OBERLIN
COLLEGE & CONSERVATORY

REpowering Schools Hybrid System Design: Dorseys' Learning Center

PROJECT REPORT

Authors: Otavio Paz Nascimento
Ryan Fontanez

Advisor: Charles Newcomb

December 2023

Oberlin, OH

Contents

1. Executive project summary..... 2
2. Summary of application..... 4
3. Description of location, load, renewable energy sources and design constraints..... 4
4. Modeling parameters and design robustness..... 5
4.1. Wind system..... 5
4.2. Solar system..... 6
5. Proposed design..... 7
6. Considerations for system implementation..... 8
7. Summary of testing..... 11
8. Areas of further investigation..... 11
Appendix..... 12

1. Executive project summary

This project aims to provide an off-grid power supply for the Dorseys' remote learning center. The multi-purpose learning center offers a space for a wide range of needs. It can be a place to disconnect for those who need a retreat from the modern world, a classroom for focused group learning, and even an art studio.

The Amish-built learning center has three buildings: the **classroom/cabin** (see Figure 1), an **outhouse** (see Figure 2) with a composting toilet and a **sugar shed** (see Figure 2). The cabin has a wood stove for cooking and heating, a lofted sleeping area, and a study area in the main room. The sugar shed is used during the sugaring season to make maple syrup. Each building comes with a unique set of needs.



Figure 1 – Cabin



Figure 2 – Outhouse and Sugar shed (left to right)

The cabin has no built-in lighting and gets very dark at night and in the winter months. Adding overhead lights and desk lamps would greatly help the space. A typical user also needs access to electrical outlets to charge their phone or laptop.

During the sugaring season, the sugar shed is used 24/7 to boil sap, which requires constant light during the nighttime hours.

The composting toilet (Separett Villa 9215) constantly requires a small fan and a lamp for light when in use.

The learning center can be used for up to days, meaning it needs to provide consistent power for an extended period, even when it is dark or overcast. One of the goals of the learning center is to provide a space to reconnect with yourself and nature. In this light, we aim to provide power via an entirely off-grid, renewable energy system.

2. Summary of application

Based on the needs outlined in the executive summary, we propose a hybrid renewable energy system to provide energy to the learning center.

A photovoltaic (PV) array will be the primary power source, supplemented by a micro wind turbine. Based on the system's calculated loads, we settled on an array of four 365W panels. These will be roof-mounted on the cabin to limit the impact on the surrounding environment. Two panels will be joined in series and then connected to two charge controllers. From there, they will combine with the micro wind turbine output and a 2400Wh battery. These parts combined will feed into an inverter connected to a load center. This load center will then distribute power to the three buildings.

3. Description of location, load, renewable energy sources and design constraints

The site, located in North Central Ohio, faces south onto a large clearing in a woodland area (see Figure 3). Due to being in this location, the site gets an average of 3.9 fixed tilt sunlight hours per day. Being surrounded by woods, the site is extremely protected and receives minimal wind. The area experiences all four seasons and is subject to rain, snow, and falling leaves in autumn. To preserve the site's visual appeal, we are constrained to the roofs of the buildings to rack any solar panels.



Figure 3 – Drone footage of the site

4. Modeling parameters and design robustness

This report will describe the tools the team have used to design the hybrid system: wind and solar system. It is important to add that the primary objective of implementing the wind system is to serve as an educational tool and it aims to promote awareness and understanding of sustainable practices among the individuals utilizing the learning center space.

4.1. Wind system

For the wind system, our approach involved leveraging the information provided by the National Renewable Energy Laboratory (NREL) maps, accessible through the WINDExchange platform, to determine the wind potential in Ohio. Specifically, we utilized the NREL maps data to evaluate the wind resources in the surrounding areas of Cleveland. According to the data, these areas exhibit an average wind speed ranging from 6.5 to 6.75 m/s at a height of 100m, indicating a suboptimal wind resource.

Additionally, we considered the “Ohio - Annual Average Wind Speed at 30m” data, which revealed that the Lorain County area, where Oberlin is situated, experiences a wind speed of 5 m/s[1].

We considered these mesoscale maps to enhance the precision of our assessment, since they were developed by AWS True Power (TrueWind). The research behind the maps involves the use of simulated wind data from a mesoscale model in Measure-Correlate-Predict (MCP), a technique for estimating long-term wind speeds at a wind project site. Proper use of MCP is crucial as it provides accurate predictions of long-term wind conditions, essential for the success of wind energy projects[2].

We also integrated data from the Global Wind Atlas (see Figure 4) to understand the wind conditions specific to the site, mainly the direction of the wind (see Figure 5). This decision was guided by the credibility and reliability of the GWA dataset, which has undergone validation by DTU Wind Energy. The validation process involved leveraging data from ESMAP-funded measurement campaigns and other publicly available high-quality wind data.

[1] Wind Energy in Ohio, "WINDExchange," U.S. Department of Energy, accessed October 19, 2023, https://windexchange.energy.gov/states/oh.

[2] M. Taylor, J. Freedman, K. Waight, and M. Brower, "USING SIMULATED WIND DATA FROM A MESOSCALE MODEL IN MCP," AWS TrueWind, May 2009, accessed December 21, 2023.

`

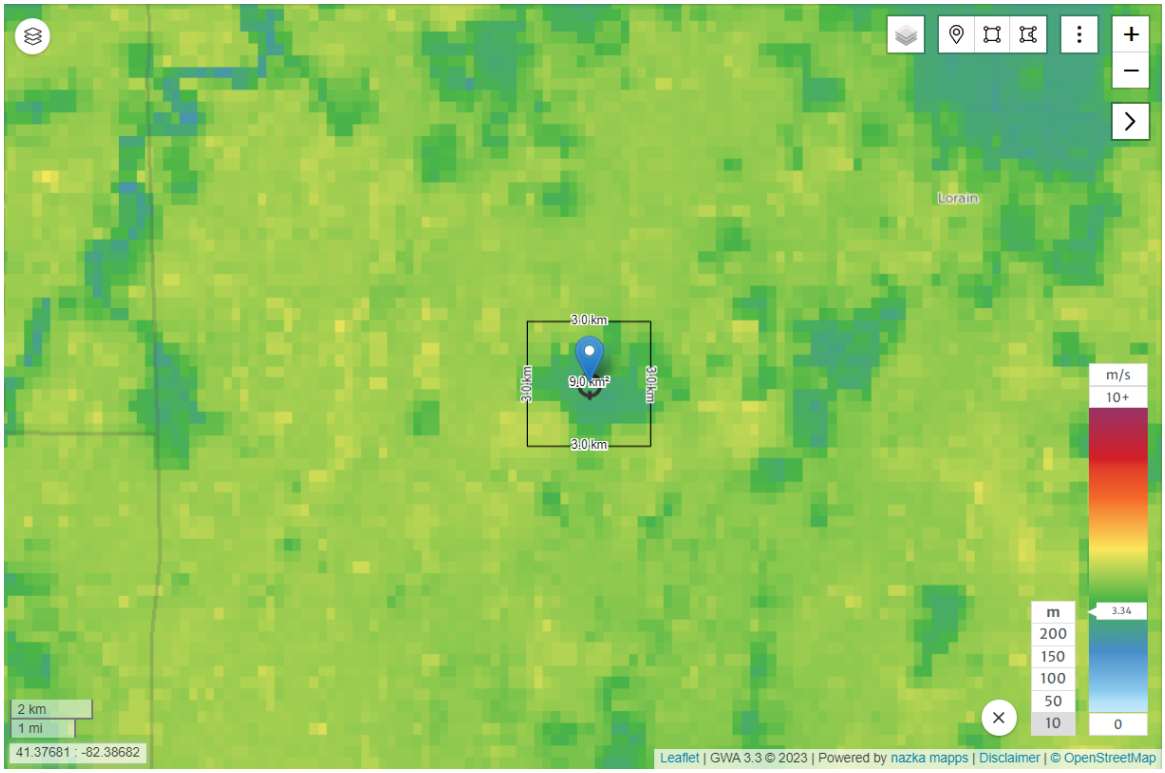


Figure 4 – GWA view of Oberlin/OH

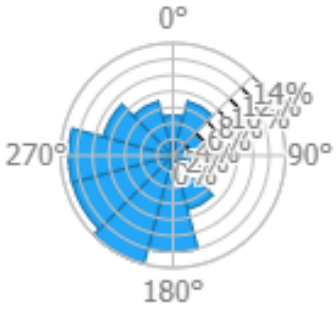


Figure 5 – Wind Frequency Rose of site

4.2. Solar system

For the solar system, we utilized the PVWatts platform, a tool developed by the National Renewable Energy Laboratory (NREL) that estimates the electricity generation of a grid-connected photovoltaic (PV) system. This platform utilizes hourly solar resource data from the NREL National Solar Radiation Database (NSRDB) and other sources worldwide.

PVWatts operates using hourly typical meteorological year (TMY) data, representing one year's worth of solar resource conditions over a multi-year period. The platform considers the latitude and longitude of the system's location, providing valuable insights into solar irradiance and meteorological data specific to the project site.

We initially employed the ShadowCalculator by KameoCode to estimate potential shading patterns. However, it has come to our attention that the map data in the tool may not be fully updated. In response to this, we sought alternative methods to ensure accurate shading assessments.

According to the information provided by the client, the roof in question consistently receives sunlight. Considering the geographical location of Oberlin at 41.2939° N, with the roof facing south and no significant obstructions, except by two trees to the south of the properties, we anticipate minimal shading effects (see Figure 6).



Figure 6 – Drone footage of the property

5. Proposed design

The proposed design is divided into a Design Overview, detailing the components and operation, and Estimations, where calculated performance predictions are derived from owner interviews and tools like PVWatts and NREL maps of Ohio.

The site of the project is located at the back of the Dorseys' property (see Figure 3).

5.1. Design overview

The project's design takes Dorseys' expectations and the team's capabilities and limitations into consideration.

It's a 12V hybrid system that utilizes mainly solar energy to accommodate the energy needs of the properties.

The energy generation components include four Q CELLS 365W Solar Panel and the Air X Marine Wind Turbine Generator. The solar panel, rated at 365W, will be arranged in two arrays of 730W on the roof south-facing with an azimuth angle of 180, while the turbine operates at 400W, and it will be installed on 10ft schedule 40 1-1/2" pole on the ground facing southwest.

Two Tracer AN Series 60A MPPT Charge Controllers will serve as a key component to efficiently manage and regulate the charging of the two HYG12-200Ah Rechargeable Gel Deep Cycle 12V batteries. This charge controller is versatile, accommodating input voltages from 12V to 48V, providing flexibility for the system. The battery will have a DC Disconnect B60 switch to turn off the circuit between a DC bus and the battery and a 100A Type T Fuse for safety reasons.

The Pelican 1550 Case provides secure storage for sensitive equipment, such as batteries and inverters.

For monitoring and data collection, the project expects to incorporate a HOBO 4-Channel Analog Data Logger, DC Voltage and DC Current Sensors, providing insights into system performance if more funding is available. However, the team has discussed other alternatives to collect the energy generation data and inform the residents on this matter.

5.2. Estimations

In the initial phase, we conducted interviews with the space owners to understand their energy needs. Using this information, we developed a spreadsheet with detailed calculations and estimations to predict energy usage in worst-case scenarios (see Appendix). This comprehensive approach included the use of the Outhouse, Sugar shed and the cabin simultaneously during the month of February with lights, charging phones, rechargeable lanterns, and laptops.

For the solar system, we utilized the PVWatts website to estimate electricity generation (see Figure 7) and solar irradiation. Our calculations considered potential losses due to shading, providing a more realistic projection of solar energy output. A day with constant electricity usage in February averaged 650.83 Wh for the Cabin occupied by a person, Sugar Shed being used for the entire day, and Outhouse.

RESULTS

1,710 kWh/Year*

System output may range from 1,657 to 1,749 kWh per year near this location.

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)
January	2.24	80
February	3.19	103
March	4.14	144
April	5.06	164
May	5.95	193
June	6.30	192
July	6.43	199
August	5.93	186
September	5.21	161
October	3.91	133
November	2.50	85
December	1.97	70
Annual	4.40	1,710

Figure 7 – PVWatts estimation for Oberlin/OH

Considering the desired pack of two 200Ah Deep Cycle batteries, we estimated an autonomy of 4.4 days with a Net Watt-hour of 2880Wh (60% of the full capacity of the pack). The system will take approximately 2.1 days to refill after depletion.

In the case of the wind system, information from the NREL maps of Ohio provided by WINDExchange allowed us to estimate average power generation. However, based on our estimations, the wind system is primarily ornamental due to the specific wind characteristics in the area. This aligns with our commitment to transparency and practicality, ensuring that the project meets both functional and aesthetic objectives.

To evaluate the wind resources, we employed the Wind Profile Calculator from the Swiss Wind Power Data website. Augmented by wind data obtained from NREL maps, we conducted a preliminary estimation of the wind resources available at our location (see Figure 8).

height above ground	wind speed
150 m	6.86 m/s
140 m	6.78 m/s
130 m	6.70 m/s
120 m	6.61 m/s
110 m	6.50 m/s
100 m	6.39 m/s
90 m	6.27 m/s
80 m	6.14 m/s
70 m	5.98 m/s
60 m	5.80 m/s
50 m	5.59 m/s
40 m	5.33 m/s
30 m	5.00 m/s
20 m	4.53 m/s
10 m	3.73 m/s

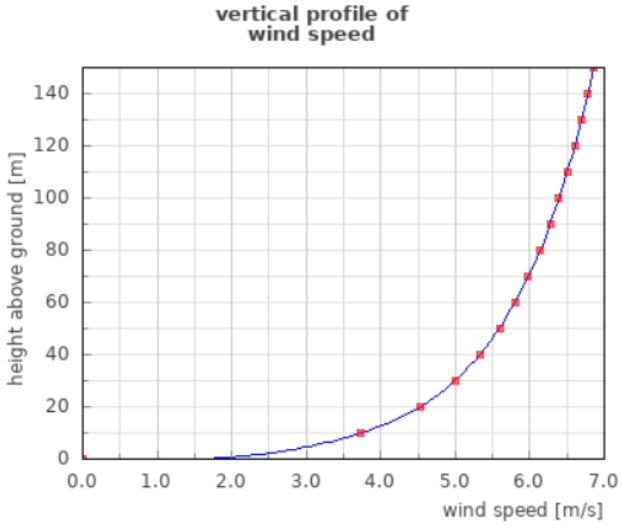


Figure 8 - Logarithmic wind profile results

Through this combined effort, we conducted a preliminary estimation of the wind resources at our location. However, it is noteworthy that the average wind speed determined is considerably below the minimum requirement for an effective wind turbine system. We are also considering the proximity to buildings and trees around the area (see Figure 3). Consequently, we do not anticipate generating significant energy from the wind component of our system.

6. Considerations for system implementation

The long-term plans for this project are still undetermined. The owner of the site is considering the possibility of connecting the learning center to the grid in the next three to five years. In this scenario, the intention would be to find a permanent application for the system that still preserves its original goals. Creating an off grid charging center in the sports fields, an interactive display of renewable energies at the local elementary school, or a mobile cart to power speakers for large outdoor events are all ideas that are being discussed.

Additionally, we predict some challenges for the implementation of electrical system, primarily due to the spatial arrangement of buildings. Since that the structures are adjacent but not interconnected, we need to establish links while preserving the aesthetic.

In the upcoming semester, our focus will be on securing additional funding. We plan to approach the Green Edge Fund (Oberlin College's ecological fund for projects and initiatives) once we start the implementation.

In any case, maintaining the ideals and design intentions would be the highest priority.

7. Summary of testing

We faced some challenges in terms of the testing due to time and skills constraints. While we couldn't conduct comprehensive testing, we did assess the luminosity of a similar string lights we will be installing in the cabin.

We plan to address this limitation by conducting detailed consumption tests on specific devices, utilizing a Kill-A-Watt (P3 P4400) for accurate measurement during the Spring Term.

8. Areas of further investigation

We would like to incorporate some method of visualizing the data that we gather about our system and utilize it for educational purposes. The Environmental Dashboard is an environmental communications technology which allows for the residents of the city of Oberlin to study their resource use in real time. Implementing a page on its website to give live updates on how our system is producing and consuming energy would be an excellent way of educating the public about renewable energy technologies and their uses on a small scale. Another goal would be to develop a system that allows the owner of the learning center to closely monitor the activity of the system and receive warnings as to possible issues.

We would also like to research energy saving technologies and techniques that we can incorporate into our system. An example of this would be seeing how electrical light dimmers can reduce the electricity used by a lamp or string lights.

Category	Item	Manufacturer/Brand	Quantity
Solar System	Tracer AN Series 60A MPPT Charge Controller (12V/24V/36V/48V)	EPEVER	2
	Q CELLS 365W Solar Panel 120 Cell 365QPDG10+ BK	Hanwha Q CELLS	4
	Screws, conduits (EMT), and clips	-	-
Wind System	Air X Marine Wind Turbine Generator 400W / 12V 24V W/ Controller	Primus Wind Power	1
	10ft Short Pole (Schedule 40 1-1/2")	-	1
Hybrid System	Inverter PROwatt SW 1000 (12V DC Input)	Xantrex	1
	DC Disconnect Switch B60 12V-110V DC Miniature Circuit Breaker, 60A, 1 Pole	Chtaixi	3
	HYG12-200Ah Rechargeable Gel Deep Cycle 12V	ACOPOWER	2
	90015A Battery Switch 12-48V Waterproof Heavy-Duty Battery Power	Nilight	1
	Type T Fuse 100A	-	1
Datalogging System	HOBO 4-Channel Analog Data Logger	HOBO	1
	DC Voltage and DC Current Sensors	HOBO	1
Others	GFCI outlet	-	2
	RV Male Edison / Share Plug	-	1
	Pelican 1550	-	1

EPEVER

Tracer-AN(50A-100A) Series

MPPT solar charge controller

Overview

Tracer-AN(50A-100A) series is the largest charge controller series in EPEVER's product range and can take up to 5KW solar panel. For even more power, the user can use PAL-ADP-50N to connect max. 6 units of a control-ler in parallel for up to 30KW system. The multiple dry contact signals are designed for a diversified application.

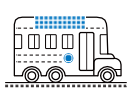
Features

- MPPT tracking efficiency above 99.5%
- Maximum charge conversion efficiency as high as 98%
- Support lead-acid and lithium-ion batteries
- Common negative grounding, Charging current up to 100A
- Charging power and current limitation function
- High-temperature charging power derating function
- 3 relays design for different demand: utility, generator and load
- Support up to 6 units in parallel
- Remote temperature and voltage sensor design
- Isolated RS-485 with 5VDC/200mA and MODBUS protocol





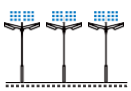


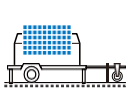












Technical Specifications

Model	Tracer 6210AN	Tracer 5415AN	Tracer 6415AN	Tracer 8415AN	Tracer 10415AN	Tracer 5420AN	Tracer 6420AN	Tracer 8420AN	Tracer 10420AN
Nominal system voltage	12/24VDC/Auto	12/24/36/48VDC/Auto							
Battery type	Lead-acid(Sealed/Gel/Flooded)/Lithium($LiFePO_4$/$Li(NiCoMn)O_2$)/User								
Battery input voltage range	8V ~ 32V	8V ~ 68V	8V ~ 68V	8V ~ 68V	8V ~ 68V	8V ~ 68V	8V ~ 68V	8V ~ 68V	8V ~ 68V
Rated charge current	60A	50A	60A	80A	100A	50A	60A	80A	100A
Rated charge power	750W/12V 1500W/24V	625W/12V 1250W/24V 1875W/36V 2500W/48V	750W/12V 1500W/24V 2250W/36V 3000W/48V	1000W/12V 2000W/24V 3000W/36V 4000W/48V	1250W/12V 2500W/24V 3750W/36V 5000W/48V	625W/12V 1250W/24V 1875W/36V 2500W/48V	750W/12V 1500W/24V 2250W/36V 3000W/48V	1000W/12V 2000W/24V 3000W/36V 4000W/48V	1250W/12V 2500W/24V 3750W/36V 5000W/48V
Max. conversion efficiency	98.00%	98.30%	98.60%	98.50%	98.60%	98.30%	98.10%	98.50%	98.50%
Tracking efficiency	⩾99.5%								
Max. PV open circuit voltage	100V(At minimum operating environment temperature) 92V(At 25℃ environment temperature)	150V (At minimum operating environment temperature) 138V (At 25℃ environment temperature)				200V (At minimum operating environment temperature) 180V(At 25℃ environment temperature)			
MPP voltage range	(Battery Voltage+2V) ~ 72V	(Battery Voltage+2V) ~ 108V				(Battery Voltage+2V) ~ 144V			
Equalization voltage	Sealed:14.6V,Flooded:14.8V,User-defined:9-17V								
Boost voltage	Gel:14.2V,Sealed:14.4V,Flooded:14.6V,User-defined:9-17V								
Float voltage	Gel/Sealed/Flooded:13.8V,User-defined:9-17V								
Low voltage reconnect voltage	Gel/Sealed/Flooded:12.6V,User-defined:9-17V								
Low voltage disconnect voltage	Gel/Sealed/Flooded:11.1V,User-defined:9-17V								
Self-consumption	98mA/12V;60mA/24V;50mA/36V;46mA/48V								
Temperature compensation (for lead-acid battery)	-3mV/℃/2V(Default)								
Relative humidity	5% to 95% (N.C.)								
Enclosure	IP20								
Communication interface	RS485(5VDC/200mA,Two RJ45 ports in parallel)								
Grounding	Common negative								
Operating temperature range	-25℃ ~ +60℃(derating above 45℃)								
Dimensions (LxWxH)(mm)	340×232×105.2	261×216×119	340×236×119	394×240×134	394×242×143	261×216×119	340×236×119	394×240×134	394×242×143
Net weight	3.5kg	3.5kg	4.5kg	6.1kg	7.4kg	3.5kg	4.5kg	6.1kg	7.4kg

1. The controlller can't automatically identify system voltage if lithium batteries were connected.

2. The voltage point is for 12V system, please *2 in 24V system, *3 in 36V system, *4 in 48V system.

© HUIZHOU EPEVER TECHNOLOGY CO., LTD All rights reserved.
Subject to change without notice

HUIZHOU EPEVER TECHNOLOGY CO., LTD.
Beijing Tel: +86-10-82894896
Huizhou Tel: +86-752-3889706

Download Catalogue

powered by Q.ANTUM DUO Z

PRELIMINARY



Q.PEAK DUO BLK-G10+
350-370

ENDURING HIGH PERFORMANCE

Quality Controlled PV
www.tuv.com
ID 1111232615

GERMANY'S MOST POPULAR PROVIDER
Life & Living Award 2021
1st Place Solar Technology

25 YR Warranty
Product & Performance

EUPD RESEARCH TOP BRAND PV MODULES EUROPE 2021

Q CELLS Yield Security



BREAKING THE 20 % EFFICIENCY BARRIER
Q.ANTUM DUO Z Technology with zero gap cell layout boosts module efficiency up to 20.9 %.

THE MOST THOROUGH TESTING PROGRAMME IN THE INDUSTRY
Q CELLS is the first solar module manufacturer to pass the most comprehensive quality programme in the industry: The new "Quality Controlled PV" of the independent certification institute TÜV Rheinland.

INNOVATIVE ALL-WEATHER TECHNOLOGY
Optimal yields, whatever the weather with excellent low-light and temperature behaviour.

ENDURING HIGH PERFORMANCE
Long-term yield security with Anti LID Technology, Anti PID Technology[1], Hot-Spot Protect and Traceable Quality Tra.Q™.

EXTREME WEATHER RATING
High-tech aluminium alloy frame, certified for high snow (5400 Pa) and wind loads (4000 Pa).

A RELIABLE INVESTMENT
Inclusive 25-year product warranty and 25-year linear performance warranty[2].

[1] APT test conditions according to IEC / TS 62804-1:2015, method A (–1500 V, 96 h)
[2] See data sheet on rear for further information.

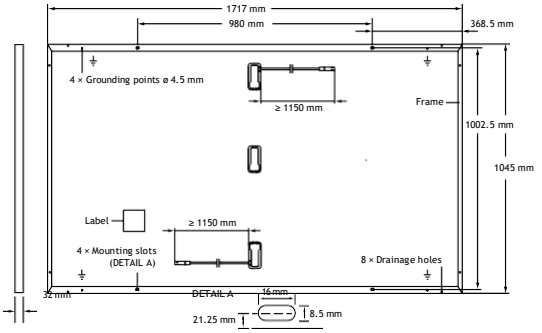
THE IDEAL SOLUTION FOR:
Rooftop arrays on residential buildings

Engineered in Germany

Q CELLS

MECHANICAL SPECIFICATION

Format	1717 mm × 1045 mm × 32 mm (including frame)
Weight	19.9 kg
Front Cover	3.2 mm thermally pre-stressed glass with anti-reflection technology
Back Cover	Composite film
Frame	Black anodised aluminium
Cell	6 × 20 monocrystalline Q.ANTUM solar half cells
Junction box	53-101 mm × 32-60 mm × 15-18 mm Protection class IP67, with bypass diodes
Cable	4 mm² Solar cable; (+) ≥ 1150 mm, (−) ≥ 1150 mm
Connector	Stäubli MC4; IP68

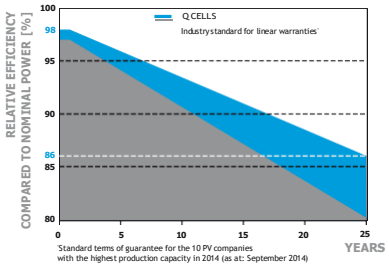


ELECTRICAL CHARACTERISTICS

POWER CLASS				350	355	360	365	370
MINIMUM PERFORMANCE AT STANDARD TEST CONDITIONS, STC[1] (POWER TOLERANCE +5 W / −0 W)								
Minimum	Power at MPP[1]	P_{MPP}	[W]	350	355	360	365	370
	Short Circuit Current[1]	I_{SC}	[A]	10.97	11.00	11.04	11.07	11.10
	Open Circuit Voltage[1]	V_{OC}	[V]	41.11	41.14	41.18	41.21	41.24
	Current at MPP	I_{MPP}	[A]	10.37	10.43	10.49	10.56	10.62
	Voltage at MPP	V_{MPP}	[V]	33.76	34.03	34.31	34.58	34.84
	Efficiency[1]	η	[%]	≥ 19.5	≥ 19.8	≥ 20.1	≥ 20.3	≥ 20.6
MINIMUM PERFORMANCE AT NORMAL OPERATING CONDITIONS, NMOT[2]								
Minimum	Power at MPP	P_{MPP}	[W]	262.6	266.3	270.1	273.8	277.6
	Short Circuit Current	I_{SC}	[A]	8.84	8.87	8.89	8.92	8.95
	Open Circuit Voltage	V_{OC}	[V]	38.77	38.80	38.83	38.86	38.90
	Current at MPP	I_{MPP}	[A]	8.14	8.20	8.26	8.31	8.37
	Voltage at MPP	V_{MPP}	[V]	32.24	32.48	32.71	32.94	33.17

[1]Measurement tolerances P_{MPP} ±3%; I_{SC}; V_{OC} ±5% at STC: 1000 W/m², 25 ± 2 °C, AM 1.5 according to IEC 60904-3 • [2]800 W/m², NMOT, spectrum AM 1.5

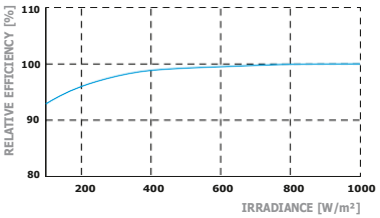
Q CELLS PERFORMANCE WARRANTY



At least 98 % of nominal power during first year. Thereafter max. 0.5 % degradation per year. At least 93.5 % of nominal power up to 10 years. At least 86 % of nominal power up to 25 years.

All data within measurement tolerances. Full warranties in accordance with the warranty terms of the Q CELLS sales organisation of your respective country.

PERFORMANCE AT LOW IRRADIANCE



Typical module performance under low irradiance conditions in comparison to STC conditions (25 °C, 1000 W/m²).

TEMPERATURE COEFFICIENTS							
Temperature Coefficient of I_{SC}	α	[% / K]	+0.04	Temperature Coefficient of V_{OC}	β	[% / K]	−0.27
Temperature Coefficient of P_{MPP}	γ	[% / K]	−0.34	Nominal Module Operating Temperature	NMOT	[°C]	43 ± 3

PROPERTIES FOR SYSTEM DESIGN

Maximum System Voltage	V_{SYS}	[V]	1000	PV module classification	Class II
Maximum Reverse Current	I_R	[A]	20	Fire Rating based on ANSI / UL 61730	C / TYPE 2
Max. Design Load, Push / Pull		[Pa]	3600 / 2660	Permitted Module Temperature on Continuous Duty	−40 °C - +85 °C
Max. Test Load, Push / Pull		[Pa]	5400 / 4000		

QUALIFICATIONS AND CERTIFICATES

Quality Controlled PV - TÜV Rheinland;
IEC 61215:2016; IEC 61730:2016.
This data sheet complies
with DIN EN 50380.
QCPV Certification ongoing.

TÜV Rheinland CERTIFIED
www.tuv.com
ID 1111220277

CE

Note: Installation instructions must be followed. See the installation and operating manual or contact our technical service department for further information on approved installation and use of this product.

Hanwha Q CELLS GmbH
Sonnenallee 17-21, 06766 Bitterfeld-Wolfen, Germany | **TEL** +49 (0)3494 66 99-23444 | **FAX** +49 (0)3494 66 99-23000 | **EMAIL** sales@q-cells.com | **WEB** www.q-cells.com

Specifications subject to technical changes © Q CELLS Q.PEAK DUO BLK-G10+_350-370_2021-08_Rev01_EN

Engineered in Germany

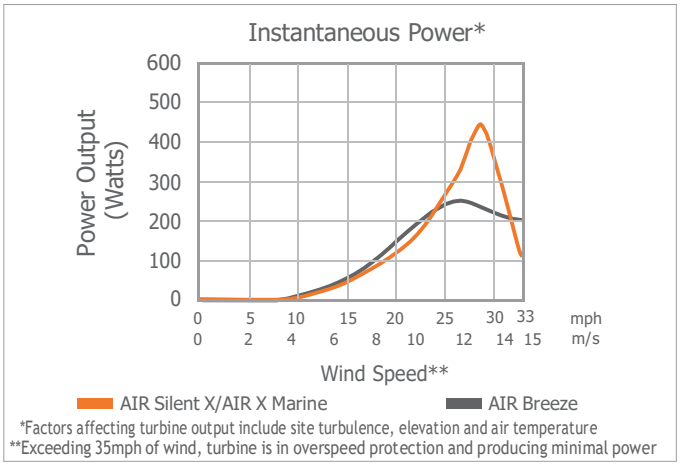
Q CELLS

TURBINE SPECIFICATIONS

Technical Specifications

AIR Breeze/AIR Silent X/AIR X Marine	
Energy	AIR Breeze: Approx. 95 amp-hr. per day at 5.5 m/s (12 mph avg) AIR Silent X/AIR X Marine: Approx. 90 amp-hr. per day at 5.5 m/s (12 mph avg)
Optimal Operating Environment	AIR Breeze: Quiet operation in low to moderate wind regimes AIR X Marine: Industrial application in moderate to high wind regimes AIR Silent X: Very quiet operation in all wind regimes.
Swept Area	1.07 m^2 (11.5 ft^2)
Rotor Diameter	1.17 m (46 in)
Weight	5.9 kg (13 lb)
Shipping Dimensions	686 x 318 x 229 mm (27 x 12.5 x 9 in) 7.7 kg (17 lb)
Startup Wind Speed	AIR Breeze: 3.13 m/s (7 mph) AIR Silent X/AIR X Marine: 3.59 m/s (8 mph)
Voltage	12, 24 and 48 VDC
Turbine Controller	Mircoprocessor-based smart controller
Body	Cast aluminum, corrosion resistant, white aircraft quality paint with a clean "marine grade" finish
Blades	AIR Breeze/AIR X Marine: (3) Injection-molded composite - Black AIR Silent X: (3) Hand laminated, carbon fiber (with low sound emissions) - Multi-color with new precision fit hub design
Alternator	Permanent magnet brushless
Overspeed Protection	Electronic torque control
Survival Wind Speed	40.2 m/s (90 mph)
Mount	1.5 in schedule 40 pipe 48 mm (1.9 in) outer diameter
Tower	9 ft Marine Tower (Aluminum mast/ stays and stainless hardware)
Warranty	5 year limited warranty
Certifications	CE SP
New Digital Wind Control Panel (WCP-D) available for all AIR units and voltages	

AIR Power Curve



*Factors affecting turbine output include site turbulence, elevation and air temperature
**Exceeding 35mph of wind, turbine is in overspeed protection and producing minimal power

3 AIR Turbines - 3 Blade Set Types

TURBINE	LOCATION	APPLICATION	WIND	SOUND
AIR X Marine	Marine	Industrial - off shore	High	High
AIR Silent X	Marine	Sailing	All	Very Low (CF Blades)
AIR Breeze	Marine	Sailing - Residential	Mod.	Low

* All AIR Models are 12/24/48V - Turbine is voltage specific per the battery bank. Not field adjustable.

** All 2021 AIR turbines are Lithium-Ion Battey compatible.



primuswindpower

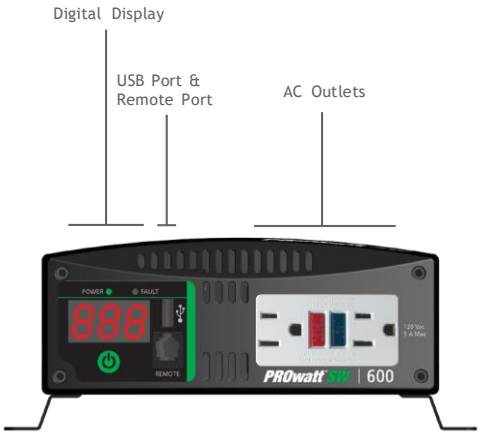
MANUFACTURED IN COLORADO, USA

www.primuswindpower.com | info@primuswindpower.com





TOP VIEW



SIDE VIEW

INVERTER FEATURES

- Digital display of output power and DC volts
- Built-in USB port to power USB-powered devices
- Optional on/off Remote Control Panel
- Automatic AC transfer function and hardwire through the optional Transfer Switch
- Senses when outside AC Power is present and transfers the load from the inverter to the source of incoming power
- Heavy duty terminals for trouble-free battery connection

PROTECTION FEATURES

- Low voltage shutdown (10.0 VDC)
- Low voltage alarm (10.7 VDC)
- Over voltage protection (15.0 VDC)
- Overload shutdown
- Over temperature shutdown
- GFCI protection (PROwatt SW 600, 1000, 2000)

PROwatt SW ACCESSORIES



PROwatt SW Remote On/Off Switch
(808-9001)



PROwatt SW 15 A Transfer Relay
(808-0915)

ELECTRICAL SPECS - INVERTER

	PROwatt SW 600	PROwatt SW 1000	PROwatt SW 2000
Continuous Power	540 W	900 W	1800 W
Surge Capacity (peak)	1200 W	2000 W	3000 W
DC Input	12 VDC (nominal)	12 VDC (nominal)	12 VDC (nominal)
AC Output Frequency	60 ± 0.5 Hz	60 ± 0.5 Hz	60 ± 0.5 Hz
AC Output Voltage Range	104-127 Vac	104-127 Vac	104-127 Vac
USB Output	5 V / 500 mA	5 V / 500 mA	5 V / 500 mA
Output Waveform	True Sine Wave	True Sine Wave	True Sine Wave
Optimum Efficiency	90%	90%	90%
No Load Current Draw	< 0.6 A	< 0.6 A	< 0.6 A
Input Voltage Range	10.5-15.5 VDC	10.5-15.5 VDC	10.5-5.5 VDC

GENERAL SPECS

	PROwatt SW 600	PROwatt SW 1000	PROwatt SW 2000
Operating Temperature Range	32°F-104°F (0°C-40°C)	32°F-104°F (0°C-40°C)	32°F-104°F (0°C-40°C)
AC Receptacle	Dual GFCI	Dual GFCI	Dual GFCI
USB Receptacle	Single port (Type A)	Single port (Type A)	Single port (Type A)
DC Connection	Hardwire	Hardwire	Hardwire
Recommended DC Fuse	150 A	150 A	250 A
Digital Display	DC Voltage AC output power and error codes	DC Voltage AC output power and error codes	DC Voltage AC output power and error codes
Part Number	806-1206	806-1210	806-1220
L x W x H (without flanges)	3.5 x 8.7 x 12.2” (89 x 220 x 310 mm)	3.5 x 8.7 x 13.4” (89 x 220 x 339 mm)	3.9 x 11.8 x 13.7” (100 x 299 x 348 mm)
Net Weight	6.5 lb (3.0 kg)	7.2 lb (3.3 kg)	10.7 lb (4.9 kg)

REGULATORY APPROVALS

	PROwatt SW 600, 1000, 2000
Safety	UL458 with marine supplement 01 (R2006) - General Use Power Supplies. CSA 107.1
EMC	FCC Part 15, Class A

HYG12V200 12V200AH

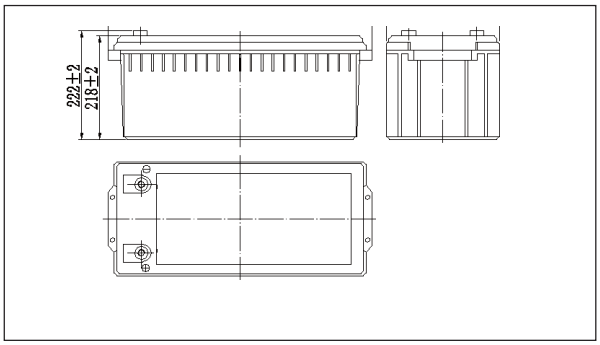
Rechargeable Deep Cycle GEL 12V 200 Ah Battery

Specifications

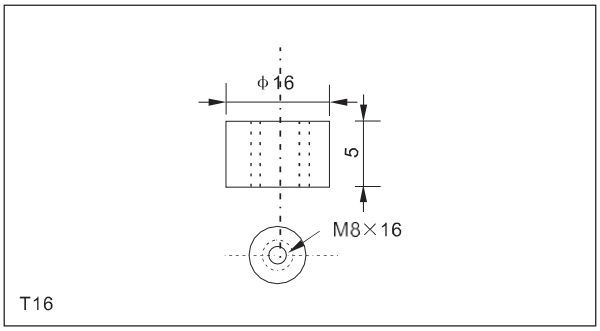
Nominal Voltage		12V
Rated capacity (10 hour rate)		200Ah
Dimensions	Length	522±2mm(20.55inch)
	Width	238±2mm(9.37inch)
	Height	218±2mm(8.58inch)
	Total Height	222±2mm(8.74inch)
Approx. Weight		62.5kg(137.8lbs)±3%



Outer dimensions (mm)



Terminal Type (mm)



Characteristics

Capacity (25℃)	10HR(10.8V)	200Ah
	3HR(10.8V)	150Ah
	1HR(10.5V)	110Ah
Terminal type		T16
Internal resistance (Fully charged,25℃)		Approx.3.3mΩ
Capacity affected by temperature (10HR)	40℃	102%
	25℃	100%
	0℃	85%
	-15℃	65%
Self-discharge (25℃)	3 months	Remaining Capacity:91%
	6 months	Remaining Capacity:82%
	12 month	Remaining Capacity:65%
Nominal operating temperature		25℃ ±3℃(77℉ ±5℉)
Operating temperature range	Discharge	-15℃~50℃(5℉~122℉)
	Charge	-10℃~50℃(14℉~122℉)
	Storage	-20℃~50℃(-4℉~122℉)
Float charging voltage(25℃)		13.50 to 13.80V Temperature compensation: -18mV/℃
Cyclic charging voltage(25℃)		14.40 to 14.70V Temperature compensation: -30mV/℃
Maximum charging current		40A
Maximum discharge current		1400A(5 sec.)
Designed floating life(20℃)		12years

Construction

Component	Positive plate	Negative plate	Container	Cover	Separator	Electrolyte	Safety valve	Terminal
Raw material	Lead dioxide	Lead	ABS	ABS	AGM	Gel	Rubber	Copper

Constant Current Discharge Characteristics Unit: A(25℃,77℉)

F.V/Time	15min	30min	60min	2h	3h	4h	5h	6h	8h	10h	20h
9.60V	320	194	120	73.1	52.0	40.8	34.7	30.6	24.5	20.4	10.8
9.90V	312	190	118	72.6	51.7	40.6	34.5	30.4	24.3	20.3	10.8
10.2V	301	184	115	72.0	51.4	40.3	34.2	30.2	24.2	20.3	10.7
10.5V	291	180	112	70.9	51.0	40.0	34.0	30.0	24.0	20.1	10.7
10.8V	275	173	108	69.1	50.0	38.8	33.0	29.1	23.3	20.0	10.6

Constant Power Discharge Characteristics Unit: W(25℃,77℉)

F.V/Time	15min	30min	60min	2h	3h	4h	5h	6h	8h	10h	20h
9.60V	3514	2177	1368	846	612	480	410	362	291	243	129
9.90V	3429	2133	1347	841	608	477	408	360	289	243	129
10.2V	3303	2068	1313	834	604	474	405	357	287	242	129
10.5V	3190	2018	1272	821	600	470	402	355	285	240	128
10.8V	3022	1944	1231	800	588	456	390	344	277	239	127

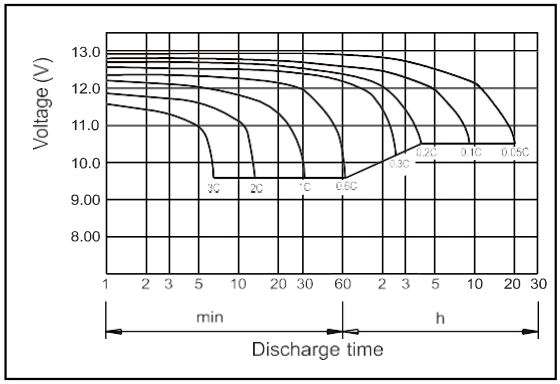
Note: The above characteristics data can be obtained within three charge or discharge cycles.

MH47211

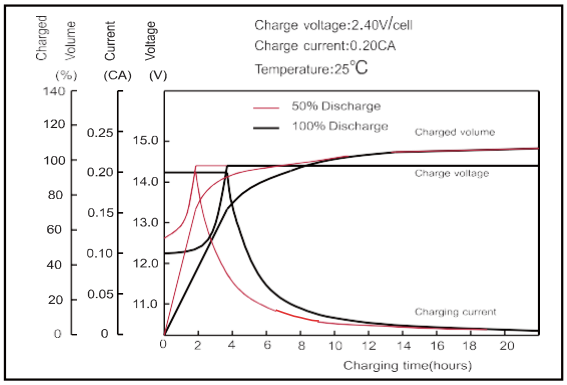
HYG12V200 12V200AH

Rechargeable Deep Cycle GEL 12V 200 Ah Battery

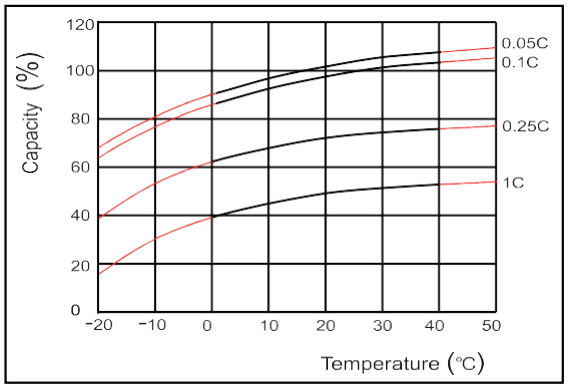
Discharge characteristics(25°C)



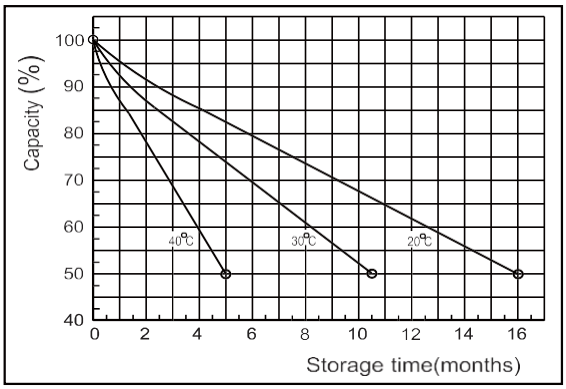
Charging characteristics (25°C)



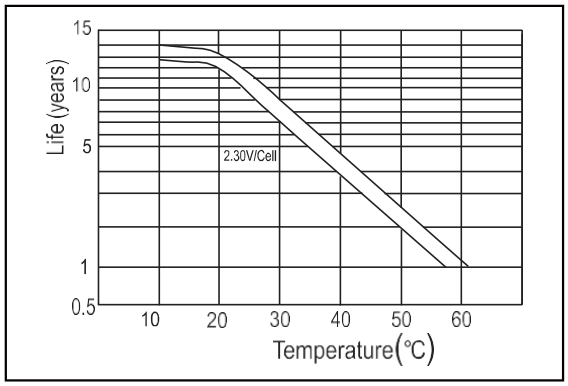
Temperature effects on Capacity



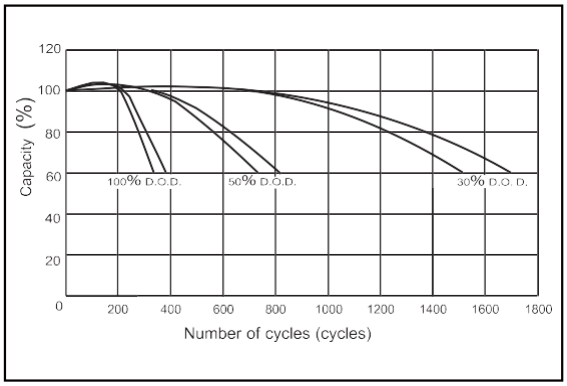
Self-discharge characteristics



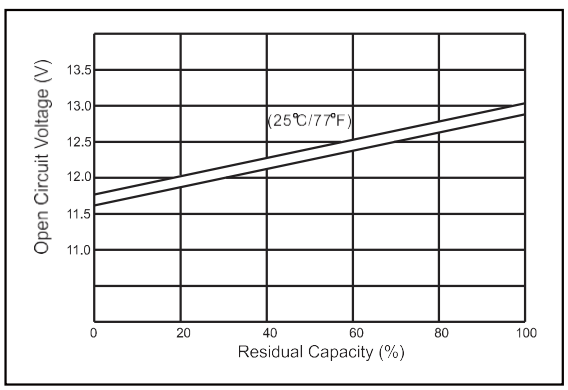
Floating life on Temperature



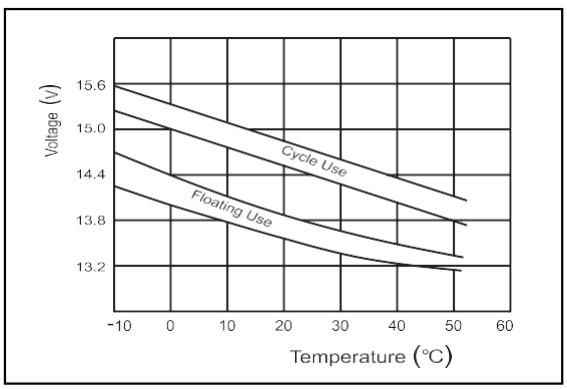
Cycle life on D.O.D (25℃)



The relationship for OCV and Capacity (25℃)



The relationship for Charging voltage and Temperature



Power Your Green Life!

www.ACOPower.com

USA Sales: 4120 Valley Blvd, Ste B, Walnut, CA 91789, USA
Tel:+1-626-575 8822/7722 Fax: 626-800 2255
Email: sales@acopower.com

HOBO® 4-Channel Analog Data Logger (UX120-006M) Manual



The HOBO 4-Channel Analog data logger has 16-bit resolution and can record up to 1.9 million measurements or events. The four external channels accept a variety of sensors, including temperature and split-core AC current sensors as well as 4-20 mA and voltage input cables (sold separately). Using HOBOware®, you can easily configure an alarm to trip when the sensor reading rises above or falls below a measurement that you specify. Or, you can set up burst logging in which the logger records data at a different interval during certain conditions. The logger can also calculate minimum, maximum, average, and standard deviation statistics. This easy-to-use data logger has a built-in LCD screen to check current readings and to monitor logging status, battery use, and memory consumption in between readouts.

HOBO 4-Channel Analog Data Logger

UX120-006M

Included Items:

- Command™ strip
- Double-sided tape
- Hook & loop strap
- Two AAA 1.5 V alkaline batteries

Required Items:

- HOBOware 3.6 or later
- USB cable (included with software)

Sensors and cables available at www.onsetcomp.com.

Specifications

Logger with Cable Type	CABLE-4-20mA	CABLE-2.5-STEREO	CABLE-ADAP5	CABLE-ADAP10	CABLE-ADAP24
Measurement Range	0 to 20.1 mA	0 to 2.5 V	0 to 5.0 V	0 to 10 V	0 to 24 V
Accuracy	±0.001 mA ±0.2% of reading	±0.1 mV ±0.1% of reading	±0.2 mV ±0.3% of reading	±0.4 mV ±0.3% of reading	±1.0 mV ±0.3% of reading
Resolution	0.3 µA	40 µV	80 µV	160 µV	384 µV

Logger	
Operating Range	Logging: -20° to 70°C (-4° to 158°F); 0 to 95% RH (non-condensing); Launch/Readout: 0° to 50°C (32° to 122°F) per USB specification
Logging Rate	1 second to 18 hours, 12 minutes, 15 seconds
Logging Modes	Fixed interval (normal), burst, or statistics
Memory Modes	Wrap when full or stop when full
Start Modes	Immediate, push button, date & time, or next interval
Stop Modes	When memory full, push button, or date & time
Restart Mode	Push button
Time Accuracy	±1 minute per month at 25°C (77°F), see Plot A
Power Source	Two AAA 1.5 V alkaline batteries, user replaceable, and USB cable
Battery Life	1 year, typical with logging rate of 1 minute and sampling interval of 15 seconds or greater
Memory	4 MB (1.9 million measurements, maximum)
Download Type	USB 2.0 interface
Full Memory Download Time	Approximately 1.5 minutes
LCD	LCD is visible from 0° to 50°C (32° to 122°F); the LCD may react slowly or go blank in temperatures outside this range
Size	10.8 x 5.41 x 2.54 cm (4.25 x 2.13 x 1 in.)
Weight	107.5 g (3.79 oz)
Environmental Rating	IP50
CE	The CE Marking identifies this product as complying with all relevant directives in the European Union (EU).

Note: The HOBO U-Shuttle (U-DT-1) is not compatible with this logger.

Category	Item	Quantity	Cost per unit ($)	Total Cost ($)
Solar System	60A MPPT Solar Charge Controller	2	269.99	539.98
	Q CELLS 365W Solar Panel 120 Cell 365QPDG10+ BK	4	253.68	1014.72
Wind System	Air X Marine Wind Turbine Generator 400W / 12V 24V W/ Controller	1	1,249.00	1249
	10ft short pole (Schedule 40 1-1/2")	1	25.87	25.87
Hybrid System	Inverter PROwatt SW 1000	1	336.26	336.26
	DC Disconnect Switch B6012V-110V DC Miniature Circuit Breaker, 60 Amp 1 Pole Battery	4	9.47	37.88
	HYG12-200Ah Rechargeable Gel Deep Cycle 12V	2	389	778
	90015A Battery Switch 12-48V Waterproof Heavy Duty Battery Power	1	12.14	12.14
	Type T Fuse 100A	1	32	32
Datalogging System	**Choice 1: Hobo System**			
	HOBO 4-Channel Analog Data Logger w/ Sensors	2		500
	Choice 2: Microcontroller System			
	PZEM-004T Sensor	2	13.66	27.32
	NodeMCU ESP8266	1	7.99	7.99
Others	GFCI outlet	2	17.17	34.34
	Screws, conduits (EMT), and clips			200
	Light bulbs and fixtures			100
	RV Male Edison / Share Plug	1	8.48	8.48
	Pelican 1550	1	85.95	85.95
Total Cost with Hobo:	4954.62			
Total Cost with Microcontoller:	4489.93			

	Cabin							Maple Shed		Outhouse		TOTAL
	Lamp 1 (Overhead light - Kitchen)	Lamp 2 (Work desk)	Lantern (Rechargeable)	Outlet 1 - Charging a phone	Outlet 2 - Charging a laptop	Heater (Not installed)	String Lights - 34 sockets	Lamp 1	Outlet 1 - Charging a phone	Toilet	Lamp	Power consumption at a given time
Hours\Watts	6.0 W	2.0 W	2.025 W	20.0 W	50.0 W	.0 W	34.0 W	6.0 W	20.0 W	2.50 W	2.0 W	
0:00								1		1		8.50 W
1:00								1		1		8.50 W
2:00								1		1		8.50 W
3:00								1		1		8.50 W
4:00								1		1		8.50 W
5:00								1		1		8.50 W
6:00	1						1	1		1		48.50 W
7:00	1						1	1		1	0.1	48.70 W
8:00									1	1		22.50 W
9:00			1						1	1		24.525 W
10:00			1							1		4.525 W
11:00			1							1		4.525 W
12:00			1							1		4.525 W
13:00			1							1		4.525 W
14:00			1							1		4.525 W
15:00			1							1	0.1	4.725 W
16:00			1							1		4.525 W
17:00			1		1		1	1		1		94.525 W
18:00	1	1		1	1		1	1		1		120.50 W
19:00	1	1		1			1	1		1		70.50 W
20:00		1				1	1	1		1		44.50 W
21:00						1	1	1		1	0.1	42.70 W
22:00							1	1		1		42.50 W
23:00								1		1		8.50 W
Consumption (Wh)	**24. Wh**	**6. Wh**	**18.23 Wh**	**40. Wh**	**100. Wh**	**. Wh**	**272. Wh**	**90. Wh**	**40. Wh**	**60. Wh**	**.6 Wh**	-
Total (Wh)	**460.23 Wh**							**130. Wh**		**60.6 Wh**		**650.83 Wh**
Share	**3.69%**	**0.92%**	**2.80%**	**6.15%**	**15.37%**	**0.00%**	**41.79%**	**13.83%**	**6.15%**	**9.22%**	**0.09%**	
Information (worst case scenario)	**Peak use:** 3 weeks People already know make this type of life work (without energy) No need for a space heater on all the time (good insulation) Jan./Feb., April, August/September							**Peak use:** Shifts of 4-6 hours 24hrs/day 4-5 week period February and March		**Peak use:** Occasionally But when it's being used, a lot of people tend to go		

Battery				
Voltage	Amp-Hr	Watt-Hr	Net Wh (60%)	Autonomy (days)
12	200	2400	2880	4.43
12	200	2400		

1.653810335	days to refill after depletion

4		panels
365	1460	W

1.3	Multiplier	1300 W

Solar Calculation - From PVWatts		
1710	AC-kWh/yr	@ 20.28% losses
1641.6	Net AC kWh/yr	@ 96% eff
2011.764706	DC Gross kWh/yr	(AC kWh / (1-%loss)
5.511684126	Avg Daily DC kWh	

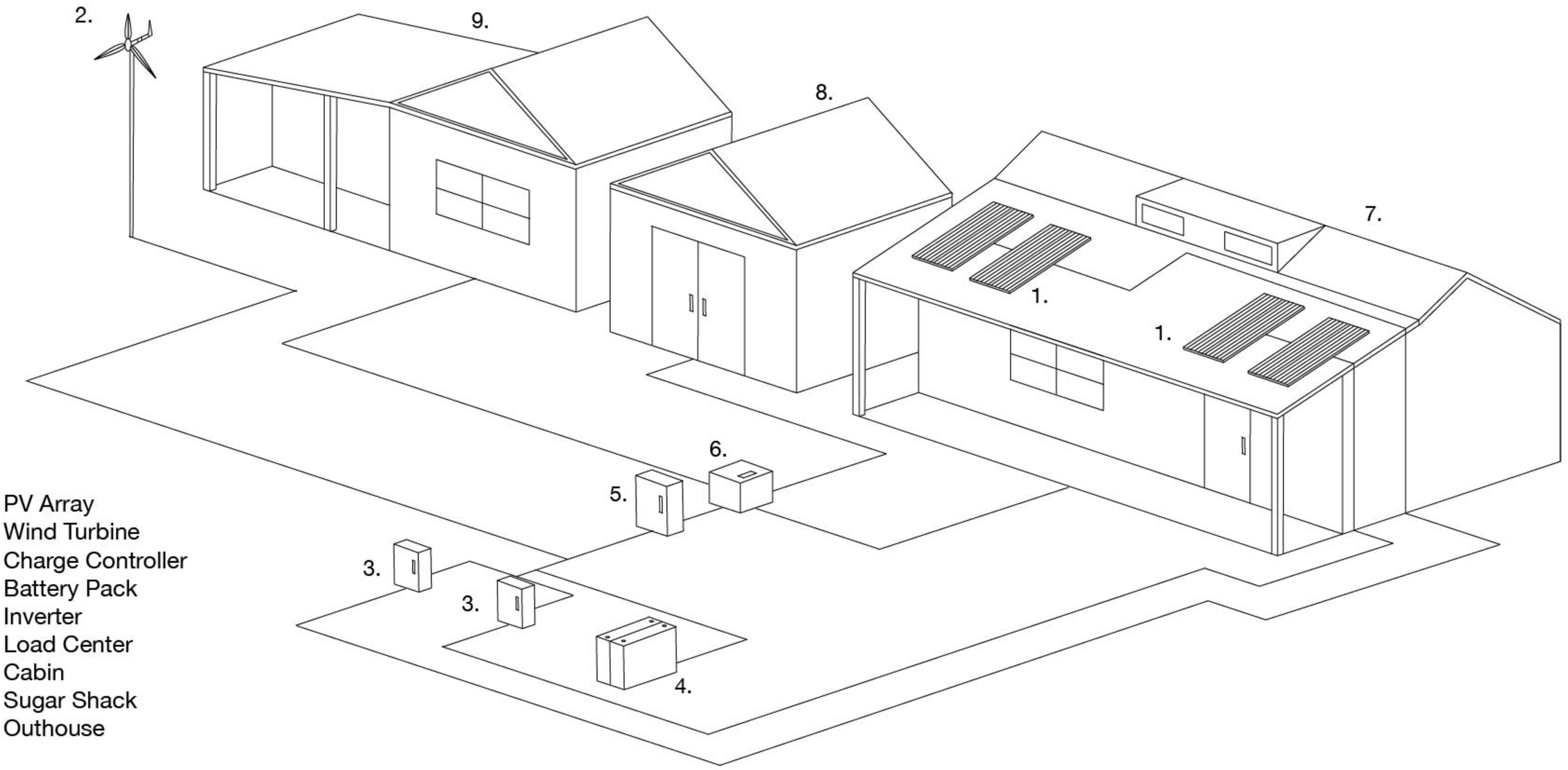
103	kWh/month (Feb)	low month
3.322580645	kWh/day (Feb)	-
2.491935484	kWh/day (available)	with round trip efficiency of 75%
2.392258065	kWh/day (AC)	with inverter efficiency of 96%
1.435354839	kWh/day (AC)	with shade from trees
1.86596129	Scaled per U7	-

1365.96129	net excess
2.108405282	days to refill

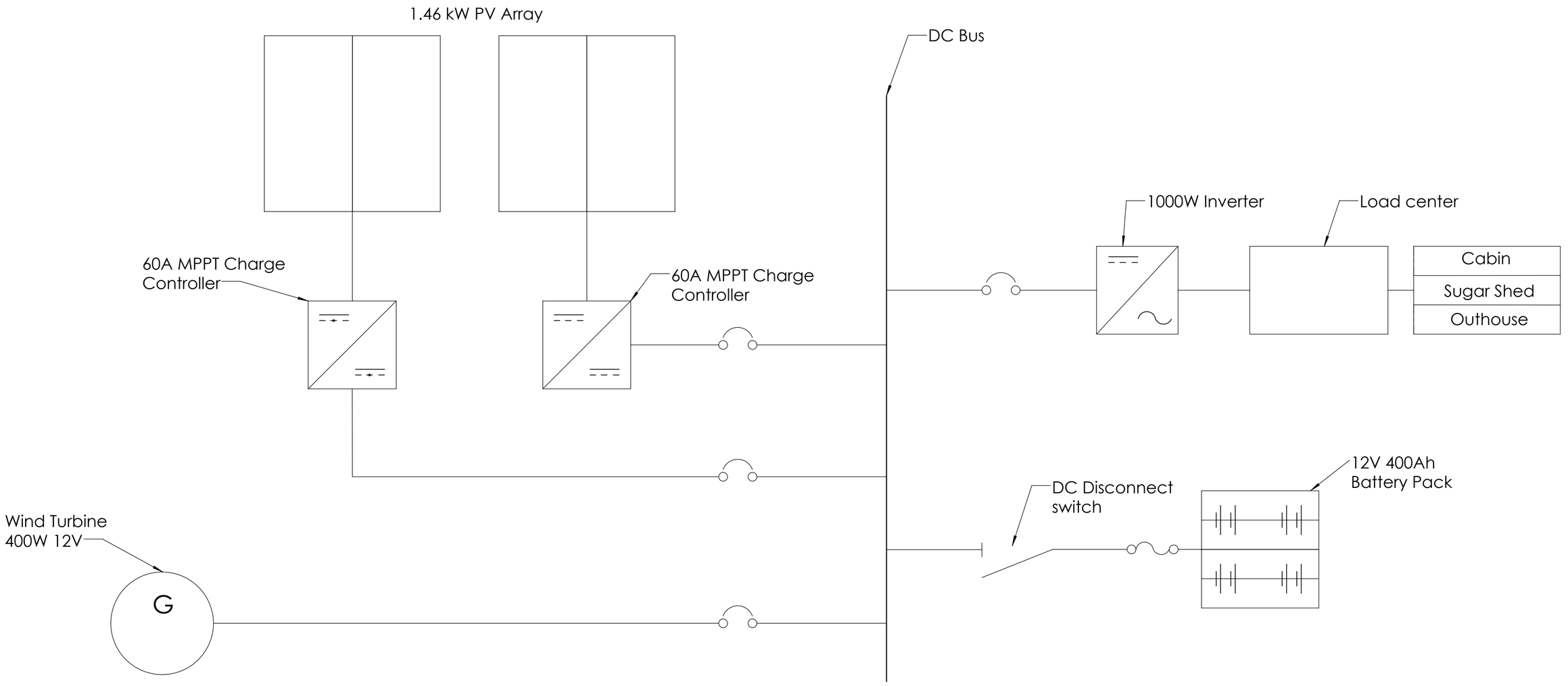
1741.43 Wh	Daily Extra

Hybrid System - Dorseys' Learning Center

Oberlin College



1. PV Array
2. Wind Turbine
3. Charge Controller
4. Battery Pack
5. Inverter
6. Load Center
7. Cabin
8. Sugar Shack
9. Outhouse



Hybrid System - Dorseys' Learning Center
Oberlin College

SOLIDWORKS Educational Product. For Instructional Use Only.

To ensure a better integration of our system and follow the demands of our client, we expect to follow the procedures outlined below:

1) The primary power source, the PV array, will be mounted on the cabin's roof in an array of two panels (see Figure 1). This placement not only reduces the price of racking installation but also minimizes the system's visual footprint, maintaining the secluded nature of the learning center. The cabin's roof faces south, so we expect to have an efficient position of the array.



Figure 1 – Panel distribution on the roof

2) The assembly plan also includes a micro wind turbine adjacent to the cabin, facing southwest. It is important to note that, as outlined in our report, the turbine is primarily ornamental due to the limited wind resources in the area. While its contribution to energy generation might be limited, the presence of an additional renewable energy source is valuable for the students and alumni who will utilize the learning center space and the team who designed this report.

3) The 2400Wh battery and the PROwatt 1000 SW inverter will be ground-mounted within a weather-proof enclosure situated outside the main building. This configuration safeguards the equipment and facilitates access for maintenance and cable connections.

4) To ensure a simple implementation, the electrical connections between the components and the buildings will be next to the enclosure previously mentioned. Within a load center, initially, we will distribute the AC energy to the buildings with cables, but our client has future plans to install a more permanent electrical connections to the space. The datalogging system will be located at the load center.