ENEL 674 Industrial and Commercial Power Systems

Group 7

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<u>Project Milestone 2</u>

Renewable Energy or Alternative Sources

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Executive Summary

There are various renewable energy sources available like solar, wind and etc. For our design, we are considering the solar energy. We are taking multiple scenarios of solar intensity for the given location. For our case, we are taking a case of solar panel installation in the parking lot instead of going for solar rooftop panels. Solar energy is a renewable resource that uses the sun's energy to produce heat and power. It is a plentiful, clean, and sustainable source of energy that can lessen our reliance on fossil fuels and slow down global warming.

Solar energy harvesting technology has advanced quickly, making it more affordable and available to individuals, corporations, and governments. Photovoltaic (PV) or solar panels may transform sunshine into electricity that can be used to power residences and other structures or put into the grid.

Solar renewable energy has the potential to play a key role in the shift to a clean and sustainable energy future, even though there are still some obstacles to be solved, such as storage and intermittency. In here, we will discuss the detailed analysis for the solar power generation at the given site.

1. How does it work?

1. Solar panels are typically installed on the roof/flat surface of the home/building or garage. These photovoltaic (PV) cells convert sunlight into direct current (DC) power.
2. The inverter(s) convert DC electricity from the solar array to the AC electricity found in the building.
3. The inverter feeds electricity into the electrical distribution system.
4. The bidirectional meter which is supplied free of charge by the Wires Owner, keeps track of both the energy imported from the grid and the energy exported to the grid. Savings and export credits are reflected on your electricity bill.
5. Your home/building remains connected to the utility grid to supply you with electricity when you need more power than your system is producing, such as at night.

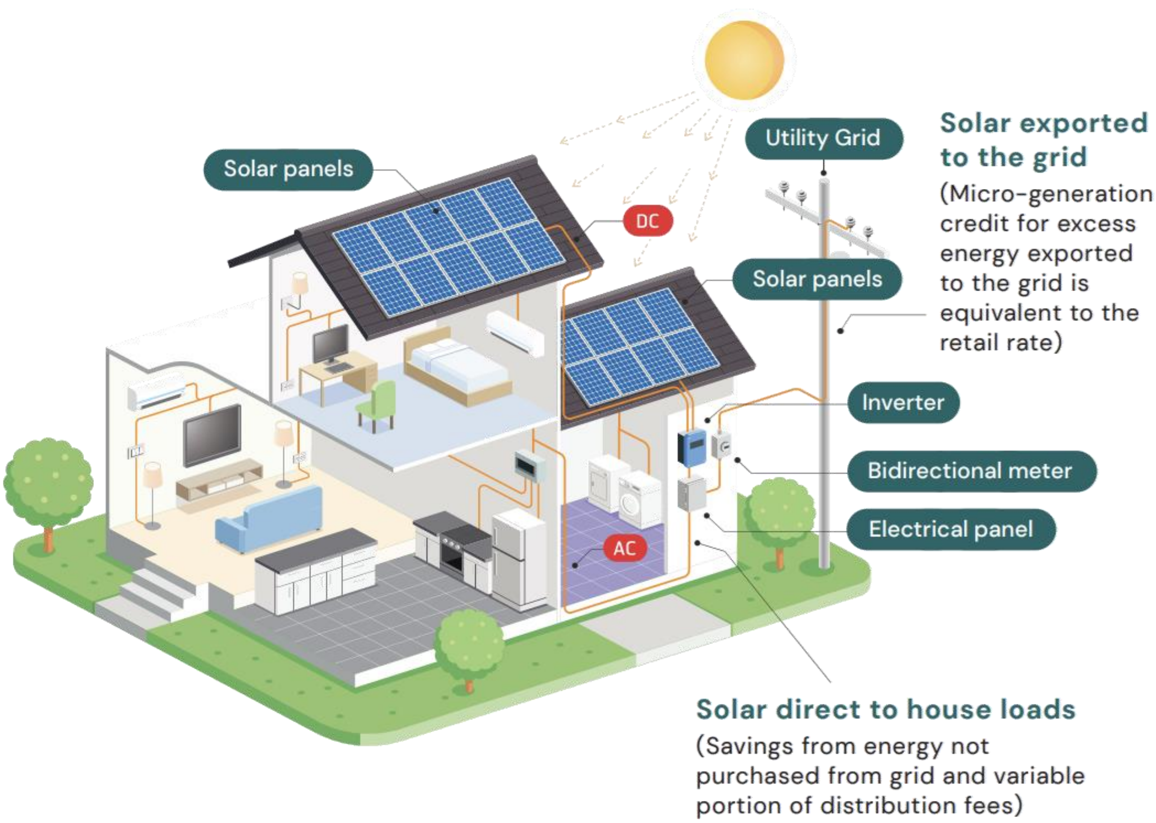

Figure 1 : Solar House

2. Why solar Energy?

Renewable: Solar energy is a renewable source of energy, meaning that it can be replenished over time. As long as the sun continues to shine, solar energy will be available to be converted into electricity.

Clean: Solar energy does not produce harmful pollutants or emissions. Unlike fossil fuels, solar energy does not contribute to air pollution or greenhouse gas emissions, which are major contributors to climate change.

Abundant: Solar energy is abundant and available almost everywhere on the planet. The amount of solar energy that reaches the Earth's surface in one hour is more than enough to meet the world's energy needs for an entire year.

Low maintenance: Solar panels require minimal maintenance, and once installed, they can continue to produce electricity for many years. This reduces the need for ongoing maintenance and repairs, which can also reduce costs.

Longevity: Solar panels have a long lifespan of up to 25 years or more. This means that they can continue to produce electricity for many years without needing to be replaced.

3. Solar Panel Placement

We are installing solar panel at Medicine Hat, AB, Canada which is located at $50.0290° N, 110.7032° W$. By using NREL, we analyse that the optimum tilt angle and azimuth angle for the solar panel to get the maximum solar radiation is $33°$ & $172°$ SE. For all below calculations, we have considered the mentioned angle. Here, we are commissioning solar panel at flat surface in open space. So, roof pitch angle would be $0°$. The reason we are not commissioning solar panel at rooftop is due to the weight of solar panel and snow during the winter, difficulty in maintenance & cleaning and limited space for expansion.

4. Availability of Sun in Medicine Hat

Below data shows the available solar radiation at Medicine Hat over the year including following loss factors. i.e., Soiling(2%), Snow(10%), Mismatch (2%), Wiring(2%), Connections(0.5%), Light Induced Degradation(1.5%), Name Plate Rating(1%).

Months	**Solar Radiation** $\frac{\frac{kWh}{m^2}}{day}$	**Months**	**Solar Radiation** $\frac{\frac{kWh}{m^2}}{day}$
Jan	2.1	**Jul**	7
Feb	2.83	**Aug**	6.56
Mar	4.41	**Sep**	5.17
Apr	5.61	**Oct**	3.67
May	5.91	**Nov**	2.1
Jun	6.07	**Dec**	1.79
Total: - 4.44			

Table 1 : Availability of solar radiation at Medicine Hat from NREL

5. Solar panel specifications

We have chosen below mentioned solar panel for our design.

THE Vertex BIFACIAL DUAL GLASS MONOCRYSTALLINE MODULE

PRODUCT	*POWER RANGE*	*MAIMUM POWER OUTPUT*	*MAXIMUM EFFICIENCY*	*POWER TOLERANCE POSITIVE*
$TSM - DG18MC.20(II)$	$480 - 505\ W$	$505\ W$	21%	$0 \sim +5W$

❖ **High customer value**

• Lower LCOE (Levelized Cost Of Energy), reduced BOS (Balance of System) cost, shorter payback time

• Lowest guaranteed rst year and annual degradation; extended 30-year warranty

• Designed for compatibility with existing mainstream system components

• Higher return on Investment

❖ **High power up to 505W**

• Large area cells based on 210mm silicon wafers and 1/3-cut cell technology

• Up to 21.0% module e-ciency with high density interconnect technology

• Multi-busbar technology for better light trapping eect, lower series resistance and improved current collection

❖ **High reliability**

• Minimized micro-cracks with innovative non-destructive cutting technology

• Ensured PID resistance through cell process and module material control

• Resistant to harsh environments such as salt, ammonia, sand, high temperature and high humidity areas

• Mechanical performance up to 5400 Pa positive load and 2400 Pa negative load

❖ **High energy yield**

• Excellent IAM (Incident Angle Modier) and low irradiation performance, validated by 3rd party certi-cations

• The unique design provides optimized energy production under inter-row shading conditions

• Up to 25% additional power gain from back side depending on albedo

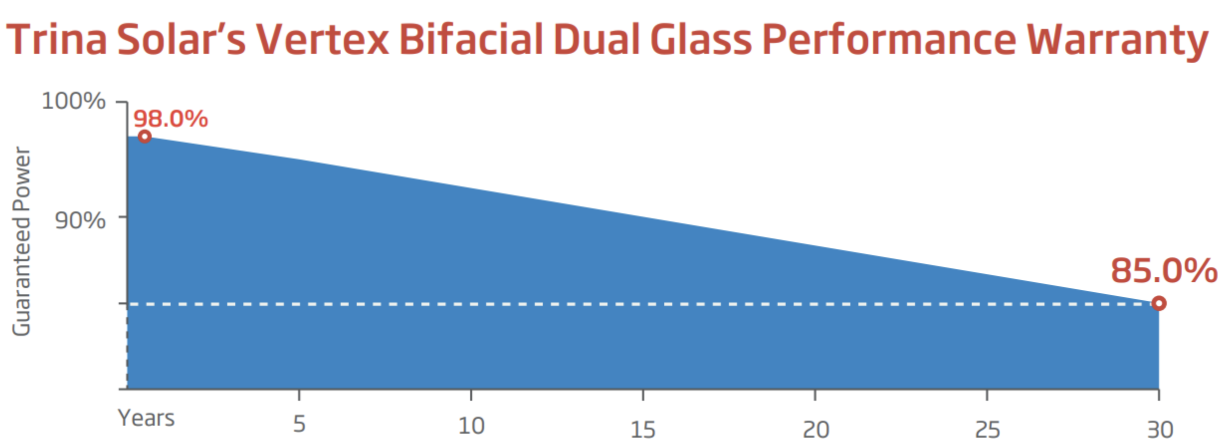

Figure 2 : Performance over the 30-year period

6. Solar Panel Physical Design & Characteristics

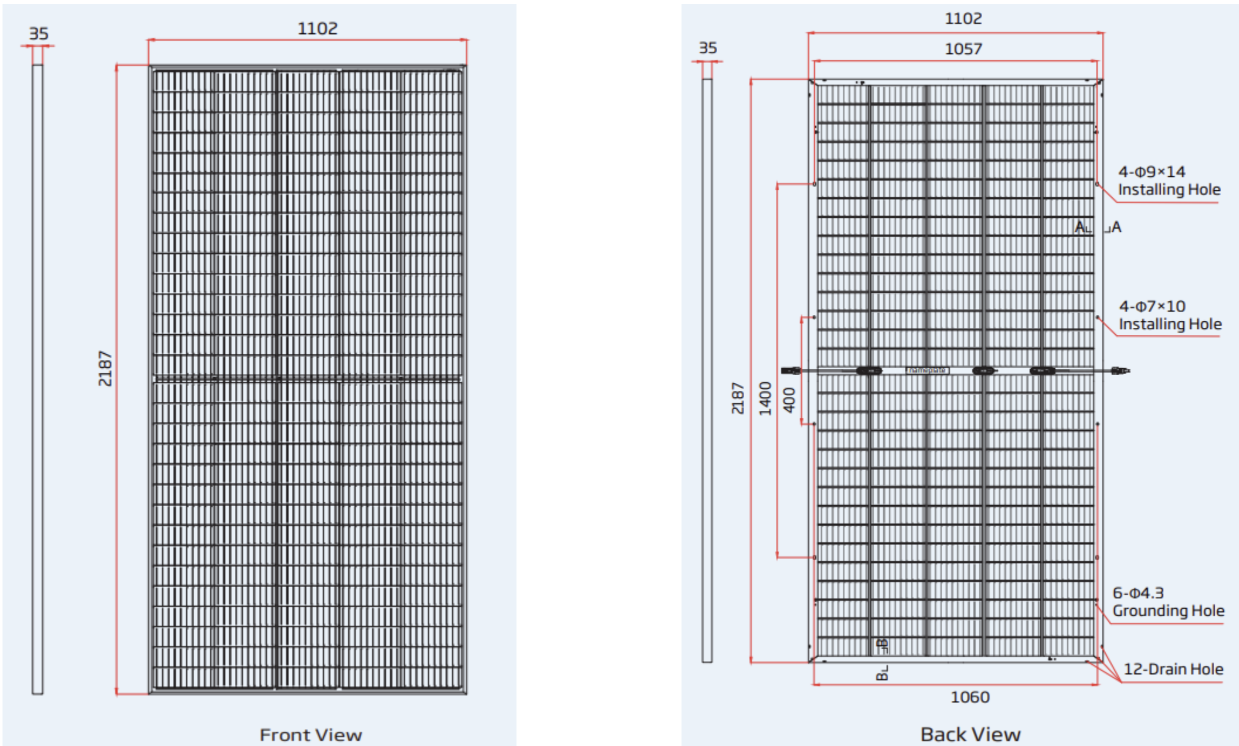

Figure 3 : Solar panel Physical Design

ELECTRICAL DATA (STC)

Peak Power Watts-P_{MAX} (Wp)*	480	485	490	495	500	505
Power Tolerance-P_{MAX} (W)	0 ~ +5					
Maximum Power Voltage-V_{MPP} (V)	42.2	42.5	42.8	43.1	43.4	43.7
Maximum Power Current-I_{MPP} (A)	11.38	11.42	11.45	11.49	11.53	11.56
Open Circuit Voltage-V_{OC} (V)	50.7	50.9	51.1	51.3	51.5	51.7
Short Circuit Current-I_{SC} (A)	11.97	12.01	12.05	12.09	12.13	12.17
Module Efficiency η_m (%)	19.9	20.1	20.3	20.5	20.7	21.0

STC: Irradiance 1000W/m², Cell Temperature 25°C, Air Mass AM1.5.
*Measuring tolerance: ±3%.

Table 2 : Electrical Datasheet of the panel

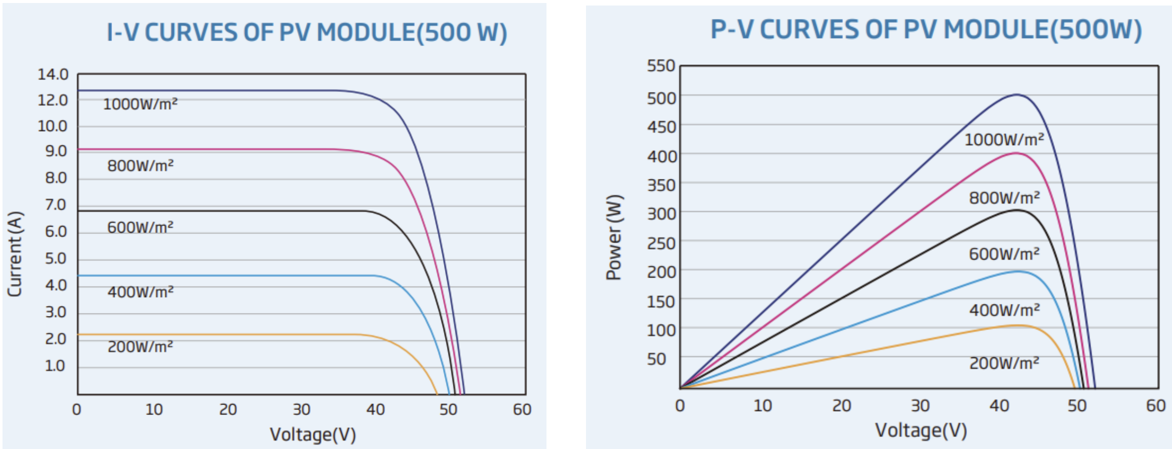

Figure 4 : Effect of solar intensity on the solar panel current(A) and power output(W)

7. Effect of weather on Solar panel output

Normal operating cell temperature for the given solar panel is $43°\ C$. Average day time temperature in Medicine Hat is comparatively very low. Temperature Coefficient of $P_{max} = -0.34\%/°\mathrm{C}$ and Temperature Coefficient of $V = -0.25\%/°\mathrm{C}$. Considering the effect of weather, solar panel output is as shown below,

Months	Average daytime temperature $(°C)$	Temp difference from NOCT $(°C)$	% change in Pmax $Watt$	% change in Vmax V	Power output per panel $Watt$ $/panel$	Actual Voltage output V $/panel$
Jan	-5.0	48.0	-16.3	-12.0	418.4	38.2
Feb	-3.0	46.0	-15.6	-11.5	421.8	38.4
Mar	3.0	40.0	-13.6	-10.0	432.0	39.1
Apr	10.0	33.0	-11.2	-8.3	443.9	39.8
May	16.0	27.0	-9.2	-6.8	454.1	40.5
Jun	20.0	23.0	-7.8	-5.8	460.9	40.9
Jul	23.0	20.0	-6.8	-5.0	466.0	41.2
Aug	22.0	21.0	-7.1	-5.3	464.3	41.1
Sep	16.0	27.0	-9.2	-6.8	454.1	40.5
Oct	9.0	34.0	-11.6	-8.5	442.2	39.7
Nov	1.0	42.0	-14.3	-10.5	428.6	38.8
Dec	-5.0	48.0	-16.3	-12.0	418.4	38.2

Table 3 : Effect of temperature on solar panel output

Average solar panel output per panel $= 442.1\ Watt$ considering change in normal operating cell temperature.

8. Number of required Solar panel

Months	Area of panel (m^2)	Solar Radiation $\frac{\frac{kWh}{m^2}}{day}$	Ideal power output $\frac{\frac{kWh}{m^2}}{day}$	Actual power output per panel per day $\frac{\frac{kWh}{m^2}}{day}$	Days in month	Actual power output per panel per month $\left(\frac{kWatt}{panel}\right)$
Jan	2.3	2.1	4.8	4.0	31.0	125.3
Feb		2.8	6.5	5.5	28.0	153.7
Mar		4.4	10.1	8.8	31.0	271.7
Apr		5.6	12.9	11.5	30.0	343.7
May		5.9	13.6	12.3	31.0	382.7
Jun		6.1	14.0	12.9	30.0	386.1
Jul		7.0	16.1	15.0	31.0	465.2
Aug		6.6	15.1	14.0	31.0	434.3
Sep		5.2	11.9	10.8	30.0	324.0
Oct		3.7	8.4	7.5	31.0	231.4
Nov		2.1	4.8	4.1	30.0	124.2
Dec		1.8	4.1	3.4	31.0	106.8
Total						3349.1

Table 4 : Total energy output from one solar panel

From the above table, we can see that a solar panel can generate an average of 3349.1 kwh over the year considering all the losses, effect of weather and for predicted solar intensity.

Area required

Considering 15 % of area margin apart from solar panel for solar panel installation,

Total Required Area = $Number\ of\ Solar\ panel * 2.3\ \frac{m^2}{panel} * 1.15$

9. Cost Benefits & Payback Period

A 505W solar panel's cost might change based on the manufacturer, quality, and location, among other things. A high-quality 505W solar panel typically costs between \$300 and \$500 USD per panel. But, depending on the market and demand, prices could be higher or lower.

It's vital to remember that the cost of a solar energy system does not only include the price of the solar panel. Installation expenses, permits, labour prices, and maintenance costs are other variables that may affect total cost.

The long-term savings and advantages of using solar energy should be considered in addition to solar panel costs. Your electricity bills may be decreased or eliminated thanks to solar panels, which also offer a clean, sustainable energy source.

Assumption

- Considering the per kWh rebate from Solar Generation $0.08\,\frac{\$}{kWh}$.
- Panel cost will be the same irrespective of quantities.
- Overall data is considered for particularly medicine hat.
- Overall cost is considered upon our research, and we can provide references upon request.

Cost

Component	Solar Panels	Structure	Labour Cost	Misc
Unit Cost	$700\$/panel$	$1\ \$/W$	$1\ \$/W$	$0.5\ \$/W$

Table 5 : Cost of the components

Payback Period Analysis

Number of Panel	24	36	48	60	72	84	96
Total # KW panel installed (KW)	12.1	18.2	24.2	30.3	36.4	42.4	48.5
Price rebate per unit generation $(\$/kwh)$	0.08						
Total installation cost (\$)	51780	76165	101149	126026	149576	172764	196314
Total Unit generated over the year (kwh)	80378	120568	160757	200946	241135	281324	321514
Payback Period (Yrs)	8.1	7.9	7.9	7.8	7.8	7.7	7.6

Table 6 : Payback period vs Solar capacity installed

10. Inverter Design

Inverted design depends on some of the most important factors that include:

- **Capacity:** The inverter's capacity should match the solar panel's maximum capacity. This is important to ensure that the inverter can handle the maximum power output of the solar panels.
- **Efficiency:** Inverter efficiency is a crucial factor in determining the overall efficiency of the solar system. A high-efficiency inverter will ensure that a larger percentage of the solar energy is converted into usable electricity.
- **Type of Inverter:** There are different types of inverters, including string inverters, microinverters, and power optimizers. The choice of inverter will depend on the specific requirements of the solar system.
- **MPPT:** The inverter should have a maximum power point tracking (MPPT) feature to ensure that the system operates at maximum efficiency by tracking changes in solar panel output and adjusting the inverter's input accordingly.
- **Durability:** The inverter should be designed to withstand harsh environmental conditions, such as extreme temperatures, humidity, and dust. This will ensure that the inverter has a long lifespan and operates optimally.
- **Safety:** Safety is an essential consideration when designing an inverter for a solar system. The inverter should have built-in safety features, such as overload protection and ground fault protection, to prevent damage to the system and ensure the safety of people and property.
- **Compatibility:** The inverter should be compatible with the type of solar panel used in the system, as well as any other components, such as batteries or charge controllers.

We have chosen some inverter design of the inverter brand depends on the required rating.

Three Phase Grid Tie Solar Inverter						
Inverter Rating	**Cost**	**Frequency**	**MPPT Tracking Voltage Range**	**Model Number**	**Output Voltage**	
15kW	$4,680.11	50Hz/60Hz	200-820V	ATO-TLC15000	Default AC 3-phase 380V±5%, (Optional: 208V, 240V, 460V, 480V with ±5% tolerance)	LINK
20kW	$5,515.80	50Hz/60Hz	200-820V	ATO-TLC20000	Default AC 3-phase 380V±5%, (Optional: 208V, 240V, 460V, 480V with ±5% tolerance)	LINK
25kW	$6,259.42	50Hz/60Hz	200-820V	ATO-TLC25000	Default AC 3-phase 380V±5%, (Optional: 208V, 240V, 460V, 480V with ±5% tolerance)	LINK
30kW	$6,949.43	50Hz/60Hz	200-820V	ATO-TLC30000	Default AC 3-phase 380V±5%, (Optional: 208V, 240V, 460V, 480V with ±5% tolerance)	LINK
40kW	$8,276.37	50Hz/60Hz	200-820V	ATO-TLC40000	Default AC 3-phase 380V±5%, (Optional: 208V, 240V, 460V, 480V with ±5% tolerance)	LINK
50kW	$7,914.36	50Hz/60Hz	200-820V	ATO-LTC50000	Default AC 3-phase 380V±5%, (Optional: 208V, 240V, 460V, 480V with ±5% tolerance)	LINK

Features of Inverter

- Can be applied to various fields, mainly for solar power, wind power, battery power, and scenery lamp power.
- Strong IP65 protection, completed sealed cover suitable for harsh environment.
- Advanced MPPT tracking technology, wide MPPT voltage range.
- No isolation transformer H6 full-bridge configuration, highest efficiency reaches 97%.
- Over voltage, short circuit, overload, overheating, anti-islanding protection etc.
- Multiple inverters can be operated in parallel.
- LCD display, convenient for user to monitor main parameters.
- Support various communication modes.

11. Conclusion:

- We have discussed various renewable power sources. Our suggestion is the solar panel installation. We mentioned different sizes of the solar panels installation and analysed the power output as well.
- We counted the ideal payback time for the capital cost of the solar installation.
- Based on the location, our recommendation would be the solar panel installation depending upon the client's budget. We prioritize the solar over wind power generators.
- In future, we can provide the electric vehicle charging station in the parking lot itself depending upon the popularity of the EV and that modification is easy.
- We need the tiny space for placing the inverter. Our recommendation would be online generation so, best design of the inverter room would be somewhere close to the electrical room where the main supply is coming from utility. But the design can change upon the need and the modifications.