintenance costs [2]. Composite materials have the potential to edge out aluminum and become the industry standard due to their falling costs, and their far superior performance [3].

There are many design considerations to account for when building wind turbine towers. Turbine towers are a crucial element of wind turbine construction because they provide the necessary height to take advantage of higher wind speeds as well as providing stability [4]. Wind turbine towers are under high amounts of stress, and therefore highly susceptible to yielding, which is the deformation of a material to the point where it can no longer return to its original state [5][6]. Steel is often chosen for the construction of these towers for its high modulus of elasticity of 200 GPa [6]. Other than its elasticity steel is largely chosen for its lower costs when compared to other suitable materials [2].

Turbine generators are also an important technology to consider in the construction of wind turbines, as they allow the mechanical energy created by the rotors to be transformed into electrical energy [7]. Generators can transform mechanical energy into electric energy using the concepts of Faraday's Law and can be thought of as working in much the opposite way that a motor does [7]. While a motor uses alternating electrical charges to induce a magnetic field and turn a shaft, generators spin in a magnetic field to induce an electrical charge [7]. Permanent magnets, like boron and rare earth elements, are often used to induce these magnetic fields as they are more efficient and require less maintenance than electromagnets [2]. However, the increasing prices of rare earth metals has driven the industry to find new materials that offer similar efficiency at a lower price [8]. One such material is ferrite which can offer similar efficiency to neodymium magnets, and has the potential to save manufacturers up to 20% in costs over time [8]. However, the trade off is that ferrite has a much lower magnetic force than neodymium, and as such nearly the mass of ferrite required is 10 times that of a similarly efficient neodymium magnet. This would undoubtedly add to the cost of neodymium generators in practice, as it would require stronger and possibly shorter towers to properly support the weight [8].

1. R. Lacal-Arántegui, "Materials use in electricity generators in wind turbines - – state-of-the-art and future specifications," *Journal of Cleaner Production,* Vol. 87. pp. 277, 280, Aug. 2014. Available: https://doi.org/10.1016/j.jclepro.2014.09.047
2. E. Hau, *Wind Turbines: Fundamentals, Technologies, Application, Economics.* New York: Springer Heidelberg, 2013.
3. M. Froese, "How are blade materials and manufacturing changing to keep up with larger turbines?," Windpower Engineering & Development, Jan. 4, 2017, [Online]. Available: https://www.windpowerengineering.com/blade-materials-manufacturing-changing-keep-larger-turbines/#:~:text=%E2%80%9CToday's%20turbine%20blades%20and%20components,and%20a%20high%2Dtemperature%20tolerance [Accessed: Sept. 28 2017].
4. M. Veljkovic et al., *Wind Energy Systems: Optimising Design and Construction for Safe and Reliable Operation.* Woodhead Publishing, 2011.
5. J. Nicholson, "Design of wind turbine tower and foundation systems: optimization approach," *Iowa Research Online,* pp. 8-9, May. 2011. Available: https://doi.org/10.17077/etd.bhnu76gr
6. "Modulus of elasticity of: Steel, concrete & aluminum," Study.com [Online]. Available: https://study.com/academy/lesson/modulus-of-elasticity-steel-concrete-aluminum.html#:~:text=The%20modulus%20of%20elasticity%20is,69%20GPa%20(10%2C000%2C000%20psi).. [Accessed: Sept 28 2020].
7. K. Daware, "Basic construction and working of a DC generator, ElectricalEasy," [Online Article]. Available: https://www.electricaleasy.com/2012/12/basic-construction-and-working-of-dc.html [Sept. 27, 2020].

N. A. Bhuiyan, A. McDonald, “Optimisation and comparison of generators with different magnet materials for a 6MW offshore direct drive wind turbine,” *University of Strathclyde,* pp.1,4,5,6, Apr. 2016. Available: https://strathprints.strath.ac.uk/56794/1/Bhuiyan_McDonald_IET_PEMD_2016_Optimisation_and_comparison_of_generators_with_different_magnet.pdf

Full Name: Luigi Quattrociocchi	MacID: quattrl

Introduction:

The purpose of wind turbines is to convert the energy from the wind into electricity. They do this by operating on the same principal that powers traditional electric fans, except in reverse: “Wind turns the propeller-like blades of a turbine around a rotor, which spins a generator, which creates electricity” [1].

Design factors:

There are many different types of models of wind turbines, (although the main two categories are “Horizontal-Axis” and “Vertical-Axis” turbines [1]). The reason for this is because there are many uncertainties in their aerodynamic modelling, such as three-dimensional geometric and rotational effects, instationary effects, yaw effects, stall, tower effects, etc., which all contribute to unknown responses [2].

The height of the rotor is a factor, as places of higher altitudes have more wind due to atmospheric factors. Also, there are less obstructions such as hills, trees, or buildings in the way [3].

The rotor itself has a direct impact on the amount of energy produced: The amount of energy produced has a positive relationship with the size of the rotor, but also with the cost. In short, the larger the rotor the better (ignoring cost) [3].

[1] Energy.gov. 2020. How Do Wind Turbines Work?. [online] Available at: <https://www.energy.gov/eere/wind/how-do-wind-turbines-work> [Accessed 28 September 2020].

[2] T. Maedam G, Shepers, Wind Energy Systems. Woodhead Publishing, 2011.

[3] AENews. 2020 What Factors Affect The Output of Wind Turbines?. [online] Available at <http://www.alternative-energy-news.info/what-factors-affect-the-output-of-wind-turbines/> [Accessed 27 September 2020].

Team Number: Tues-36

Please list Team Member that is submitting the memo.

Full Name: Rahul Mahesh	MacID: maheshr

Introduction: Wind energy is a form of “solar energy” [1]. Wind energy (or wind power) describes the process by which wind is used to generate electricity. Wind turbines convert the kinetic energy in the wind into mechanical power.

Wind power is the fastest growing alternative energy segment, providing an attractive cost structure relative to other alternative energy. Wind energy has played a significant role in “North American and European countries, and some developing countries such as China and India” [2]. “In 2009, over 37 GW of new wind capacity were installed over the world, bringing the total wind capacity to 158 GW. There is no doubt that wind power will play a major role as the world moves towards a sustainable energy future” [2].

Design Factors Wind Turbines: An overall wind energy system can be divided into following components [3]:

1. Model of the wind.
2. Turbine model.
3. Shaft and gearbox model.
4. Generator model.
5. Control system model

The mechanical parts of the wind turbine generator are the first three components. Basically, the generator produces the “electro-mechanical link between the turbine and the power system and the control system controls the output of the generator. The mechanical system of the wind turbines plays a big role in the energy transformation”[3]. Most of the simple wind turbine gear box consists of two main shafts, “the low speed shaft which is basically connected with the wind turbine blades, and the second one which is called the high speed shaft connected directly to the generator”[3].

Wind turbines produce electricity by using the “power of the wind to drive an electrical generator”[4]. “Wind passes over the blades, generating lift and exerting a turning force”[4]. “The rotating blades turn a shaft inside the nacelle, which goes into a gearbox. The gearbox increases the rotational speed to that which is appropriate for the generator, which uses magnetic fields to convert the rotational energy into electrical energy”[4].

1. References: [1] Wind 101 by American Wind Energy Association. Made in USA in 2020. [Online.] Available : http://www.awea.org/faq/wwt_basics.html
2. [2] Wind *Power Generation and Wind Turbine Design* by W. Tong. Made in the USA by WIT Press in 2010. [Online]. Available: https://www.witpress.com/books/978-1-84564-205-1
3. [3] Ramakrishnan, V, Chapter 2” Mathematical Modeling of Wind Energy System”, Simulation Study of Wind Energy Conversion Systems, Bharath University, http://hdl.handle.net/10603/30.
4. [4] Olimpo Anaya-Lara,Nick Jenkins, Janaka Ekanayake, Phill Cartwright, Mike Hughes, Wind Energy Generation: Modeling and Control, 2009 John Wiley & Sons, Ltd.

Team Number: Tues-36

Please list Team Member that is submitting the memo.

Full Name: Tuong Minh Doan	MacID: doant6

Introduction:

Wind turbines are devices that convert the kinetic energy of wind currents into useful energy suitable for human activities. Historically speaking, humans have been using wind power for thousands of years. From propelling boats, powering water pumps, grinding grains to generating electricity. The most common type of modern-day wind turbines are usually tall structures with three propeller-like blades perpendicular to the ground. These structures are often located in large open fields rich in wind currents. Their main purpose is to convert the kinetic energy of wind into electrical energy through the use of internal generators connected to the wheel mechanism of the turbine.

Design factors:

- <u>Aerodynamic Lift:</u> The aerodynamic of the turbine blades determines how much lift the blade will experience. According to the Bernoulli's principle, fast travelling air creates low pressures zone which can causes lift as objects tend to move from high pressure zone to low pressure zone [1, 39]. Therefor, the design of the aerofoils must be able to adhere to this principle in order to generate lift. One side of the aerofoil must be longer or more curved in order to generate faster wind currents which in turn, creates a low-pressure zone on said side of the aerofoil [1, 40].

- Appropriate Turbine Tower Structure: The turbine towers structure plays an important role. Depending on the type of wind turbines (horizontal or vertical axis), the structure of the towers can vary. However, they are typically tall structures which allow the turbines to reach wind currents travelling at high velocity [2]. These towers are typically made of steel alloy [3], resulting in a sturdy and resilient structure capable of supporting its load and withstanding the wind pressure.

- Aerofoil material: The material of the aerofoil can determine the its length and wind turbine efficiency. Longer blades are usually more unstable and less reliable [4]. This is due to longer blades experiencing more lift and drag, along with a higher inertia value which increases wear and probability of malfunctions. In order to compensate for these two factors, the aerofoils must be lighter and more durable as its length increases. Manufacturers typically turn to composites for to solve this dilemma. "Materials of the wind turbine blade market include resins of glass fiber reinforced polyester, glass fiber reinforced epoxy, and carbon fiber reinforced poxy." [4]

References:

[1] Jamieson, P., 2018. *Innovation In Wind Turbine Design*. 2nd ed. Hoboken: J. Wiley & Sons.
[2] Miller-Willson, K., n.d. *Design Of A Wind Turbine*. [online] Greenliving.lovetoknow.com. Available at: <https://greenliving.lovetoknow.com/Design_of_a_Wind_Turbine> [Accessed 29 September 2020].
[3] Blog.swantonweld.com. 2017. *Different Types Of Wind Turbine Towers Made With Steel*. [online] Available at: <https://blog.swantonweld.com/steel-wind-turbine-towers> [Accessed 29 September 2020].

[4] Froese, M., 2017. *How Are Blade Materials And Manufacturing Changing To Keep Up With Larger Turbines?*. [online] Windpower Engineering & Development. Available at: <https://www.windpowerengineering.com/blade-materials-manufacturing-changing-keep-larger-turbines/> [Accessed 29 September 2020].

Team Number: Tues-36

Please list Team Member that is submitting the memo.

Full Name: Brian Tang	MacID: tangb17

Copy-and-paste the pre-project research memo for one team member in the space below

Introduction: Currently, wind turbines along with solar make up 90% of renewable energy sources. Due to climate change people are starting to invest more money into green energy in order to reduce our carbon footprint [1]. In 2018, the world's first floating wind turbines where placed 15 miles off the Aberdeenshire Coast. They operated at 65% efficiency [2]. Since the average wind turbine is 30-50% efficient, that is a significant difference in efficiency [3]. Having wind turbines deployed offshore has its benefits such as higher wind speeds and steadier winds making it a much more reliable source of energy. Some downsides are that storms can destroy the turbines which have high construction costs [2]. Unfortunately, wind turbines have more cons than expected. The North Platte River in Casper, Wyoming has become a resting place for 1000 turbine blades. Blades being made of fibreglass makes them light and strong, but hard to recycle. A process where fibreglass is transformed into small pellets has been developed in order to help recycle the old blades. Old blades are also being converted into children's playground. One has already been created in Alborg Denmark. Since blades are getting bigger in order to produce more energy, they are also becoming harder to transport and recycle [4].

Design factors: Older blades are made from glass fibre and newer ones are made of carbon fibre, these composite materials are light and strong [4]. Larger size allows them to access the faster winds higher in the sky. This leads to more energy production and a decrease in number of turbines. Less turbines reduces transportation, installation and maintenance costs [4].

Copy the references below (use IEEE format)

[1] A. S. Darwish and R. Al-Dabbagh, "Wind energy state of the art: present and future technology advancements" Renewable Energy and Environmental Sustainability [Online], vol. 5, no. 7, pp. 1 Apr. 2020. Available: https://www.rees-journal.org/articles/rees/full_html/2020/01/rees190010/rees190010.html#S1

[2] M. Froese "World's first floating wind farm delivers promising results" Windpower Engineering [Online] Oct. 2018. Available: https://www.windpowerengineering.com/worlds-first-floating-wind-farm-delivers-promising-results/

[3] “how do wind turbines work?” Renewable Energy Supplier [Online] Available: https://www.goodenergy.co.uk/how-do-wind-turbines-work/
[4] P. Belton “What happens to all the old wind turbines?” BBC News [Online] 7 Feb. 2020. Available: https://www.bbc.com/news/business-51325101

*If you are in a team of 5, please copy and paste the above on a new page

MILESTONE 1 (STAGE 1) – INITIAL PROBLEM STATEMENT

Team Number: Tues-36

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 initial problem statement you should be focusing on main function(s) of wind turbine.**

A device to capture the kinetic energy of wind and transform it into electrical power.

MILESTONE 1 (STAGE 3) – REFINED OBJECTIVE TREES

Team Number: Tues-36

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.

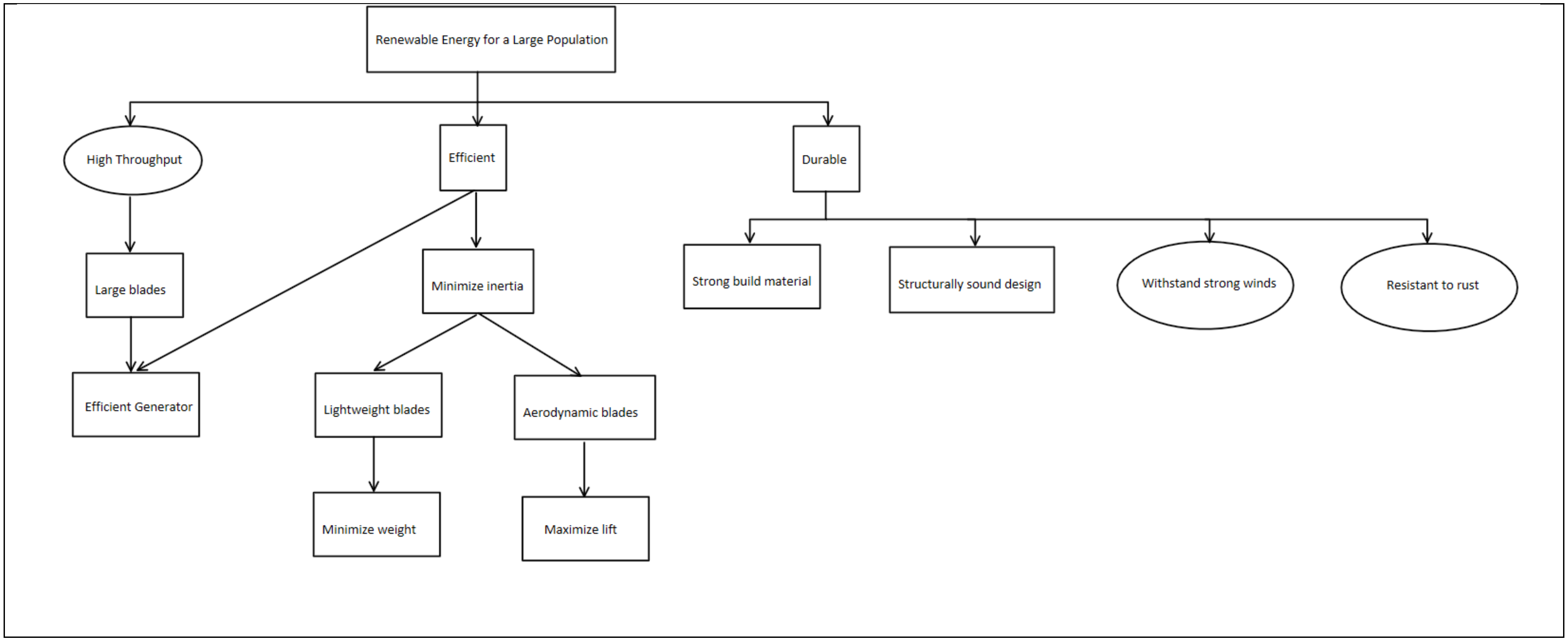
Engineering Scenario #1

The title of the scenario

Renewable energy for a large population

Team objective tree diagram for scenario #1

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



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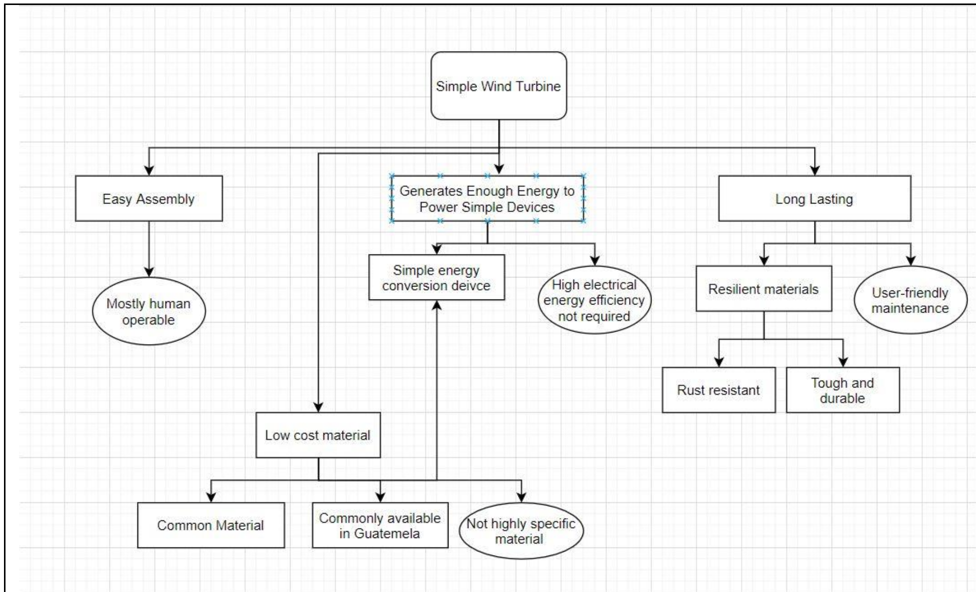
Engineering Scenario #2

The title of the scenario

EWB Humanitarian Aid Mission

Team objective tree diagram for scenario #2

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



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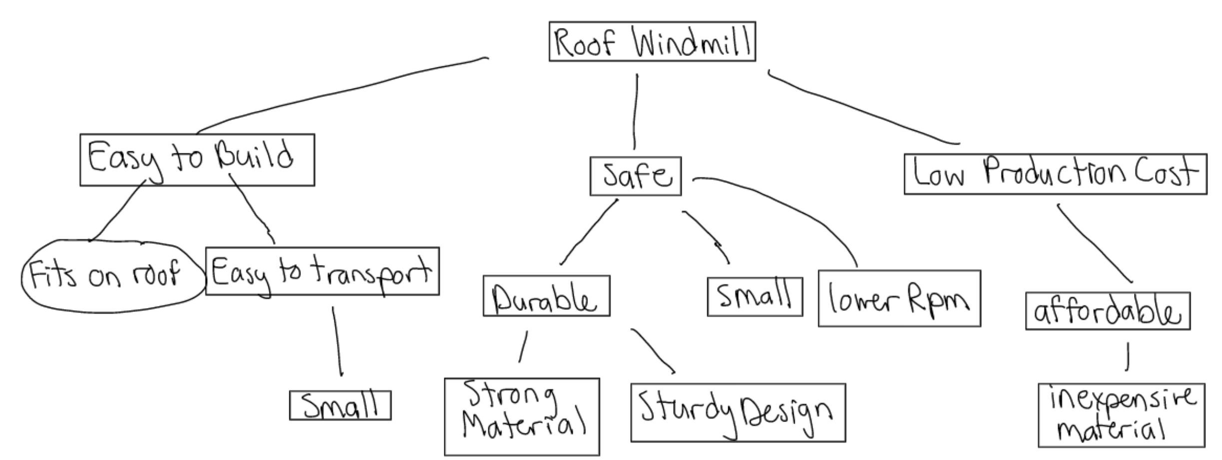
Engineering Scenario #3

The title of the scenario

The Roof Generator

Team objective tree diagram for scenario #3

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



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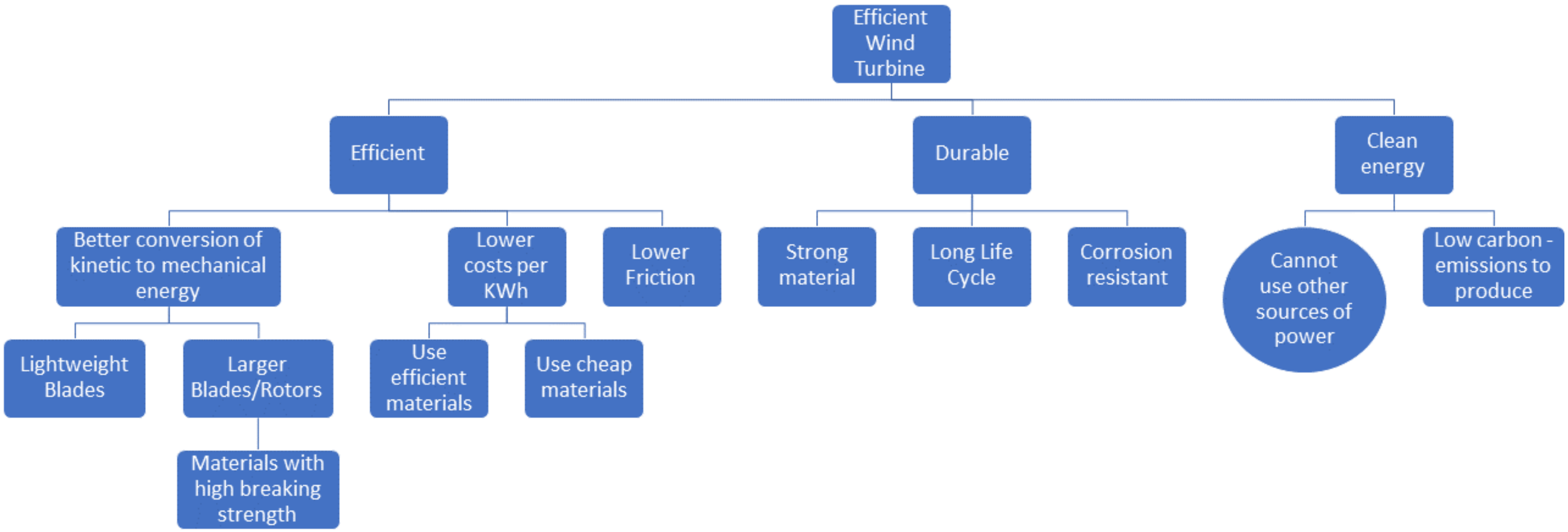
Engineering Scenario #4

The title of the scenario

A Pioneer in Clean Energy

Team objective tree diagram for scenario #4

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


Efficient Wind Turbine
Efficient
Durable
Clean energy
Better conversion of kinetic to mechanical energy
Lower costs per KWh
Lower Friction
Strong material
Long Life Cycle
Corrosion resistant
Cannot use other sources of power
Low carbon - emissions to produce
Lightweight Blades
Larger Blades/Rotors
Use efficient materials
Use cheap materials
Materials with high breaking strength