Alternative Power Source To Draw Underground Water

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Project Description

CEMEX

- Large aggregate mining operation located on Babbitt Ranches
- Use high volume of water for production and dust suppression
- Currently running diesel generators that must be replaced to conform to new Tier 4 EPA standards

Problem Statement Recapitulation

- The Client requests a solution that will draw water from 1700 feet while maintaining the current flow rate of 75 gal/min and reducing the overall cost.

Energies Considered

- Geothermal
  - –Lack of availability in Northern Arizona
- Biomass
  - –Associated transportation cost
- Natural Gas
  - –No readily available source
- Wind
  - –Poor resource at site

Project Selection

- Established evaluation criteria and decision matrices.
  - Solar in concert with batteries
  - Solar with diesel generator backup
  - Diesel generator that conforms to Tier 4

Solar Power in Concert with Batteries

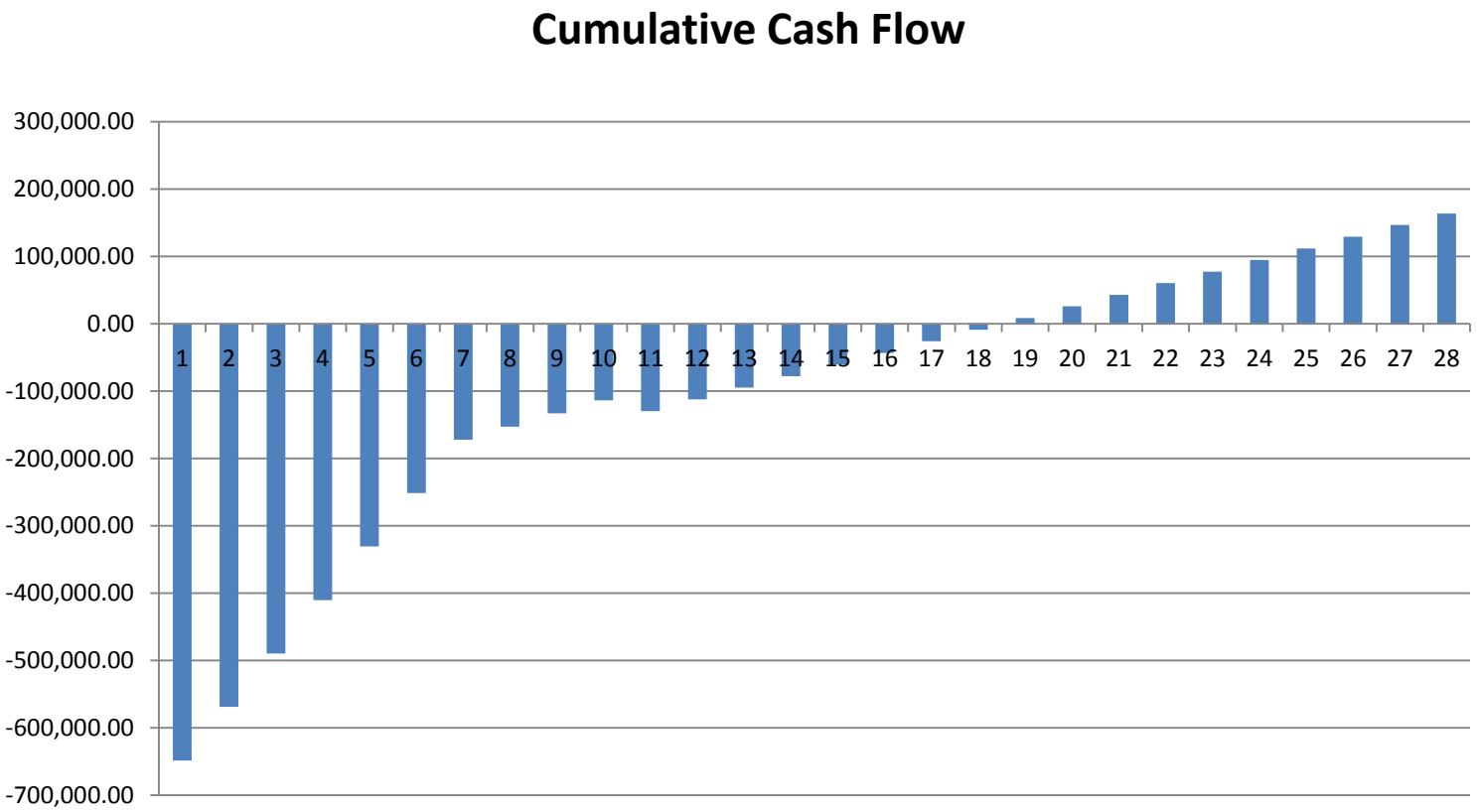
- 6 days of autonomous function
  - Recommended for systems with no backup
- 11 year maximum life
- 18 year payoff to offset diesel costs
  - Using diesel generator at maximum
- Battery array is not feasible

Solar Power with Diesel Generator

- Average cost per watt (DC) installed - $10.00

Year Of Operation	At Installation
Gross Installation Cost	-$1,000,620.00
Federal Tax Credit	$300,186.00
Annual System Maintenance	
AZ Solar Energy Production Tax Credit	$2,103.70
State Credits Corporate Rate	$50,000.00
APS Utility Rebate	$60,037.20
Inverter Cost	-$60,000.00
Tax Savings from MACRS Depreciation (5yr)	
Diesel Fuel Savings /year	
Generator Fuel Cost	
Generator Purchase	-$35,000.00
Generator Tier 4 Maintenance Program	-$5,000.00
Annual Cash Flow	-$648,293.10
Cumulative Cash Flow	-$648,293.10

Solar Power with Diesel Generator



Proposal (CEMEX)

- Solar Panels with Diesel Generator
  - $1,000,000
  - Payoff time of 19 years

- Diesel Generator
  - Cummings QSB 3.3
  - $40,000 with maintenance program

Revised Project Description

- Will be working with Babbitt Ranches
- Cedar Ranch well
- Main head waters for many locations
- Shallower Depth
- Lower flow rate

Revised Problem Statement

- The Client requests an alternative energy solution that will draw water from the Cedar Ranch well. The system must meet water demands while reducing the average annual cost of operation over a five to seven year span.

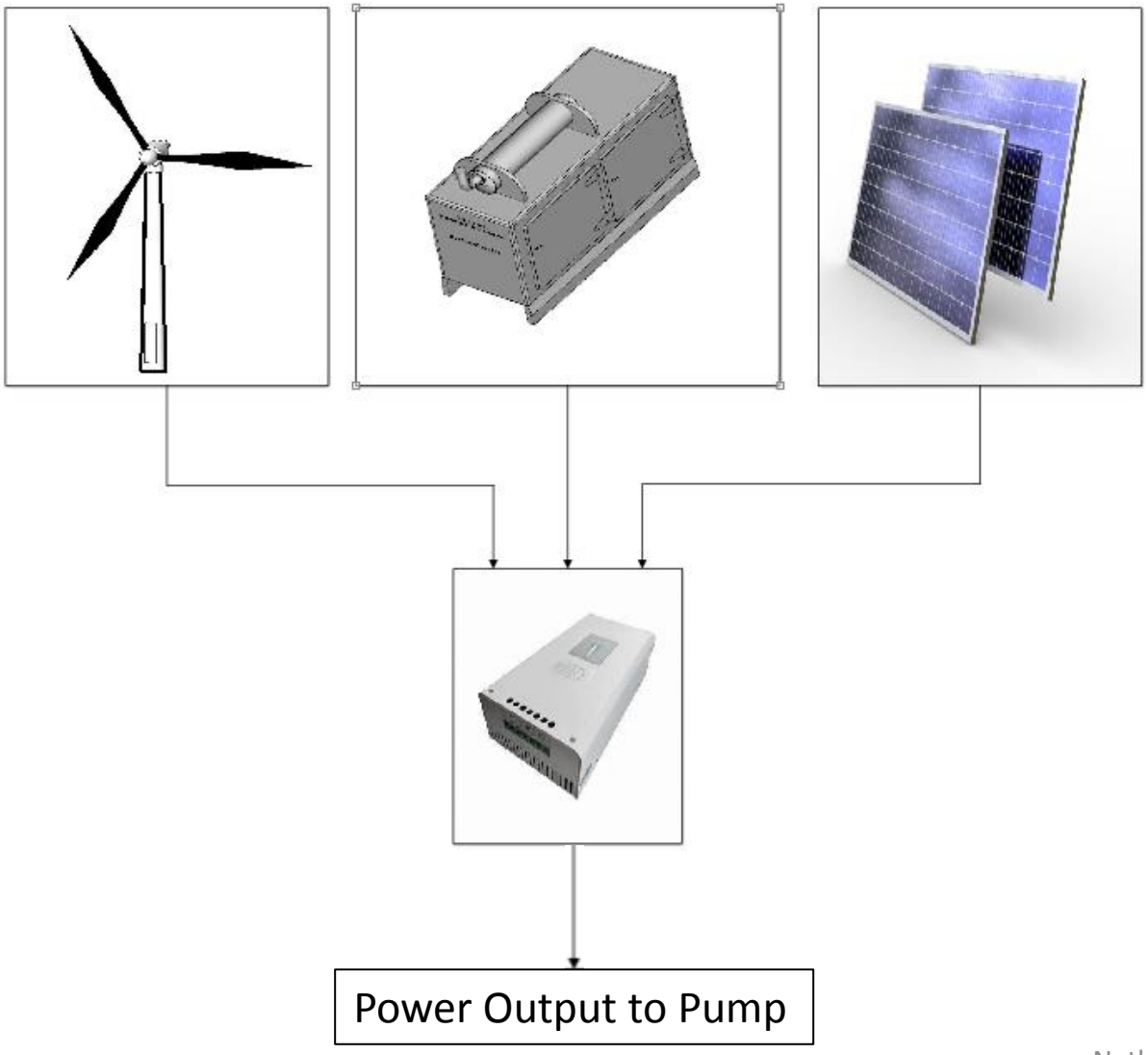
Constraints

- Well depths from 800-1200 feet
- Flow rate varies 2-12 gallons per minute
- Alternative energy must be 80%-100% of total energy used

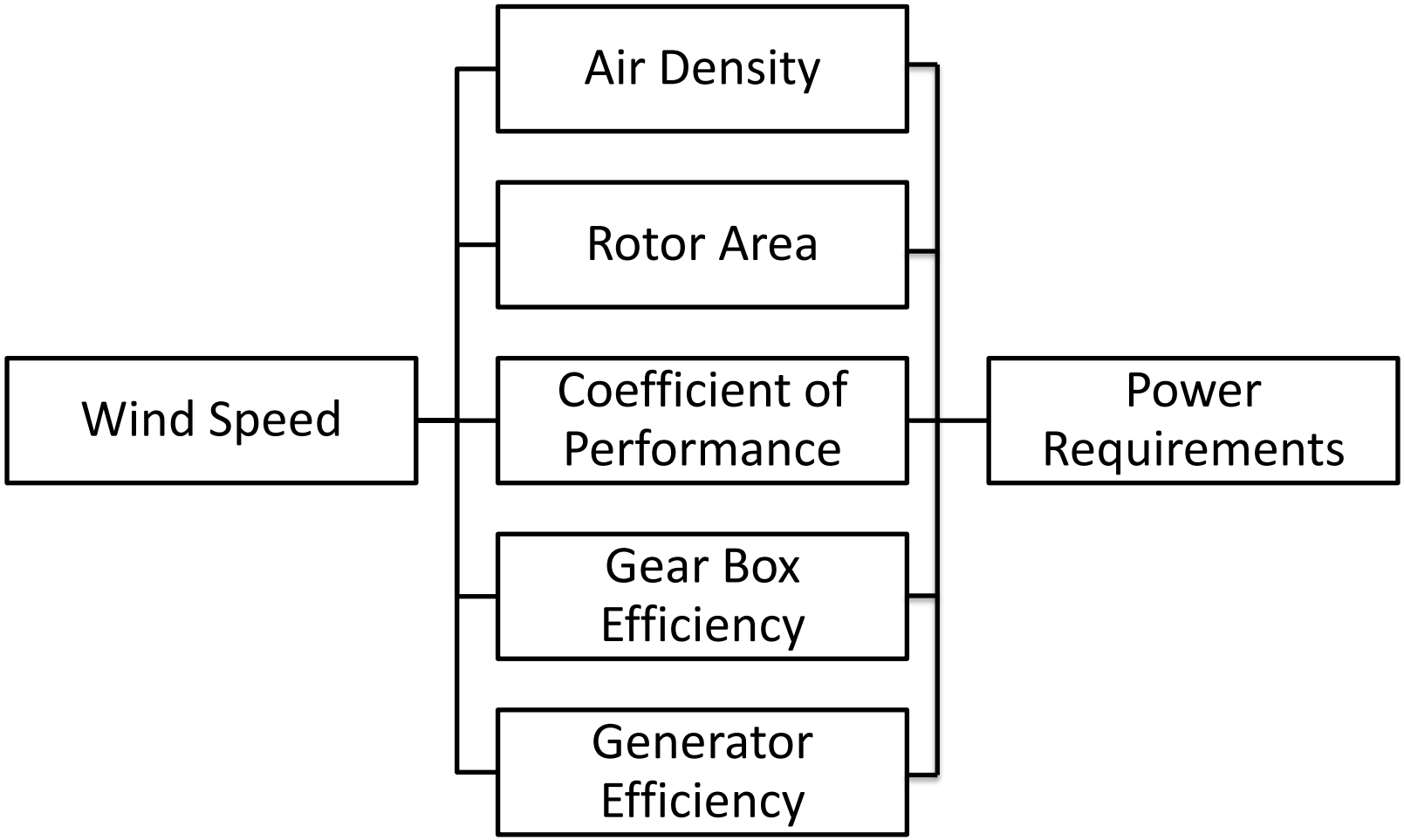
Simulink Simulation

- Input wind and solar data
- Simulate real time operation of system and various subsystems
  - Wind Model
  - Solar Model
  - Battery Model
  - Backup Generator Model
  - Controller Model

Simulation Top Layer



Wind Turbine Model



Pump Power Specifications

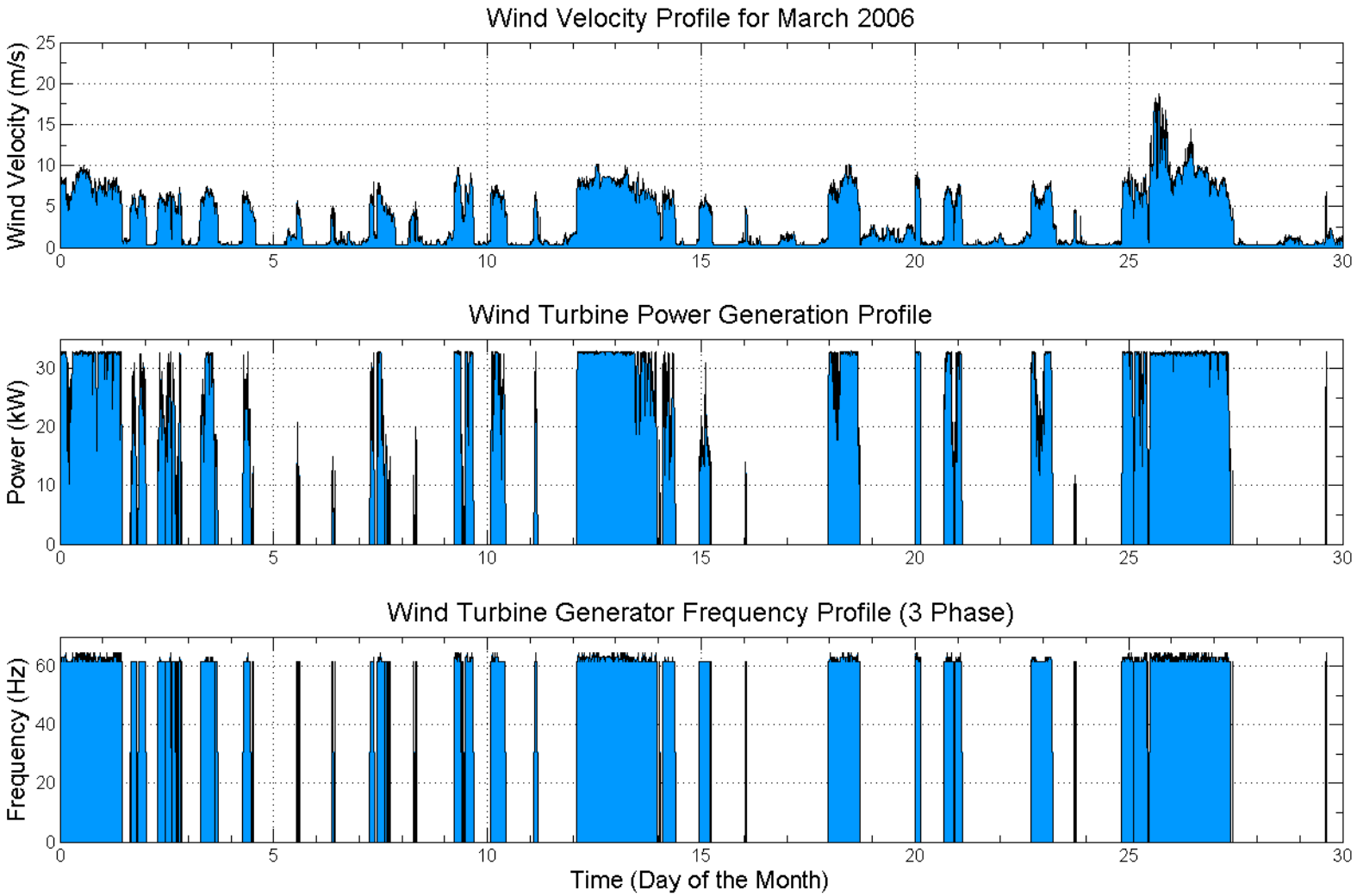
- Pump requires 3 Phase, 60 Hz, 460 V
- Generator Selection - 6 pole generator
- Generator RPM requirements - 1200 RPM
- Required gear box ratio from optimum rotor shaft RPM

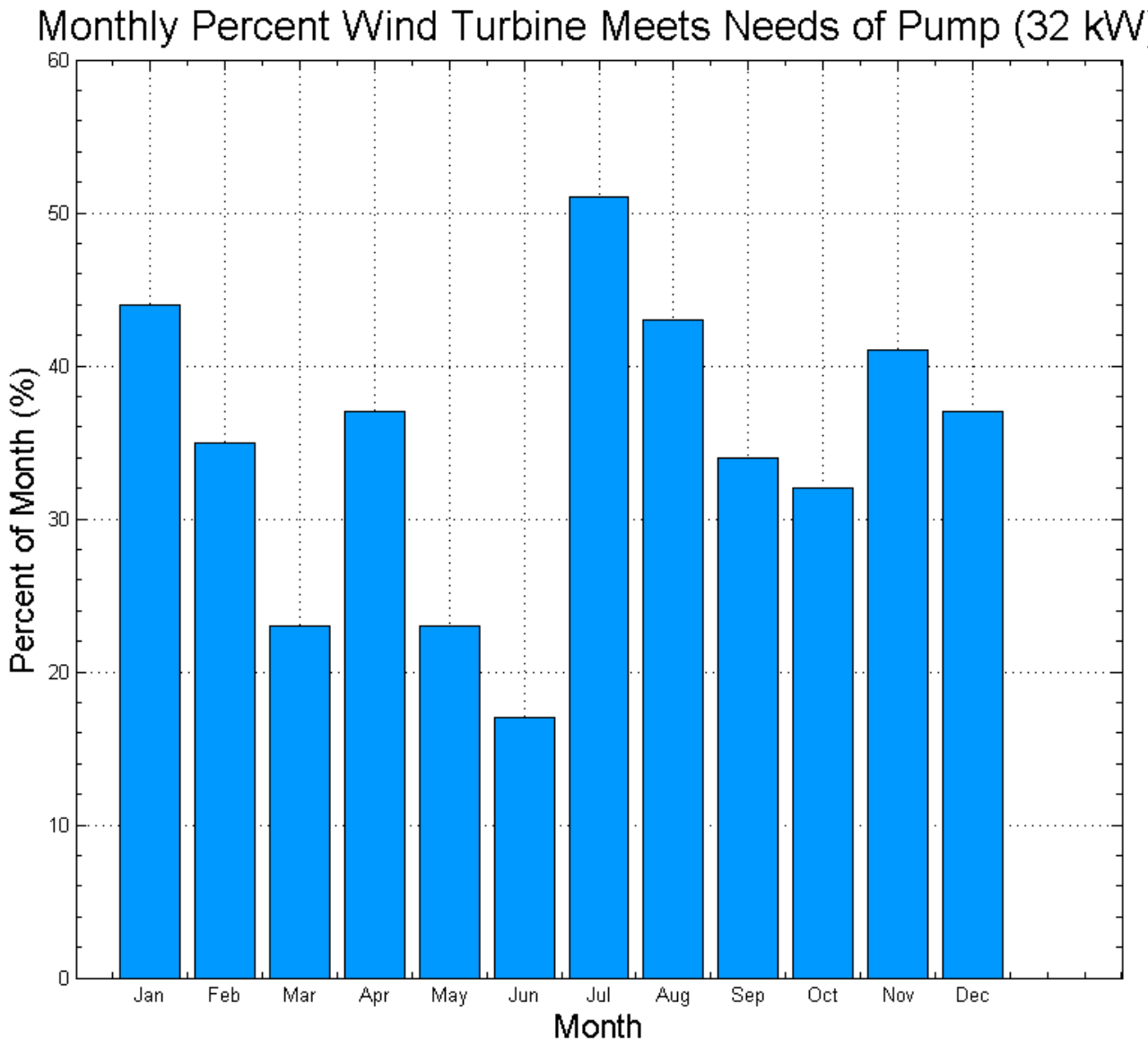
Wind Turbine System

- $P = \frac{\pi}{8}\rho D^2 v^3 \eta_{gb}\eta_{gen}C_p(\lambda, \beta)$
- Wind velocity from Mesa Butte
  - Rayleigh Distribution shows usable wind velocity average of 7.9 $\frac{m}{s}$, 73% of the time
- Rotor diameter selection: 30m

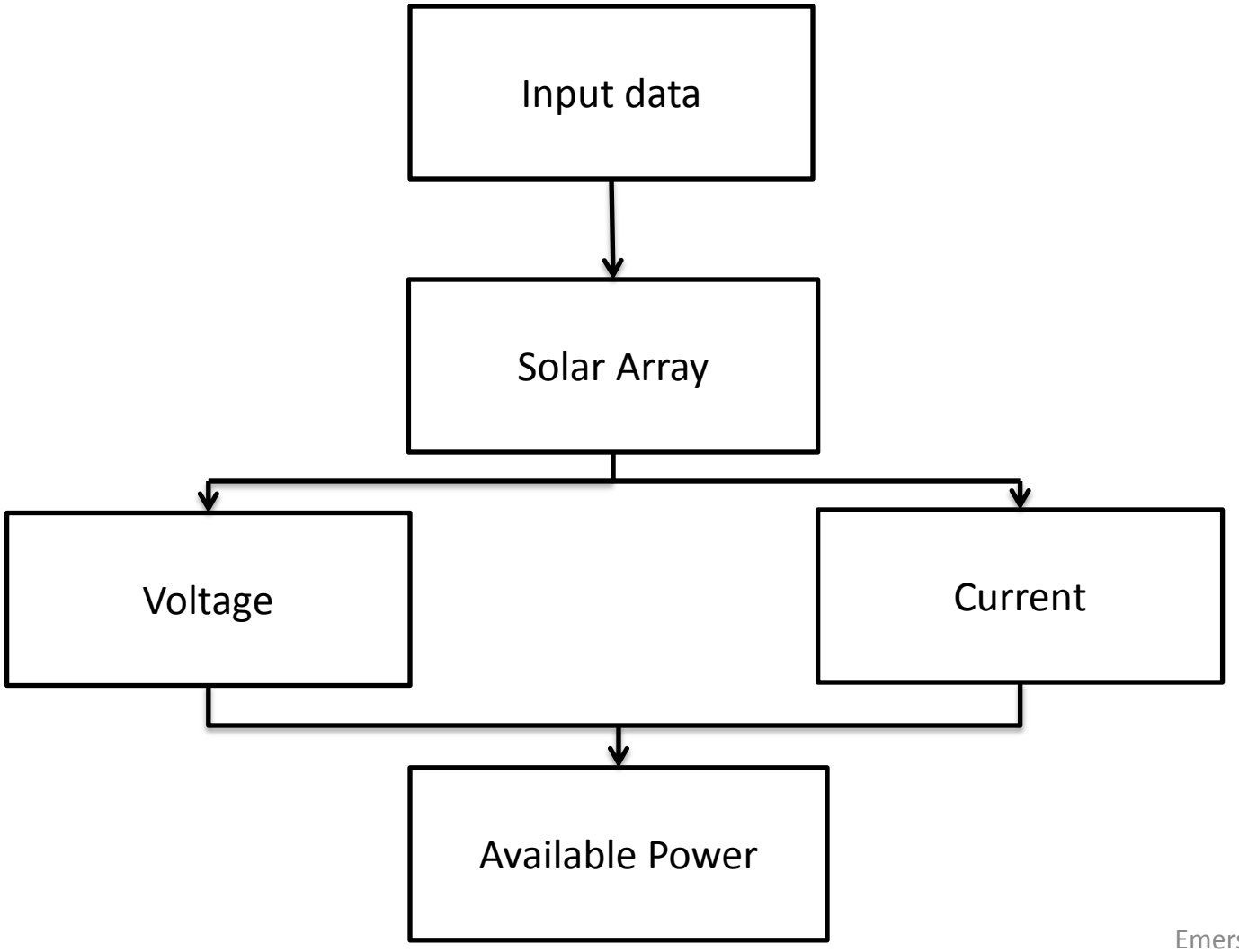
Wind Turbine Optimization

- Optimization Algorithm
  - Optimized the coefficient of performance, $C_{p,}$ by selecting the parameter values that produced $34 \pm 1\ kW$.
  - Accomplished by altering the blade angle, β, with respect to wind velocity, v, while maintaining shaft speed at $1230 \pm 30\ RPM$.


Wind Velocity Profile for March 2006
Wind Velocity (m/s)
0
5
10
15
20
25
0
5
10
15
20
25
30
Wind Turbine Power Generation Profile
Power (kW)
0
10
20
30
0
5
10
15
20
25
30
Wind Turbine Generator Frequency Profile (3 Phase)
Frequency (Hz)
0
20
40
60
0
5
10
15
20
25
30
Time (Day of the Month)


Monthly Percent Wind Turbine Meets Needs of Pump (32 kW)
Percent of Month (%)
0
10
20
30
40
50
60
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

Solar Model

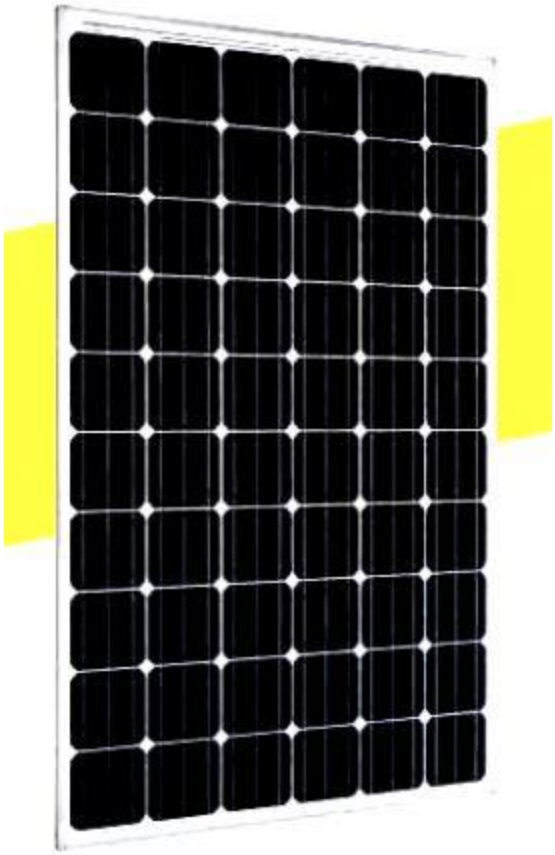


Array Specifications

- 30 x 30 Panels
  - Optimized cost vs. power production
- 900 Panels Total
- Easily changed in Simulation

Solar Panel Specifications

- SunModule 250W
  - Open Circuit Voltage: 0.63 V
  - Closed Circuit Current: 8.28 A
  - Cell Type: Mono-Crystalline
  - 14.9 % Efficiency
- Predefined Simulink solar cell



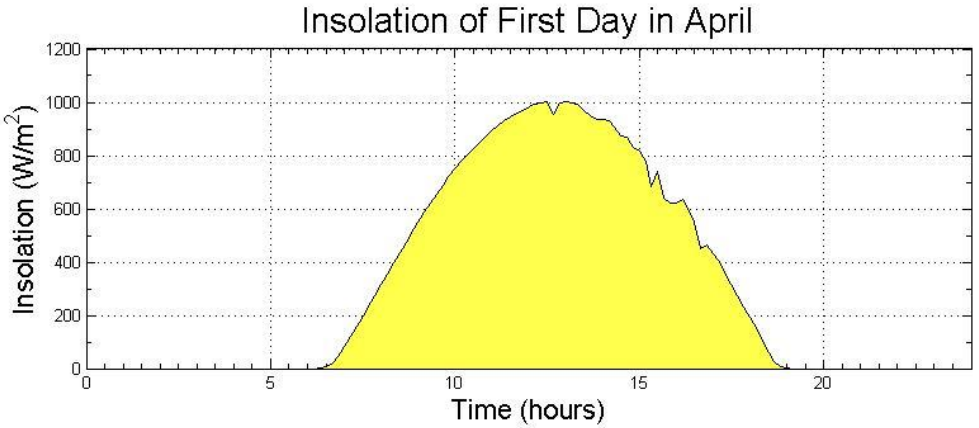
Voltage Regulation

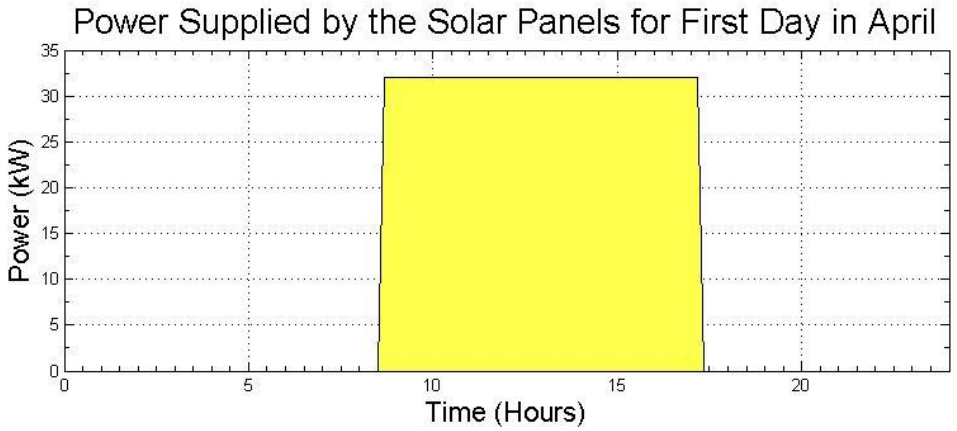
- Insolation Varies with Time
- Oversized Array
- Voltage Bucker Regulator Before Controller
  - Regulates Voltage
  - Transformer-Based Technology
  - 95% Efficiency

Solar Model Results

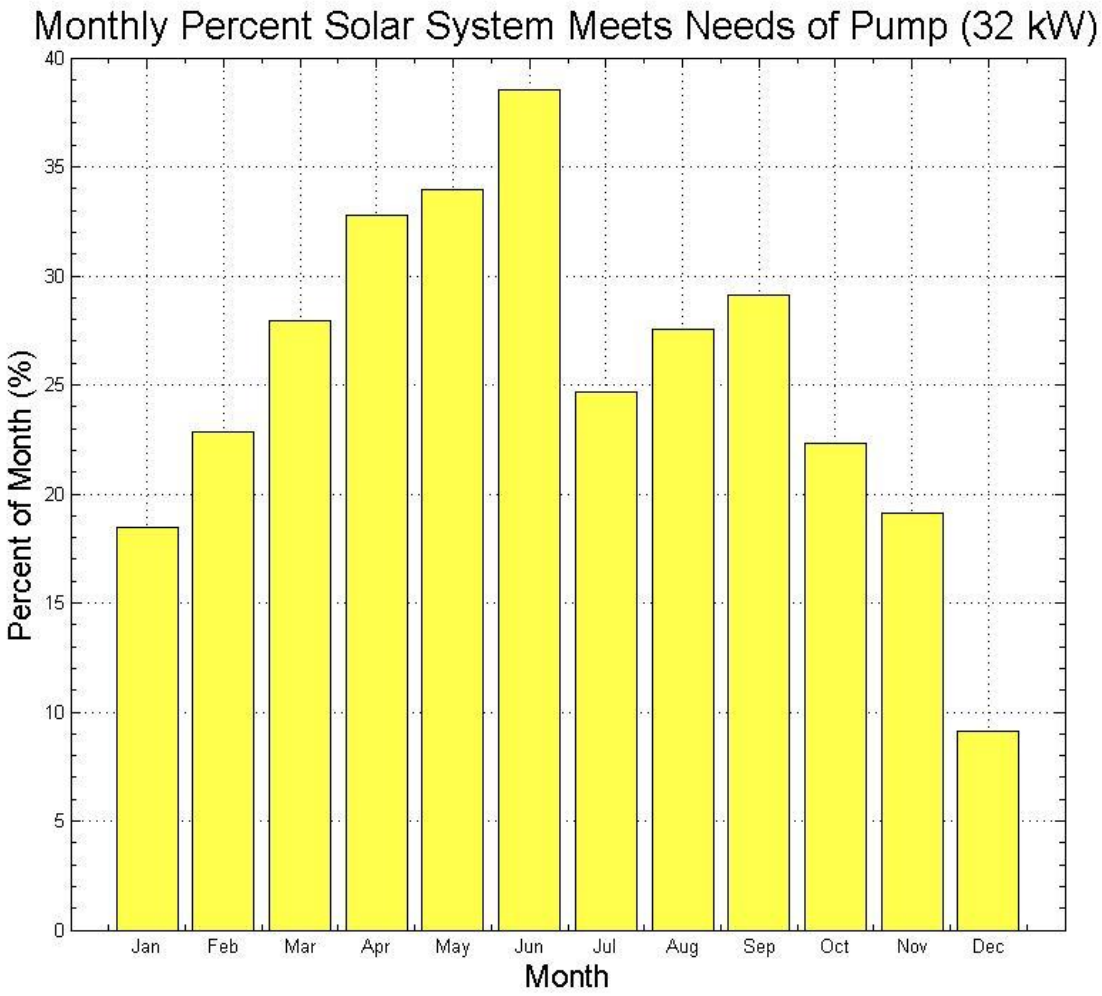
- Supplies Power to Pump if Wind Power not Sufficient
- Insolation Above 450 W/m^2
- 56 MW-hr/year

Results: Example 1





Results: Monthly



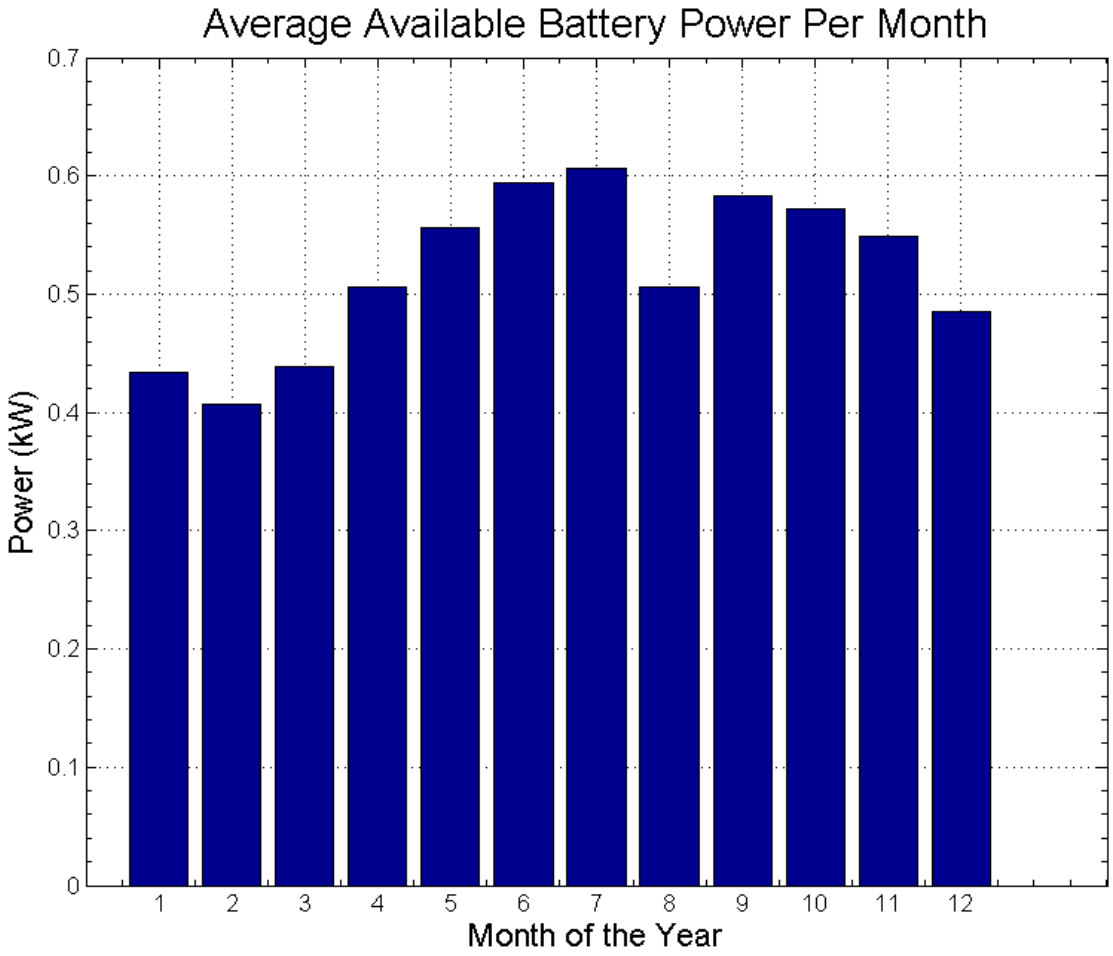
Battery Model

DC system Voltage	480V
AC Avg. Daily Load/Inverter Efficiency	
divided by DC system Voltage	1667 Ah
Days of Autonomy	1 day
Discharge Limit	0.50%
Battery Ah Capacity	1720 Ah
Battery Voltage	24V
Batteries in Parallel	2 Batteries
Batteries in series	20 Batteries
Total Batteries	40 Batteries

Battery Model

- Uses unused Solar Power
  - When wind or generator are power source
  - Extra power from Solar Model

Battery Model Results



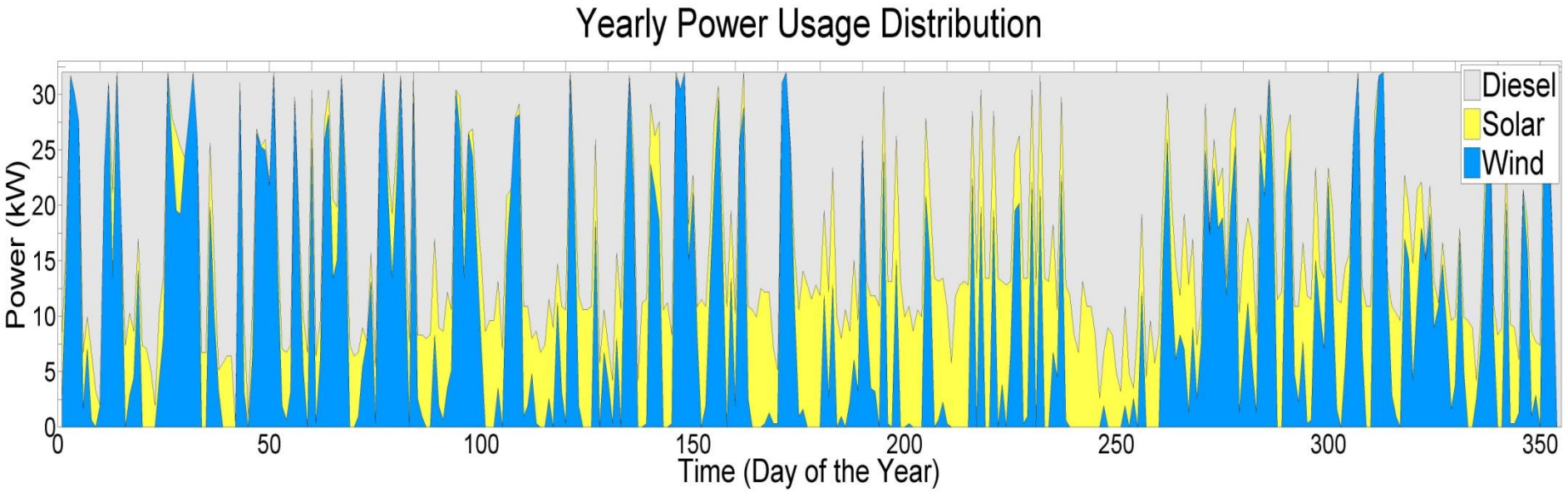
Battery Model Conclusion

- In order to get 32 kW Power from the Batteries the solar array needs to be increased significantly
- Current total cost just for the Batteries is $6800/Battery, which gives a total of $272000

Controller Model

- Reads outputs from solar and wind models
- Selects sufficient power source to meet demand
- Sets priority on wind, then solar
- Defaults to generator power if alternative power is insufficient

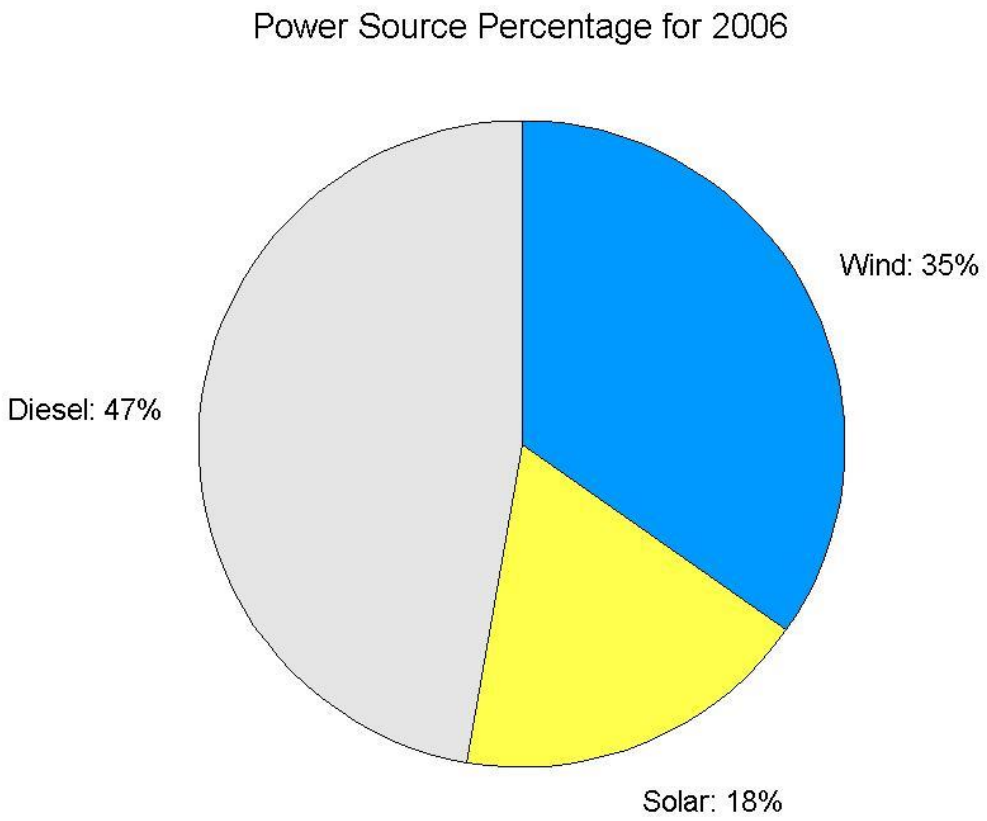
Simulation Output



Analysis

	Wind (%)	Solar (%)	Diesel (%)	Diesel Saved (%)
Jan	44	11	45	55
Feb	35	17	48	52
Mar	23	20	56	44
Apr	37	20	42	58
May	23	25	52	48
Jun	17	32	51	49
Jul	51	17	33	67
Aug	43	18	38	62
Sep	34	20	45	55
Oct	32	14	55	45
Nov	41	11	49	51
Dec	37	10	53	47
Avg	35	18	47	53

Analysis



Conclusion

- Created a simulation that optimized power produced by alternative energy
- Created flexible model to handle variable conditions and display important information
- Showed that the system would save 53% on current fuel consumption

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Questions?