SUMMARY

Wind energy is undoubtedly a necessary sustainable energy source to meet the demand. It is one of the cleanest way of generating electricity and wind turbines do this job. They have a great portion of providing energy through renewable resources and the sector increases exponentially. As technology and material science develop, wind turbines get bigger. However, they still have downsides to be considered. They need huge amount of investments, creates large amount of carbon footprint in manufacturing, some parts are not recyclable, and they are harmful to the local environment by being noisy and dangerous for birds.

In this aspect, small wind turbines might be a solution to provide energy for rural areas. People and small businesses can have the opportunity to create their own energy with a small amount of investment and attract people. This would bring a demographic equilibrium between cities and rural areas. In addition, there is an opportunity to reinvigorate the local economy by getting the local workforce done with the tower and blades.

The purpose of the project reveals a 'truly' renewable wind turbine for rural areas by consuming the least possible amount of natural resources. So, the harm to the environment can be minimized and energy demands can be met at some level. The target user profile is a couple of country houses, farms, and small workshops. As the energy demand increase, more wind turbines can be built near fields. Since mechanical components cannot be manufactured by natural resources, the scope of the project is the design and analysis of blades and tower with proper materials. Noise will be another factor to be considered to minimize noise pollution as much as possible.

The first part of the project is started by querying the meaning of 'small' wind turbine and researching safety standards to specify requirements. IEC standards were taken as the reference for safety requirements. The average electricity consumption of an average house is researched to determine the sufficient wind turbine power. Then a market research is made, in which the existing products and their solutions are discussed. Their comparison is made on a table to see the difference between them.

All trends and options about wind turbine design and materials are discussed in the third section. At the end, the wind turbine is decided to be an upwind type. Material choices were wood for blades and steel for the tower. The tower is preferred to have a lattice design to minimize the embodied energy. The next section was about theoretical research on wind characteristics, aerodynamics of blades, and design calculations. It

includes parameters to be considered in design and equations. Information found is used in the design and analysis.

The blade size is calculated accordingly to the assumed average wind speed in the rotor design section. Power needed to provide energy for the stated need. The optimum tip-speed-ratio is found for an adequate amount of efficiency and less noise. 4 airfoil profiles that are suitable for the purpose and tested in XFOIL software. The behaviour of each airfoil is reviewed at different angle of attacks. Giguere SG6051 is chosen because it provided the highest lift over drag ratio and has a thick trailing edge, which makes production easier. The chosen airfoil is precisely reviewed again to find the proper angle of attack. For the design, the blade is divided into 6 sections, and parameters are calculated. Those parameters were mainly the chord length and angle of a twist to obtain an optimum shape. The optimum shape is optimized and converted to a realistic blade for manufacturing. The final blade model is tested at different wind speeds at QBLADE, then a structural analysis is made by the finite element method. The vane area needed to passively turn the rotor to the direction of the wind is calculated and design is made accordingly. Parameters in the generator were also defined and a suitable gearbox type is found.

The design of blades is made accordingly to the tip-speed ratio of 5 since it provides the required amount of power and be less noisy. It is ideally able to provide up to 13.5 kW of power when the rotational speed of blades is ~65 RPM. It corresponds to a thrust value of ~2600 N, and torque of ~2000 Nm. Finite element method analysis by QBLADE software calculates that the load on each blade can reach up to 3.06 MPa at a maximum operational wind speed of $20\, m/s$. The maximum amount of load is on lateral edges and the least load is on the tip.

The final part of the project was about the design of the wind turbine tower and structural analysis. The tower is required to withstand 40 m/s of wind speed conditions while the rotor is not operating. To demonstrate the behaviour of the structure, an analysis of the tower is made by the modal analysis method via Sap 2000 software. Loads on the tower at the extreme condition are calculated and different situations are entered into the software. Probable loads on the tower are wind load on the hub by the rotor, wind load on the tower structure, and dead load on the tower by the rotor. Diagram of deformations and frequency of the structure is obtained as the result. It is proven that the tower structure is able to survive in the required conditions. In conclusion, ~47 per cent of embodied energy efficiency and recycability option is obtained at the end.

The project demonstrated the possibilities of building a wind turbine from natural resources by using the least amount of energy possible. This is an achievement since it is finalized with a structurally proven wind turbine. The rotor and tower take a large portion of material consumption and this makes it suitable for the aim. Nevertheless, the project can be extended in the future to analyse many more aspects in detail. For instance, the blade design can be done again in more detail by testing more airfoil profiles, more sections can be used in analysis, and more than one airfoil profiles can be used throughout the blade. The optimization process can be done in more detail by testing different angle of twist ratios and chord length ratios. In addition, deep research can be done with bio-based materials, which is also an environmental-friendly solution to be used as a blade material. Other future research topics might be noise analysis and wind farm calculations. For the tower, the next step would be converting the material to wood to decrease the embodied energy even more.