CITY OF WINNIPEG TRANSIT
BUS ELECTRIFICATION PROGRAM
SOLAR PV INTEGRATION PLAN
PHASE 2

PRE-FEASIBILITY ENERGY ASSESSMENT

JULY 31, 2020

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Presented to:

Erin Cooke
Project Manager - Bus Electrification Program
Winnipeg Transit
421 Osborne St, Winnipeg, MB R3L 2A2
M: 204-226-3557
E: ecooke@winnipeg.ca
W: winnipeg.ca

Prepared by:

Andrea Kraj, P.Eng, Ph.D.
President and Principal Engineer
Core Renewable Energy Inc.
M: 204-510-2637
E: akraj@corenergy.ca
W: corenergy.ca

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Andrea G. Kraj, Ph.D, P.Eng

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1 INTRODUCTION

In the next 25 years, Winnipeg expects to grow to nearly one million people. Winnipeg Transit is currently developing the Winnipeg Transit Master Plan to lay a vision for the future transit system and determine the steps needed to achieve it. In due process, Winnipeg Transit is considering the electrification of the bus fleet as they think ahead about the future transit system.

Zero-emission battery-electric propulsion transit buses are expected to significantly reduce greenhouse gas and smog-causing criteria air contaminant emissions. In Manitoba, where the electrical grid is renewable, the use of electric propulsion buses is expected to translate to an estimated reduction of 160 tonnes of greenhouse gas emissions, per bus, per year. However, the high electrical demands of the expanded fleet will place a large load on the existing grid system, thus requiring Winnipeg Transit to look at options of self-generating their electrical power using solar power and battery storage at the transit garage.

Winnipeg Transit currently sources electric power through Manitoba Hydro. Manitoba Hydro has confirmed the ability to provide a reliable, steady supply of electricity to power 20 electric buses, comprising Phase 1 of the Bus Electrification Program. However, Manitoba Hydro is unable to supply the power requirements for Phase 2 of the Bus Electrification Program, which will include expansion of the fleet to 100 electric buses. With the requirement to electrify 40 percent of the bus fleet (approximately 288 buses) by 2030, Winnipeg Transit is considering the long-term impact of their bus electrification plan.

As a result, Winnipeg Transit is seeking to create a clean energy, renewable, self-powering system to support the current and future needs of the Bus Electrification Program. The solar energy and battery storage system, otherwise known as a **Microgrid Energy System**, for the City of Winnipeg Bus Electrification Program, could potential be entirely off-grid or grid-tied. The microgrid will facilitate Electric Bus (EB) charging facilities. Additionally, the microgrid design will be to best suit the geography, topography and climate of the preferred site at the Winnipeg Transit Brandon Garage.

For the initial step, Winnipeg Transit has engaged CORE Renewable Energy Inc. ("CORE") to conduct a pre-feasibility assessment of the Microgrid Energy System for budgetary purposes. Specifically, this involves an assessment of the conceptual design, system performance, costs and requirements for the installation and operation of a Solar-Photovoltaic Energy and Storage System. Winnipeg Transit has identified the preferred site of the microgrid to be located at the property civically described as **597 Carlaw Ave, Winnipeg, MB R3L 0V3 (“Winnipeg Transit Brandon Garage”).** Winnipeg Transit has expressed intent to access provincial and/or federal funding opportunities, to the extent possible.

This report consists of the Class 5 (+/-50%) pre-feasibility assessment, along with the preliminary conceptual designs and general drawings (non-stamped) of a Microgrid Energy System located at the Winnipeg Transit Brandon Garage. The energy resource assessment explains the energy usage and solar resource potential at the client’s facility.

The first step of the study was to characterize the solar resources of the area by identifying the mean solar irradiation roof-height from global data collected at the site. This site resource is approximated and can be measured more accurately with instrumentation, however that is beyond the scope of this study. For larger utility scale solar energy projects in the mega-watt scale, measurement of solar resource is important to ensure the accuracy of the large-scale system and the impact it can have on other systems, especially if grid-connected. Typically, measurements are taken over a minimum period of 1-year to provide a seasonal scope of the resource and are on-going once the system is implemented. This is something to keep in mind for the long-term vision of this project as it scales. From this data, a one-year assessment of the capacity factor and energy estimate is approximated and the performance of the system is estimated for the life-time of the project, set to a minimum of 30-years. The life-time of the equipment is dependent on the maintenance and operation of the system. The solar panels have a warranty of 30-years, however the inverters only have a 10-year warranty. Replacement costs for the inverters have been included in this study as well. The performance degradation of the panels is included, as is the increasing costs of the utility power rates. Also, a preliminary constraint analysis is completed, defining the constraints and restrictions to be considered for the solar energy system in the physical and human environment. Using the findings from the preliminary constraint analysis, in conjunction with the solar data, determines the potential of a solar energy system with battery storage for the given study area. Finally, the solar energy and battery backup system equipment is described in the report and an economic analysis is provided with assumptions.

This report consist of the energy resource assessment in section 2, followed by the constraint analysis in section 3. The proposed configuration and energy yield is described in section 4 and the economic analysis in section 5. Conclusions and recommendations are provided in section 6. The appendices contain the technical specifications for the proposed equipment, the economic evaluation, and the conceptual design drawings.

The data contained in this report is preliminary, for budgetary purposes and uses global energy resource data collection.

2 ENERGY RESOURCE ASSESSMENT

2.1 BACKGROUND INFORMATION

Accurate energy production estimates require the use of resource measurements acquired over the long-term from meteorological instrumentation. When such data is not available, numerical models are used for the prediction of long-term solar energy performance. For the City of Winnipeg Transit (COWT) project, solar data measurements were approximated using global meteorological data sources for the region where the project site is located in Winnipeg, Manitoba. The hourly values are synthetic data that are constructed from the irradiance data available for ground stations as averages of 1981-2000, 1991-2010 or 1996-2015 depending on the place and satellite data for 1996-2015. The reference ground station taken in this analysis is the Winnipeg James Armstrong Richardson International Airport, located 7 km from the project site. On-going long-term measurements are advantageous in order to obtain the long-term solar resource characterization that is required to properly assess the solar resource at the proposed site. Using measured data is substantially more accurate than using numerical models and solar maps to approximate solar energy production at the utility scale. Therefore, for this preliminary assessment, in order to gain a sense of the hourly solar irradiation and associated meteorological data, the solar resource data was taken from the reference station meteorological data and extrapolated for the site, under the assumption that the solar resource for the given region has great spatial coherence, thus permitting extrapolation of data over longer distances (hundreds of kilometers) than the station-to-site distance of this project [1].

2.1.1 LOCATION

The preferred site of the microgrid is at the property civically described as **597 Carlaw Ave, Winnipeg, MB R3L 0V3 ("Winnipeg Transit Brandon Garage").** It is located in central Winnipeg. The GPS coordinates are 49°51'52.26"N and 97° 8'36.40"W.

Figure 2-1: Winnipeg Transit Brandon Garage aerial view and location according to Google

2.2 ENERGY USAGE

The following section explains the current energy usage at the Winnipeg Transit Brandon Garage from historic data collected through the City of Winnipeg Transit for previous Battery Electric Bus (BEB) studies.

Winnipeg Transit conducted a pilot study to operate a small fleet of electric buses integrated into their normal operations as the first stage in fleet electrification. Transit anticipated operating a maximum of 20 battery-electric buses charging rotationally [2]. From this previous pilot study, Winnipeg Transit concluded that an average daily energy consumption for a fleet of 20 battery electric buses varies from 4,730kWh on weekdays to 2,440 kWh and 1,385kWh on Saturday and Sunday respectively. Buses may operate on different routes to test their performance, but the maximum potential daily consumption is not expected to exceed 5,900 kWh. This information is shown in Table 2-1 and displayed in Figure 2-2 as Power Demand by Time of Day referenced from the Winnipeg Transit Charger Overview report [2] provided by the client.

Table 2-1: COWT Average daily and annual energy consumption and required electric power for a 20-electric bus fleet

Daily	Daily Energy Consumption [kWh]	Annual Energy Consumption [kWh]	Electric Power Requirements [kW]
Weekdays	4,730	1,229,800	967
Saturdays	2,440	126,880	100
Sundays	1,385	72,020	57
Total	27,475	1,428,700	1,123

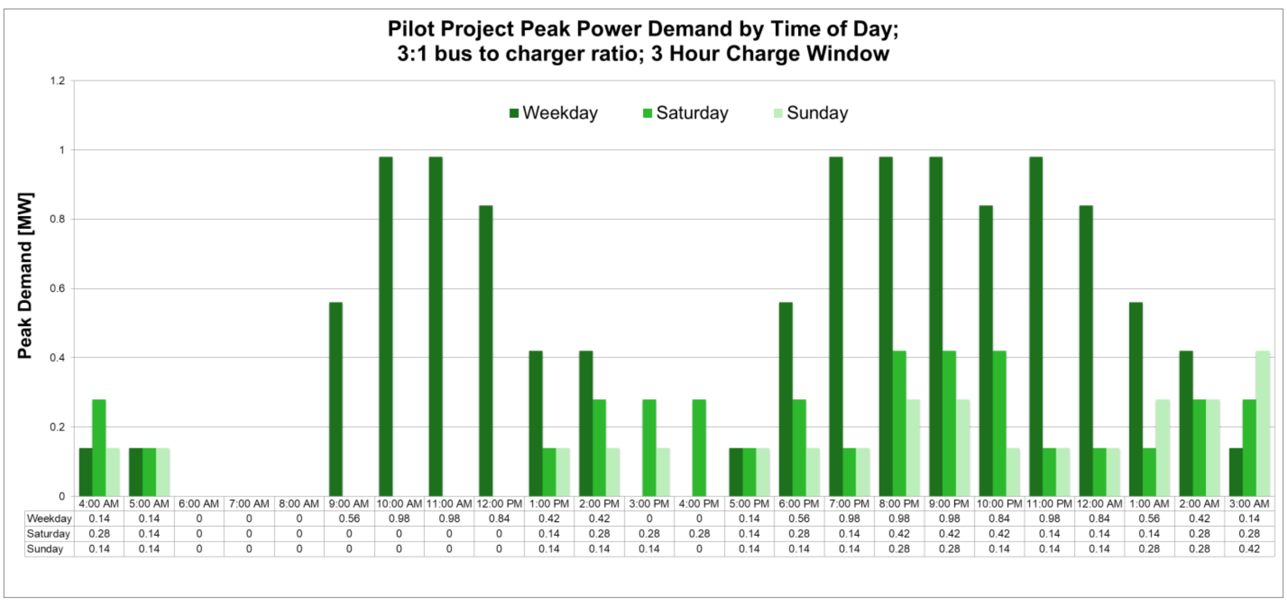


Figure 2-2: COWT Pilot Project Power Demand by Time of Day [2]

The energy consumption for the bus electrification program will continue to increase as new BEB are commissioned. The graph in Figure 2-3 shows the increasing annual energy consumption (AEC) due to potential battery electric bus (BEB) fleet expansion of 40 percent by 2030. Beginning in 2020 with an AEC of 1,428,700 kWh/year for 20 BEBs, and assuming that the fleet would expand in multiples of 20 buses every 2 years to meet the electrification requirement date. The trendline for energy consumption in this graph shows the potential trajectory of annual energy consumption, starting with the initial 20 buses that are electrified by hydro power in phase 1 of the program and the remainder of the fleet electrified by solar power and battery chargers until 2030. The x-axis shows the increasing consumption by generation resource and cumulative BEB fleet expansion as it increases over years, respectively. This takes place in the first 10 years of the initial solar energy system development.

With each cohort of 20 solar charged BEBs requiring 1,428,700 kWh/year or a rough equivalent of a 1.1-MW energy system, a 40% electrified fleet could require as much as 16,287,180 kWh/year or 12.8 MW solar energy system, assuming the annual equivalent full sunlight hours for Manitoba is 1,272 h [3].

Solar energy systems have a minimum warrantied life-time (on main components) of usually 30-years, as per OEM specifications. This means that if the fleet were to continue to steadily grow and become more electrified over the lifetime of the initial solar installation, the peak energy consumption could reach 40,000 MWh/y in 30 years as shown in Figure 2-4.

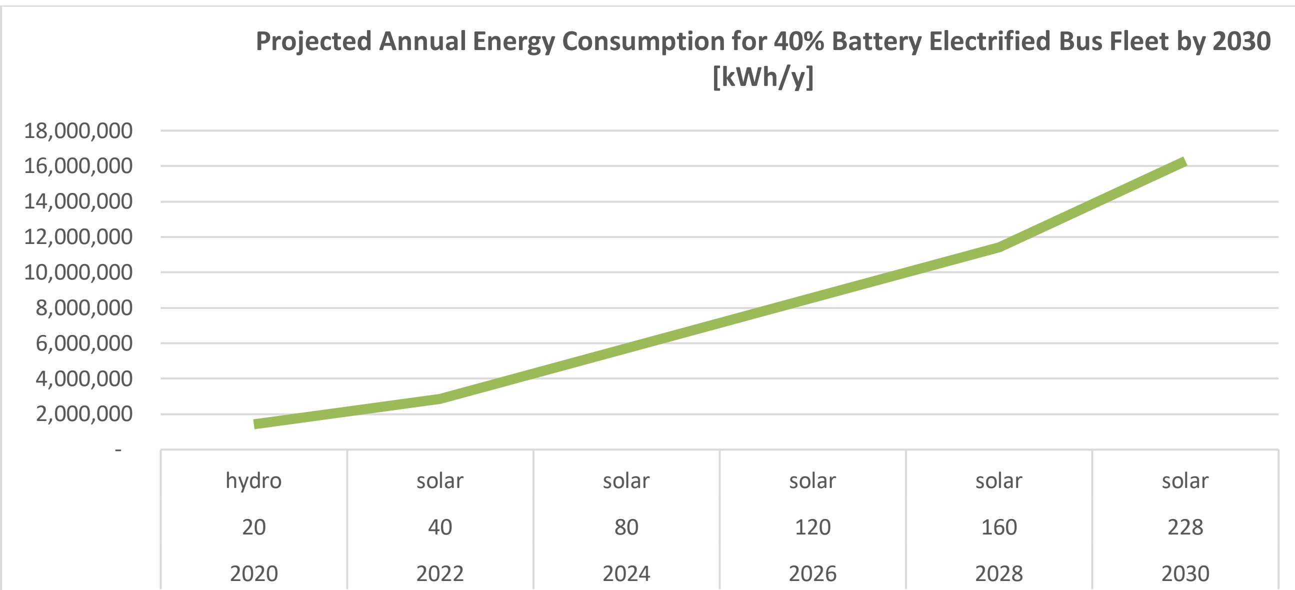


Figure 2-3: Projected Annual Energy Consumption for 40% Fleet Expansion [2]

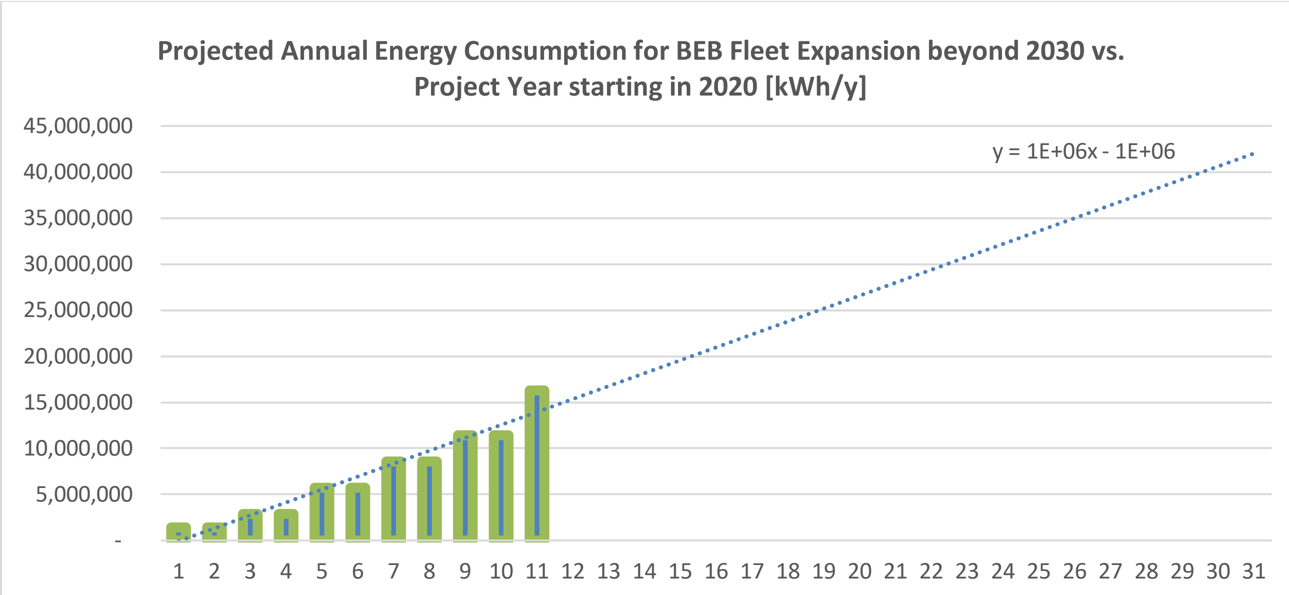


Figure 2-4: Projected Annual Energy Consumption for Fleet Expansion beyond 2030.

2.3 ELECTRICITY RATES AND RATE INCREASES

On June 1, 2019, the electricity rates changed to reflect an average revenue increase of 2.5% for most customer classes. This increase was approved by the Public Utilities Board of Manitoba (PUB). Rates for the general service small non-demand class have been adjusted to more accurately reflect the cost to serve these customers.

Table 2-2: Average rate increases in 2019 by Manitoba Hydro customer class

Summary of the average increases by customer class	
Class	**Average increase**
Residential	2.5%
Residential First Nations on-reserve	0.0%
General service small non-demand	1.3%
General service small demand	2.5%
General service medium	2.5%
General service large 750 V to 30 kV	2.5%
General service large 30 to 100 kV	2.5%
General service large >100 kV	2.5%
Area & roadway lighting	2.5%

As energy consumption increases, the cost of electricity is positioned to increase as well for commercial rate payers. Table 2-2 indicates that in both the medium and large service customer classes, electricity rates increased 2.5%.

2.3.1 HISTORIC RATE DATA INCREASES

Manitoba Hydro provides historical rate increase information from which forecasted rates can be extrapolated to gain a sense of the cost of future consumption, given the significant increases Winnipeg Transit anticipates with an electrified bus fleet. Table 2-3 and Table 2-4 respectively indicate that for both the existing medium service customer class that Winnipeg Transit uses at the Brandon Garage and the future transition to the large service class due to fleet electrification at the Brandon Garage, rate increases are to be expected, corresponding to the life-time of the solar energy installation. The Brandon Garage is currently under the General Service medium customer class and is charged according to Table 2-3. However, Winnipeg Transit anticipates upgrading to the General Service large customer class exceeding 750 V but not exceeding 30 kV, with the installation of the bus chargers at the Brandon Garage. The Fort Rouge garage is currently at this large customer class and the service for the anticipated new garage to be built is 60 kV, requiring Winnipeg Transit to upgrade to the next rate class of General Service large – customer-owned transformation; exceeding 30 kV but not exceeding 100 kV.

Table 2-3: General Service medium – utility-owned transformation; billing demand exceeding 200 kVA [4]

General service medium – utility-owned transformation; billing demand exceeding 200 kVA						
Effective date	**Basic monthly charge**	**First 11,000 kWh (¢/kWh)**	**Next 8,500 kWh (¢/kWh)**	**Balance of kWh (¢/kWh)**	**First 50 kVA of monthly recorded demand**	**Balance of kVA**
2019 Jun	$31.58	9.017	6.662	4.211	No charge	$10.78

Table 2-4: Service large – customer-owned transformation; exceeding 750 V but not exceeding 30 kV [4]

General service large – customer-owned transformation; exceeding 750 V but not exceeding 30 kV			
Effective date	**Energy charge**	**Demand charge**	**Energy charge Increase**
	(¢/kWh)	**($)**	**%**
2015	3.472	$8.02	
2016	3.589	$8.29	3.4%
2017	3.709	$8.57	3.3%
2018	3.859	$8.92	4.0%
2019	3.955	$9.14	2.5%

Figure 2-5 shows a simplified linear projection of increases to energy charge and demand charges based on historical data provided by Manitoba Hydro for the General service large class exceeding 750 V but not exceed 30 kV, indicating that in 30 years, this customer class could be paying 8 cents/kWh and $18 in demand charges.

Demand charges are defined by Manitoba Hydro as “that portion of the charge for electric service based upon the electric capacity (kVA) consumed and billed on the basis of the billing demand under an applicable rate schedule.” [https://www.hydro.mb.ca/regulatory_affairs/definitions/#electricity]

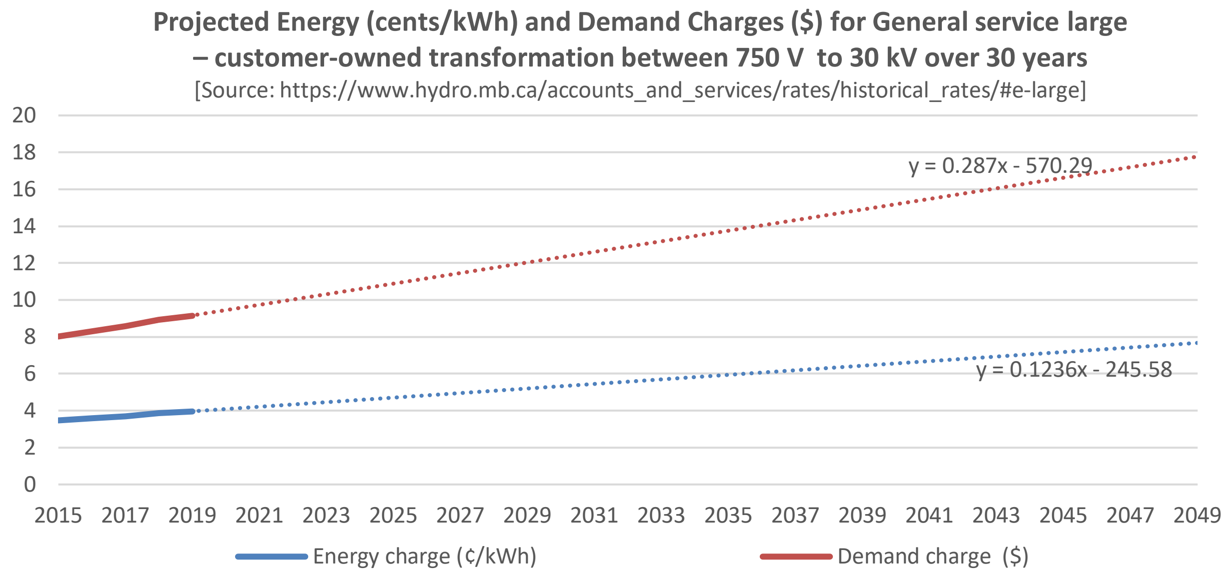


Figure 2-5: Projected Energy and Demand Charges

2.3.2 CURRENT ELECTRITY RATES FROM MANITOBA HYDRO

The current Manitoba Hydro commercial electricity rates for customer classes are defined in Table 2-5 for general service medium and in Table 2-6 for general service large between 750 V – 30 kV. The costs listed in Table 2-5 would be relevant to the existing rates that Winnipeg Transit is paying at the Brandon Garage. The costs listed in Table 2-6 are relevant to the future system incorporating the bus chargers using the battery energy storage system (BESS) and the solar-PV energy generation system at the Brandon Garage. The costs listed Table 2-6 are used in the economic analysis of this study presented in section 5, and assume that demand charges are not applied at this time. Upon further analysis and electrical engineering studies, the role that demand charges have in the pricing strategy can be determined.

Table 2-5: Current Manitoba Hydro electricity rates for general service medium customer class, July 2020 [5]

General service medium	
Charge	**Cost**
Basic monthly charge	$31.58
First 11,000 kWh	9.012¢/kWh
Next 8,500 kWh	6.662¢/kWh
Balance of kWh	4.211¢/kWh
First 50 kVA of monthly recorded demand	No charge
Balance of recorded demand	$10.78/kVA
Minimum monthly bill is the basic charge plus demand charge.	

Table 2-6: Current Manitoba Hydro electricity rates for general service large, 750 V- 30 kV customer class, July 2020 [5]

General service large – exceeding 750 V but not exceeding 30 kV	
Charge	**Cost**
Energy charge	3.955¢/kWh
Demand charge	$9.14/kVA
Minimum monthly bill is the demand charge.	

Considering the above current electricity rates for the large general service customer class and implementing the average electricity rate increases in customer class between 2.5%-4.0% to reflect the historic rate increases presented in Table 2-2, an approximation of potential rate increases over the 30-year period of the project minimum life-time is presented to understand the equivalent costs that would be expected if electricity were to be supplied by Manitoba Hydro over the same period as the lifetime of the solar-energy system. With the rate of electricity price increasing and a historical trend to verify it, Winnipeg Transit will likely be paying more that 6 cents per kWh in the near future in additional to demand charges, and likely over $0.12 per kWh in the next 30 years using a modest electricity rate increase, as shown in Figure 2-6.

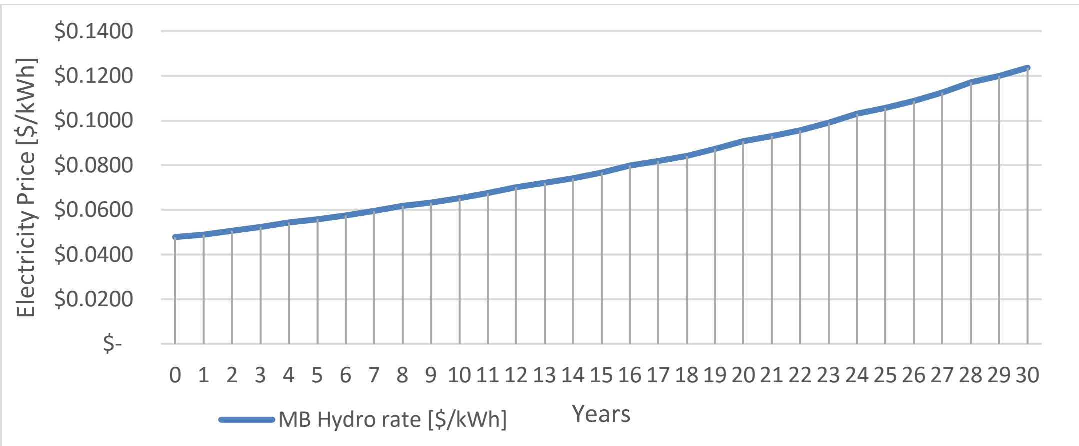


Figure 2-6: Potential Manitoba Hydro electricity rates over a period of 30 years for general service large (750V-30kV) customer class

Implementing these rates to the previously mentioned projected annual energy consumption for the expansion of the BEB fleet by 2030 presented in Figure 2-3, indicated that the cost for year one and year two would be just under $100,000 dollars per year to power the fleet from Manitoba Hydro's grid, if Manitoba Hydro (MH) had the power available to support this load. However, by 2030, with the expansion to 40% electrified fleet, the cost of hydro power would be over $1,000,000 dollars. Despite the energy charge from MH remaining relatively low for general service large customers, the demand charges are an unknown additional cost at this time that may add a significant cost to Winnipeg Transit if remaining dependent on Manitoba Hydro to supply electricity for the growing fleet of battery electric buses. This result it shown in Figure 2-7 without demand charges included.

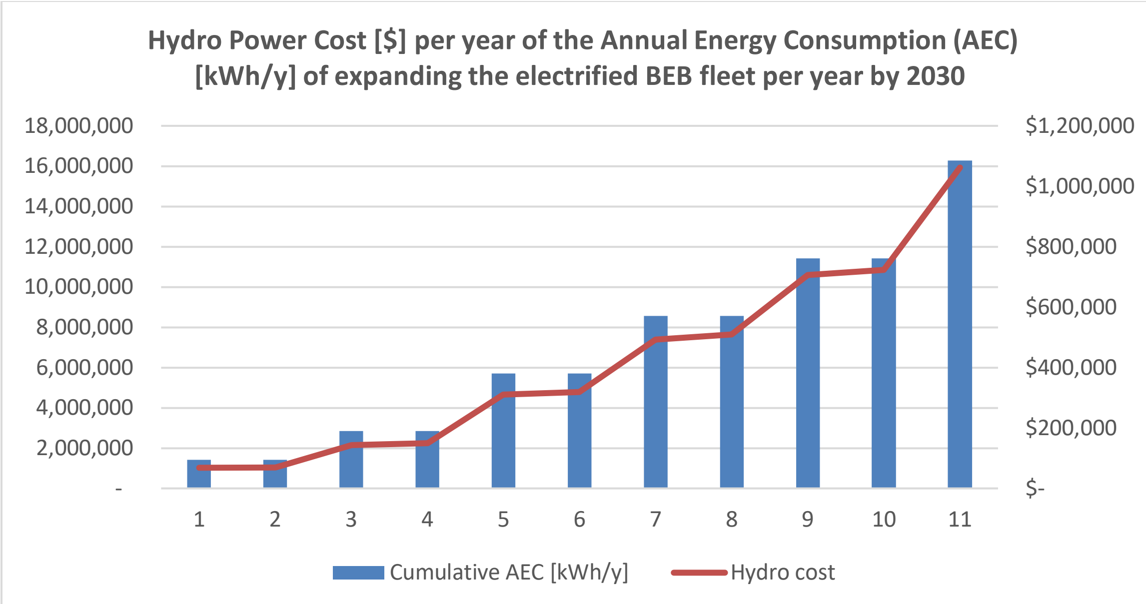


Figure 2-7: The cost [$CAD] of hydro power per year for an expanded electrified BEB fleet by 2030

2.4 SOLAR RESOURCE ASSESSMENT

The global horizontal incident radiation in a typical year, at a given location, is required to determine the characteristic solar resource of a site. Insolation is the rate of delivery of solar radiation per unit of horizontal surface, also referred to as global irradiance. The global irradiance on a horizontal surface or global horizontal irradiance (GHR), on Earth, consists of the direct irradiance and diffuse irradiance. On a tilted surface, there is another irradiance component, which is the component reflected from the ground. The average ground reflection is about 20% of the global irradiance. Irradiance measures in units of W/m^2. The solar irradiance over a period is solar irradiation. To calculate the power of the PV panels, the area of the PV panels must be accounted for.

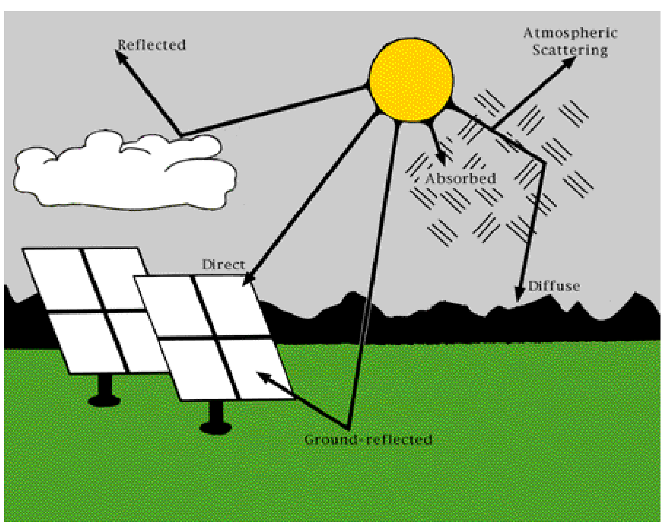


Figure 2-8: Solar radiation components resulting from interactions with the atmosphere. Image by Al Hicks, NREL

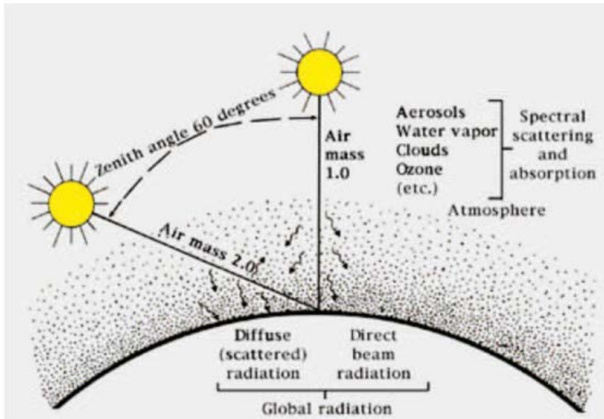


Figure 2-9: Scattering of the direct-beam photons from the sun by the atmosphere produces diffuse radiation that varies with AM (Marion et al. 1992). Image by NREL

The preliminary solar resource assessment is conducted from approximated global meteorological data sources available for ground stations as averages of data between 1981-2000, 1991-2010 or 1996-2015 depending on the place and satellite data for 1996-2015.The reference ground station is taken as the Winnipeg James Armstrong Richardson International Airport, located 7 km from the project site. For this preliminary assessment, in order to gain a sense of the hourly solar irradiation and associated meteorological data, the solar resource data was taken from the reference station meteorological data and extrapolated for the site, under the assumption that the solar resource for the given region has great spatial coherence, thus permitting extrapolation of data over longer distances (hundreds of kilometers) than the station-to-site distance of this project [1].

The Meteonorm database was used as the source for the data. Meteonorm generates accurate and representative typical years for any location on earth and consists of more than 30 different weather parameters. The database consists of more than 8 000 weather stations, five geostationary satellites and a globally calibrated aerosol climatology. On this basis, sophisticated interpolation models, based on more than 30 years of experience, provided results with high accuracy for the project location. Due to the proximity of the Brandon Garage site to the data collection point, the solar resource data is approximated to be equivalent for the project site. The conclusions that are drawn from this data provide an approximation of the potential annual solar resource available at this site. Data collected is for the project site identified in Table 2-7.

Table 2-7: Project location in GPS coordinates

LATITUDE:	49°51'53.585"N 49.8648846
LONGITUDE:	97° 8'35.359"W -97.1431553
ELEVATION:	235 m.a.s.l.

Global Horizontal Irradiance (GHI) is the total solar radiation incident on a horizontal surface. It is the sum of Direct Normal Irradiance (DNI), Diffuse Horizontal Irradiance, and ground-reflected radiation. Figure 2-10 shows the Hourly Incident Global irradiation for seasonal dates in a year for Winnipeg, MB.

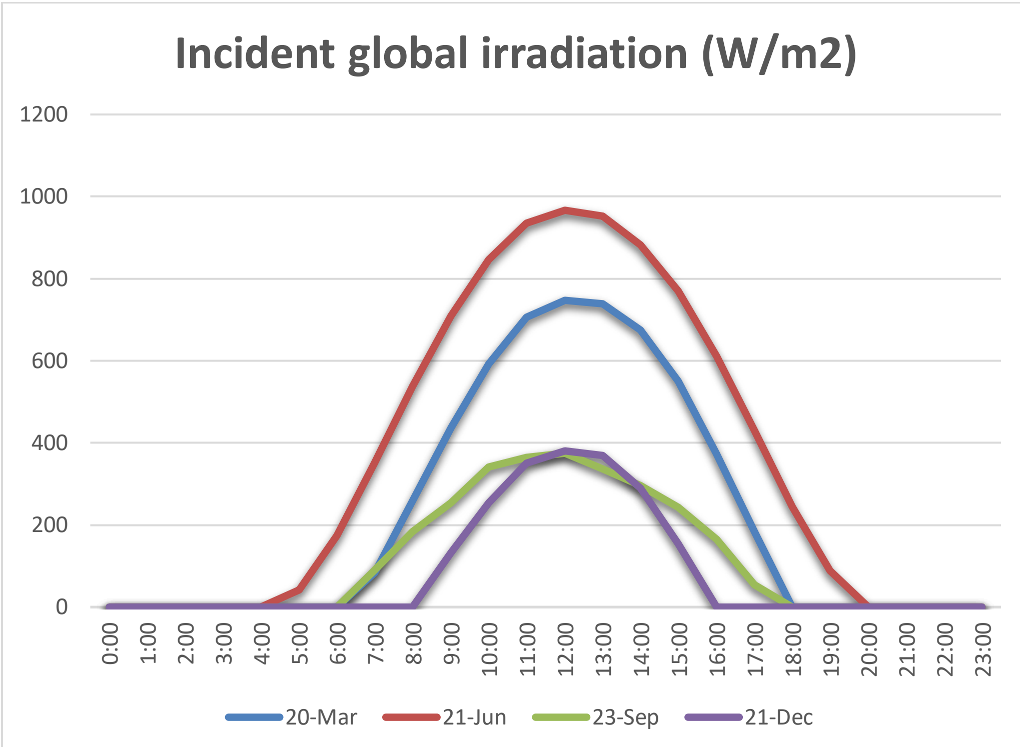


Figure 2-10: Hourly Incident Global irradiation for seasonal dates in a year for Winnipeg, MB

Figure 2-11 compares the Incident global irradiation with the effective global irradiation for these same season dates as in Figure 2-10 to indicate the losses that are applied to the irradiation as it travels through the atmosphere to reach the PV-panel surface.

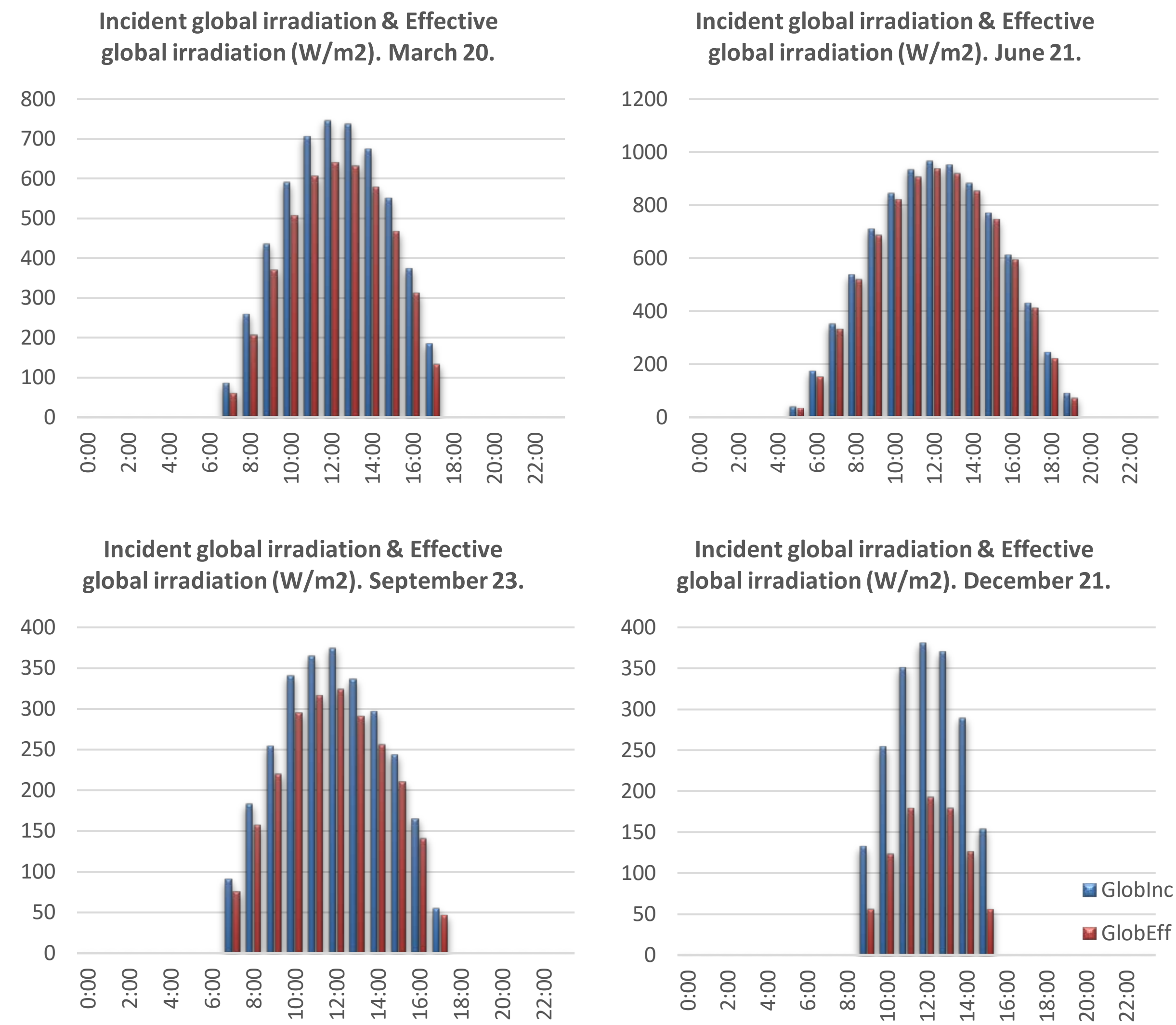


Figure 2-11: Comparison of incident global irradiation and effective global irradiation for seasonal dates in a year for Winnipeg, MB.

The global effective incident energy is defined as the energy that contacts the PV panels and accounts for the losses incurred for travelling through the atmosphere due to dust, scatter and particulate etc. The amount of global effective incident energy per month in a year for Winnipeg, MB is shown in Figure 2-12.

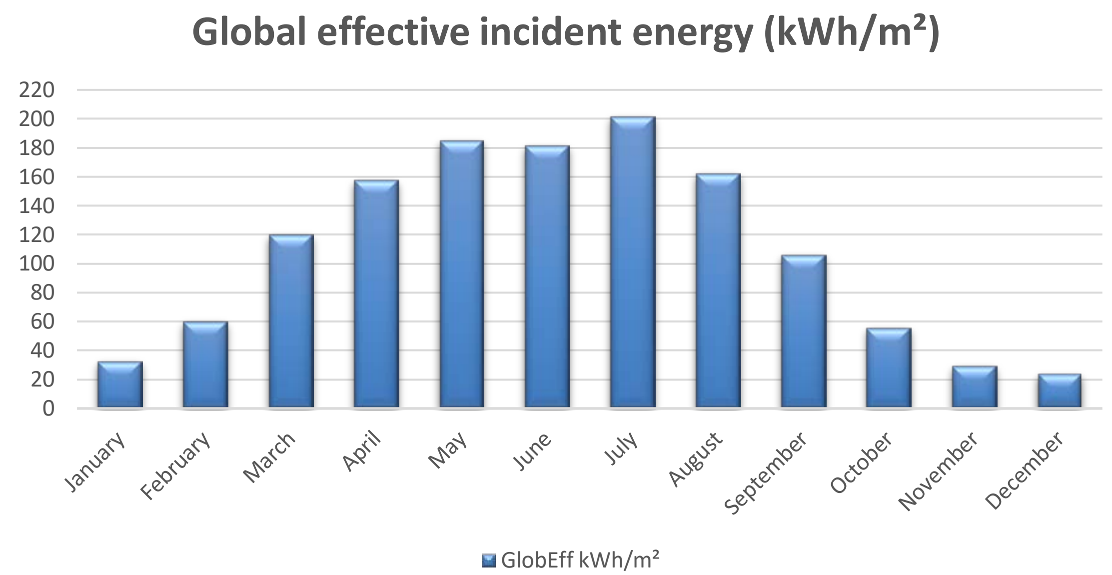


Figure 2-12: Global effective incident energy (kWh/m²) per month in a year for Winnipeg, MB

Figure 2-13 shows the varying solar paths throughout the year in Winnipeg, Manitoba. At the summer solstice in June, indicated by reference point 1 in Figure 2-13, the sun begins to rise before 6 am and sets after 7pm. Conversely, at the winter solstice, indicated by point 7 in the same figure, the sun begins to rise after 8am and sets before 5pm. The impact of the solar hours available at different times of the year directly effects the global effective incident energy available to the PV panels, despite the amount of annual solar irradiation available in the same location.

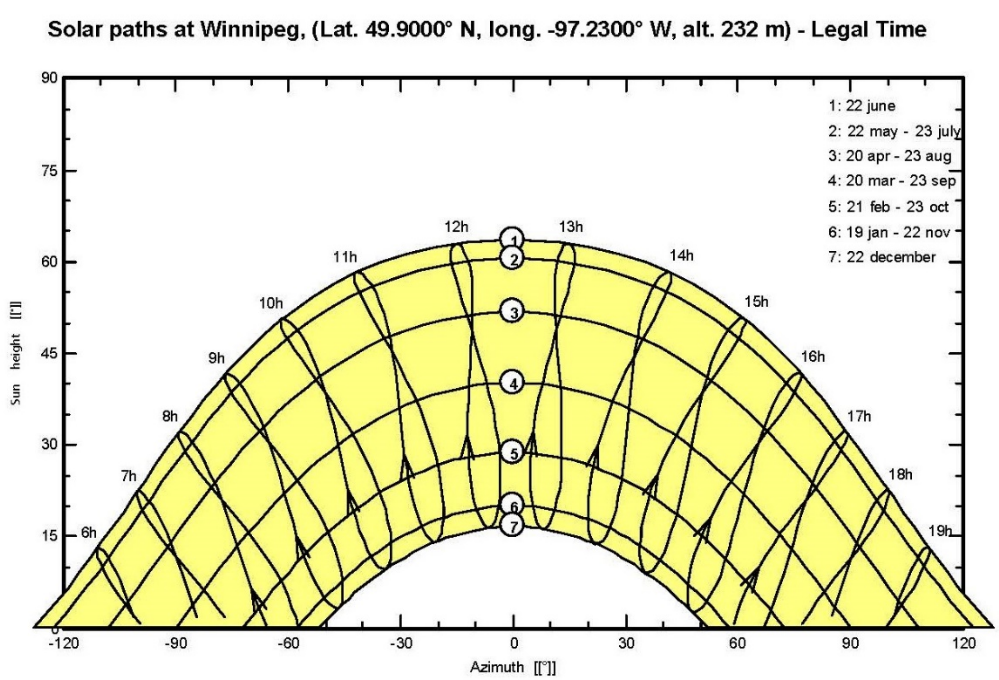


Figure 2-13: Apparent sun path variations during one year in Winnipeg, Manitoba

3 PV SYSTEM COMPONENTS

Solar PV technology converts energy from solar radiation directly into electricity. Solar PV cells are the electricity-generating component of a solar energy system. When sunlight (photons) strikes a PV cell, an electric current is produced by stimulating electrons (negative charges) in a layer in the cell designed to give up electrons easily. The existing electric field in the solar cell pulls these electrons to another layer. By connecting the cell to an external load, this current (movement of charges) can then be used to power the load, e.g. light bulb.

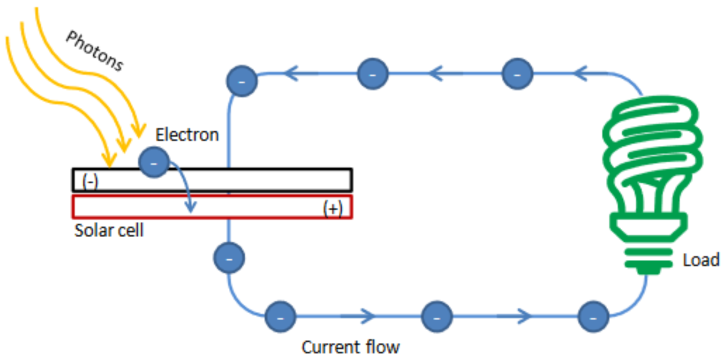


Figure 3-1: Generation of electricity from PV cells

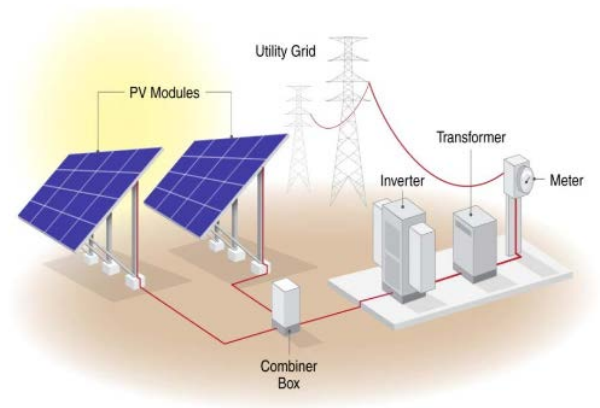
PV cells are assembled into a PV panel or module. PV modules are then connected to create an array. The modules are connected in series and then in parallel as needed to reach the specific voltage and current requirements for the array. The direct current (DC) electricity generated the array is then converted by an inverter to alternating current (AC) that can be consumed by adjoining buildings and facilities or exported to the electricity grid. PV system size varies from small residential (2 kilowatts (kW)-10 kW), commercial (100 kW-500 kW), to large utility scale (5+ megawatts (MW)).

3.1 MAJOR COMPONENTS

A typical PV system is made up of several key components:

- PV modules
- Inverter
- Balance-of-system (BOS) components
- Battery (optional and off grid system)

A diagram of a ground mounted versus roof-top mounted commercial solar energy system is shown in Figure 3-2. The following section will describe the key components of the proposed design and the technical specifications of the equipment.



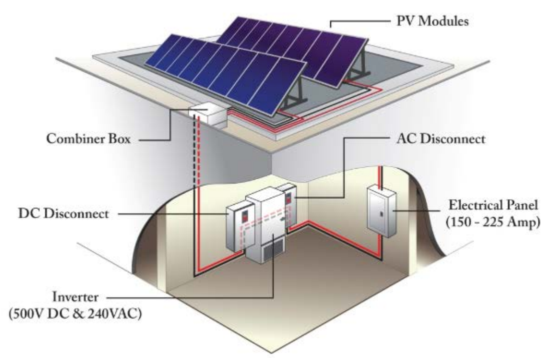


Figure 3-2: Ground mounted and roof-top mounted solar energy system diagrams, respectively

3.2 PV MODULES

Module technologies are differentiated by the type of PV material used, resulting in a range of conversion efficiencies from light energy to electrical energy. The module efficiency is a measure of the percentage of solar energy converted into electricity. A typical PV module is UL listed and tested to withstand certain wind, snow, and hail loads. PV modules are rated in terms of maximum allowable pressure on the module surface. For example, a PV panel rating for wind, snow, and hail loads that shows the maximum pressure for snow load and wind load at 5,400 and 2,400 Pascal (Pa), respectively.

PV modules are not rated to specific wind speeds (mph, kph) or snow loads (psf, Pa) because the racking system will incorporate features to adjust the tilt angle of the array, taken into account when calculating the maximum pressure on the modules.

The PV technology widely used for facility- and utility-scale projects is crystalline silicon.

3.2.1 CRYSTALLINE SILICON

Traditional solar cells are made from silicon. Silicon is quite abundant and nontoxic. It builds on a strong industry from both the supply (silicon industry) and product side. This technology has been demonstrated as a consistent and high efficiency technology over 30 years in the field. The performance degradation, a reduction in power generation due to long-term exposure, is under 1% per year. Silicon modules have typical power production warranties in the 25 to 30 year range but can continue producing energy beyond this timeframe. Typical overall efficiency of silicon solar modules is between 12% and 18%. However, some manufacturers of mono-crystalline modules have demonstrated an overall efficiency over 21%. This range of efficiencies represents significant variation among the crystalline silicon. The technology is generally divided into mono- and multi-crystalline technologies, which indicates the presence of grain-boundaries (i.e., multiple crystals) in the cell materials and is controlled by raw material selection and manufacturing technique. Crystalline silicon modules are widely used based on deployments worldwide and commonly used for the facility-scale application.

3.2.2 RECOMMENDED PV MODULE TECHNOLOGY

The PV module technology recommended for implementation in this study is the Canadian Solar HiKu Super high power mono PERC module, rated at 440 W. It is a mono-crystalline panel. It produces 26% more power than conventional modules and up to 4.5% lower levelized cost of electricity (LCOE), better shading tolerate and low temperature coefficient. It has a lower internal current and lower hot spot temperature as well as enhanced module reliability. It can withstand heavy snow loads of up to 5400 Pa and wind loads up to 3600 Pa. It has a 25-year linear power output warranty and a 12-year enhanced product warranty on materials and workmanship. The technical specifications for this product are provided in the appendices.

PERC stands for “passivated emitter and rear contact” or “rear cell”. Solar panels built with PERC cells have an additional layer on the back of the traditional solar cells. This additional layer allows more sunlight to be captured and turned into electricity, making PERC cells more efficient than traditional cells. PERC modules are also able to mitigate rear recombination and prevent longer wavelengths from becoming heat that would impair the cell’s performance. PERC modules now have an efficiency that is 1 percentage point higher than that of standard modules. Given that a standard module typically has an efficiency of 20%, a system using PERC modules will generate about 5% more energy than a system using standard modules, all else being equal. An example of the proposed PV module with PERC technology is displayed in Figure 3-3.

Figure 3-3: Canadian Solar HiKu Super high power mono PERC module, rated at 440 W [https://www.canadiansolar.com/hiku/]

An example of a project of similar nature using the proposed panels by Canadian Solar is presented in Figure

3-4. This project is roughly half the size of the proposed project at the Brandon Garage.

Dual Cell HiKu Module 0.55 MW Commercial Solar Rooftop

Project Name	Proyecto auto consumo Persax
System Capacity / Type	0.55 MW / Commercial Solar Rooftop
Module Type	HiKu CS3W-P
Location	Alicante, Spain
Installed	2019

Figure 3-4: Example of the Canadian Solar HiKu Module used in 0.55 MW Commercial solar rooftop in Spain [https://www.canadiansolar.com/emea-commercial-projects-proyecto-auto-consumo-persax/]

3.3 INVERTER

Inverters convert DC electricity from the PV array into AC and can connect seamlessly to the electricity grid. Inverter efficiencies can be as high as 98.5%. Inverters also sense the utility power frequency and synchronize the PV-produced power to that frequency. When utility power is not present, the inverter will stop producing AC power into the grid that can be dangerous to utility workers that are trying to fix what they assume is a de-energized distribution system. This safety feature is built into all grid-connected inverters in the market. Electricity produced from the PV system may be fed to a step-up transformer to increase the voltage to match the grid. There are two primary types of inverters for grid-connected systems: string and micro-inverters. Each type has strengths and weakness and may be recommended for different types of installations. String inverters are most common and typically range in size from 1.5 kW to 1,000 kW. These inverters tend to be less expensive on a capacity basis, and typically have high efficiency and lower operations and maintenance (O&M) costs. String inverters offer various sizes and capacities to handle a large range of voltage output. For larger systems, string inverters are combined in parallel to produce a single point of interconnection with the grid or in this case, microgrid system. Warranties typically run between 5 and 10 years, with 10 years being the current industry standard. On larger units, extended warranties up to

20 years are possible. Given that the expected life of the PV modules is 25 to 30 years, an operator can expect to replace a string inverter at least one time during the life of the PV system. With string inverters, small amounts of shading on a solar module will significantly affect the entire array production.

The core job of a PV inverter is to convert the DC from solar cells into AC, however, inverters are currently being engineered for additional responsibilities useful to both the PV system and microgrid, such as grid integration and monitoring. For example, if PV generation needs to be reduced to help balance generation and load in a microgrid, the inverter can curtail PV output via control set-point(s). Inverters also have the capability to “ride through” frequent minor disturbances, as in the case of weak grids or microgrids. Adjustments to inverter trip levels and clearing times that are acceptable to the utility can allow the PV system to stay online and respond accordingly to relatively short-term, minor events. In some cases, this function can actually help the grid to self-heal from a disturbance. Inverters have a wide variety of designs, capabilities, and features and inverter technology continues to evolve at a rapid pace. It is important to ensure that the selected inverters have the advanced capabilities necessary to ensure microgrid-ready status.

3.3.1 RECOMMENDED INVERTER TECHNOLOGY

The inverter technology recommended for implementation in this study is the Solectria XGI™ 1000-65kW Transformerless String Inverter. The Yaskawa Solectria Solar XGI 1000 commercial string inverter is designed for high reliability and built with the highest quality components. Components were selected, tested and proven to last beyond their warranty. The XGI 1000 inverters provide advanced grid-support functionality and meet the latest IEEE 1547 and UL 1741 standards for safety. By meeting the IEEE 1547 standard, this inverter is capable of supporting microgrid compatibility. Offering a wide mounting-angle range (5 – 90° from horizontal), the XGI inverters can be installed to meet NEC (National Electrical Code in the USA) array-level rapid shutdown requirements which are industry leading standards. An example of the proposed inverter technology is displayed in Figure 3-5. The technical specifications for this product are provided in the appendices.

Figure 3-5: Solectria XGI™ 1000-65kW Transformerless String Inverter [https://www.solectria.com/pv-inverters/commercial-string-inverters/xgi-1000/]

Some of the benefits of this product include access to all inverters on-site via Wi-Fi from one location, low cost of O&M, remote diagnostics, remote software & firmware upgrades, 4 MPPTs (maximum power point trackers), advanced grid-support functions and integrated AFCI. The product meets the following Safety Listings & Certifications: FCC Part 15, Class A; UL 1741/IEEE 1547; UL 1741SA, CA Rule 21 (pending); UL 1998 and UL1699B.

As an original equipment manufacturer (OEM), Yaskawa Solectria Solar has significant experience in power electronics and inverter experience compared among others in the industry. The quality and reliability of the product is proven and tested, and they have developed industry leading grid-tied PV inverters ranging from 14kW to 750kW, providing solutions for commercial and utility-scale systems.

3.4 BALANCE-OF-SYSTEM (BOS) COMPONENTS

In addition to the solar modules and inverter, a solar PV system consists of other parts called BOS components, which include:

- Mounting racks and hardware for the modules
- Wiring for electrical connections

3.4.1 MOUNTING SYSTEMS

The structure holding the PV modules is referred to as the mounting system. There are two primary applications of PV mounting systems: roof-mounted and ground-mounted systems. The mounting system can be either directly anchored into the roof or ground or ballasted on the surface without roof or ground penetration. For buildings, PV panels are mounted to the roof pitch. For flat roofs, though the ideal tilt is equal to latitude, the panels are typically mounted at 10° to 15° tilt. Higher tilt may result in higher wind loads and self-shading. Mounting systems should be selected and designed to withstand local wind loads, which range from 145 kph to 193 kph range for most areas outside of hurricane zones. Depending on the region, and especially for where this project is situated, snow and ice loads are also design considerations for the mounting system.

Typical ground-mounted systems can also be categorized as fixed tilt or tracking. Fixed-tilt mounting systems are characterized by modules installed at a set angle, typically based on site latitude and wind conditions, to increase exposure to solar radiation throughout the year. Fixed-tilt systems are the most common type. Fixed-tilt systems may have lower maintenance costs but generate less energy (kWh) per unit power (kW) of capacity than tracking systems.

Tracking systems rotate the PV modules so they are following the sun as it moves across the sky. The tracking systems increases energy output for roughly the same amount of space required for the fixed tilt system. This could be a very good justification for going with a tracking system if the project has some space restrictions. However, they also may increase maintenance and equipment costs slightly and bulky weight to the system. Single-axis tracking, in which PV is rotated on a single axis, can increase energy output up to 25% or more. With dual-axis tracking, PV is able to directly face the sun all day, potentially increasing output up to 35% or more. The selection of mounting type is dependent on many factors including installation size, electricity rates, government incentives, land constraints, latitude, and local weather.

3.4.2 WIRING FOR ELECTRICAL CONNECTIONS

Electrical connections, including wiring, disconnect switches, fuses, and breakers are required to meet electrical codes for both safety and equipment protection. In most traditional applications, wiring from (i) the arrays to inverters and (ii) inverters to point of interconnection is generally run inside electrical conduits. Systems to be designed to the Electrical and Building codes of the jurisdiction.

3.4.3 RECOMMENDED RACKING TECHNOLOGY

The racking technology recommended for implementation in this study is the ballasted system by KB Racking EkonoRack 2.0 and is KB Racking's most popular and bestselling mounting system. The EkonoRack 2.0 is the simplest non-penetrating solar mounting solution for commercial flat rooftops. The system's ETL Certification attests to its high standard of safety and robust design, allowing it to be grounded with only one grounding lug per array. The innovative design is composed of only one major component, acting as a ballast tray, windshield mount and multiple panel support as shown in Figure 3-6 and 3-7. The system's pre-attached roof mats save time on installation and provide maximum protection for the roof.

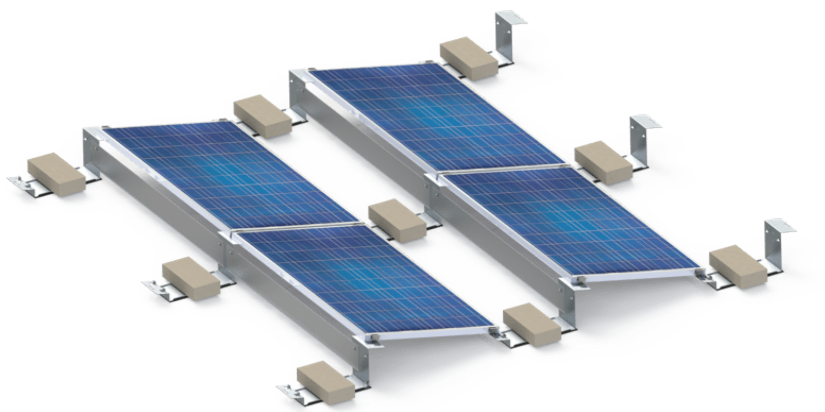


Figure 3-6: A rendering of the solar PV installation using EkonoRack 2.0 racking method

Figure 3-7: The ballast tray of the EkonoRack 2.0 racking system

The latest generation, EkonoRack 2.0 is more cost-effective, resilient, and dependable. It is designed for flat roofs, and are lightweight and easy to install. The key features of this racking system include its simple, click in clamps; high grade, corrosion free aluminum components and 25 year standard- product warranty with extended warranty available. Other features include single point grounding per array due to UL 2703 Listing; single tool installation; class A fire tested for Type 1 and Type 2 panels; non-penetrating installation preventing leaks; integrated rubber roof protection mats for a hassle-free installation; fast installation with click-in module clamps up to 3-4kW/man-hour; and available as a wire management solution.

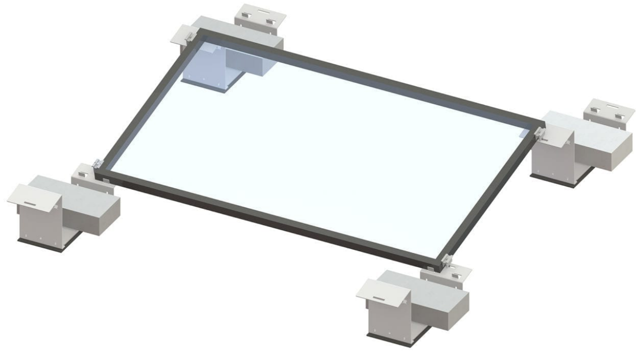


Figure 3-8: The 3-main components for the EkonoRack 2.0 installation

As shown in Figure 3-8, the EkonoRack 2.0 consists of only three main components for rapid installation. Pre-attached roof protection mats are also provided, approved by major roofing manufacturers. The innovative designs enables for customizable row spacing, tilt angle, and orientation, making it an ideal choice for a wider array of operating environments. Since it is a ballasted system, there is no need for any roof penetration to anchor the PV modules to the roof. An example of the proposed racking method for a similar tilted and sized installation is displayed in Figure 3-9. The technical specifications for this product are provided in the appendices.

Figure 3-9: An example of a KB Racking EkonoRack 2.0, 1MW, 10 degree tilt installation

KB Racking specializes in providing commercial solar mounting solutions for rooftops across North America. They manufacture ballasted and anchored solar racking systems for flat roof projects, as well as customized solutions for metal roofs. They work closely with their customers to provide a smooth and seamless experience throughout the entire project cycle. KB Racking was formed in 2010 to deliver high-quality solar mounting systems that can be depended on for years to come. The EkonoRack product

3.5 BATTERY (GRID-TIED AND OFF GRID SYSTEM)

A fundamental characteristic of a PV system is that power is produced only while sunlight is available. Batteries accumulate energy created by PV system and store it to be used at night or when there is no other energy input. For a grid-tied system, where batteries are not inherently required, they may be beneficially included for load matching or power conditioning.

3.5.1 RECOMMENDED BATTERY ENERGY STORAGE SYSTEM (BESS) TECHNOLOGY

The battery energy storage system (BESS) technology recommended for implementation in this study is the EverVolt™ C&I Panasonic BESS by Panasonic Eco Solutions Canada. The EverVolt C&I offers reliable, efficient energy storage for a wide range of grid-connected and behind-the-meter applications. Designed to comply with the stringent power requirements of electric utilities and large enterprises, the EverVolt C&I provides a complete energy storage system, including batteries, PCS, controls and rigorous safety features. Engineered to perform—guaranteed to last—the EverVolt C&I is the latest intelligent energy storage solution from a proven technology partner. An example of the proposed BESS technology is displayed in Figure 3-10. The technical specifications for this product are provided in the appendices.

Figure 3-10: EverVolt™ C&I Panasonic BESS by Panasonic Eco Solutions Canada

The benefits of this product include peak shaving, load shifting, frequency and grid forming, microgrid compatibility, proven safety, reliable performance and best in class warranty. This product uses the Panasonic DCB_106 lithium ion NCA battery with and Energy Capacity of 756 kWh. It contains a fire suppression system and is certified to UL 1741, UL 1973, UL 9450 and UL 9540A (pending).

Panasonic brings a long, distinguished track-record of successful innovation to the development of turnkey integrated energy storage solutions for commercial and industrial C&I enterprises. Backed by a best-in-class warranty and O&M support from Panasonic, EverVolt C&I solutions are pre-engineered, built and tested prior to delivery, ensuring rapid on-site installation and smooth connection to existing electrical systems. Panasonic's plug-and-play EverVolt C&I technology is highly adaptable—perfect for enterprises wishing to participate in energy markets and government incentive programs. Panasonic Eco Solutions is already implementing this technology successfully for similar projects in other jurisdictions of Canada.

3.6 THE MICROGRID SYSTEM

With resilience at the forefront of energy planning, microgrids are rapidly moving into the mainstream. A major driver for this trend includes the increase in natural and man-made disasters and the need to secure crucial services and critical infrastructure in the event of an extended power outage. Microgrids that include solar photovoltaics (PV) as a generating source have the ability to not only provide power when the grid is down, they can also reduce energy costs when the grid is available.

A microgrid is a group of interconnected loads and distributed energy resources that is usually attached to a centralized grid and designed to connect and disconnect from the grid. The interconnection of the system components can be done in either grid-tied with net-metering mode or off-grid in an islanded mode. Grid-connected, microgrid assets can provide economic benefits to owners through activities such as peak shaving, demand response and ancillary services; while also helping to facilitate the integration of renewable energy. In island-mode, microgrids are disconnected from the utility grid and can produce and distribute electricity independently. Serving areas as small as a single building to an entire community, a microgrid can allow facilities such as Winnipeg Transit to operate in the event of a grid outage or self-generate to power a fleet of battery electric buses. With solar PV as a generating source, microgrids can provide localized power for an extended period of time.

In the case of a solar PV generator and battery storage microgrid, a “master inverter” with battery storage can be selected to sets microgrid frequency and voltage. Therefore, the inverters and their functionality as distributed resources in planned electrical islands should comply with applicable provisions described in the IEEE Series of Interconnection Standards, specifically current and revised versions of IEEE Std. 1547 *Standard for Interconnecting Distributed Resources with Electric Power Systems*. Also, ensuring that the selected PV inverters should be multi-mode DC to AC inverters capable of switching between grid- interactive mode and microgrid (intentional island) mode. These inverters, in conjunction with a system supervisory controller, should be capable of bi-directional real and reactive power flow. Additionally, the IEEE Smart Grid Interoperability Series of Standards should be consulted with and referenced in further development of the Winnipeg Transit microgrid, specially current and revised versions of *Standards IEEE P2030.1 Draft Guide for Electric-Sourced Transportation Infrastructure* and *IEEE 2030.2 Guide for the Interoperability of Energy Storage Systems Integrated with the Electric Power Infrastructure* available through the IEEE Standards Association.

3.6.1 POWER FACTOR CONSIDERATIONS

PV systems can affect the power factor (PF) in an electrical system and microgrids can have unique power factor needs. Power Factor is defined as the ratio between the active power (W) and the apparent power (VA). Power factor will vary between 0 and 1, and be either leading or lagging. The solar PV project should be analyzed for PF impact and benefit from a technical and economic perspective in grid-connected and islanded modes. If it is determined site load PF will be affected; inverters, dedicated power electronics, or traditional capacitor banks can provide reactive power (VAR) support and improve PF. The full cost of all the options should be considered. This result can be determined once a full electrical engineering study is conducted with a revised economic analysis, since this is beyond the scope of this report.

3.7 PV SYSTEM MONITORING

Monitoring PV systems can be essential for reliable functioning and maximum yield of a system. It can be as simple as reading values such as produced AC power, daily kilowatt-hours, and cumulative kilowatt-hours locally on an LCD display on the inverter. For more sophisticated monitoring and control purposes, environmental data such as module temperature, ambient temperature, solar radiation, and wind speed can be collected. Remote control and monitoring can be performed by various remote connections and are often web based. Systems can send alerts and status messages to the control center or user. Data can be stored in the memory of the inverter or in external data loggers for further system analysis. Weather stations are typically installed at large scale systems. Weather data such as solar radiation and temperature can be used to predict energy production, enabling comparison of the target and actual system output and performance and identification of under-performing arrays. Operators may also use this data to identify required maintenance, shade on modules, accumulated soiling on modules, etc. Monitoring system data can also be used for outreach and education. This can be achieved with publicly available, online displays; wall-mounted systems; and smart phone applications to name a few.

4 GENERAL TECHNICAL AND SITE SPECIFIC CONSIDERATIONS AND CONSTRAINT ANALYSIS

4.1 GENERAL SITE CONSIDERATIONS

Site considerations for both roof- and ground-mounted systems include:

- Compliance with the National Environmental Policies
- National Historic Preservation policies
- Endangered Species Act (ESA), and other environmental laws
- Utility requirements
- BOS placement
- Site master plan
- Computer network connectivity authority
- Climate considerations
- Vegetation considerations

In this preliminary assessment, the constraints and restriction have only been applied to the solar panel positions on the rooftop of the Brandon Garage. Other required energy infrastructure (access roads, electrical substation and collector system) have not been taken into account.

This constraint analysis allows for a better understanding of the usable space by identifying the known constraints which the developer and the designer may face when choosing solar energy equipment positions. The preliminary constraint analysis also helps the project developer to prioritize which studies or consultations should be done immediately, and which are not urgent or not necessary. Finally, used in conjunction with solar mapping, it will aid the developer in selecting the appropriate project orientation.

4.2 DEFINITIONS

The present constraint analysis defines three types of areas: Available, Constraint, and Inspection zones.

- A **Constraint Zone** is designed as an area where, at the times of the study, there is a strong assumption that a solar panels or associated energy equipment could not be installed because of restrictive regulations, existing infrastructure, or terrain/location features;

- An **Inspection Zone** is defined as an area where a field inspection or an additional analysis is necessary in order to determine its final status: constrained or available;

- An **Available Zone** is defined as an area where solar energy equipment could be placed since no information or data available at the time of the study indicates the contrary.

The Inspection Zones will disappear as the research field work reveals how each element will be classified. The Constraint and Inspection Zones are classified under three different categories: physical, biological and human.

- Inspection and Constraint Zones due to the physical environment are referring to zones where construction is considered difficult or impossible because of terrain features (lakes, slopes, marshes, rivers); or location obstacles are present.

- Inspection and Constraint Zones due to the biological environment are referring to zones where energy equipment positions are considered difficult due to environment protection measures enforced by one or more of the government levels (Municipal wildlife conservation area, Provincial or Federal Park, Area of Natural and Scientific Interest);

- Inspection and Constraint Zones due to the human environment are referring to zones where energy equipment positioning or construction is considered difficult or impossible because of existing infrastructures (telecom towers, railroads, roads, buildings, chimneys, escape routes) or due to the fact that the actual human land use or the terrain is in conflict with a potential energy project construction (touristic infrastructures, glare regulation, aircraft landing corridor, Environment Canada weather radar).

The following section describes the physical and human elements related to solar energy equipment positions that are taken into account in this analysis. A complete account of biological and human elements related to solar energy effects on the environment would need to be separately completed in an Environmental Assessment Screening report, in order to confirm that there is no anticipated negative impact on placing a solar energy project in the potential site area.

Security fences should be used if people or animals are likely to intrude. Fencing should be at least 1.8-m tall, preferably with barbed wire and fitted with locking gates in high-profile areas where intrusion attempts are unlikely. Less elaborate fences may suffice in areas that are generally secure and where only the curious need be discouraged from meddling with the equipment. It may not be possible to keep smaller animals out of the station compound, and precautions should be taken to ensure that the equipment, cabling, and supports can withstand encounters with these animals. Rodents, birds, and other wildlife may be able to move through the wires or jump over or burrow under fences. In particular, signal cabling between modules or sensors at or near ground level is prone to gnawing by rodents and should be run through a protective conduit or buried. Any buried cable should either be specified for use underground or run through conduit approved for underground use. Underground utilities and other objects should be investigated before postholes are dug or anchors sunk.

International Building Code
Fire considerations
In article IBC 1509.7.2, it says that “rooftop-mounted PV systems must not diminish the fire classification of the roof system.”
In order to meet the IBC code here, one must ensure the system and equipment used have a UL fire-tested class rating that either matches or exceeds that of the existing roofing material.

Structural loading considerations
IBC section 3403 says “alterations to the existing building or structure shall be made to ensure that the existing building or structure together with the addition are no less conforming with the provisions of this code than the existing building or structure was prior to the addition.”
This means that when adding solar to an existing structure, an installer cannot exceed what the building or structure was originally engineered to support.

International Fire Code
The IFC states in article 605.11.3.2.1 that “modules should be located in a manner that provides access

pathway for firefighters." It also says in article 605.11.3.2.4 that "panels/modules installed shall be located no higher than 3 ft. below the ridge to allow for fire department ventilation operations."

National Electrical Code and the Canadian Electrical Code
NEC 690 and CSA C22 define electrical safety requirements for PV systems.

Equipment grounding required: Exposed non-current-carrying metal parts of PV module frames, electrical equipment and conductor enclosures must be grounded.

Structure as equipment grounding conductor: Devices listed and identified for grounding the metal frames of solar modules or other equipment can bond exposed metal surfaces or other equipment to mounting structures. Metal mounting structures (other than building steel) used for grounding purposes should be identified as equipment-grounding conductors or have identified bonding jumpers or devices connected between the separate metal sections bonded to the grounding system.

PV mounting systems and devices: Devices and systems used for mounting PV modules that are also used to provide grounding of the module frames should be identified for the purpose of grounding solar panels.

Adjacent modules: Devices identified and listed for bonding the metal frames of PV modules can bond one panel to an adjacent one.

To ensure NEC and CSA requirements are met, one should follow the racking manufacturer's torque specifications to tighten down all connection points. These connections provide the bonding and grounding for the system when assembled properly.

The UL listing of the racking system should be checked to make sure it has been tested and listed under UL 703 for the provision of bonding and grounding required within the codes.

4.3 PHYSICAL ENVIRONMENT

This section deals with constraint and inspection zones within the study area due to the physical environment.

During the construction phase, cranes will be used to lift PV panels and other equipment to the rooftop. A 30 m setback is applied to make sure there is enough room around the crane and construction zones. To make sure the banks of rivers, lakes, wetlands, and streams are will protected; an additional 30 m is added for a total set back distance of 60 m.

Table 4-1: Constraint and Inspection Zones due to Physical Environment

Type	Definition	Additional Setback around zone [m]	Notes	Source
Constraints	Rivers / Wetland	60	Setback from embankment in order to take into account road and crane pad construction.	NTDB
Inspections	10 – 12 % slopes	30	When slopes are steeper than 10%, bringing heavy pieces of equipment on terrain is difficult. Setback from zone for crane pad construction required.	n/a

4.4 HUMAN ENVIRONMENT

This section deals with constraint and inspection zones within the study area due to the human environment. The setback distance for the fall down zone of a typical commercial size solar panel lifted by a crane, applied for safety reasons, is equal to the total height (assuming 10m) of the building plus 10% (approximately 11 - 15 m). Most of the Zoning By-Laws will also require a setback distance from a dwellings. Consideration for approach to runways should be given to determine is glare will impact aircraft.

4.5 ROOFTOP SOLAR CONSIDERATIONS

Rooftop systems need to take into account several different factors including:

- Roof age and condition
- Roof warranty
- Structural loading
- Fire safety guidelines
- Historic preservation.

The age and condition of the roofing material are two issues of concern when assessing conditions for a rooftop system. Solar systems typically have a life of 25 to 30 years. If the roof needs replaced during this time the system will most likely need to be removed and reinstalled. This could add significantly to the levelized cost of electricity (LCOE) of the system and possibly make it uneconomical. Roof warranty can also be an issue as there can be disputes on who is responsible for fixing future roof problems, the solar system installer or roofing installer. It is recommended to contact the company responsible for the roof warranty and discuss what is needed to keep the warranty intact. If it is a new building, or if a new roof will be installed in conjunction with the solar system, a good option may be that one company is responsible for both the solar system and roof installation.

The structural loading of the roof is another key consideration. An assessment of the additional structural load the roof can carry must be performed. The most common PV installation method for flat roofs is a ballasted racking system. The typical weight of a ballasted PV system is about 4 pounds per square foot but varies based on design wind speed, collector tilt, and system design. If very little or no extra load can be placed on the existing roof structure, then an estimation of what is needed to increase the structural strength should be made. If roof structure enhancements are needed, they can be completed separately or included in the scope of the solar system installation. Structural enhancements can be expensive and may make solar uneconomical. Rooftop systems may also need to comply with fire safety guidelines. Local fire authorities should be contacted to determine requirements and confirm that none of the requirements would make a system unfeasible.

Table 4-2: Summary of Technical Considerations, Challenges, and Best Practices for Rooftop Mounted Commercial Solar Project

Technical Considerations	Challenges	Best Practices
Design		
Wind and Snow Loading	· Ensure that PV system is compliant with localized wind speed design criteria · Ensure that PV system is designed to handle localized snow loads	· Wind: o Minimize the height of the array o Utilize heavier, more robust anchoring systems (i.e., ballasted, concrete slabs, shallow-poured concrete footers/pre- case concrete footers) · Snow: raise the height of the module 2-3 feet off the ground to minimize impacts from snow accumulation on the ground · Combined: Consider both wind and snow loads to establish tilt angle, i.e. higher tilt angles will allow snow to slide off, but will result in increased wind loading on the system
Construction		
Site Security	· Prevent unauthorized access to construction site · Protect against theft and vandalism	· Install permanent perimeter fencing prior to construction · Consider use of temporary, lockable storage sheds to secure PV modules and BOS equipment · Consider hiring security patrol service
Installation Protection	· Ensure proper PPE and fall protection guarding is used for installers · First-aid and safety training for installers	· Install temporary guard rails around roof top perimeter prior to construction · Keep first-aid equipment on site and ensure construction crew is trained in case of emergency
Site Security	· Prevent unauthorized access to PV system · Protect against theft and vandalism	· Install permanent perimeter fencing prior to construction · Security cameras · Security lighting with motion sensors · Consider use of temporary, lockable storage sheds to secure PV modules and BOS equipment · Consider hiring security patrol service
Operations & Maintenance		
Adherence with Rooftop Post-closure Operation, Maintenance, and Monitoring Plans	· Ensure compliance with rooftop post-closure plans	· Consider combining rooftop maintenance and PV system maintenance inspections to obtain operational and cost efficiencies · Use PV system monitoring and analysis to identify potential issues on the rooftop
Module Washing and Water Management Plan or Natural Cleansing	· Clean modules to remove dust and silt to maximize PV system output	· Consider natural cleansing from storm events · Avoid use of chemical cleansers in unless necessary · If water cleansing is used and no on-site water is available, ensure that water application is not too heavy for the weight bearing capacity of the rooftop
System Monitoring and Troubleshooting	· Ensure optimal performance of PV system	· Use remote monitoring system in conjunction with on-site weather station to identify system performance anomalies and to trouble shoot and isolate potential PV system problems

4.6 CONSTRAINT RECOMMENDATIONS AND NEXT STEPS

In order to refine the constraint and inspection elements, further inspection of the potential site is required. In addition to the described constraints and recommended inspections, the following analysis and terrain validations are recommended:

- Restrictions due to small airport and runways to determine if glare will be an issue on approach for aircraft to nearby airports
- Precise inventory of buildings present in the area in order to establish a precise list of dwellings for zooming bylaws if necessary.

5 PROPOSED CONFIGURATIONS AND ENERGY YIELD

Given the needs of Winnipeg Transit to electrify the bus fleet using the Brandon Garage in Winnipeg, Manitoba, a solar photovoltaic energy system with battery energy storage system was designed to maximum rooftop availability and generation capacity.

The microgrid system design was conducted using the following assumptions and limitations:

- Maximum installed capacity is limited to the project area constrained to the rooftop of the Brandon Garage for this study.
- The shading analysis only accounted for the objects measured on the site rooftop above the PV-panels and does not include the obstacles surrounding the building.
- Wiring for electrical systems is not measured and is assumed in bulk for preliminary design purposes
- The influences of electrical components beyond the inverter are not analyzed as a full electrical engineering study must be conducted
- Roof loads are assumed to be within the capacity of the building to support the additional loads on the rooftop due to the PV-system components and associated wind and snow loading
- A 4-foot perimeter setback from the edges of the building rooftop has been assumed as sufficient per building code requirements
- Setbacks from building corners due to wind loading are unnecessary
- Access pathways to rooftop objects and setback distances from obstacles are sufficient and double as fire access pathways
- 10-degree tilt angle of solar panels in single rows spaced at 1.43m is used
- PV panels are orientated 21-degrees off direct south towards the west (azimuth) for best fit
- A range of 1 to 13 BESS units is possible to be used, depending on the charging cycle and available solar power throughout the year.
- Grid-tied system configuration is assumed

Measurements taken:

- All roof obstacles were measured on site and applied to the design and constraint analysis.

5.1 SYSTEM CONFIGURATION

The installed capacity of the solar energy system consists of 2,520 solar panels, rated at 440 W dc, providing a total nominal power of 1.1 MW dc. There are 14 inverters with a nominal power rating of 65kW ac. This provides a total nominal power of 910 kW ac. This results in a DC to AC ratio is 1.22. The proposed configuration is composed of the following components, previously described in section 4, and listed in Table 5-1.

Table 5-1: System Components

Component	Product	Quantity	Nominal Power, Pnom	Total Pnom
PV-panels	CS3W-440MS	2520	440 W dc	1109 kWp
Inverters	XGI 65-1000	14	65 kW ac	910 kWac
BESS	EverVolt C&I	4	250kW/1MWh	4h autonomy
Racking	EkonoRack 2.0 Ballast trays	698	Total Ballast Weight: 95,058 kg	Total System Weight: 165,777kg

The EverVolt C&I product is a 250kW/2-hr duration and can be modified to a 4-hr duration by adding battery racks. Four of these enclosures are recommended to be deployed for each 1-MW of solar capacity to give each site a total installed capacity of 1MW/4MWh, based on a project of similar nature and scale in another Canadian jurisdiction.

The design parameters for the project site at the Brandon Garage are listed in Table 5-2.

Table 5-2: Design Parameters

Geographical Site	Brandon Garage
Latitude	49.86^{o}N
Longitude	-97.14^{o}W
Azimuth	21^{o}
Tilt	10^{o}
Row Spacing	1.43 m
Inter-row Spacing	0.39 m
Edge setback	1.22 m
Panel position	landscape

A rendering of the PV solar energy system on the rooftop of the Brandon Garage is provided in Figure 5-1.

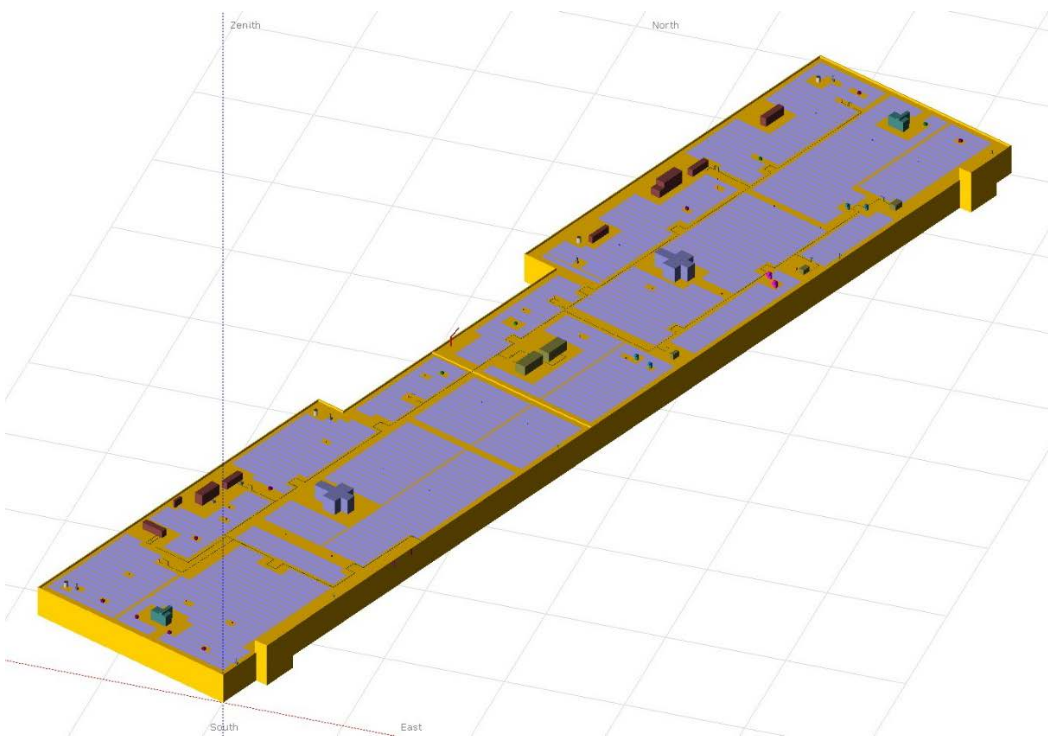


Figure 5-1: Winnipeg Transit Microgrid, 1.1MWdc Solar PV –Battery at the Brandon Garage

The top-view of the proposed solar-PV layout is presented in Figure 5-2. Detailed layout drawings for the conceptual design are provided in the appendices, along with sectioned drawings in detail. The racking report is also provided for reference to PV rooftop position and loads in the appendices.

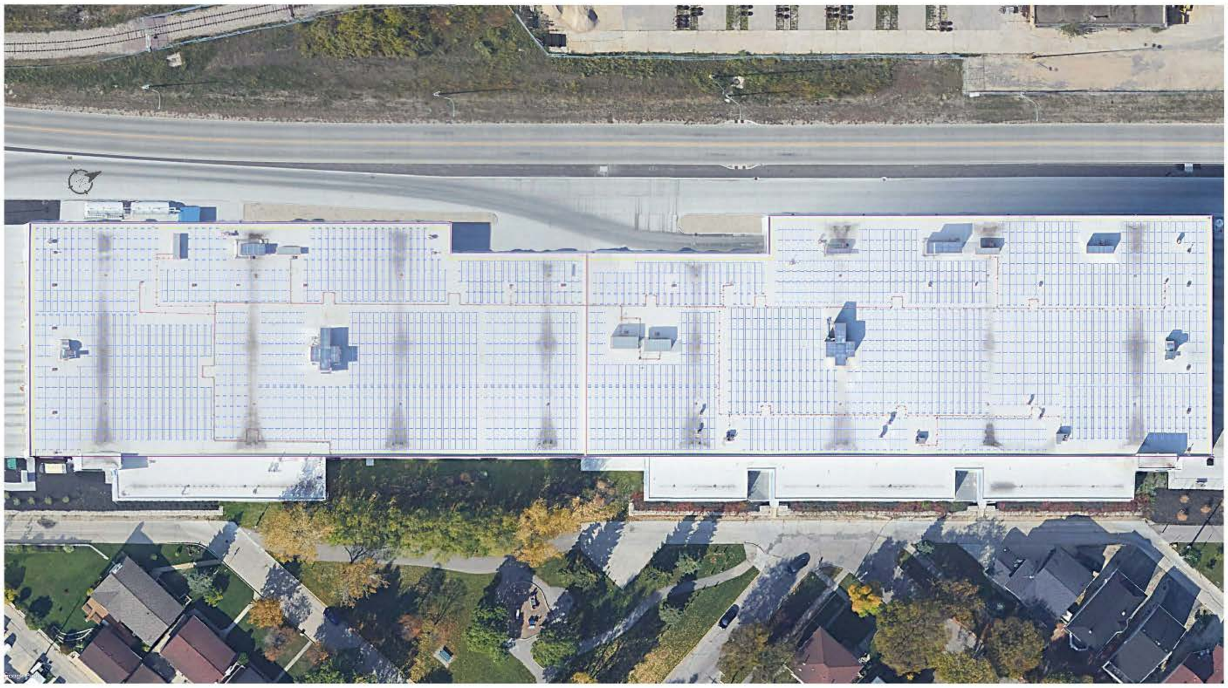


Figure 5-2: Top-view of the solar-PV layout on the Brandon Garage rooftop

5.2 SOLAR CAPACITY FACTOR & ENERGY ESTIMATE

Photovoltaic (PV) solar panels generate power from the sun by directly converting sunlight to electricity. The solar panel, the first component of an electric solar energy system, is a collection of individual silicon cells that generate electricity from sunlight. Sunlight is composed of photons, which are particles of energy. When the sunlight hits the PV cells, some of the energy reflects away, passes through the panels, or absorbs into the cells to generate electricity.

There are several losses that occur as the energy is converted. The energy estimate accounts for the losses shown in Figure 5-3, such as shading losses, soiling loss, temperature, quality, mismatch and wiring losses and inverter losses. After accounting for these losses, the available energy at the inverter output which is the energy injected to the microgrid is 1,341 MWh per year. Figure 5-4 shows the PV-system normalized production and performance ratio per month in a year at the Brandon Garage.

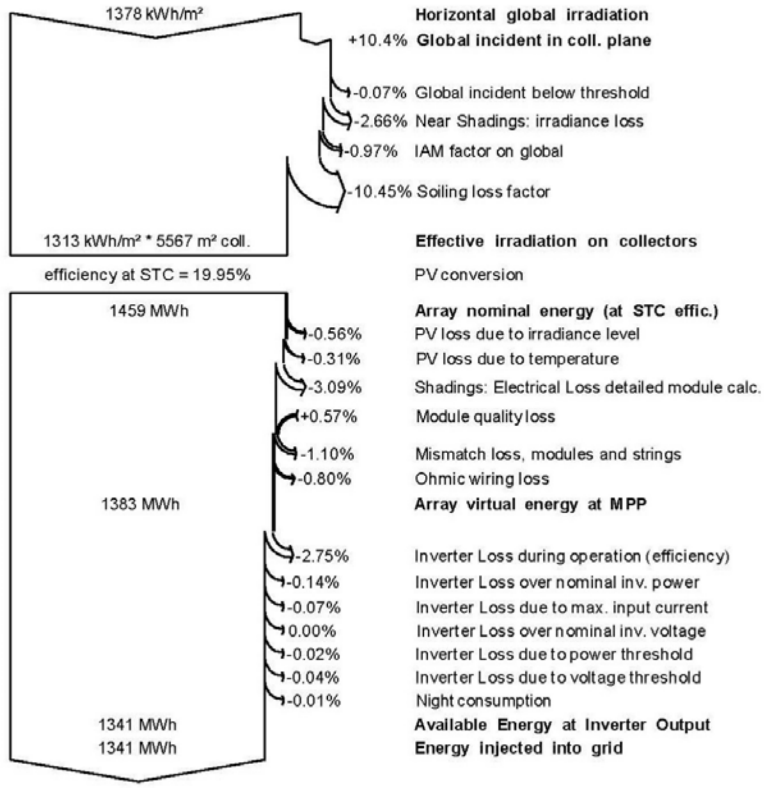


Figure 5-3: PV system losses over whole year

Main simulation results

System Production	**Produced Energy**	**1341 MWh/year**	Specific prod.	1209 kWh/kWp/year
	Performance Ratio PR	79.50 %		

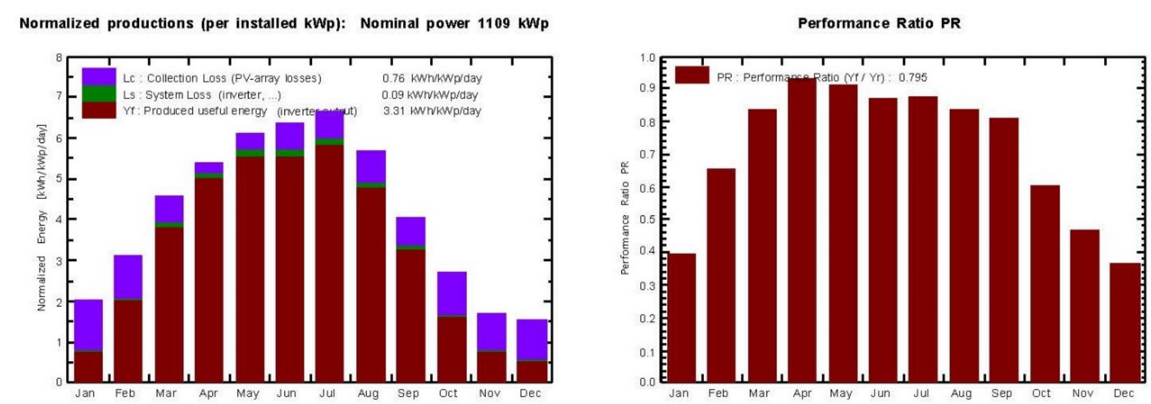


Figure 5-4: PV-system normalized production and performance ratio per month in a year

The system output power distribution injected to the grid over the course of one-year of generation is shown in Figure 5-5, indicating a steady accumulation of power with various peaks and dips across the period of January 1 to December 31 in a given year.

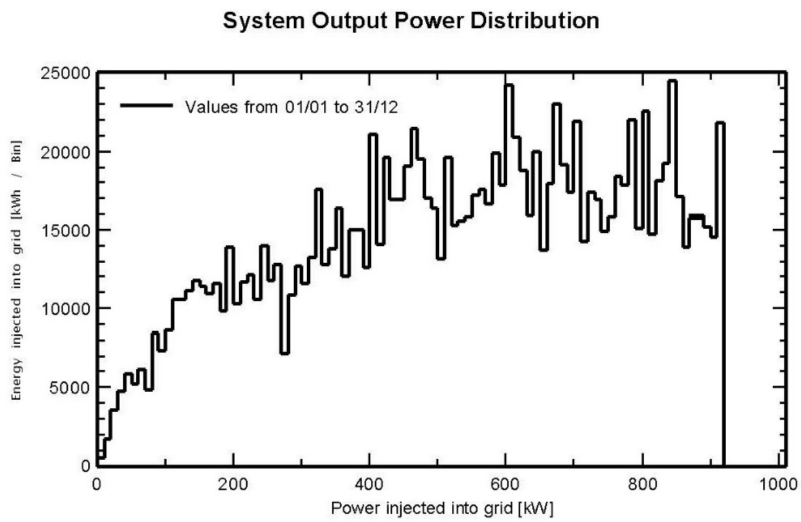


Figure 5-5: PV-System output power distribution from January 1 to December 31.

The Brandon Garage solar-PV rooftop produces enough power per year to support an addition of approximately 19 buses to the BEB fleet. Overtime, slight power degration will occur as follows, reducing the number of BEB able to be supported by this solar power system as shown in Figure 5-6. Planning for additional solar expansion to maintain the existing 20 BEB fleet while growing the fleet will be critical to ensure enough solar power exists to support the fleet electrification.

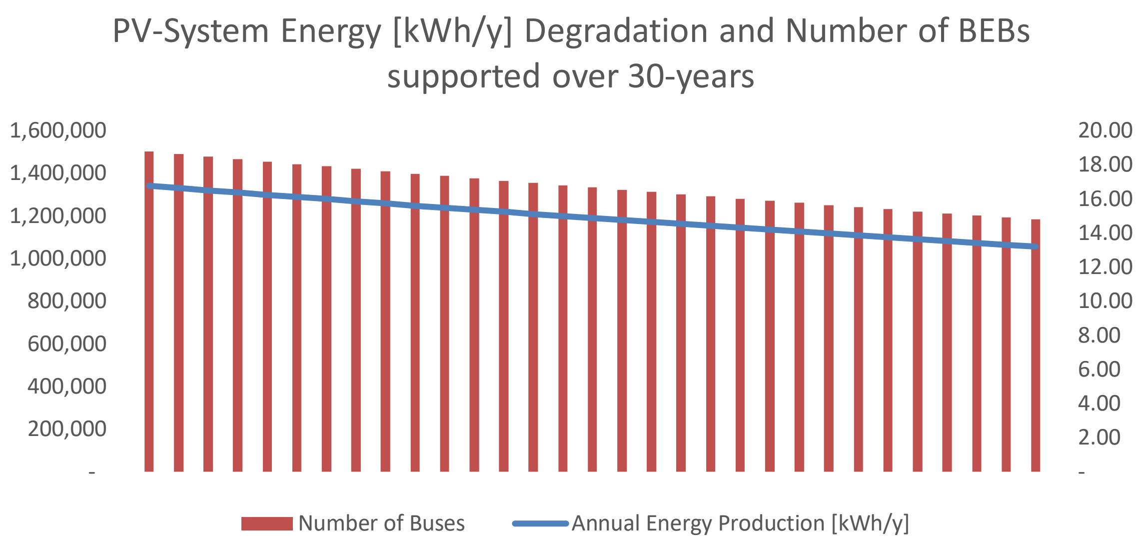


Figure 5-6: PV-System power degradation over 30-years and impact on number of buses powered

5.3 CONFIGURATION OPTIONS

Winnipeg Transit must determine which type of the power producer category to belong to with the microgrid generating system as this will impact the interconnection with or without the Manitoba Hydro grid. There are two ways to configure the microgrid, either grid-tie with or without net-metering; or islanded, meaning isolating the microgrid from the grid.

5.3.1 GRID-TIED AND NET-METERING

Manitoba Hydro requires any distributed resource that will be connecting to their grid to follow the requirements for distributed resource (DR) interconnection from Manitoba Hydro. These include:

1. meet MH ***Technical Requirements***
2. comply with MH ***Distributed Resource Interconnection Procedures***
3. complete the ***Interconnection Request***
4. provide a single line diagram sealed by an engineer that includes all information required by MH electrical inspectors;
5. provide the generation system's major components data sheets.

Winnipeg Transit would likely conform to either of these categories associated with the MH grid:

Table 5-3: Distributed resource interconnection categories by Manitoba Hydro for Winnipeg Transit solar project

Type II: load displacement only	Type III: load displacement plus excess to grid
This system can parallel indefinitely and is used for load displacement. It meets some of your electricity needs and reduces the energy bill while MH provides the rest of Winnipeg Transit's electricity requirements. Requirements for interconnection approval:	This system can parallel indefinitely and allows excess electricity that you generate to flow into the MH grid. Power flow is limited by the local hosting capacity and size of the existing facility electrical service. Requirements for interconnection approval:
• meet all requirements 1-5 listed above;	meet all requirements 1-5 listed above;
• use a CSA-approved closed-transition transfer switch;	• may require an Engineering Study which may require a consultant;
• install a reverse power relay to prevent power flow back onto the grid.	• use a CSA-approved closed-transition transfer switch;
•	• pay for a bi-directional meter and any utility service upgrades

Net-metering is a term used to describe the mechanism for resale of excess electricity generation from an independent power producer (IPP) for sale to the utility. Manitoba Hydro allows net-metering from various sources, including solar. This is called non-utility generation. The electricity that the IPP generates can reduce the amount of electricity purchased from Manitoba Hydro when grid connected.

When generating more energy than consuming, the excess energy can be sold to Manitoba Hydro at the non-utility generation price, which is reviewed annually. Manitoba Hydro will purchase excess electricity (produced at less than 100 kW) for $0.02949/kWh between April 1, 2020 to March 31, 2021. For generation greater than 100kW, Manitoba Hydro will need to be contacted to arrange separate power purchase arrangements.

Due to the low buy-back price that Manitoba Hydro (MH) has set for net-metering, self-generators that use most of the energy that they generate, rather than selling excess to MH, typically have better paybacks. To determine the optimal configuration, a power-flow study is recommended along with a further detailed economic analysis considering net-metering and demand-charge effects on the financial feasibility of the system.

5.3.2 ISLANDED

This system would operate completely isolated from the MH grid. However, this is not how this study has been conducted. Further analysis would be required to pair the proper equipment to function in this mode entirely.

5.4 PERFORMANCE GUARANTEE

Different methods exist to evaluate the plant's performance guarantee. In all cases, on-site measurements of the solar resource are necessary. For PV systems, the yield prediction is generally based on GHI. Hence, it is also common for a performance guarantee to use GHI as the basis for determining whether a plant has performed as promised; however, some companies have noted that the performance characterization of a PV plant can be accomplished with a lower uncertainty by using GTI instead. Moreover, specific irradiance sensors (such as reference cells or reference modules that closely match the PV module response) may be chosen to match the expected response of the PV modules (thus reducing angle-of-incidence and spectral effects).

6 ECONOMIC ANALYSIS

6.1 CONSIDERATIONS, ASSUMPTIONS

The following assumptions were used in the economic analysis:

- The exchange rate for USD to CAD was is set to 1.33.
- Operation and Maintenance costs $18/kW capacity/year
- Discount rate of 3.2%
- Basic charge for general service large (750V -30kV) customer class for MH grid rates is $0.03955/kWh and with the 2.5% city tax, GST on the city tax, PST and GST, the full rate is $0.04782/kWh.
- A BESS configuration of 1MW/4MWh is used and 4-units are implemented, using full EPC costing for the BESS of $5.8M
- Demand chargers not included.
- Solar degradation rate of 0.8% is applied to panel performance over lifetime
- Manitoba Hydro rates increase according to Figure 2-6: Potential Manitoba Hydro electricity rates over a period of 30 years for general service large (750V-30kV) customer class.

For budgetary purposes the following costs for either BESS configuration that is available are listed in Table 6-1.

Table 6-1: Budgetary Costs for 2-h and 4-h BESS Configurations

Panasonic BESS EverVolt	Qty	250kW/500kW, 2-hr Discharge	Total Cost, 2h-discharge	1MW/4MWh, 4-hr Discharge	Total Cost, 4h-discharge
Product only	4	$475,000	$1,900,000	$ 950,000	$ 3,800,000
Full EPC	4	$725,000	$2,900,000	$ 1,450,000	$ 5,800,000

6.2 LEVELIZED COST OF ELECTRICITY

The levelized cost of energy (LCOE), also known as Levelized Energy Cost, LEC, is the price at which electricity must be generated from a specific source to break even over the lifetime of the project. It is an economic assessment of the cost of the energy-generating system including all the costs over its lifetime.

The cost of electricity per unit of energy consumed (power-hour) generated by different sources is a calculation of the cost of generating electricity at the point of connection to a load or electricity grid. It includes the initial capital, discount rate, as well as the costs of continuous operation, fuel, and maintenance. In short, the calculation for the LCOE is the net present value of total life cycle costs of the project divided by the quantity of energy produced over the system life.

6.3 COST ESTIMATE

Option 1: Solar-energy system without BESS
Includes:

- All power equipment (except BESS)
- Engineering services and studies
- Construction materials
- Installation labour
- Site security
- Permitting

Total Price (before shipping, duties, taxes)	$ 1,894,301

It is estimated to cost Winnipeg Transit $3,541,266 to purchase electricity from Manitoba Hydro to support an expansion of only 20 BEBs over the next 30-years. However, if the proposed configuration were to be implemented, Winnipeg Transit could earn a 30-year savings of $2,897,988 and a ROI of 53% over this period.

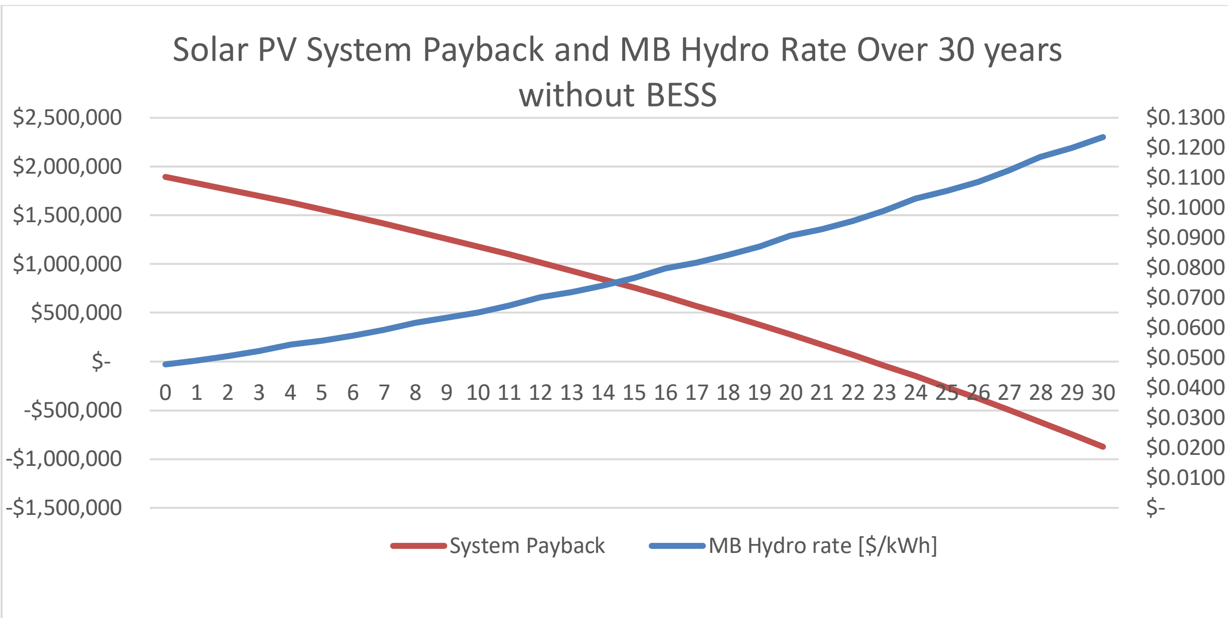


Figure 6-1: PV system PBP and MB Hydro rate increases for general service large customer class over 30 years without BESS

Despite the performance of the system, the static payback period of this system appears to be 30 years, while the dynamic payback period that accounts for PV-system performance degradation and utility rate increases over the lifetime of the installation indicates a PBP of 23 years as shown in Figure 6-1. Both are incredibly long due to the low utility rate for purchased power in the general service large customer class by Manitoba Hydro. However, demand charges have not been taken into account. Upon further study from the electrical engineering design and interconnection study, the demand charges can be determined and applied to a refined economic analysis.

However, the LCOE for this case is $0.095/kWh, which Manitoba Hydro could charge by the 21-year point.

Furthermore, if the utility cannot support providing the necessary power to Winnipeg Transit, will need to determine if it is worth investing in a BESS integrated system or providing an "electrified" fleet by selling back generated power to Manitoba Hydro via Net-metering. Given the existing net-metering prices are lower than the cost to self-generate power, Winnipeg Transit must determine if it will negotiate a power purchase agreement with Manitoba Hydro for a more equitable rate or if investing in the battery energy storage system will be preferred. Further studies are required to determine the impact of demand charges on the cost of electricity from Manitoba Hydro, as well as power flow modelling of bus chargers to determine interconnection requirements with Manitoba Hydro or functionality as an independent microgrid.

Option 2: Solar energy system with BESS
Includes:

- All power equipment including BESS
- Engineering services and studies
- Construction materials
- Installation labour
- Site security
- Permitting

Total Price (before shipping, duties, taxes)	$ 8,622,301

In this case, due to the high costs of the BESS, and the low utility rate power, there is no reasonable PBP as shown in Figure 6-2. Demand charges are not included in this study and could have a significant impact on the cost-benefit of a BESS integrated system. If the proposed configuration with the BESS were to be implemented, the return on investment in the same 30-year period would be -66%, meaning there is no immediate ROI.

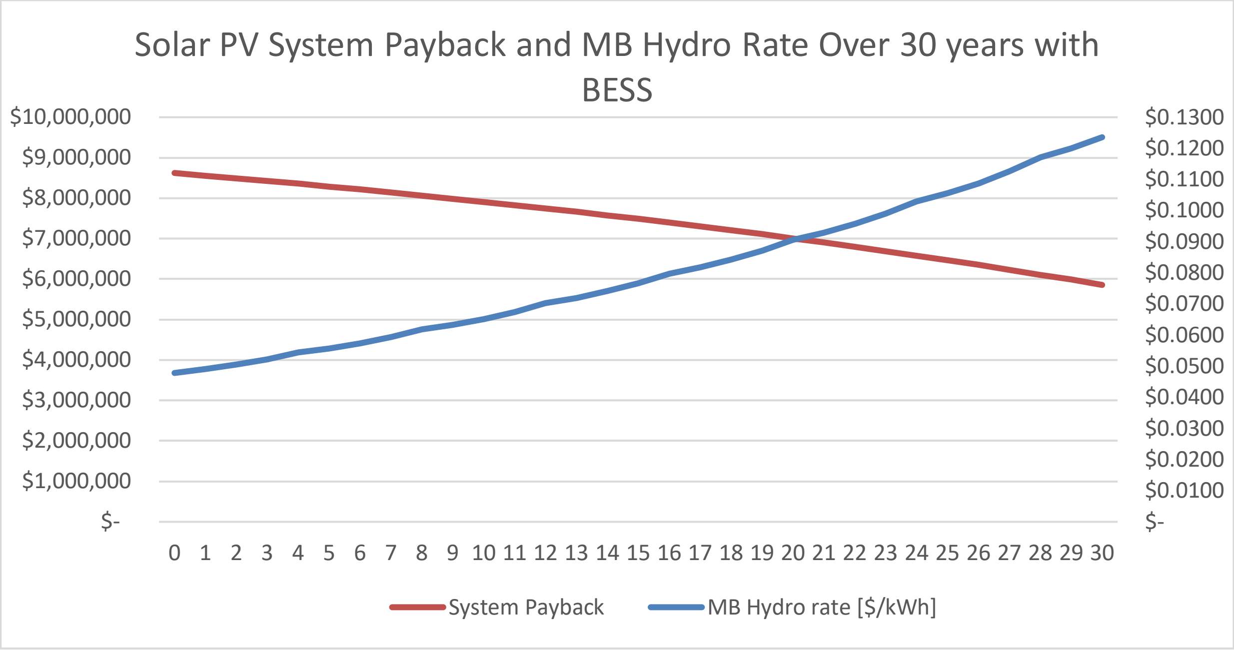


Figure 6-2: : PV system PBP and MB Hydro rate increases for general service large customer class over 30 years without BESS

The LCOE for this case is $0.375/kWh, which could be reasonable if demand charges were experienced or if MH rates increased substantially.

6.3.1 NET-METERING ECONOMICS

Net-metering is a term used to describe the mechanism for resale of excess electricity generation from an independent power producer (IPP) for sale to the utility. Manitoba Hydro allows net-metering from various sources, including solar. This is called non-utility generation. The electricity that the IPP generates can reduce the amount of electricity purchased from Manitoba Hydro when grid connected.

When generating more energy than consuming, the excess energy can be sold to Manitoba Hydro at the non-utility generation price, which is reviewed annually. Manitoba Hydro will purchase excess electricity (produced at less than 100 kW) for $0.02949/kWh between April 1, 2020 to March 31, 2021. For generation greater than 100kW, Manitoba Hydro will need to be contacted to arrange separate power purchase arrangements.

Due to the low buy-back price that Manitoba Hydro (MH) has set for net-metering, self-generators that use most of the energy that they generate, rather than selling excess to MH, typically have better paybacks. An economic analysis that incorporates expected demand chargers and power flow timing for grid integrated impacts would be required to refine the economic analysis and determine if net-metering is a viable option for Winnipeg Transit.

7 CONCLUSION

Cities, utilities, businesses, universities, and communities are turning to microgrids for supplemental and backup power. The transition to electrified mobility has begun and Winnipeg Transit is planning for the expansion of the bus fleet to meet the target of 40% electrified by 2030. It is a tremendous task to achieve this goal in the next 10-years and proper power planning is critical to ensure it will be met. Microgrids, with the integration of renewable energy resources and storage, allow the benefit to continue to operate when the grid is down; serve as a grid resource; provide economic benefits to owners; and help move Winnipeg Transit toward a resilient, clean energy future with an electrified fleet.

The solar resource studied at the site of the Brandon Garage in Winnipeg, MB is capable of providing 1,341 MWh/y of electricity. Despite slight power performance degradation over the lifetime of the project system, at 30 years, the solar panels are robust to continue to provide resilient power over that period. However, due to the limitation of the available area at the Brandon Garage, only 1.1MWdc of solar capacity was capable of fitting on the rooftop. Given that a fleet of 20 BEBs requires 1,428,700 kWh/y, this site would only be able to power approximately 18-19 buses. Knowing that Winnipeg Transit will need to move to a 40% electrified fleet by 2030, or approximately 288 buses, Winnipeg Transit will be in need of other site locations of to implement the solar energy systems it requires to power this amount of buses.

There is a possibility of structuring the microgrid as grid-tied with net-metering to Manitoba Hydro. This would enable using the Manitoba Hydro grid as a battery backup system rather than installing the BESS specified in this study, due to the high cost, and poor PBP and ROI. Without the BESS, the solar energy system provides the additional power that Winnipeg Transit requires and that Manitoba Hydro has indicated it cannot support for fleet expansion beyond 20 BEBs as this time. This configuration provides a ROI of 53% and a PBP of 23 years. With Manitoba Hydro rates expected to increase over this period, this option is a feasible consideration. It should be noted that due to the low utility rates for the general service large customer class, purchasing power from Manitoba Hydro is more affordable then the BESS system. However, if MH does not have the capacity to provide the power for purchase, then other options must be considered. Furthermore, the price at which MH purchases Winnipeg Transit’s power must be negotiated and will impact the feasibility of the project in the long-run, since the existing net-metering rate is very low and technically not available to generators that have systems larger than 100kW. A future power purchase agreement may be required. Firstly, an interconnection study with MH would identify if the project is viable to connect to their grid.

The results presented in this study are based on the global solar resource data extrapolated from the station at the Winnipeg International airport to the Brandon Garage site. As the project is expected to expand in scope and size, re-evaluating the solar resource using on site measurement for an entire annual periods and monitoring (tracking) onsite will be important considerations as this project scales to the utility size power plant.

The constraint analysis did not find any major hurdles to the construction of a future solar energy project based on industry standards and practices. However, a list of recommendations was included in section 3 in order to refine the constraints and prepare efficiently for future permitting processes. It should be noted that some elements absent from the preliminary constraint analysis could have a sensible impact on the future project, and are best to be further assessed before proceeding.

From the conceptual layout and preliminary energy estimate, along with the energy demand of the expanded

BEB fleet, there were two options for the microgrid configuration. Option 1 considers the solar energy system without the BESS, producing an annual energy production (AEP) of 1,341,000 kWh and depends on purchasing remaining demand from Manitoba Hydro. While, option 2 includes the same solar PV system and produces the same AEP from solar, but adds four BESS units to provide backup power of 1MW/4MWh, for a 4-hr discharge capacity. However, this option did not provide a viable payback period or return on investment.

7.1 RECOMMENDATIONS AND NEXT STEPS

The following recommendations and studies are provided as recommendations in refining the design for the Winnipeg Transit Solar Energy Project:

1. Refine the solar-PV system design based on other integrated studies and complete a detailed feasibility study
2. Conduct a charge flow economic analysis to determine if grid-tied or islanded configurations is preferred.
3. Obtain further quoting for equipment and services to purchase and install the system.
4. Obtain rates and agreements with Manitoba Hydro if interconnection is required
5. Consider the site described as 421 Osborne St, Winnipeg, MB R3L 2A2 ("Winnipeg Transit Fort Rouge Garage") along with any other potential sites that may be available for expansion.
6. Conduct an electrical engineering study to determine step-up transformer requirements and interconnection requirements
7. Conduct a structural engineering study to determine roof capacity and wind and snow load impact
8. Conduct an interconnection study with MBH if grid-tied system selected.
9. Determine if MBH will charge demand-charges for the interconnected system or not
10. Obtain permitting requirements from the City of Winnipeg
11. Confirm fire code requirements and access routes
12. Confirm electrical Code requirements
13. Confirm building code requirements
14. Determine storage space for housing the battery system as well as system integration and interconnection points to BESS if necessary
15. Consider display screens and locations around the building and across Winnipeg Transit for monitoring systems to showcase the renewable energy generation and microgrid, such as a dedicated control room as well as public and staff interaction points

Additional recommendations for major project expansion include:

- Meteorological onsite data collection
- Evaluation of the interconnection points with more precision
- Refinement of the constraints and complete inspection points by following the recommendations listed in section 3, especially if other locations and ground-sites are to be considered.

8 REFERENCES

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[4] Manitoba Hydro historic rates
https://www.hydro.mb.ca/accounts_and_services/rates/historical_rates/#e-large

[5]Manitoba Hydro commercial rates
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9 APPENDICES

9.1 PRODUCT TECHNICAL SPECIFICATIONS
9.2 CONCEPTUAL DESIGN DRAWINGS
9.3 TECHNICAL REPORTS

NEW

CanadianSolar

HiKu

SUPER HIGH POWER MONO PERC MODULE

425 W ~ 450 W

CS3W-425|430|435|440|445|450MS

MORE POWER

26 % more power than conventional modules

Up to 4.5 % lower LCOE
Up to 2.7 % lower system cost

42°C

Low NMOT: 42 ± 3 °C
Low temperature coefficient (Pmax): -0.36 % / °C

Better shading tolerance

MORE RELIABLE

Lower internal current, lower hot spot temperature

Cell crack risk limited in small region, enhance the module reliability

Heavy snow load up to 5400 Pa, wind load up to 3600 Pa*

* For detail information, please refer to Installation Manual.

25 years **linear power output warranty***

12 years **enhanced product warranty on materials and workmanship***

*According to the applicable Canadian Solar Limited Warranty Statement.

MANAGEMENT SYSTEM CERTIFICATES*

ISO 9001:2015 / Quality management system
ISO 14001:2015 / Standards for environmental management system
OHSAS 18001:2007 / International standards for occupational health & safety

PRODUCT CERTIFICATES*

IEC 61215 / IEC 61730: VDE / CE
UL 1703: CSA / Take-e-way

* As there are different certification requirements in different markets, please contact your local Canadian Solar sales representative for the specific certificates applicable to the products in the region in which the products are to be used.

CANADIAN SOLAR (USA), INC. is committed to providing high quality solar products, solar system solutions and services to customers around the world. No. 1 module supplier for quality and performance/price ratio in IHS Module Customer Insight Survey. As a leading PV project developer and manufacturer of solar modules with over 36 GW deployed around the world since 2001.

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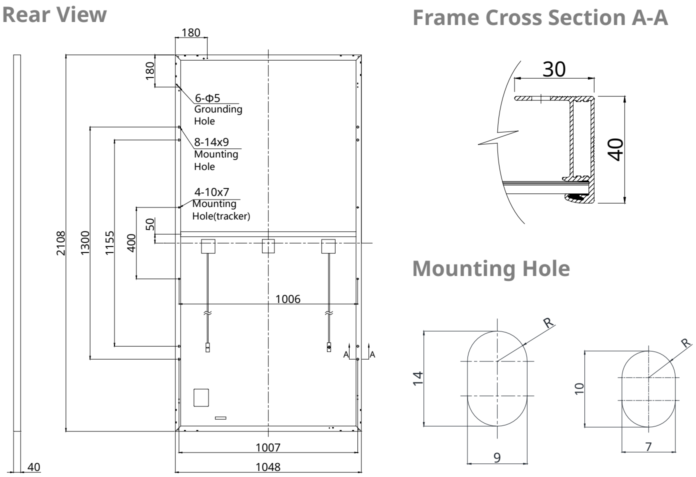
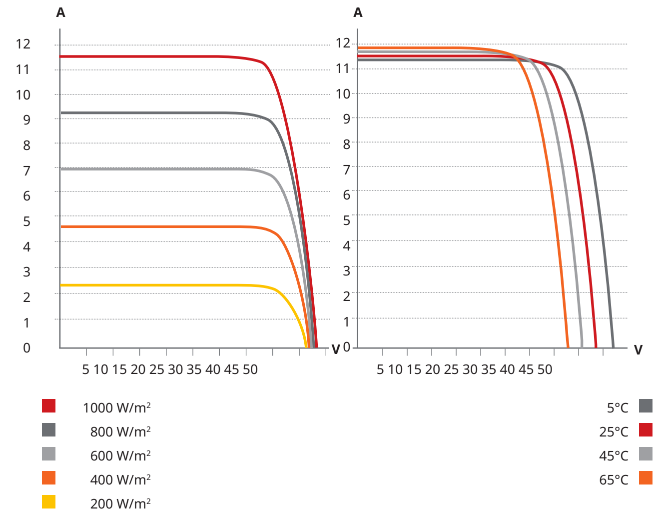
ENGINEERING DRAWING (mm)



CS3W-435MS / I-V CURVES



ELECTRICAL DATA | STC*

CS3W	425MS	430MS	435MS	440MS	445MS	450MS
Nominal Max. Power (Pmax)	425 W	430 W	435 W	440 W	445 W	450 W
Opt. Operating Voltage (Vmp)	39.5 V	39.7 V	39.9 V	40.1 V	40.3 V	40.5 V
Opt. Operating Current (Imp)	10.76 A	10.84 A	10.91 A	10.98 A	11.05 A	11.12 A
Open Circuit Voltage (Voc)	47.7 V	47.9 V	48.1 V	48.3 V	48.5 V	48.7 V
Short Circuit Current (Isc)	11.37 A	11.42 A	11.47 A	11.53 A	11.59 A	11.65 A
Module Efficiency	19.24%	19.46%	19.69%	19.92%	20.14%	20.37%
Operating Temperature	-40°C ~ +85°C					
Max. System Voltage	1500V (IEC/UL) or 1000V (IEC/UL)					
Module Fire Performance	TYPE 1 (UL 1703) or CLASS C (IEC 61730)					
Max. Series Fuse Rating	20 A					
Application Classification	Class A					
Power Tolerance	0 ~ + 5 W					

* Under Standard Test Conditions (STC) of irradiance of 1000 W/m², spectrum AM 1.5 and cell temperature of 25°C.

ELECTRICAL DATA | NMOT*

CS3W	425MS	430MS	435MS	440MS	445MS	450MS
Nominal Max. Power (Pmax)	316 W	320 W	324 W	328 W	331 W	335 W
Opt. Operating Voltage (Vmp)	36.8 V	36.9 V	37.1 V	37.3 V	37.5 V	37.7 V
Opt. Operating Current (Imp)	8.60 A	8.67 A	8.73 A	8.79 A	8.84 A	8.89 A
Open Circuit Voltage (Voc)	44.7 V	44.9 V	45.1 V	45.3 V	45.5 V	45.6 V
Short Circuit Current (Isc)	9.17 A	9.21 A	9.25 A	9.30 A	9.35 A	9.40 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 X 6)]
Dimensions	2108 X 1048 X 40 mm (83.0 X 41.3 X 1.57 in)
Weight	24.9 kg (54.9 lbs)
Front Cover	3.2 mm tempered glass
Frame	Anodized aluminium alloy, crossbar enhanced
J-Box	IP68, 3 bypass diodes
Cable	4 mm² (IEC), 12 AWG (UL)
Cable Length (Including Connector)	1670 mm (65.7 in)
Connector	T4 series
Per Pallet	27 pieces
Per Container (40' HQ)	594 pieces

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

TEMPERATURE CHARACTERISTICS

Specification	Data
Temperature Coefficient (Pmax)	-0.36 % / °C
Temperature Coefficient (Voc)	-0.29 % / °C
Temperature Coefficient (Isc)	0.05 % / °C
Nominal Module Operating Temperature	42 ± 3°C

PARTNER SECTION

* The specifications and key features contained in this datasheet may deviate slightly from our actual products due to the on-going innovation and product enhancement. Canadian Solar Inc. reserves the right to make necessary adjustment to the information described herein at any time without further notice.
Please be kindly advised that PV modules should be handled and installed by qualified people who have professional skills and please carefully read the safety and installation instructions before using our PV modules.

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Simple solutions you can count on.

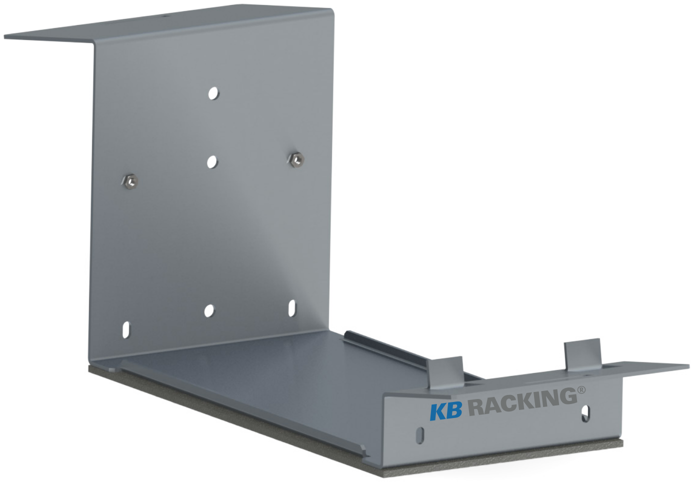
EKONORACK 2.0

Flat Roof Mounting System

LOW COST - LOW WEIGHT - QUICK INSTALL

EKONORACK 2.0 is the simplest non-penetrating solar mounting solution for commercial flat rooftops. The system's ETL Certification attests to its high standard of safety and robust design, allowing it to be grounded with only one grounding lug per array.

EKONORACK 2.0's innovative design is composed of only one major component, acting as a ballast tray, windshield mount and multiple panel support. The system's pre-attached roof mats save time on installation and provide maximum protection for the roof.



FEATURES

- ETL Certified to UL standard 2703
- Single point grounding/ bonding per array
- Customizable row spacing available
- Windshields include integrated press-fit nuts for a faster installation
- Integrated rubber roof protection mats for hassle-free installation
- Wind deflectors optimize performance and lower ballast requirements
- Fast installation with click-in module clamps: up to 3-4kW/man-hour
- High-grade, corrosion-free aluminum components
- 25-year standard product warranty, extended warranty available

ETL CLASSIFIED

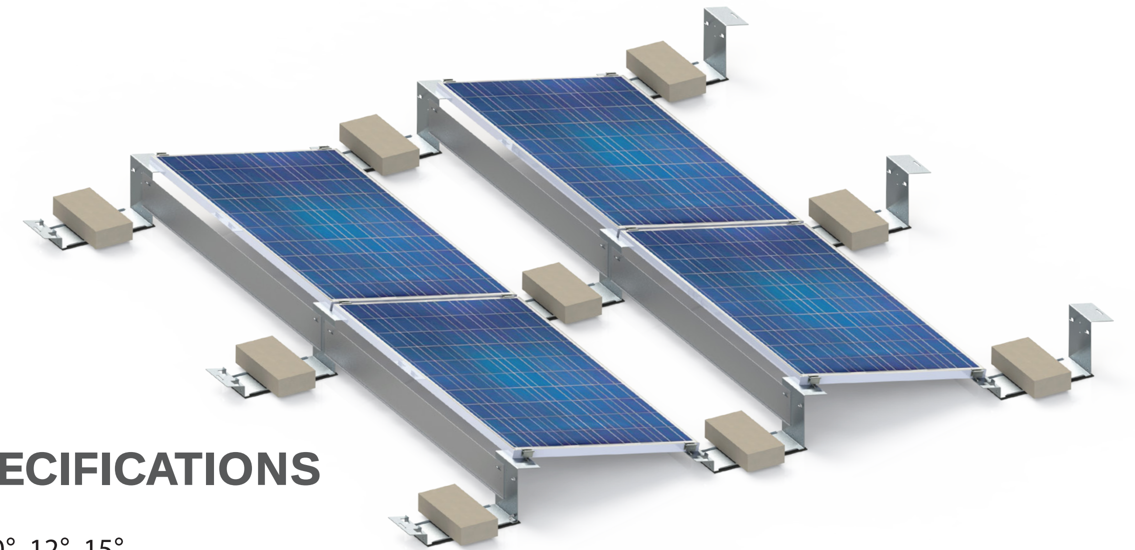
C US

LISTED

Intertek

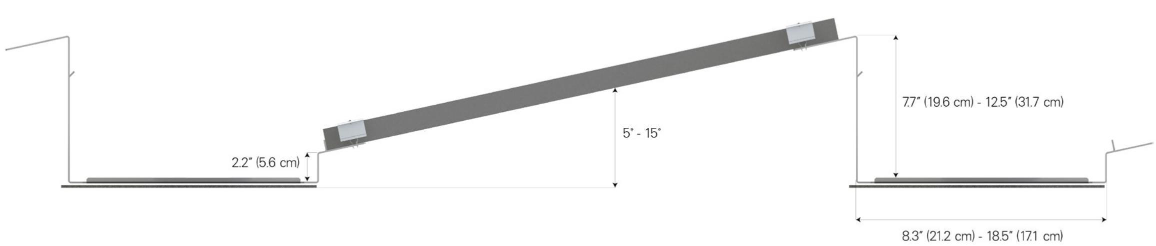
EKONORACK 2.0

Flat Roof Mounting System



TECHNICAL SPECIFICATIONS

Inclinations	5°, 10°, 12½°, 15°
Distribution Load	3 - 8 lbs/ ft
Orientation Panel	Landscape, Portrait (5°)
Panel Type	Framed PV module
Material	Aluminum, stainless steel fasteners
Module Size	All standard 60 & 72 cell panels
Row Spacing	49.21 - 58.27"/ 1.25 - 1.48m
Dimensions (LxWxH)	Standard 10° system: 15 x 8 x 8.4"/ 38.1 x 20.4 x 21.3cm
Roof Type	All types of flat roofs
Roof Pitch	Up to 5°
Grounding Method	Grounded once per array - ETL Certified grounding method
Building Height	Up to 60'/ 18.3m (higher upon request)
Ballast Weight	Customizable to wind zone and exposure category
Wind Speed	Up to 170 mph (274 km/h) for Exposure B; 170 mph (274 km/h) for Exposure C
Wind Tunnel Testing	Boundary layer wind tunnel tested by RWDI - based on ASCE 7-10, NBCC 2005, IBC 2012 & OBC 2012 standards
Patent Number	US D774,874 S



YASKAWA

SOLECTRIA XGI 1000

Premium 3-Phase Transformerless Commercial String Inverters

Features

- Made in the USA with global components
- Buy American Act (BAA) compliant
- 60kW and 65kW
- Built to last
- Lowest cost of labor/installation
- Access to all inverters on-site via WiFi from one location
- Lowest cost of O&M
- Remote diagnostics
- Remote software & firmware upgrades
- 5-90° installation angles
- Configured in the Factory: 4 MPPTs; 1 MPPT; Optional Large AC Lugs
- Advanced grid-support functions
- Integrated AFCI
- SunSpec Modbus Certified

Options

- Web-based monitoring
- Revenue grade metering

Yaskawa Solectria Solar's XGI 1000 commercial string inverters are designed for high reliability and built with the highest quality components. Components were selected, tested and proven to last beyond their warranty. The XGI 1000 inverters meet the latest IEEE 1547 and UL 1741 standards for safety. Offering a wide mounting-angle range (5 – 90° from horizontal), the XGI inverters can be installed to meet NEC rapid shutdown requirements (inquire for more details). Designed and engineered in Lawrence, MA, the XGI inverters are assembled and tested at Yaskawa America's facilities in Buffalo Grove, IL.

The all new XGI 1000 inverters are Made in the USA with global components and are compliant with the Buy American Act.

MADE IN THE USA
With U.S. and Global Components

SOLECTRIA SOLAR

SOLECTRIA XGI 1000

Specifications

	XGI 1000-60/60	XGI 1000-60/65	XGI 1000-65/65
DC Input			
Absolute Maximum Input Voltage	1000 VDC	1000 VDC	1000 VDC
Maximum Power Input Voltage Range (MPPT)	580-850 VDC	600-850 VDC	600-850 VDC
Operating Voltage Range (MPPT)	350-950 VDC	350-950 VDC	350-950 VDC
Maximum Operating Input Current (Clipping Point)	105.6 A (26.4 A per zone)	105.6 A (26.4 A per zone)	110.6 A (27.65 A per zone)
Maximum Rated PV Input (per MPPT)	22.5 kW	22.5 kW	24.4 kW
Number of MPP Trackers	Independent Mode: 4 Combined Mode: 1	Independent Mode: 4 Combined Mode: 1	Independent Mode: 4 Combined Mode: 1
Number of PV Source Circuits (Fused Inputs)	4 per MPPT; 16 total	4 per MPPT; 16 total	4 per MPPT; 16 total
Maximum PV Current (Isc x 1.25) per Zone / Total Maximum PV Current	50 A / 180 A	50 A / 180 A	50 A / 180 A
Maximum Recommended DC to AC Ratio	1.5	1.5	1.5
AC Output			
Nominal Output Voltage	480 VAC, 3-Ph	480 VAC, 3-Ph	480 VAC, 3-Ph
AC Voltage Range	-12 / +10%	-12 / +10%	-12 / +10%
Continuous Real Output Power	60 kW	60 kW	65 kW
Continuous Apparent Output Power	60 kVA	65 kVA	65 kVA
Maximum Output Current	72.2 A	78.2 A	78.2 A
Nominal Output Frequency	60 Hz	60 Hz	60 Hz
Power Factor (Unity default)	+/- 0.85 Adjustable	+/- 0.85 Adjustable	+/- 0.85 Adjustable
Total Harmonic Distortion (THD) @ Rated Power	<3%	<3%	<3%
Grid Connection Type	3-Ph + N/GND	3-Ph + N/GND	3-Ph + N/GND
Fault Current Contribution (1 cycle RMS)	93.9 A	101.7 A	101.7 A
Recommended AC Overcurrent Device Rating	100 A (AC Maximum Output Current x 1.25)		
Efficiency			
Peak Efficiency / CEC Average Efficiency	98.2% / 98.0%	98.2% / 98.0%	98.2% / 98.0%
Tare Loss	<1 W	<1 W	<1 W
Temperature			
Ambient Temperature Range	-40°F to 140°F (-40°C to 60°C)		
De-Rating Temperature	122°F (50°C)	113°F (45°C)	
Storage Temperature Range	-40°F to 167°F (-40°C to 75°C)		
Relative Humidity (non-condensing)	0-95%		
Operating Altitude	9,842.5 ft (3,000 m)		
Communications			
Advanced Graphical User Interface	WiFi		
Communication Interface	RJ-45 Ethernet		
Third-Party Monitoring Protocol	Sunspec Modbus TCP/IP		
Firmware Updates	Remote/Local		
Testing & Certifications			
Safety Listings & Certifications / Testing Agency	UL 1741 / IEEE 1547, UL 1699B, UL 1998 / Intertek		
FCC Compliance	FCC Part 15, Class A		
Warranty			
Standard Limited Warranty	10 Years		
Enclosure			
Acoustic Noise Rating	55 dBA @ 3 m		
DC Disconnect	Integrated, 2 Pole		
Dimensions (H x W x D), Mounting Angle	45.8 in. x 28.3 in. x 11.6 in. (1163 x 719 x 295 mm), 5-90° Measured from horizontal		
Weight	Inverter: 123 lbs (55.8 kg); Wiring Box: 53 lbs (24.1 kg)		
Enclosure Rating and Finish	Type 4X, Polyester Powder-Coated Aluminum		
Wiring Box Configuration (From the Factory)			
Independent Mode: 4 MPPT Combined Mode: 1 MPPT	DC Fuse Holders (12 - 8AWG Cu only); AC Terminals (3AWG -1/0 Cu or 1AWG - 1/0 Al); N and PE (8 - 4AWG Cu or 6 - 4AWG Al)		
OPTION: Large AC Lugs	DC Fuse Holders (12 - 8AWG Cu only); AC Terminals (3AWG - 3/0 Cu or 1AWG - 3/0 Al); N and PE (6AWG - 1/0 Cu or 6AWG - 1/0 Al)		

Specifications subject to change.

SOLECTRIA SOLAR

Yaskawa Solectria Solar
360 Merrimack Street
Lawrence, MA 01843
solectria.com

1-978-683-9700
Email: inverters@solectria.com

Document FL.XGI1000.01
9/11/2019

YASKAWA

EverVolt™

Panasonic

EverVolt™ C&I

Energy Storage Solutions

Intelligent Battery Energy Storage

The EverVolt C&I offers reliable, efficient energy storage for a wide range of grid-connected and behind-the-meter applications. Designed to comply with the stringent power requirements of electric utilities and large enterprises, the EverVolt C&I provides a complete energy storage system, including batteries, PCS, controls and rigorous safety features. Engineered to perform—guaranteed to last—the EverVolt C&I is the latest intelligent energy storage solution from a proven technology partner.

Guaranteed Energy Storage Solutions

Panasonic brings a long, distinguished track-record of successful innovation to the development of turnkey integrated energy storage solutions for commercial and industrial C&I enterprises. Backed by a best-in-class warranty and O&M support from Panasonic, EverVolt C&I solutions are pre-engineered, built and tested prior to delivery, ensuring rapid on-site installation and smooth connection to existing electrical systems. Panasonic's plug-and-play EverVolt C&I technology is highly adaptable—perfect for enterprises wishing to participate in energy markets and government incentive programs.

Peak Shaving

Load Shifting

Frequency & Grid Forming

Micro-Grid

Proven Safety

Reliable Performance

Best-in-Class Warranty

Panasonic

System Specification	Panasonic BESS 2HR
Interconnection	
Maximum Output Power	250 KVA / 250 kW
Dispatchable Energy	500 kWh
Nominal Grid Voltage	480 VAC Delta/3 Wire Wye
Nominal Grid Frequency	60 Hz
Maximum AC Current Output	300 A
THD	< 3%
Peak Efficiency	99%
Battery	
Battery Type	Panasonic DCB_106
Cell Type	Lithium Ion NCA
DC Voltage Range	750 - 1000 VDC
Energy Capacity	756 kWh (Initial Usable Capacity)
Enclosure	
Approximate Dimensions (WxHxD)	108" x 144" x 56"
Approximate Weight (with batteries)	10,300 kg
Environment	Nema 3R
Operating Temperature Range	-30° to +60 °C
Altitude	< 1000 m
Cooling	Forced Air
Fire Suppression System of Battery Unit	Novec 1230 Aerosol
Noise Rating	< 70 dB
Certification	UL 1741, UL 1973, UL 9450, UL 9540A (pending)
Functional Control	
Operational Input/Output Range	0-100%
Interconnection Modes	Grid Forming, Grid Following
Ancillary Functions	kVAR, Frequency Regulation, Phase Balancing
Communication Interfaces	Ethernet LAN/LTE
Operational Settings	Scheduled, Load Leveling, Utility Event Response

* System efficiency can vary based on site location due to climate controlled conditions and distance to the point of connection.

Learn more about Panasonic's Battery Energy Storage Systems

https://na.panasonic.com/ca/energy-solutions
EnergyStorage@ca.panasonic.com
(905) 238-4024

Notes:

PROPOSED LAYOUT
(NOT FOR CONSTRUCTION, ONLY FOR REFERENCE)

REV:	DESCRIPTION:	BY:	DATE:
B	PROPOSED SOLAR PANELS LAYOUT WITH RACKING.	NFF	29/07/2020
A	PRELIMINARY SOLAR PANELS LAYOUT.	NFF	23/03/2020

STATUS: PRELIMINARY DESIGN

CLIENT: WINNIPEG TRANSIT
421 OSBORNE STREET
WINNIPEG

DESIGNER: CORE RENEWABLE ENERGY
WINNIPEG

SITE: BRANDON GARAGE

TITLE: SOLAR PANELS LAYOUT

SCALE AT A0:	DATE:	DRAWN:	CHECKED:
1:250	29/07/2020	NFF	AK

PROJECT NO:	DRAWING NO:	REVISION:
T0001	A0/001	B

Notes:

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CORE RENEWABLE ENERGY

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421 OSBORNE STREET
WINNIPEG

DESIGNER: CORE RENEWABLE ENERGY
WINNIPEG

SITE: BRANDON GARAGE

TITLE: SOLAR PANELS LAYOUT
SECTION I

SCALE AT A0:	DATE:	DRAWN:	CHECKED:
1:90	29/07/2020	NFF	AK

PROJECT NO:	DRAWING NO:	REVISION:
T0001	A0/001/S1	B

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421 OSBORNE STREET
WINNIPEG

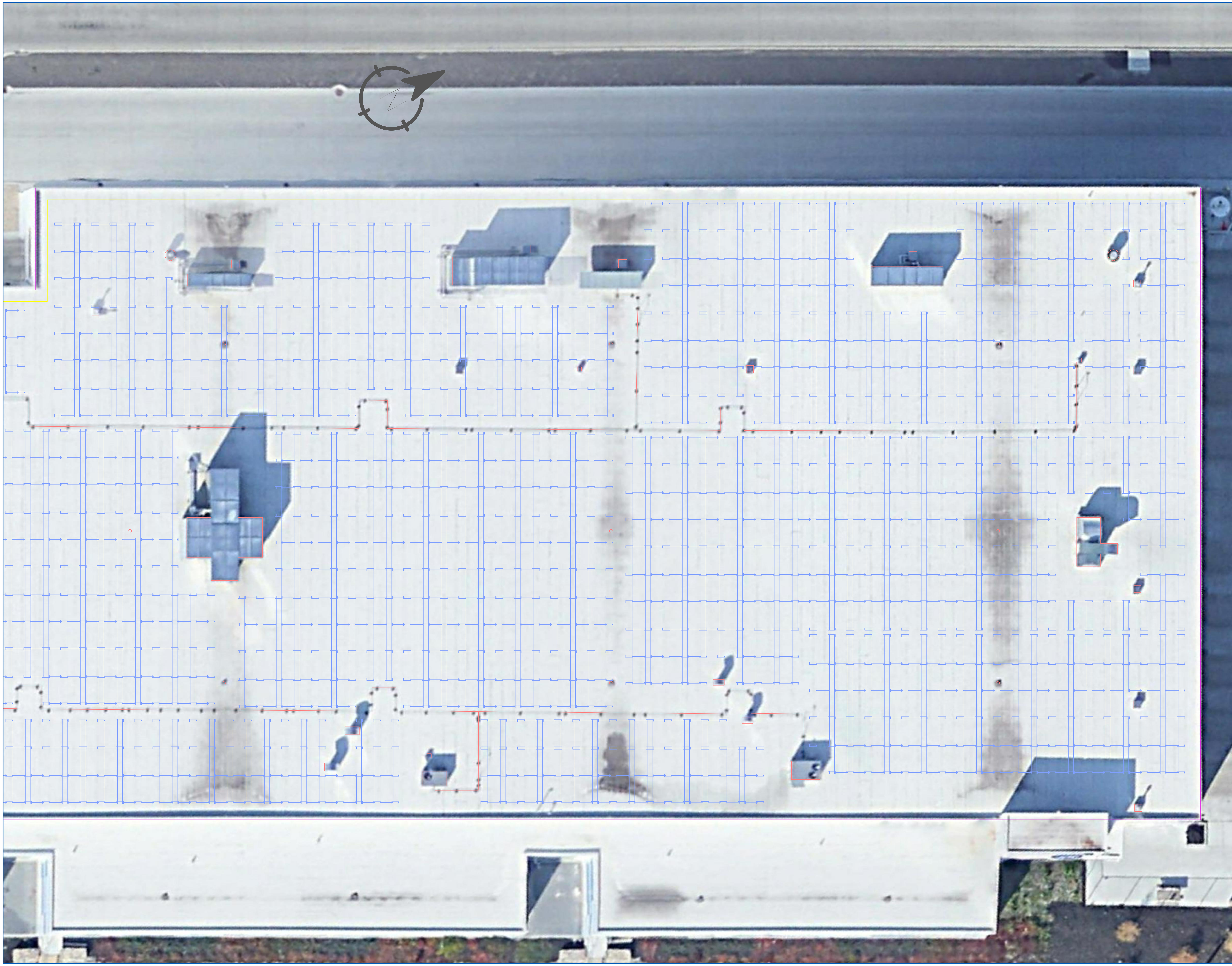
DESIGNER: CORE RENEWABLE ENERGY
WINNIPEG

SITE: BRANDON GARAGE

TITLE: SOLAR PANELS LAYOUT
SECTION II

SCALE AT A0:	DATE:	DRAWN:	CHECKED:
1:90	29/07/2020	NFF	AK

PROJECT NO:	DRAWING NO:	REVISION:
T0001	A0/001/S2	B



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B	PROPOSED SOLAR PANELS LAYOUT WITH RACKING.	NFF	29/07/2020
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STATUS: PRELIMINARY DESIGN

CORE RENEWABLE ENERGY

CLIENT: WINNIPEG TRANSIT
421 OSBORNE STREET
WINNIPEG

DESIGNER: CORE RENEWABLE ENERGY
WINNIPEG

SITE: BRANDON GARAGE

TITLE: SOLAR PANELS LAYOUT
SECTION III

SCALE AT A0:	DATE:	DRAWN:	CHECKED:
1:90	29/07/2020	NFF	AK

PROJECT NO:	DRAWING NO:	REVISION:
T0001	A0/001/S3	B


Zenith
North
West
South
East

Grid-Connected System: Simulation parameters

Project : **transit**

Geographical Site — **City Centre** — Country **Canada**

Situation — Latitude 49.86° N — Longitude -97.14° W
Time defined as — Legal Time: Time zone UT-6 — Altitude 241 m
Albedo 0.20

Meteo data: **City Centre** — Meteonorm 7.2 (1981-2000) - Synthetic

Simulation variant : **65**

Simulation date 29/07/20 13h20

Simulation parameters — System type: **Sheds on a building**

Collector Plane Orientation — Tilt 10° — Azimuth 21°

Sheds configuration — Nb. of sheds 470 — Identical arrays
Sheds spacing 1.43 m — Collector width 1.05 m
Shading limit angle — Limit profile angle 24.7° — Ground cov. Ratio (GCR) 73.4 %

Models used — Transposition Perez — Diffuse Perez, Meteonorm

Horizon — Free Horizon

Near Shadings — Detailed electrical calculation (acc. to module layout)

User's needs : Unlimited load (grid)

PV Array Characteristics

PV module Si-mono — Model **CS3W-440MS 1500V**
Custom parameters definition — Manufacturer Canadian Solar Inc.
Number of PV modules — In series 15 modules — In parallel 168 strings
Total number of PV modules — Nb. modules 2520 — Unit Nom. Power 440 Wp
Array global power — Nominal (STC) **1109 kWp** — At operating cond. 1013 kWp (50°C)
Array operating characteristics (50°C) — U mpp 549 V — I mpp 1845 A
Total area — Module area **5567 m²**

Inverter — Model **XGI 65-1000 1-2-18**
Custom parameters definition — Manufacturer Yaskawa Solectria Solar
Characteristics — Operating Voltage 350-850 V — Unit Nom. Power 65.0 kWac

Inverter pack — Nb. of inverters 56 * MPPT 25 % — Total Power 910 kWac
Pnom ratio 1.22

PV Array loss factors

Array Soiling Losses — Average loss Fraction 17.8 %

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
41.8%	27.9%	13.7%	0.0%	0.0%	2.4%	0.3%	6.0%	10.3%	31.1%	38.1%	42.6%

Thermal Loss factor — Uc (const) 29.0 W/m²K — Uv (wind) 0.0 W/m²K / m/s

Wiring Ohmic Loss — Global array res. 4.9 mOhm — Loss Fraction 1.5 % at STC
Module Quality Loss — Loss Fraction -0.6 %
Module Mismatch Losses — Loss Fraction 1.0 % at MPP
Strings Mismatch loss — Loss Fraction 0.10 %
Incidence effect (IAM): User defined profile

20°	40°	60°	65°	70°	75°	80°	85°	90°
1.000	1.000	1.000	0.990	0.960	0.920	0.840	0.720	0.000

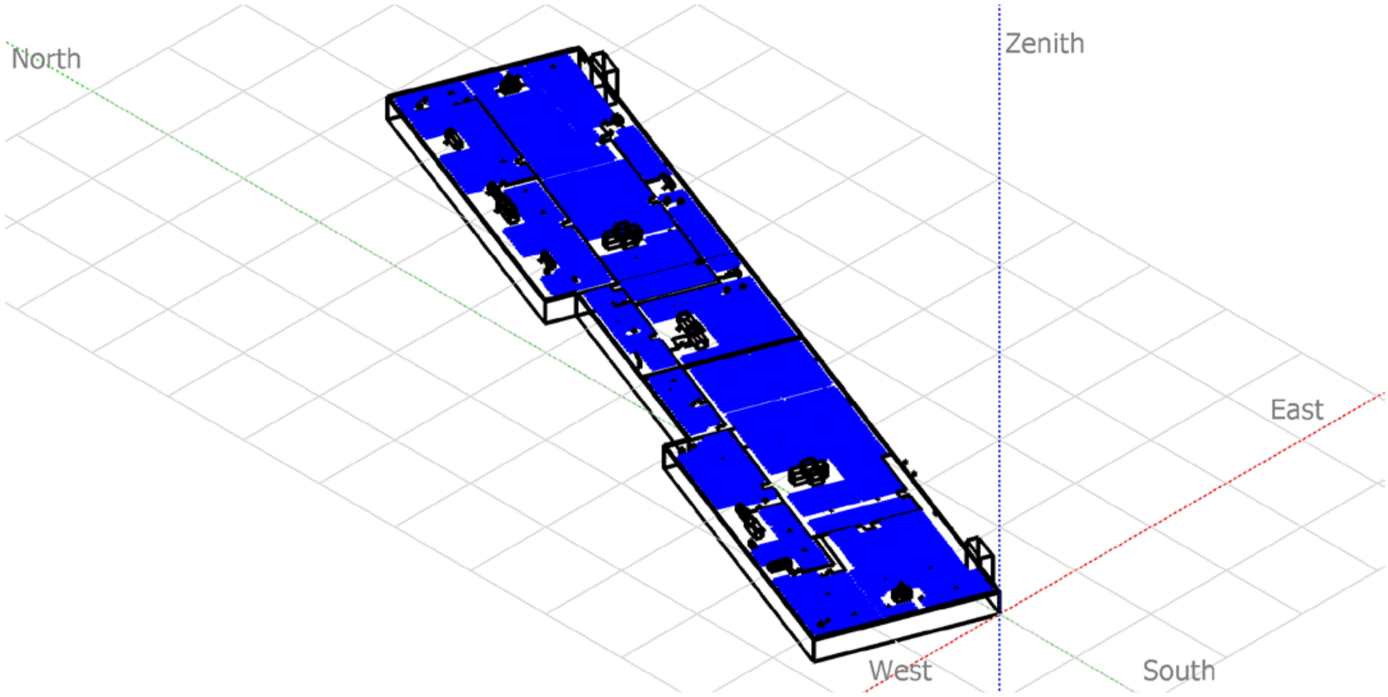
Grid-Connected System: Near shading definition

Project : **transit**

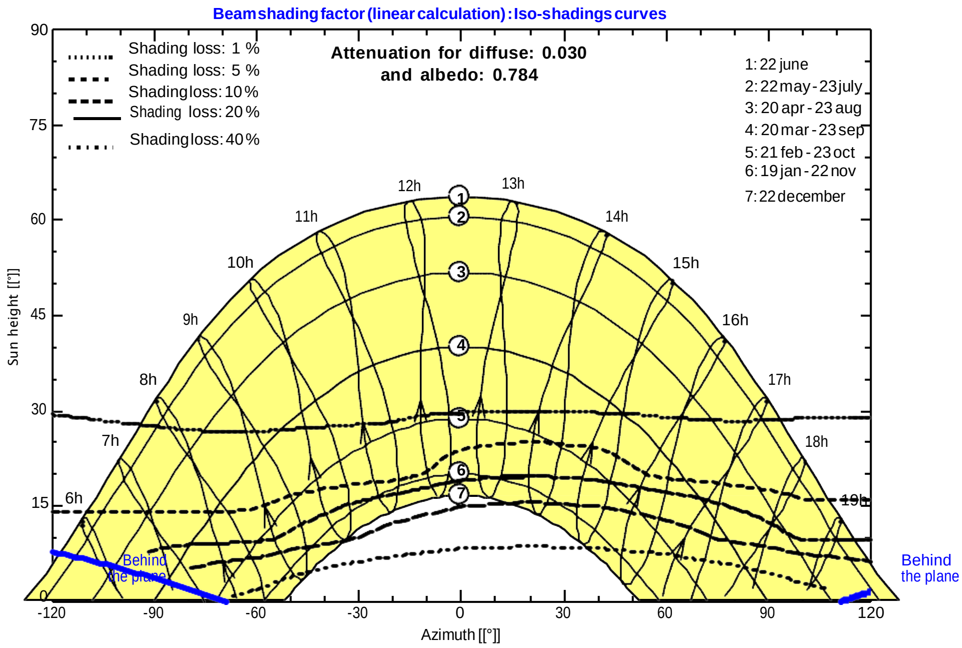
Simulation variant : **65**

Main system parameters	System type	**Sheds on a building**		
Near Shadings	Detailed electrical calculation	(acc. to module layout)		
PV Field Orientation	tilt	10°	azimuth	21°
PV modules	Model	CS3W-440MS 1500V	Pnom	440 Wp
PV Array	Nb. of modules	2520	Pnom total	**1109 kWp**
Inverter	Model	XGI 65-1000 1-2-18	Pnom	65.0 kW ac
Inverter pack	Nb. of units	14.0	Pnom total	**910 kW ac**
User's needs	Unlimited load (grid)			

Perspective of the PV-field and surrounding shading scene



Iso-shadings diagram



Grid-Connected System: Main results

Project : **transit**

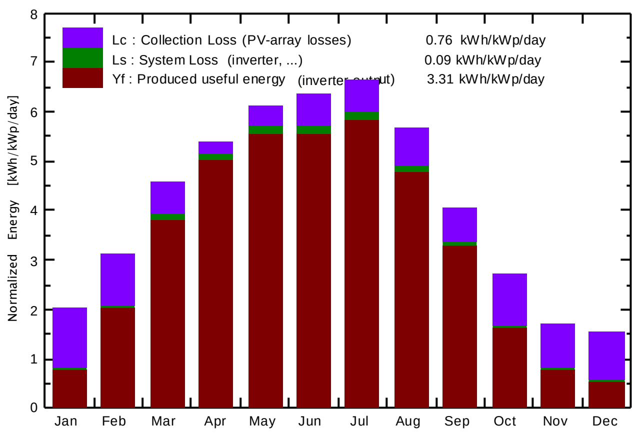
Simulation variant : **65**

Main system parameters System type **Sheds on a building**

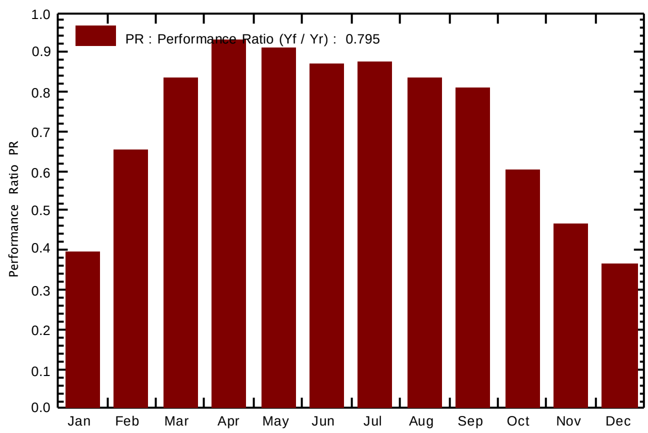
Near Shadings Detailed electrical calculation (acc. to module layout)
PV Field Orientation tilt 10° azimuth 21°
PV modules Model CS3W-440MS 1500V Pnom 440 Wp
PV Array Nb. of modules 2520 Pnom total **1109 kWp**
Inverter Model XGI 65-1000 1-2-18 Pnom 65.0 kW ac
Inverter pack Nb. of units 14.0 Pnom total **910 kW ac**
User's needs Unlimited load (grid)

Main simulation results
System Production **Produced Energy** **1341 MWh/year** Specific prod. 1209 kWh/kWp/year
Performance Ratio PR 79.50 %

Normalized productions (per installed kWp): Nominal power 1109 kWp



Performance Ratio PR



65

Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR
January	44.6	14.90	-15.50	62.6	32.2	28.8	27.6	0.398
February	68.7	21.39	-14.39	87.2	59.9	64.8	63.0	0.652
March	122.0	35.69	-6.18	142.5	119.8	135.2	131.8	0.835
April	150.5	60.91	4.87	161.4	157.4	171.7	167.2	0.934
May	183.0	75.17	10.85	189.5	184.9	196.3	191.0	0.909
June	187.2	80.30	16.58	190.6	181.4	189.5	184.4	0.873
July	201.5	76.03	20.13	206.7	201.4	206.3	200.7	0.876
August	166.6	65.87	18.84	176.6	162.1	168.6	164.0	0.838
September	110.2	49.34	13.86	121.5	105.9	112.2	109.1	0.810
October	70.6	32.46	5.32	84.1	55.5	58.3	56.5	0.606
November	39.7	19.10	-2.73	50.9	29.1	27.5	26.4	0.467
December	33.5	14.16	-12.46	47.9	23.5	20.3	19.4	0.365
Year	1378.2	545.31	3.36	1521.3	1313.1	1379.4	1341.0	0.795

Legends:
- GlobHor: Horizontal global irradiation
- DiffHor: Horizontal diffuse irradiation
- T_Amb: Ambient Temperature
- GlobInc: Global incident in coll. plane
- GlobEff: Effective Global, corr. for IAM and shadings
- EArray: Effective energy at the output of the array
- E_Grid: Energy injected into grid
- PR: Performance Ratio

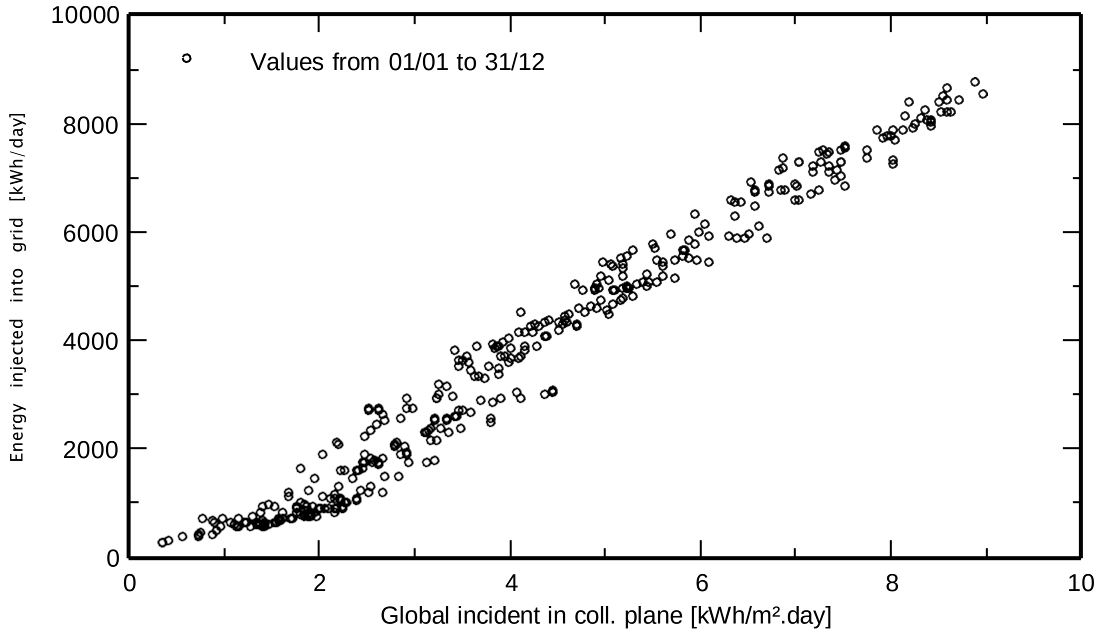
Grid-Connected System: Special graphs

Project : **transit**

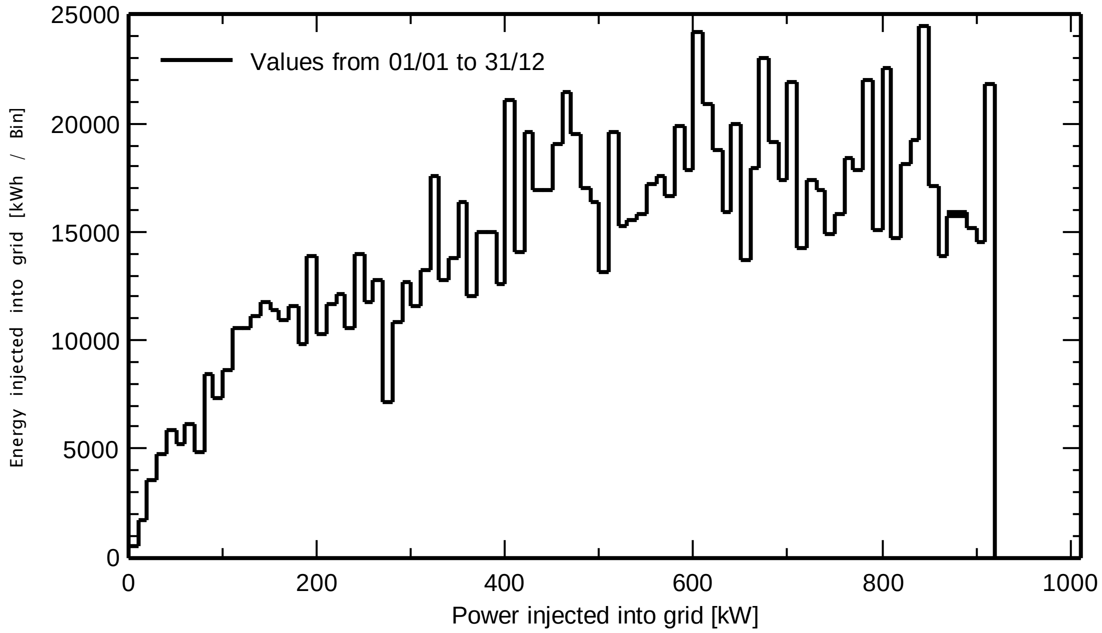
Simulation variant : **65**

Main system parameters	System type	**Sheds on a building**		
Near Shadings	Detailed electrical calculation	(acc. to module layout)		
PV Field Orientation	tilt	10°	azimuth	21°
PV modules	Model	CS3W-440MS 1500V	Pnom	440 Wp
PV Array	Nb. of modules	2520	Pnom total	**1109 kWp**
Inverter	Model	XGI 65-1000 1-2-18	Pnom	65.0 kW ac
Inverter pack	Nb. of units	14.0	Pnom total	**910 kW ac**
User's needs	Unlimited load (grid)			

Daily Input/Output diagram



System Output Power Distribution



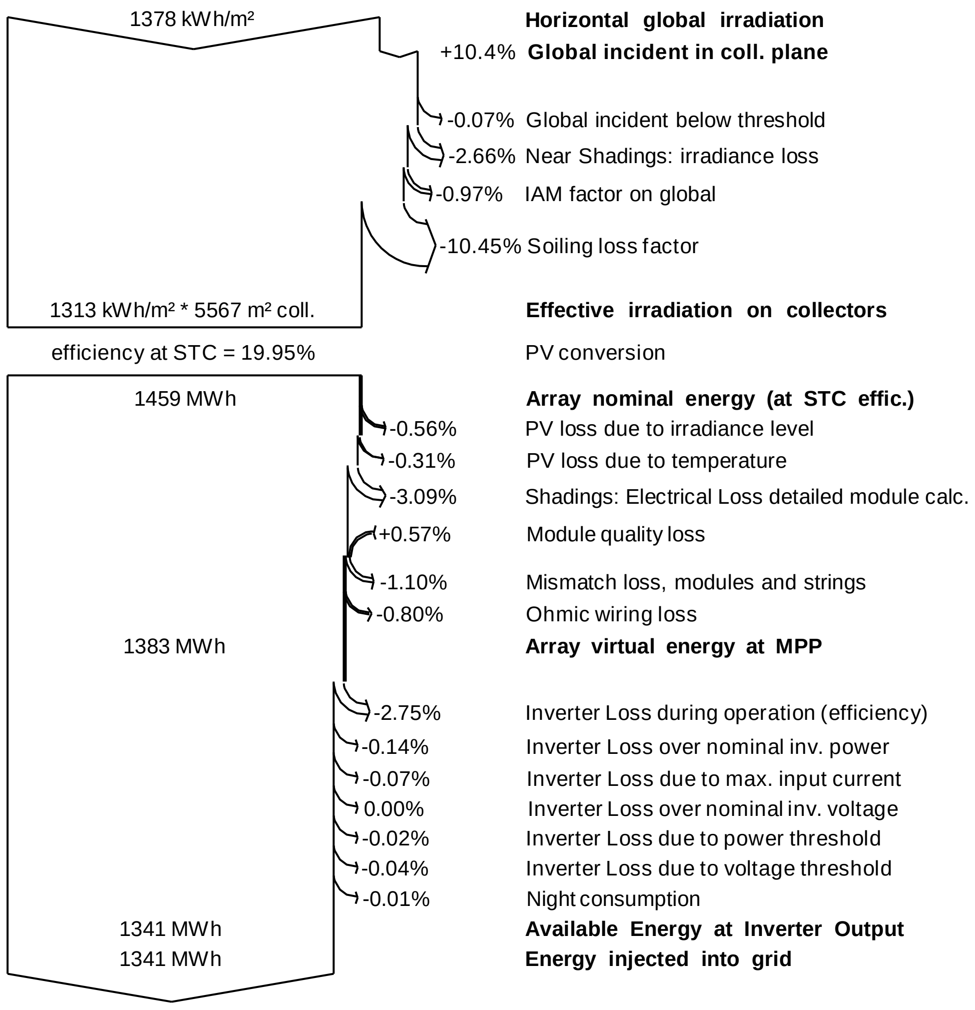
Grid-Connected System: Loss diagram

Project : **transit**

Simulation variant : **65**

Main system parameters	System type	**Sheds on a building**		
Near Shadings	Detailed electrical calculation	(acc. to module layout)		
PV Field Orientation	tilt	10°	azimuth	21°
PV modules	Model	CS3W-440MS 1500V	Pnom	440 Wp
PV Array	Nb. of modules	2520	Pnom total	**1109 kWp**
Inverter	Model	XGI 65-1000 1-2-18	Pnom	65.0 kW ac
Inverter pack	Nb. of units	14.0	Pnom total	**910 kW ac**
User's needs	Unlimited load (grid)			

Loss diagram over the whole year



City Project - 1108.8 kW (dc)

49.8648,-97.1433, Winnipeg, MB

MECHANICAL PLAN SET BY:

KB RACKING INC.
1 ATLANTIC AVENUE, SUITE 210
TORONTO, ON M6K 3E7

DRAWING INDEX

NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

ENGINEER'S SEAL

DRAWING TITLE: COVER PAGE

PROJECT: City Project 49.8648,-97.1433 Winnipeg, MB

CLIENT: Core Renewable Energy

PROVIDER

KB RACKING®

1 ATLANTIC AVENUE, SUITE 210
TORONTO, ONTARIO M6K 3E7
CANADA

TOLL - FREE TEL: 1.888.661.3204
LOCAL TEL: 416 532 2500
EMAIL: info@kbracking.com

WWW.KBRACKING.COM

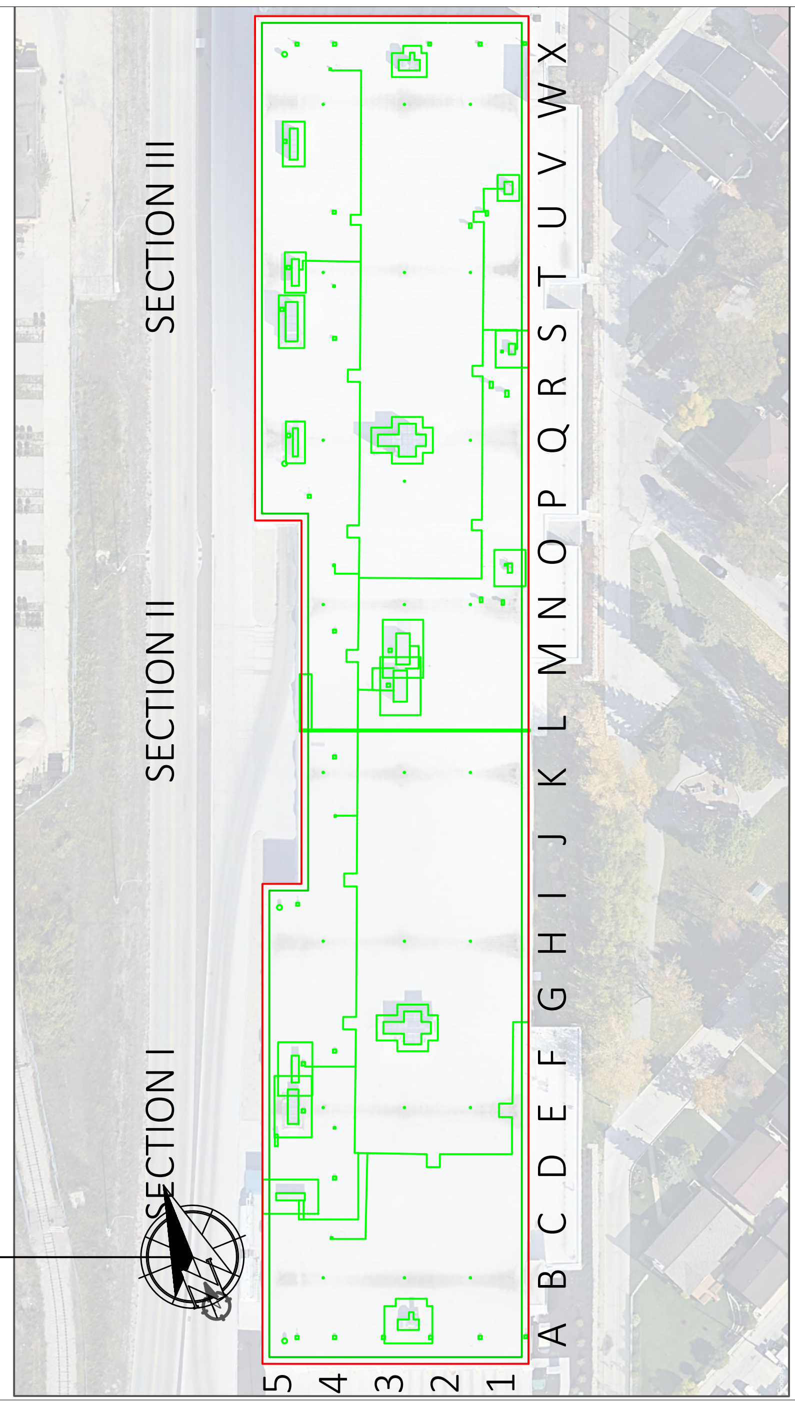
DRAWN BY:	CHECKED BY:	VERSION:
Y.T.	-	3

PROJECT NO.: -	DRAWING NO. C-1.0
DATE: 2020/07/30	
SHEET: 1 OF 46	

Project Information	
Client Name	Core Renewable Energy
Project Name	City Project
Project Address	49.8648,-97.1433, Winnipeg, MB
Total Panel Count	2520
Project Size (kW)	1108.8
System	
Panel Name	Canadian Solar 440W
Panel Weight (kg)	24.9
Panel Length (mm)	2108
Panel Width (mm)	1048
Panel Thickness (mm)	40
Panel Power (W)	440
Panel Cell Type	72
System Orientation	Landscape
System Tilt (deg)	10
Racking Weight Per Panel (kg)	3.163
System Row Spacing (m)	1.43
Inter-Row Spacing (m)	0.391
Reinforcement	NO
Environment	
Importance Category	Normal
Terrain Type	Rough
Wind Pressure: q50 (kPa)	0.45
Exposure Factor: Ce	0.7
Wind Load Factor: αw	1.4
Dead Load Factor: αD	0.9
Closeness Factor	1.0
RoofType	Custom
Friction Coefficient	0.68
Setback (m)	1.22

Buildings		
Building	Building Height (m)	Building Parapet (mm)
1	6.54	305

SITE PLAN



GENERAL NOTES:

1. THIS REPORT PROVIDES BALLAST AND LAYOUT INFORMATION FOR THE SOLAR SYSTEM.
2. SEE INSTALLATION DRAWINGS AND INSTALLATION LAYOUT FOR DIMENSIONS AND ARRAY INFORMATION.
3. BALLAST SYSTEM IS DESIGNED BASED ON THE FOLLOWING REFERENCES:
   - 3.1 NATIONAL BUILDING CODE OF CANADA (NBCC) 2005 and 2010
     - Importance Category for buildings (Section 4.1.2.1)
     - Iw = Importance Factor for wind (Section 4.1.7.1)
     - Ce = Exposure Factor (Section 4.1.7.1)
     - aw = Wind Load Factor (Section 4.1.3.2)
     - aD = Dead Load Factor (Section 4.1.3.2)
   - 3.2 ONTARIO BUILDING CODE (OBC) 2012
   - 3.3 KB RACKING ROOF-MOUNTED PV RACKING SYSTEMS WIND PRESSURE STUDY, RWDI #1600846, MARCH 10, 2017

*Ballast to Resist Uplift = $(\alpha w \cdot Iw \cdot q50 \cdot Ce \cdot |CpCg|uplift \cdot Auplift - \alpha D \cdot M)/\alpha D$

*Ballast to Resist Drag = $[\alpha w \cdot q50 \cdot Ce \cdot (1000/9.81) \cdot [(CpCg)drag \cdot Adrag \cdot (1/fn) + |CpCg|uplift \cdot Auplift] - \alpha D \cdot M]/\alpha D$

4. A PROFESSIONAL STRUCTURAL ENGINEER LICENSED WHERE THE RACKING SYSTEM WILL BE INSTALLED IS REQUIRED TO APPROVE THE DESIGN.
5. THE STRUCTURAL ENGINEER OF THE BUILDING IS RESPONSIBLE TO CHECK THE ADEQUACY OF THE BUILDING'S STRUCTURAL CAPACITY TO SUPPORT THE LOADS INDICATED ON THIS DRAWING.
6. THE MOUNTING SYSTEM SHALL BE INSTALLED AS PER KB RACKING SPECIFICATIONS AND PROCEDURES.
7. INSTALL THE SPECIFIED PHOTOVOLTAIC MODULES ONLY. ANY CHANGES IN THE MODULE SIZE OR TYPE MUST BE NOTIFIED TO KB RACKING INC.
8. ANY CHANGES IN THE MOUNTING SYSTEM LAYOUT IS NOT PERMITTED UNLESS APPROVED BY KB RACKING INC.

NOTE: AVERAGE PSF LOADS REPRESENT THE UNIFORMLY DISTRIBUTED LOAD IMPOSED BY THE RACKING INSTALLATION ON THE ROOF. AVERAGE LOADS SHOULD NOT BE USED FOR THE STRUCTURAL REVIEW OF THE SUPPORTING ROOF STRUCTURE WITHOUT CONSIDERATION FOR LOCALIZED PSF LOADS WHICH MAY BE MORE SIGNIFICANT. LOCALIZED PSF LOADS PER PANEL ARE ACCOMPANIED WITHIN THIS REPORT IN THE FOLLOWING PAGES.

KB RACKING INC. HAS NO LIABILITY FOR THE USE OF THIS REPORT BY THE CUSTOMER. IF THERE ARE ANY QUESTIONS OR CONCERNS, PLEASE CONTACT KB RACKING INC.

NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LOADING INFORMATION

Array	Number of Panels	Array Area (m²)	Area Reduction Factor	Uplift Ballast (kg)	Drag Ballast (kg)	Additional Ballast per Panel Due to Drag (kg)	Total Ballast for Array (kg)	Average PSF
1	190	578.18	0.1237	7508.62	391.82	0.00	7508.62	4.54
2	205	623.82	0.1201	6787.22	240.52	0.00	6787.22	4.12
3	98	298.22	0.1663	3895.50	1217.83	0.00	3895.50	4.55
4	153	465.59	0.1362	6367.24	779.20	0.00	6367.24	4.68
5	185	562.96	0.1250	5532.95	436.33	0.00	5532.95	3.91
6	43	130.85	0.2391	2247.28	1296.73	0.00	2247.28	5.40
7	135	410.81	0.1461	4313.59	1011.56	0.00	4313.59	4.04
8	65	197.80	0.1909	3444.97	1196.38	0.00	3444.97	5.45
9	77	234.31	0.1797	4081.08	1207.77	0.00	4081.08	5.45
10	70	213.01	0.1861	3054.71	1206.88	0.00	3054.71	4.82
11	104	316.48	0.1630	4231.49	1209.19	0.00	4231.49	4.62
12	60	182.58	0.1970	2965.45	1193.25	0.00	2965.45	5.21
13	91	276.92	0.1702	2770.97	1215.79	0.00	2770.97	3.94
14	78	237.36	0.1788	2784.62	1206.12	0.00	2784.62	4.28
15	124	377.34	0.1521	4756.84	1111.02	0.00	4756.84	4.46
16	126	383.42	0.1510	3662.14	1095.34	0.00	3662.14	3.85
17	218	663.38	0.1169	7544.56	87.81	0.00	7544.56	4.21
18	70	213.01	0.1861	3575.93	1206.88	0.00	3575.93	5.32
19	47	143.02	0.2270	1765.93	1278.09	0.00	1765.93	4.41
20	120	365.16	0.1543	4539.73	1139.19	0.00	4539.73	4.43
21	261	794.23	0.1082	9227.55	-447.58	0.00	9227.55	4.27
Total	2520		Total Ballast Weight	95058.37		Total System Weight	165777.13	

ENGINEER'S SEAL

DRAWING TITLE: SITE PLAN-PROJECT SUMMARY

PROJECT: City Project 49.8648,-97.1433 Winnipeg, MB

CLIENT: Core Renewable Energy

PROVIDER

KB RACKING®

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EMAIL: info@kbracking.com

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DRAWN BY:	CHECKED BY:	VERSION:
Y.T.	-	3

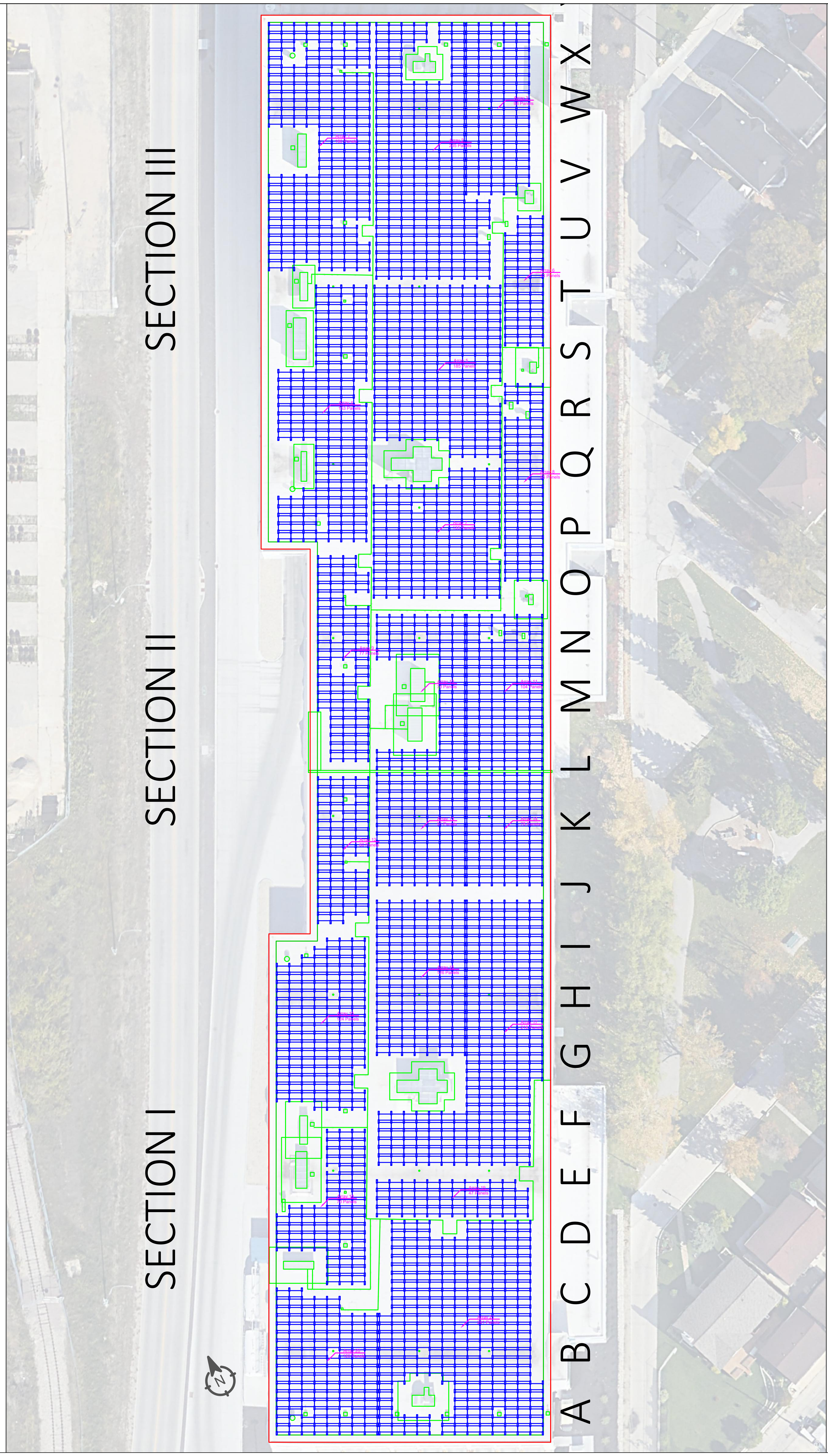
PROJECT NO.: -

DATE: 2020/07/30

SHEET: 2 OF 46

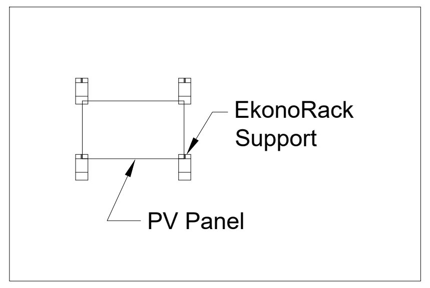
DRAWING NO. M-1.0

NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m



ARRAY LAYOUT

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: ROOF PLAN

PROJECT: City Project
49.8648,-97.1433
Winnipeg, MB

CLIENT: Core Renewable Energy

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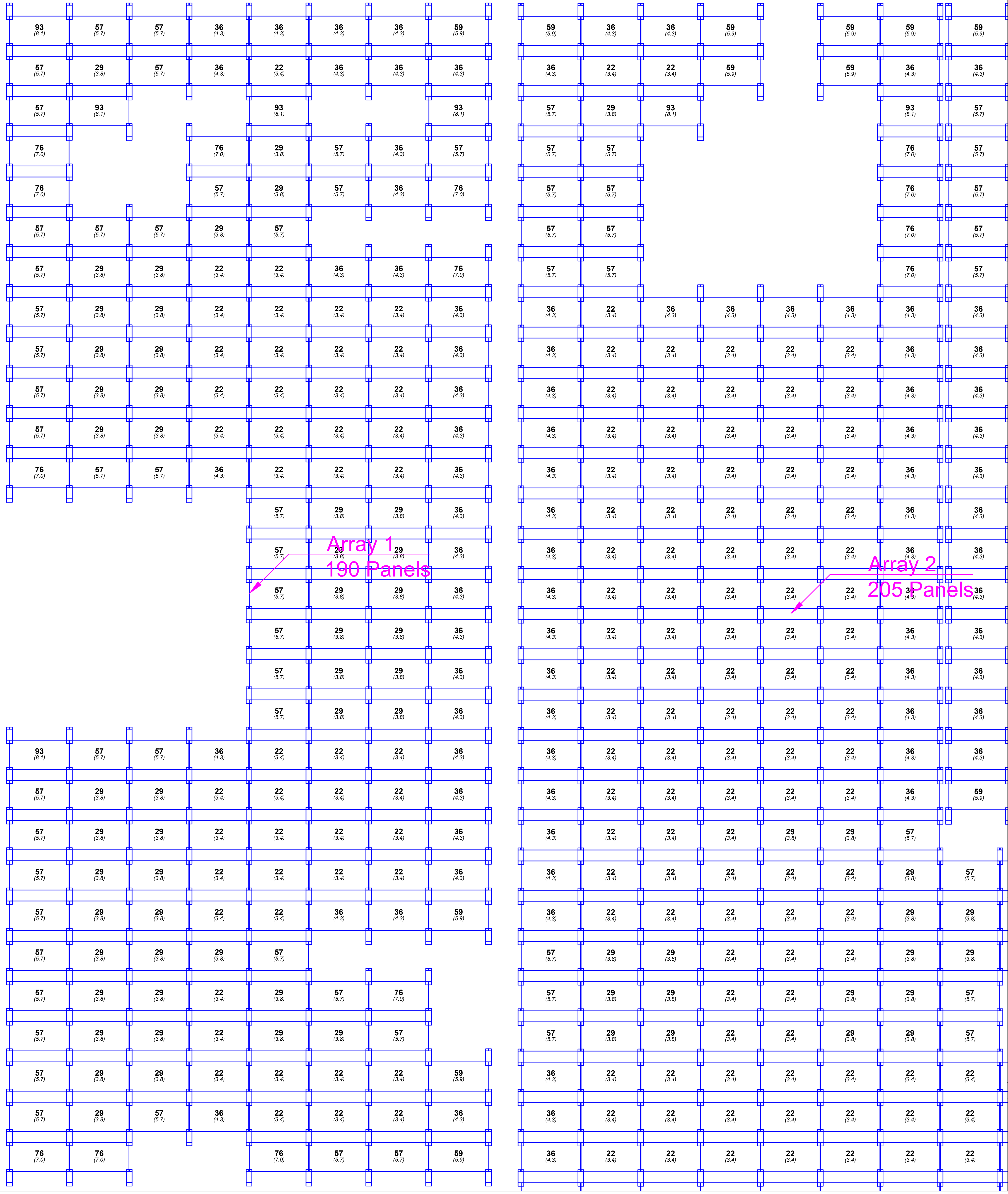
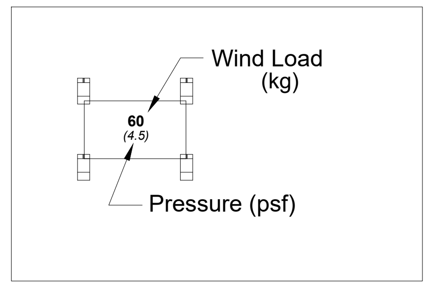
DRAWN BY:	CHECKED BY:	VERSION:
Y.T.	-	3

PROJECT NO.: -
DATE: 2020/07/30
SHEET: 3 OF 46
DRAWING NO. M-2.0



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: LOAD ARRAY 1

PROJECT: City Project
49.8648,-97.1433
Winnipeg, MB

CLIENT: Core Renewable Energy

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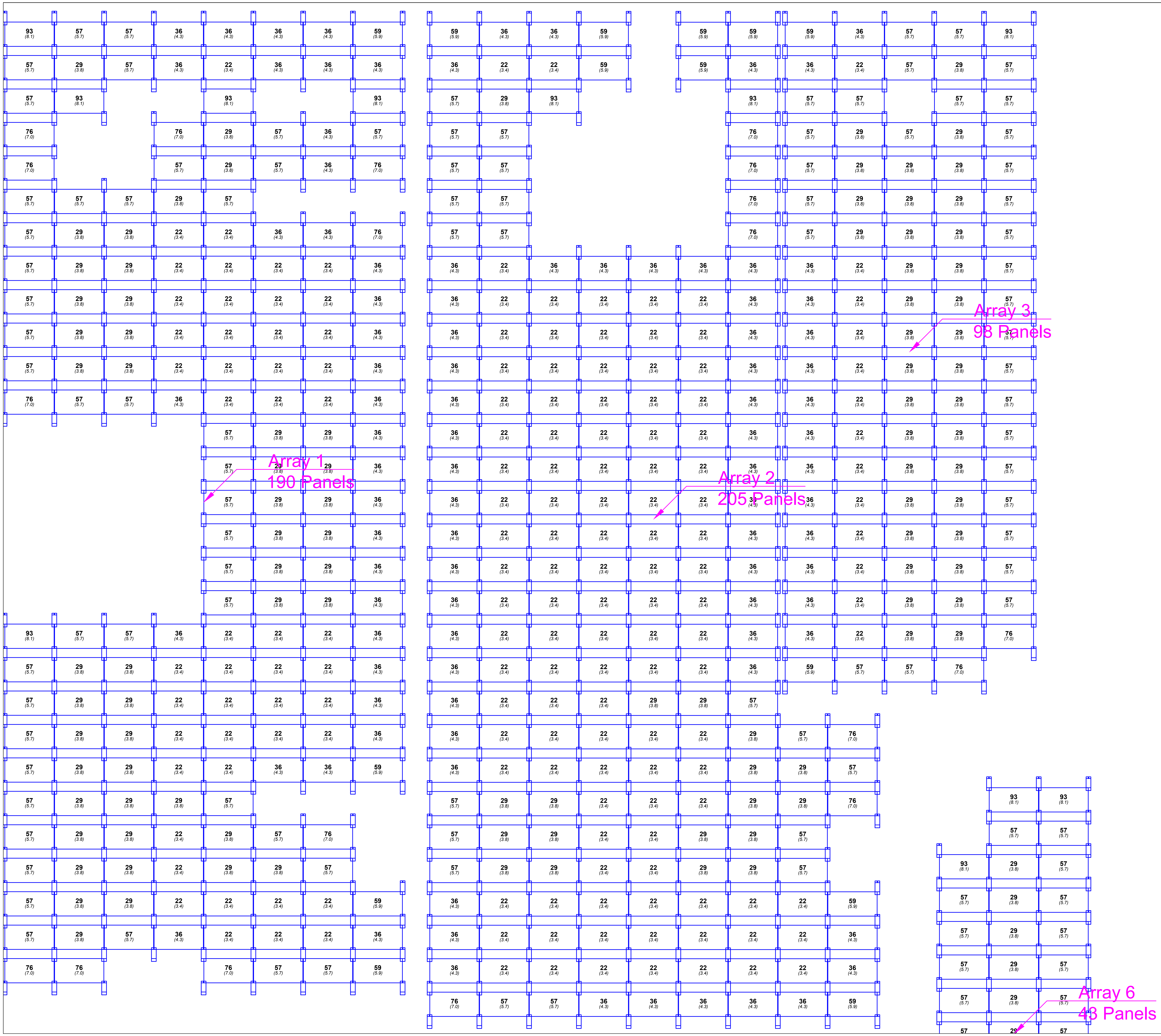
Y.T.	-	3

PROJECT NO.: -

DATE: 2020/07/30

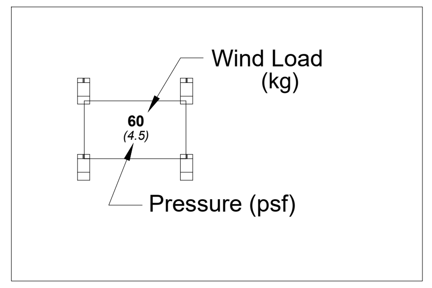
SHEET: 4 OF 46

DRAWING NO. M-3.1



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: LOAD ARRAY 2

PROJECT: City Project
49.8648,-97.1433
Winnipeg, MB

CLIENT: Core Renewable Energy

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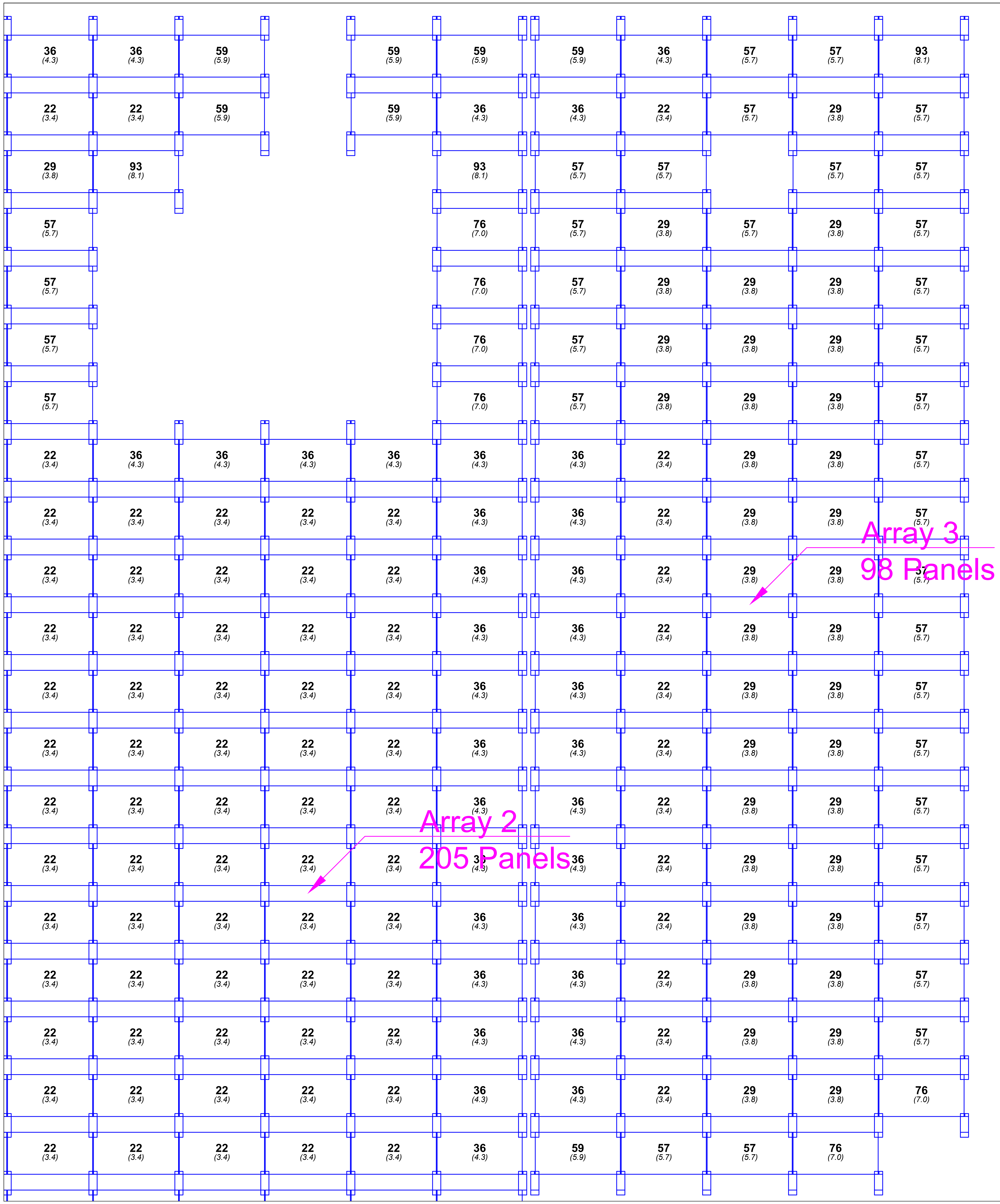
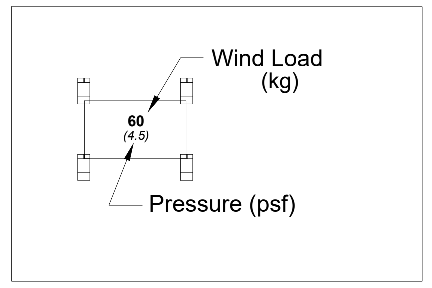
Y.T.	-	3

PROJECT NO.: -
DATE: 2020/07/30
SHEET: 5 OF 46
DRAWING NO. M-3.2



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: LOAD ARRAY 3

PROJECT: City Project
49.8648,-97.1433
Winnipeg, MB

CLIENT: Core Renewable Energy

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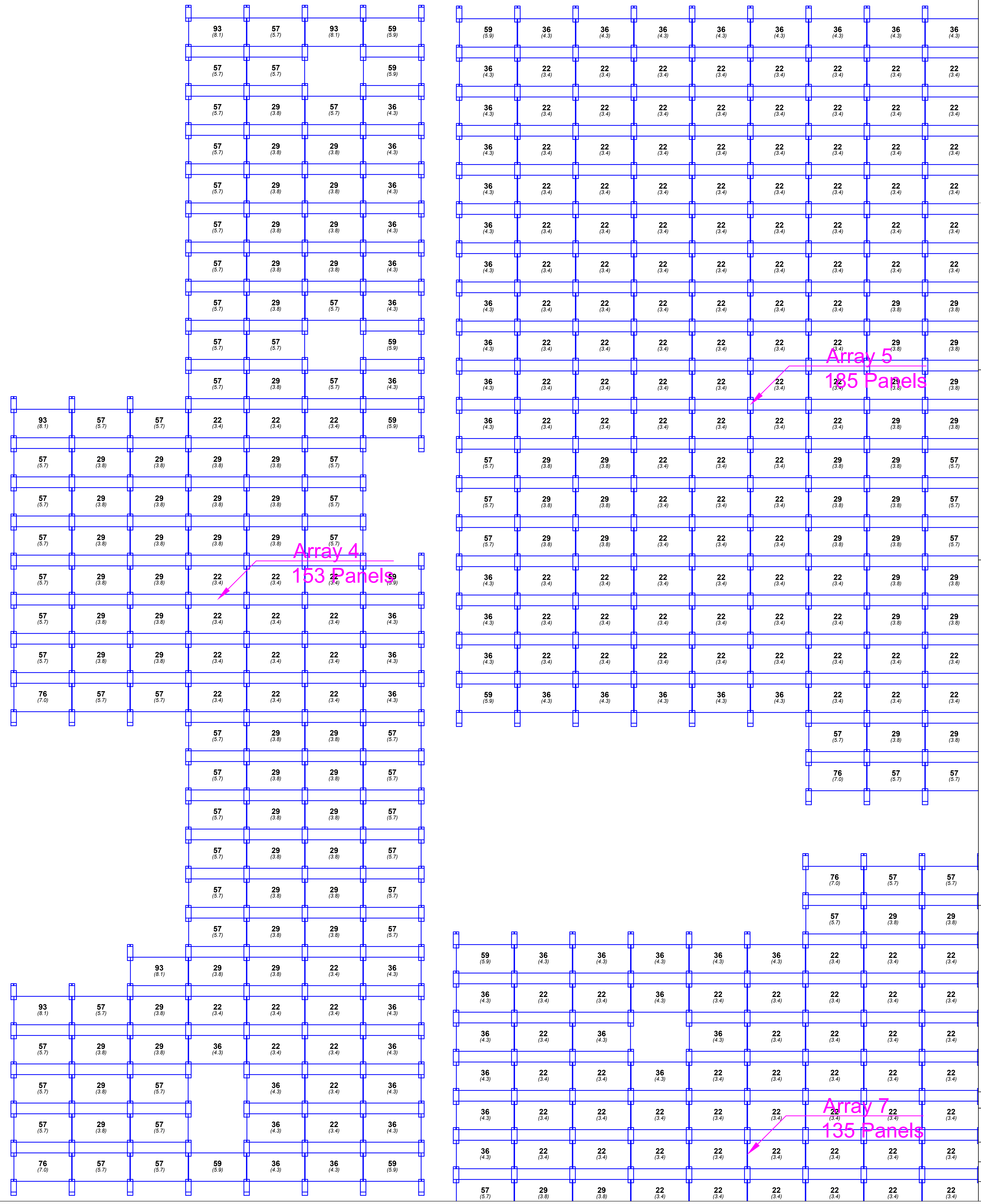
Y.T.	-	3

PROJECT NO.: -

DATE: 2020/07/30

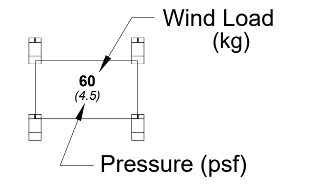
SHEET: 6 OF 46

DRAWING NO. M-3.3



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: LOAD ARRAY 4

PROJECT: City Project
49.8648,-97.1433
Winnipeg, MB

CLIENT: Core Renewable Energy

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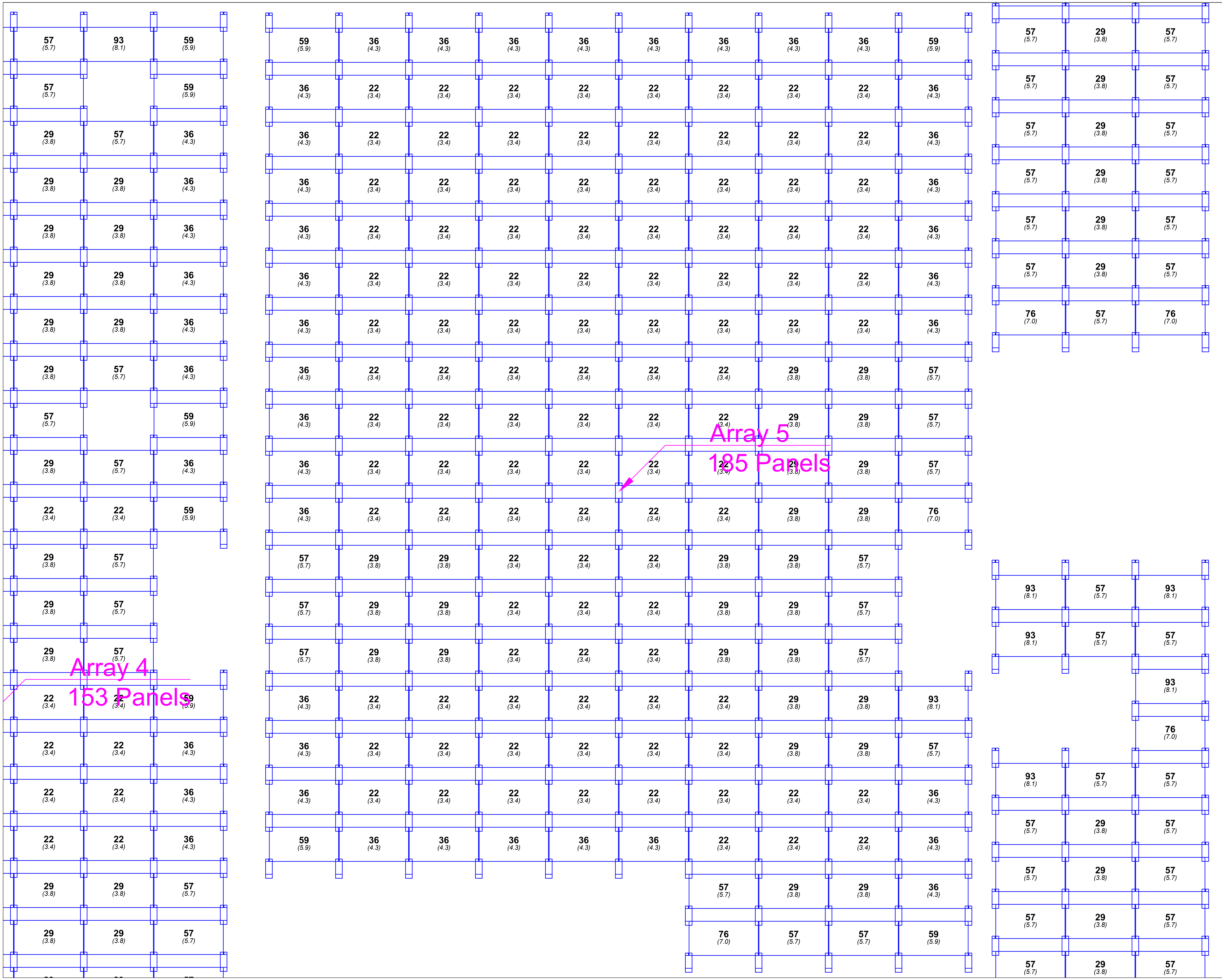
Y.T.	-	3

PROJECT NO.: -

DRAWING NO. M-3.4

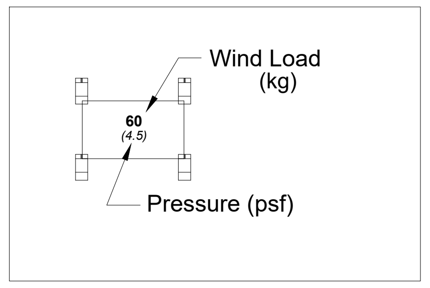
DATE: 2020/07/30

SHEET: 7 OF 46



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: LOAD ARRAY 5

PROJECT: City Project
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Winnipeg, MB

CLIENT: Core Renewable Energy

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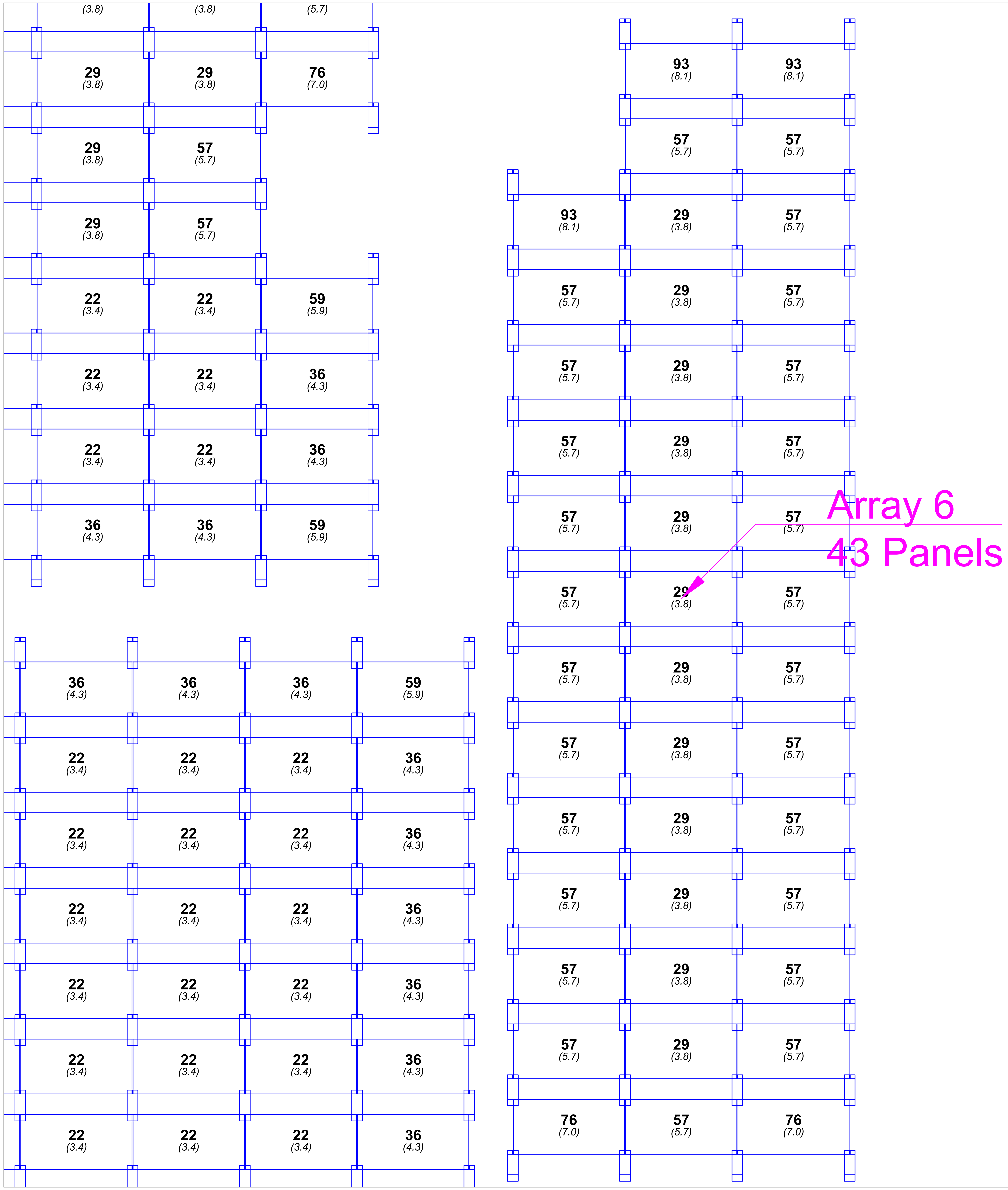
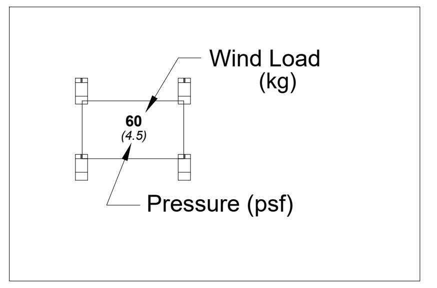
Y.T.	-	3

PROJECT NO.: -
DATE: 2020/07/30
SHEET: 8 OF 46
DRAWING NO. M-3.5



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: LOAD ARRAY 6

PROJECT: City Project
49.8648,-97.1433
Winnipeg, MB

CLIENT: Core Renewable Energy

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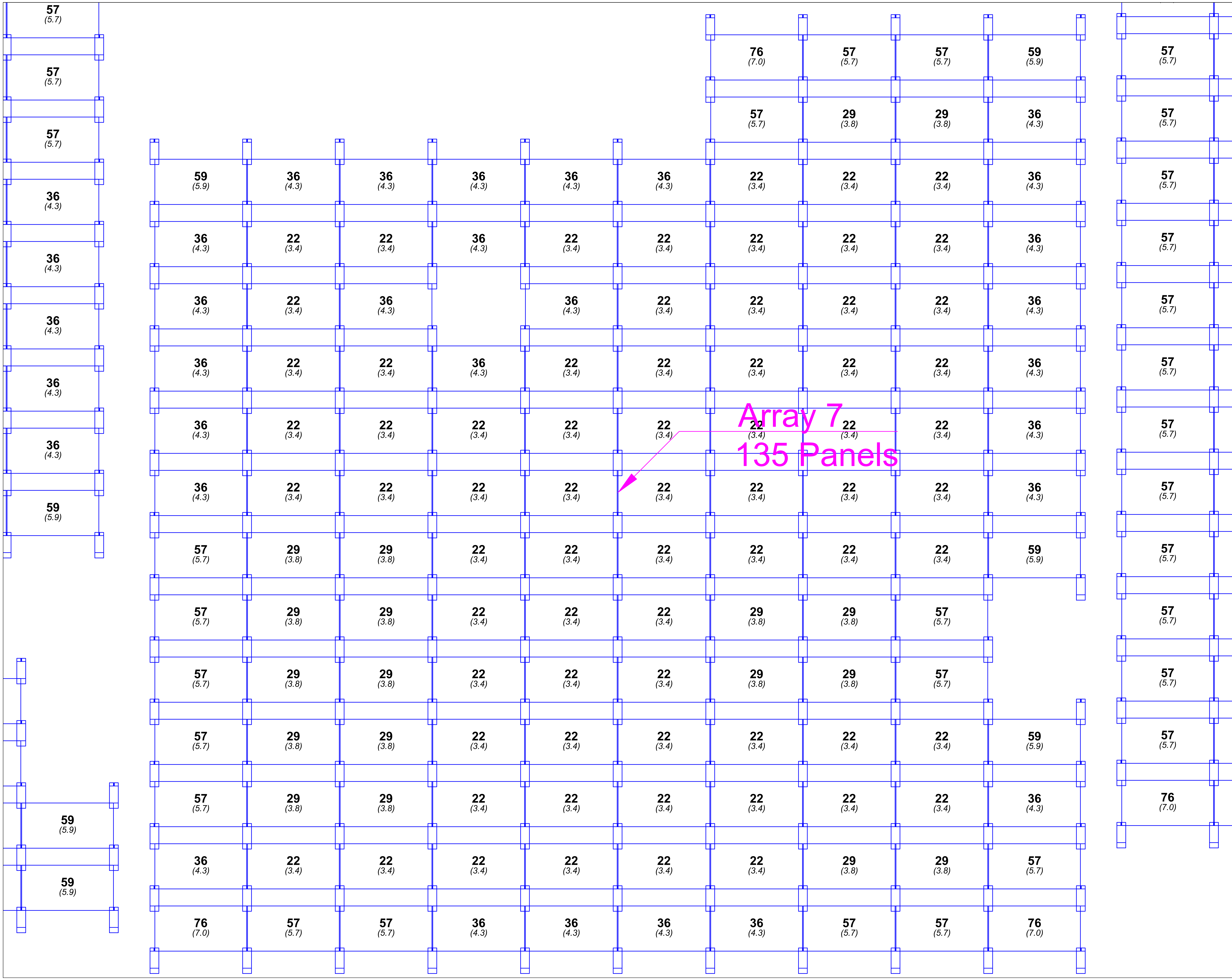
DRAWN BY:	CHECKED BY:	VERSION:
Y.T.	-	3

PROJECT NO.: -	DRAWING NO.: M-3.6
DATE: 2020/07/30	
SHEET: 9 OF 46	



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND

Wind Load (kg)
60
(4.5)
Pressure (psf)

ENGINEER'S SEAL

DRAWING TITLE: LOAD ARRAY 7

PROJECT: City Project
49.8648,-97.1433
Winnipeg, MB

CLIENT: Core Renewable Energy

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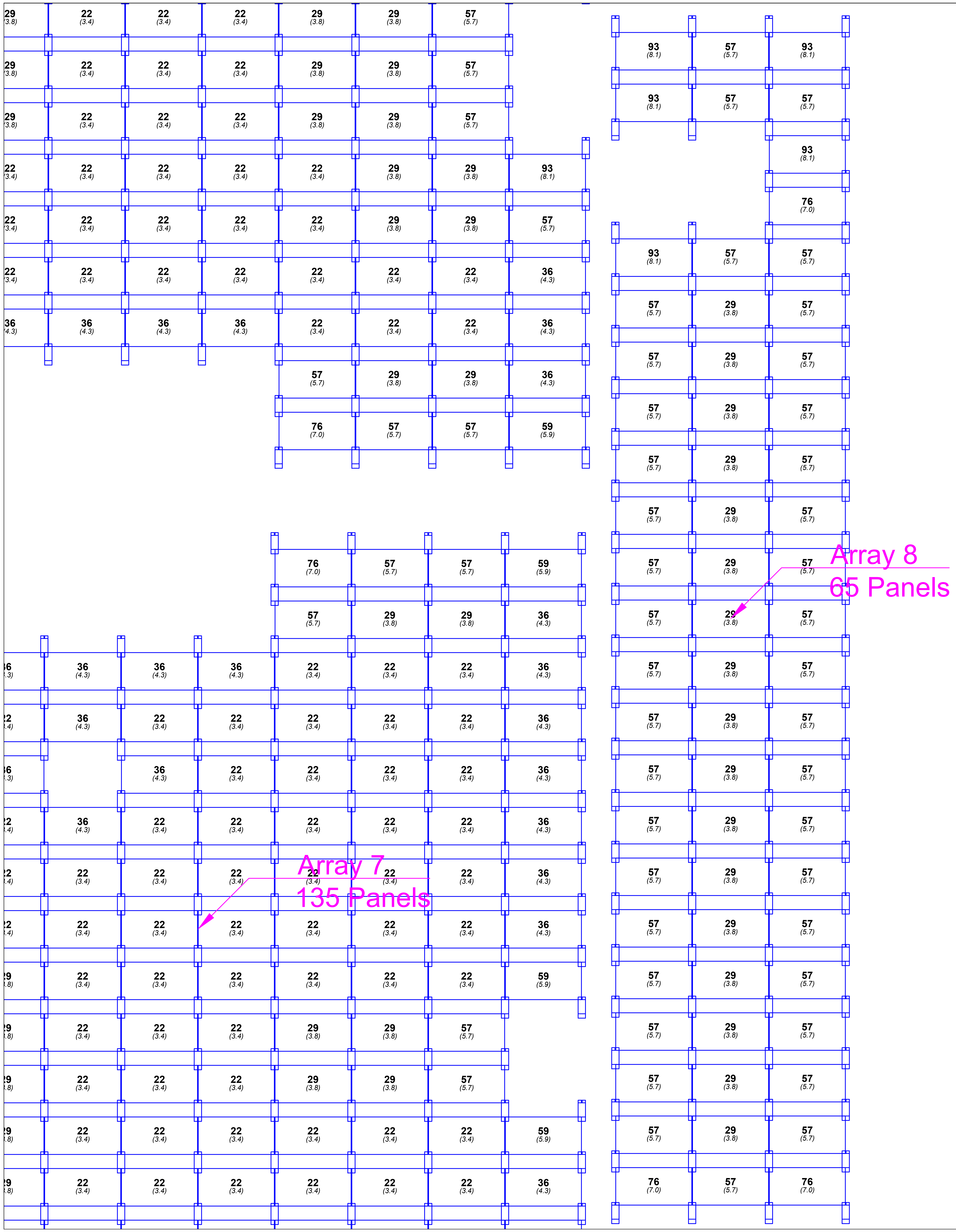
Y.T.	-	3

PROJECT NO.: -

DATE: 2020/07/30

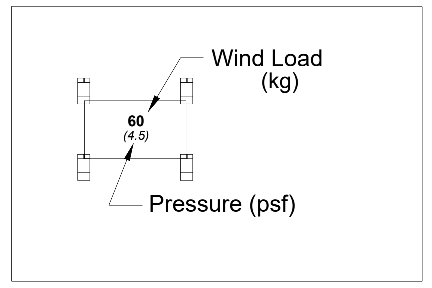
SHEET: 10 OF 46

DRAWING NO. M-3.7



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: LOAD ARRAY 8

PROJECT: City Project
49.8648,-97.1433
Winnipeg, MB

CLIENT: Core Renewable Energy

PROVIDER
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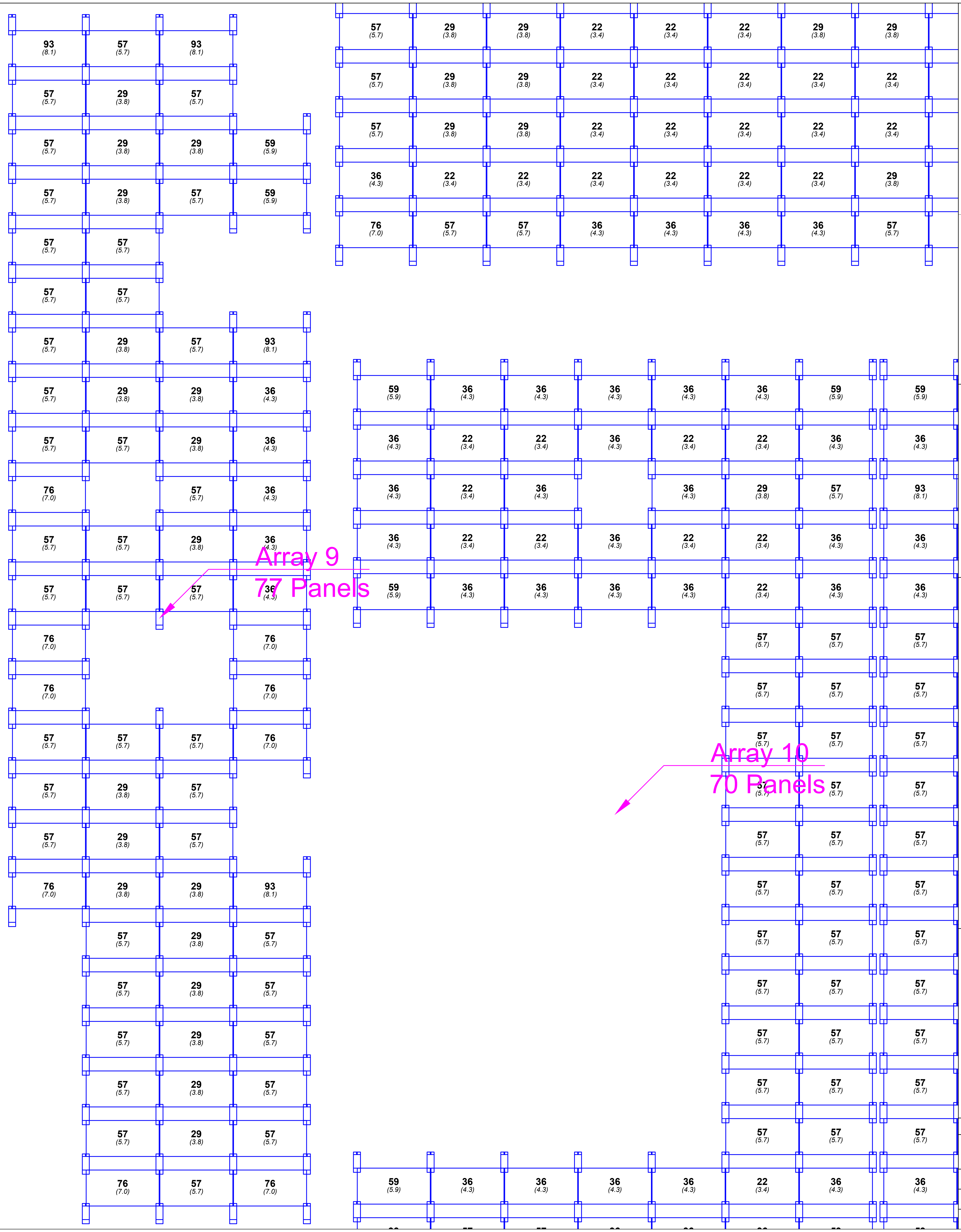
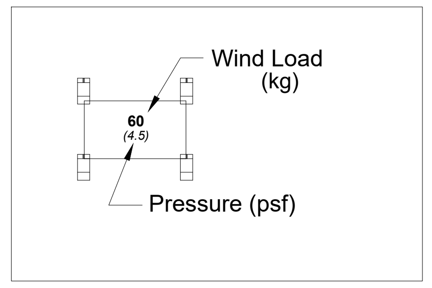
Y.T.	-	3

PROJECT NO.: -	DRAWING NO. M-3.8
DATE: 2020/07/30	
SHEET: 11 OF 46	



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: LOAD ARRAY 9

PROJECT: City Project
49.8648,-97.1433
Winnipeg, MB

CLIENT: Core Renewable Energy

PROVIDER

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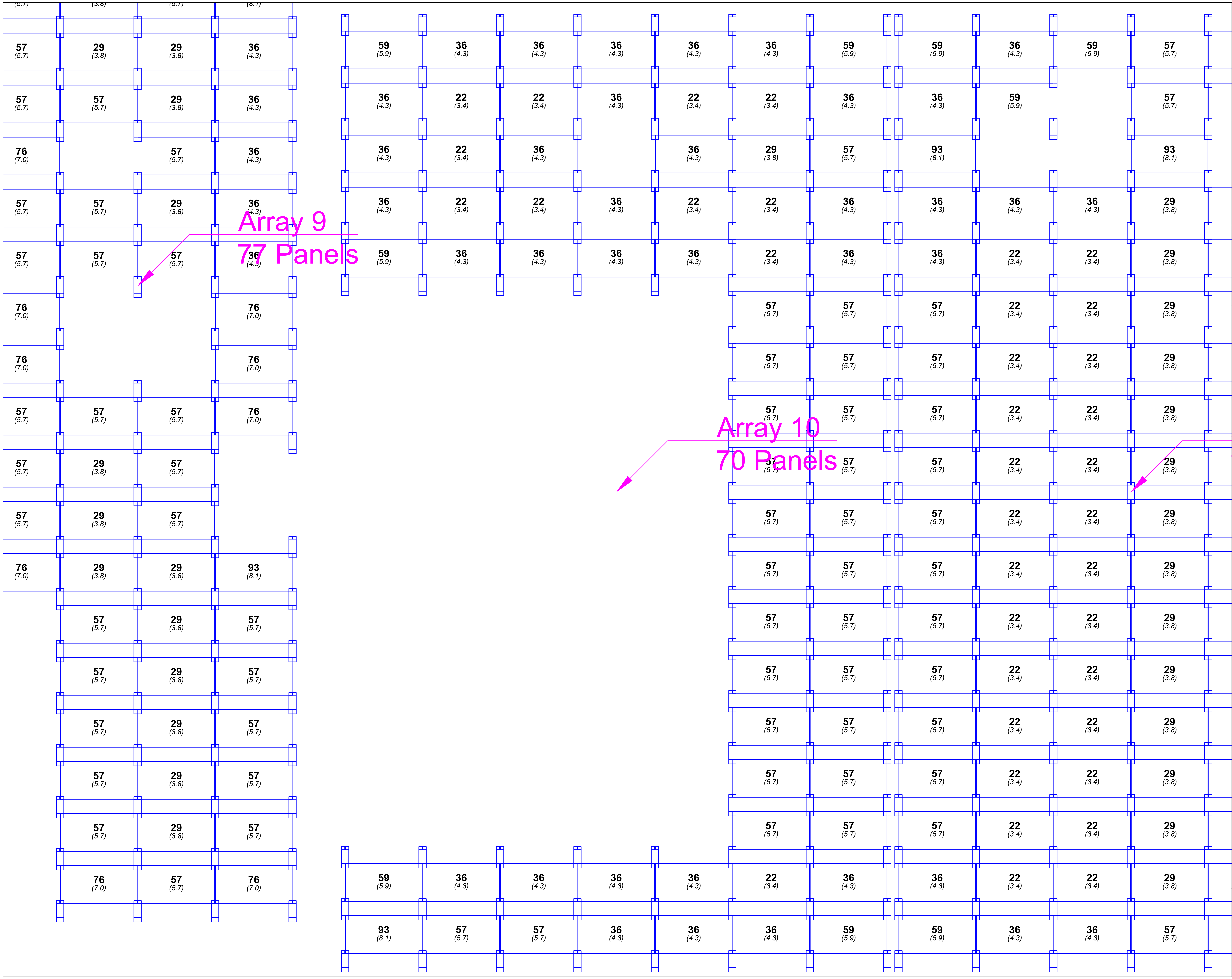
Y.T.	-	3

PROJECT NO.: -
DATE: 2020/07/30
SHEET: 12 OF 46
DRAWING NO. M-3.9



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND

Wind Load (kg)
Pressure (psf)

ENGINEER'S SEAL

DRAWING TITLE: LOAD ARRAY 10

PROJECT: City Project
49.8648,-97.1433
Winnipeg, MB

CLIENT: Core Renewable Energy

PROVIDER

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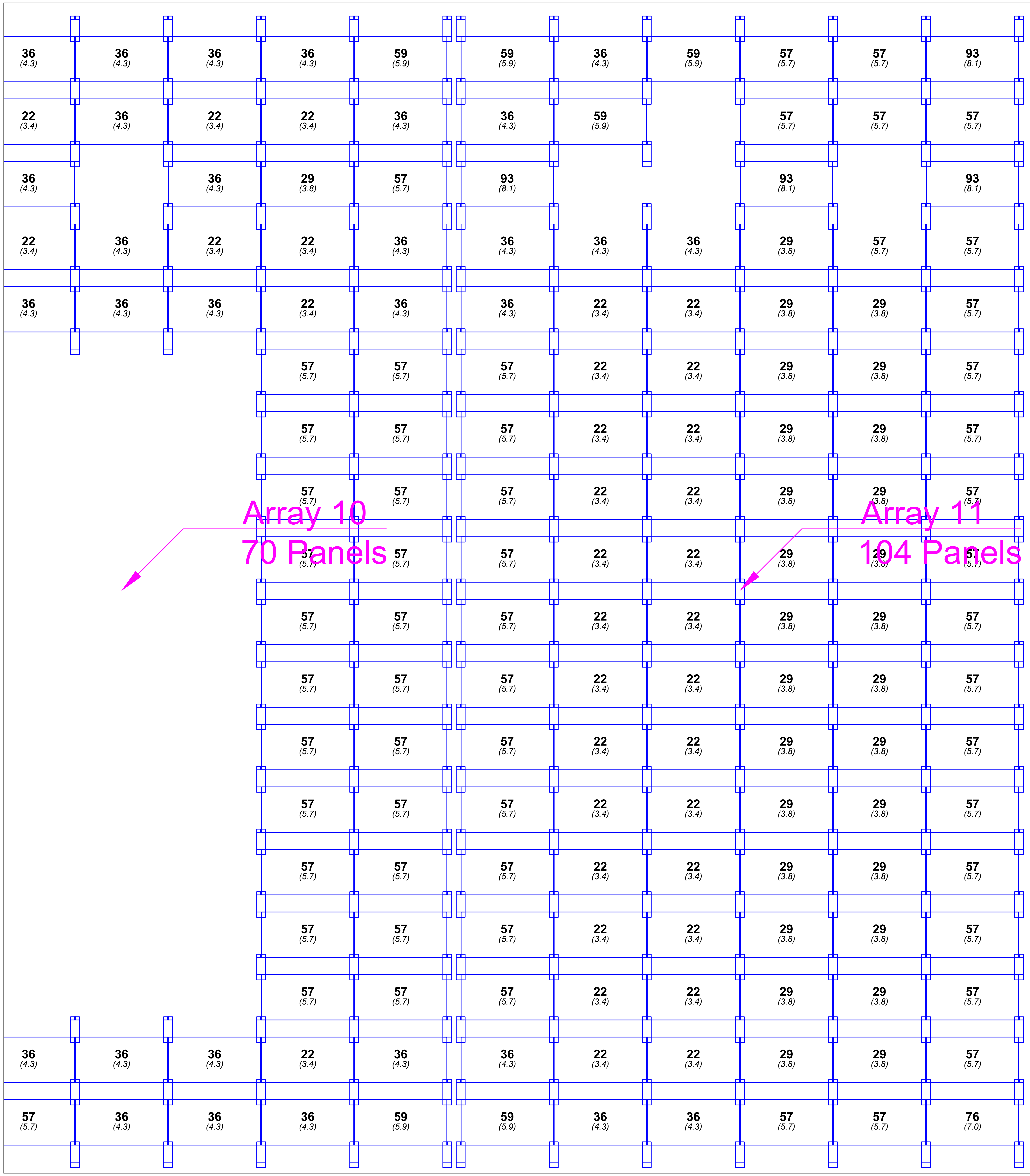
DRAWN BY:	CHECKED BY:	VERSION:
Y.T.	-	3

PROJECT NO.: -
DATE: 2020/07/30
SHEET: 13 OF 46
DRAWING NO. M-3.10



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND

Wind Load (kg)
60 (4.3)
Pressure (psf)

ENGINEER'S SEAL

DRAWING TITLE: LOAD ARRAY 11

PROJECT: City Project
49.8648,-97.1433
Winnipeg, MB

CLIENT: Core Renewable Energy

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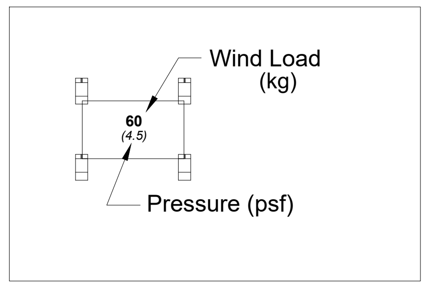
Y.T.	-	3

PROJECT NO.: -
DATE: 2020/07/30
SHEET: 14 OF 46
DRAWING NO. M-3.11

NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: LOAD ARRAY 12

PROJECT: City Project
49.8648,-97.1433
Winnipeg, MB

CLIENT: Core Renewable Energy

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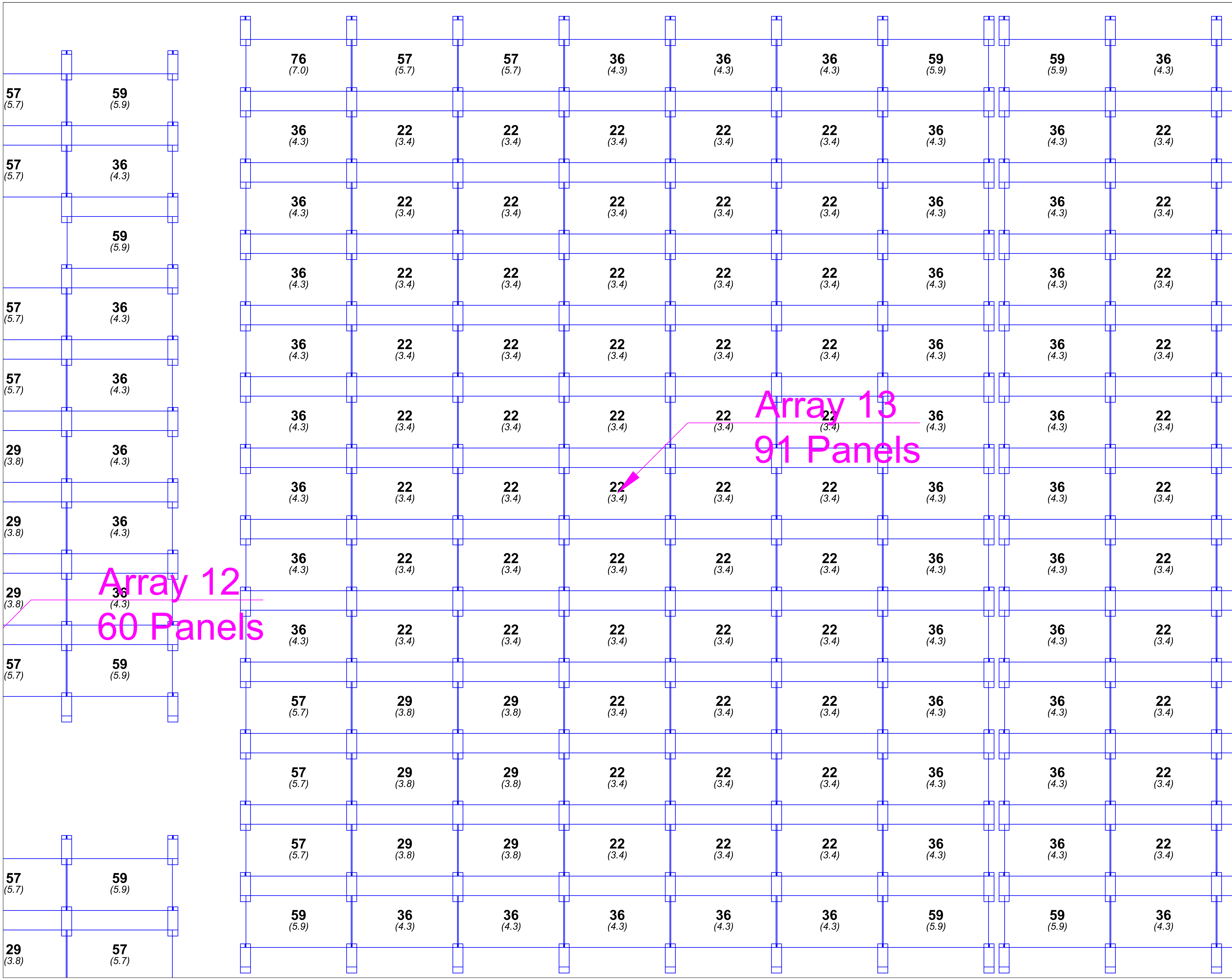
Y.T.	-	3

PROJECT NO.: -

DATE: 2020/07/30

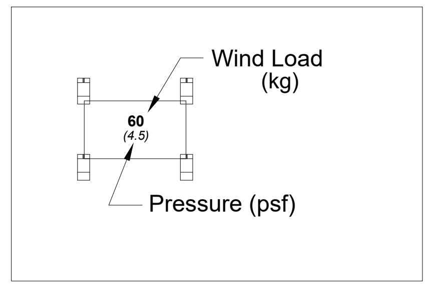
SHEET: 15 OF 46

DRAWING NO. M-3.12



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: LOAD ARRAY 13

PROJECT: City Project
49.8648,-97.1433
Winnipeg, MB

CLIENT: Core Renewable Energy

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PROJECT NO.: -

DATE: 2020/07/30

SHEET: 16 OF 46

DRAWING NO. M-3.13

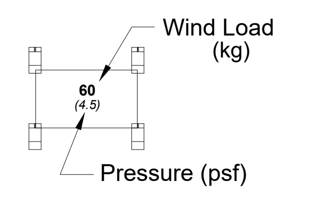
Array 13
91 Panels

Array 14
78 Panels

36 (4.3)	36 (4.3)	59 (5.9)	59 (5.9)	36 (4.3)	36 (4.3)	57 (5.7)	57 (5.7)	76 (7.0)
22 (3.4)	22 (3.4)	36 (4.3)	36 (4.3)	22 (3.4)	22 (3.4)	29 (3.8)	29 (3.8)	57 (5.7)
22 (3.4)	22 (3.4)	36 (4.3)	36 (4.3)	22 (3.4)	22 (3.4)	29 (3.8)	29 (3.8)	57 (5.7)
22 (3.4)	22 (3.4)	36 (4.3)	36 (4.3)	22 (3.4)	22 (3.4)	29 (3.8)	29 (3.8)	57 (5.7)
22 (3.4)	22 (3.4)	36 (4.3)	36 (4.3)	22 (3.4)	22 (3.4)	29 (3.8)	29 (3.8)	57 (5.7)
22 (3.4)	22 (3.4)	36 (4.3)	36 (4.3)	22 (3.4)	22 (3.4)	29 (3.8)	29 (3.8)	57 (5.7)
22 (3.4)	22 (3.4)	36 (4.3)	36 (4.3)	22 (3.4)	22 (3.4)	29 (3.8)	29 (3.8)	57 (5.7)
22 (3.4)	22 (3.4)	36 (4.3)	36 (4.3)	22 (3.4)	22 (3.4)	29 (3.8)	29 (3.8)	57 (5.7)
22 (3.4)	22 (3.4)	36 (4.3)	36 (4.3)	22 (3.4)	22 (3.4)	29 (3.8)	29 (3.8)	57 (5.7)
22 (3.4)	22 (3.4)	36 (4.3)	36 (4.3)	22 (3.4)	22 (3.4)	29 (3.8)	29 (3.8)	57 (5.7)
22 (3.4)	22 (3.4)	36 (4.3)	36 (4.3)	22 (3.4)	22 (3.4)	29 (3.8)	29 (3.8)	57 (5.7)
22 (3.4)	22 (3.4)	36 (4.3)	36 (4.3)	22 (3.4)	22 (3.4)	29 (3.8)	29 (3.8)	57 (5.7)
36 (4.3)	36 (4.3)	59 (5.9)	59 (5.9)	36 (4.3)	36 (4.3)	57 (5.7)	57 (5.7)	76 (7.0)

NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: LOAD ARRAY 14

PROJECT: City Project
49.8648,-97.1433
Winnipeg, MB

CLIENT: Core Renewable Energy

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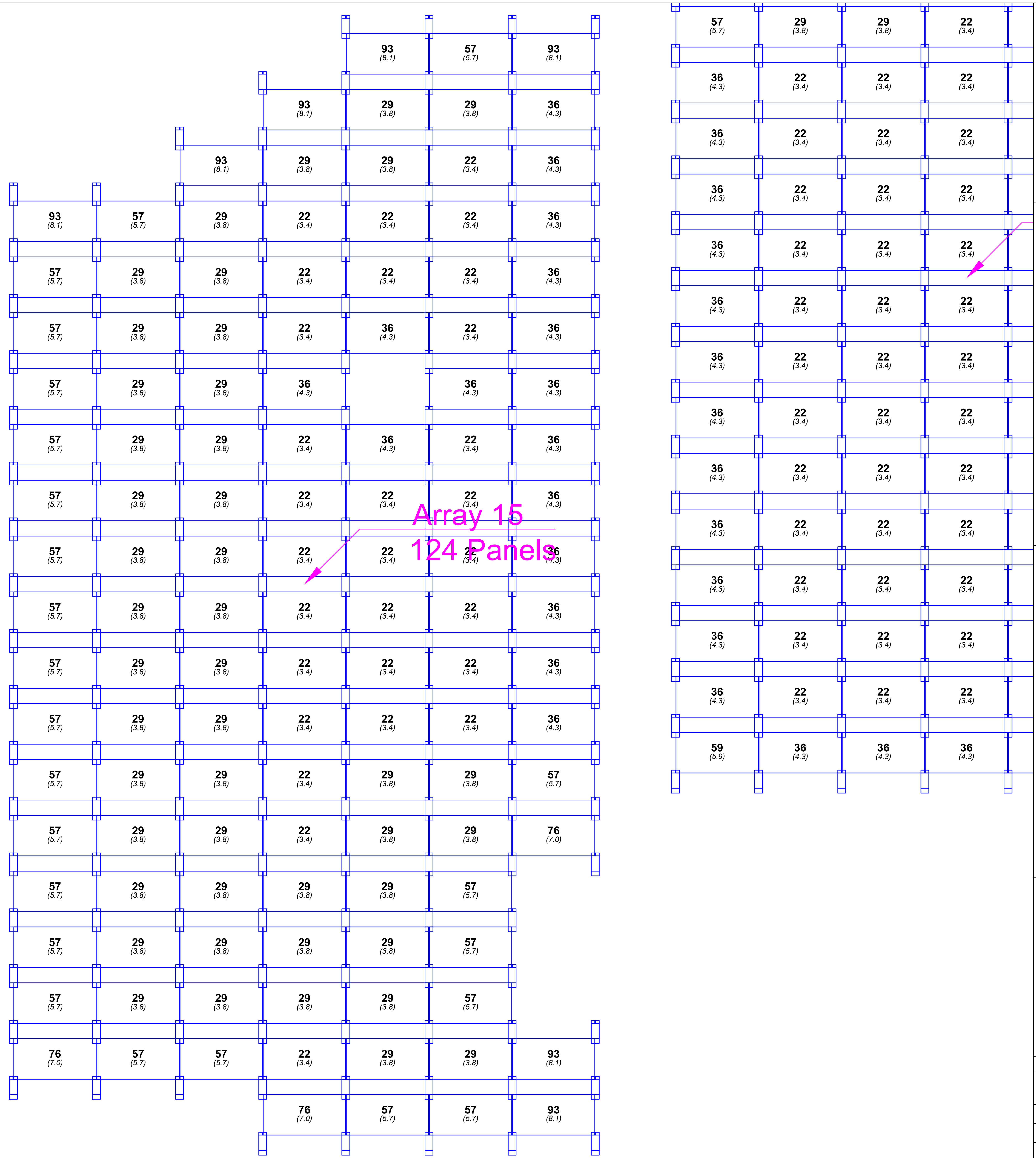
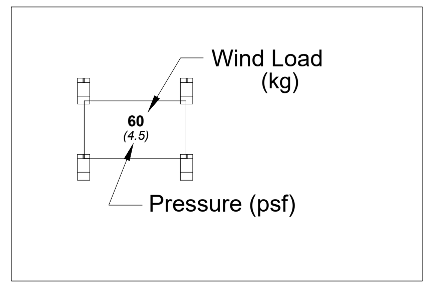
DRAWN BY:	CHECKED BY:	VERSION:
Y.T.	-	3

PROJECT NO.: -
DATE: 2020/07/30
SHEET: 17 OF 46
DRAWING NO. M-3.14

NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m



LEGEND



ENGINEER'S SEAL

DRAWING TITLE: LOAD ARRAY 15

PROJECT: City Project
49.8648,-97.1433
Winnipeg, MB

CLIENT: Core Renewable Energy

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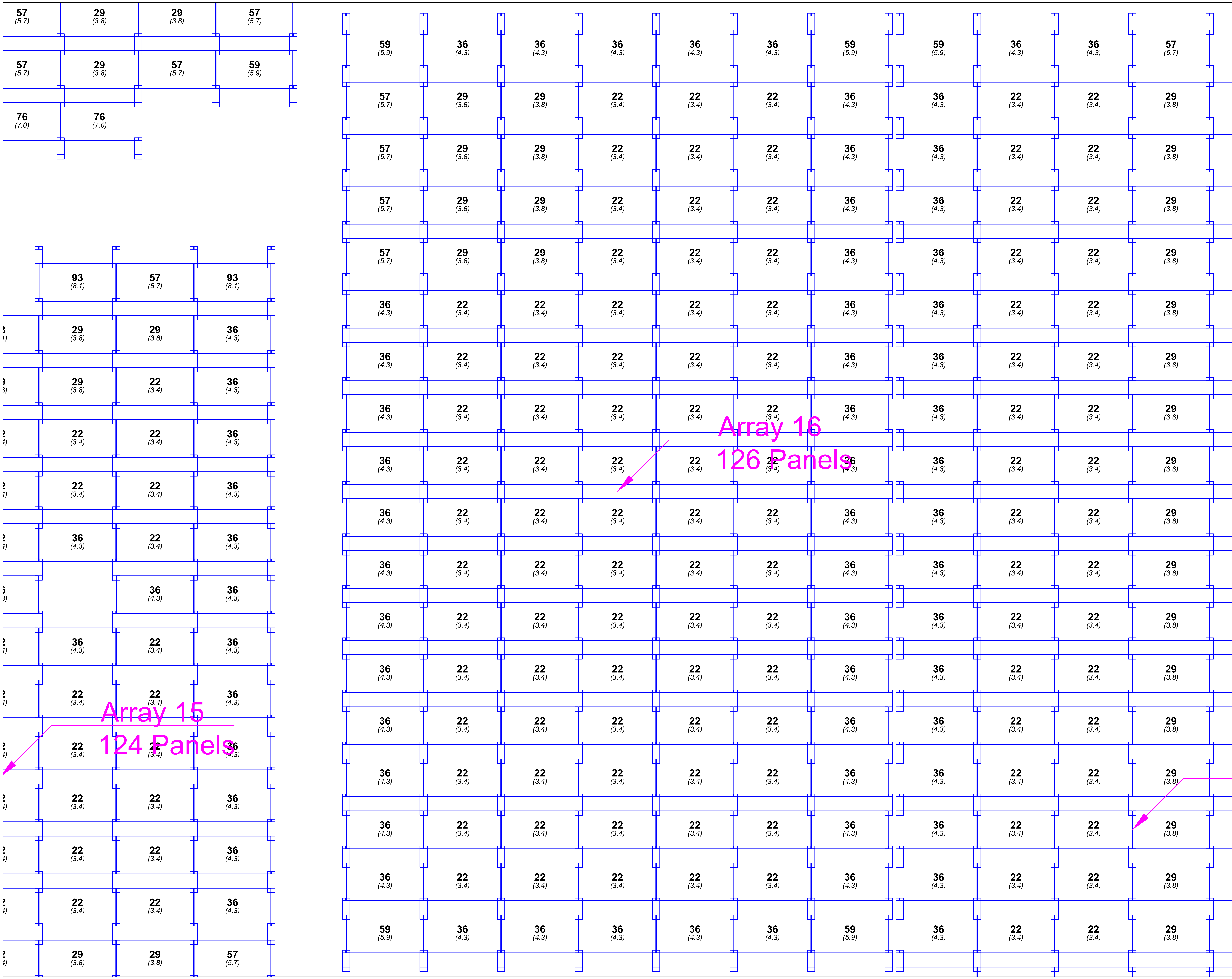
PROJECT NO.: -

DATE: 2020/07/30

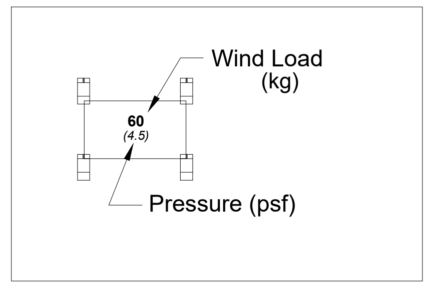
SHEET: 18 OF 46

DRAWING NO. M-3.15



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: LOAD ARRAY 16

PROJECT: City Project
49.8648,-97.1433
Winnipeg, MB

CLIENT: Core Renewable Energy

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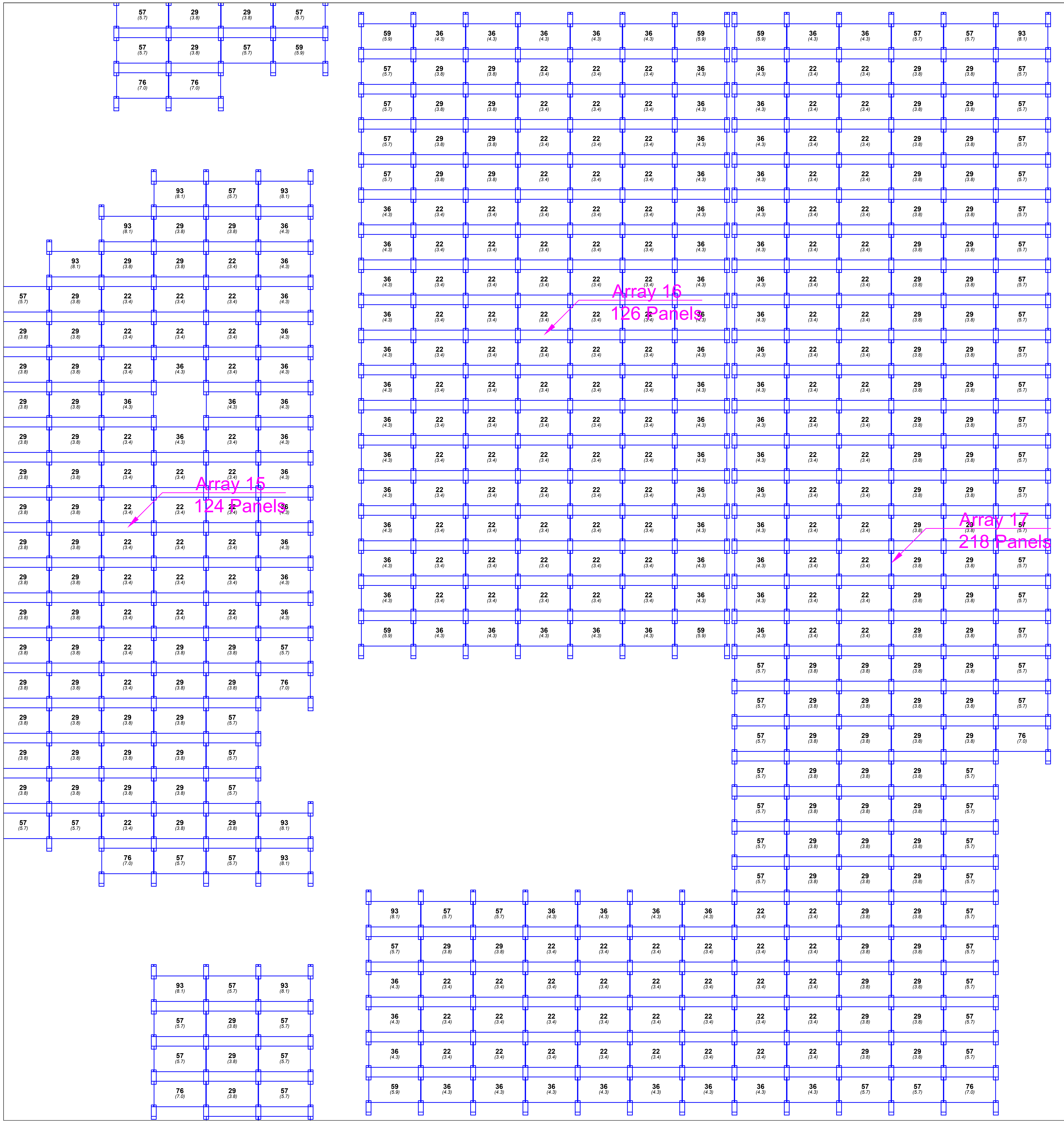
PROJECT NO.: -

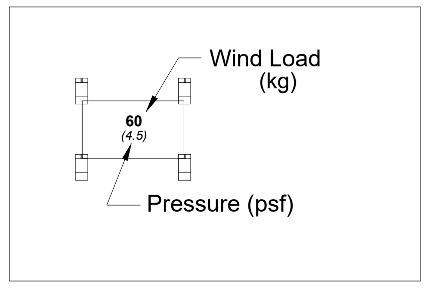
DATE: 2020/07/30

DRAWING NO. M-3.16



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: LOAD ARRAY 17

PROJECT: City Project
49.8648,-97.1433
Winnipeg, MB

CLIENT: Core Renewable Energy

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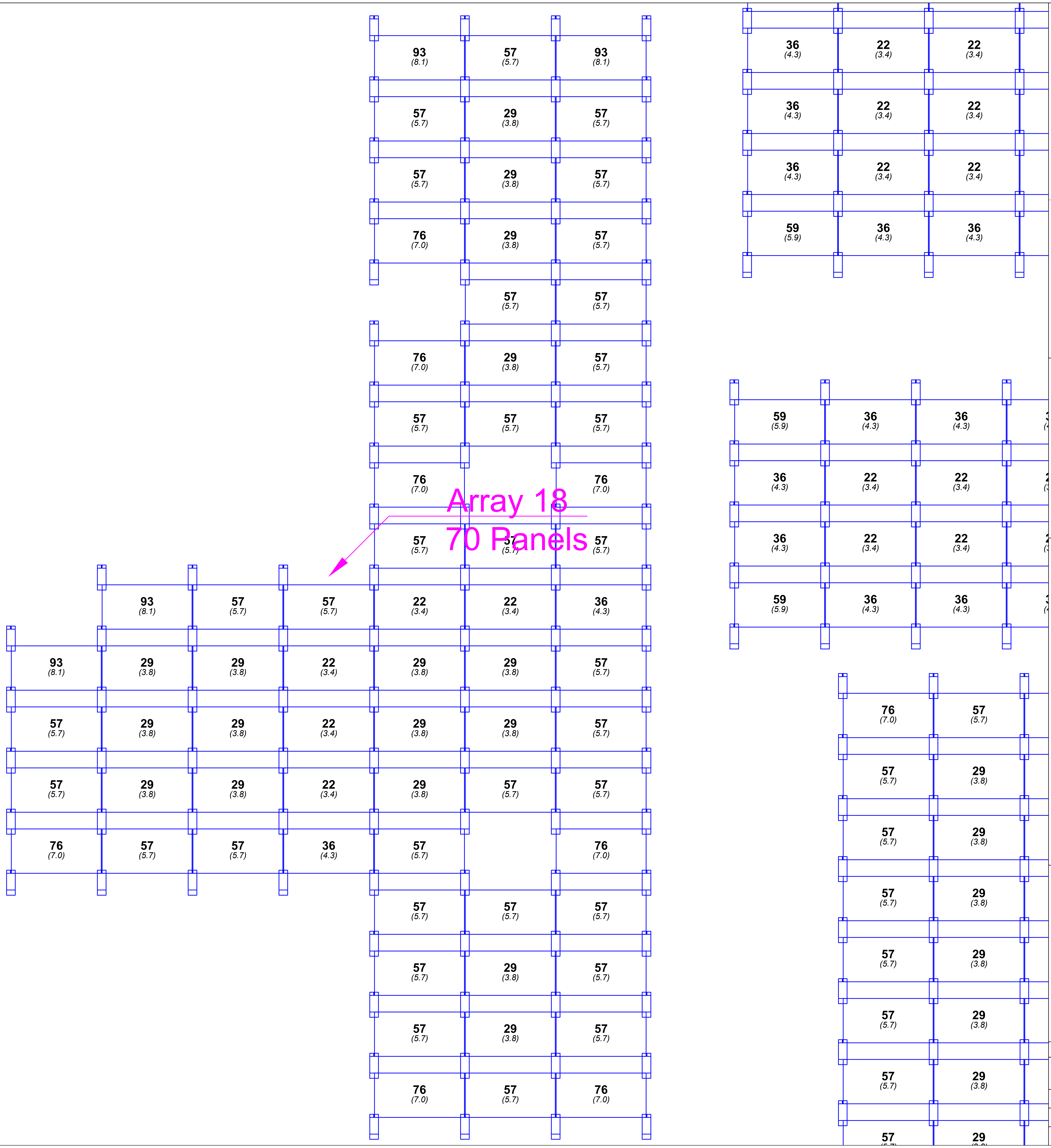
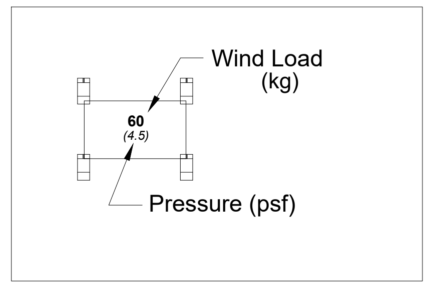
PROJECT NO.: -	DRAWING NO. M-3.17
DATE: 2020/07/30	
SHEET: 20 OF 46	



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: LOAD ARRAY 18

PROJECT: City Project
49.8648,-97.1433
Winnipeg, MB

CLIENT: Core Renewable Energy

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Y.T.	-	3

PROJECT NO.: -

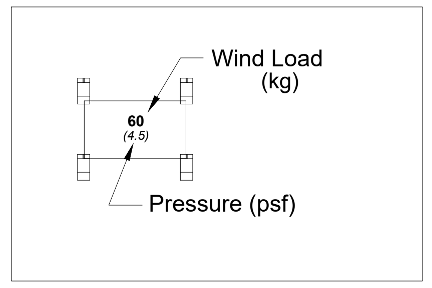
DATE: 2020/07/30

SHEET: 21 OF 46

DRAWING NO. M-3.18

NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: LOAD ARRAY 19

PROJECT: City Project 49.8648,-97.1433 Winnipeg, MB

CLIENT: Core Renewable Energy

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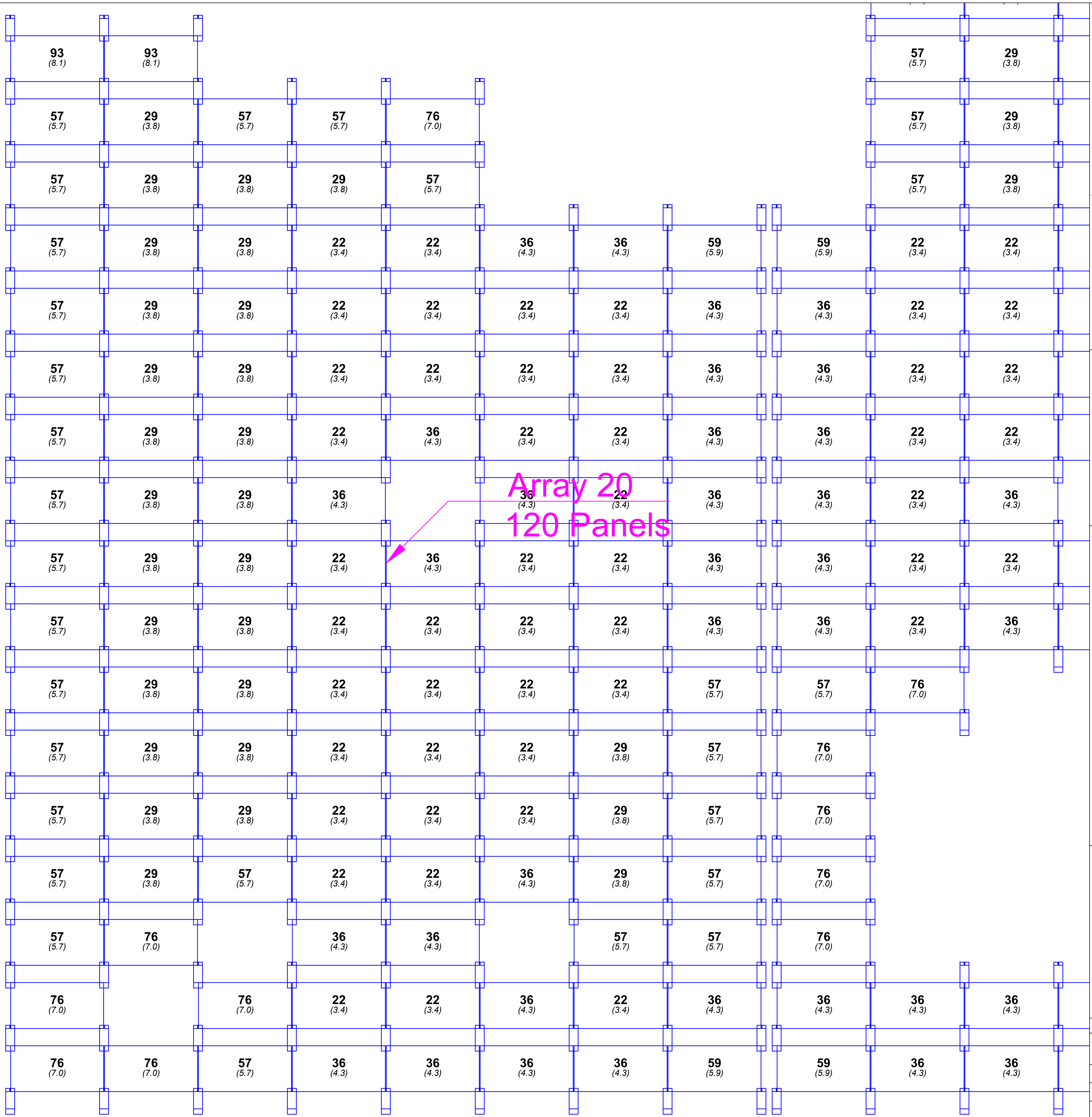
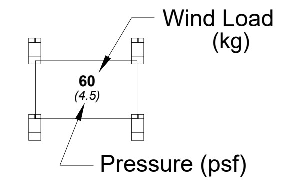
PROJECT NO.: -
DATE: 2020/07/30
SHEET: 22 OF 46
DRAWING NO. M-3.19



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: LOAD ARRAY 20

PROJECT: City Project
49.8648,-97.1433
Winnipeg, MB

CLIENT: Core Renewable Energy

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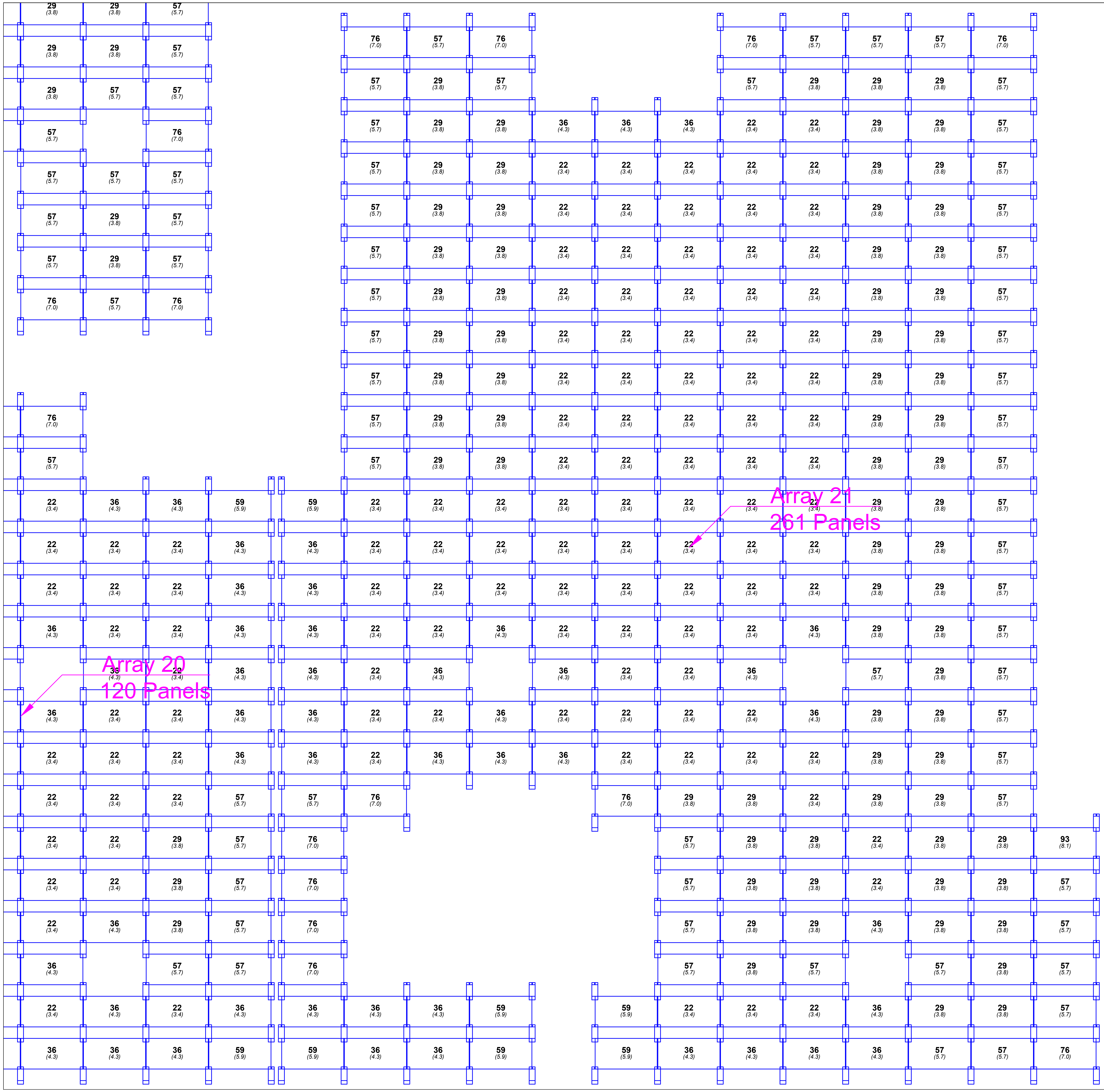
Y.T.	-	3

PROJECT NO.: -
DATE: 2020/07/30
SHEET: 23 OF 46
DRAWING NO. M-3.20



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND

Wind Load (kg)
60
(4.5)
Pressure (psf)

ENGINEER'S SEAL

DRAWING TITLE: LOAD ARRAY 21

PROJECT: City Project
49.8648,-97.1433
Winnipeg, MB

CLIENT: Core Renewable Energy

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PROJECT NO.: -
DATE: 2020/07/30
SHEET: 24 OF 46
DRAWING NO. M-3.21

City Project - 1108.8 kW (dc)

49.8648,-97.1433, Winnipeg, MB

	Total Ballast (kg)	Stone Quantities 16x8x4in Large (14.5 kg)	Ballast Trays
Array 01	7627.00	526	58
Array 02	7221.00	498	30
Array 03	3886.00	268	32
Array 04	6423.50	443	57
Array 05	6061.00	418	17
Array 06	2276.50	157	31
Array 07	4596.50	317	13
Array 08	3509.00	242	50
Array 09	4031.00	278	52
Array 10	3132.00	216	21
Array 11	4466.00	308	43
Array 12	2929.00	202	33
Array 13	2958.00	204	7
Array 14	2871.00	198	16
Array 15	4915.50	339	38
Array 16	3958.50	273	7
Array 17	7859.00	542	46
Array 18	3552.50	245	43
Array 19	1856.00	128	12
Array 20	4741.50	327	34
Array 21	9715.00	670	58
Totals	98585.50	6799	698
Recommended Ballast	95058.36		
Additional Ballast Weight	3527.14		

NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

ENGINEER'S SEAL

DRAWING TITLE: PAVER LAYOUT

PROJECT: City Project
49.8648,-97.1433
Winnipeg, MB

CLIENT: Core Renewable Energy

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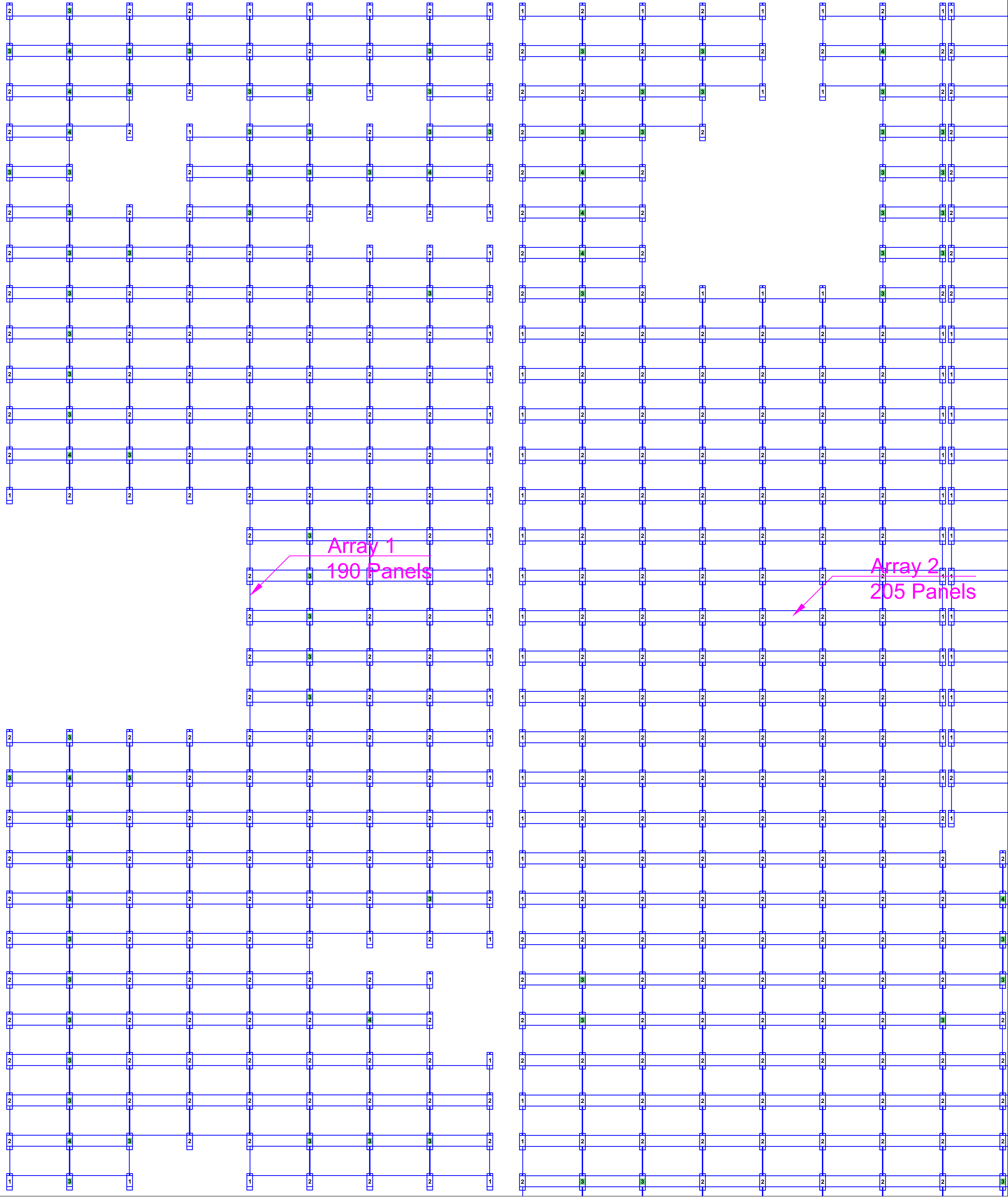
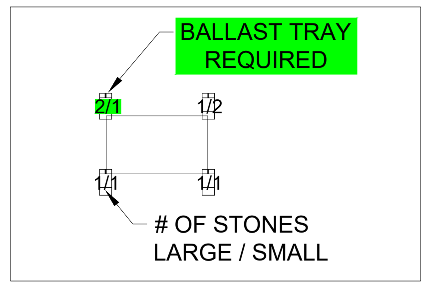
PROJECT NO.: -
DATE: 2020/07/30
SHEET: 25 OF 46
DRAWING NO. M-4.0



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: PAVER ARRAY 1

PROJECT: City Project
49.8648,-97.1433
Winnipeg, MB

CLIENT: Core Renewable Energy

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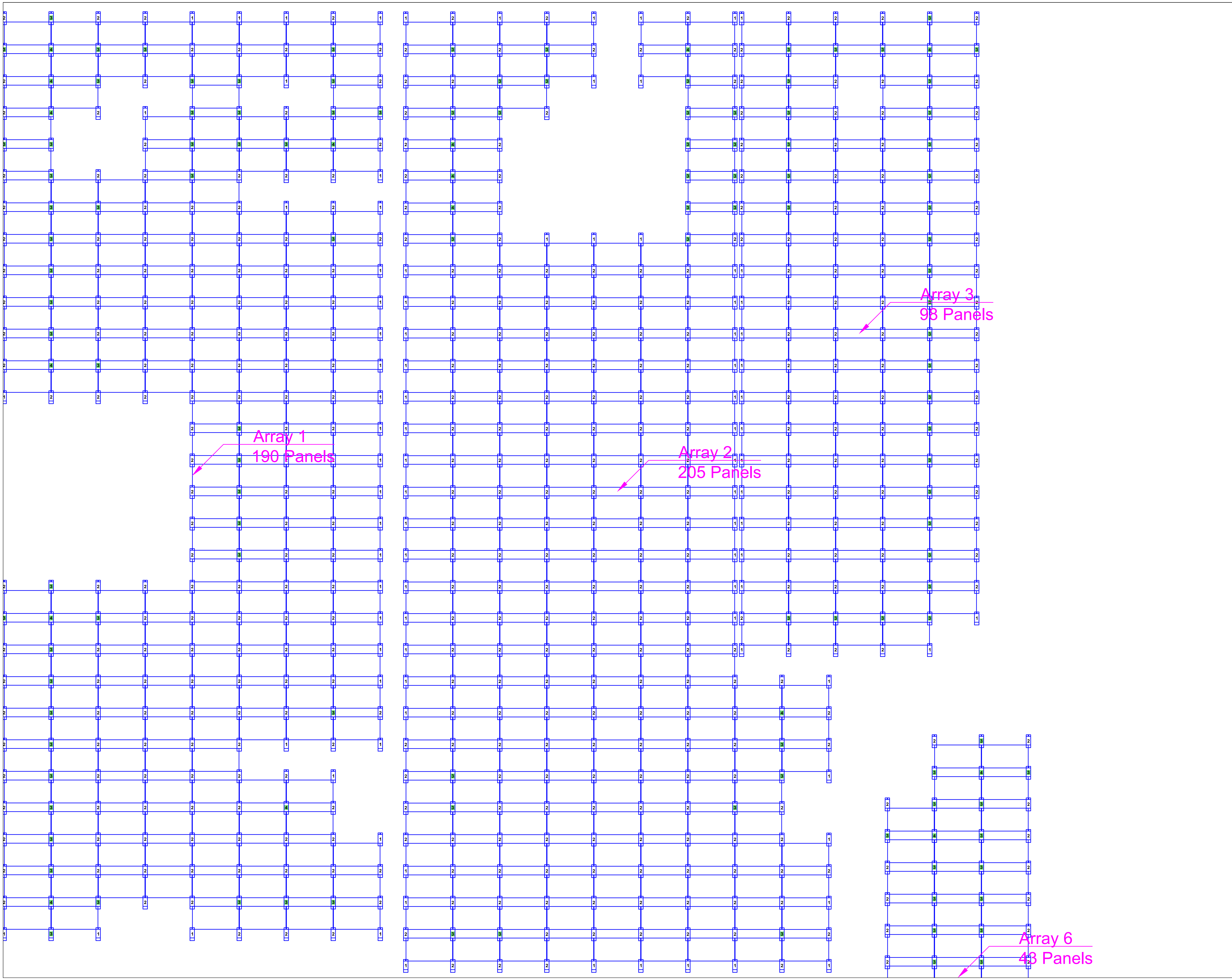
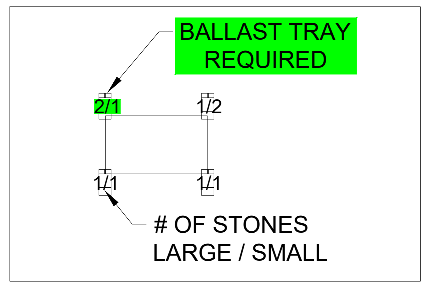
Y.T.	-	3

PROJECT NO.: -
DATE: 2020/07/30
SHEET: 26 OF 46
DRAWING NO. M-4.1



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: PAVER ARRAY 2

PROJECT: City Project
49.8648,-97.1433
Winnipeg, MB

CLIENT: Core Renewable Energy

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DRAWN BY:	CHECKED BY:	VERSION:
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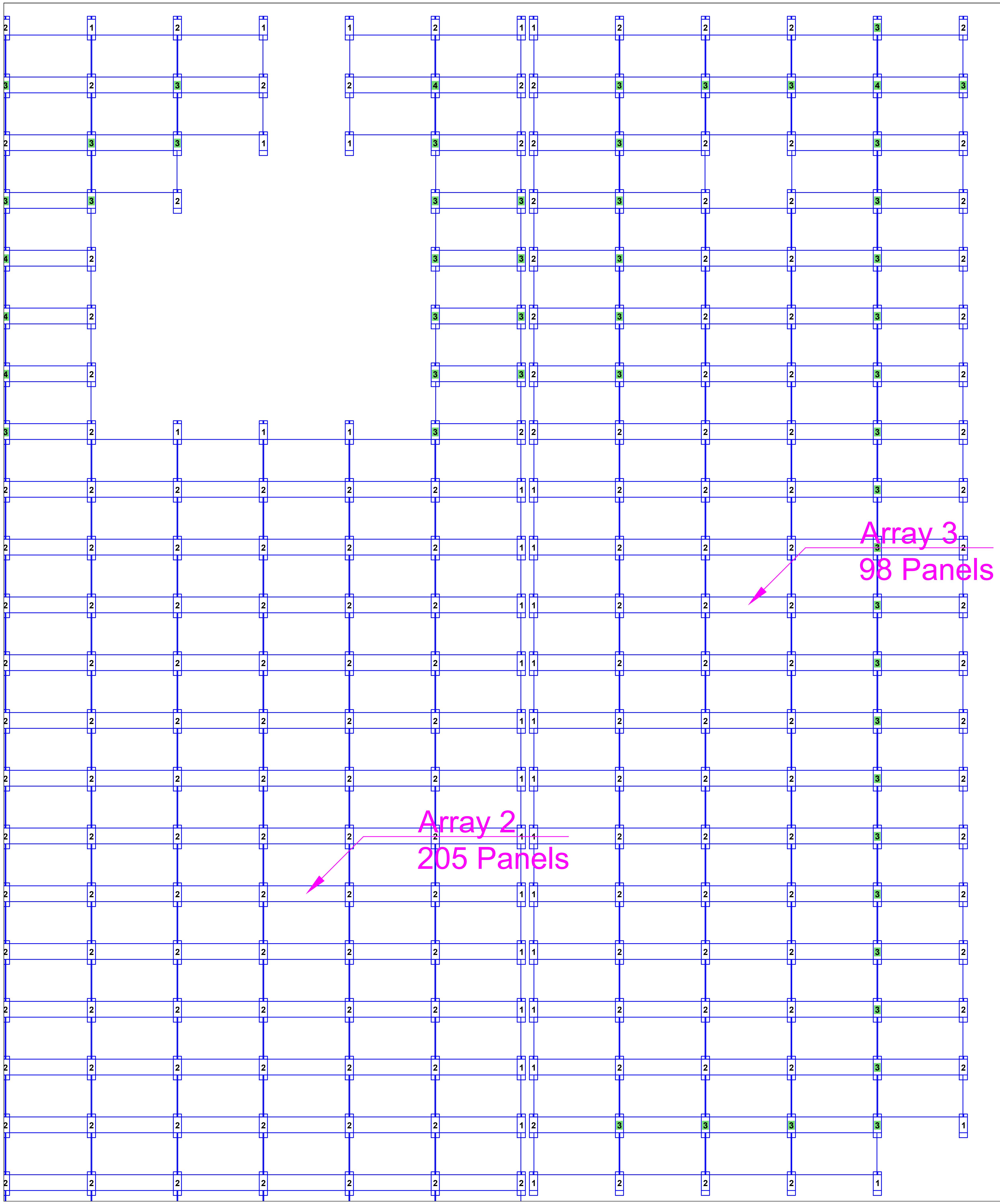
PROJECT NO.: -

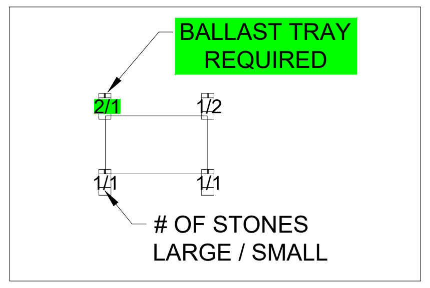
DATE: 2020/07/30

DRAWING NO. M-4.2



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: PAVER ARRAY 3

PROJECT: City Project
49.8648,-97.1433
Winnipeg, MB

CLIENT: Core Renewable Energy

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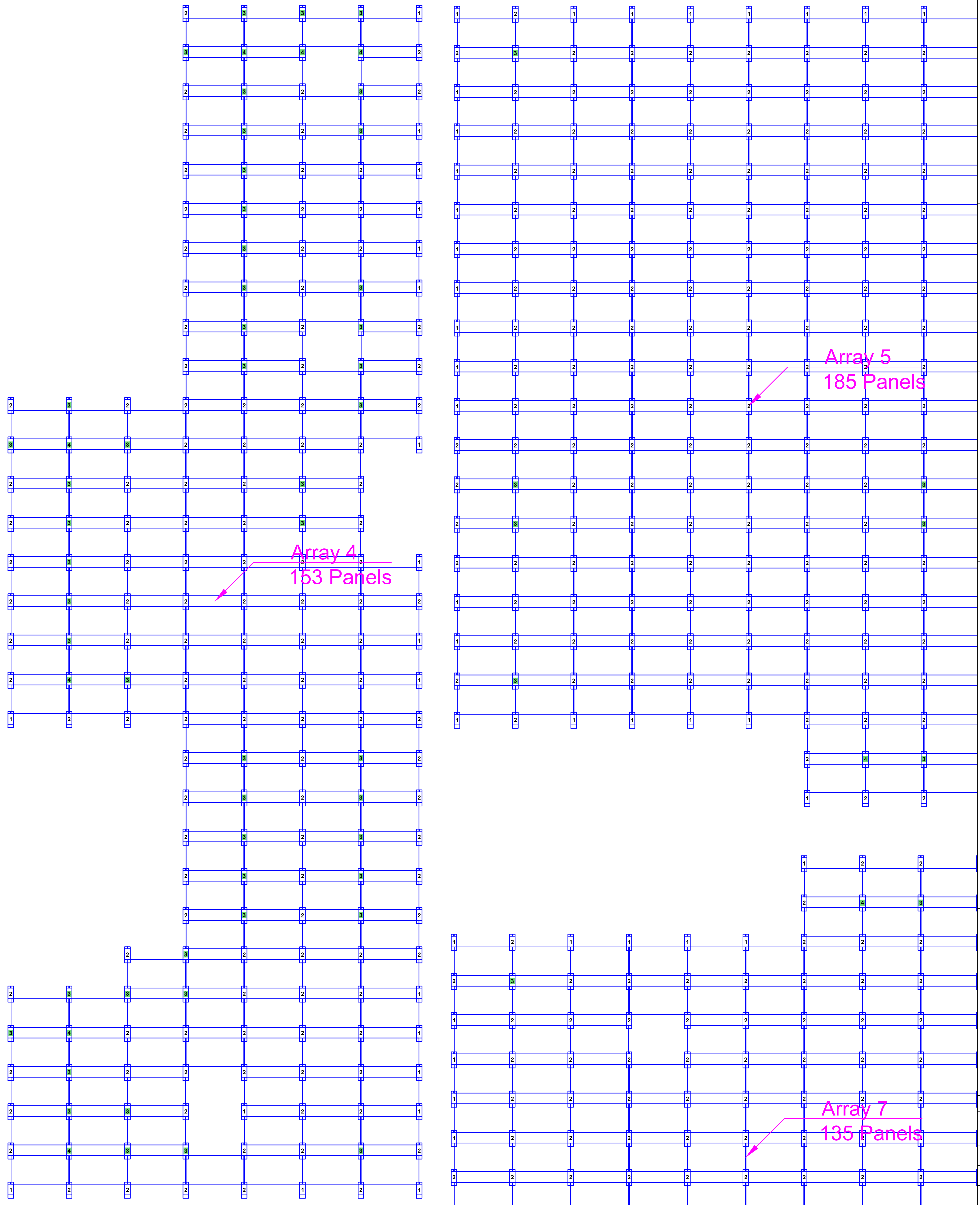
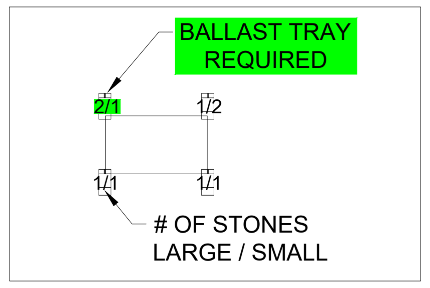
PROJECT NO.: -
DATE: 2020/07/30
SHEET: 28 OF 46
DRAWING NO. M-4.3



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: PAVER ARRAY 4

PROJECT: City Project
49.8648,-97.1433
Winnipeg, MB

CLIENT: Core Renewable Energy

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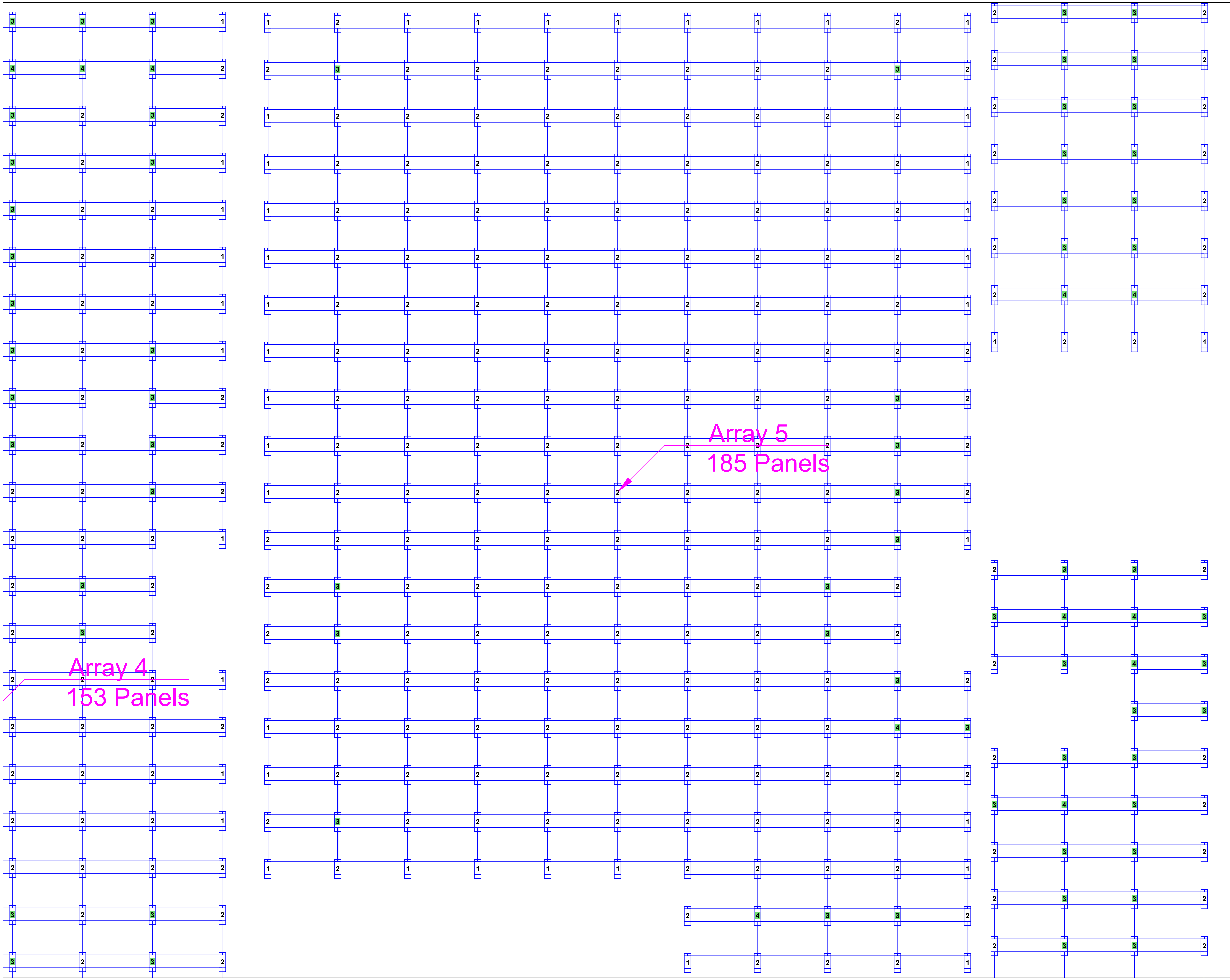
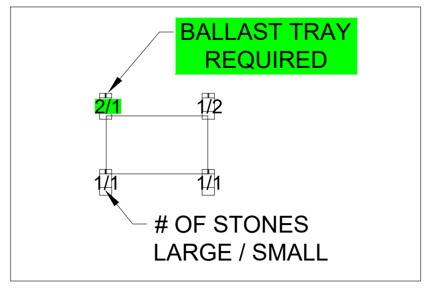
DRAWN BY:	CHECKED BY:	VERSION:
Y.T.	-	3

PROJECT NO.: -
DATE: 2020/07/30
SHEET: 29 OF 46
DRAWING NO. M-4.4



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: PAVER ARRAY 5

PROJECT: City Project
49.8648,-97.1433
Winnipeg, MB

CLIENT: Core Renewable Energy

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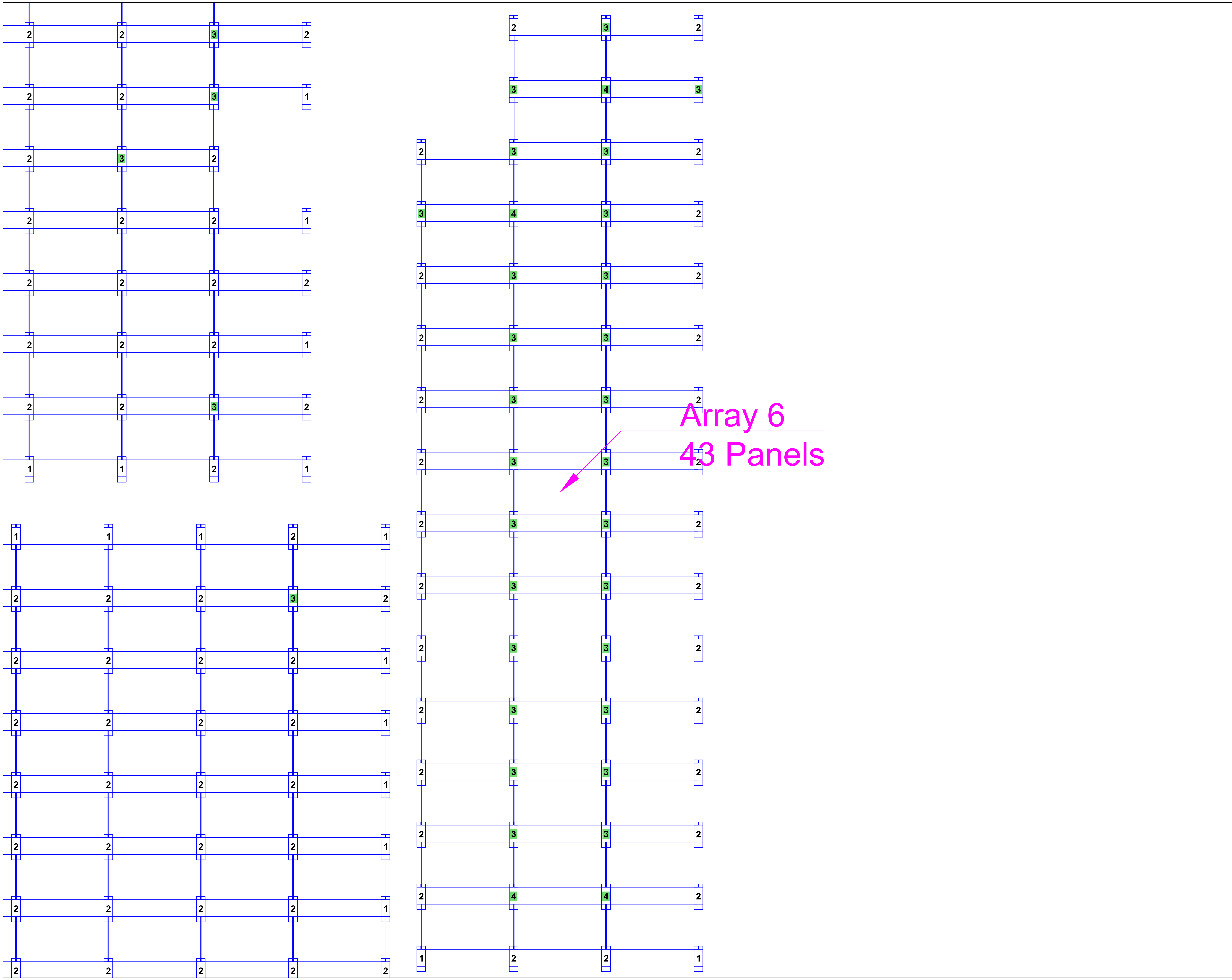
Y.T.	-	3

PROJECT NO.: -
DATE: 2020/07/30
SHEET: 30 OF 46
DRAWING NO. M-4.5



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND

BALLAST TRAY REQUIRED
2/1 1/2 1/1 1/1
OF STONES LARGE / SMALL

ENGINEER'S SEAL

DRAWING TITLE: PAVER ARRAY 6

PROJECT: City Project
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Winnipeg, MB

CLIENT: Core Renewable Energy

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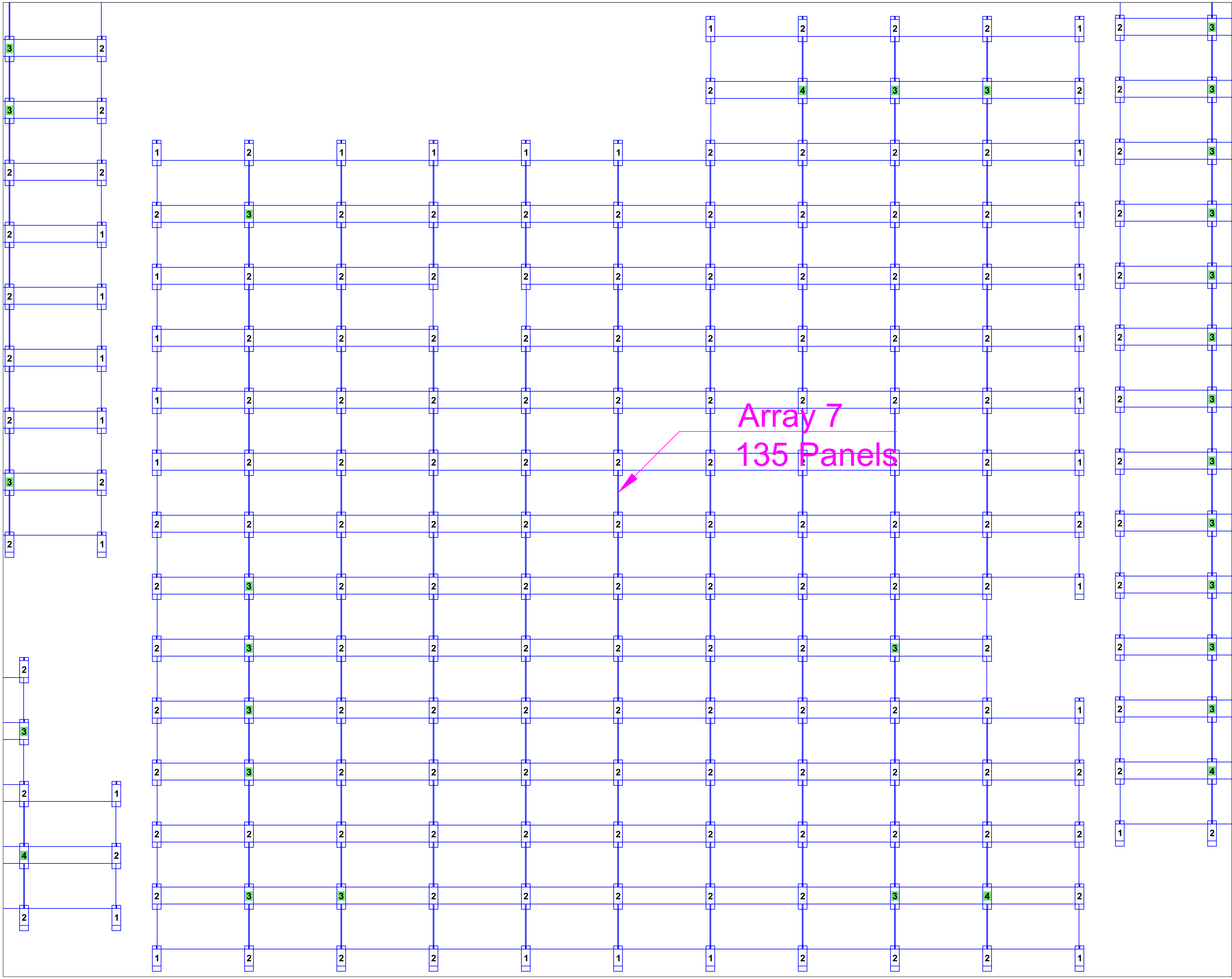
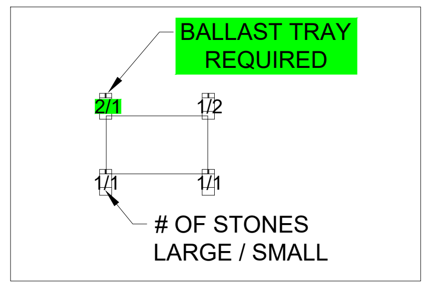
Y.T.	-	3

PROJECT NO.: -
DATE: 2020/07/30
SHEET: 31 OF 46
DRAWING NO. M-4.6



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: PAVER ARRAY 7

PROJECT: City Project
49.8648,-97.1433
Winnipeg, MB

CLIENT: Core Renewable Energy

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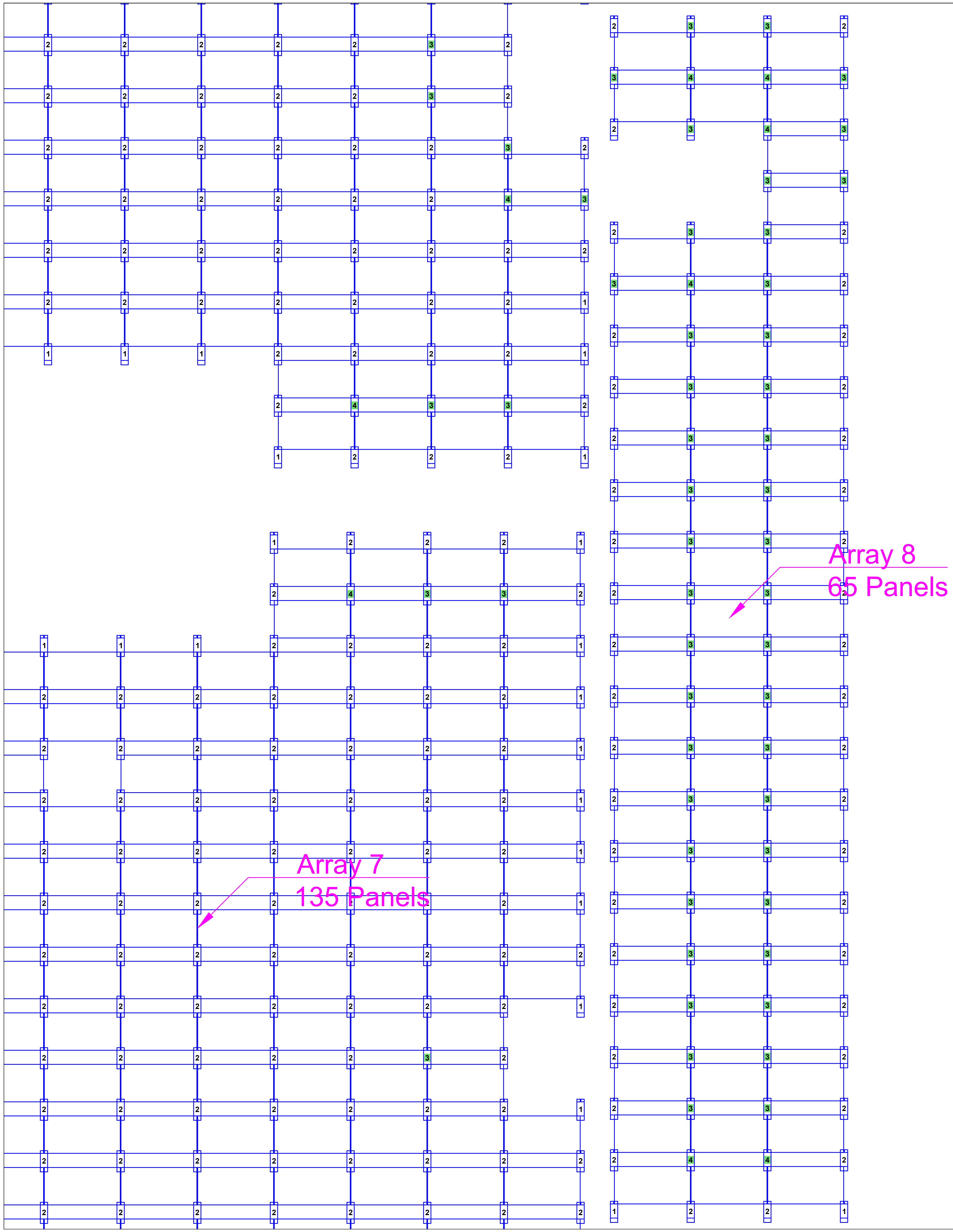
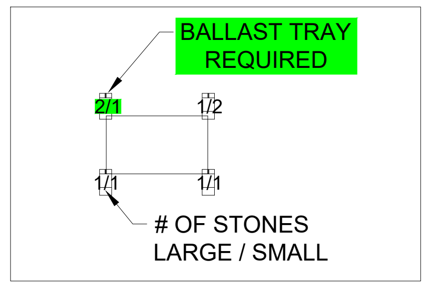
Y.T.	-	3

PROJECT NO.: -
DATE: 2020/07/30
SHEET: 32 OF 46
DRAWING NO. M-4.7



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: PAVER ARRAY 8

PROJECT: City Project 49.8648,-97.1433 Winnipeg, MB

CLIENT: Core Renewable Energy

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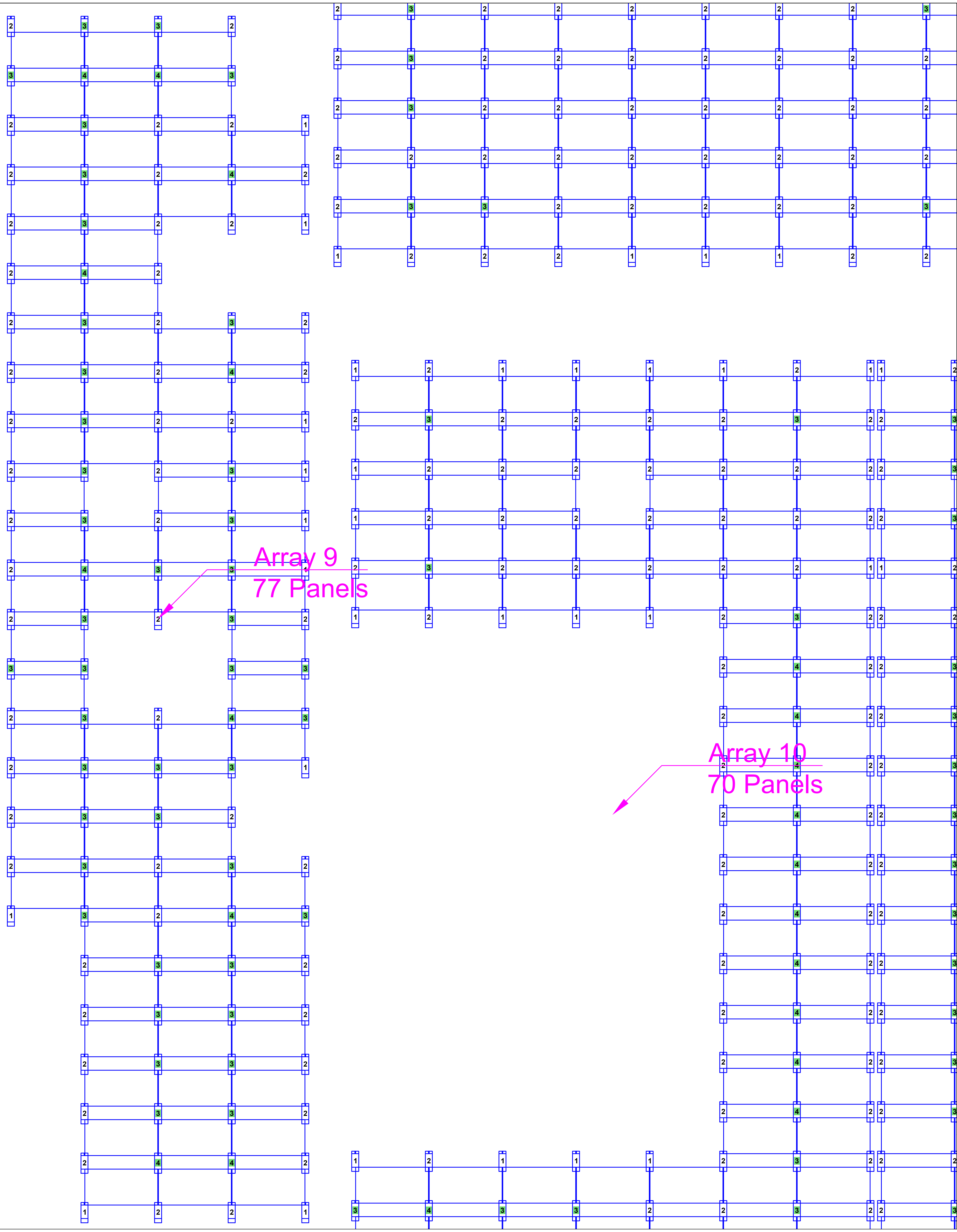
PROJECT NO.: -

DATE: 2020/07/30

DRAWING NO. M-4.8



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND

BALLAST TRAY REQUIRED
2/1 1/2
1/1 1/1
OF STONES LARGE / SMALL

ENGINEER'S SEAL

DRAWING TITLE: PAVER ARRAY 9

PROJECT: City Project
49.8648,-97.1433
Winnipeg, MB

CLIENT: Core Renewable Energy

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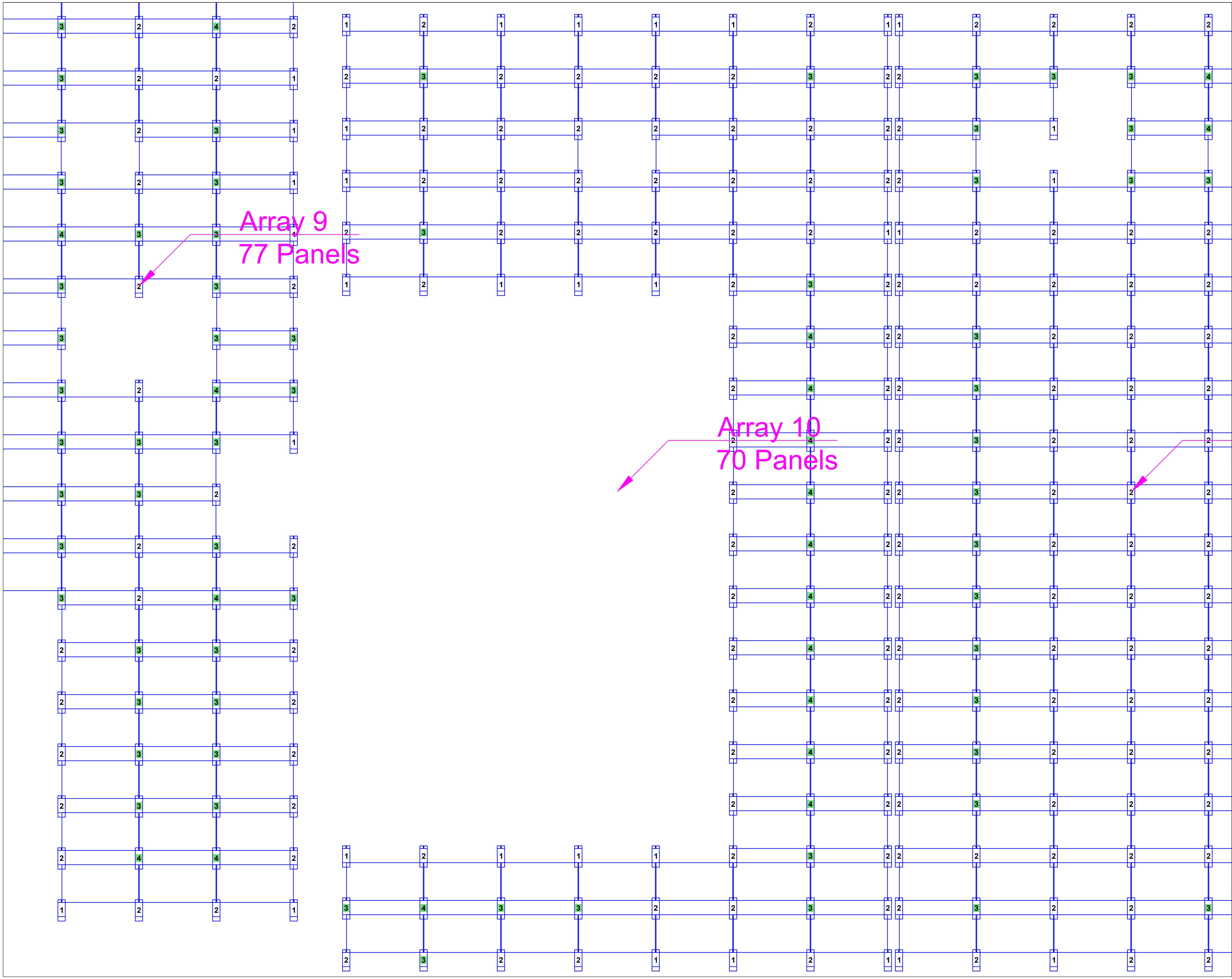
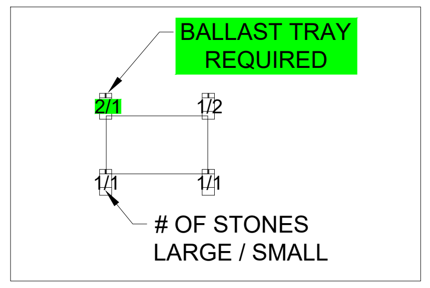
PROJECT NO.: -
DATE: 2020/07/30
SHEET: 34 OF 46
DRAWING NO. M-4.9



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: PAVER ARRAY 10

PROJECT: City Project
49.8648,-97.1433
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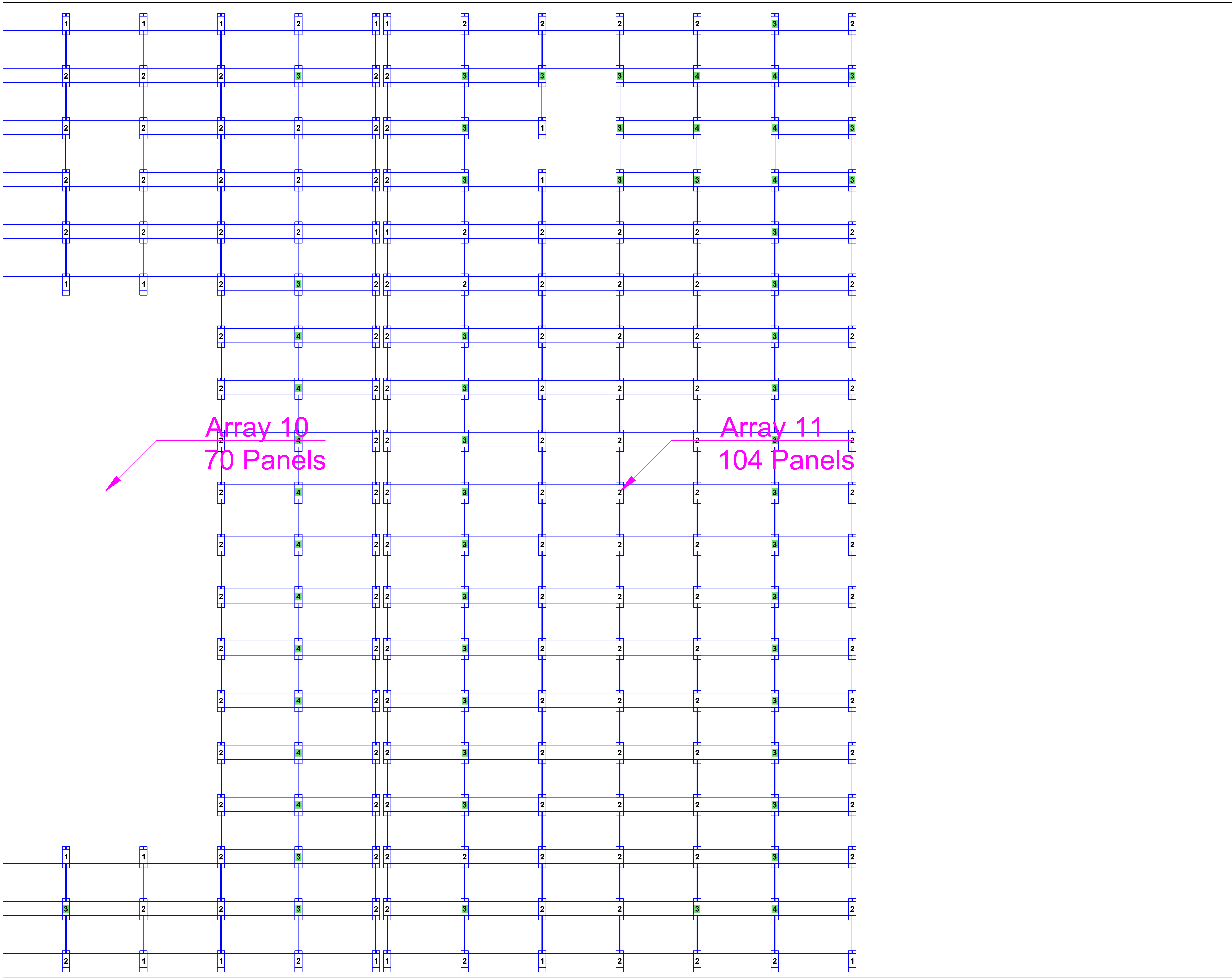
PROJECT NO.: -

DATE: 2020/07/30

SHEET: 35 OF 46

DRAWING NO. M-4.10



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND

BALLAST TRAY REQUIRED
2/1 1/2
1/1 1/1
OF STONES LARGE / SMALL

ENGINEER'S SEAL

DRAWING TITLE: PAVER ARRAY 11

PROJECT: City Project
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CLIENT: Core Renewable Energy

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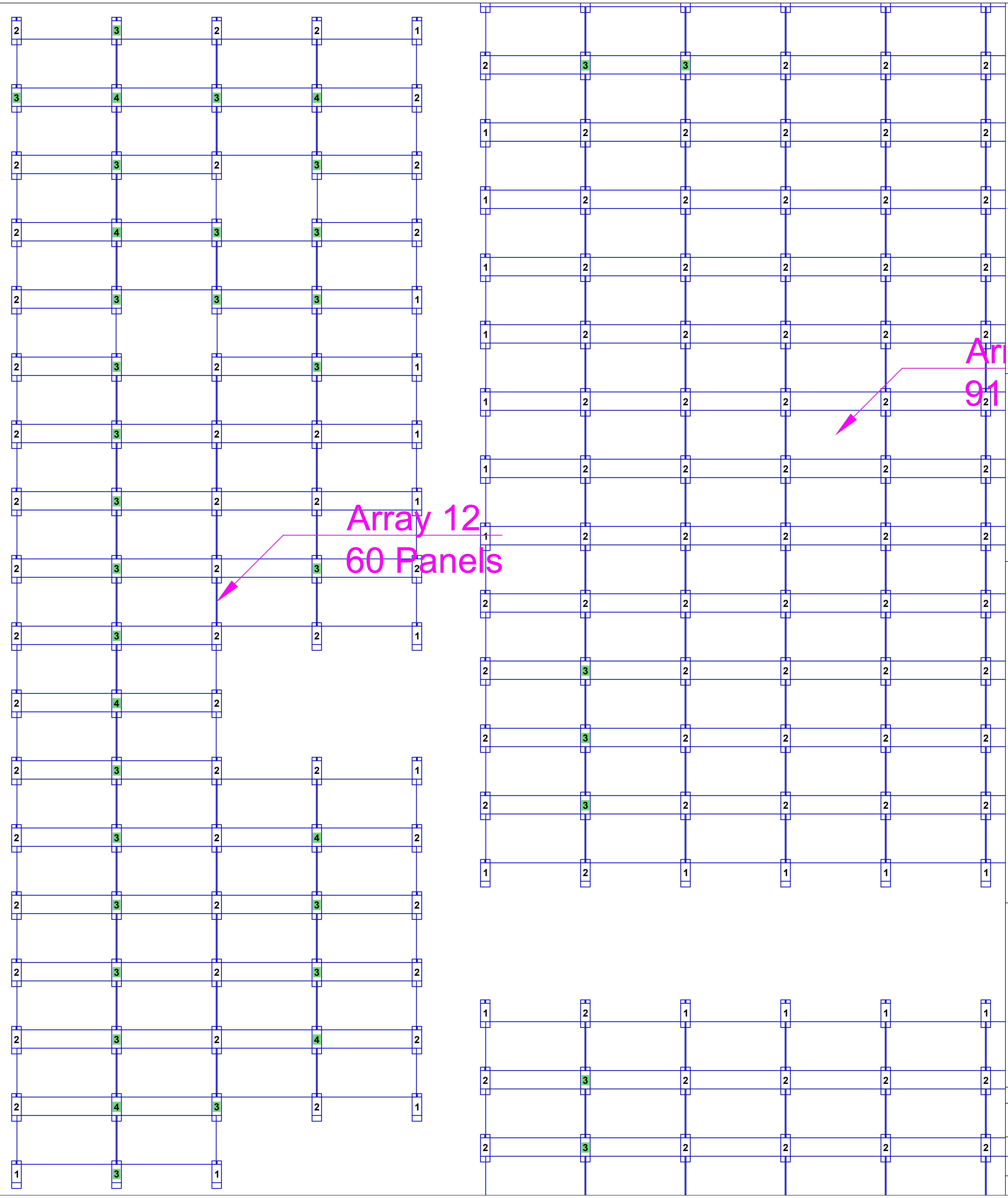
PROJECT NO.: -

DATE: 2020/07/30

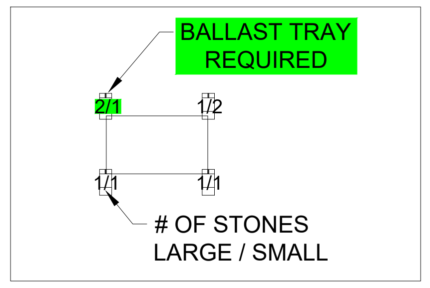
SHEET: 36 OF 46

DRAWING NO. M-4.11



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: PAVER ARRAY 12

PROJECT: City Project
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Winnipeg, MB

CLIENT: Core Renewable Energy

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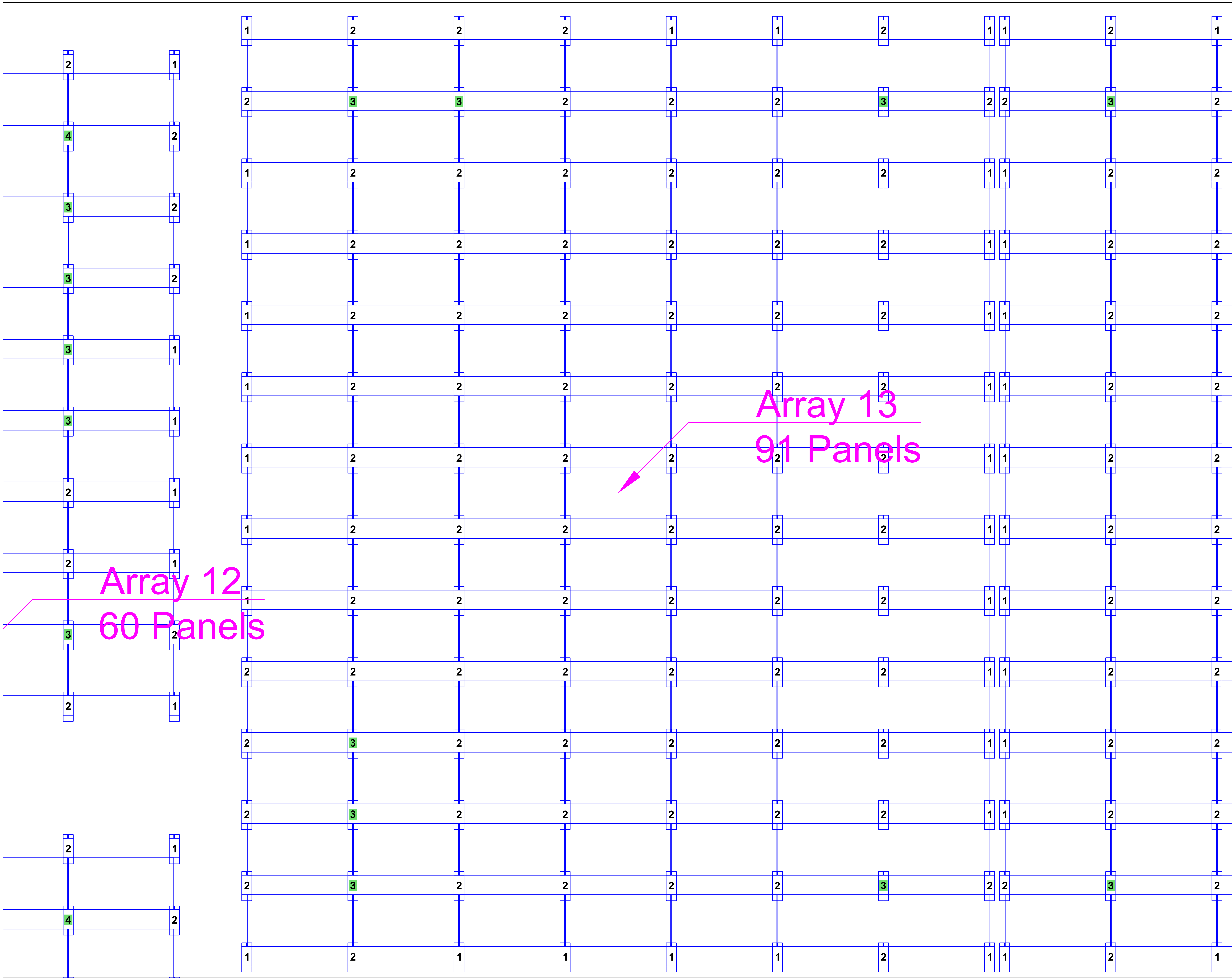
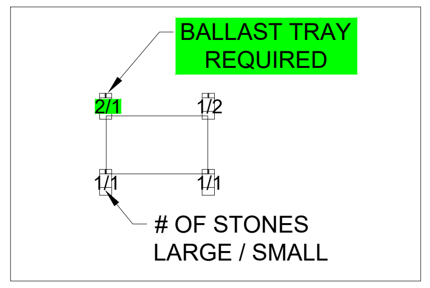
PROJECT NO.: -	DRAWING NO. M-4.12
DATE: 2020/07/30	
SHEET: 37 OF 46	



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: PAVER ARRAY 13

PROJECT: City Project
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Winnipeg, MB

CLIENT: Core Renewable Energy

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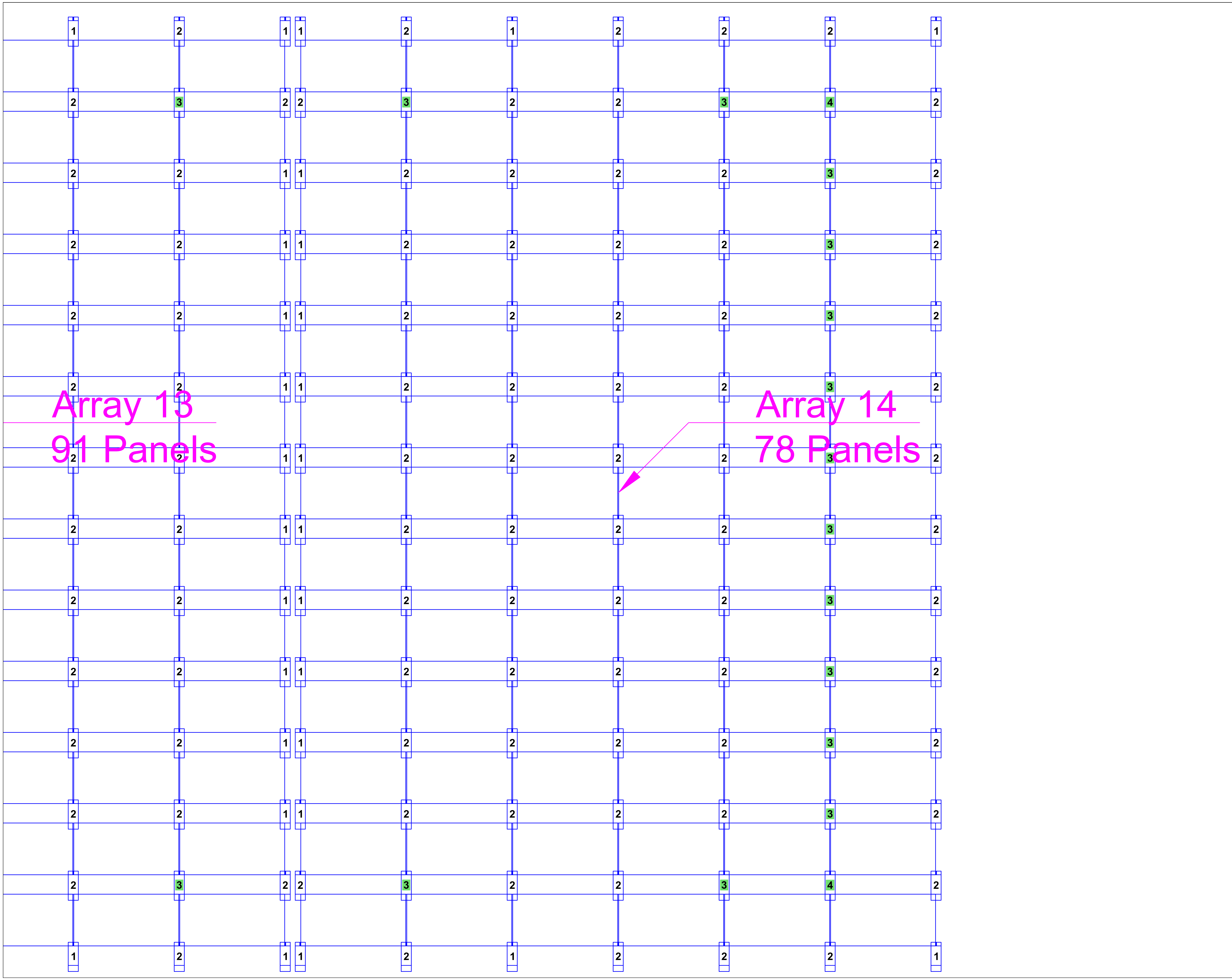
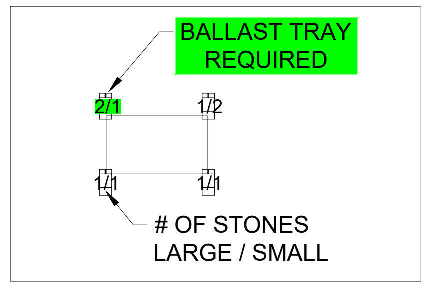
PROJECT NO.: -
DATE: 2020/07/30
SHEET: 38 OF 46
DRAWING NO. M-4.13



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: PAVER ARRAY 14

PROJECT: City Project
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CLIENT: Core Renewable Energy

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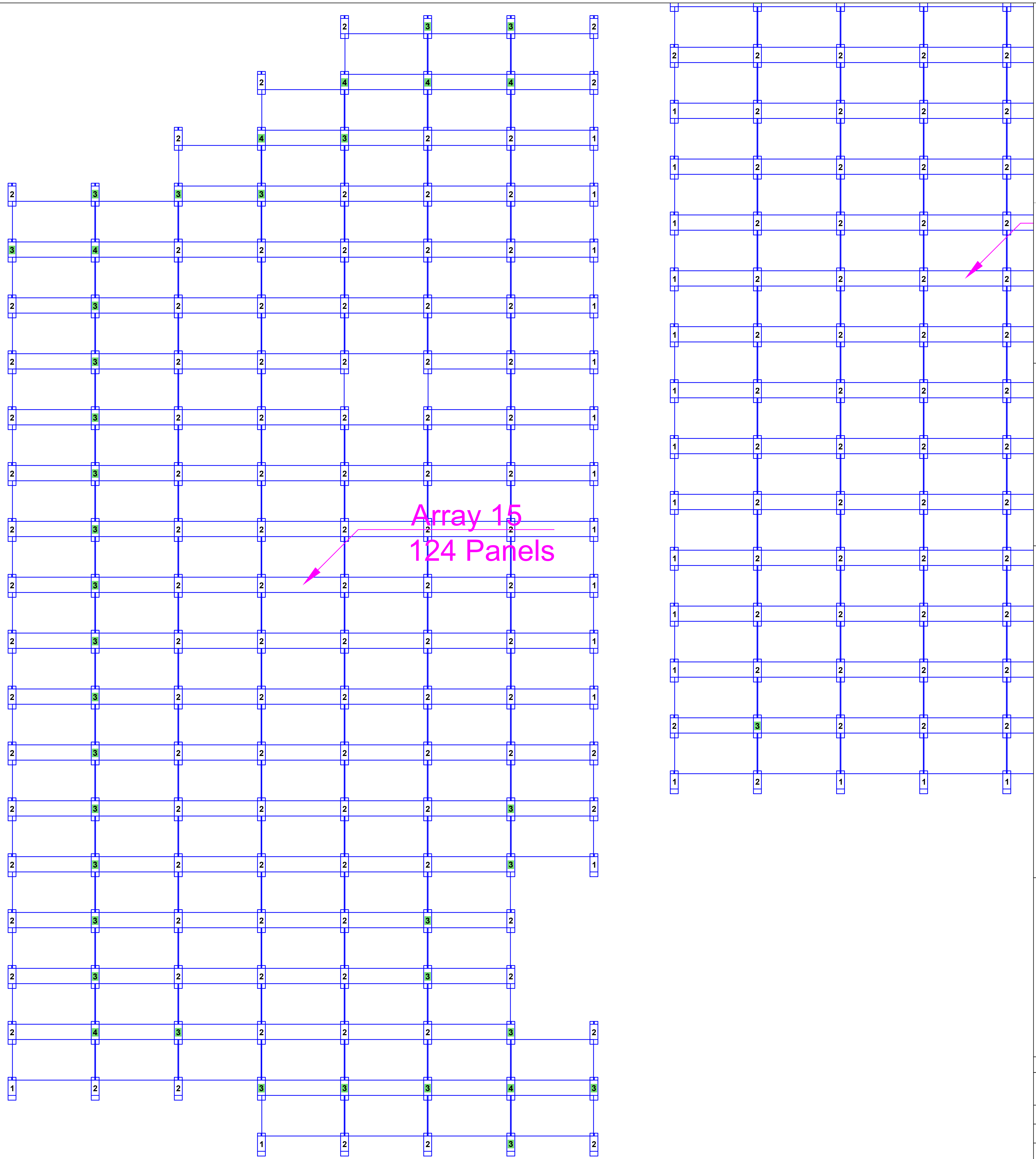
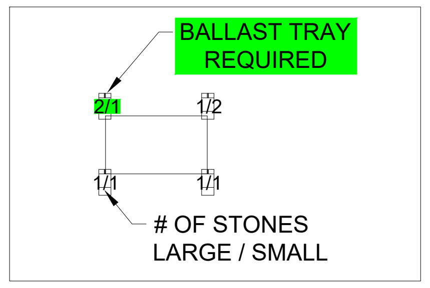
PROJECT NO.: -
DATE: 2020/07/30
DRAWING NO.: M-4.14



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: PAVER ARRAY 15

PROJECT: City Project
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CLIENT: Core Renewable Energy

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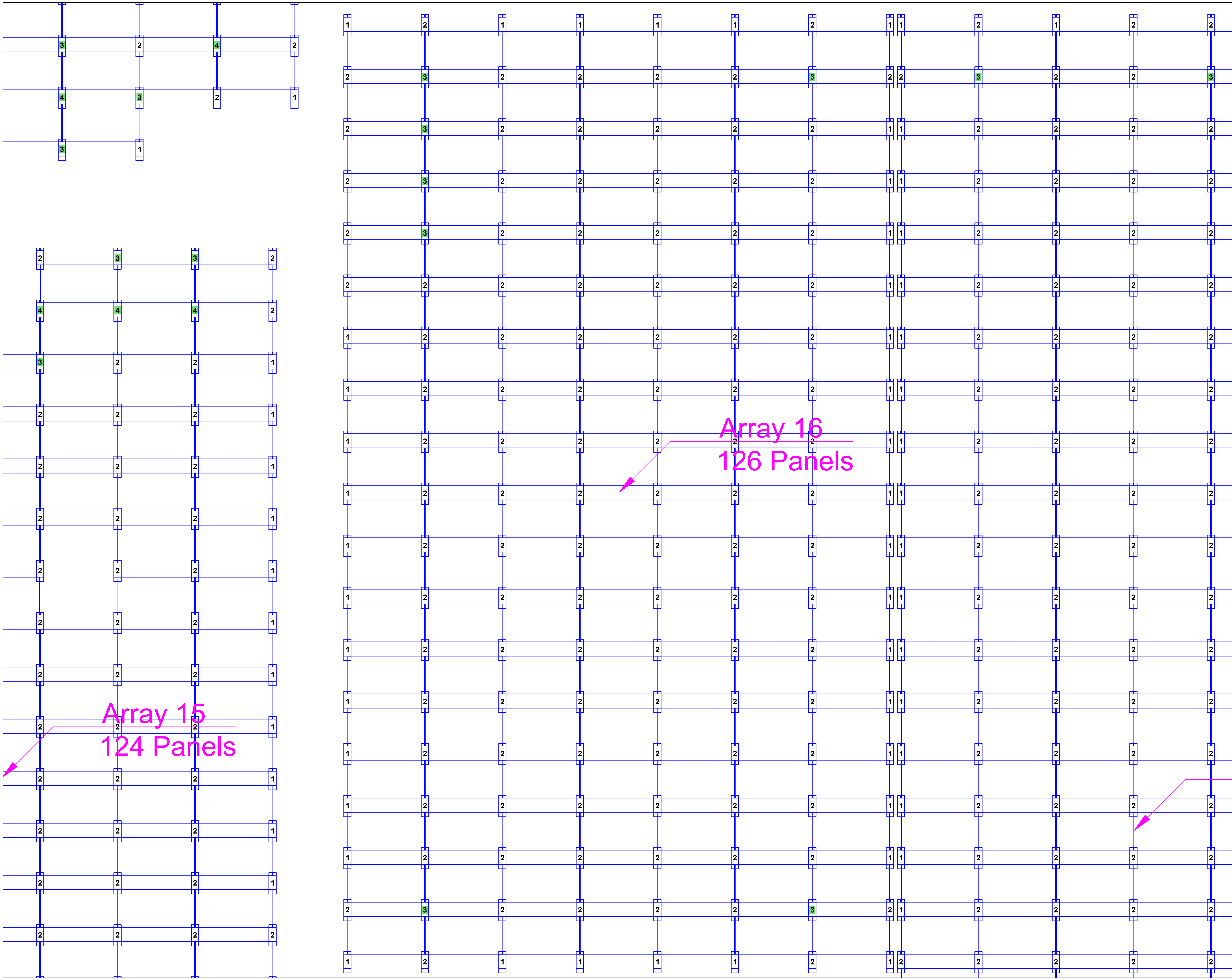
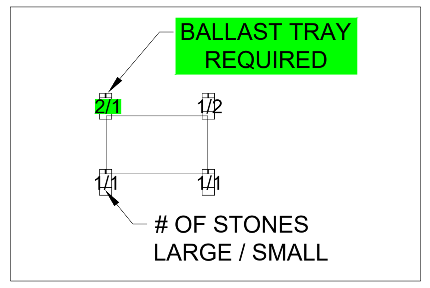
PROJECT NO.: -
DATE: 2020/07/30
SHEET: 40 OF 46
DRAWING NO. M-4.15



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: PAVER ARRAY 16

PROJECT: City Project
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Winnipeg, MB

CLIENT: Core Renewable Energy

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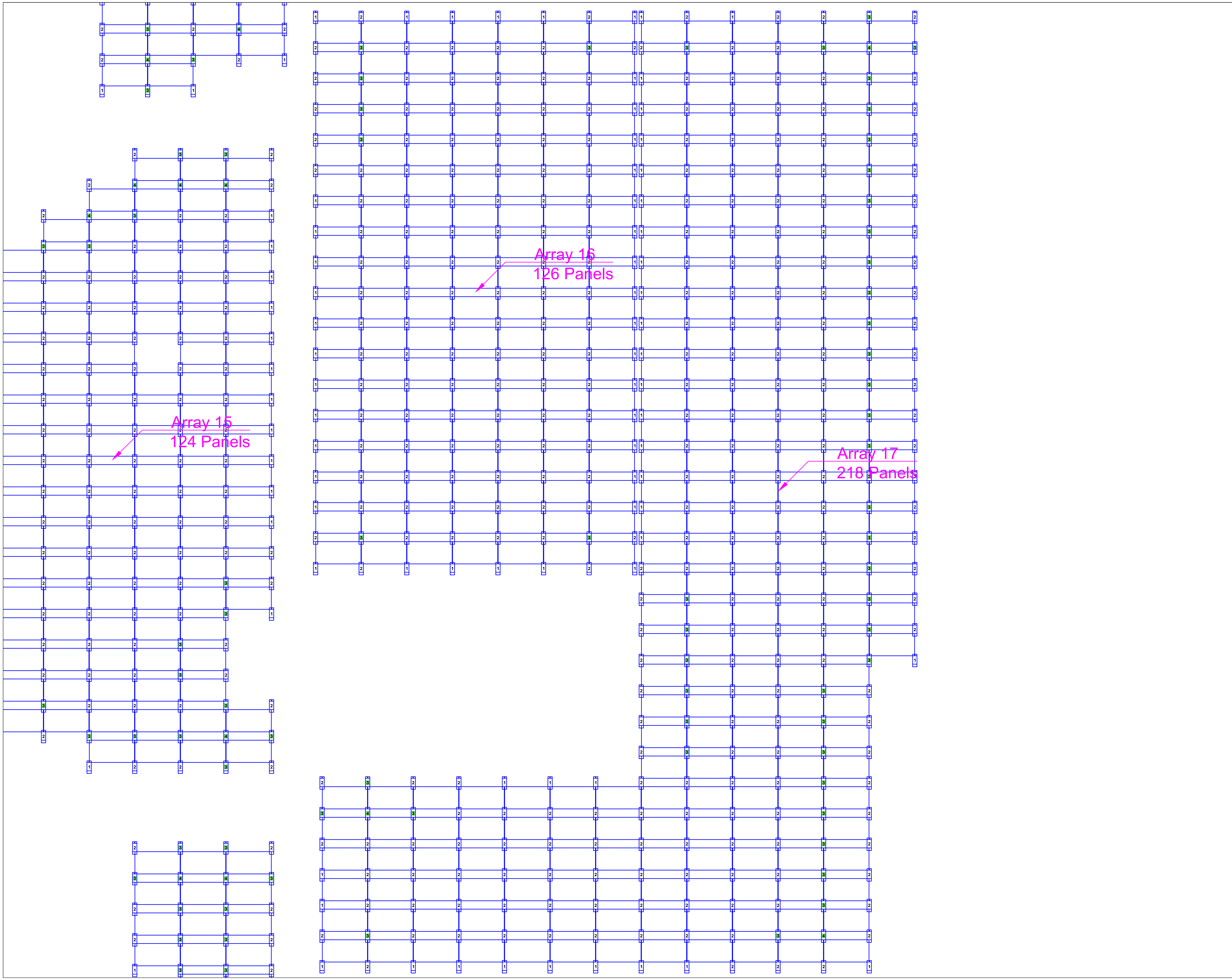
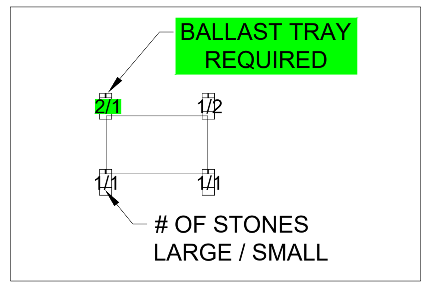
PROJECT NO.: -
DATE: 2020/07/30
SHEET: 41 OF 46
DRAWING NO. M-4.16



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: PAVER ARRAY 17

PROJECT: City Project
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Winnipeg, MB

CLIENT: Core Renewable Energy

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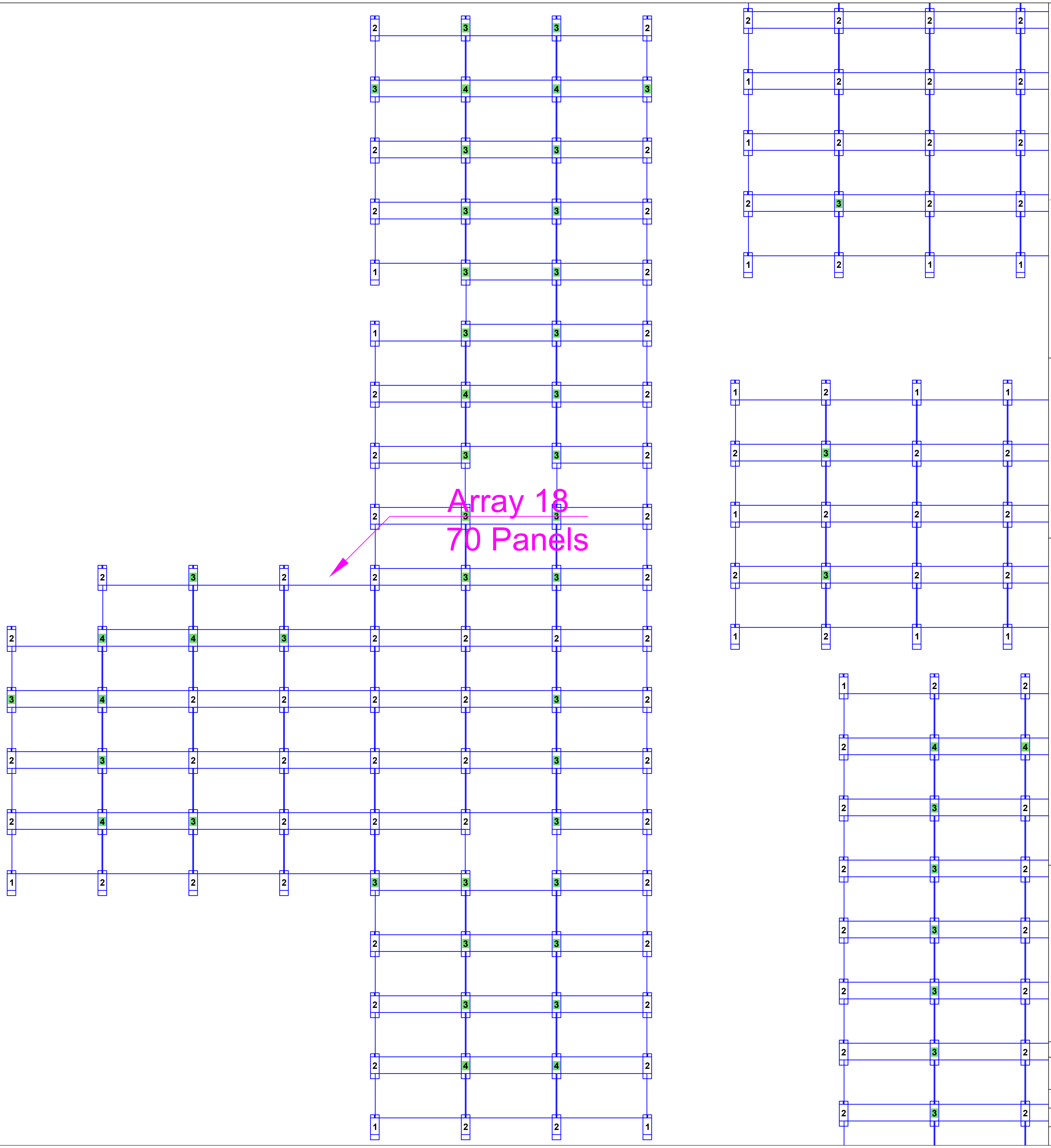
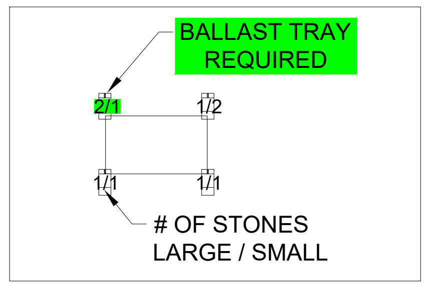
PROJECT NO.: -	DRAWING NO. M-4.17
DATE: 2020/07/30	
SHEET: 42 OF 46	



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: PAVER ARRAY 18

PROJECT: City Project
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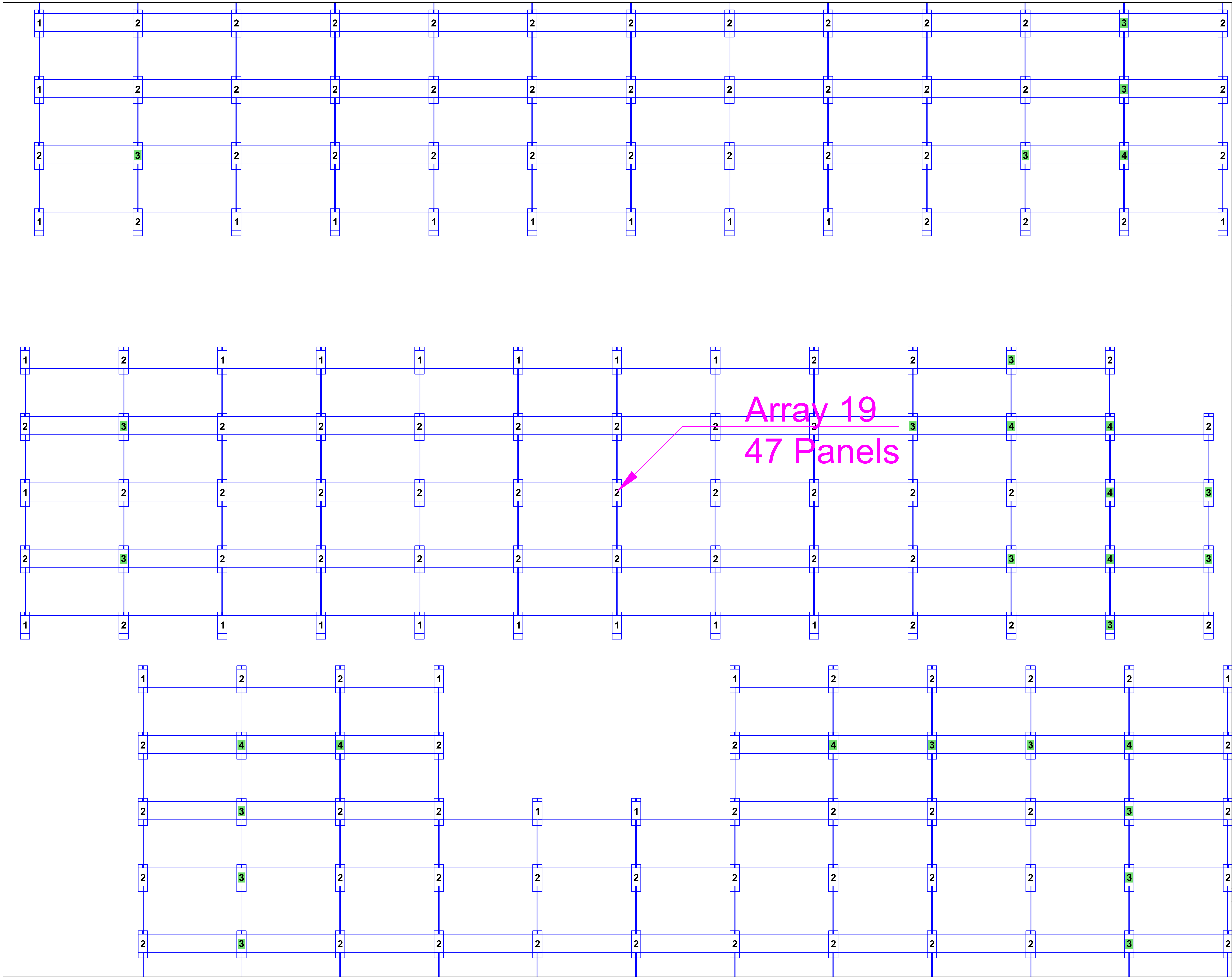
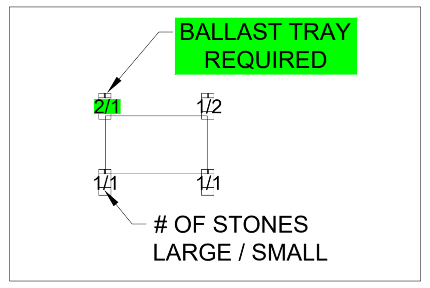
PROJECT NO.: -
DATE: 2020/07/30
SHEET: 43 OF 46
DRAWING NO. M-4.18



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: PAVER ARRAY 19

PROJECT: City Project
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Winnipeg, MB

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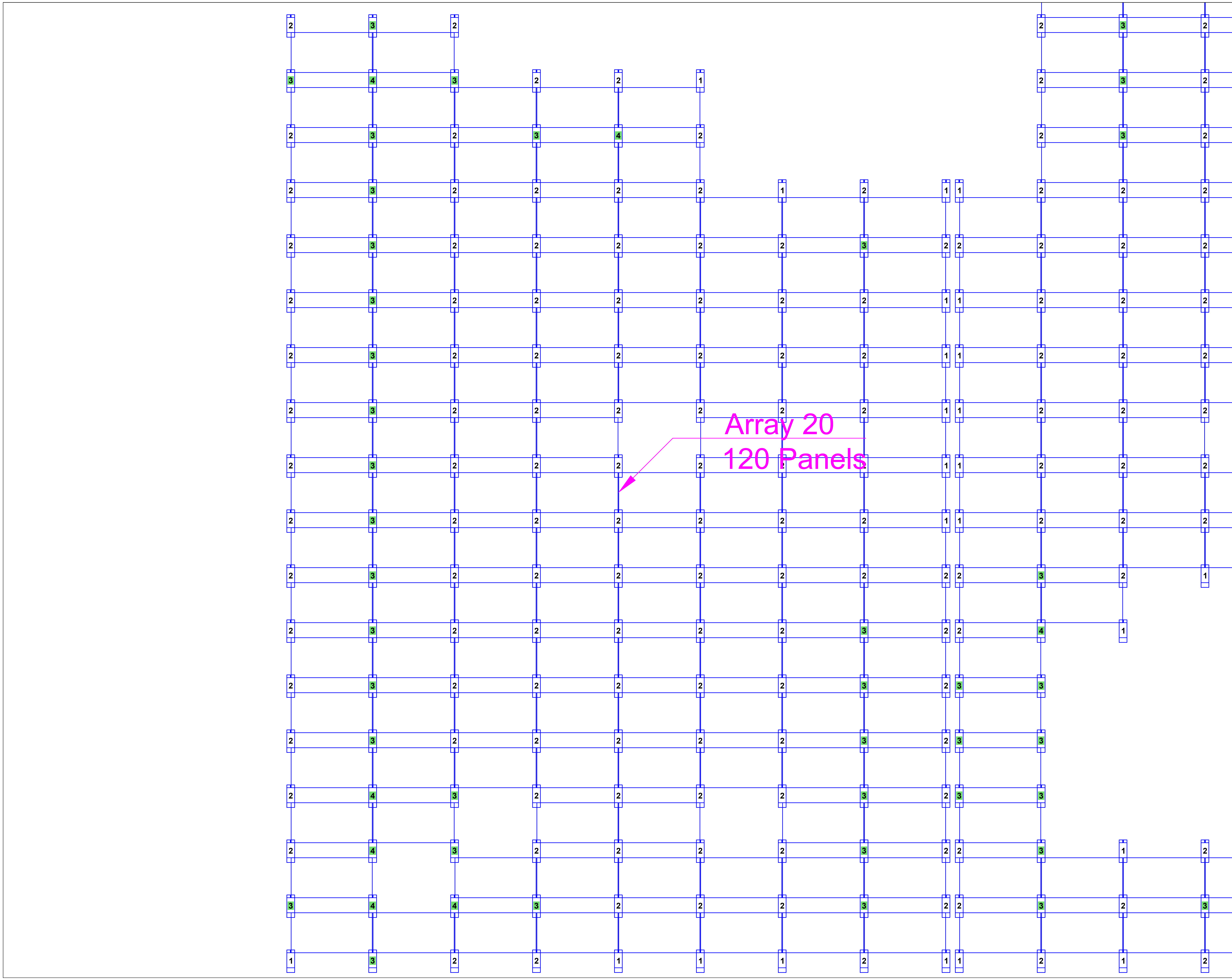
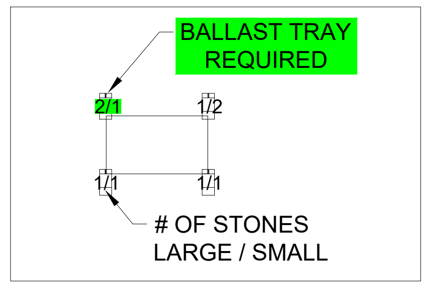
PROJECT NO.: -
DATE: 2020/07/30
SHEET: 44 OF 46
DRAWING NO. M-4.19



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: PAVER ARRAY 20

PROJECT: City Project
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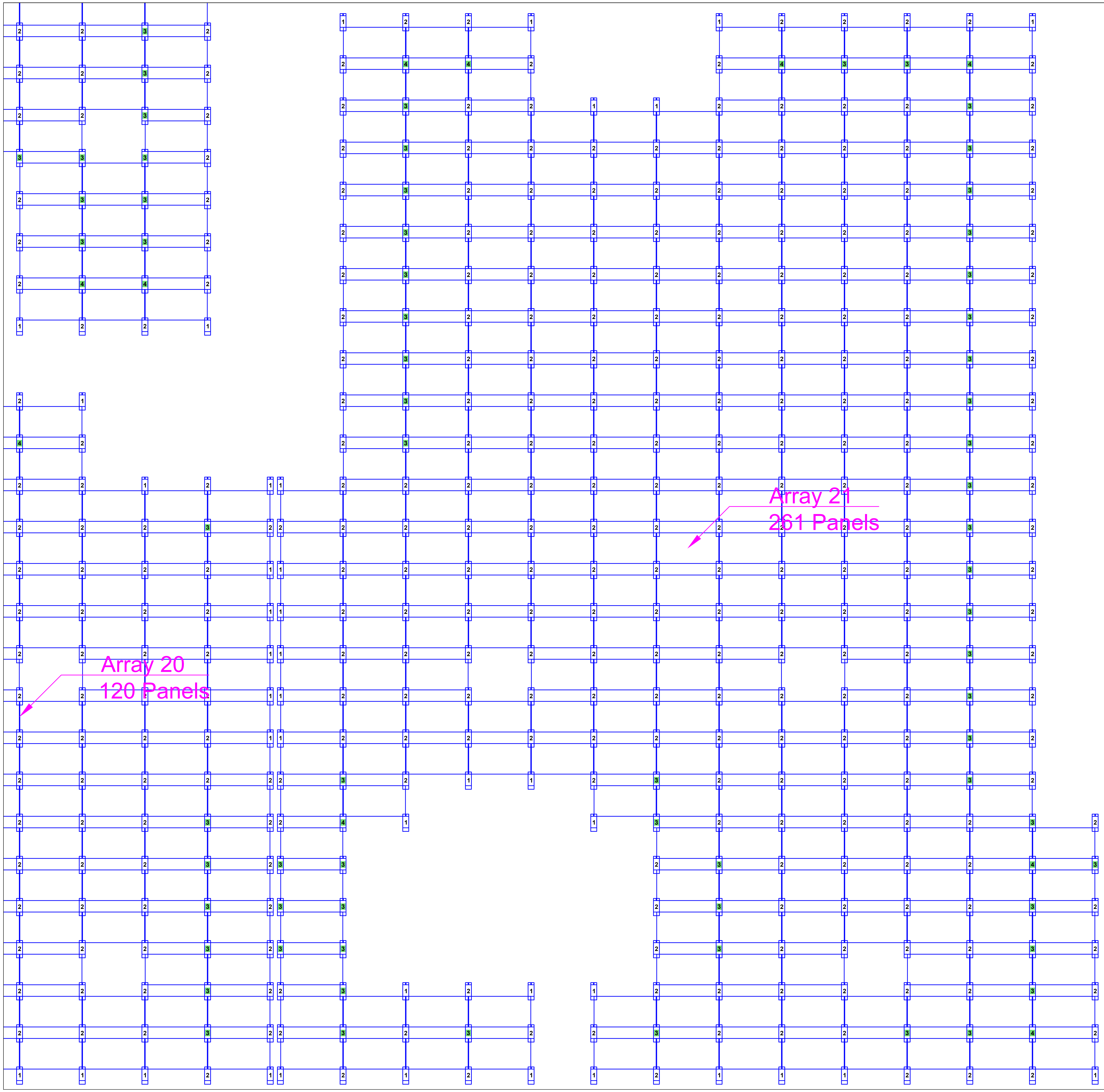
PROJECT NO.: -

DATE: 2020/07/30

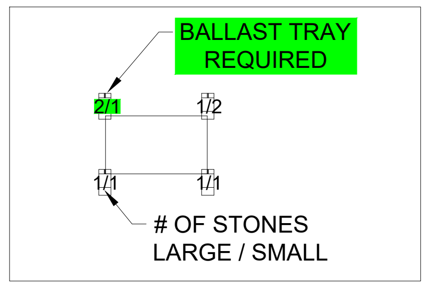
SHEET: 45 OF 46

DRAWING NO. M-4.20



NOTE:
2520 Modules (CS 440W)
DC Output: 1108.80 kW (DC)
EkonoRack: 10 Degree Tilt
Row Spacing: 1.43m
Inter-Row Spacing: 0.39m
Setback from edge: 1.22m

LEGEND



ENGINEER'S SEAL

DRAWING TITLE: PAVER ARRAY 21

PROJECT: City Project
49.8648,-97.1433
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CLIENT: Core Renewable Energy

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PROJECT NO.: -

DATE: 2020/07/30

DRAWING NO.: M-4.21

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