Document Title:

Green Roof Team

Temporary Wind Turbine 2022

Green Roof Team
Southern Illinois University Carbondale

Last Updated: 02/20/2022

Acknowledgement

The Green Roof Team appreciates the support of stakeholders across campus reframing the SIU Green Roof into an interdisciplinary space for participatory learning. Most importantly, recognizing the SIU's Advanced Energy Institute (AEI) for their sponsorship of the Green Roof’s website and support towards the Green Roof Team’s renewable energy projects. The SIU Facilities and Energy Management (FEM), specifically Justin Harrell and Brian Gorecki, for their time, design approval, and assistance with installation. The SIU Sustainability Office for offering the Green Fund Grant which partially funded the project. The SIU Foundation for launching the SalukiFunder and SIU Day of Giving Campaigns for fundraising towards the project. Dr. John Groninger, associate Dean of the College of Agricultural, Life and Physical Sciences, and Dr. Brevik, Dean of College of Agricultural, Life and Physical Sciences, for his support towards the Green Roof Project which enabled the renewable energy initiatives to grow and develop. And most importantly the SIU Research Park from where the Green Roof Project was initiated by offering the University Innovation Fellows program and managing the financial accounting for the project of which made all Green Roof Project activities possible.

Foreword

The Green Roof Team formed in Fall 2019 for the purpose of executing the Green Roof Project. The goal was to transform the SIU Green Roof, an existing green space, into an interdisciplinary space for academic research across campus. Our solution included a marketing campaign for showcasing opportunities sampled by the Green Roof Team who pursued different projects including a smart irrigation system, temporary wind turbine, and photovoltaic system.

The Green Roof Team under the University Innovation Fellows program secured stakeholder support across campus for the Green Roof Project. One field integrated is renewable energy which focused on promoting the future of electrification in the world where SIU Carbondale is a well-known university for its research in clean coal and operating a coal-fired power plant on campus which produces steam, which is used to heat campus buildings, produce chilled water for cooling, and to generate electricity. As a result, the team is bringing a new resource with the intent of inspiring future years, student engagement hands-on with renewable energy.

The Green Roof Team's Renewable Energy Initiative is encompassed in a two year plan:

2020-2021	Design and install a Temporary Wind Turbine on the SIU Agriculture Building. Start an initial solar feasibility and inquire steps for a future installation.
2021-2022	Redesign the Temporary Wind Turbine with a focus on increasing the tower's height and manufacturing the blades in-house. Competed in NREL's Solar District Cup and further a future solar installation.
2022-2023	Execute a grid-tied solar installation.

The Renewable Energy Initiative consists of the Wind and Solar Energy projects of the Green Roof Team and focused on providing Salukis and involved students with the hands-on training of renewable energy and aerospace design.

Table of Contents

Executive Summary

The Temporary Wind Turbine is a subproject of the Green Roof Project by the Green Roof Team's Wind Turbine and Solar Teams. The project's focus is on the design, approval, and installation of a non-permanent small wind turbine on SIU Agriculture Building's Roof Area C. The chosen site, Roof Area C, was recommended by Facilities and Energy Management with consideration of the roof warranty's expiration of 2009 and access to the building's mechanical room through Roof Area D seen in Figure 1 and a detailed layout drawing in Appendix C.

This proposal outlines and shows the technical feasibility for a redesigned Temporary Wind Turbine, similar to the 2021 installation with ballast, and connected by guy wire to a temporary anchor, a solar module, in all four cardinal directions for further support on Roof Area C where the tower's design is found in Appendix B.

Based on our calculations seen in Appendix D, the Wind Turbine will be ballasted with 375lb of sand where the structure's total mass is 530lb and surface area is 7 square foot leading to a dead load of 75 pounds per square foot. Since our wind wheel diameter is larger than last year and tower maximum adjustable height is taller, we are incorporating guy wires to solar modules to ensure an overturning factor of safety of 1.50. The minimum solar ballast per module is 241lb of sand and dead load is 10.70 pounds per square foot to ensure an overturning safety factor of 1.5 at 70mph. The guy wire's tension force is 340lbf which is below the breaking strength of the largest capable size for our guy wire ring, 3/8" (ultimate strength of 15,400lbf) where we will **select 3/16" guy wire with an ultimate strength of 3,990lbf**, located at the highest extension for the wind turbine where **the tower's extension is denoted as x_1**. Iterations of varying tower extension heights, x_1, and wind wheel diameters at 70mph can be found in Appendix D.

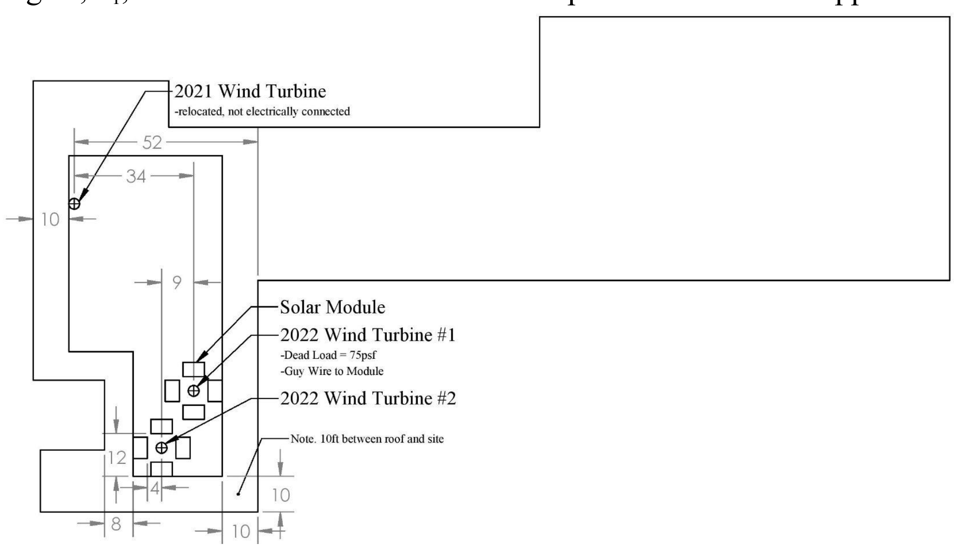

Figure 1. Project Site - Roof Area C Proposed Layout

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Scope of Work

Green Roof Team — Fall 2021 - Spring 2022

The Green Roof Team will be responsible for providing preliminary calculations and designs for FEM's approval, then preparing the Wind Turbine mounts, rubber matting, rigid PVC, solar modules, solar racking, and ballast at the Agriculture Building's breezeway for installation with FEM's assistance, see below, then installing any other materials by carrying up the ladder at a later date in April if not ready by the installation, see Figure 2 for proposed Gantt Chart.

NOTE. The solar modules will not be electrically connected due to funding, the modules act as a temporary anchor for the wind turbine's guy wires.

Facilities and Energy Management (FEM) — Spring 2022

We ask FEM to assist the Green Roof Team in late March/early April by providing a cherry picker for moving the powdercoated Wind Turbine mount, solar module, solar racking, and ballast at a minimum to Roof Area C.

Green Roof Team — Fall 2022 - Spring 2023

Pending funding, the Green Roof Team will be responsible for creating a visual display below the Agriculture Building's breezeway for showing the energy production by the PV system along with promotional content for engaging with students interested in the Green Roof. Additionally, procuring funding for purchasing equipment and labor from FEM for interconnecting the solar array.

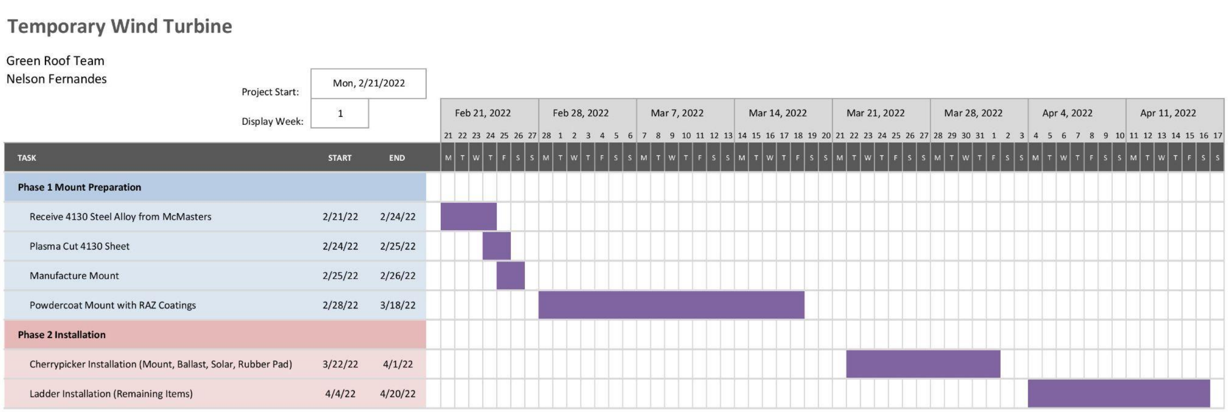

Figure 2. Proposed Installation Gantt Chart

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Engineering Design

This section describes the Wind Turbine's mount, blades, electrical system's design as well as the solar system's design. Below, Figure 3 depicts the proposed Roof Area C's layout. There is a minimum 10 foot space between the edge of the roof to any material. We will move the 2021 Wind Turbine currently installed to a more visible area, above the building's breezeway near the parking lot and not electrically connected as a cost savings. The two new proposed Wind Turbines will be connected using 12 AWG wire running through rigid pvc pipe conduit until the south edge of the roof where a flexible pvc pipe conduit will be used to run the wires to Roof Area B where an energy storage device described in the Electrical System section is located. Each Wind Turbine will be ballasted and connected to four solar modules by guy wires for ensuring an overturning safety factor of at least 1.5 given a 70 mph wind gust.

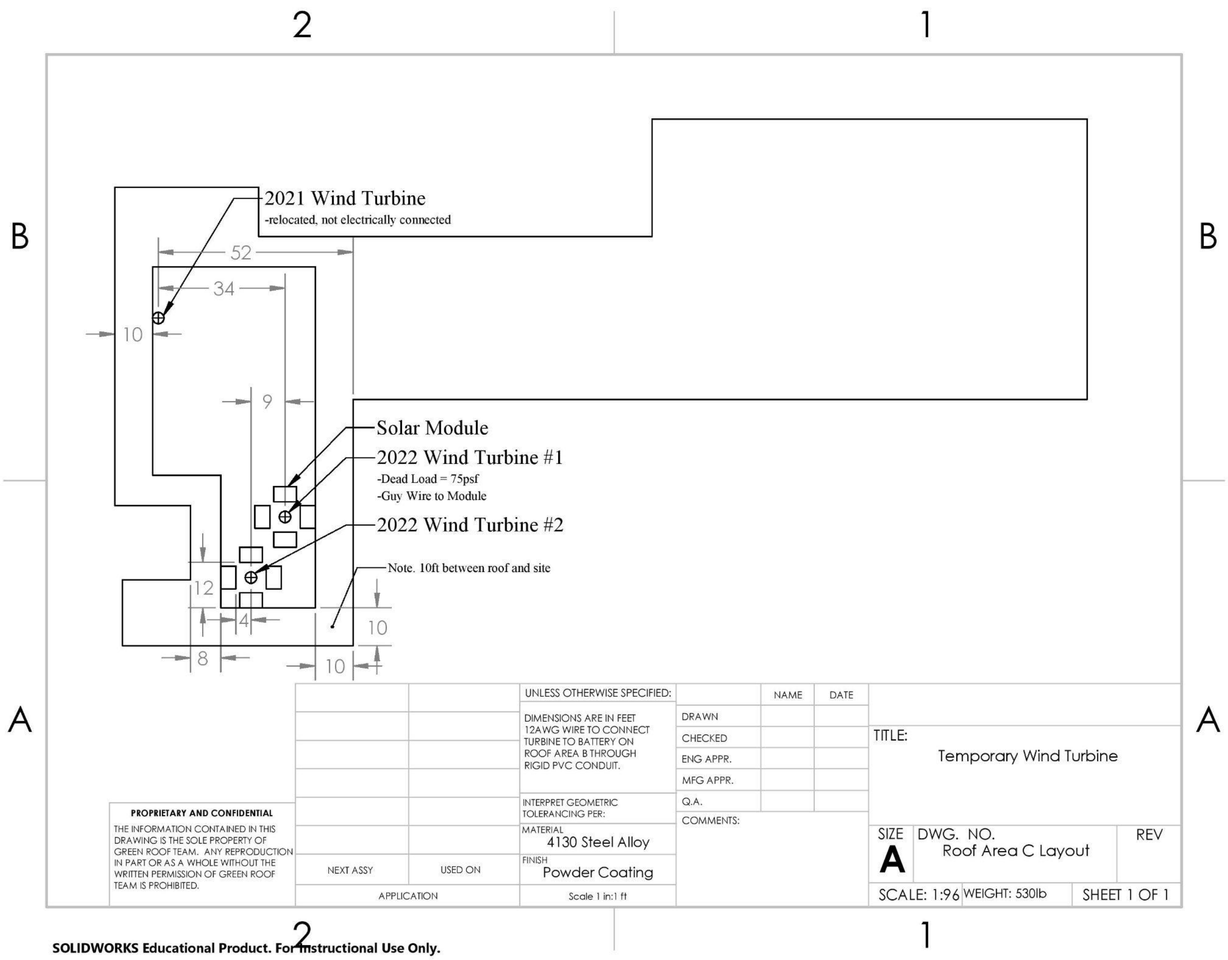

Figure 3. Roof C Layout

Tower Design

The drawing for the proposed Wind Turbine mount is seen in Figure 5 on the following page and Appendix B. The **base is identical to the 2021 Wind Turbine with ballast** to counteract the moment created by a 70mph wind gust. Due to the choice of a horizontal axis wind turbine with a larger wind wheel diameter and desire for a taller tower, **we selected to design an adjustable tower by using a pin**, bolt, similar to an adjustable basketball hoop. The centroid for the maximum height of the Wind Turbine's hub is 11.5 feet from the ground where x_1 is 3.5 feet and there is one foot of the inner tube inside of the outer tube. **At this height, the guy wire's tension is 340lbf where each solar module will require at least 241lb of ballast to maintain an overturning safety factor of 1.5** for the system. Figure 4 below is the most extreme iteration for varying the tower's extension, x_1, given the largest expected wind wheel diameter, 51", and max wind gust, 70mph. The **guy wire ring will be located at x_1**, the maximum height without interfering with the blades.

x_1=	V_Max, mph=	Wind Wheel Diameter=	Guy Wire Force=	Solar Ballast=
0.00	70	51	315.74	223.26
0.50	70	51	320.39	226.55
1.00	70	51	324.39	229.38
1.50	70	51	327.87	231.84
2.00	70	51	330.91	233.99
2.50	70	51	333.61	235.90
3.00	70	51	336.00	237.59
3.50	70	51	338.15	239.11
4.00	70	51	340.09	240.48

Figure 4. Most Extreme Iteration

The tower will be manufactured with 4130 alloy steel from McMaster-Carr for their Young's Modulus of 205 GPA and weldability. A 36" x 36" x 1/4" sheet will be cut into a 35" diameter circle where the corners will be welded as gussets. A **hole will be drilled in the center for water drainage from inside the hollow tubes**. A **rubber matting will be used underneath to protect the roof**.

Due to McMaster-Carr's inventory, we were limited to tube sizes. As a result, we chose a 2" inner tube to fit our Generator's and Guy Wire Ring's constraints. The inner tube has a wall thickness of 0.095". The outer tube has an outer diameter of 2.5" and inner diameter of 2.124". We will have a **rubber sheet between the inner and outer tubes to fill the 0.124" gap** since any other tubes with a tighter fit were unavailable. With the choice of 4130 alloy steel, column buckling was not a concern.

One additional calculation conducted was the **fundamental natural frequency** of the tower which equated to **0.46Hz at $x_1 = 4$** and **0.86Hz at $x_1 = 0$**. A rubber pad will be placed between the generator and the inner tube to further reduce vibrational noise generated by the structure.

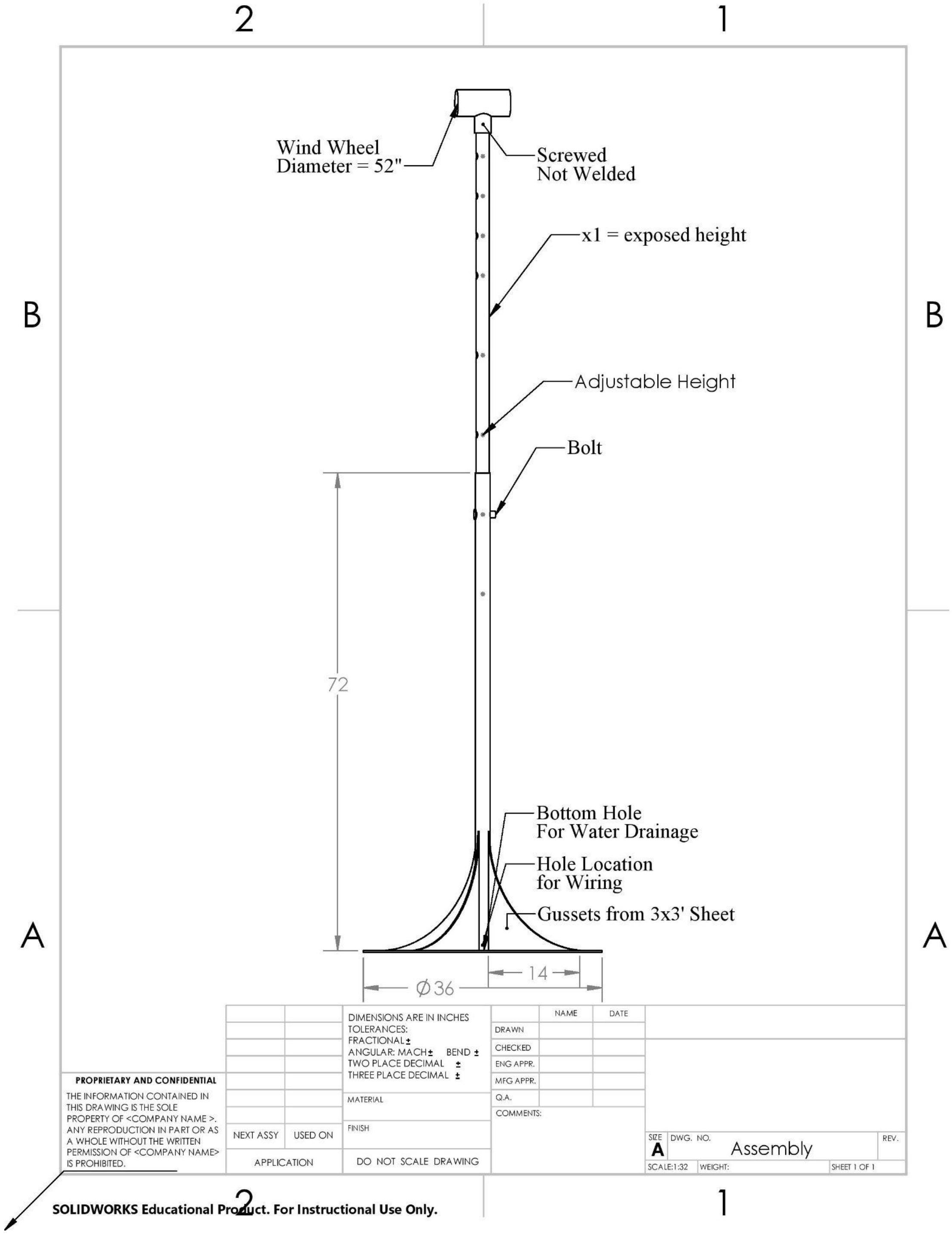

Figure 5. Assembly Drawing

With the assembly modeled in Solidworks, an analysis was conducted and depicted in Figure 6 below. A force was given at the Wind Turbine's maximum hub for a **wheel wind diameter of 52"** and a 70 mph wind speed. The **force was calculated to be 178lbf**.

The results show a **displacement of 6.1"** at the Wind Turbine's hub which is twice the displacement of the 2021 Wind Turbine at 70mph and their respective wind wheel diameter.

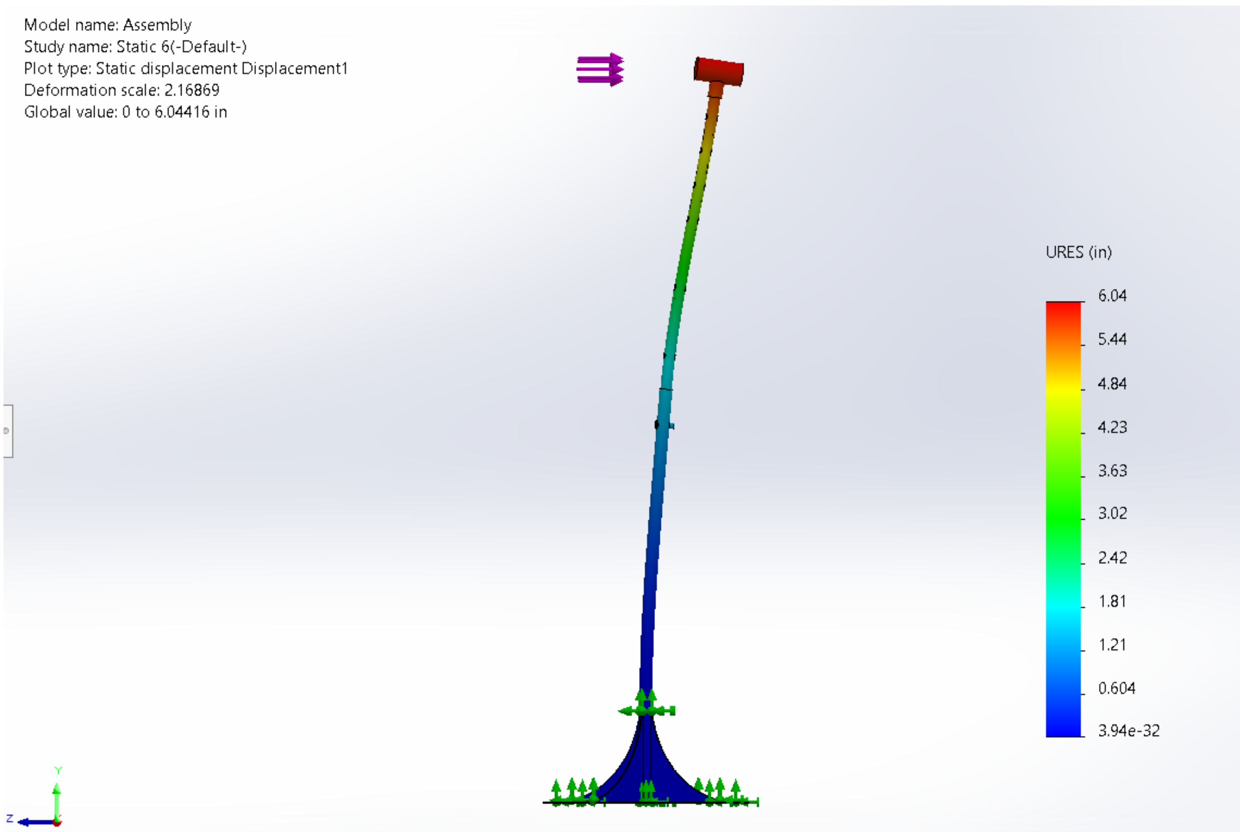

Figure 6. Solidworks Simulation - Displacement given a 70mph Wind Speed (178lbf)

Blade Design

The design process started with a Computational Fluid Dynamics (CFD) simulation of the SIU Agriculture Building seen in Figure 7 based on wind data from the Southern Illinois Airport. The simulation provided an estimated wind speed over Roof Area C based on the wind's interaction with the surrounding trees and buildings.

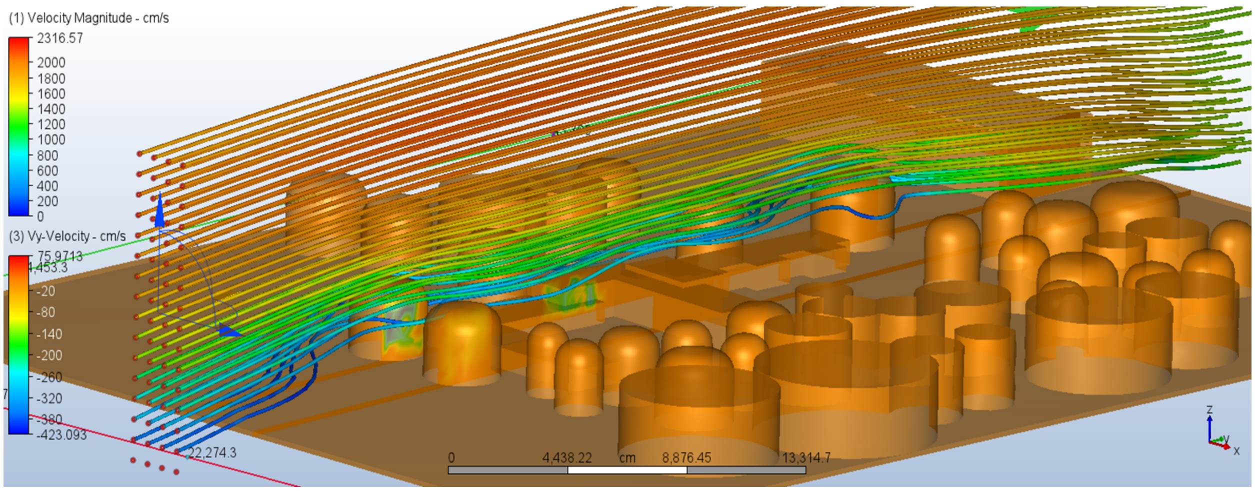

Figure 7. CFD analysis of the wind pattern in the green roof.

Based on the anticipated wind speed from the simulation, we applied the Blade Element Moment (BEM) Theory for evaluating the performance of the airfoils based on their aerodynamic and structural characteristics. In BEM, the blade is divided into elements and the loads are calculated within each element. Then, the calculations uses the relationship of various factors such as the tip-speed ratio, number of blades, airfoil aerodynamic characteristics, forces generated, etc, for the definition of the optimized chords and twist angles. This method allows not only the simplification of the blade design process, but the development of blades with multiple airfoil shapes along its radius.

For a reliable application of the BEM theory, the software Q-Blade, an open source wind turbine rotor blade calculation and design software, was used. Seven undergraduate students were able to define an air foil seen in Figure 8, compute their polar performance, and simulate the performance as seen in Figure 9.

Multiple airfoils and blade configurations were tested before selecting the specific blades for Roof Area C two new VAWTs. The final airfoils selected produce a high lift for small winds, based on the CFD simulation. A **3 blade configure was chosen** with consideration of a 5 blade configure choice due to performance, manufacturing, and cost effectiveness.

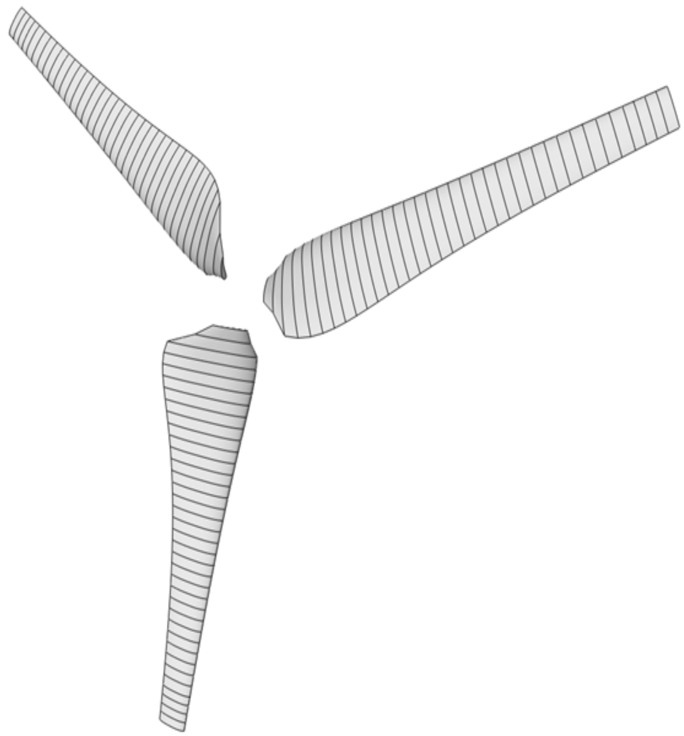

Figure 8. Blades designed in the Qblade software.

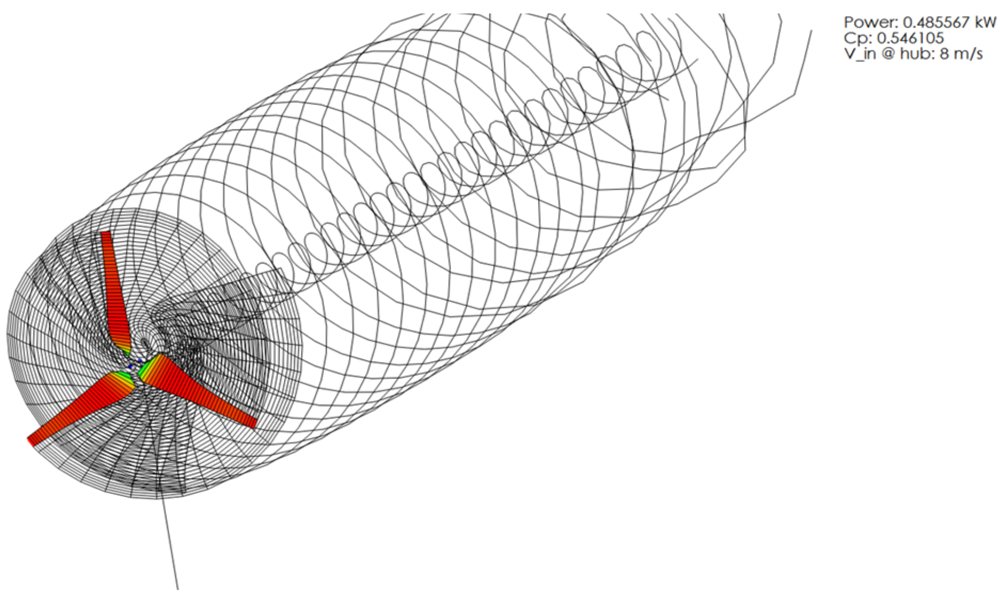

Figure 9. Green Roof wind turbine simulation with the power output.

Based on a material selection process through CES EduPack, owned by Ansys, **Carbon Fiber was selected** due to its ability ot manufacture the blades with a manual wet layup process and mechanical characteristics: strength, stiffness, density, facture toughness. We specifically selected carbon fiber woven sheets at 210 grams per square meter, 2x2 3,000 twill fiber **for the blades**. This is the most common carbon fiber type used in a variety of applications for high-performance materials.

The blades shall be **manufactured using a manual wet, open mold layup process** employing a 3D-printed mold. This process is common with fiberglass and other similar composites. A mold for the blades will be printed from a FDM 3D printer. Layer by layer, epoxy is brushed onto the mold and then carbon fiber sheets are gently laid on top. The carbon fiber cures and removed from the mold. Epoxy is applied to any areas of imperfections, allowed to cure, and then a finishing layer is applied for UV resistance.

Overall, this method is simple and cost effective for individual parts manufacturing. The method will produce carbon fiber blades that are resistant to environmental stresses and will harness wind energy in an optimized fashion.

	All values are averages		
Material	Resistance to Fast Fracture (Specific Fracture Toughness, K_{ic} / ρ)	Specific Stiffness (MN*m/kg)	Price (USD/kg)
Epoxy/HS Carbon Fiber, UD prepreg, UD lay-up, 90 Deg	0.0425	90.1	39.4
Epoxy/S-Glass Fiber, UD prepreg, UD lay-up	0.0451	25	24.6
Polyester/E-Glass Fiber, woven fabric, 65wt% glass, biaxial lay-up	0.0209	11.1	2.23

Figure 10. Blade Material Selection

Electrical System

The electrical system was redesigned from the 2021 Wind Turbine where a **custom PCB designed** with the assistance of our mentor at dlhBOWLES will replace the distributed power board. The board in its weatherproof container will be located in a weatherproofed battery box on Roof Area B. All wiring will be connected directly into the board shown in Figure 11. The Wind Charge Controller, described in Appendix F, will be plugged directly into the board along with the wind sensors, anemometer and wind vane, and **12V battery**. A **10A fuse** will be used to protect the charge controller and microcontrollers, which is larger than the calculated 2A required. Each Wind Turbine will have their own board to monitor their individual power generation, but connected to a single battery due to the low power generation expected.

An additional consideration is connecting one solar module to the battery for ensuring the battery's health. The remaining proposed seven modules will not be connected for cost savings and technical feasibility since low energy levels will be consumed daily.

Design 1 will have a total of 183 feet and **Design 2 will have a total of 162 feet of 12 AWG wire** running from their respective generator through their mount, then **rigid pvc on Roof Area C**, then **flexible pvc down to Roof Area B** for connecting to the energy storage device.

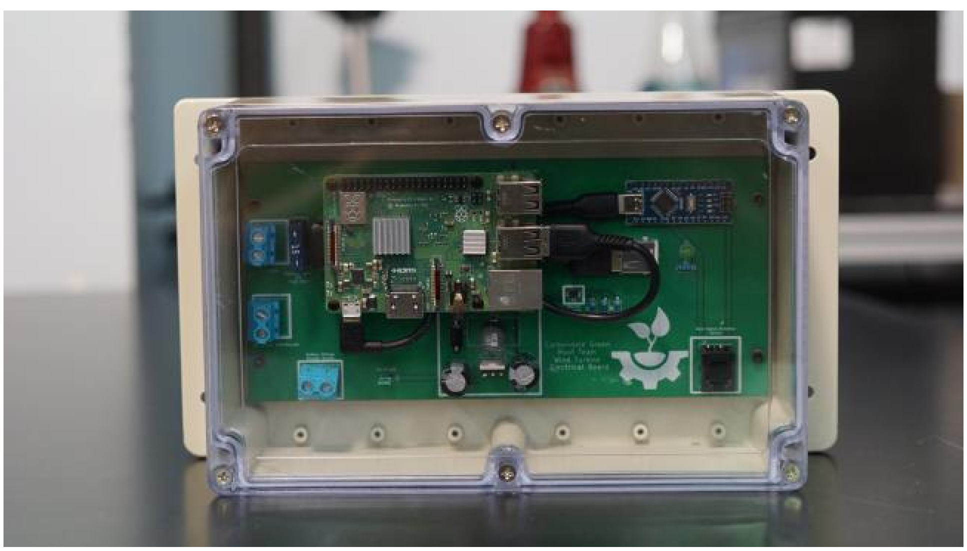

Figure 11. Custom Design PVC Board based on 2021 Wind Turbine

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Solar Array

The system was designed in Aurora Solar, seen in Figures 13-14, based on lessons we learned through NREL's Solar District Cup. This software allows the design, simulation and financial analysis of a system. We chose the module model: CS3U 375 MB-AG based on the item's availability locally and a potential discount by our sponsor, Supplied Energy, along with a mount from QCells. Figure 12 shows the position of the modules based on our layout in conjunction to the Wind Turbines seen in Appendix C. The modules' center is 90° in relation to the center of the Wind Turbine based on the guy wire calculations. The modules are facing southwards with a 10° for optimal solar exposure.

When fully connected, the 3kW$_{dc}$ system can generate an expected 3,600kWh/year based on PVWatts found in Appendix E. Please note we will not connect any modules due to insufficient funds for an interconnection at this moment as described previously. We will consider connecting one module to our energy storage device for ensuring the battery's health. Otherwise, the primary role of the modules will serve as a temporary anchor for the Wind Turbines.

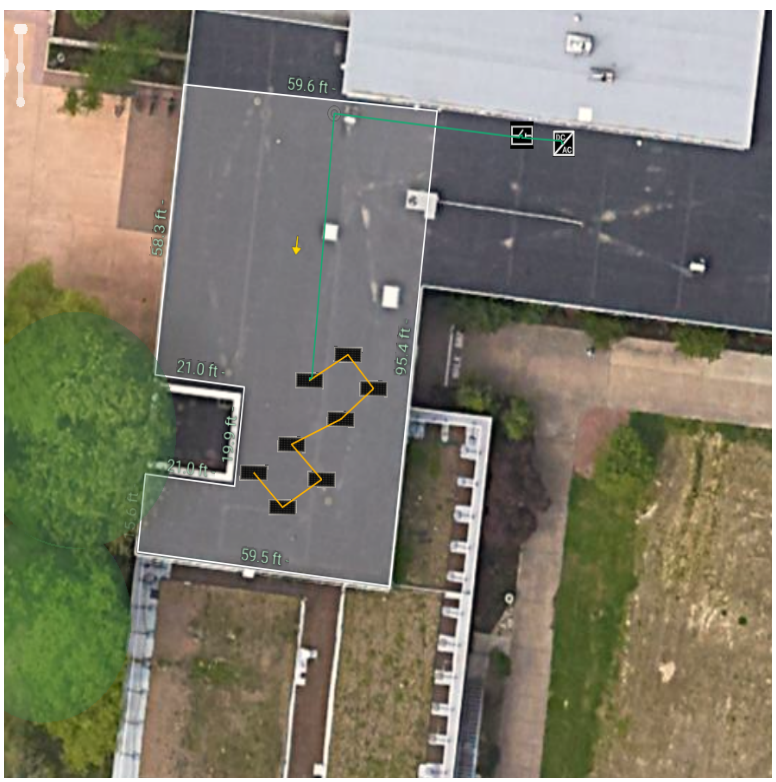

Figure 12. PV System Wiring

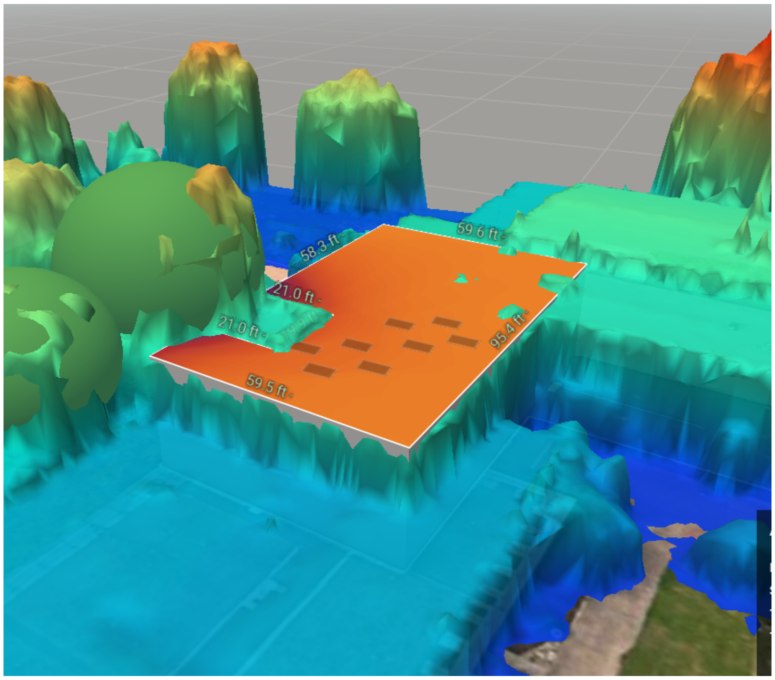

Figure 13. LIDAR view of the Site

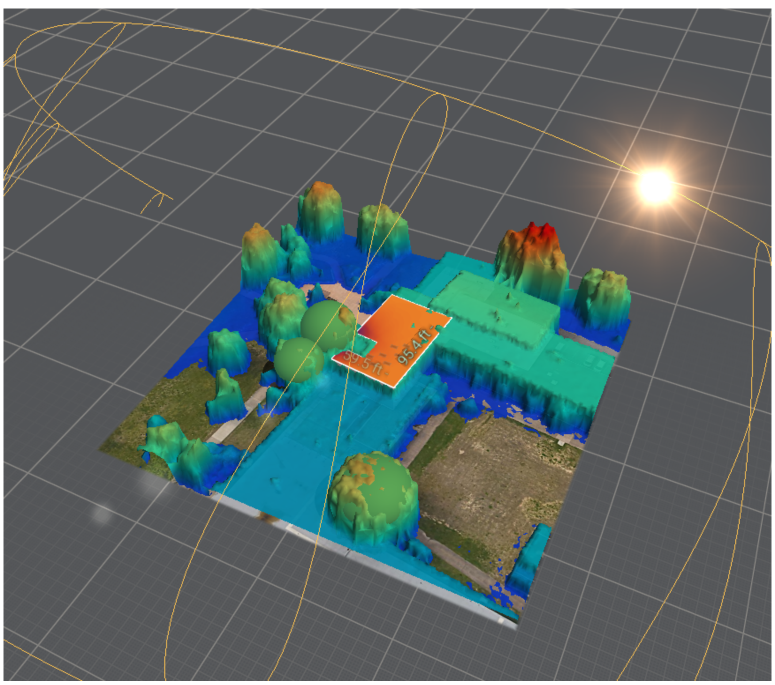

Figure 14. Animation View of the Site

Appendix A. Letters of Support

SIU CARBONDALE SOUTHERN ILLINOIS UNIVERSITY COLLEGE OF AGRICULTURAL, LIFE, AND PHYSICAL SCIENCES

COLLEGE OF AGRICULTURAL, LIFE, AND PHYSICAL SCIENCES
AGRICULTURE BUILDING
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618/453-2469
618/453-2505 FAX

December 7, 2021

To: Plant and Service Operations

From: Eric C. Brevik, Dean

Subject: Win turbine and solar roof project

This memo is on behalf of the Green Roof Project. I support their request to install a ballast-mounted small wind turbine and photovoltaic system on the Agriculture Building. Representatives of the Green Roof Team met with me and explained their plans. They have put a lot of work into the project and design concerns have been carefully considered. The project will also provide valuable information on the utilization of alternative energy on campus, which supports the Sustainability Pillar of the SIU Strategic Plan. Please let me know if you have any questions.

Sincerely,

Eric C. Brevik

Eric Brevik

Dean of the College of Agricultural, Life, and Physical Sciences

CALPS.SIU.EDU

SIU Southern Illinois University
CARBONDALE

Scott Ishman
Interim Dean, College of Agricultural, Life, and Physical Sciences
Office: 618 | 536-6666
email: sishman@cos.siu.edu

April 29,2021

To: Plant and Service Operations

From: Scott E Ishman, Interim Dean

Subject: Wind Turbine Installation

I am writing this memo on behalf of the Green Roof Project supporting their request to have a temporary wind turbine installed on the Agriculture Building. I have read the design report provided to me by Mr. Fernandes and feel that this has been carefully considered. I applaud Mr. Fernandes and his team for their innovative thinking and perseverance in making this a reality. It will provide valuable information on assessing the viability of utilizing wind energy as an energy alternative and contribute to the sustainability efforts on our campus. Please consider this my approval and if you have any questions or concerns please feel free to contact me.

Sincerely yours,

Scott E Ishman

Scott Ishman
Interim Dean, College of Agricultural, Life and Physical Sciences

Neckers Room 157- Mail Code 4403 • Southern Illinois University Carbondale
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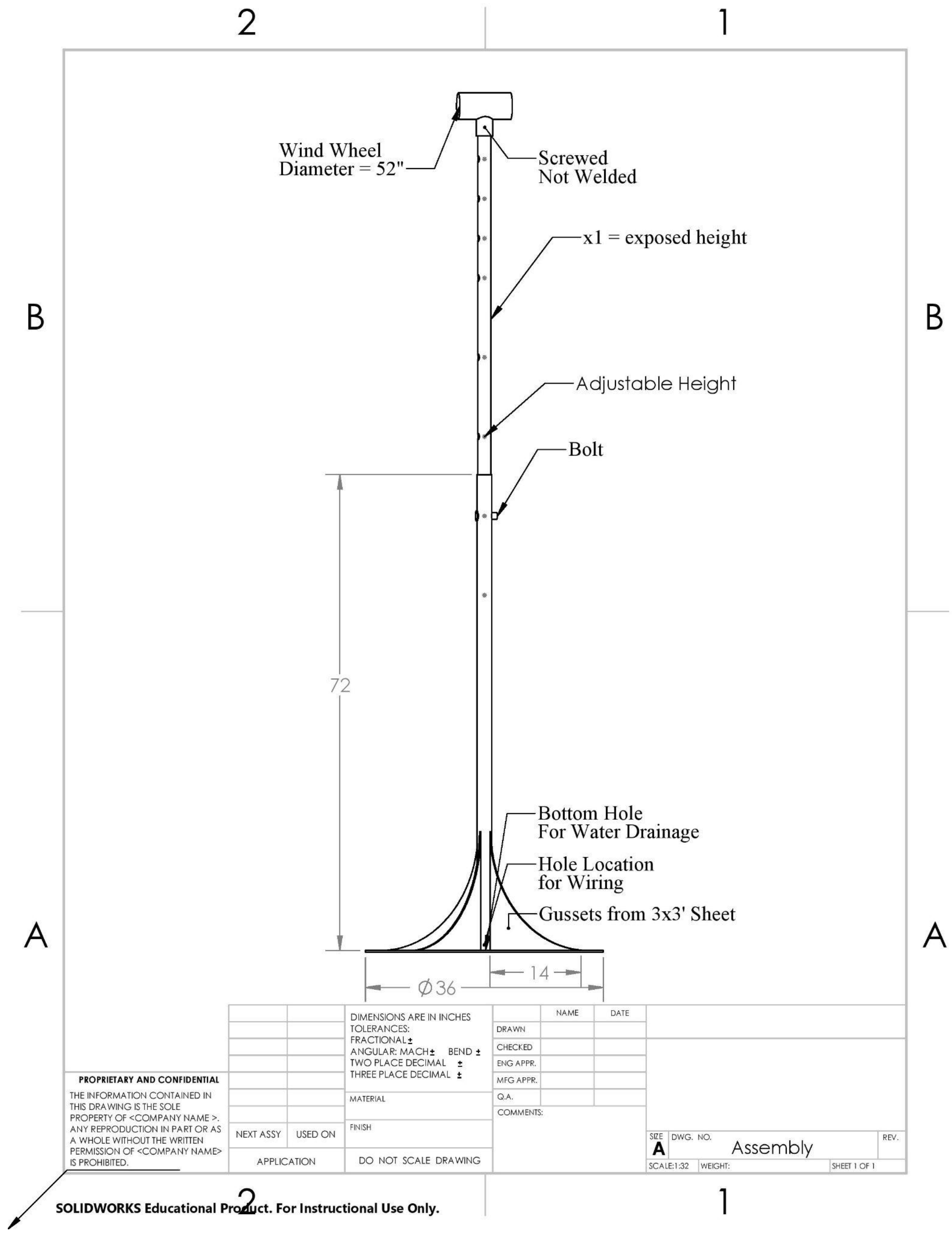
Appendix B. Structural Drawing

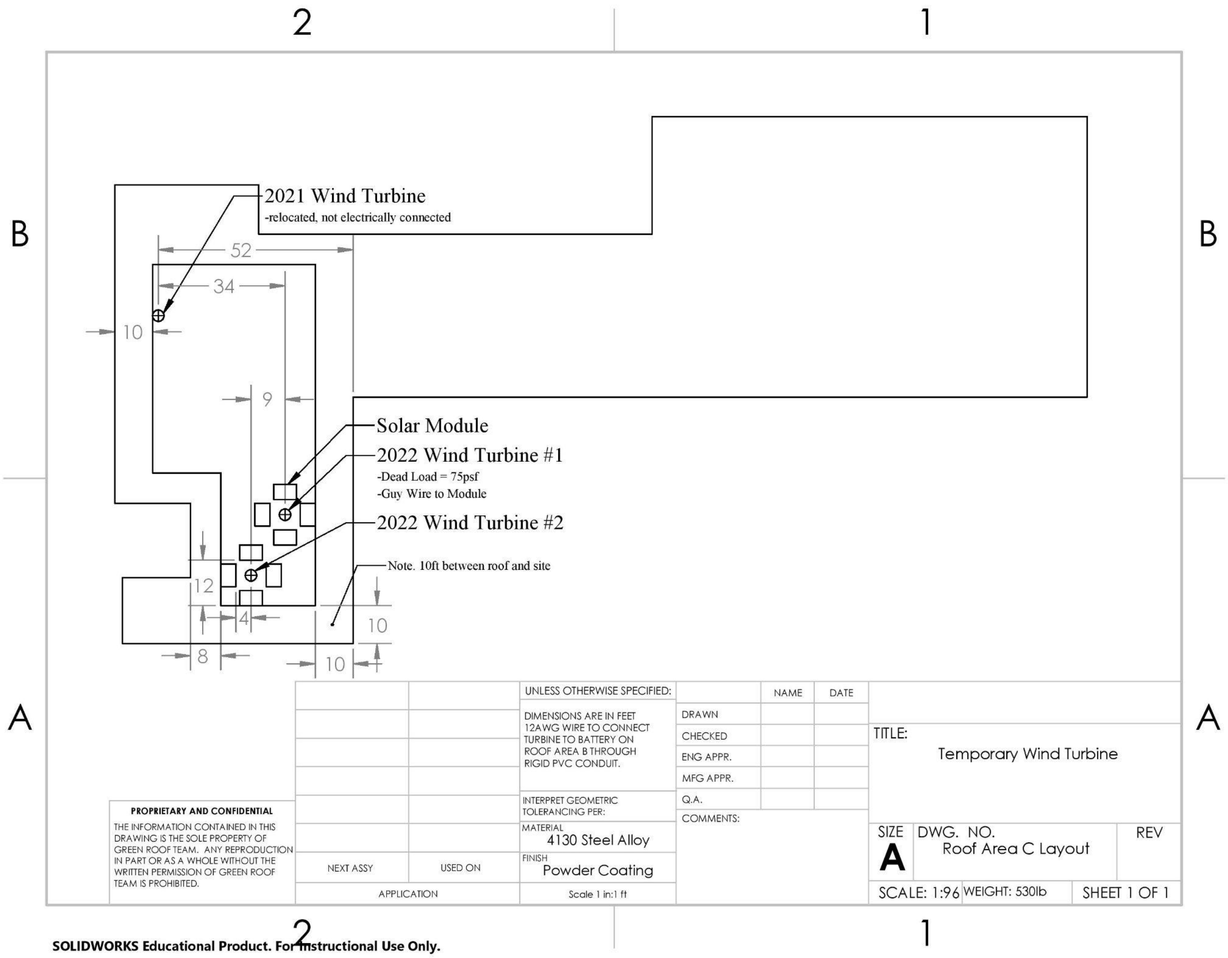
Note. x_1 is the distance between the top of the outer tube and bottom of the wind wheel diameter which varies between 0 and 3.5 feet. Material Specification can be found in Appendix F.

Note. Dimensions are in inches.



Appendix C. Roof Layout Drawing

Note. There is a minimum of 10 feet between the edge of the roof and any item. Rigid PVC will be used as conduit on Roof Area C and flexible PVC when moving to Roof Area B.



Appendix D. Structural Calculation

1.0 Constant Values x_1= 0.00 ft

1.1 Material Specification

Location		Material	Quantity	x - Width (in)	x - Width (ft)	z - Thickness (in)	z - Thickness (ft)	y - Height (in)	y - Height (ft)	Weight (lbf)	Sum Weight (lbf)	Center of Mass (ft)	Sum CM (ft)	y_bar (ft-lbf)	Sum y_bar (ft-lbf)	Notes
α	Sheet	4130 Steel Alloy Sheet	1	36.00	3.0000	36.00	3.0000	0.25	0.0208	72.27	72.27	0.0104	0.01	0.7528	0.7528	
β	Outer Tube	4130 Steel Alloy Outer Tube	1	2.50	0.2083	2.50	0.2083	72.00	6.0000	18.00	18.00	3.0208	3.02	54.3750	54.3750	
γ	Gusset	4130 Steel Alloy Gussets	4	18.00	1.5000	0.25	0.0208	18.00	1.5000	4.94	19.75	0.5208	2.08	10.2854	41.1417	
δ	Inner Tube	4130 Steel Alloy Inner Tube	1	2.00	0.1667	2.00	0.1667	20.25	1.6875	18.00	18.00	6.8646	6.86	123.5625	123.5625	length is 6ft, "y - Height" is measured ground to top
ε	Locking Collar	Zinc Plated	1	3.50	0.2917	3.50	0.2917	1.00	0.0833	1.00	1.00	6.0625	6.06	6.0625	6.0625	Fits pole size 2 3/8"
ζ	Guy Wire Plate	Zinc Plated	1	4.75	0.3958	4.75	0.3958	0.13	0.0104	1.00	1.00	6.1094	6.11	6.1094	6.1094	Fits Pole Size 2 3/8"
η	Bolt		1		0.0000		0.0000		0.0000		0.00		0.00	0.0000	0.0000	
θ	Generator	Aluminum Alloy Generator	1	7.00	0.5833	5.75	0.4792	5.75	0.4792	25.00	25.00	7.9479	7.95	198.6979	198.6979	
ι	Blades	Nylon Fiber Blades	3	0.50	0.0417		0.0000	22.00	1.8333		0.00		0.00	0.0000	0.0000	
	Module			45.55	3.7958	71.07	5.9225	9.77	0.8142							
		Sand Ballast	7.50					20	1.6667	50	375.13	0.8333	6.25	312.6056	2,345.3348	
											530.14		38.35		430.70	

1.2 Coefficients

E_4130= 29,700.00 ksi

2.0 Calculations

2.1 Force Applied, Wind on Point E

ρ_air= 0.0765 lbm/ft^3

V_Max, mph= 70.00 mph *70mph as max gust
V_Max, ft/s= 102.69 ft/s

Wind Wheel Diameter= 51.18 in *51.18in from manufacturer
4.27 ft
A_swept= 14.29 ft^2

F_E= 179.11 lbf

2.2 Moment Applied, Wind on Point F

height= 8.09 ft
width= 1.50 ft
angle= 0.18 radians
10.50 degrees
hypothenuse= 8.23 ft

Moment_F= **1,449.64** lbf-ft

2.3 Moment Reaction, Mass on Point D

height= 0.73 ft
8.78 in
width= 1.50 ft
18.00 in
angle= 0.45 radians
25.99 degrees
hypothenuse= 1.67 ft

Moment_D= **795.22** lb-ft

2.4 Moment Reaction, Moment on Guy Wire Plate

Height from Ground= 6.11 ft

Guy Wire Length= 8.64 ft
Degree= 45.00 degree

Minimum Moment_GW= **1,379.25** lb-ft

Minimum Force_GW= **319.27** lbf

3.0 Calculations Analysis

3.1 Velocity Tipping

Overturning Safety Factor= 1.50 *=(E59+E68)/(E47)

Velocity Tipping= 85.73 mph

3.2 Deadload

F_dead,Max= 75.00 psf
F_dead= 75.00 psf

Max Ballast Weight= 375.13 lbf
#50lbm sandbags= 7.50 #bags

3.3 Natural Frequency

Modulus of Elasticity (E)= 29,732,736.70 psi
Moment of Inertia of Tower Cross-Section (I)= 14.06 lbf-in^2
Mass of Tower= 128.02 lbf-in^2
Mass of Turbine= 25.00 lbf-in^2

Natural Frequency (f_n)= 0.86 Hz

3.4 Solar Ballast

Minimum Solar Ballast= 225.76 lbf

Module Roof Surface Area= 22.48 ft^2

F_dead,solar= 10.04 psf

NOTE.

1 The Guy Wire Plate has an inner diameter of 2"; therefore, will be placed on the inner tube and sit on the outer tube with a locking collar above.

2.1B. Wind Wheel Diameter Iteration 1

F_dead=	75.00	psf
Ballast Weight=	377.13	lb
x_1=	0	ft

V_Max, mph=	70	70	70	70	70	70
Wind Wheel Diameter=	36.00	39.00	42.00	45.00	48.00	51.00
F_E=	88.62	104.00	120.62	138.46	157.54	177.85
Moment_F=	717.24	841.76	976.24	1,120.69	1,275.09	1,439.46
Moment_D=	795.22	795.22	795.22	795.22	795.22	795.22
Moment_GW,MIN	280.65	467.43	669.15	885.82	1,117.43	1,363.98
F_GW_MIN	64.96	108.20	154.90	205.05	258.66	315.74
Overturning Safety Factor=	1.50	1.50	1.50	1.50	1.50	1.50
Velocity Tipping=	85.73	85.73	85.73	85.73	85.73	85.73
Minimum Solar Ballast=	45.94	76.51	109.53	144.99	182.90	223.26
F_dead,solar=	2.04	3.40	4.87	6.45	8.14	9.93

2.1B. Wind Wheel Diameter Iteration 2

F_dead=	75.00	psf
Ballast Weight=	377.13	lb
x_1=	0.5	ft

V_Max, mph=	70	70	70	70	70	70
Wind Wheel Diameter=	36.00	39.00	42.00	45.00	48.00	51.00
F_E=	88.62	104.00	120.62	138.46	157.54	177.85
Moment_F=	761.55	893.76	1,036.55	1,189.92	1,353.86	1,528.39
Moment_D=	795.22	795.22	795.22	795.22	795.22	795.22
Moment_GW,MIN	347.11	545.43	759.61	989.66	1,235.58	1,497.36
F_GW_MIN	74.27	116.71	162.54	211.76	264.38	320.39
Overturning Safety Factor=	1.50	1.50	1.50	1.50	1.50	1.50
Velocity Tipping=	85.73	85.73	85.73	85.73	85.73	85.73
Minimum Solar Ballast=	52.52	82.52	114.93	149.74	186.94	226.55
F_dead,solar=	2.34	3.67	5.11	6.66	8.32	10.08

2.1B. Wind Wheel Diameter Iteration 3

F_dead=	75.00	psf
Ballast Weight=	377.13	lb
x_1=	1	ft

V_Max, mph=	70	70	70	70	70	70
Wind Wheel Diameter=	36.00	39.00	42.00	45.00	48.00	51.00
F_E=	88.62	104.00	120.62	138.46	157.54	177.85
Moment_F=	805.86	945.76	1,096.86	1,259.15	1,432.64	1,617.31
Moment_D=	795.22	795.22	795.22	795.22	795.22	795.22
Moment_GW,MIN	413.57	623.43	850.08	1,093.51	1,353.74	1,630.75
F_GW_MIN	82.27	124.01	169.10	217.52	269.29	324.39
Overturning Safety Factor=	1.50	1.50	1.50	1.50	1.50	1.50
Velocity Tipping=	85.73	85.73	85.73	85.73	85.73	85.73
Minimum Solar Ballast=	58.17	87.69	119.57	153.81	190.42	229.38
F_dead,solar=	2.59	3.90	5.32	6.84	8.47	10.20

2.1B. Wind Wheel Diameter Iteration 4

F_dead=	75.00	psf
Ballast Weight=	377.13	lb
x_1=	1.5	ft

V_Max, mph=	70	70	70	70	70	70
Wind Wheel Diameter=	36.00	39.00	42.00	45.00	48.00	51.00
F_E=	88.62	104.00	120.62	138.46	157.54	177.85
Moment_F=	850.17	997.76	1,157.17	1,328.38	1,511.41	1,706.23
Moment_D=	795.22	795.22	795.22	795.22	795.22	795.22
Moment_GW,MIN	480.03	701.43	940.54	1,197.36	1,471.89	1,764.14
F_GW_MIN	89.21	130.36	174.80	222.53	273.55	327.87
Overturning Safety Factor=	1.50	1.50	1.50	1.50	1.50	1.50
Velocity Tipping=	85.73	85.73	85.73	85.73	85.73	85.73
Minimum Solar Ballast=	63.08	92.18	123.60	157.35	193.43	231.84
F_dead,solar=	2.81	4.10	5.50	7.00	8.60	10.31

2.1B. Wind Wheel Diameter Iteration 5

F_dead=	75.00	psf
Ballast Weight=	377.13	lb
x_1=	2	ft

V_Max, mph=	70	70	70	70	70	70
Wind Wheel Diameter=	36.00	39.00	42.00	45.00	48.00	51.00
F_E=	88.62	104.00	120.62	138.46	157.54	177.85
Moment_F=	894.47	1,049.76	1,217.48	1,397.62	1,590.18	1,795.16
Moment_D=	795.22	795.22	795.22	795.22	795.22	795.22
Moment_GW,MIN	546.50	779.43	1,031.00	1,301.21	1,590.05	1,897.52
F_GW_MIN	95.30	135.93	179.80	226.92	277.29	330.91
Overturning Safety Factor=	1.50	1.50	1.50	1.50	1.50	1.50
Velocity Tipping=	85.73	85.73	85.73	85.73	85.73	85.73
Minimum Solar Ballast=	67.39	96.11	127.14	160.46	196.08	233.99
F_dead,solar=	3.00	4.28	5.66	7.14	8.72	10.41

2.1B. Wind Wheel Diameter Iteration 6

F_dead=	75.00	psf
Ballast Weight=	377.13	lb
x_1=	2.5	ft

V_Max, mph=	70	70	70	70	70	70
Wind Wheel Diameter=	36.00	39.00	42.00	45.00	48.00	51.00
F_E=	88.62	104.00	120.62	138.46	157.54	177.85
Moment_F=	938.78	1,101.77	1,277.79	1,466.85	1,668.95	1,884.08
Moment_D=	795.22	795.22	795.22	795.22	795.22	795.22
Moment_GW,MIN	612.96	857.43	1,121.46	1,405.05	1,708.20	2,030.91
F_GW_MIN	100.69	140.85	184.22	230.80	280.60	333.61
Overturning Safety Factor=	1.50	1.50	1.50	1.50	1.50	1.50
Velocity Tipping=	85.73	85.73	85.73	85.73	85.73	85.73
Minimum Solar Ballast=	71.20	99.59	130.26	163.20	198.41	235.90
F_dead,solar=	3.17	4.43	5.79	7.26	8.83	10.49

2.1B. Wind Wheel Diameter Iteration 7

F_dead=	75.00	psf
Ballast Weight=	377.13	lb
x_1=	3	ft

V_Max, mph=	70	70	70	70	70	70
Wind Wheel Diameter=	36.00	39.00	42.00	45.00	48.00	51.00
F_E=	88.62	104.00	120.62	138.46	157.54	177.85
Moment_F=	983.09	1,153.77	1,338.10	1,536.08	1,747.72	1,973.01
Moment_D=	795.22	795.22	795.22	795.22	795.22	795.22
Moment_GW,MIN	679.42	935.43	1,211.93	1,508.90	1,826.36	2,164.30
F_GW_MIN	105.48	145.22	188.15	234.25	283.54	336.00
Overturning Safety Factor=	1.50	1.50	1.50	1.50	1.50	1.50
Velocity Tipping=	85.73	85.73	85.73	85.73	85.73	85.73
Minimum Solar Ballast=	74.58	102.69	133.04	165.64	200.49	237.59
F_dead,solar=	3.32	4.57	5.92	7.37	8.92	10.57

2.1B. Wind Wheel Diameter Iteration 8

F_dead=	75.00	psf
Ballast Weight=	377.13	lb
x_1=	3.5	ft

V_Max, mph=	70	70	70	70	70	70
Wind Wheel Diameter=	36.00	39.00	42.00	45.00	48.00	51.00
F_E=	88.62	104.00	120.62	138.46	157.54	177.85
Moment_F=	1,027.40	1,205.77	1,398.40	1,605.31	1,826.49	2,061.93
Moment_D=	795.22	795.22	795.22	795.22	795.22	795.22
Moment_GW,MIN	745.88	1,013.43	1,302.39	1,612.75	1,944.51	2,297.68
F_GW_MIN	109.77	149.15	191.67	237.35	286.17	338.15
Overturning Safety Factor=	1.50	1.50	1.50	1.50	1.50	1.50
Velocity Tipping=	85.73	85.73	85.73	85.73	85.73	85.73
Minimum Solar Ballast=	77.62	105.46	135.53	167.83	202.36	239.11
F_dead,solar=	3.45	4.69	6.03	7.47	9.00	10.64

2.1B. Wind Wheel Diameter Iteration 9

F_dead=	75.00	psf
Ballast Weight=	377.13	lb
x_1=	4	ft

V_Max, mph=	70	70	70	70	70	70
Wind Wheel Diameter=	36.00	39.00	42.00	45.00	48.00	51.00
F_E=	88.62	104.00	120.62	138.46	157.54	177.85
Moment_F=	1,071.71	1,257.77	1,458.71	1,674.54	1,905.26	2,150.86
Moment_D=	795.22	795.22	795.22	795.22	795.22	795.22
Moment_GW,MIN	812.34	1,091.44	1,392.85	1,716.60	2,062.67	2,431.07
F_GW_MIN	113.64	152.68	194.85	240.14	288.55	340.09
Overturning Safety Factor=	1.50	1.50	1.50	1.50	1.50	1.50
Velocity Tipping=	85.73	85.73	85.73	85.73	85.73	85.73
Minimum Solar Ballast=	80.36	107.96	137.78	169.80	204.04	240.48
F_dead,solar=	3.57	4.80	6.13	7.55	9.08	10.70

Appendix E. PV Watts Solar Feasibility

Note. Assuming 8 modules of 330W_{dc} with optimal angle.

2/19/22, 5:42 PM PVWatts Calculator

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Caution: Photovoltaic system performance predictions calculated by PVWatts® include many inherent assumptions and uncertainties and do not reflect variations between PV technologies nor site-specific characteristics except as represented by PVWatts® inputs. For example, PV modules with better performance are not differentiated within PVWatts® from lesser performing modules. Both NREL and private companies provide more sophisticated PV modeling tools (such as the System Advisor Model at https://sam.nrel.gov) that allow for more precise and complex modeling of PV systems.

The expected range is based on 30 years of actual weather data at the given location and is intended to provide an indication of the variation you might see. For more information, please refer to this NREL report: The Error Report.

The energy output range is based on analysis of 30 years of historical weather data for nearby, and is intended to provide an indication of the possible interannual variability in generation for a Fixed (open rack) PV system at this location.

RESULTS

3,603 kWh/Year*

System output may range from 3,453 to 3,789 kWh per year near this location.

Month	Solar Radiation (kWh / m[2] / day)	AC Energy (kWh)	Value ($)
January	3.14	211	19
February	3.94	241	22
March	4.70	298	27
April	5.55	335	30
May	6.09	372	34
June	6.65	377	34
July	6.56	380	34
August	6.31	360	33
September	5.73	323	29
October	4.79	299	27
November	3.57	225	20
December	2.70	181	16
Annual	4.98	3,602	$ 325

Location and Station Identification	
Requested Location	carbondale, il
Weather Data Source	Lat, Lon: 37.73, -89.22 0.4 mi
Latitude	37.73° N
Longitude	89.22° W
PV System Specifications *(Residential)*	
DC System Size	2.6 kW
Module Type	Standard
Array Type	Fixed (open rack)
Array Tilt	20°
Array Azimuth	180°
System Losses	14.08%
Inverter Efficiency	96%
DC to AC Size Ratio	1.2
Economics	
Average Retail Electricity Rate	0.091 $/kWh
Performance Metrics	
Capacity Factor	15.8%

https://pvwatts.nrel.gov/pvwatts.php 1/1

Appendix F. Manufacturer's Specifications

4130 Alloy Steel - Sheet

Note. The sheet will have the plasma cutter to cut the sheet into a circle with a diameter of 3' and a hole of 1-1.5" in the center to allow water drainage from inside the tube.

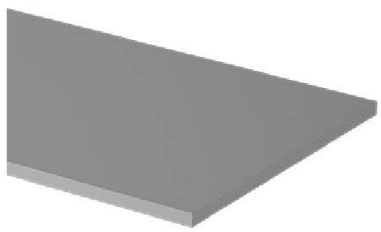
2/19/22, 5:25 PM Easy-to-Weld 4130 Alloy Steel, 36" x 36" x 1/4" | McMaster-Carr

McMASTER-CARR.

Easy-to-Weld 4130 Alloy Steel

36" x 36" x 1/4"

$311.32 Each
4459T291



Material	4130 Alloy Steel
Shape	Sheet and Bar
Shape Type	Sheets
Thickness	1/4"
Thickness Tolerance	-0.009" to 0.009"
Tolerance Rating	Standard
Width	36"
Width Tolerance	-1/16" to 1/16"
Length	36"
Length Tolerance	-1/16" to 1/16"
Yield Strength	50,000 psi
Fabrication	Hot Rolled
Heat Treatment	Annealed (Softened)
Hardness	Rockwell B85
Hardness Rating	Medium
Maximum Hardness After Heat Treatment	Rockwell C60
Heat Treatable	Yes
Certificate	Material Certificate with Traceable Lot Number
Appearance	Plain
Temperature Range	Not Rated
Specifications Met	SAE AMS6350, SAE AMS6351
Flatness Tolerance	Not Rated
Coefficient of Thermal Expansion	7.6×10^{-6}
Elongation	26.5%
Material Composition	
Aluminum	0.039%
Carbon	0.27-0.34%
Chromium	0.80-1.15%
Copper	0-0.25%
Hydrogen	0-2 ppm Max.

https://www.mcmaster.com/4459T291/ 1/3

Manganese	0.35-0.60%
Molybdenum	0.15-0.25%
Nickel	0-0.25%
Niobium	0.05% Max.
Phosphorus	0.011-0.035%
Silicon	0.15-0.40%
Sulfur	0.002-0.04%
Titanium	0.03% Max.
Vanadium	0-0.035%
Iron	Remainder
Warning Message	Physical and mechanical properties are not guaranteed. They are intended only as a basis for comparison and not for design purposes.
Additional Specifications	SDS
RoHS	RoHS 3 (2015/863/EU) Compliant
REACH	REACH (EC 1907/2006) (01/19/2021, 211 SVHC) Compliant
DFARS	Specialty Metals Compliant (252.225-7008, 252.225-7009)
Country of Origin	United States
USMCA Qualifying	No
Schedule B	722599.0002
ECCN	EAR99

4130 alloy steel has a low carbon content for good weldability. It's often used for gears, fasteners, and structural applications.

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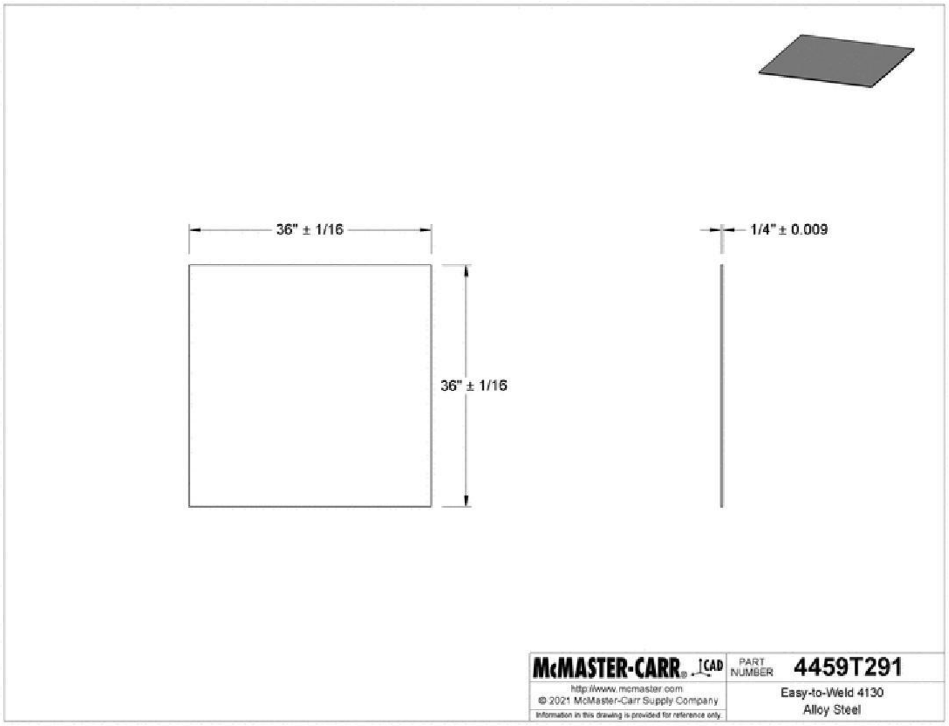

The information in this 3-D model is provided for reference only.

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4130 Alloy Steel - Outer Tube

Note. A hole will be drilled at the bottom between gussets for the 12 AWG wire to exit.

McMASTER-CARR.

Easy-to-Weld 4130 Alloy Steel Round Tube

0.188" Wall Thickness, 2-1/2" OD

89955K701

Material	4130 Alloy Steel
Shape	Round Tube
Shape Type	Round Tubes
Wall Thickness	0.188"
Wall Thickness Tolerance	-0.028" to 0.028"
Tolerance Rating	Standard
OD	2 1/2"
OD Tolerance	-0.010" to 0.010"
ID	2.124"
ID Tolerance	Not Rated
Yield Strength	70,000 psi
Fabrication	Cold Worked
Hardness	Rockwell C20
Hardness Rating	Hard
Maximum Hardness After Heat Treatment	Rockwell C49
Heat Treatable	Yes
Certificate	Material Certificate with Traceable Lot Number
Appearance	Plain
Temperature Range	Not Rated
Specifications Met	MIL-T-6736, SAE AMS-T-6736, SAE AMS6360
Straightness Tolerance	0.030" per 3 ft.
Coefficient of Thermal Expansion	7.6×10^{-6}
Elongation	26.5%
Material Composition	
Aluminum	0.039%
Carbon	0.27-0.34%
Chromium	0.80-1.15%
Copper	0-0.25%
Hydrogen	0-2 ppm Max.

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Manganese	0.35-0.60%
Molybdenum	0.15-0.25%
Nickel	0-0.25%
Niobium	0.05% Max.
Phosphorus	0.011-0.035%
Silicon	0.15-0.40%
Sulfur	0.002-0.04%
Titanium	0.03% Max.
Vanadium	0-0.035%
Iron	Remainder
Warning Message	Physical and mechanical properties are not guaranteed. They are intended only as a basis for comparison and not for design purposes.
Length Tolerance	Plus
Length	1 ft., 3 ft., 6 ft.
RoHS	Not Compliant
REACH	Not Compliant
DFARS	Specialty Metals COTS-Exempt
Country of Origin	Argentina, Australia, Brazil, Canada, France, Germany, India, Israel, Italy, Japan, New Zealand, Poland, Sweden, Taiwan, Ukraine, United Kingdom, or United States
USMCA Qualifying	No
Schedule B	730451.0000
ECCN	9A991

4130 alloy steel has a low carbon content that provides good weldability. It's often used for gears, fasteners, and structural applications. These tubes meet military specifications and SAE dimensional standards.

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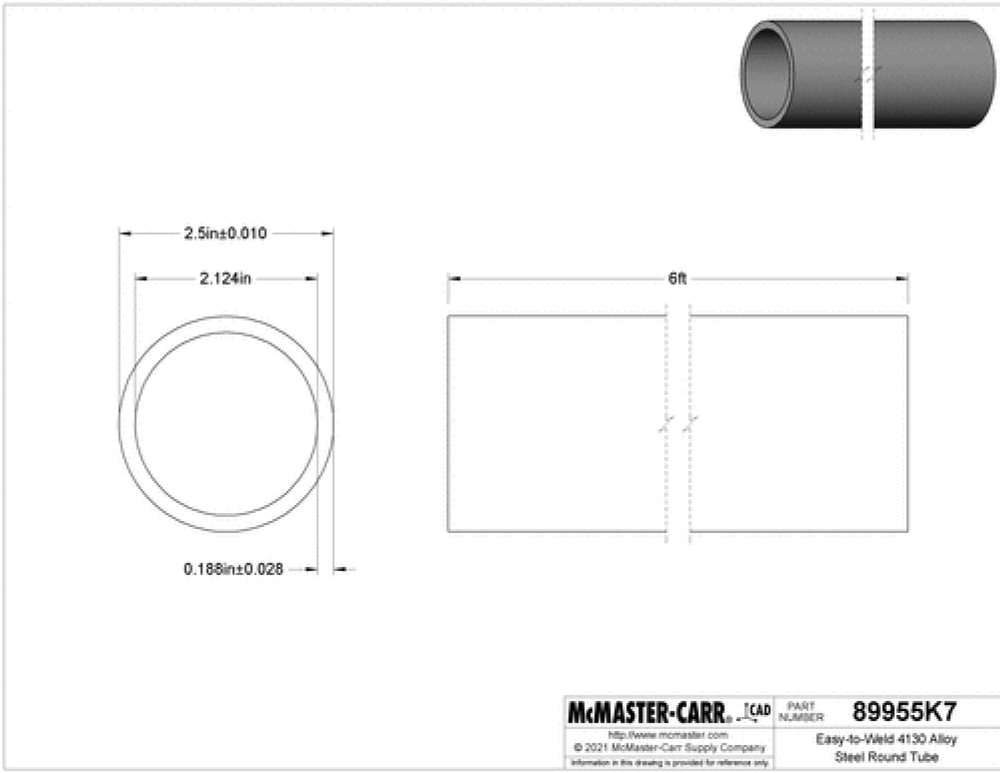
2.5in±0.010
2.124in
0.188in±0.028
6ft
McMASTER-CARR
PART NUMBER
89955K7
http://www.mcmaster.com
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Information in this drawing is provided for reference only.
Easy-to-Weld 4130 Alloy
Steel Round Tube

4130 Alloy Steel - Inner Tube

2/19/22, 5:24 PM Easy-to-Weld 4130 Alloy Steel Round Tube, 0.095" Wall Thickness, 2" OD | McMaster-Carr

McMASTER-CARR.

Easy-to-Weld 4130 Alloy Steel Round Tube

0.095" Wall Thickness, 2" OD

89955K388

Material	4130 Alloy Steel
Shape	Round Tube
Shape Type	Round Tubes
Wall Thickness	0.095"
Wall Thickness Tolerance	-0.014" to 0.014"
Tolerance Rating	Standard
OD	2"
OD Tolerance	-0.010" to 0.010"
ID	1.81"
ID Tolerance	Not Rated
Yield Strength	70,000 psi
Fabrication	Cold Worked
Hardness	Rockwell C20
Hardness Rating	Hard
Maximum Hardness After Heat Treatment	Rockwell C49
Heat Treatable	Yes
Certificate	Material Certificate with Traceable Lot Number
Appearance	Plain
Temperature Range	Not Rated
Specifications Met	MIL-T-6736, SAE AMS-T-6736, SAE AMS6360
Straightness Tolerance	0.030" per 3 ft.
Coefficient of Thermal Expansion	7.6×10^{-6}
Elongation	26.5%
Material Composition	
Aluminum	0.039%
Carbon	0.27-0.34%
Chromium	0.80-1.15%
Copper	0-0.25%
Hydrogen	0-2 ppm Max.

https://www.mcmaster.com/89955K388/ 1/2

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Manganese	0.35-0.60%
Molybdenum	0.15-0.25%
Nickel	0-0.25%
Niobium	0.05% Max.
Phosphorus	0.011-0.035%
Silicon	0.15-0.40%
Sulfur	0.002-0.04%
Titanium	0.03% Max.
Vanadium	0-0.035%
Iron	Remainder
Warning Message	Physical and mechanical properties are not guaranteed. They are intended only as a basis for comparison and not for design purposes.
Length Tolerance	Plus
Length	1 ft., 3 ft., 6 ft.
RoHS	Not Compliant
REACH	Not Compliant
DFARS	Specialty Metals COTS-Exempt
Country of Origin	Argentina, Australia, Brazil, Canada, France, Germany, India, Israel, Italy, Japan, New Zealand, Poland, Sweden, Taiwan, Ukraine, United Kingdom, or United States
USMCA Qualifying	No
Schedule B	730451.0000
ECCN	9A991

4130 alloy steel has a low carbon content that provides good weldability. It's often used for gears, fasteners, and structural applications. These tubes meet military specifications and SAE dimensional standards.

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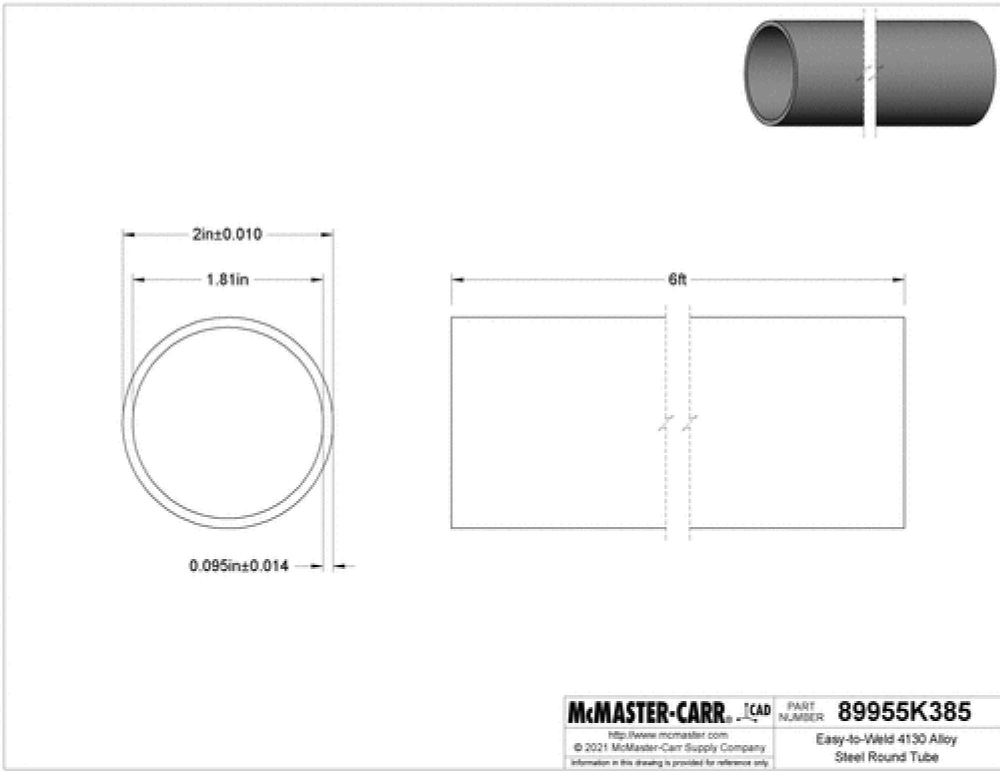
2in±0.010
1.81in
6ft
0.095in±0.014
McMASTER-CARR
PART NUMBER
89955K385
http://www.mcmaster.com
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Information in this drawing is provided for reference only.
Easy-to-Weld 4130 Alloy
Steel Round Tube

Guy Wire

Note. Both the guy wire ring and locking collar will fit the inner tube proposed.

Guy Wire Ring

Missouri Wind And Solar

Now: $8.88

Write a Review

SKU: GY34RING-2

Diameter: * 2 Inch

Quantity: 1

ADD TO CART

Wind Turbine Locking Collar

Missouri Wind And Solar

Now: $10.69

Write a Review

SKU: COLLAR-2IN

Diameter: * 2 Inch

Optional Nylon Washer: * No Washer

Quantity: 1

ADD TO CART

OVERVIEW

PRODUCT DESCRIPTION

Guy Wire Ring

For use with our wind turbine locking collar. The locking collar provides your wind turbine tower guy wire rings something to rest on with no welding required.

Adding guy wires to your wind turbine tower reduces swaying and vibration that decreases wind turbine output.

Guy Wire Ring Features:

- Fits up to 1/4" guy wire
- Configured for 3 or 4 guy wires
- 1/8 inch (3.27 mm)

	1.5 Inch Guy Wire Ring (GY34RING) Powder Coated	**2 Inch Guy Wire Ring** (GY34RING_2) Zinc Plated
Inside Diameter:	1 15/16 Inches (49 mm)	2 7/16 Inches (61.9 mm)
Outside Diameter:	4 3/4 Inches (120.65 mm)	
Guy Wire Hole Diameter:	3/8 Inches (9.5 mm)	3/8 Inches (9.5 mm)
Fits Pole Size:	1 7/8 Inches OD (47.6 mm)	2 3/8 Inches OD(60.3 mm)

Recommended Use (locking collar not included):

Wind Turbine Generator

Note. We are manufacturing the blades to fit this wind turbine's hub with carbon fiber.

Wind wheel diameter

Specifications:

Rated power:400 W

Maximum power:410 W

Number of blades:3

Rated voltage:24 V

Start-up wind speed:2.5 m/s

Rated wind speed :13 m/s

Working speed:3-25 m/s

Survival wind speed:40 m/s

Wind wheel diameter: 51.18 inch

- Blade Material: Nylon Fiber
- Generator Type: 3-Phase AC Permanent Magnet Generator
- Braking Method: Electromagnetic
- Wind Direction Adjustment: Automatically Adjust The Windward Angle
- Operating Temperature: -40 ~ 80 ℃
- Magnetic Material: Neodymium Iron Boron
- Cabin Material: Die Casting Aluminum Alloy

Package Content:

Wind Turbine x 1

Blades x 3

Controller x 1

Nose Cone x 1

Set Screws and Nuts x 1

Installation Notes x 1

Anemometer x 1 (no battery)

Note:Without tower tube

(We recommend: steel pipes or iron pipes, diameter :55±2mm)

- Application
- 1. For Home Use
- 2. For Monitoring Use
- 3. For Boat / Marine Use
- 4. For Wind Solar Hybrid Streetlight Use And More

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High efficiency

1.Three-phase permanent magnet synchronous motor. Efficient and compact ac generator with high performance NdFeB permanent magnet.

2. A fully integrated voltage regulator that automatically shuts down when the battery is fully charged.

3.The fan is controlled by MPPT intelligent microprocessor, which can effectively adjust current and voltage.

4.The unique magnetic circuit design makes the starting torque very small, which can effectively ensure the wind turbine's breeze starting ability.

High quality

1.The wind turbine is made entirely of high quality aluminum and stainless steel fittings. It is not only lightweight, small in size, but also compact in shape.

2.The blade material is made of high-strength plastic with 30% carbon fiber and anti-UV anti-corrosion material, which is both beautiful and durable.

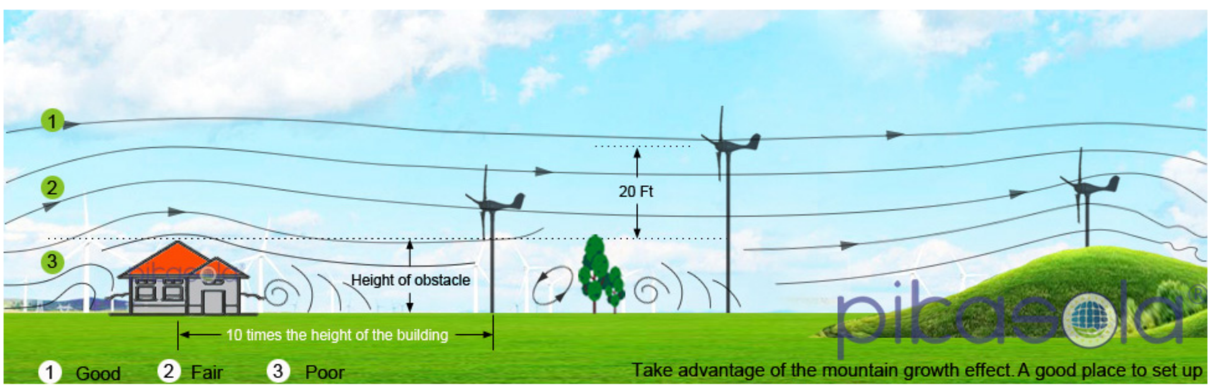
3.The surface of the wind turbine is coated with a special process that provides excellent resistance to oxidation and corrosion under any harsh conditions, as well as excellent corrosion resistance, water resistance and sand resistance.

Easy installation

1． Nesting the black leather cushion inside the reducing joint of the wind turbine then putting the tower inside reducing joint. Connecting the cover of reducing joint by screws and fastening. Tightening the screws by hex key.

2． The three wires of the wind turbine are connected to the transmission cable, each pair of wires is not less than 30 mm, and the tape at the connection end is at 100 mm.

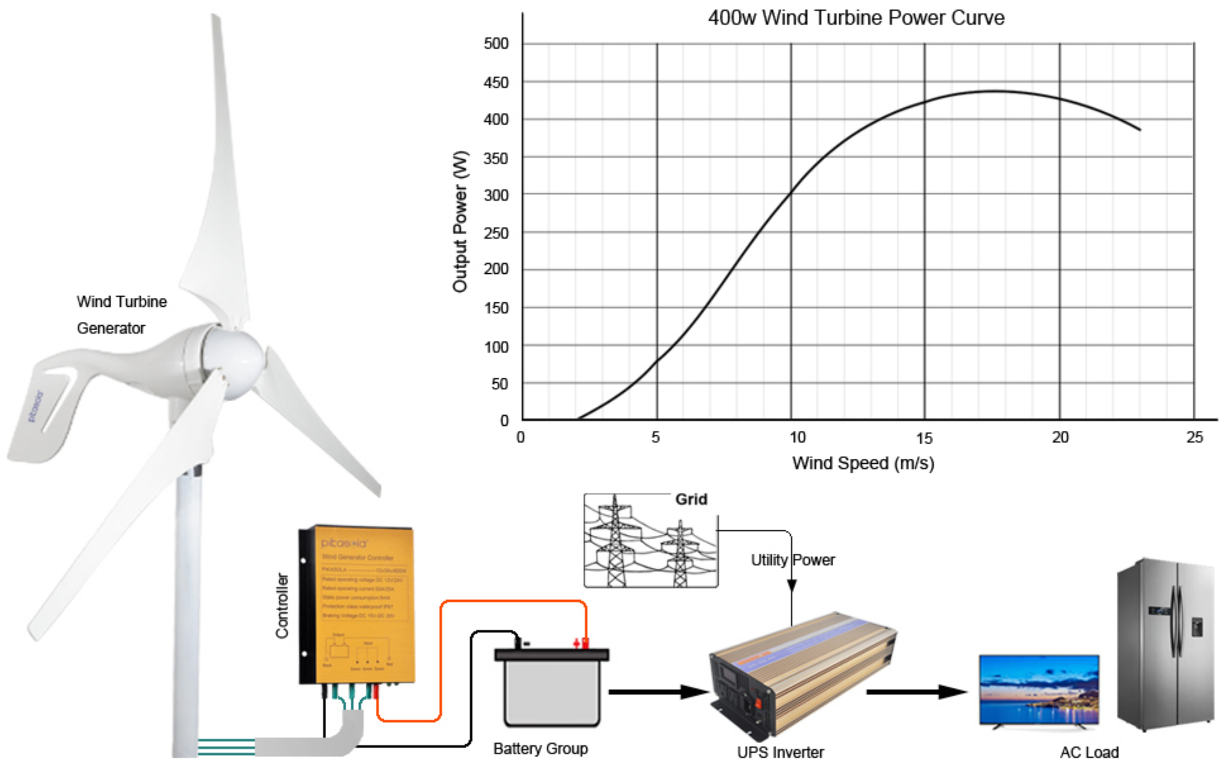
3． Connect the wind turbine's cable to the controller and the battery must be connected to the controller before wiring.



1. The wind turbine should be installed where there is strong wind or no tall buildings and obstacles, If installing the wind turbines near the obstacles, the position is better as far as possible from obstructions, or the installation height should be 20Ft higher than the top of obstructions(As show), which can make full use of the wind power.

2. We can make use of the growth effect on the hills (As show). It's a good place to set up

3. It's should avoid the cliff, the turbulent region.



Feature:

1. Starting with low speed; high wind energy utilization; beautiful appearance; low vibration on operation.

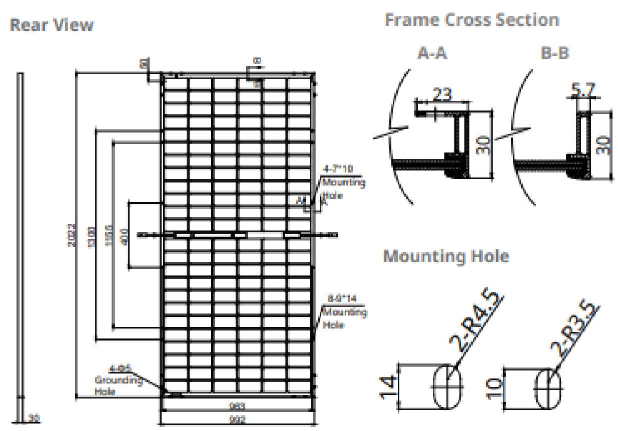
2.Being installed by human design and easy for installation, maintenance and repair.

3.Being molded through precise injection with new process, together with the optimized design of aerodynamic contour and structure, our wind turbine blades have such advantages: high utilization of wind energy which contributes to the annual energy output.

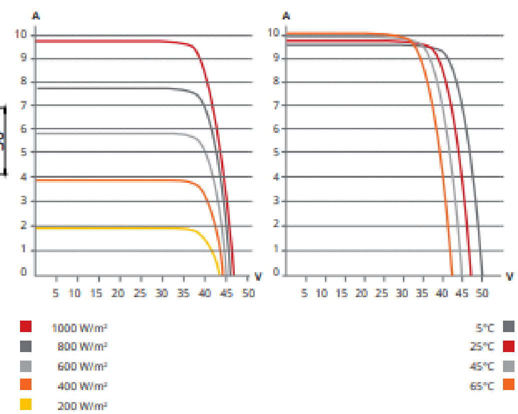
4.Our generators, adopting patented permanent magnet rotor alternator, with a special kind of stater design, efficiently decrease resistance torque of the generators.

Solar Module

ENGINEERING DRAWING (mm)



CS3U-370MB-AG / I-V CURVES



ELECTRICAL DATA | STC*

		Nominal Max. Power (Pmax)	Opt. Operating Voltage (Vmp)	Opt. Operating Current (Imp)	Open Circuit Voltage (Voc)	Short Circuit Current (Isc)	Module Efficiency
CS3U-370MB-AG		370 W	39.6 V	9.35 A	47.4 V	9.85 A	18.45%
Bifacial Gain**	5%	389 W	39.6 V	9.82 A	47.4 V	10.34 A	19.39%
	10%	407 W	39.6 V	10.29 A	47.4 V	10.84 A	20.29%
	20%	444 W	39.6 V	11.22 A	47.4 V	11.82 A	22.14%
	30%	481 W	39.6 V	12.16 A	47.4 V	12.81 A	23.98%
CS3U-375MB-AG		375 W	39.8 V	9.43 A	47.6 V	9.93 A	18.70%
Bifacial Gain**	5%	394 W	39.8 V	9.9 A	47.6 V	10.43 A	19.64%
	10%	413 W	39.8 V	10.37 A	47.6 V	10.92 A	20.59%
	20%	450 W	39.8 V	11.32 A	47.6 V	11.92 A	22.43%
	30%	488 W	39.8 V	12.26 A	47.6 V	12.91 A	24.33%
CS3U-380MB-AG		380 W	40 V	9.5 A	47.8 V	10.01 A	18.94%
Bifacial Gain**	5%	399 W	40 V	9.98 A	47.8 V	10.51 A	19.89%
	10%	418 W	40 V	10.45 A	47.8 V	11.01 A	20.84%
	20%	456 W	40 V	11.4 A	47.8 V	12.01 A	22.73%
	30%	494 W	40 V	12.35 A	47.8 V	13.01 A	24.63%
CS3U-385MB-AG		385 W	40.2 V	9.58 A	48 V	10.09 A	19.19%
Bifacial Gain**	5%	404 W	40.2 V	10.06 A	48 V	10.59 A	20.14%
	10%	424 W	40.2 V	10.54 A	48 V	11.1 A	21.14%
	20%	462 W	40.2 V	11.5 A	48 V	12.11 A	23.03%
	30%	501 W	40.2 V	12.45 A	48 V	13.12 A	24.98%

* Under Standard Test Conditions (STC) of irradiance of 1000 W/m², spectrum AM 1.5 and cell temperature of 25°C.
** Bifacial Gain: The additional gain from the back side compared to the power of the front side at the standard test condition. It depends on mounting (structure, height, tilt angle etc.) and albedo of the ground.

ELECTRICAL DATA

Operating Temperature	-40°C ~ +85°C
Max. System Voltage	1500 V (IEC/UL) or 1000 V (IEC/UL)
Module Fire Performance	TYPE 3 / Type 13 (UL 1703) or CLASS A (IEC61730)
Max. Series Fuse Rating	20 A
Application Classification	Class A
Power Tolerance	0 ~ + 5 W
Power Bifaciality*	70 %

* Power Bifaciality = $Pmax_{rear}$ / $Pmax_{front}$, both $Pmax_{rear}$ and $Pmax_{front}$ are tested under STC, Bifaciality Tolerance: ± 5 %

ELECTRICAL DATA | NMOT*

	Nominal Max. Power (Pmax)	Opt. Operating Voltage (Vmp)	Opt. Operating Current (Imp)	Open Circuit Voltage (Voc)	Short Circuit Current (Isc)
CS3U-370MB-AG	276 W	36.7 V	7.51 A	44.6 V	7.94 A
CS3U-375MB-AG	280 W	36.9 V	7.58 A	44.8 V	8.01 A
CS3U-380MB-AG	284 W	37.1 V	7.64 A	45.0 V	8.07 A
CS3U-385MB-AG	287 W	37.3 V	7.70 A	45.1 V	8.14 A

* Under Nominal Module Operating Temperature (NMOT), irradiance of 800 W/m² spectrum AM 1.5, ambient temperature 20°C, wind speed 1 m/s.

MECHANICAL DATA

Specification	Data
Cell Type	Mono-crystalline
Cell Arrangement	144 [2 X (12 X6)]
Dimensions	2022 × 992 × 30 mm (79.6 × 39.1 × 1.18 in)
Weight	25.7 kg (56.7 lbs)
Front / Back Glass	2.0 mm heat strengthened glass
Frame	Anodized aluminium alloy
J-Box	IP68, 3 diodes
Cable	4.0 mm² (IEC), 12 AWG (UL)
Cable Length (Including Connector)	Portrait: 400 mm (15.7 in) (+) / 280 mm (11.0 in) (-); landscape: 1400 mm (55.1 in); leap-frog connection: 1670 mm (65.7 in)*
Connector	T4 series
Per Pallet	35 pieces
Per Container (40' HQ)	770 pieces or 595 pieces (only for US and Canada)

* For detailed information, please contact your local Canadian Solar sales and technical representatives.

TEMPERATURE CHARACTERISTICS

Specification	Data
Temperature Coefficient (Pmax)	-0.37 % / °C
Temperature Coefficient (Voc)	-0.29 % / °C
Temperature Coefficient (Isc)	0.05 % / °C
Nominal Module Operating Temperature	41 ± 3°C

Solar Racking

Note. We will receive a discount through our sponsors: C.H. Electrical and Supplied Energy.

BI-DIRECTIONAL Q CELLS FLAT ROOF SYSTEM

Q.FLAT-G4 is the perfect flat roof system for an easy, fast and safe installation without the need for any roof penetration. The innovative mounting system minimises the installation effort and the float-mounting of the modules increases the long-term stability and safety. With a power density of 165 Wp/m² and a 10° inclination (as compared to 70 Wp/m² with a standard 30°-mounted system)[1] Q.FLAT-G4 is the best solution for highest yields.

MAXIMUM YIELDS
Flat roof space utilisation of up to 82% – twice as much as an installation with 30° inclination.

EASY AND FAST INSTALLATION
Sequential installation of sub structure and modules as well as the innovative mounting – up to 50% cost reduction compared with a standard 30°-mounted system.

SAFE CONSTRUCTION
Long-term stability due to strainless, float-mounting of the modules.

MINIMUM STATIC LOAD
Lightweight construction as well as minimal additional ballast.

VERIFIED QUALITY
Certifed in accordance with the most comprehensive quality program on the PV market – VDE Quality Tested.

REDUCING REQUIRED MEASUREMENTS
After the first section is positioned, the distance to the following sections are set by the positioning of the ballast carriers.

EUPD RESEARCH TOP BRAND PV MODULES EUROPE 2018

Q CELLS YIELD SECURITY: ANTI PID TECHNOLOGY (APT), HOT-SPOT PROTECT (HSP), TRACEABLE QUALITY (TRA.Q™), ANTI LID TECHNOLOGY (ALT)

VDE Quality Tested, www.VDEinfo.com ID. 40032587

Photon: Q CELLS Best polycrystalline solar module 2014, Q.PRO-G2 235, 174 modules tested

[1] when using 330 Wp modules

THE IDEAL SOLUTION FOR:

Commercial and industrial rooftop installations

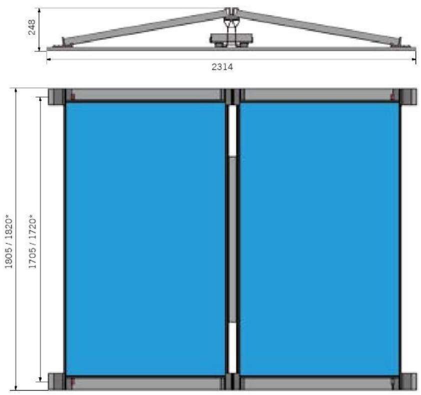
Engineered in **Germany**

Q CELLS

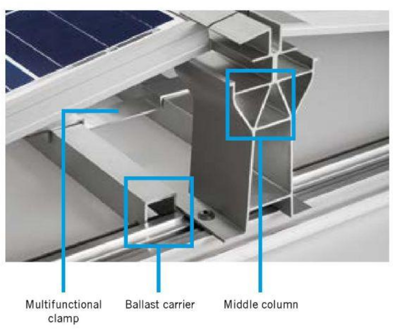
MECHANICAL SPECIFICATION

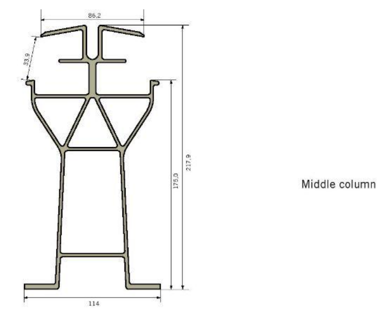
Dimensions	2314 mm × 1805 mm / 1820 mm* × 248 mm
Dimension between axes of a module pair	1705 mm / 1720 mm*
Inclination	10°
Max. roof inclination	5°
Standard parts	Multifunction clamp, Ballast carrier, Module spacer, Girder, Nut (stainless steel), Screw DIN EN ISO 7380-2 (stainless steel), Middle column, End clamp, Roofing protection mat (aluminium cover)
Optional parts	Multifunction clamp, Grounding clamp Self drilling screw
Material of components	Mill-finish aluminium
Modules	Q.PLUS BFR-G4.1, Q.PLUS-G4.3, Q.PEAK-G4.1, Q.PEAK BLK-G4.1, Q.PEAK DUO-G5, Q.PEAK DUO BLK-G5
Power classes of the modules	275-330 Wp
Module cable	4 mm² solar cable; (+) ≥ 1000 mm, (-) ≥ 1000 mm
Module connectors	Multi-Contact MC4, IP68

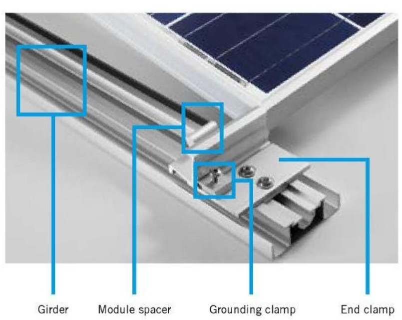
*for Q.PEAK DUO-G5, Q.PEAK DUO BLK-G5

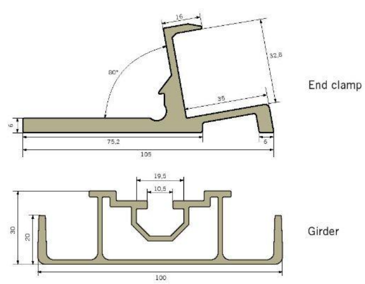


SYSTEM DETAILS









NOTE: Installation instructions must be followed. See the installation and operating manual or contact the technical service for further information on approved installation and use of this product. For detailed information on the Q CELLS solar modules, please refer to the valid module data sheet. The data sheet and installation manual are available on www.q-cells.co.uk.

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