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المؤتمر الدولي الثاني والعشرون لإدارة الأصول والمرافق والصيانة
The 22nd International Asset, Facility & Maintenance Management Conference

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Design and Performance Analysis of a Hybrid Solar Power System for Meeting Energy Needs in University Buildings: Environmental and Economic Impacts - A Case Study of Sulaiman Al-Rajhi University

26-28 January 2025
The Ritz-Carlton Jeddah, Kingdom of Saudi Arabia

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Outline

- Introduction
- Objectives

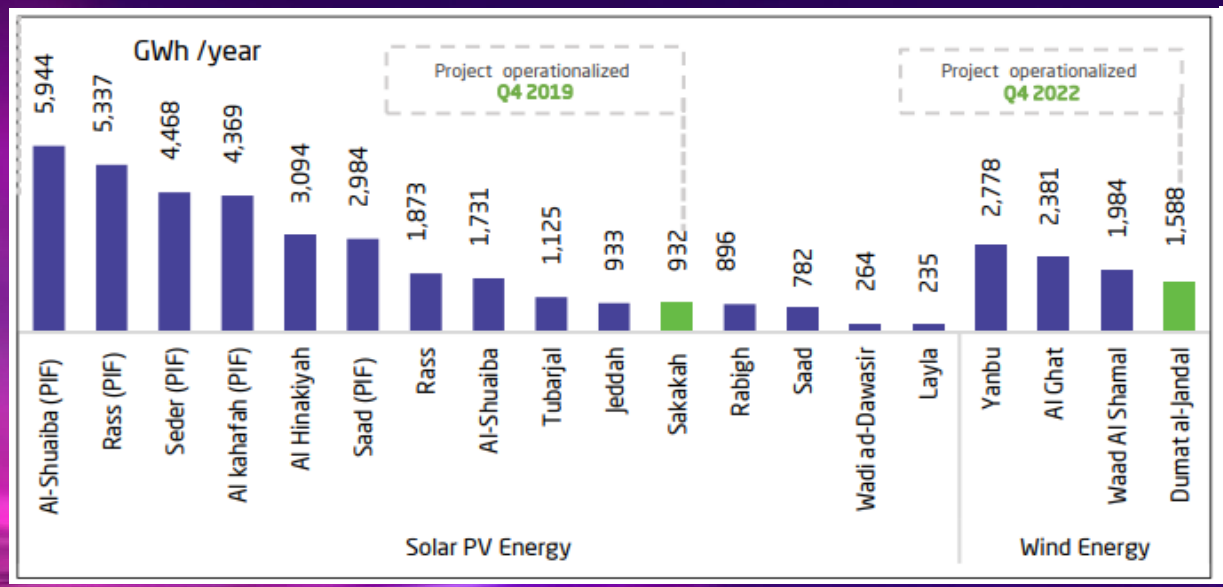
- Methodology
- Results & Analysis

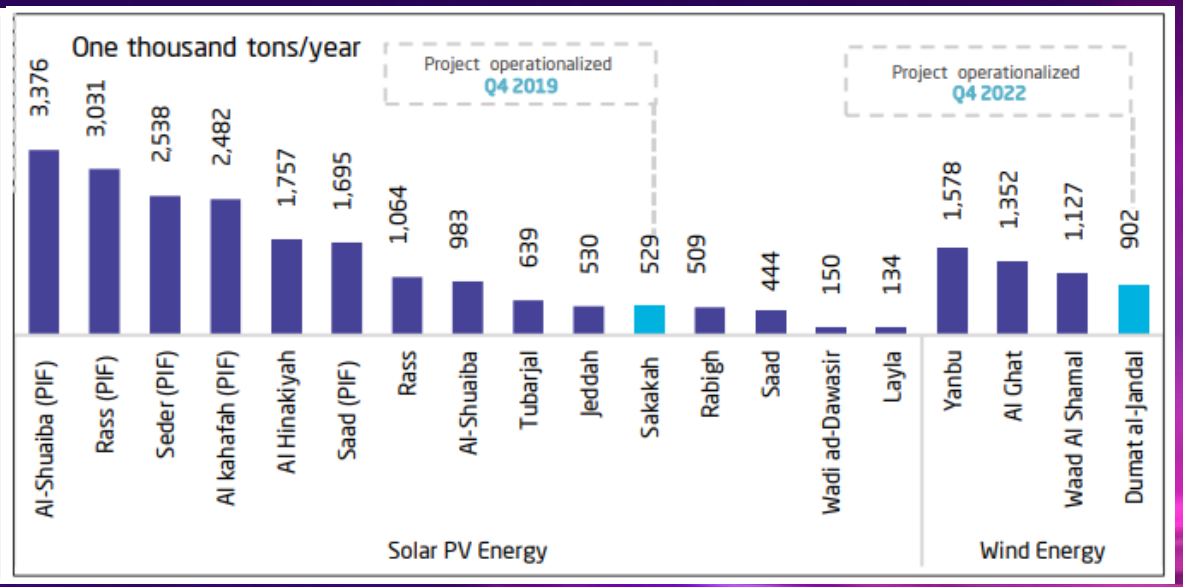
- Conclusions
- Future Work

•Rapid growth in electricity demand in Saudi Arabia.

Introduction

- Rapid growth in electricity demand in Saudi Arabia.
- Vision 2030 fostering solar energy adoption.
- Universities as prime showcases for renewable solutions.

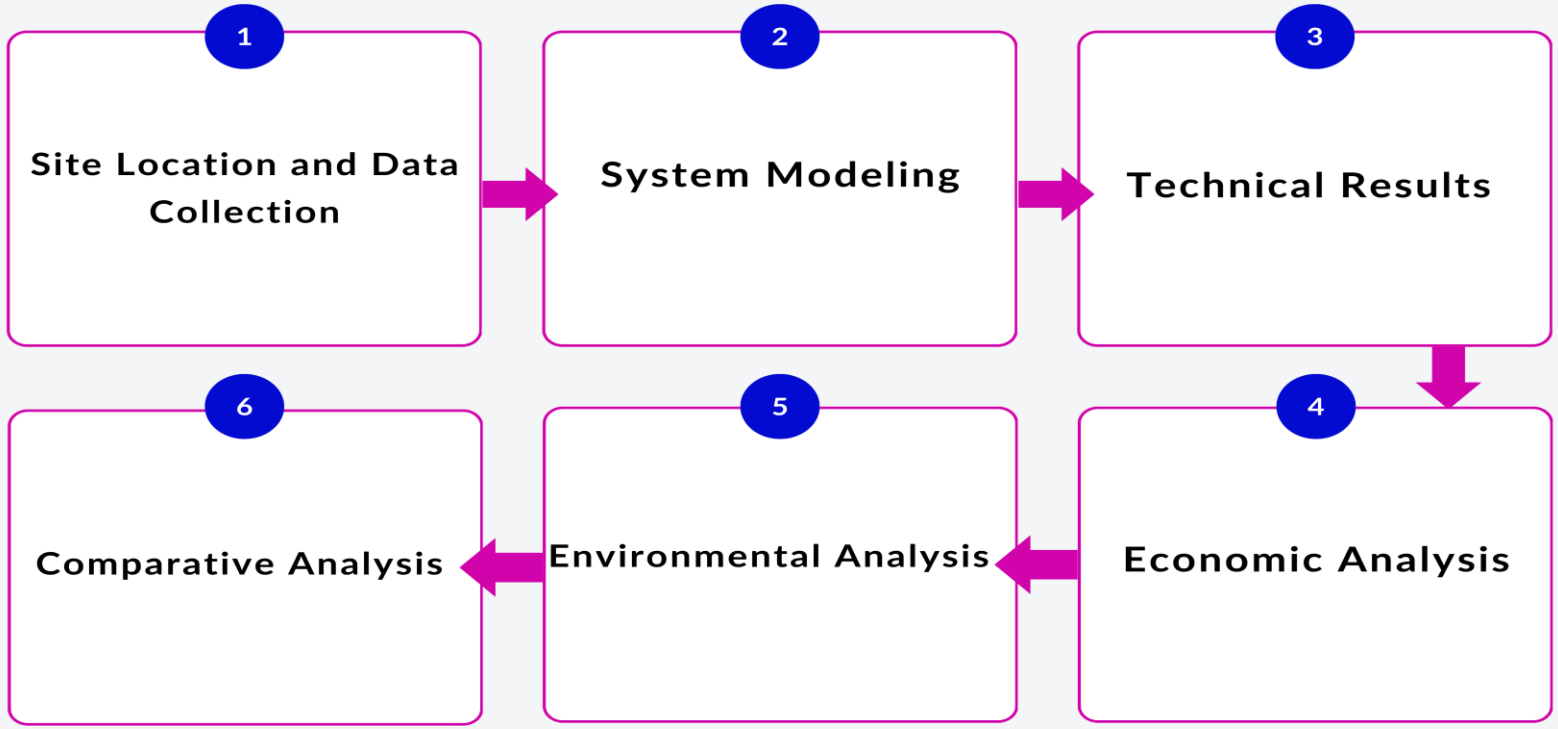




Objectives

- Technical Evaluation of two hybrid solar solutions.
- Advanced Financial Analysis: Payback, NPV, IRR.
- Environmental & Social Impact: CO_2 reduction, community engagement.

METHODOLOGY



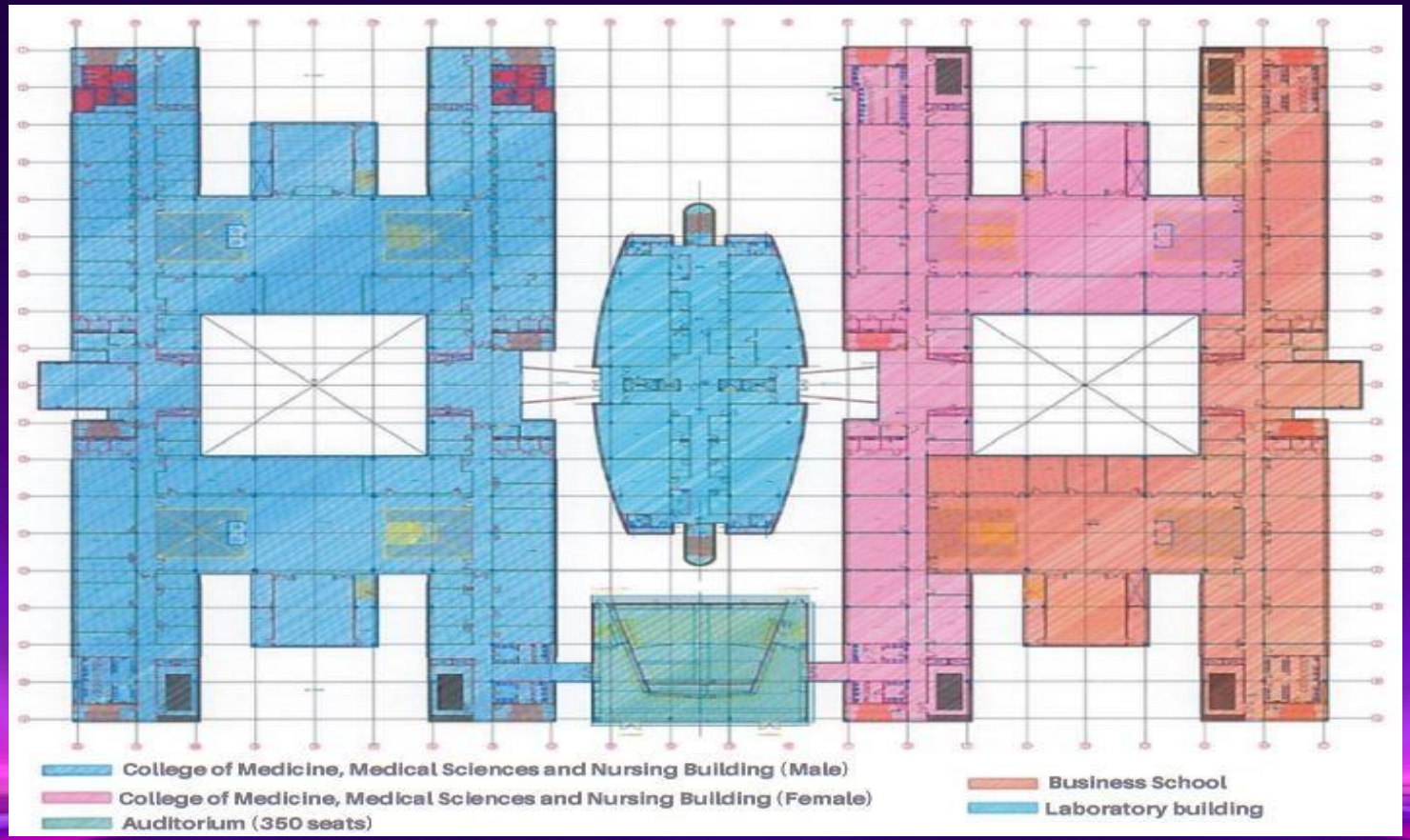
Sulaiman Al-Rajhi University

Location of the Building: Sulaiman Al-Rajhi University is located in the city of Al-Bukayriyah, one of the cities in the Qassim region of Saudi Arabia. The city is situated in the central part of the Kingdom, specifically in the Najd region. Al-Bukayriyah has a desert climate characterized by extreme heat in the summer and cold temperatures in the winter. Coordinates: 26°15'00"N, 43°46'00"E / 26.25°N, 43.76667°E.

Description of the Building: Sulaiman Al-Rajhi University is a private, non-profit university founded by the Sulaiman Bin Abdul Aziz Al-Rajhi Charitable Foundation and located in Al-Bukayriyah, Saudi Arabia. The university consists of four colleges: Medicine, Nursing, Applied Medical Sciences, and Business.
The university complex is composed of five sections: Parts 1, 2, 3, 4, and 5. Parts 1 to 4 are five-story buildings, while Part 5 is a four-story building. The total conditioned area of the complex is 58,000 square meters.

The building is primarily used for educational purposes and includes classrooms, laboratories, libraries, halls, and administrative offices. The building is generally in use from 7:00 AM to 6:00 PM, with some parts of the buildings also used on Fridays and Saturdays.

Sulaiman Al-Rajhi University



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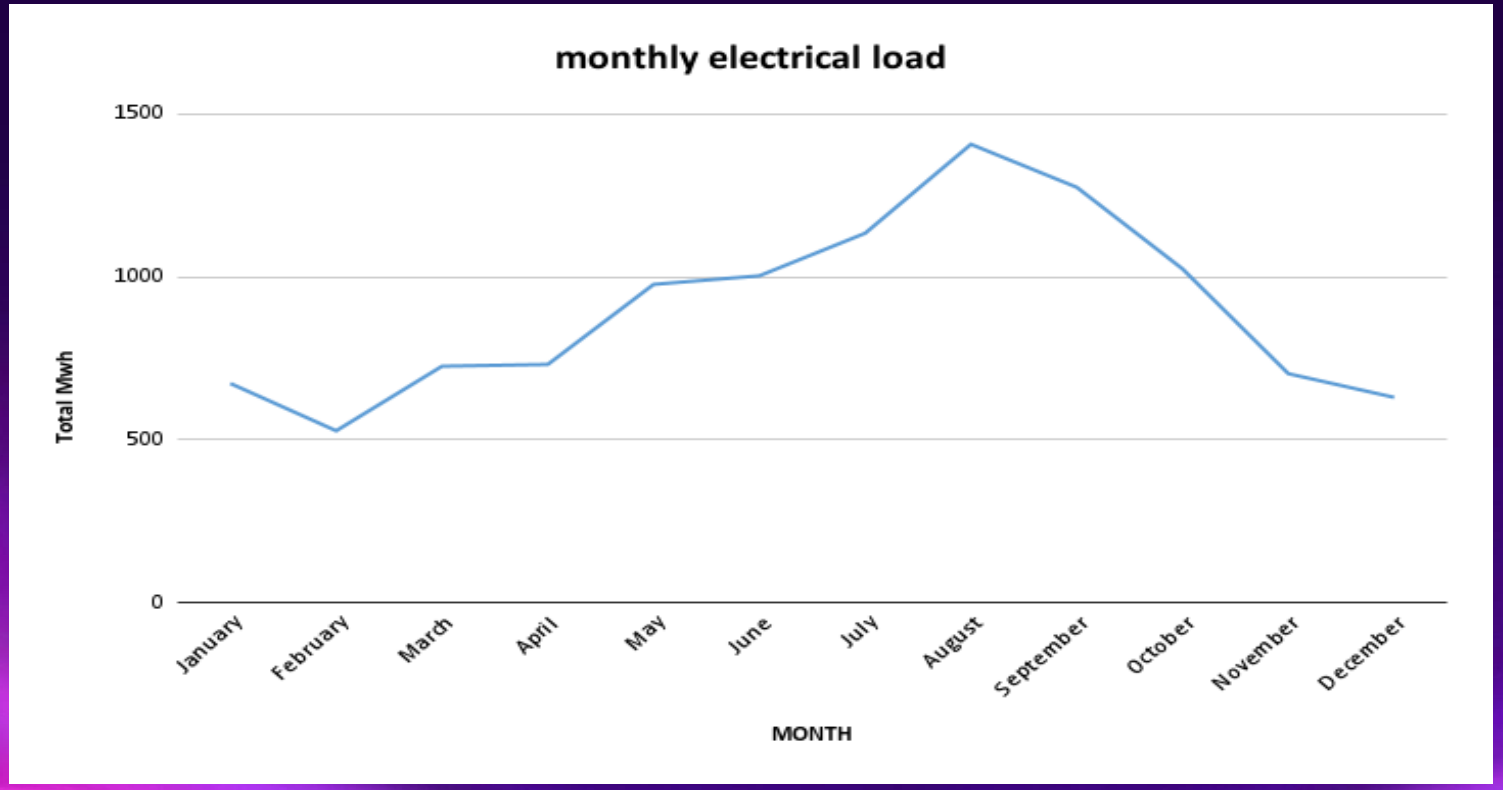
Site Location and Data Collection

Item	Data
Location	Al-Bukayriyah, Qassim region, Saudi Arabia (approx. 26°15'00"N, 43°46'00"E).
Facility Description	Five building sections (4–5 stories each), total conditioned area ~58,000 m^2.
Annual Load	~931,006 kWh, peaking during summer months due to high cooling demands.
Solar Irradiance	Average GHI ~6.17 kWh/m^2/day from NSRDB and NASA POWER.

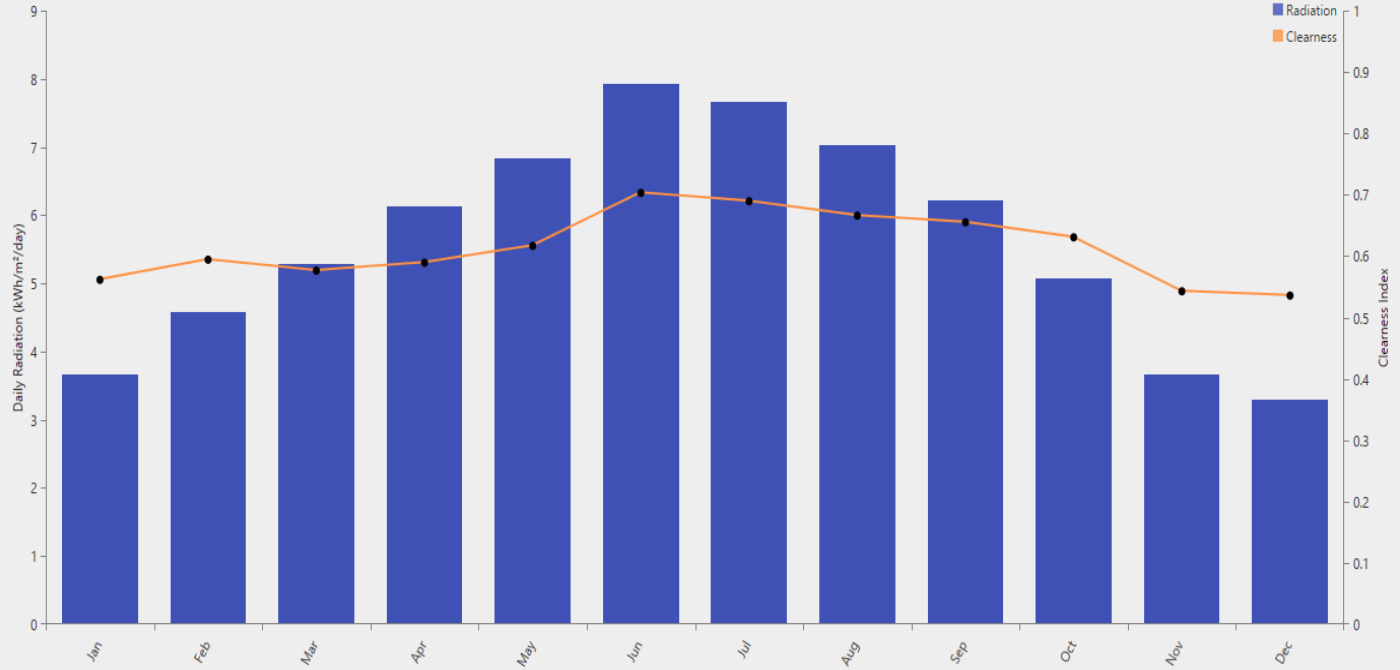
Energy Consumption Data



Solar Radiation Data

Monthly Average Solar Global Horizontal Irradiance (GHI) Data

Month	Clearness Index	Daily Radiation (kWh/m²/day)
Jan	0.561	3.670
Feb	0.594	4.580
Mar	0.576	5.290
Apr	0.589	6.130
May	0.616	6.830
Jun	0.703	7.930
Jul	0.689	7.670
Aug	0.666	7.030
Sep	0.655	6.210
Oct	0.630	5.070
Nov	0.543	3.660
Dec	0.536	3.300



Downloaded at 7/10/2024 2:38:07 PM from:
NASA Prediction of Worldwide Energy Resource (POWER) database.
Monthly averages for global horizontal radiation over 22-year period (Jul 1983 - Jun 2005)
cellMidpointLatitude: 26.25
cellMidpointLongitude: 43.75

Annual Average (kWh/m²/day): 5.61

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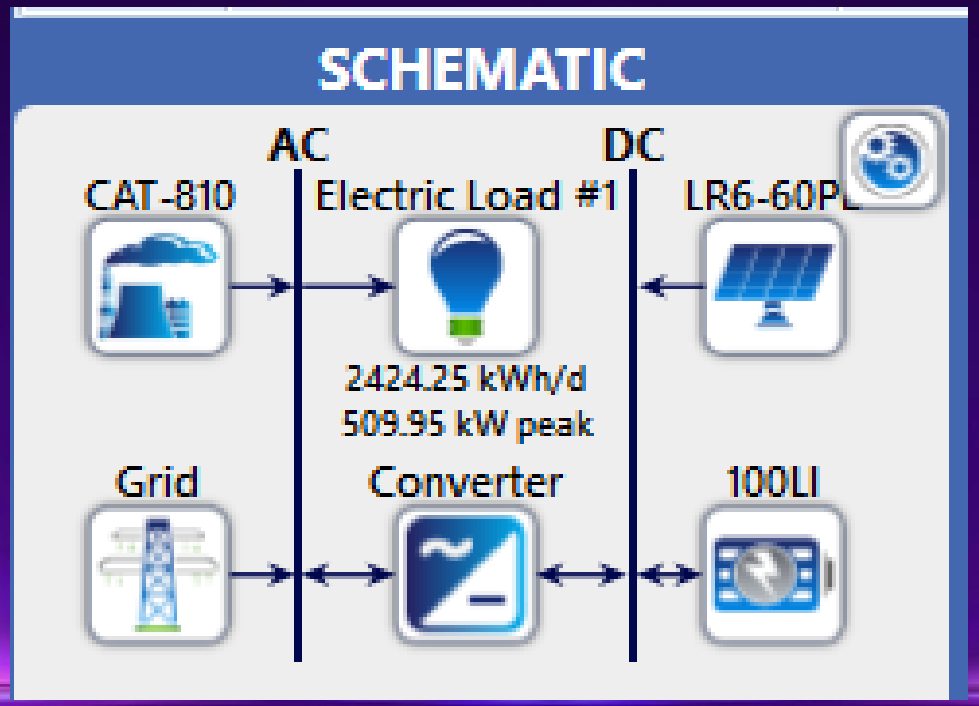
System Design

Using HOMER Software: HOMER (Hybrid Optimization of Multiple Energy Resources) software used to design and analyze the hybrid solar power system. This software allows for simulating system performance and evaluating economic feasibility.



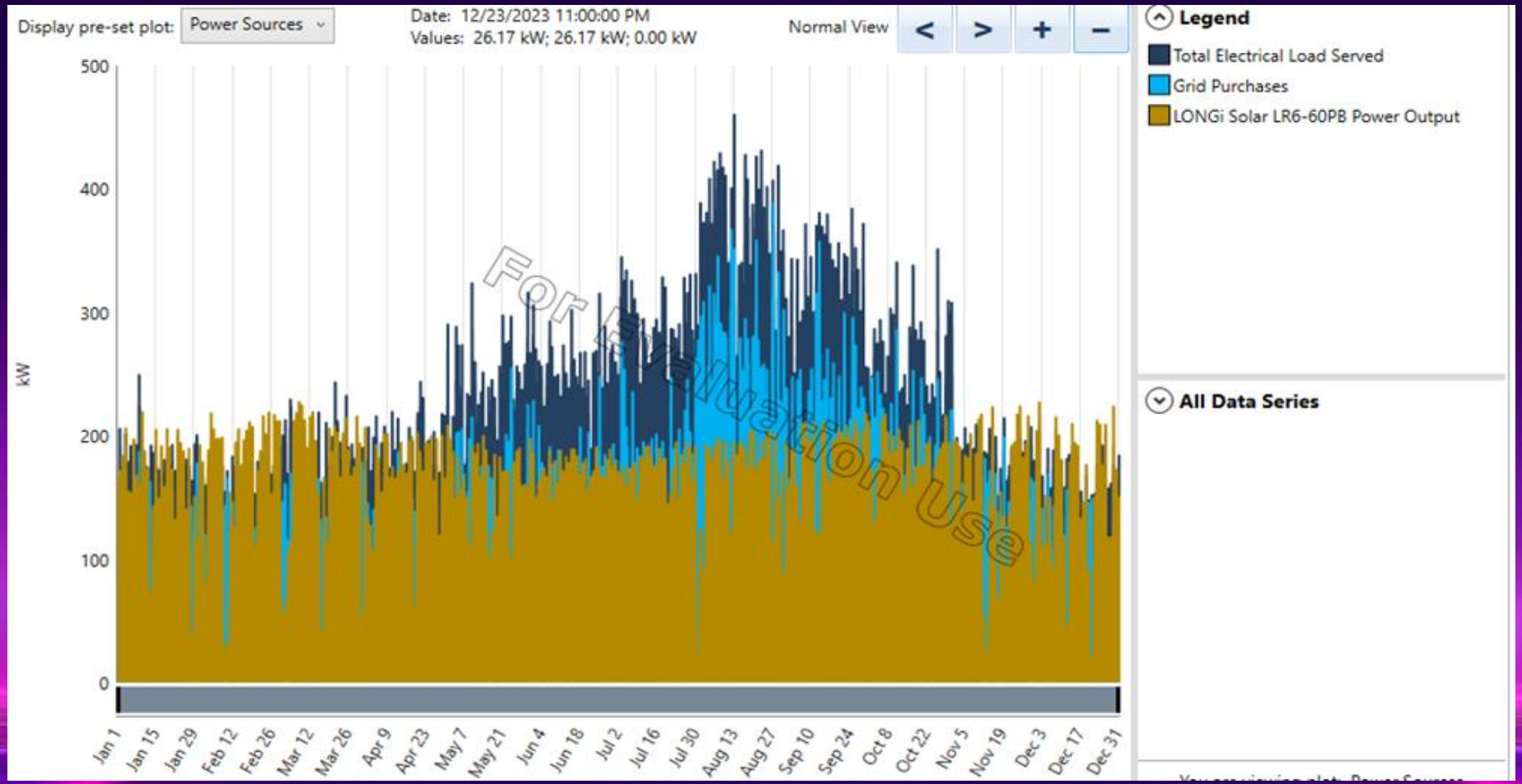
System Design

Component	Data
PV Panels	**(LONGi 295W):** ~3,636 panels covering ~6,000 m². Total capacity ~1.1 MW.
Inverters	Sized to meet the maximum load requirements.
Backup Generator	**Backup Generator:** For emergency use in case of grid outages.
Grid	Electricity priced at 0.18 SAR/kWh (buy), with surplus fed at 0.049 SAR/kWh.

Technical Results (System Performance)

Item	Data
Annual Energy Production	~425,427 kWh (45.7% of the total annual consumption).
Load Coverage	• Grid purchases cover about 54.3% of the remaining demand. • Seasonal variations in solar production

Technical Results (System Performance)



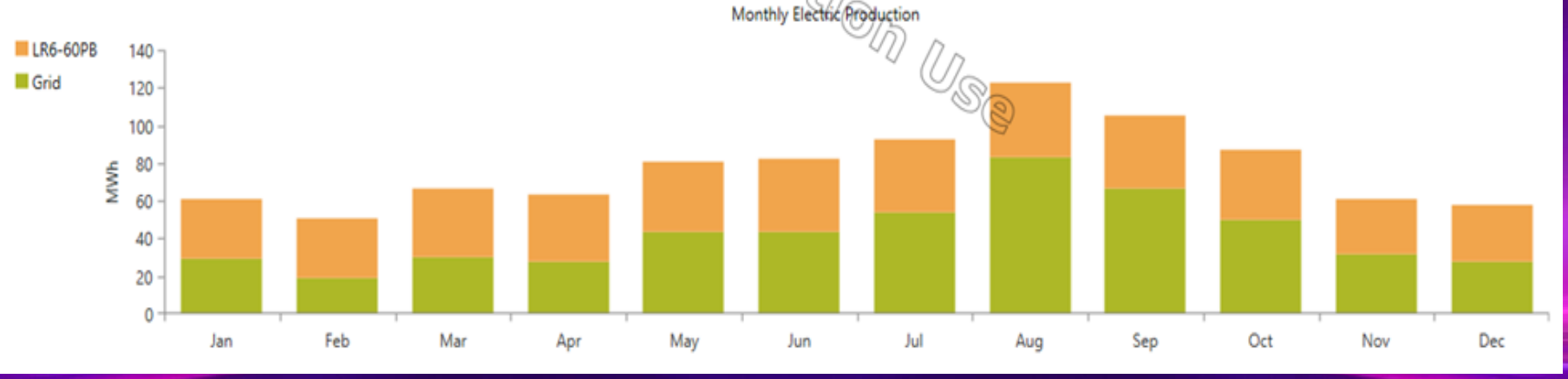
Technical Results (System Performance)

Production	kWh/yr	%
LONGi Solar LR6-60PB	425,427	45.7
Grid Purchases	505,580	54.3
Total	931,006	100

Consumption	kWh/yr	%
AC Primary Load	884,852	97.7
DC Primary Load	0	0
Deferrable Load	0	0
Grid Sales	20,593	2.27
Total	905,445	100

Quantity	kWh/yr	%
Excess Electricity	4,516	0.485
Unmet Electric Load	0	0
Capacity Shortage	0	0

Quantity	Value	Units
Renewable Fraction	44.2	%
Max. Renew. Penetration	129	%



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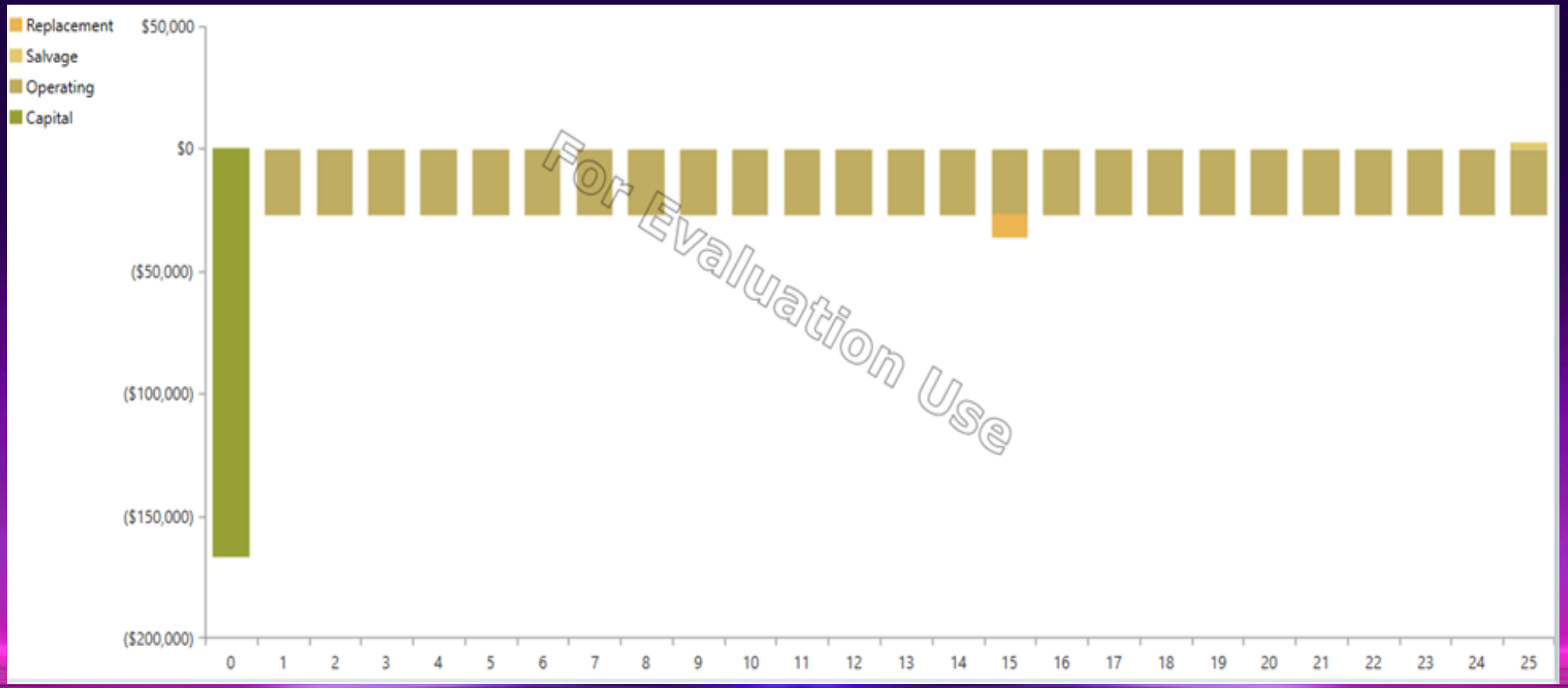
Economic Analysis

Item	Data
Capital Investment	~1,112,188 SAR (including panels, inverters, and installation).
Annual O&M Costs	Typically 1–2% of the total capital cost.
Annual Savings	~76,372.39 SAR
Payback Period	~14.56 years

Economic Analysis



Environmental and Social Impact

Item	Data
Carbon Emissions Reduction	~232,163.64 kg CO_2 per year.
Sustainability Perspective	Reduced dependency on conventional grid power Promotes environmental awareness among stakeholders.
Educational Dimension	Serves as a living lab for students Live data for research projects on renewable energy.

Comparative Analysis of Hybrid Solar Power Systems at Sulaiman Al-Rajhi University

System A (HOMER Model)	System B (SAM)
PV Capacity: ~1.1 MW (3,636 LONGi 295W panels)	**PV Capacity:** ~2.0 MW (8,040 SunPower SPR-X20-255 panels)
Annual Production: Approximately 425,427 kWh/year	**Annual Production:** Approximately 4,034,828 kWh/year
Renewable Penetration: ~45–50%	**Operation:** Fully grid-tied; production drops after solar peak hours

Economic Comparison

System A (HOMER Model)	System B (SAM)
Capital Cost ≈ 1,112,188 SAR	Capital Cost ≈ 3,595,187 SAR
Annual Savings ≈ 76,372 SAR	Annual Savings ≈ 193,672 SAR
Payback Period ≈ 14–15 years	Payback Period ≈ 12.9 years

- **Advanced Financial Metrics: NPV & IRR:** Both systems yield positive NPVs; System B exhibits a higher IRR due to greater absolute savings despite higher capital investment.
- **Sensitivity:** System B—though having higher upfront costs—demonstrates stronger sensitivity to increased grid tariffs and lower O&M costs.

Environmental

System A (HOMER Model)	System B (SAM)
Approximately 232,000 kg CO_2 reduced per year.	Approximately 2.81 million kg CO_2 reduced per yea.

Future Work

- Real-Time Data Analytics and IoT Integration.
- Comprehensive Life Cycle Assessment and Environmental-Economic Modeling.
- AI-Driven Energy Optimization and Predictive Management.

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