Residential Photovoltaic Arrays

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Semester Project

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Project Objectives

- **Minimize Payback Period**
  - ❖ **Least Expensive Array**
  - ❖ **Aesthetics a concern**
- **Maximize Power Output**
  - ❖ **Limited Roof Area**
  - ❖ **Roof Orientation a concern**

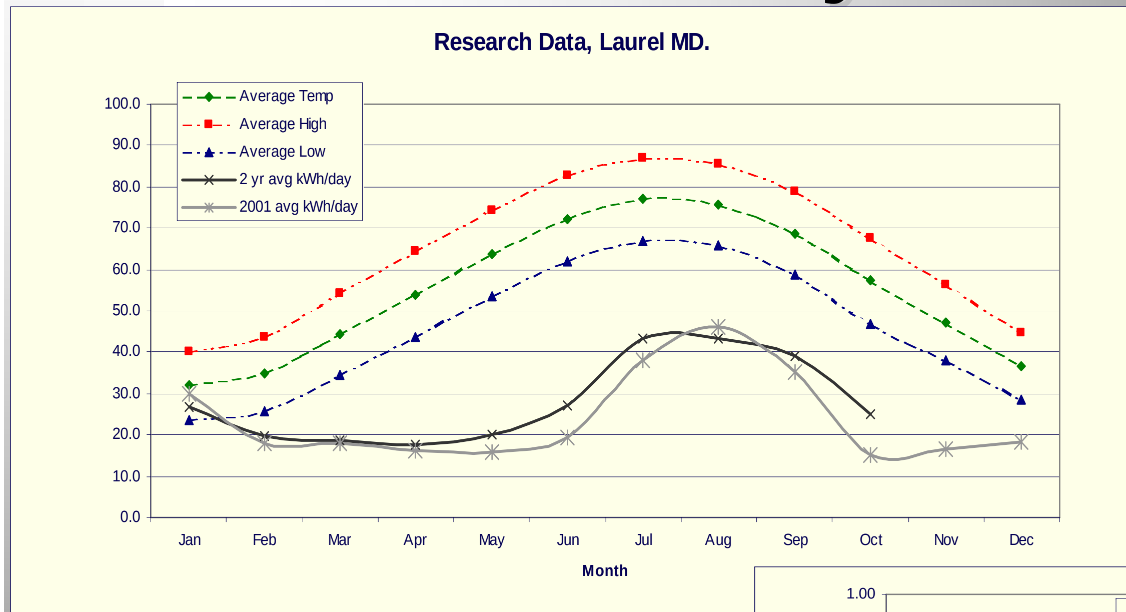
Site Description

- 2 Story Colonial Built in 1999.
- Approximately 1,990 square feet.
  - About 566 sq. ft. of usable roof area.
- Average electricity consumption 13,800 kWh/year.
- US 1997 average electrical consumption per household was 10,215 kWh/yr.

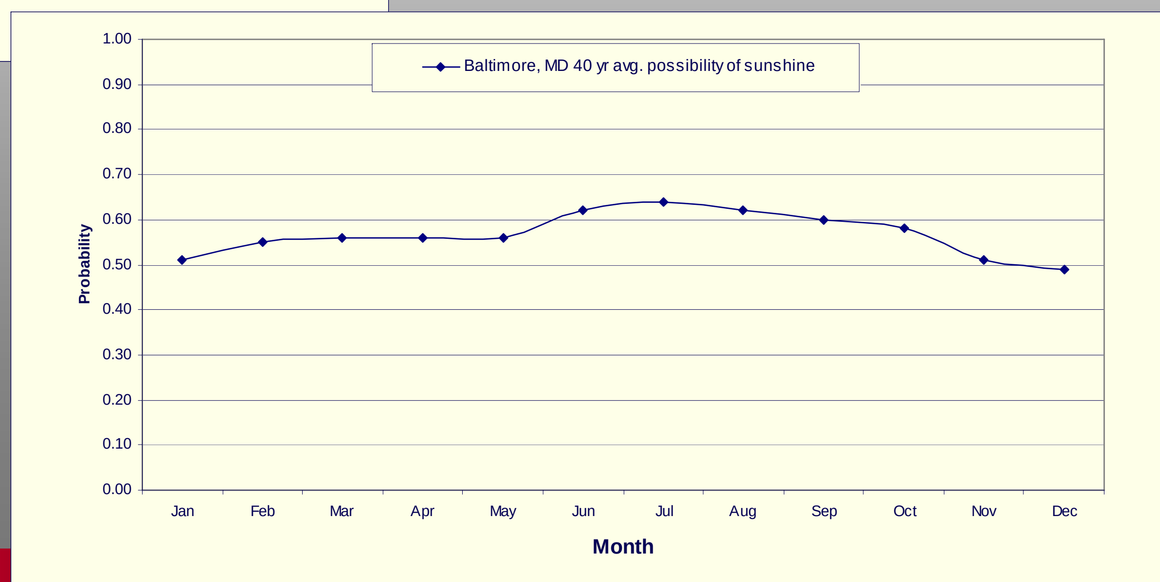
Site Description

- Roof area faces west - lots of afternoon sun. Not ideal, but still acceptable due to lack of shading.
- Electricity consumption correlates with available solar energy.

Weather Analysis



- Laurel research consists of 30 year averages.
- For the chart below, the definition of “sunshine” was not found.



Array Competitive Analysis

- **Array must be integrated into roof.**
  - **Community association covenants**
  - **Lack of suitable yard area**
- **Aesthetically pleasing**
  - **Low visual impact**
- **All PV arrays are expensive at this time.**

FOR MORE INFO...

- https://www.altenergystore.com/cart/1130?cQdmRWjo;
- http://www.cetsolar.com/architecturalssp.htm

Array Competitive Analysis

- **Raised Seam Roofing**
- **Cheapest per watt in terms of materials and labor.**
- **May not be pleasing due to industrial appearance.**
- **Comes in 64 or 128 watt sizes.**

A 1.5 kW DC system was installed on a National Association of Home Builders (NAHB) 21st Century Townhouse in Maryland. The 18-panel system is grid connected. It has a 16-kWh battery backup

Array Competitive Analysis

- Shingle type arrays
  - Larger capacity array per area
- More expensive
  - More modules
  - More labor because of additional roof penetrations and wiring issues.

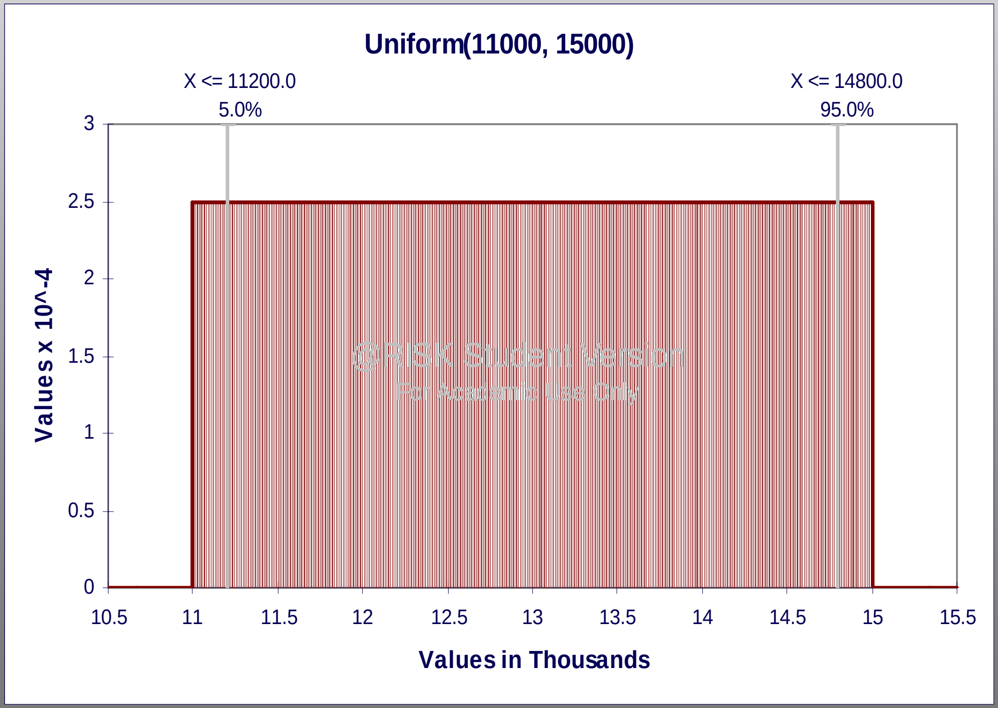
A 2.0 kilowatt DC grid-connected system operating at the Southface Energy & Environmental Resource Center in Atlanta, Georgia. The grid-connected system is configured at 48 volts DC using a 4,000 watt inverter.

Uncertainties

- Four major categories
  - Installation and materials costs
  - Power generated (reduced monthly bills)
  - Electricity Rates
  - Interest Rates

Uncertainties

- **Installation and materials cost**
  - **Called local installers to get a feel for pricing. Decided a uniform distribution between \$11,000 and \$15,000 per kW capacity adequately represented potential installation costs.**



Uncertainties

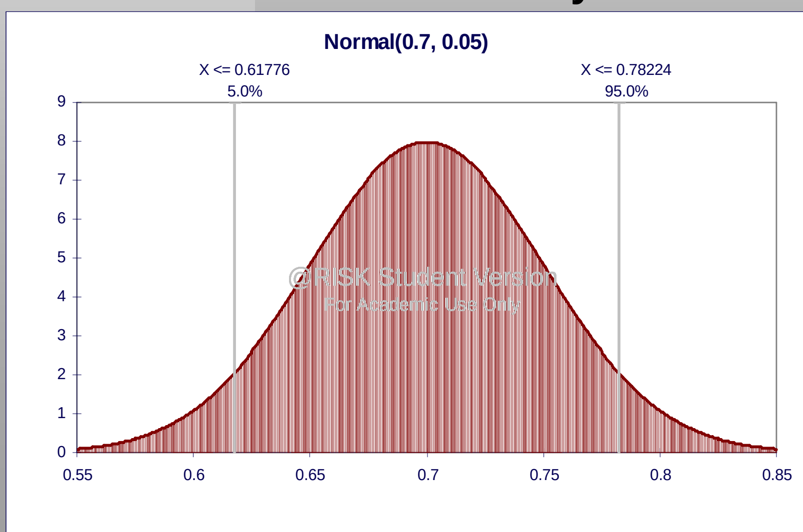
- **Power Generated**
  - **Used Department of Energy's web application "PV WATTS" to estimate electrical power generated by arrays of different sizes.**

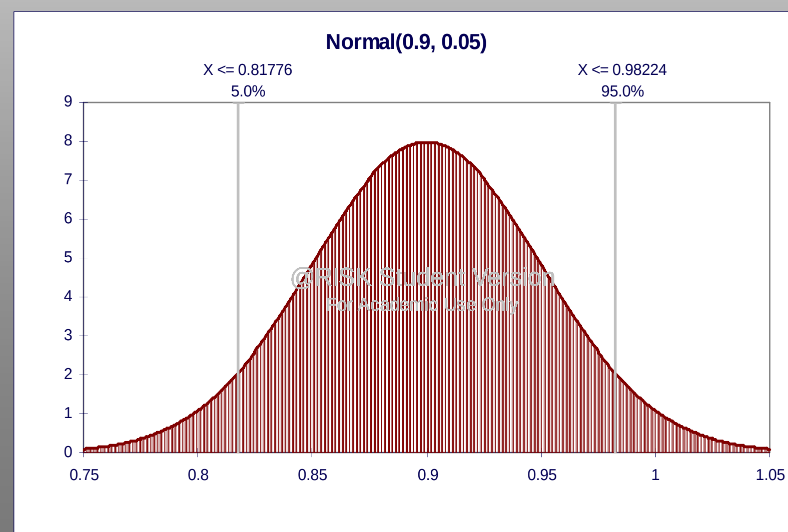
Station Identification	
Cell ID:	263375
State:	
Latitude:	39.1 ° N
Longitude:	76.9 ° W
PV System Specifications	
AC Rating	4.00 kW
Array Type	
Array Tilt:	36.9 °
Array Azimuth:	270.0 °
Energy Specifications	
UtilityCost/kWh	$0.07
UtilityCost (summer)/kWh:	$0.09

Month	***Energy (kWh)***	***Energy Value ($)***
1	228	$ 15.75
2	271	$ 18.72
3	461	$ 31.85
4	507	$ 35.03
5	580	$ 40.08
6	583	$50.76
7	585	$50.93
8	512	$44.58
9	434	$37.79
10	355	$ 24.53
11	226	$ 15.62
12	194	$ 13.40
Year	4936	$ 379.04

Uncertainties

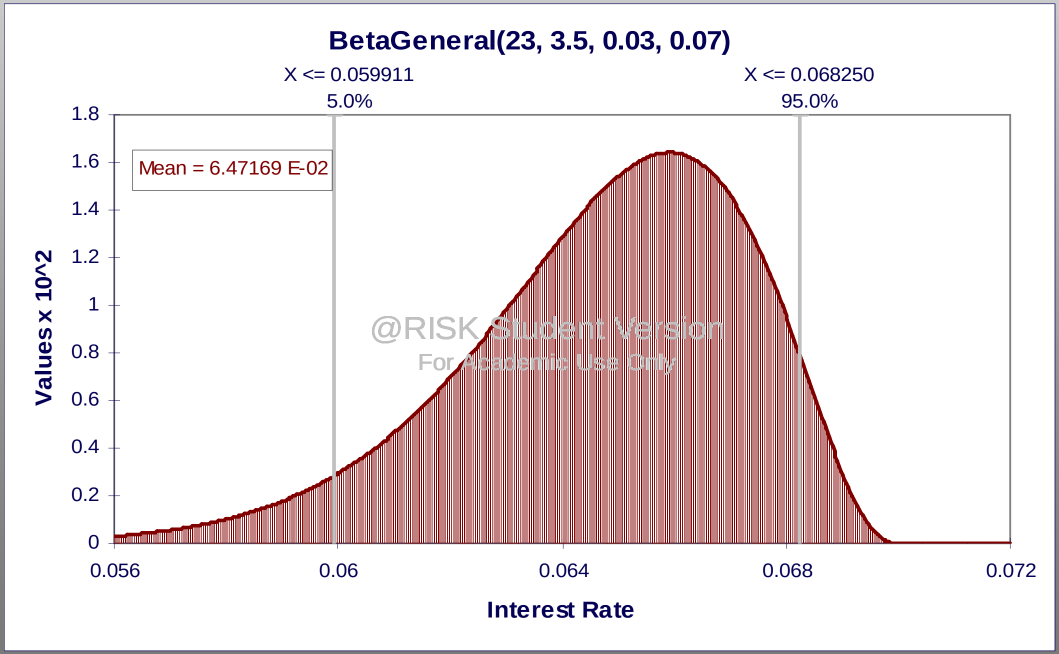
- **Electricity Rates**
  - **I collected 23 months of data for my house.**
  - **Non Summer rates averaged about $0.07/kWh**
  - **Summer Rates averaged around $0.09/kWh**
  - **I decided a uniform distribution for each rate with a mean as above and a standard deviation of 0.05 best represented my uncertainty about the electricity rates.**





Uncertainties

- **Interest Rates**
  - **The project would have to be financed.**
  - **Interest rates are currently very low.**
  - **I felt that interest rates are more likely to rise than they are to fall. I chose a beta distribution to represent my uncertainty about future interest rates.**

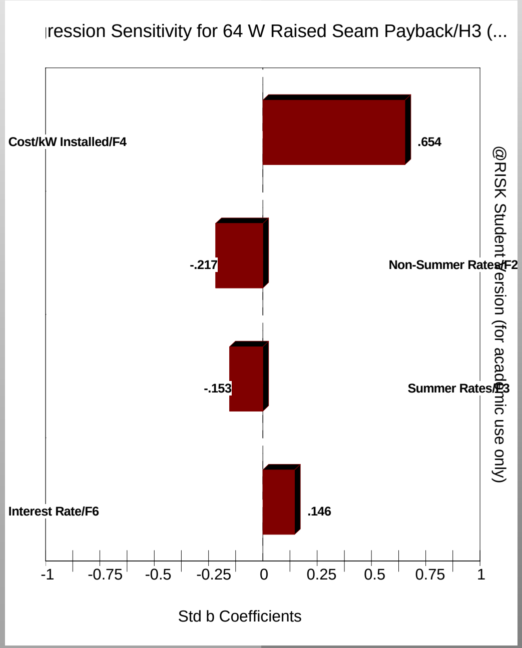


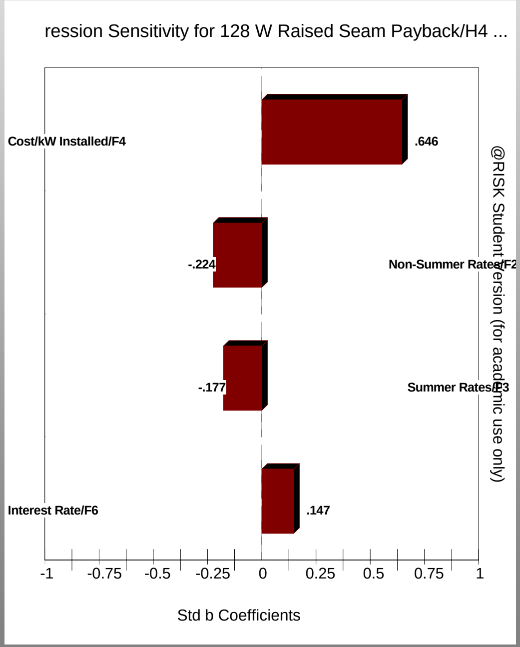
Simulation

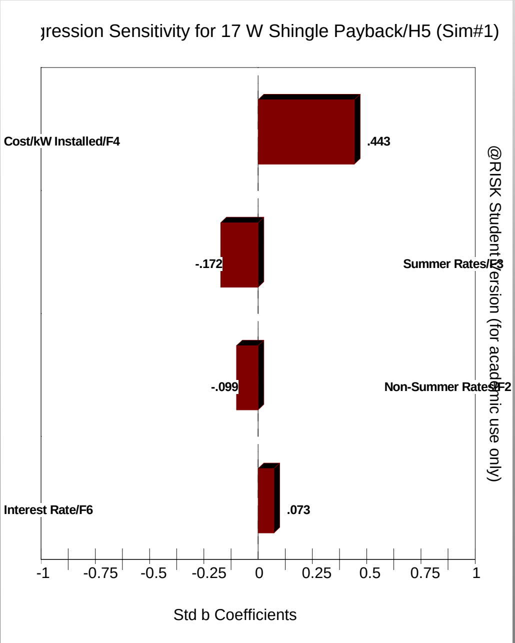
- Used @RISK to perform Monte Carlo simulation.
  - 4 different array sizes were evaluated up to 3.3 kW.
  - 5000 iterations were performed to get good convergence.
- @RISK Inputs
  - Non Summer Rates
  - Summer Rates
  - Cost/kW Installed
  - Installed Capacity
  - Interest Rate
- Also calculated array cost and payback period (Present Value).
  - Payback Equation: $PV=R*\{[(1+i)^n-1]/[i*(1+i)^n]\}$ where PV is the present value cost of the array, R is the regular payments made, i is the annual interest rate (compounded annually), and n is the number of years it takes to pay the loan.

Simulation

- **Performed Sensitivity Analysis.**
  - **In all cases, Cost/kW installed was the greatest impact on the payback period.**

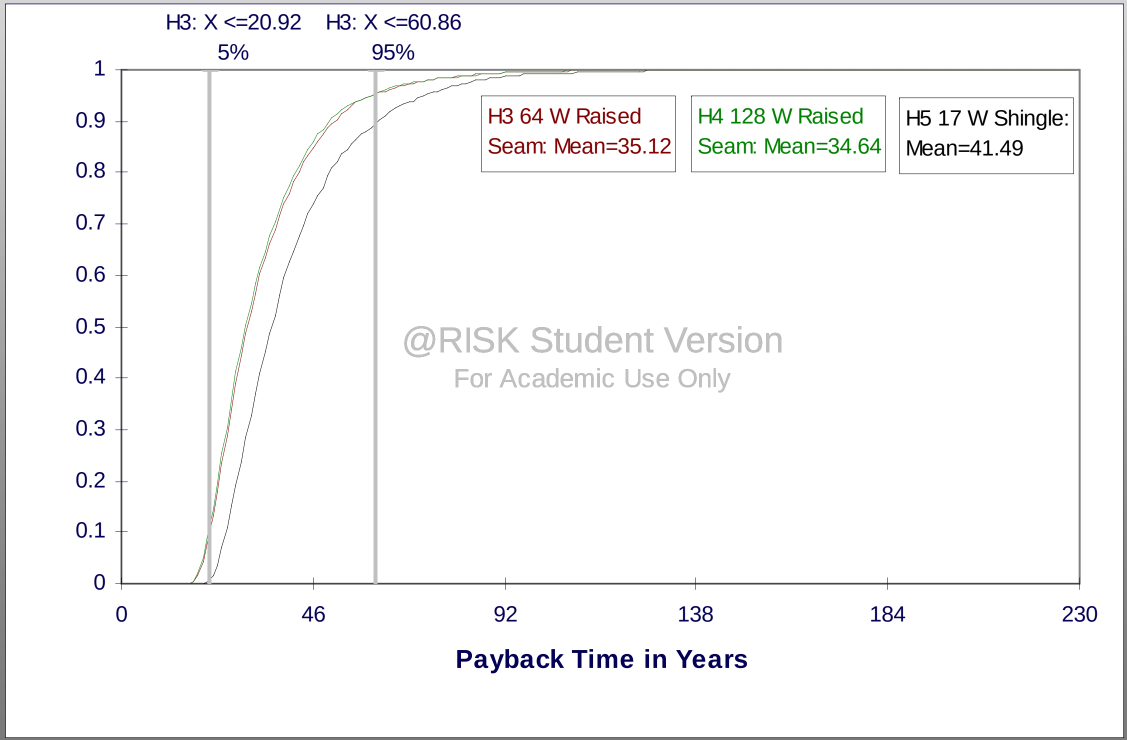






Simulation

- **Checked for Dominance.**
  - **The 128 W raised seam units dominates the simulation, as the payback period is lowest by a small margin.**
  - **Payback period remains the same within a specific unit regardless of the capacity installed.**



Conclusions and Strategy

- **Despite increasing popularity in some applications and improved manufacturing techniques, PV arrays are still VERY expensive.**
- **Installation costs for the homeowner are prohibitively high.**
- **Interest rates are not likely to drop any further.**

Conclusions and Strategy

- **Payback periods are on the order of a mortgage loan (15-30 years).**
- **Electricity costs are reasonable.**
- **PV is NOT a cost effective alternative in for the average DC Metro area homeowner.**