APOLLO SOLAR

WHITE PAPER
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REMOTE ENERGY SYSTEM COSTS: SOLAR ENERGY vs DIESEL FUEL

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Capital Expense v Operating Expense:

Energy Generation Systems for locations not served by a utility electric grid often have complex cost structures. Accurate cost of energy is essential for the owners and operators of Telecommunication Towers where energy can be over 50% of the total Operating Costs. The older systems based on Diesel Generators may have a relatively low Capital Expense (CAPEX) to install, but the ongoing Operating Expense (OPEX) is very high. Solar Power has become the lowest cost alternative. Since the PV Modules have come down from $5.00 per watt to less than $0.50 per watt, pure solar energy systems deserve a new level of attention.

The challenge is to compare systems with Diesel Generators which are mostly OPEX against the Solar Energy Systems which are mostly CAPEX. The clearest method is to calculate the Total Cost of Ownership (TCO) of both alternatives on an ongoing instantaneous basis. Chart 1 below shows the Diesel Only system with initial cost of $25,000 and continuous costs for Diesel Fuel and generator maintenance (in Brown). The Solar Systems will cost $42,000 to $97,000 initially depending on the size of the Load to be powered.

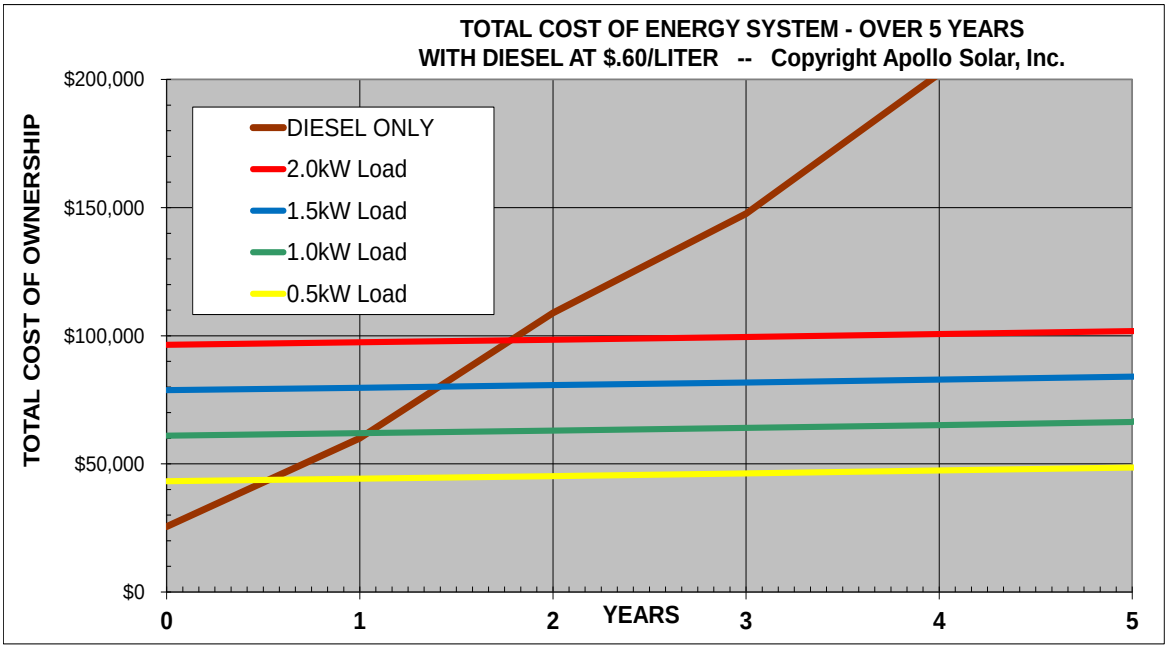

Chart 1: TOTAL COST OF OWNERSHIP - With Diesel Fuel at $0.60 per Liter.

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Number of Months to Breakeven:

The key result shown in TCO Chart 1 is the number of months to reach breakeven in costs. For example, the Red line for the Total Cost of Ownership of a Pure Solar system for a 2.0kW Load crosses the Brown line which is the TCO of the Diesel Generator at 22 months if the cost of Diesel Fuel is $0.60 per Liter. So at 22 months, a Solar system for 2.0kW of Load will pay for itself in savings from the Diesel alternative. After 22 months the Diesel Generator system will continue at the same cost of operation.

The time to breakeven depends on a number of factors. The primary factor is the price of the Diesel Fuel delivered to the site. The slope of the Brown line in Chart 1 increases with higher fuel costs. The second factor is the amount of power or the load required from the Solar system. Larger loads require more PV modules, larger battery capacity and additional charge regulators. Other factors have less of an effect on the payback period and are in the list of assumptions below.

Chart 2 below shows the results of calculations for Loads from 0.5kW to 2.0kW while varying the cost of diesel fuel. For any of these load curves, we can see that the Price of Diesel Fuel on the X-axis will determine the number of months to breakeven shown on the Y axis.

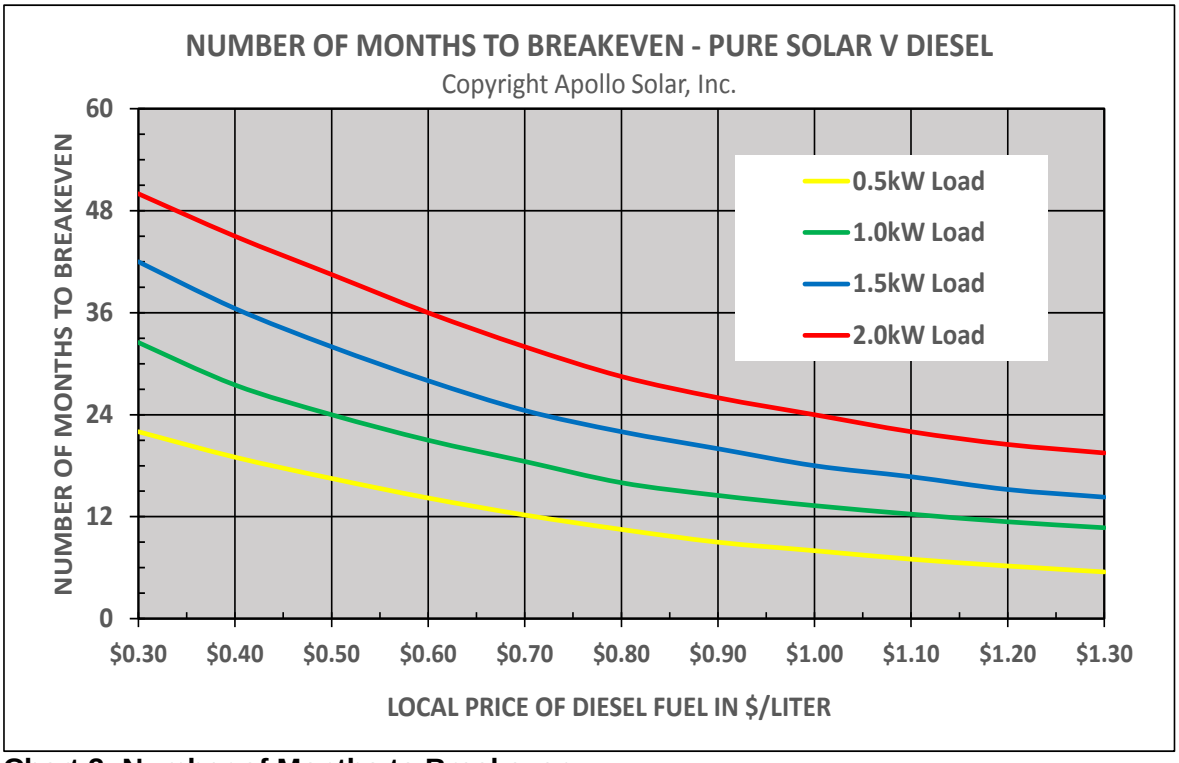

Chart 2: Number of Months to Breakeven

A 2.0kW load system will take 50 months to pay for itself if diesel fuel is $.30 per Liter while a small 0.5kW load system will pay for itself in less than 6 months if the cost of the diesel fuel is up to $1.30 per Liter. Most Energy Systems for Remote Telecom Systems will fall between these two extremes.

For full disclosure, we will point out that all Off-Grid or Remote Energy Systems depend on Batteries. The batteries are often the most costly part of the energy system and they do not last forever. All batteries have a limited number of charge-discharge cycles after which their useful capacity decreases to the point where they need to be replaced to ensure the number of days of autonomy specified for the original system. A well designed Solar energy system will extend the life of the batteries out to 6 to 10 years.

Assumptions used for the other cost factors:

The factors listed below have a 3rd order effect on the costs and therefore on the number of months to breakeven for Solar energy system against the diesel generators.

1. Fuel cost adder for delivery to remote sites: 10%
2. Cost multiplier to diesel fuel for theft of fuel: 30%.
3. Hours between Generator oil and filter changes: 250 hours.
4. Cost of maintenance visits: $200 per visit.
5. Cost to replace the Generator: $11,000.
6. Minimum Solar Irradiance used for calculations: 5.0 kWh/m^2/day
7. Number of days of autonomy: 3.0 days
8. Maximum Depth of Battery Discharge: 30%
9. Inflation affecting fuel costs: 6%

Primary Cost Factor – The Diesel Fuel:

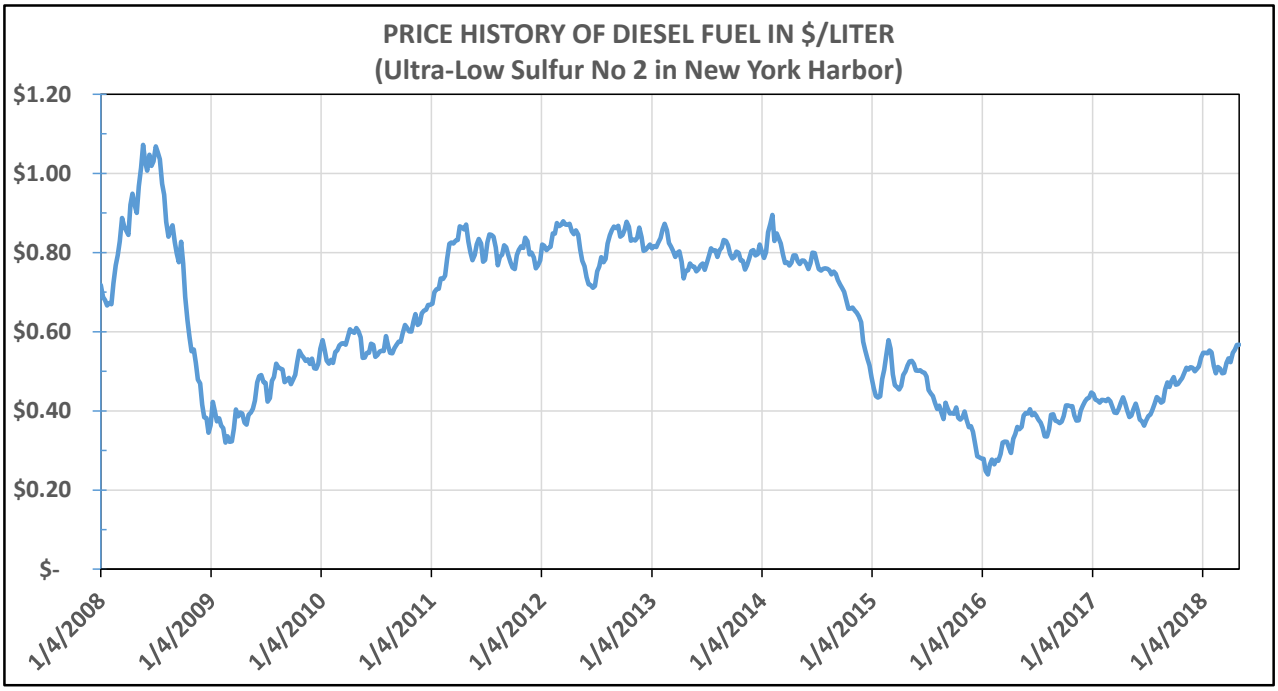

Chart 3 – Price History of Diesel Fuel - Source: U.S. Energy Information Administration

Even knowing that the future price of diesel fuel cannot be predicted, the history shown in Chart 3 above allows us to see that the price could easily vary between $0.30 and $1.00 per Liter (in New York harbor) because it has done that over the past 10 years.

The Diesel Fuel has a number of costs which add up and must be understood for any given location. Each country treats diesel fuel differently in terms of tariffs or subsidies. Refer to GlobalPetrolPrices.com/diesel_prices to find the current price in any specific country. In May 2018 the price ranged from $0.07 per Liter in Iran to $2.04 per Liter in Iceland. These numbers are generic prices "at the pump" in the port cities.

This White Paper is discussing Remote Energy System so the Telecom Tower locations are usually far from the port cities. The charge for delivery to each remote site will vary considerably. Normally the telecom site owner, or energy provider will have negotiated a contract for delivery of diesel fuel to all the remote sites. The resultant prices are not public information.

The largest factor in many countries is the amount of fuel which does NOT end up at the sites after it was paid for. The generally accepted fact is that 30% of the fuel is "lost". Telecom Tower executives have conflicting views of how to deal with this problem. There are significant costs and security concerns with many of the attempted solutions. It has been proven that when the Diesel Generator is totally replaced with a Solar Energy System, all of the fuel problems are solved because there is no longer any fuel to transport or protect.

Hybrid Solar / Diesel systems:

Happily, the modular nature of Solar PV systems allows energy systems to be designed that provide the hybrid or compromise between the CAPEX and OPEX extremes described above. Because the batteries are the largest single cost in a pure solar system and because the large batteries are required only for the occasional need for power to make it through 3 to 5 days with no solar input, it is possible to add back a small generator to cover those exceptional periods. As long as the diesel usage is just to cover the occasional need, the ongoing costs imposed by the generator can be minimized. The hybrid solution does not solve the problems with fuel delivery and theft, but it is a good step in right direction is designed properly. The optimum percentages of Solar and Diesel is beyond the scope of this white paper.

Conclusions:

1. Solar Energy is currently a cost effective solution for remote energy systems on telecom towers.

2. Solar Energy Systems have a relative high up front cost, but the high ongoing real cost of the fuel and diesel generator maintenance can pay for the installation of the Solar over a reasonable number of months.

3. Installing Solar Energy systems to replace Diesel Generators will freeze the absolute cost of the energy systems and avoid the risks imposed by the unpredictable price of the major operating cost of the energy systems.