CBC Engineers

Dayton Office

ENGINEERING REPORT

TO: Ecolibrium Solar, Inc.
507 Richland Avenue
Athens, Ohio 45701

DATE: March 14, 2018

ATTN: Mr. Kyle Basarich
Current Products Engineer

NO: 21272D-1-0318-10

Re: Critical Review of Ballast Design Calculations and Roof Top Placement Drawings for the Ecofoot5D® Solar Panel Support System, Assured Solar Energy – (111 West St.) 111 West Street Portland, Maine; CBC Report No. 21272D-1-0318-10

CBC Engineers and Associates, Ltd. (CBC) is pleased to submit our critical review of the ballast design calculations and placement shop drawings for the above referenced project. Ecolibrium Solar's Ecofoot5D® solar panel support system will be used to support new solar panels on a building rooftop at 111 West Street Portland, Maine. The structural analysis of the Ecofoot5D® system for this site has been performed in accordance with ASCE 7-10 using the design criteria shown in Table 1 below.

TABLE 1 - DESIGN CRITERIA

SITE CRITERIA DESCRIPTION	VALUE USED IN DESIGN
Basic Wind Speed – 3 Second Gust	127 mph
Occupancy Category	III
Importance Factor	1.00
Exposure Category	B
Roof Height	30 ft.
Solar Panel Module Weight	40.81 lbs (Panasonic VBHN330SA17)
L = Solar Panel Module Length	62.60 inches (Panasonic VBHN330SA17)
W = Solar Panel Module Width	41.50 inches (Panasonic VBHN330SA17)
Solar Panel Orientation	Landscape
Friction Coefficient	0.49
Existing Roof Type	EPDM
Pg = Ground Snow Load	50 psf
Seismic Design Category	B
Ss = 0.2s Response Mapped Acceleration Parameter	0.24
Ballast Block Weight	32 lbs

Determinations have been made for the theoretical minimum ballast required to resist wind and snow loading conditions, with the critical loading scenario being used to determine the overall minimum ballast required. For this project, the ballast necessary to resist uplift is the worst case loading scenario.

The wind pressure and force coefficients used in the determination of the required ballast to resist wind-induced uplift and sliding of the Ecofoot5D® ballasted arrays are based on the results of the Ecofoot2® Racking System Wind Pressure Study performed for Ecolibrium Solar, Inc. by Rowan Williams Davies & Irwin, Inc. (RWDI) as presented in their report dated December 3, 2014. Based on this study, the following two equations were provided to facilitate determination of the theoretical minimum weight of ballast required to resist wind-induced uplift and sliding using the design criteria as shown in Table 1 above. The theoretical results for the minimum required ballast at each Ecofoot5D® location in their respective location in the solar panel array are shown in the schematic attached in Appendix B. The placement shop drawing attached in Appendix C depicts the location of each Ecofoot5D® support and the actual suggested number of ballast blocks at each support as per the values shown in the Appendix B schematic.

Ballast (lb) to Resist Uplift

$$\alpha_D \cdot Ballast_{uplift} = \alpha_W \cdot q_z \cdot \left|GC_p\right|_{uplift} \cdot A_{uplift} - \alpha_D \cdot M \quad \text{(lbs)}$$

Ballast (lb) to Resist Sliding

$$\alpha_D \cdot Ballast_{drag} = \alpha_W \cdot q_z \cdot \left[\left(GC_p\right)^*_{drag} \cdot A_{drag} \cdot (1/f_n) + \left|GC_p\right|^*_{uplift} \cdot A_{uplift}\right] - \alpha_D \cdot M \quad \text{(lbs)}$$

where:

α_W	=	factor on wind load from ASCE 7-10
α_D	=	factor on dead load from ASCE 7-10
q_z	=	3-second gust wind pressure (lbs/ft^2) for site location from ASCE 7-10, including exposure factor (K_z) and directionality factor ($K_d = 0.85$) as per chapters 26 and 29 of ASCE 7-10.
M	=	self-weight of assembled system (lbs) for appropriate averaging area
f_n	=	frictional coefficient
A_{uplift}	=	area (ft^2) of panel(s) projected onto a horizontal plane
A_{drag}	=	area (ft^2) of panel(s) projected onto a vertical plane
$\left\|GC_p\right\|_{uplift}$	=	absolute value of uplift pressure coefficient for selected averaging area
$\left(GC_p\right)^*_{drag}$	=	highest drag pressure coefficient multiplied by the appropriate area reduction factor
$\left\|GC_p\right\|^*_{uplift}$	=	absolute value of highest uplift pressure coefficient multiplied by the appropriate area reduction factor

Based on a critical review of the ballast design calculations, it is the opinion of CBC that said calculations have been performed and prepared in accordance with the applicable provisions of the referenced standards and accepted industry practices. The calculations are included in Appendix A. It is also the opinion of CBC that the Ecofoot5D® placement shop drawings have also been performed and prepared in accordance with the applicable provisions of the referenced standards and accepted industry practices. The drawings are included in Appendix C. CBC has accordingly signed and sealed this report and the Ecofoot5D® placement shop drawings. As such, CBC is the Engineer of Record for the structural analysis of the Ecofoot5D® system for the above referenced project.

CBC has not evaluated the existing building structure for support of the proposed support system(s), and this is the responsibility of others than CBC. It is assumed others than CBC have evaluated the building structure for support of the proposed system(s). It is assumed the roofing system is installed according to the manufacturer's recommendations. If conditions for this project differ from those expressed herein, Ecolibrium Solar, Inc. and CBC Engineers & Associates, Ltd. should be notified immediately.

This critical review engineering report provides information regarding the Ecofoot5D® solar panel support system by Ecolibrium Solar, Inc. The solar panels are supplied and designed by others, and are attached to the Ecofoot5D® supports, with provided Ecofoot5D® hardware, according to the instructions and requirements of Ecolibrium Solar, Inc. The Ecofoot5D® system must be installed according to the instructions and requirements of Ecolibrium Solar, Inc. It is assumed that the ballast blocks will be installed in accordance with the recommendations of Ecolibrium Solar, Inc., and in such a manner so that the required ballast will be permanently available for the life of the system. The specific construction techniques and methods chosen to install the Ecofoot5D® system as per the requirements of Ecolibrium Solar, Inc. and as detailed in this report are the responsibility of the installation contractor. Independent conclusions, opinions or recommendations made by others than CBC based on the information provided herein are the responsibility of the independent party.

Our professional services have been performed and our findings obtained in accordance with generally accepted engineering principles and practices. No other warranty, expressed or implied is made. This report is not a bidding document and shall not be used for that purpose. This report has been prepared for the exclusive use of Ecolibrium Solar, Inc. for specific application to the project herein described. The report shall be used in its entirety.

Thank you for the opportunity to provide this report. If you have any questions, or require any further assistance, please contact us.

CBC Engineers & Associates, Ltd.

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Staff Engineer

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APPENDIX A
CALCULATIONS

Uplift, Sliding and Seismic Calculations

Explanation of EcoFoot System Calculations and Design Procedure

Installer Name:	Assured Solar Energy
Project Name:	111 West St
Project Address:	111 West St Portland, ME 04102 Portland, ME 4102
Date Prepared:	3/15/2018

Calculation Explanation Key Sections:

Table Of Figures:

3rd Party Engineering Resources

Rowan, Williams, Davies, & Irwin Inc (RWDI) -- Wind Tunnel Testing Per ASCE 7 / IBC
Maffei Structural Engineering -- Peer Review of Wind Tunnel Testing
Testing Engineers, Inc. -- Friction Testing per ASTM G115
CBC Engineers -- Professional Engineering Review and Certification

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Introduction, Site Specifics and Variable Definition

In order to efficiently design EcoFoot2+ and EcoFoot5D ballasted photovoltaic systems, Ecolibrium Solar makes use of a proprietary solar array design aid called "EcoCalcs". Starting with a set of design criteria, shown here in Table 1 below, EcoCalcs utilizes methodologies laid out in the ASCE7 and SEAOC PV1/PV2 documents, and derivative building codes. Actual calculations for this project are included herein, and are accompanied by a step-by-step explanation of Ecolibrium Solar's design process.

The output of EcoCalcs is a comprehensive set of ballast prescriptions, including Image 3 found on Page 5. Ballast prescriptions are applied to a proposed system layout by the Ecolibrium Solar engineering team. CBC Engineers, Ecolibrium Solar's professional engineering partner, has reviewed and verified EcoCalcs and reviews system designs to ensure that calculations and ballast prescriptions were correctly applied. Upon successful review, CBC Engineers provides a stamped design review including relevant supporting documentation (this explanation included) and a stamped, approved ballast plan.

Please note: Ecolibrium Solar and CBC engineers are not conducting a structural review of the proposed site.

Below, Table 1 and Table 2 list the design criteria and project details for a proposed system in Portland, ME. These values will be used throughout the remainder of this explanation.

Table 1: System Design Criteria

Product Line	EcoFoot 5D
ASCE7 Version	2010
Roof Type	EPDM
Roof Height (ft.)	30
Roof Slope (deg)	1.00
Min Edge Setback (in)	35
Parapet Height (in.)	0
3 Sec. Gust (mph)	127
Occupancy Category	III
Wind Exposure	B
Snow Load (psf)	50.0
Seismic Data (S_S)	0.2400
Soil Site Class	D
Coeff. Of Friction (fn)*	0.49

**req's slip sheets*

Table 2: PV Module Specifics

Module Manufacturer	Panasonic
Module Model	VBHN330SA17
Module Orientation	LANDSCAPE
Module Power (w)	330
Module Length (in)	62.60
Module Width (in)	41.50
Module Weight (lbs.)	40.81

Utilizing the inputs from Tables 1 and 2, the factors in Table 3 are generated for the site. This list of factors is used in various ways to fully define a proposed system according to calculations laid out in the SEAOC and ASCE documents. In the scope of this explanation, factors are used to calculate velocity pressure, qh as defined in ASCE7-05, Section 6.5.10, and ASCE7-10, Section 30.3.2, and ultimately the amount of ballast required to offset uplift and drag forces.

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Table 3: Calculation Inputs, Constants, and Variables

Racking Component Weight per Module	15.22	lbs.
Ballast Block Weight	32	lbs.
Asymmetric lift load Ratio (North Row)	1.8	
Asymmetric lift load Ratio (South Row)	1.6	
Ala= Effective Lift Area of PV Module	17.972	ft^2
Ada= Effective Drag Area of PV Module	1.57	ft^2
dLF1= Dead Load of Module and Attributed Racking	56.026	lbs.
Roof Setback Minimum	35	in.
Load Combination Factor for Wind	0.6	
Load Combination Factor for Seismic	1	
α (from ASCE7 Table 6-2 or 26.9.1)=	7	
zg (from ASCE7 Table 6-2 or 26.9.1)=	1200	ft.
zmin (from ASCE7 Table 6-2)=	30	ft.
z selected (from zmin & inputs)=	30	ft.
Kz= Adjustment Factor for Building Height and Exposure	0.70	
Kzt= Topographic Factor	1	
Kd= Directionality Factor	0.85	
I= Importance Factor	1	
Wind design load factor	0.6	
Dead Load design load factor	0.6	
qh= Velocity Pressure (0.00256*Kz*Kzt*Kd*V^2*I)	24.59	

An explanation of variables:

Asymmetric Lift Load Ratio: This is a ratio describing the leverage created by EcoFoot base dimensions, module attachment location and location of center of ballast mass. Assessed as a multiplier on top of ballast distribution scheme in Image 4.

dLF1= Dead Load of Module and Attributed Racking: the weight of one module and hardware attributed to that module, not including ballast.

Ala= Effective Lift Area of PV Module: The surface area of a module projected onto the horizontal plane for lift calculations.

Ada= Effective Drag Area of PV Module: The surface area of a module projected onto the horizontal plane for drag calculations.

qh= Velocity Pressure at height "h": Calculation prescribed by ASCE7-05, eq. 6-15, and ASCE7-10, eq. 30.3-1

Wind Tunnel Testing, Uplift and Drag Force Calculations

Wind tunnel testing of the EcoFoot product line to determine GCn values has been conducted by Rowan Williams Davies & Irwin Inc. (RWDI), a nationally recognized boundary-layer wind tunnel test firm. Testing was conducted in accordance with ASCE7-05, section 6.6, and ASCE7-10, section 31.2. Module-specific GCn data allows for precise application of ballast to prevent uplift. Deviation from prescriptive wind GCn values has been addressed according to SEAOC PV2 via a peer review of the wind tunnel testing and results by Maffei Structural Engineering.

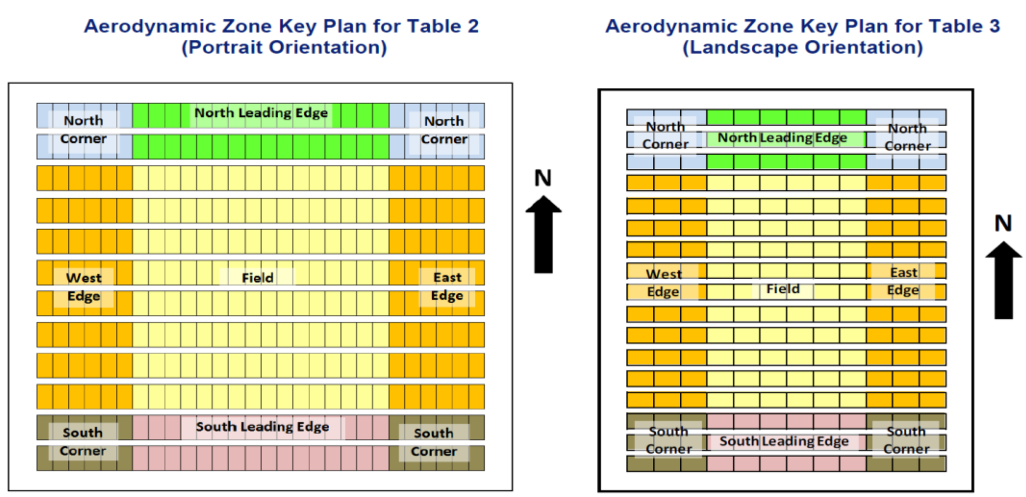
GCn and qh are used to calculate the pressure exerted on each module via the design wind pressure equations (ASCE7-05 – section 6.5.12.4, ASCE7-10 – section 30.4.2). Ballast required to offset uplift and drag forces (BWUz) is calculated with load combination calculations from ASCE7-05/10 section 2.3.2. Detailed calculations for this project are found in Table 4. Resulting required ballast BWUz is displayed graphically in Image 3.

Table 4: Ballast to Resist Uplift Calculations for Project Proposed in Portland, ME 4102

			Load Sharing Area			
		#col x #rows	3x2	3x3	5x3	Downforce
North Corner	pUz=Uplift design wind pressure in Z direction=qh*GCnUz	psf	-6.6	-6.0	-5.0	12.6
	WLFUz=Uplift wind load force in Z direction=pUz*Ala	lbs.	-117.8	-108.7	-90.6	
	DLFUz=Uplift design load using ASD combo #7 = dLF1*0.6 + WLFUz*0.6	lbs	-37.0	-31.6	-20.7	
	BWuz=ballast weight required to resist wind uplift= -DLFUz/0.6	**lbs**	61.7	52.7	34.6	
North Edge	pUz=Uplift design wind pressure in Z direction=qh*GCnUz	psf	-6.6	-5.5	-5.0	10.6
	WLFUz=Uplift wind load force in Z direction=pUz*Ala	lbs	-117.8	-99.7	-90.6	
	DLFUz=Uplift design load using ASD combo #7 = dLF1*0.6 + WLFUz*0.6	lbs	-37.0	-26.2	-20.7	
	BWuz=ballast weight required to resist wind uplift= -DLFUz/0.6	**lbs**	61.7	43.6	34.6	
E/W Edge	pUz=Uplift design wind pressure in Z direction=qh*GCnUz	psf	-6.6	-6.0	-5.0	12.6
	WLFUz=Uplift wind load force in Z direction=pUz*Ala	lbs	-117.8	-108.7	-90.6	
	DLFUz=Uplift design load using ASD combo #7 = dLF1*0.6 + WLFUz*0.6	lbs	-37.0	-31.6	-20.7	
	BWuz=ballast weight required to resist wind uplift= -DLFUz/0.6	**lbs**	61.7	52.7	34.6	
Field	pUz=Uplift design wind pressure in Z direction=qh*GCnUz	psf	-6.6	-5.5	-5.0	10.6
	WLFUz=Uplift wind load force in Z direction=pUz*Ala	lbs	-117.8	-99.7	-90.6	
	DLFUz=Uplift design load using ASD combo #7 = dLF1*0.6 + WLFUz*0.6	lbs	-37.0	-26.2	-20.7	
	BWuz=ballast weight required to resist wind uplift= -DLFUz/0.6	**lbs**	61.7	43.6	34.6	
South Corner	pUz=Uplift design wind pressure in Z direction=qh*GCnUz	psf	-6.6	-6.0	-5.0	17.6
	WLFUz=Uplift wind load force in Z direction=pUz*Ala	lbs	-117.8	-108.7	-90.6	
	DLFUz=Uplift design load using ASD combo #7 = dLF1*0.6 + WLFUz*0.6	lbs	-37.0	-31.6	-20.7	
	BWuz=ballast weight required to resist wind uplift= -DLFUz/0.6	**lbs**	61.7	52.7	34.6	
South Edge	pUz=Uplift design wind pressure in Z direction=qh*GCnUz	psf	-6.6	-5.5	-5.0	15.6
	WLFUz=Uplift wind load force in Z direction=pUz*Ala	lbs	-117.8	-99.7	-90.6	
	DLFUz=Uplift design load using ASD combo #7 = dLF1*0.6 + WLFUz*0.6	lbs	-37.0	-26.2	-20.7	
	BWuz=ballast weight required to resist wind uplift= -DLFUz/0.6	**lbs**	61.7	43.6	34.6	

The aerodynamic differences among different sub-sections of a large array are handled by various calculation sections (North Corner, North Edge, E/W Edge...) and apply according to the excerpt from the RWDI report shown below in Image 1. The highlighted sections of Table 4 correspond to specific module locations, also shown in Image 4: green - the north corners, purple - the east or west edge, orange - the deep interior. See Page 7 for expanded calculations pertaining to the highlighted sections.

Image 1: Aerodynamic Zones from RWDI Report



To check the amount of drag a given sub-array will experience, the equation in Image 2 is utilized - an excerpt from RWDI's test report. Each sub-array is checked for sliding, proceeding from the smallest to largest or until drag no longer governs total required ballast.

Table 5 lists the calculations used to identify the total required ballast to counteract drag forces and prevent sliding. Friction values have been identified by Testing Engineers (IAS accredited) according to ASTM G115 - Standard Guide for Measuring and Reporting Friction Coefficients. Unless detailed information is available pertaining to the location of the sub-array, the roof's worst case uplift GCp are utilized in calculating drag and required ballast.

Image 2: Ballast to Resist Sliding Equation

Ballast (lb) to Resist Sliding

$$\alpha_D \cdot Ballast_{drag} = \alpha_W \cdot q_z \cdot \left[(GC_p)^*_{drag} \cdot A_{drag} \cdot \left(\frac{1}{f_n}\right) + |GC_p|^*_{uplift} \cdot A_{uplift} \right] - \alpha_D \cdot M \qquad (lb)$$

Table 5: Ballast to Resist Sliding Calculation

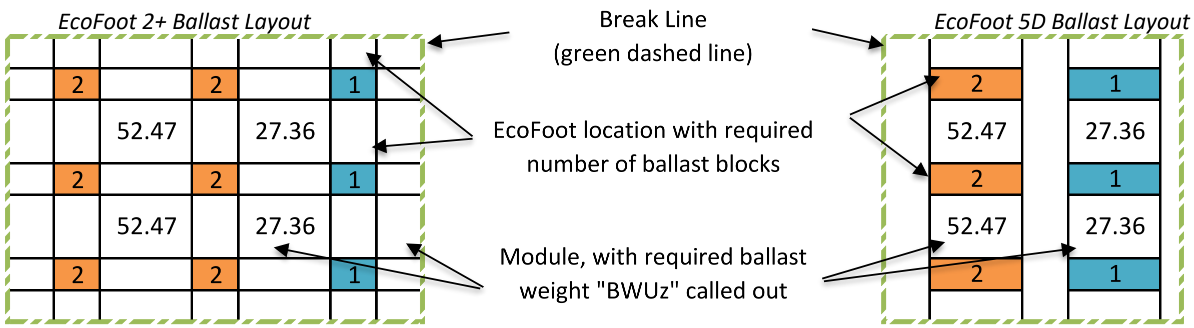
Sub-Array Module Count Total:	16
a_w = Wind Load Combination Factor =	0.6
a_d = Dead Load Combination Factor =	0.6
q_z (q_h in Table 3)=	24.59
M = dLF1 from Table 3 =	56.03
f_n (also see Table 1) =	0.49
A_{uplift} = Ala in Table 3 =	17.97
A_{drag} = Ada in Table 3 =	1.57
$GC_{p\text{-}drag}$	1.44
$GC_{p\text{-}uplift}$	-0.57
Area Reduction Factor =	0.45
$(GCp)^*_{drag}$ =	0.64
$\lvert GCp\rvert^*_{uplift}$ =	0.26
Total Required Ballast Weight (Per Image 2)=	**1725.54**
$W_{ballastblock}$ =	32
Total Required Ballast Blocks:	**54**

Ballast Application to Sheet S-1.0

For easier interpretation, the results calculated in Table 4 are laid out in graphical representations of a solar array, shown in Image 4. Ecolibrium Solar engineers and drafters make use of this graphical layout when applying ballast to a given system design.

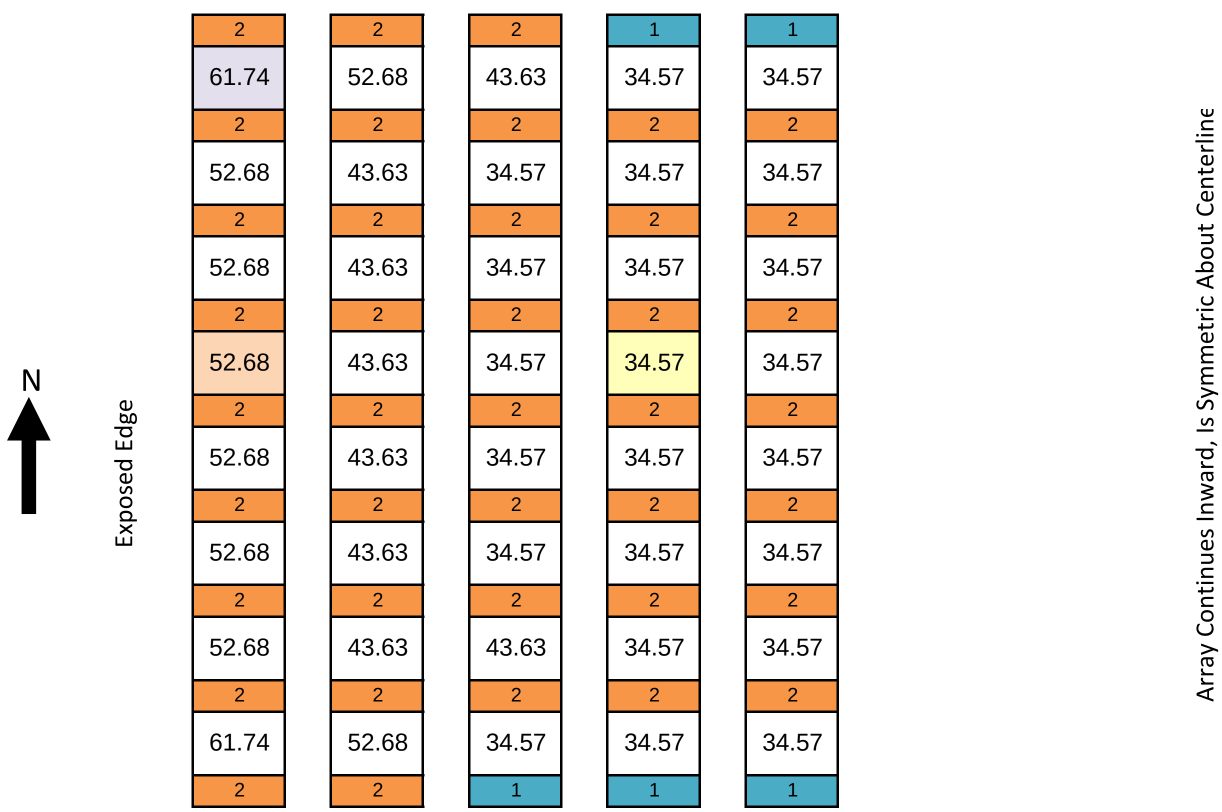
As shown in Image 3, the ballast required to resist lift - BWUz from Table 4 - is listed for each module location in Image 4. A portion of each BWUz value is distributed to each of the connected EcoFoot Bases, also detailed in Image 3 and included in Image 4. The total ballast required at each EcoFoot location is then calculated and rounded up to the next ballast block increment.

Image 3: Example of Module and Ballast Graphical Representation



The ballast prescription array shown in Image 4 is one of many similar arrays created automatically through EcoCalcs in order to address all possible array configurations. The data calculated in Table 4 was ultimately used to assign ballast to the system design in Sheet S-1.0 by Ecolibrium Solar. EcoCalcs and the resulting ballast plan S-1.0 are reviewed by CBC Engineers for correctness and completeness. Once approved, an engineering report including Sheet S-1.0 and any supporting material (this explanation included) are stamped and sealed by a professional engineer registered in the state where the project is proposed.

Image 4: Ballast Prescriptions Produced by Table 4



NOTE: The colored module locations in Image 4 correspond to the same colored areas in Table 4: green - the north corners, purple - the east or west edge, orange - the deep interior. See Page 7 for more detailed calculations.

Detailed Calculations From Table 4

North Corner Module		
GCn Value from RWDI report:	-0.27	
qh value from Table 3:	24.59	
pUz = Uplift design wind pressure in Z direction = qh*GCn:	-6.55	psf
Am = Surface Area of Module:	18.04	sqft
Θm = Module Incline:	5	deg
Ala = PV Module Lift Area = Am * Cos (Θm):	17.97	sqft
WLFUz=Uplift wind load force in Z direction=pUz*Ala	-117.77	lbf
dLF1 = Dead load of one module and attributed hardware:	56.03	lbf
DLFUz=Uplift design load using ASD combo #7 = dLF1*0.6 + WLFUz*0.6	-37.05	lbf
BWuz=ballast weight required to resist wind uplift= -DLFUz/0.6	61.74	lbf

East/West Edge Module		
GCn Value from RWDI report:	-0.25	
qh value from Table 3:	24.59	
pUz = Uplift design wind pressure in Z direction = qh*GCn:	-6.05	psf
Am = Surface Area of Module:	18.04	sqft
Θm = Module Incline:	5	deg
Ala = PV Module Lift Area = Am * Cos (Θm):	17.97	sqft
WLFUz=Uplift wind load force in Z direction=pUz*Ala	-108.71	lbf
dLF1 = Dead load of one module and attributed hardware:	56.03	lbf
DLFUz=Uplift design load using ASD combo #7 = dLF1*0.6 + WLFUz*0.6	-31.61	lbf
BWuz=ballast weight required to resist wind uplift= -DLFUz/0.6	52.68	lbf

Interior Module		
GCn Value from RWDI report:	-0.21	
qh value from Table 3:	24.59	
pUz = Uplift design wind pressure in Z direction = qh*GCn:	-5.04	psf
Am = Surface Area of Module:	18.04	sqft
Θm = Module Incline:	5	deg
Ala = PV Module Lift Area = Am * Cos (Θm):	17.97	sqft
WLFUz=Uplift wind load force in Z direction=pUz*Ala	-90.59	lbf
dLF1 = Dead load of one module and attributed hardware:	56.03	lbf
DLFUz=Uplift design load using ASD combo #7 = dLF1*0.6 + WLFUz*0.6	-20.74	lbf
BWuz=ballast weight required to resist wind uplift= -DLFUz/0.6	34.57	lbf

SEAOC PV1 - 2012 - Section 5: Unattached Arrays

Ecolibrium Solar utilizes the unattached design approach to account for seismic force as provided for by Section 16 of the California Building Code (CBC) and the Structural Engineering Association of California PV1 Requirements (SEAOC PV1-2012). Section 1613 of the CBC defines "Ballasted Photovoltaic System". SEAOC PV1 defines conservative calculations to be used to design unattached photovoltaic systems, independent of friction considerations.

The unattached approach begins with the project specific design criteria. Table 6 lists the relavent project inputs.

Table 6: Seismic Design Inputs

Site Class	D
Seismic Design Category	B
Ip	1
Fa (Site Class D)	1.6
Fa (Site Class E)	2.5
Sms = Fa x Ss	0.384
Sds = (2/3) x Sms	0.256
Occupancy Category	III
Ie	1.25

SEAOC PV1 defines the value Δ_{MPV}, which is the design seismic displacement of the array relative to the roof. This is defined in Table 7. According to SEAOC research, these values are more conservative than shake table testing.

Table 7: SEAOC PV1 Δ_{MPV} Definitions

Seismic Design Category	Δ_{MPV}
A, B, C	6 in.
D, E, F	$[(SDS - 0.4)^2] * 60$ in. $\geq$ 6 in.

For this project, the Seismic Design Category is evaluated as B, and so ΔMPV evaluates as 6 in. SEAOC PV1 Section 6 - Design of Unattached Arrays to Accommodate Seismic Displacement accommodates seismic events by providing calculations to determine the minimum separation required between arrays and roof features. In a seismic event, this minimum spacing ensures the ballasted solar system is allowed to move freely without damaging any roof features, or itself. The calculations outlined in SEAOC PV1 and results are shown in Table 8.

Table 8: SEAOC PV1 Array Setback Requirement Calculations

Condition	**Calculation**	**Result**
Between arrays of similar construction	$0.5(Ip)\Delta MPV$	3 in.
Between array and fixed object	$(Ip)\Delta MPV$	6 in.
Between array and roof edge with parapet	$(Ie)\Delta MPV$	7.5 in.
Between array and roof edge with no parapet	$1.5(Ie)\Delta MPV$	11.25 in.

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Once the minimum separation distances are defined, the maximum allowable array size is determined according to the calculations found in Section 6 pertaining to the interconnection strength of an array. Ultimately, the arrays must not break apart under the forces experienced during potential seismic events. The total horizontal force is defined in SEAOC PV1 as the larger of $0.133S_{DS}W1$ and $0.1W1$, where W1 is "the weight of the portion of the array, including ballast, on the side of the section that has smaller weight."

In practice, Ecolibrium Solar uses the SEAOC equations to calculate the maximum number of modules allowable in the north/south and east/west directions of a rectangular array. This is done by finding the maximum allowable W1 per module at the interconnection plane, based on the interconnection strengths listed in Table 9.

Table 9: EcoFoot2+ Interconnection Strength

Force Direction	Module Design Strength
E/W Horizontal Force	358 lbs.
N/S Horizontal Force	110 lbs.

As the east/west and north/south interconnection strengths are known, the SEAOC equations are rearranged to use horizontal force to determine a maximum W1 for a given section. Then from the maximum sectional W1, the maximum allowable modules on the smaller side of an array is determined from the module and racking weights, as shown in Table 10. The maximum dimensions of any given array, or 2x the maximum W1 half of an array, is also listed in Table 10. These values are used as the maximum dimensions of any array for this particular project.

Table 10: Maximum W1, and W1 side modules

East-West Calculations	
Maximum Section W1 per Module at Interconnection	3580 pounds
Maximum Section Modules from Maximum W1	24 modules
Maximum Array E/W Width (Maximum Section Modules x 2)	**48 modules**
North-South Calculations	
Maximum Section W1 per Module Interconnection	1100 pounds
Maximum Modules per Section per Module at Interconnection	7 modules
Maximum Array N/S Depth (Maximum Section Modules x 2)	**14 modules**

As per SEAOC PV1 - 2012, the system as been determined to have a coefficient of friction greater than 0.4. The coefficients of friction is based on roof material, use of a slip sheet, wet or dry conditions, and expected ballast conditions. All friction values have been identified by Testing Engineers (IAS accredited) according to ASTM G115 - Standard Guide for Measuring and Reporting Friction Coefficients, methodology that is in agreement with SEAOC and Los Angeles, CA stipulations.

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APPENDIX B
SCHEMATIC OF THEORETICAL BALLAST BLOCK REQUIREMENTS

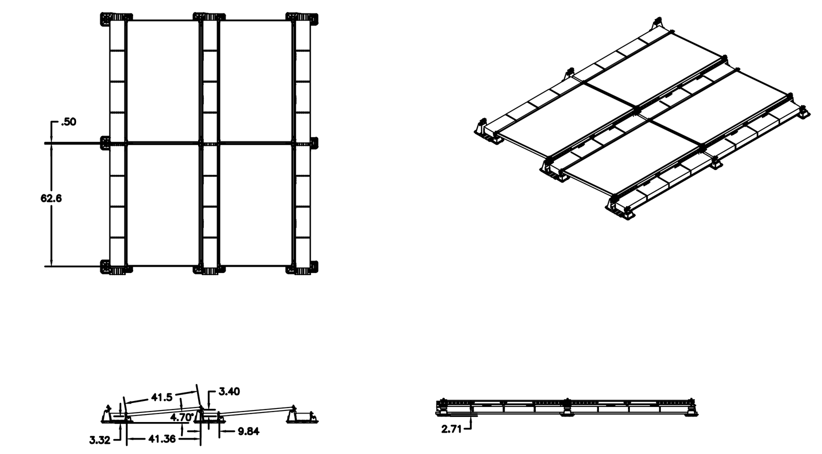
EcolibriumSolar

Rounded General Matrix

Column #   array continues to the right…

Row #	1	2	3	4	5
	2	2	2	1	1
1	North Corner	North Corner	North Corner	North Edge	North Edge
	2	2	2	2	2
2	North Corner	North Corner	North Corner	North Edge	North Edge
	2	2	2	2	2
3	North Corner	North Corner	North Corner	North Edge	North Edge
	2	2	2	2	2
4	East/West Edge	East/West Edge	East/West Edge	Field	Field
	2	2	2	2	2
5	East/West Edge	East/West Edge	East/West Edge	Field	Field
	2	2	2	2	2
6	South Corner	South Corner	South Corner	South Edge	South Edge
	2	2	2	2	2
7	South Corner	South Corner	South Corner	South Edge	South Edge
	2	2	2	2	2
8	South Corner	South Corner	South Corner	South Edge	South Edge
	2	2	1	1	1

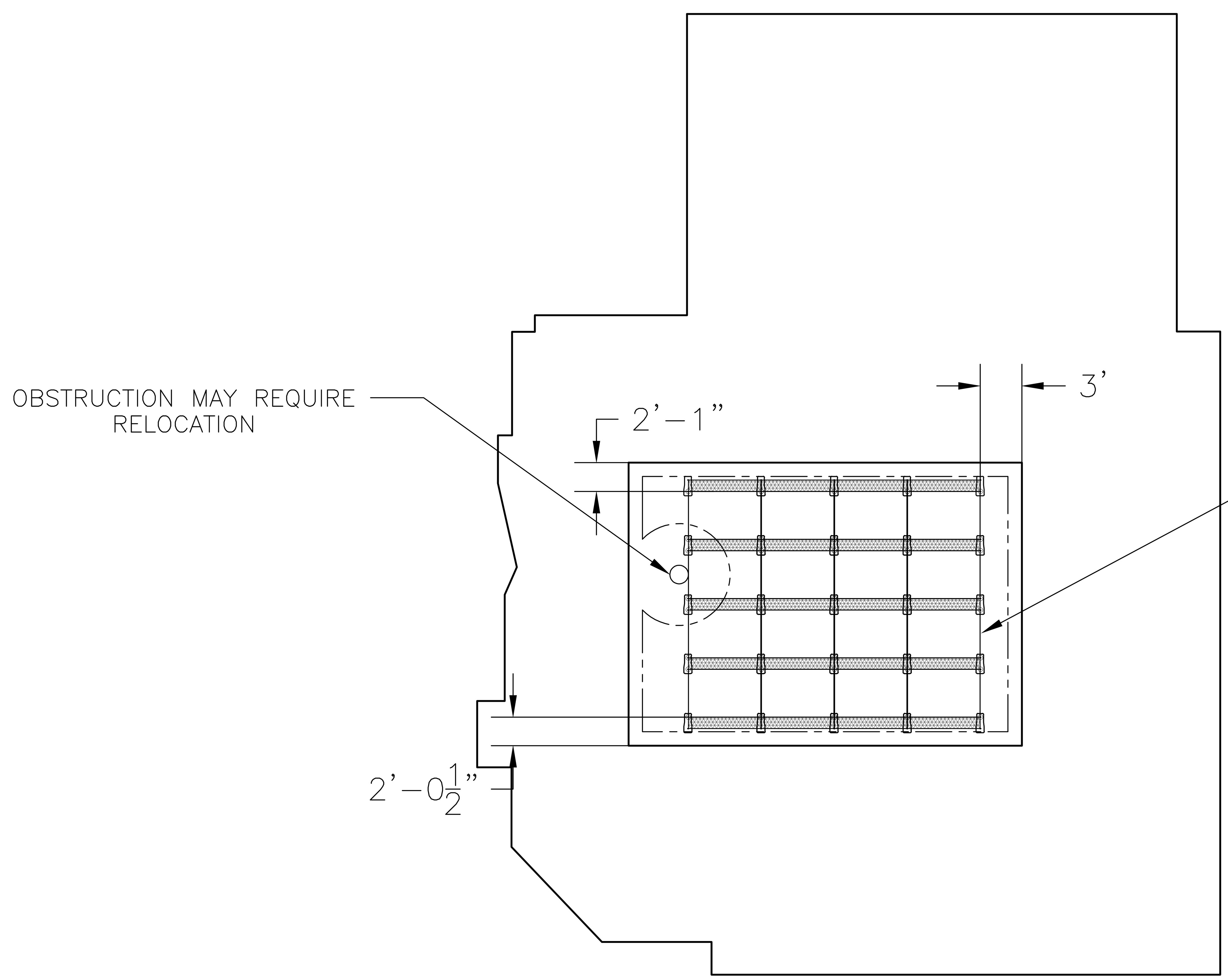
APPENDIX C
PLACEMENT SHOP DRAWINGS



PANASONIC 330W

ECOFOOT5D LANDSCAPE ELEVATION/ISO VIEWS

SCALE: NTS UNITS: INCHES



AVG PSF

ITEM	QTY	LBS	TOTAL WEIGHT
ECOFOOT 5D	25	2.5	62.5
DEFLECTORS	16	3	48.00
BALLAST TRAY	20	8	160
BALLAST BLOCKS	60	32	1920
PANELS	16	40.81	652.96
STRUT (FT)		1.82	######
ATTACHMENTS		2	##
CLEVIS SPLICES		1.23	#####
TOTAL WEIGHT	2843.46		
ARRAY AREA (sqft)	398.97184		
AVG PSF	7.13		

MODULE NOTES

- PV MODULE SPECS (W): 330
- PV MODULE QUANTITY: 16
- SYSTEM POWER RATING (STC kWdc): 5.28
- ORIENTATION/TILT (DEGREE): LANDSCAPE/9.40°

BALLAST NOTES

- BALLAST BLOCK: 16"x8"x4" @ 32 LBS

ECOFOOT 5D LOCATION DETAIL :

= BALLAST TRAY WITH 3 BLOCKS

ARRAY OF GREATEST AVERAGE PSF = 7.13

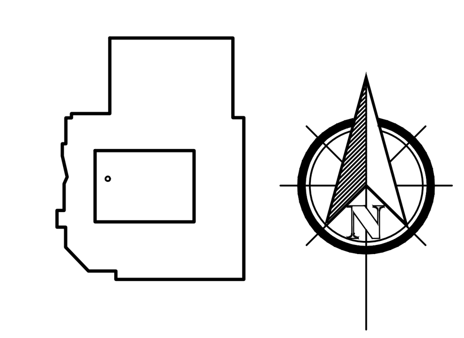
BILL OF MATERIALS

NAME	QTY
ECOFOOT 5D BASE (ES10490)	25
UNIVERSAL CLAMP KIT (ECO-002_106)	32
WIND DEFLECTOR (ES10494)	16
BALLAST TRAY (ES10486)	20
BALLAST BLOCK	60
ATTACHMENT	0
PA BRACKET (ECO-002_117)	0
MID SUPPORT KIT (ES10480)	20

SITE NOTES

BASIC WIND SPEED (MPH)	127
EXPOSURE CATEGORY	B
GROUND SNOW LOAD (PSF)	50
OCCUPANCY CATEGORY	III
SEISMIC (Ss)	0.24
ROOF HEIGHT (FT)	30
ROOFING TYPE	EPDM
BUILDING CODE	IBC 2012

PLEASE REFER TO ACCOMPANYING, SEALED LETTER DETAILING REQUISITE PROJECT DESIGN PARAMETERS. ASSOCIATED SEALED LETTER COMPLETES DESIGN SET



NO.	REVISION	BY	DATE

SHOP DRAWINGS

ECOLIBRIUM SOLAR
507 RICHLAND AVE, SUITE 202
ATHENS, OH, 45701

STATE OF MAINE
MITCHELL T. HARDEN
12588
LICENSED
PROFESSIONAL ENGINEER

CBC Engineers

THIS DRAWING IS BEING SUBMITTED AS A PART OF:
CBC REPORT:21272-1-0318-10
DATED: 3/14/18
AND SHALL ONLY BE USED IN CONJUNCTION WITH THE ABOVE REFERENCED REPORT.

PRODUCED FOR: ASSURED SOLAR ENERGY

PROJECT NAME:

111 WEST ST.
PORTLAND, MA 04102

Date: 2018-03-16	Sheet: S-1.0
Scale: NTS	
Drawn By: KRIS JONES	