Grid-Independent Solar Powered Golf Resort

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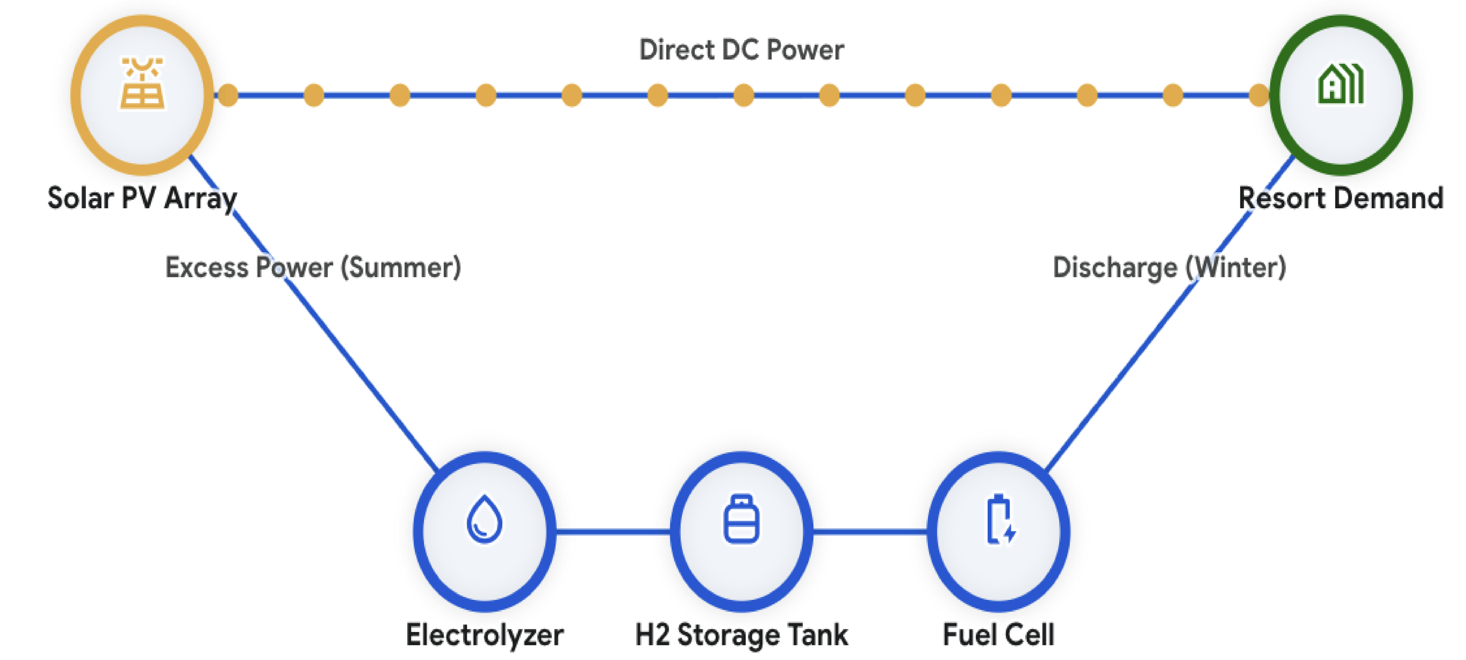
Introduction & Objectives

Project Scope: This project proposes the design of a luxury, self-sustaining, off-grid golf resort in Fort Worth, Texas. The development includes an 18-hole course, a 15,000 sq. ft. commercial clubhouse, and 40 residential guest villas (4 occupants per unit).

Objective 1 (Technical Sizing & Simulation): Design a 100% solar-powered microgrid capable of surviving worst-case Texas winter irradiance using seasonal Green Hydrogen (H_2) storage [9]. System requirements are calculated against a dynamic hourly load profile derived from GCSAA [1] and EIA [2] [3] consumption data, specifically isolating heavy loads (e.g., reclaimed water irrigation pumping) to zero-irradiance nighttime hours.

Objective 2 (Economic Optimization): Conduct a techno-economic parametric study to evaluate the "Energy Transition Elasticity Coefficient" [9]. By comparing a standard-efficiency baseline against ultra-high-efficiency building upgrades, this study quantifies the exact financial breakeven point between investing capital in microgrid generation infrastructure versus demand-side energy conservation.



System: The system stores excess power for night operations (irrigation, cart charging, nighttime housing operations) as well as winter months when solar irradiance and power generation declines. This creates a large hydrogen storage system requirement.

Load Profile & Methodologies

Baseline Demand: Energy consumption profiles were established using the Golf Course Superintendents Association of America (GCSAA) [1] and the U.S. Energy Information Administration (EIA) surveys for commercial [2] and residential [3] buildings. Total project costs include both microgrid hardware benchmarks [4][5] and architectural premiums. Scenario 2 utilizes a 6% Zero-Energy Ready premium [6], while Scenario 3 applies a 12% Passive House premium [8] to a baseline construction cost of $500,000 per villa.

Time-of-Use Shifting: To properly stress-test the hydrogen storage system, heavy commercial loads, specifically a 26 kW irrigation pumping requirement and 10 kW golf cart fleet charging, were strictly isolated to zero-irradiance nighttime hours in both peak summer conditions and low-irradiance winter cases.

Simulation Engine: The system was sized using an 8,760-hour steady-state thermodynamic spreadsheet model [9].

Reclaimed Water System: Irrigation of the course follows standard Texas practices using a reclaimed water system [13]. 250,000 gallons requires 26 kW for 6 hours [12].

Solar Array: Array size varies based upon scenario, panel type is constant and fixed. Panels arranged in ideal orientation normal to peak spring and fall solstice irradiance [11].

Scenario One – Standard Baseline

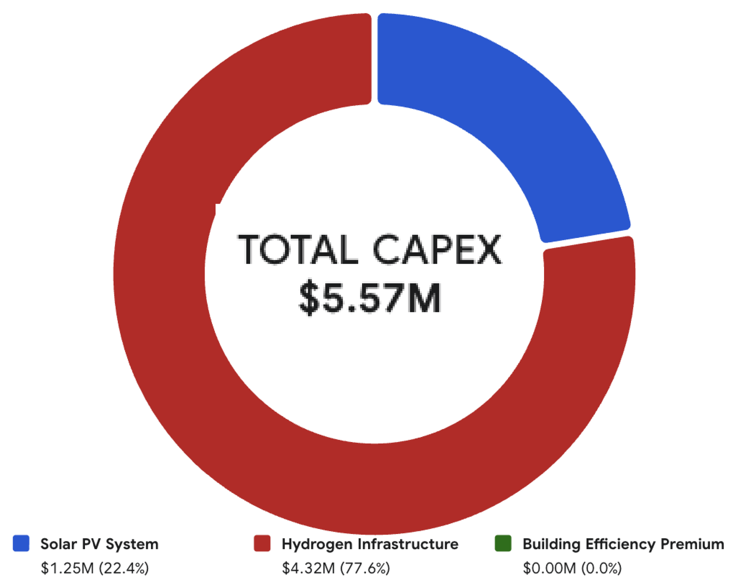
Building Specs: Standard air-source HVAC (COP A/C: 3.5), standard insulation (Conservation: 1.0).

Architectural Premium: $0

Microgrid Sizing: *Solar Array:* 3,342 m^2 (837 kW capacity)

Max H_2 Storage [10]: 125,382 kWh (3,765 kg of compressed gas)

CapEx Cost [4][5]: *$5.57 Million*



Scenario Two – Highly Efficient

Building Specs: Geothermal Heat Pumps (COP A/C: 6.5) [7] and strict thermal envelopes (Conservation: 0.5).

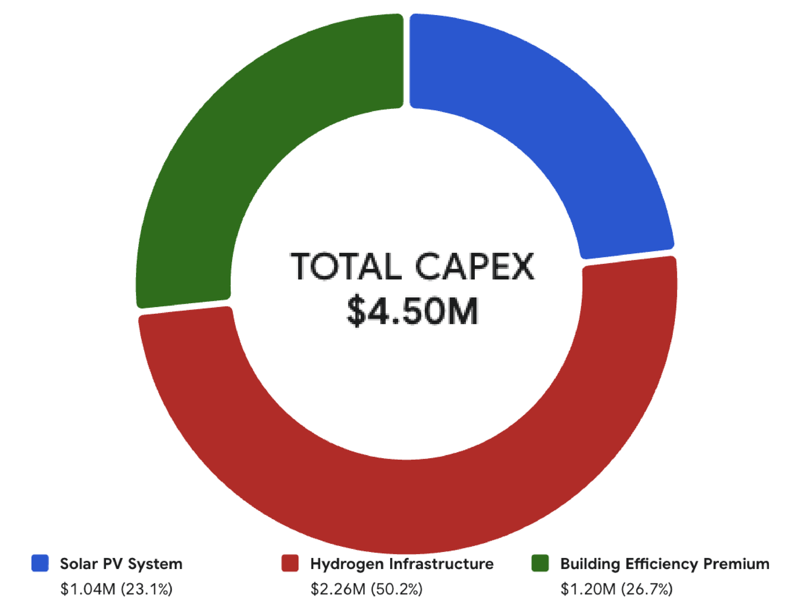
Architectural Premium [6]: $1.20 Million ($30,000 per villa).

Microgrid Sizing: *Solar Array:* 2,760 m^2 (691 kW capacity)

Max H_2 Storage [10]: 47,025 kWh (1,412 kg of compressed gas)

CapEx Cost [4][5]: $3.30 Million (Microgrid)

Total Project Cost: *$4.50 Million*



Scenario Three – Ultra High Efficiency

Building Specs: Passive House (PHIUS) standard with Energy Recovery Ventilators (COP A/C: 9.0, Conservation: 0.4).

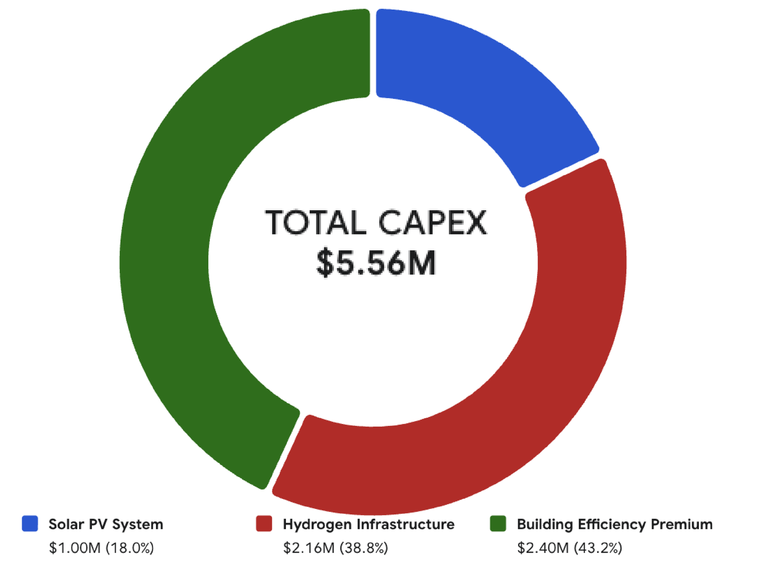
Architectural Premium [8]: $2.40 Million ($60,000 per villa).

Microgrid Sizing: *Solar Array:* 2,673 m^2 (669 kW capacity)

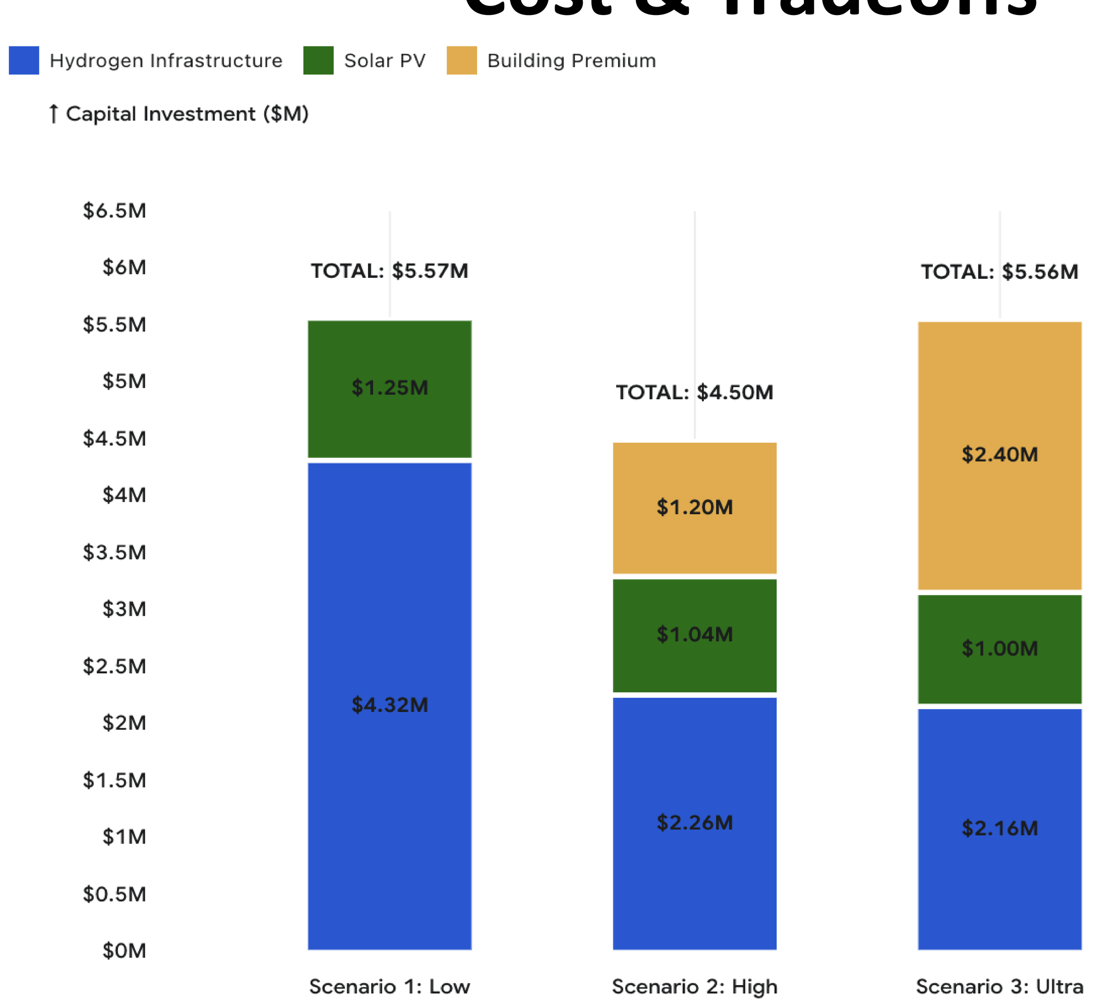
Max H_2 Storage [10]: 42,700 kWh (1,282 kg of compressed gas)

CapEx Cost [4][5]: $3.16 Million (Microgrid)

Total Project Cost: *$5.56 Million*



Cost & Tradeoffs



Solar PV Generation: Modeled at **$1.50/W**, derived from the NREL U.S. Solar Photovoltaic Cost Benchmark for commercial ground-mount systems, inclusive of turnkey balance-of-system (BOS) and labor costs [4].

Hydrogen Infrastructure: Modeled utilizing U.S. DOE Hydrogen Strategy commercial targets [5]. Proton Exchange Membrane (PEM) Electrolyzers and Fuel Cells were priced at an aggregate **$1,500/kW**. Stationary Type-IV compressed gas storage (350-bar) was priced at **$750/kg** of required storage mass.

Discussion & Conclusion

The Big Win: Upgrading the 40 villas to Geothermal HVAC and strict conservation (Scenario 2) eliminates the need to generate and store over 78,000 kWh of seasonal hydrogen, shrinking the microgrid CapEx by $2.27 Million compared to the baseline.

The Economic Optimum: When factoring in the $1.20 Million architectural premium to upgrade the buildings, Scenario 2 still nets a *$1.07 Million total project savings*.

Conclusion: The parametric study proves the "Energy Transition Elasticity Coefficient" [8] is non-linear. Moderate end-use efficiency is a strict economic prerequisite for hydrogen microgrids, successfully offsetting low round-trip efficiencies. However, extreme efficiency (Scenario 3) hits severe diminishing returns where architectural premiums outweigh the marginal infrastructure savings.

References

[1] Golf Course Superintendents Association of America (GCSAA). (2015). *Phase II Golf Course Environmental Profile: Energy Use and Energy Management Practices.*

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[4] National Renewable Energy Laboratory (NREL). (2022). *U.S. Solar Photovoltaic System and Energy Storage Cost Benchmark.*

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[6] Rocky Mountain Institute (RMI). (2018). *The Economics of Zero-Energy Homes: Single-Family Insights.*

[7] National Renewable Energy Laboratory (NREL). *National Residential Efficiency Measures Database.*

[8] Passive House Institute US (PHIUS). (2023). *Building Envelope and High-Performance HVAC Standards.*

[9] Michaelides, E.E. (2018). *Energy, the Environment, and Sustainability.* CRC Press. *(Note: Provides thermodynamic modeling, elasticity coefficients, and hydrogen Lower Heating Value).*

[10] U.S. Department of Energy (DOE) Office of Energy Efficiency & Renewable Energy. (2020). *Physical Hydrogen Storage: Compressed Gas.*

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[13] City of Fort Worth Water Department. (n.d.). *Reclaimed Water Program.* Retrieved from fortworthtexas.gov