Assignment on EE256: Rooftop Solar Plant Design and Analysis

This assignment utilizes the JRC Photovoltaic Geographical Information System (PVGIS) design tool (https://re.jrc.ec.europa.eu/pvg_tools/en/#PVP) to design and analyse a rooftop solar photovoltaic (PV) system for a hostel building. The tasks are structured to develop skills in solar plant design, resource assessment, energy output analysis, and financial evaluation.

Task 1: Characterizing the Building and Rooftop Solar Plant Design [30 marks]

Objective: Design a rooftop solar PV system for a hostel building based on site-specific data and engineering principles.

a) Site Assessment:
- Use Google Maps, Google Earth, or equivalent software to identify the hostel building assigned to you.
- Determine the approximately south-facing roof area (in square meters) suitable for solar panel installation. Account for obstructions and shading from nearby structures or trees.
- Provide a screenshot or diagram of the roof with annotations indicating usable area and any excluded sections.

b) Solar Plant Design:
- Using design techniques from the industrial lecture (e.g., panel sizing, spacing to avoid shading, and system capacity optimization), propose a suitable PV system.
- Select appropriate solar panels (specify type, efficiency, and wattage) and inverters (specify type and capacity) based on industry standards.
- Calculate the total system capacity (in kW) and the number of panels required, considering the usable roof area and panel dimensions.

c) Electrical Layout Diagram:
- Draw a single-line electrical diagram showing:
    - Arrangement of PV modules (series/parallel connections).
    - Inverter placement and connection to the grid.
    - Metering and safety devices (e.g., circuit breakers, disconnect switches).
- Use software like AutoCAD, SketchUp, or hand-drawn diagrams (scanned and uploaded).

d) Daily Energy Demand Estimation:
- Estimate the hostel's daily electrical demand (in kWh) for weekdays and weekends.
- Divide the day into logical time periods (e.g., morning: 6 AM–12 PM, afternoon: 12 PM–6 PM, evening: 6 PM–12 AM, night: 12 AM–6 AM).
- Provide a table summarizing demand for each time period, considering typical hostel activities.
- Justify assumptions based on typical hostel occupancy and equipment usage.

Task 2: Solar Resource Data Collection [10 marks]

Objective: Gather and analyse solar resource data for the hostel's location using PVGIS.

a) Location Details:
- Provide the hostel's address and its precise latitude and longitude (use Google Maps or PVGIS for accuracy).

b) Data Collection:
- Using PVGIS, complete the following table for the hostel's location:

Home address		
Parameter	Units	Home location
Latitude	^{0}	
Longitude	^{0}	
Annual global insolation (irradiation) on an optimally inclined plane	kWh/m^2.year	
Tilt angle for maximum annual insolation	^{0}	
Daily insolation (irradiation) in December at an optimum tilt angle	kWh/m^2.day	
Daily insolation (irradiation) in June at an optimum tilt angle	kWh/m^2.day	
Ratio of diffuse/global insolation throughout the year	%	

Task 3: Solar Resource Visualization [15 marks]
Objective: Visualize and interpret solar resource data to understand seasonal and daily variations.

a) Data Collection:
- Use PVGIS to extract monthly and daily solar irradiation data for the hostel's location at the optimum tilt angle.

b) Graphical Analysis:
- Create the following graphs using software like Excel, Python (Matplotlib), or PVGIS's built-in tools:
  - Graph 1: Monthly global insolation (kWh/m²) at the optimum tilt angle for all 12 months.
  - Graph 2: Average daily irradiance (W/m²) over 24 hours for March, August, and December at the optimum tilt angle.
- Ensure graphs are clearly labelled (title, axes, units, legend) and include a brief description of trends observed (e.g., seasonal variations, peak irradiance times).

c) Interpretation:
- Discuss how seasonal changes in insolation affect PV system design and performance.
- Highlight differences in irradiance patterns between March, August, and December, and their implications for energy production.

Task 4: Grid-Connected PV Plant Performance [10 marks]
Objective: Analyze the monthly energy output of the designed PV system and evaluate the impact of temperature.

a) Monthly Energy Output:
- Use PVGIS to estimate the monthly energy output (in kWh) for the grid-connected PV system designed in Task 1.
- Present the results in a table or graph, showing energy output for each month.

b) Temperature Impact:
- Obtain monthly average ambient temperatures for the hostel's location using PVGIS or a reliable weather database.
- Compare the monthly PV energy output with the corresponding average temperature.
- Discuss the effect of cell temperature on PV panel efficiency and power output, referencing the temperature coefficient of the selected panels (typically -0.3% to -0.5% per °C above 25°C).

c) Analysis:
- Explain how temperature variations influence the system's performance and suggest design considerations (e.g., ventilation, panel type) to mitigate efficiency losses.

Task 5: Annual Revenue Calculation [15 marks]
Objective: Estimate the financial benefits of the rooftop solar plant based on energy generation and consumption.
a) Energy Generation and Consumption:
- Use the annual energy output from Task 4 and the daily demand estimates from Task 1 to calculate:
  - Total annual energy generated by the PV system (kWh).
  - Total annual energy consumed by the hostel (kWh).
  - Net energy exported to the grid or imported from the grid (kWh).
- Assume net metering tariff (LKR/kWh).

b) Revenue Calculation:
- Calculate the annual revenue from:
  - Savings on electricity bills (energy consumed from PV instead of the grid).
  - Income from exporting excess energy to the grid (if applicable).

c) Discussion:
- Discuss factors affecting revenue, such as seasonal variations in generation and demand, or policy incentives.

Task 6: Financial Analysis of the PV Project [20 marks]
Objective: Evaluate the financial viability of the PV system over its operational life.
Given Data:
- Initial capital cost: LKR 100,000 per kW of installed capacity.
- Annual Operation & Maintenance (O&M) cost: LKR 50,000.
- Inverter replacement cost: LKR 400,000 after 5 years.
- Project lifespan: 15 years.
- Discount rates: 8%.

a) Project Timeline:
- Draw a timeline (e.g., using a Gantt chart or simple diagram) showing:
  - Initial investment (Year 0).
  - Annual O&M costs (Years 1–15).
  - Inverter replacement (Year 5).
  - Annual revenue from energy generation (Years 1–15).

b) Net Present Value (NPV):
- Calculate the NPV of the project
- Present cash flows in a table, including:
  - Initial investment (negative cash flow).
  - Annual revenue (from Task 5).
  - Annual O&M costs (negative cash flow).
  - Inverter replacement cost (negative cash flow in Year 5).
- Compute NPV and interpret the results.

Submission Guidelines
- Submit a single report (PDF format) including all tasks, calculations, diagrams, and graphs.
- Clearly label each task and sub-task.
- Include references for data sources (e.g., PVGIS, weather databases) and assumptions (e.g., tariffs, panel specifications).

- Ensure all calculations are shown step-by-step, and diagrams/graphs are of high quality.
- Word limit: 2,500–3,000 words (excluding tables, graphs, and references).

Group Contribution Statement:

- Include a section detailing the contributions of each group member. Assign the following roles to the five members:
  - **Project Engineer**: Oversees project coordination, ensures task integration, and manages report compilation.
  - **Design Engineer (2 – 3 Nos)**: Leads the solar plant design, including panel selection, system sizing, and electrical layout (Task 1).
  - **Solar Resource Analyst**: Manages data collection and visualization using PVGIS (Tasks 2 and 3).
  - **Performance Analyst**: Analyses energy output and temperature effects (Task 4).
  - **Financial Analyst**: Handles revenue calculations and financial analysis (Tasks 5 and 6).
- Provide a table or paragraph summarizing each member's role, specific tasks performed, and estimated percentage contribution to the project (e.g., 20% per member for equal distribution or adjusted based on workload).