EDIN
Energy Development in Island Nations
U.S. Virgin Islands

HOMER Analysis & Integrating Renewables into the Grid

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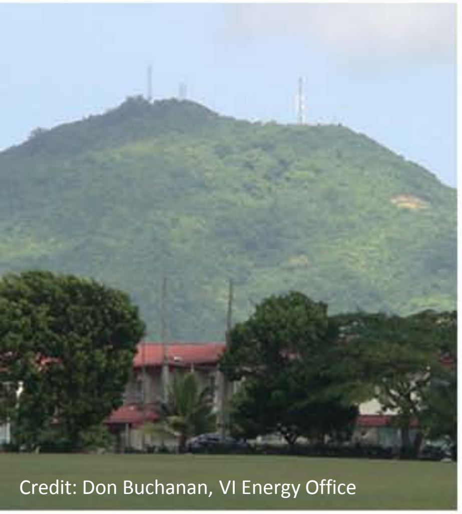
Credit: Don Buchanan, VI Energy Office


Credit: Don Buchanan, VI Energy Office


Credit: Warren Gretz, NREL

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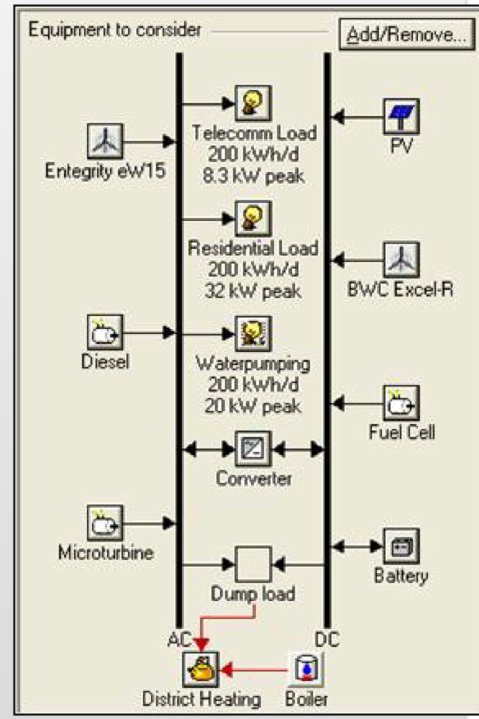
HOMER Overview

A tool for comparing and evaluating hybrid-power systems for technical and economical feasibility

- What is the most cost-effective mix of RE & fossil fuel generation?

HOMER uses simulation, optimization, and sensitivity analysis to:

- Find the lowest life-cycle cost generation mix
- Explore how optimum mix changes with different assumptions

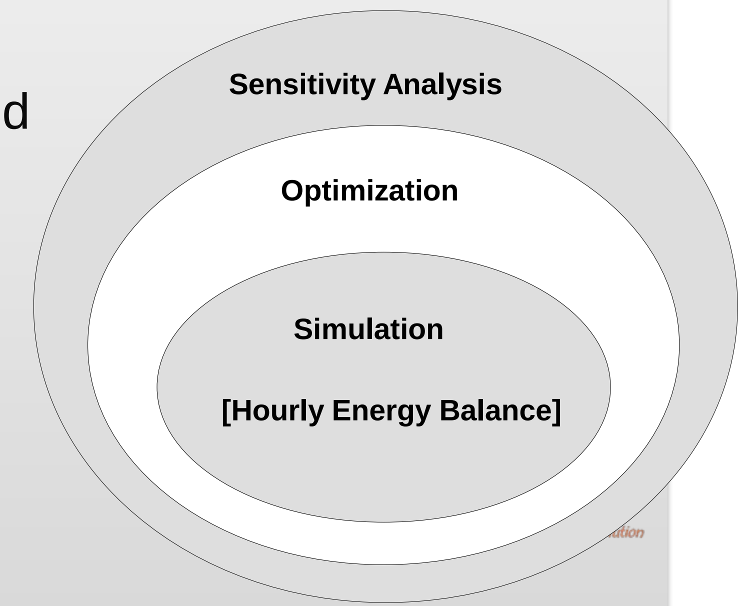


Double click on a system below for simulation results. Categorized Overall Export... Details...

PV (kW)	1.5sl	CoGen (kW)	Gen2 (kW)	Conv. (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	CoGen (hrs)
	3	7500	2200		1000	$ 9,000,000	13,068,830	$ 176,063,5...	0.278	0.65	19,171,...	8,760
		7500	2200		1000	$ 0	20,791,870	$ 265,789,8...	0.420	0.00	29,180,...	8,760
120...	2	7500	2200	1970	1000	$ 967,556,...	28,091,176	$ 1,326,655...	2.096	0.92	19,200,...	8,760
120...		7500	2200	4800	1000	$ 963,792,...	30,226,336	$ 1,350,185...	2.134	0.87	21,958,...	8,760

HOMER Modeling Tool – Overview

- **Simulation**
  - Estimate the cost and determine the feasibility of a system design
    - Compare the energy supply and demand for every hour of the year
    - Decide how to operate dispatchable sources (generators, battery, grid)
- **Optimization**
  - Simulate each system configuration and sort by net present cost (NPC)
- **Sensitivity Analysis**
  - Perform an optimization for each sensitivity variable

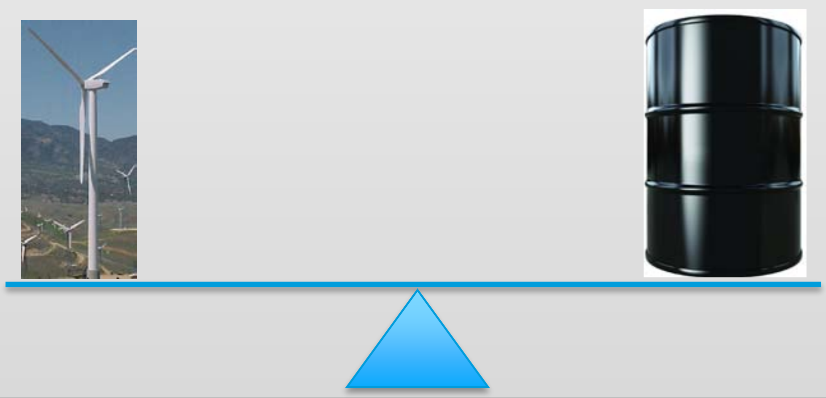


Levelized Cost of Energy (LCOE)

- The LCOE is an evaluation of **the life-cycle energy cost** and **life-cycle energy production**

- LCOE allows for ‘apples to apples’ comparisons of **alternative technologies**

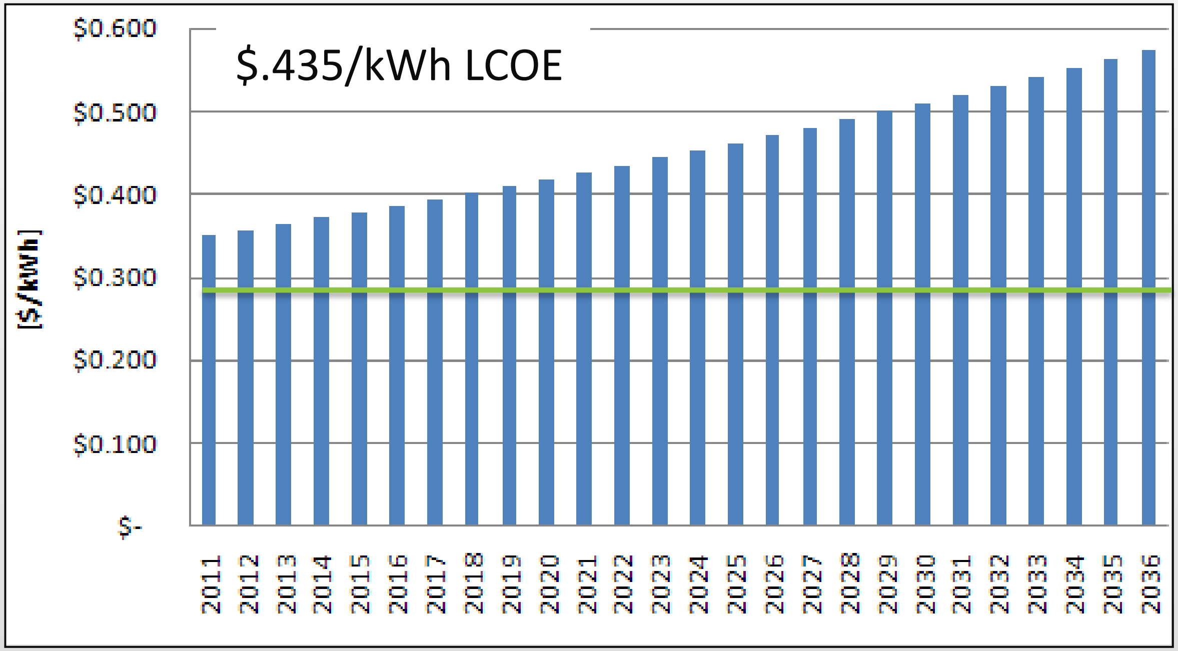
- LCOE is reported in $/kWh. It captures:
  - Capital costs
  - Operations and maintenance costs
  - Fuel costs
  - Electricity production



LCOE

Retail Electricity Example

- Assume $0.35/kWh today (2% increase/yr)
- LCOE = $.435/kWh over 25 years



NOTE: Crystal ball required. This is why sensitivity analyses are done. And this is why RE systems are often call a hedge against future energy costs.

Modeling Renewable Energy in USVI

St. Croix

- Modeled current system (before and after heat recovery steam generators)
- Modeled system with proposed 16 MW waste-to-energy (WTE) plant

St. Thomas

- Modeled current system

Renewables

- Up to 5 MW of solar PV on each system
- Up to 15 MW of wind on each system

HOMER analysis determined lowest cost generation mix for each island separately (final report to WAPA due May 1)

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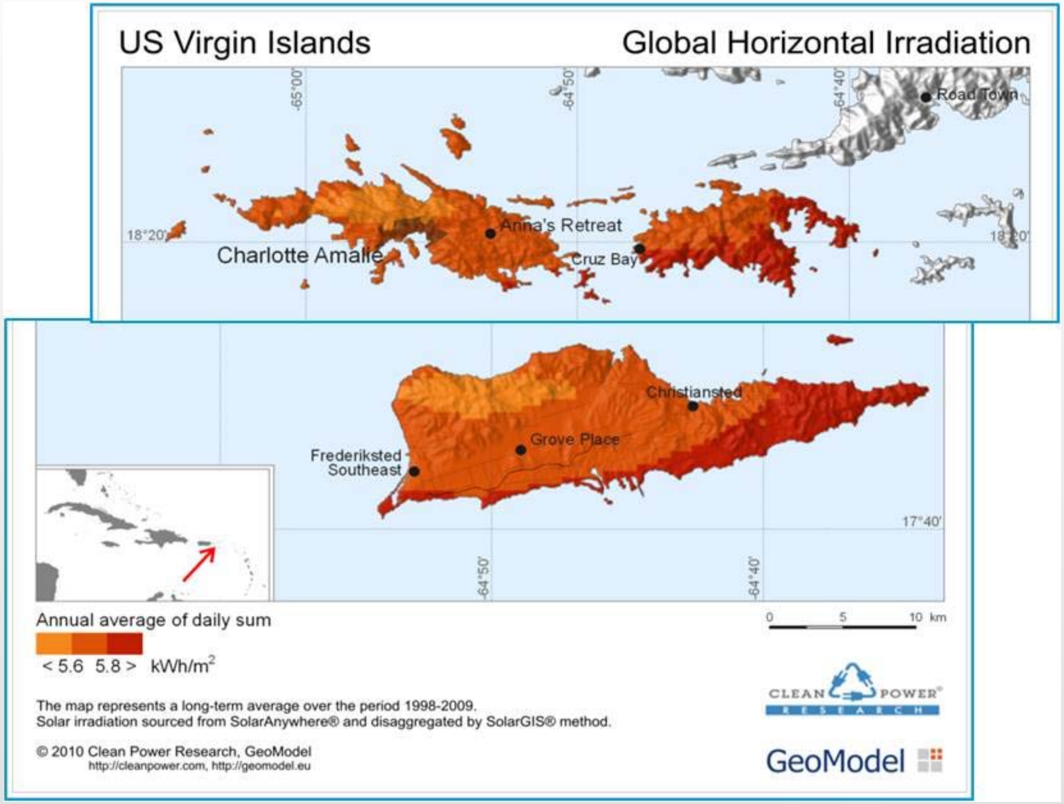
Solar Resource Data

The solar resource data for this analysis is from NASA's Surface Solar Energy Data Set, which provides monthly average solar radiation data for anywhere on the earth. The resolution is a 40 km grid (NASA 2010)

This can be downloaded from HOMER from the Latitude and Longitude.



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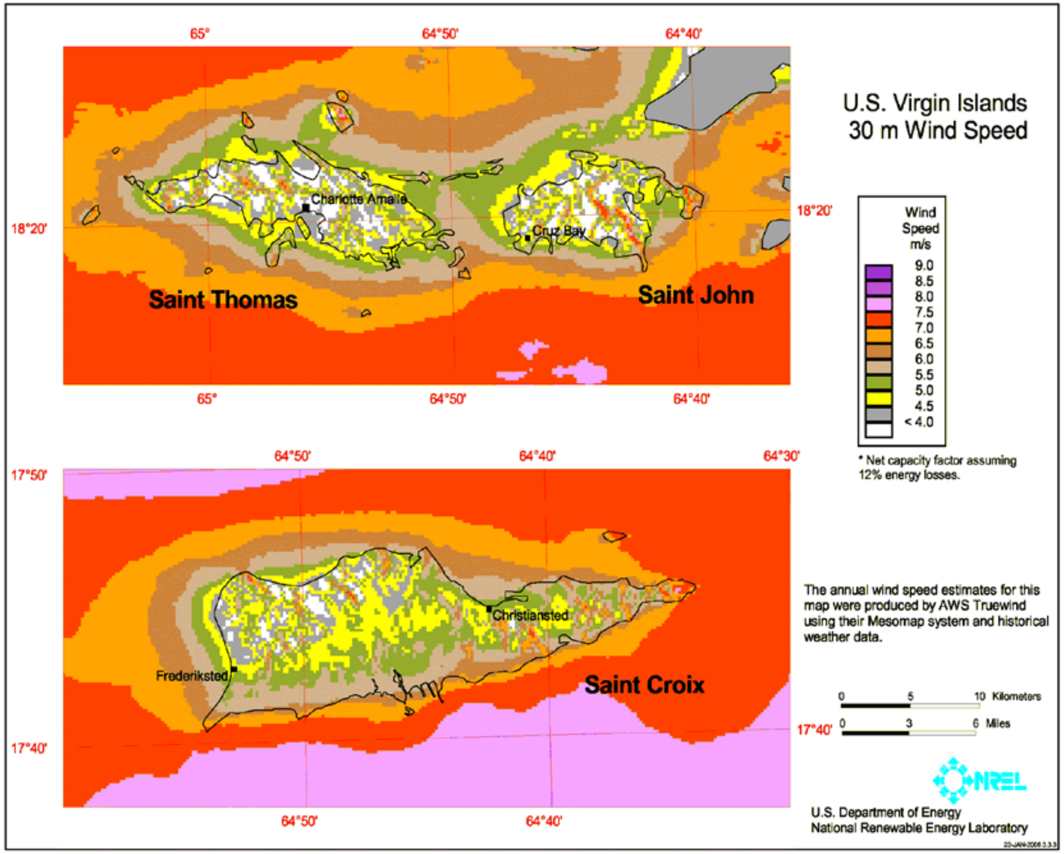
Wind Resource Data

Collaborative effort involving:

- DOE/NREL Wind Powering America program
- U.S. Virgin Islands
- NREL's wind resource group
- AWS Truewind
- Comprehensive modeling and validation process produced detailed wind resource maps with a spatial resolution of 200m
- Analysis can be updated with data from planned anemometers



St. Thomas/St. John Analysis

Credit: NREL

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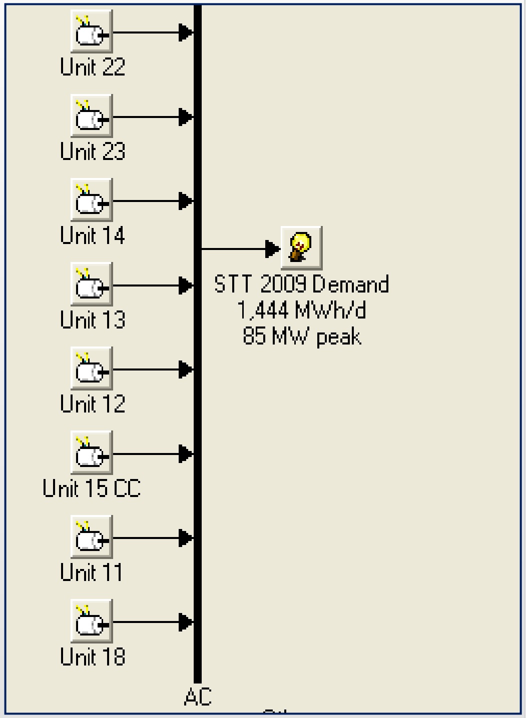
St. Thomas Base Case

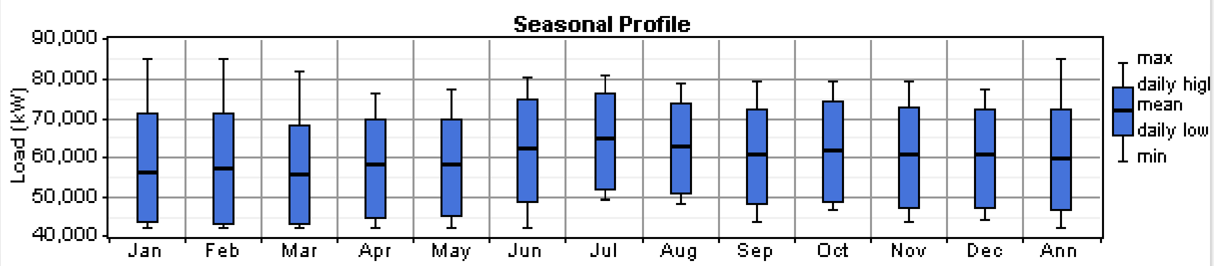
Load (primary load from April 2009 to March 2010)

- Primary load from 2009
- 84.7 MW peak
- 60.2 MW average
- 526,885 MWh/year

Diesel generators

- Created linear fuel curves for all generators using data provided by WAPA
- Did not consider energy used for desalination
- Assumed fuel-oil turbine unit 15 and steam turbine unit 11 to be a combined cycle plant with 15 as the heat source





St. Thomas Base Case Heat Rate

MMBTUs		**7,081,538**
kWhs		526,884,960
Average heat rate (Btu/kWh)		13,440
Efficiency		25.39%

LCOE: $0.265/kWh

Simulation Results

System Architecture: 22,000 kW Unit 22, 39,200 kW Unit 23, 15,100 kW Unit 14, 36,500 kW Unit 13, 15,100 kW Unit 12, 29,100 kW Unit 15 CC, 13,000 kW Unit 11, 22,000 kW Unit 18

Total NPC: $ 2,433,398,272
Levelized COE: $ 0.265/kWh
Operating Cost: $ 139,744,880/yr

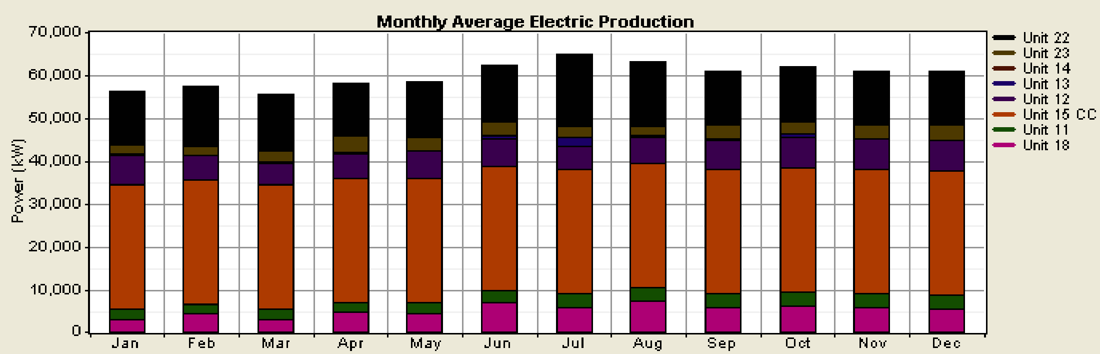
Cost Summary | Cash Flow | Electrical | 22 | 23 | 14 | 13 | 12 | 15CC | 11 | 18 | Emissions | Time Series

Production	kWh/yr	%
Unit 22	116,932,400	22
Unit 23	25,894,168	5
Unit 14	0	0
Unit 13	3,440,820	1
Unit 12	55,720,336	11
Unit 15 CC	254,941,808	48
Unit 11	24,571,428	5
Unit 18	45,408,000	9
Total	526,908,960	100

Consumption	kWh/yr	%
AC primary load	526,884,960	100
Total	526,884,960	100

Quantity	kWh/yr	%
Excess electricity	0.00	0.00
Unmet electric load	0.00	0.00
Capacity shortage	0.00	0.00

Quantity	Value
Renewable fraction	0.00
Max. renew. penetration	0.00 %



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STT Scenario 2: Base Case + PV

PV Systems:

- 5 MW at $6.00/W is an optimal solution
- No tracking
- Sloped at 18.3 degrees (latitude)

Annual Fuel Use Savings:

- #2 fuel oil savings: 2,405,408 liters=15,131 barrels/yr
- #6 fuel oil savings: 541,091 liters=3,404 barrels/yr
- Total fuel savings: 18,535 barrels/yr
- **1.6% reduction in fuel use**

Fuel Cost Savings Annually:

- $1,529,839 @ $101/barrel (#2 fuel oil)
- $291,107 @ $85.5/barrel (#6 fuel oil)
- **total cost savings annually: $1.8 M**

LCOE for PV vs Base Case:

- LCOE of PV: $0.212/kWh and LCOE for the base case $0.265/kWh
- LCOE of base case + PV: $0.265/kWh (remains the same)

Base Case
LCOE = $0.265/kWh

With Solar
LCOE = $0.265/kWh

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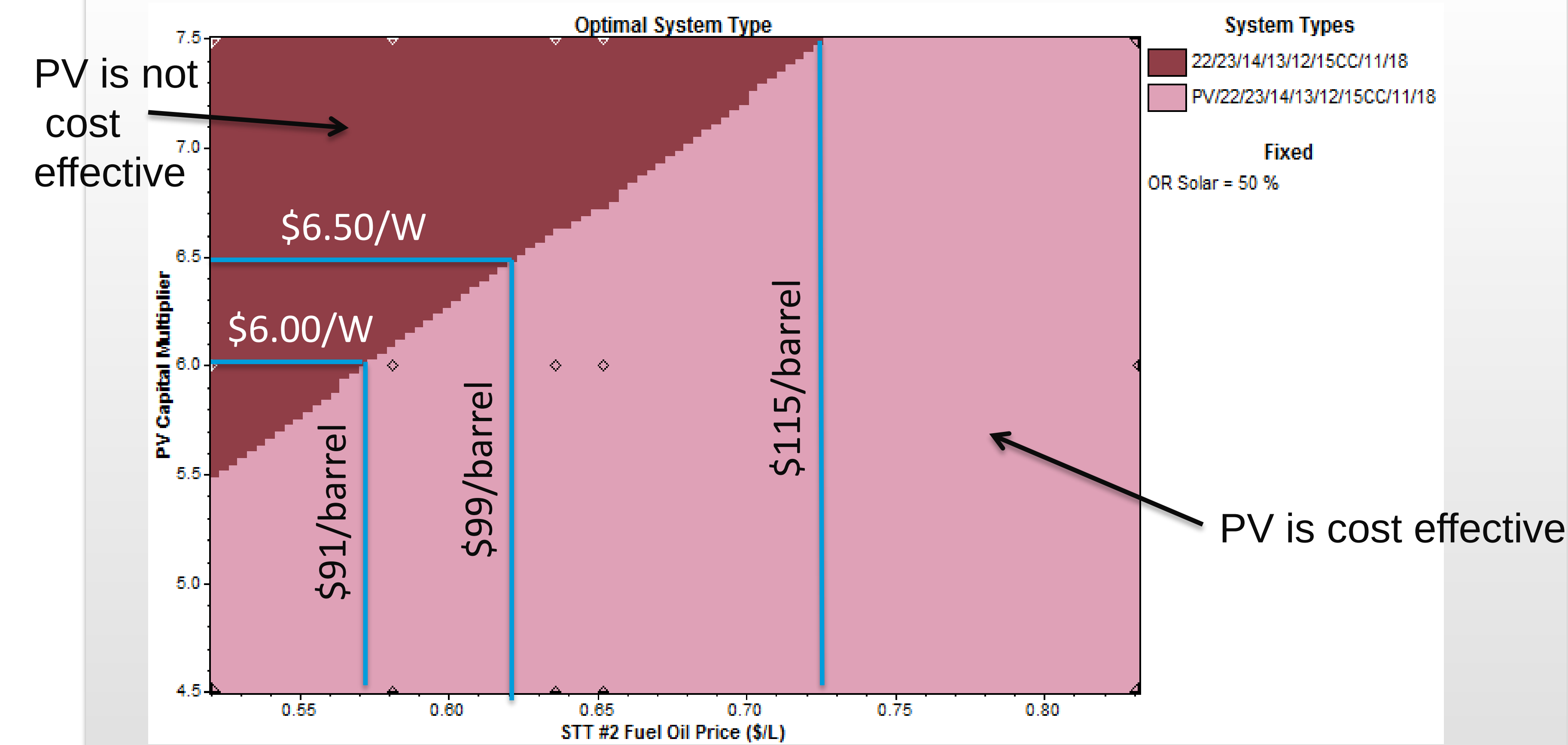
STT Scenario 2: Base Case + PV



PV is cost effective at ~ $6.00/W when diesel cost is ~ $91/barrel.

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Cost of PV Modules

PV prices have dropped 17% in the last year and 3% just in the last month

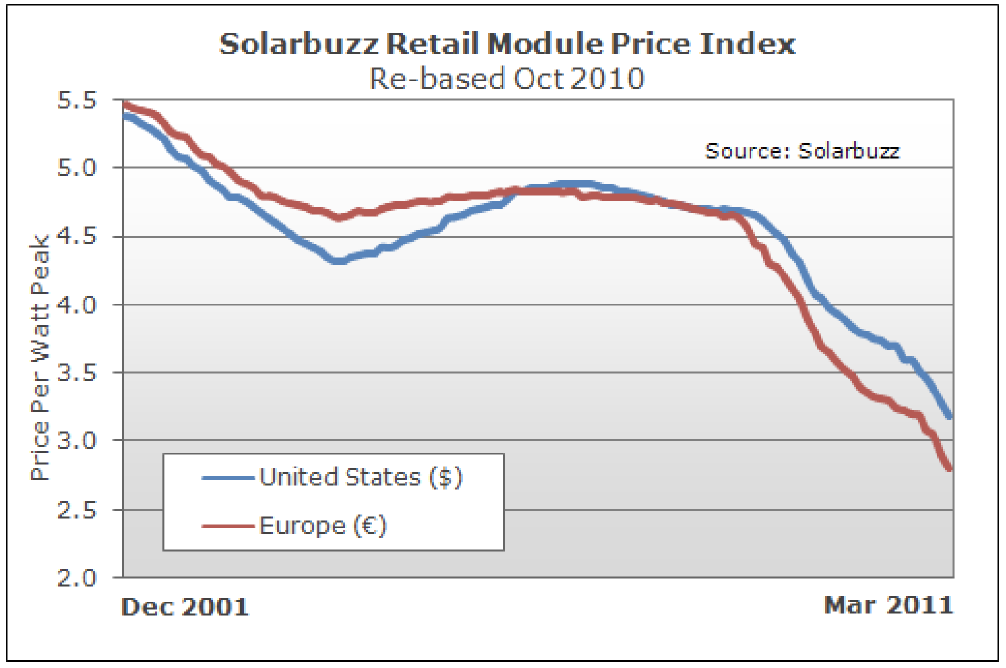

Figure from Solarbuzz Retail Module Price Index
http://solarbuzz.com/facts-and-figures/retail-price-environment/module-prices

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STT Scenario 3: Base Case + Wind

Optimal Hybrid Systems :

- 15 MW of turbines is the optimal wind/generator hybrid system
- Cost of wind turbines ~$2,500/kW
- Capacity factor = 38.8%

Annual Fuel Use Savings:

- #2 fuel oil savings: 13,735,072 liters = 86,400 barrels/year
- #6 fuel oil savings: 3,3301,919 liters = 20,771 barrels/year
- **9% reduction in fuel use**

Fuel Cost Savings Annually:

- $8,735,506@ $101/barrel (#2 fuel oil)
- $1,776,432@ $85.5/barrel (#6 fuel oil)
- **Total cost savings annually: $10.5 M**

LCOE for Wind vs Base Case:

- LCOE of PV: $0.056/kWh and LCOE for the base case $0.265/kWh
- LCOE of base case + wind**: $0.246/** kWh

Base Case
LCOE = $0.265/kWh

With Wind
LCOE = $0.246/kWh

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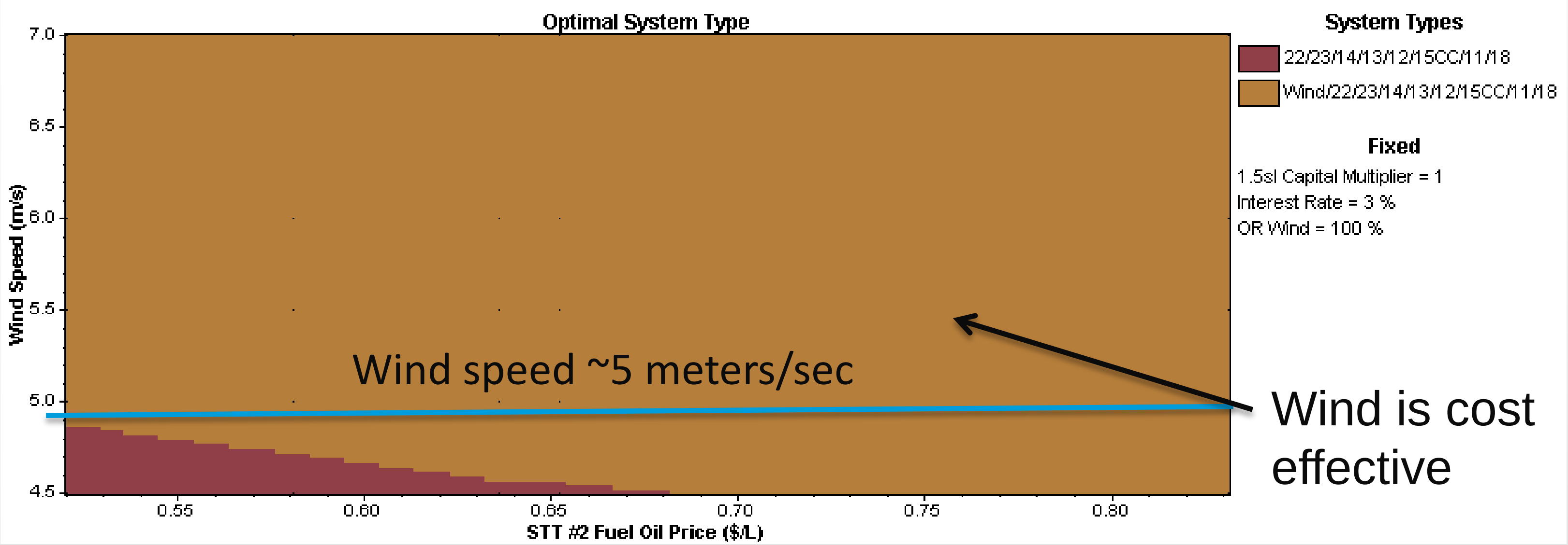
STT Scenario 3: Base Case + Wind

Wind is cost effective in almost all scenarios



15 MW of wind is the optimal solution even at low wind speeds ~5 meters/sec

St. Croix Analysis

Credit: NREL

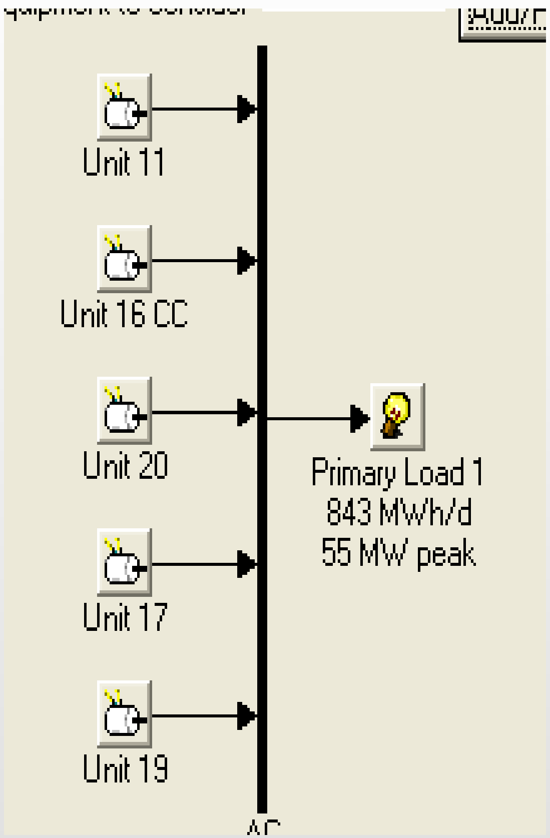
St. Croix (with new HRSG)

St. Croix

Compare base cases before and after new HRSG was installed*

St. Croix

- Case 1: Base Case**
- Case 2: Base Case + PV (modeled 5.5 MW)
- Case 3: Base Case + Wind (modeled number of turbines for 15 MW & 18 MW)
- Case 4: Base Case + 16 MW waste-to-energy plant
  - WTE is a PPA with LCOE:
  - LCOE peak = $0.183/kWh
  - LCOE off peak = $0.176/kWh



(*Note: This simulation does not take into account the energy extracted from the system to power the desalination process)

(**Note: base case will be with the new HRSG installed)

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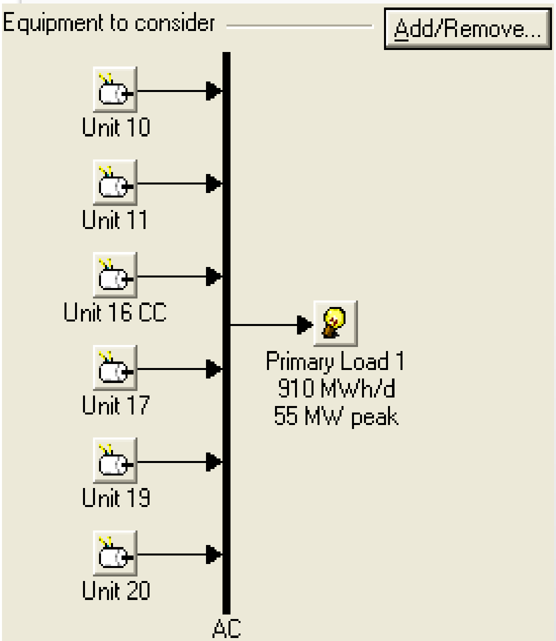
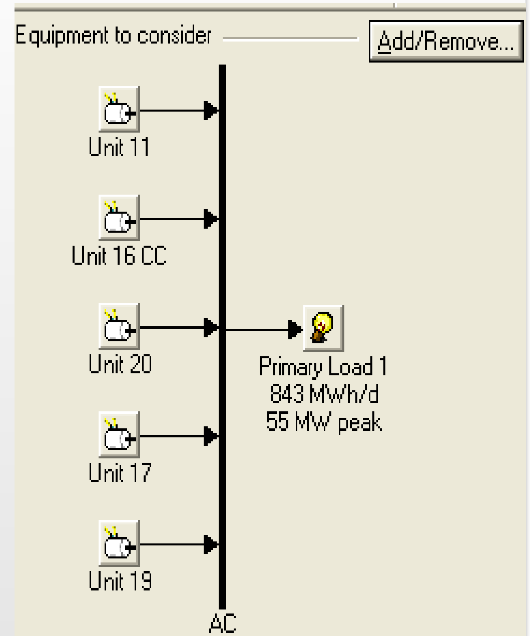
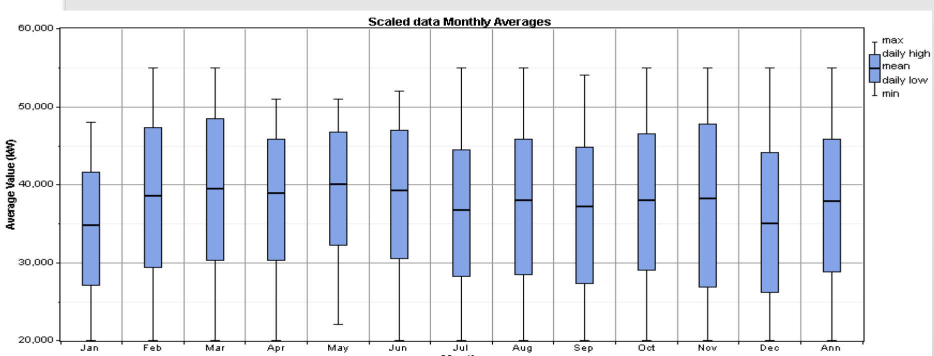
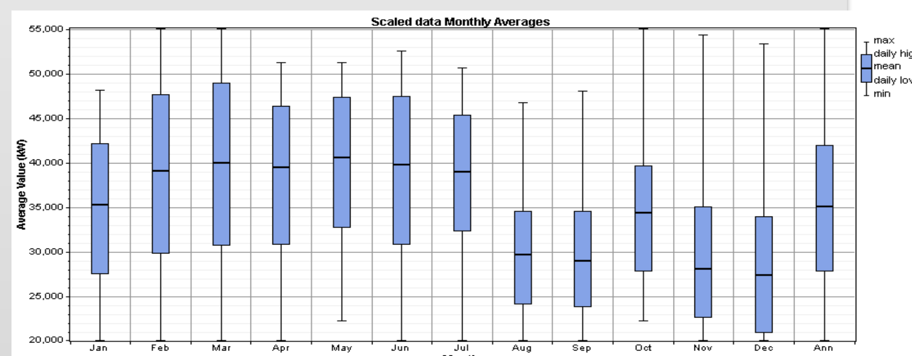
St. Croix Analysis Base Case (Before and After New HRSG)









St. Croix Base Case Heat Rate

St. Croix Base Case Heat Rate (Before New HRSG)

MMBTUs		**5,482,891**
kWhs		**332,148,608**
Average heat rate (Btu/kWh):		**16,505**
Efficiency		**20.67%**

St. Croix Base Case Heat Rate (After New HRSG)

MMBTUs		**3,406,994**
kWhs		**307,717,888**
Average heat rate (Btus/kWh)		**11,071**
Efficiency		**30.82%**

St. Croix base case efficiency increases 50%

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STX Scenario 2: Base Case + PV

PV Systems:

- 5 MW at $6.00/W is an optimal solution
- No tracking
- Sloped at 18.3 degrees (latitude)

Annual Fuel Use Savings:

- #2 fuel oil savings: 2,411,768 liters=15,160 barrels/yr
- #6 fuel oil savings: 491,826 liters=3,091 barrels/yr
- Total fuel savings: 18,251 barrels/year
- **3.2% reduction in fuel use**

Fuel Cost Savings Annually:

- $1,533,884 @ $101/barrel (#2 fuel oil)
- $264,602 @ $85.5/barrel (#6 fuel oil)
- **Total cost savings annually: $1.8 M**

LCOE for PV vs Base Case:

- LCOE of PV: $0.212/kWh and LCOE for the base case $0.231/kWh
- LCOE of base case + PV: $0.231/kWh (remains the same)

Base Case
LCOE = $0.231/kWh

With Solar
LCOE = $0.231/kWh

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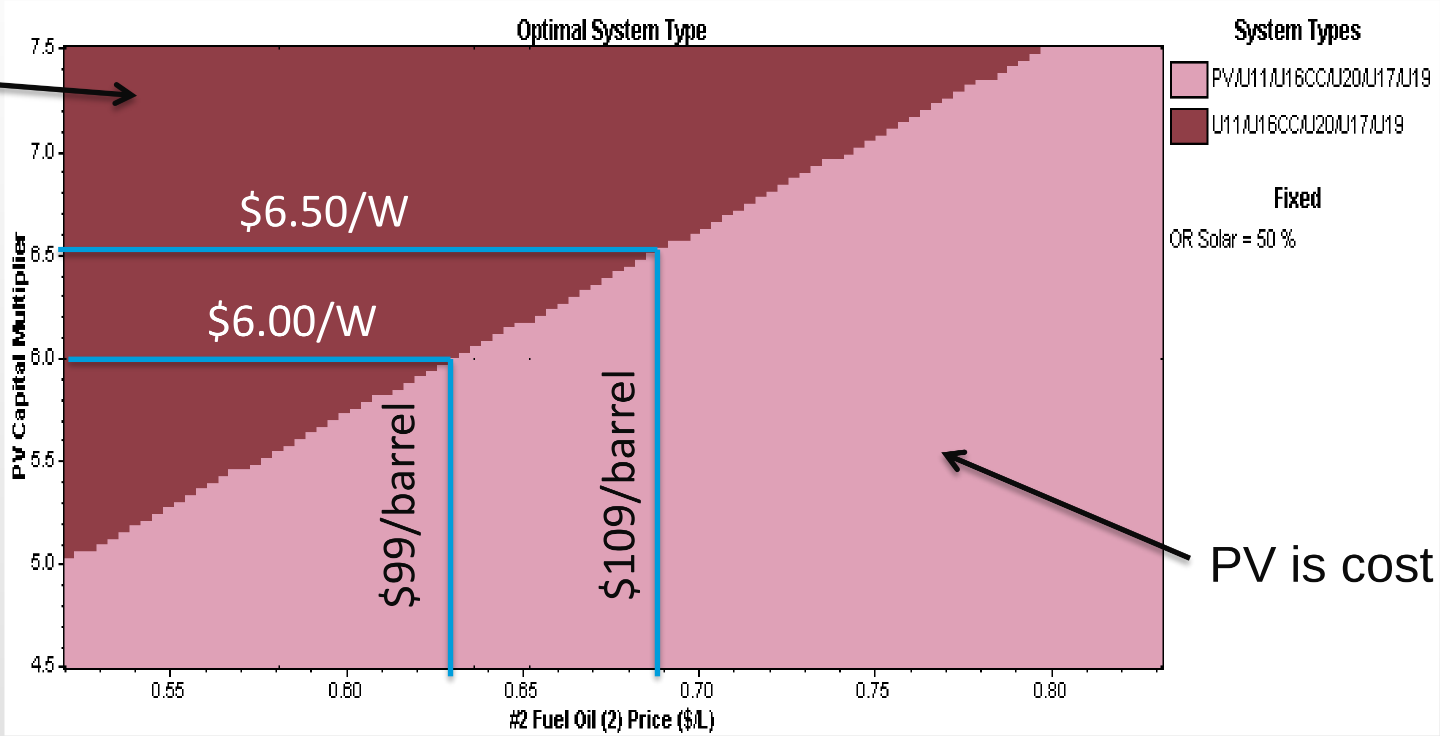
STX Scenario 2: Base Case + PV

PV is not cost effective



PV is cost effective

PV is cost effective at ~ $6.00/W when diesel cost is ~ $99/barrel

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STX Scenario 3: Base Case + Wind

Optimal Hybrid Systems :

- 15 MW of turbines is the optimal wind/generator hybrid system
- Cost of wind turbines ~$2,500/kW
- Capacity factor = 38.8%

Annual Fuel Use Savings:

- #2 fuel oil savings: 13,735,072 liters = 86,400 barrels/year
- #6 fuel oil savings: 3,3301,919 liters = 20,771 barrels/year
- **14% reduction in fuel use**

Fuel Cost Savings Annually:

- $7,985,184 @ $101/barrel (#2 fuel oil)
- $382,814 @ $85.5/barrel (#6 fuel oil)
- **Total Cost Savings Annually: $8.3 M**

LCOE for Wind vs Base Case:

- LCOE of wind: $0.056/kWh and LCOE for the base case $0.231/kWh
- LCOE of base case + wind: $**0.210kWh**

Base Case
LCOE = $0.231/kWh

With Wind
LCOE = $0.210/kWh

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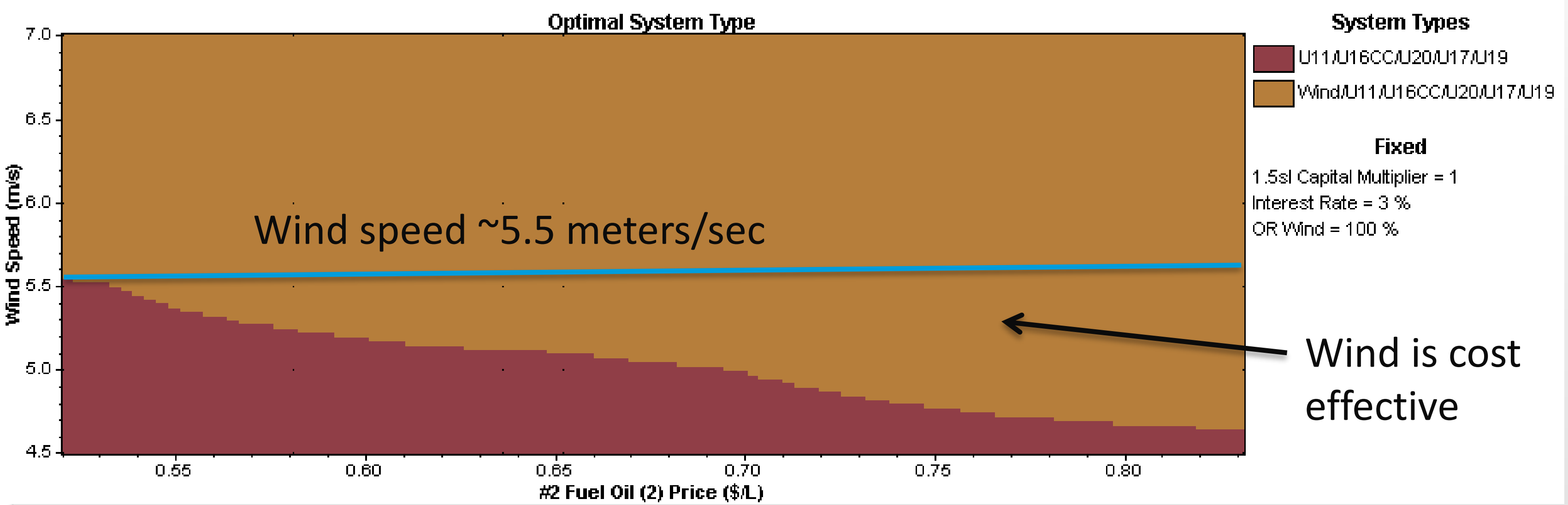
STX Scenario 3: Base Case + Wind



15 MW of wind is the optimal solution even at low wind speeds ~5.5 meters/sec

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Conclusions & Next Steps

Conclusions:

- Wind is cost effective even at low fuel prices
- 15 MW of wind can reduce the fuel usage by 9% on St. Thomas and 14% on St. Croix
- PV becomes cost effective when the cost is around $6/W or as fuel prices go above $99/barrel
- St. Croix WTE model…..TBD; will add soon

Next Steps:

- Complete HOMER Report (May 1, 2011)
- Support WAPA with technical analysis for integrating RE into the transmission & distribution system

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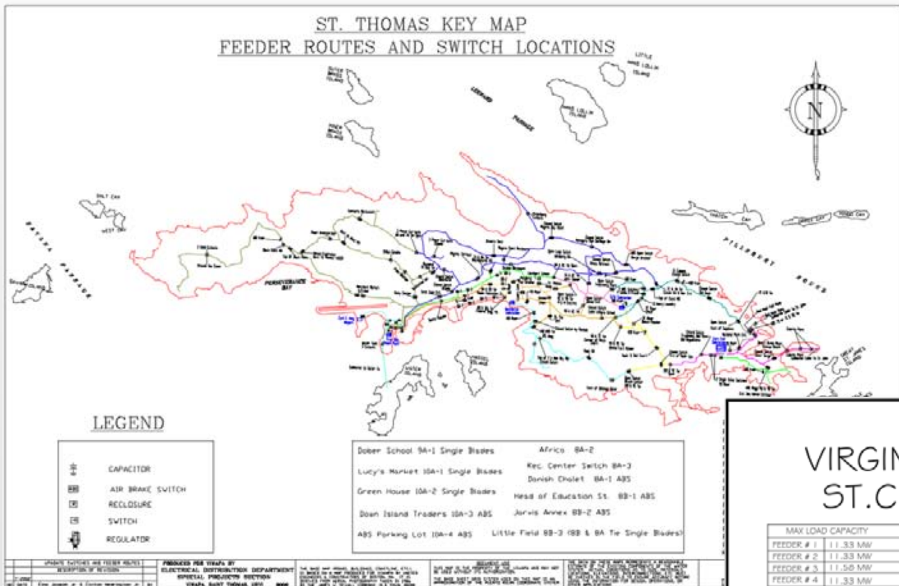
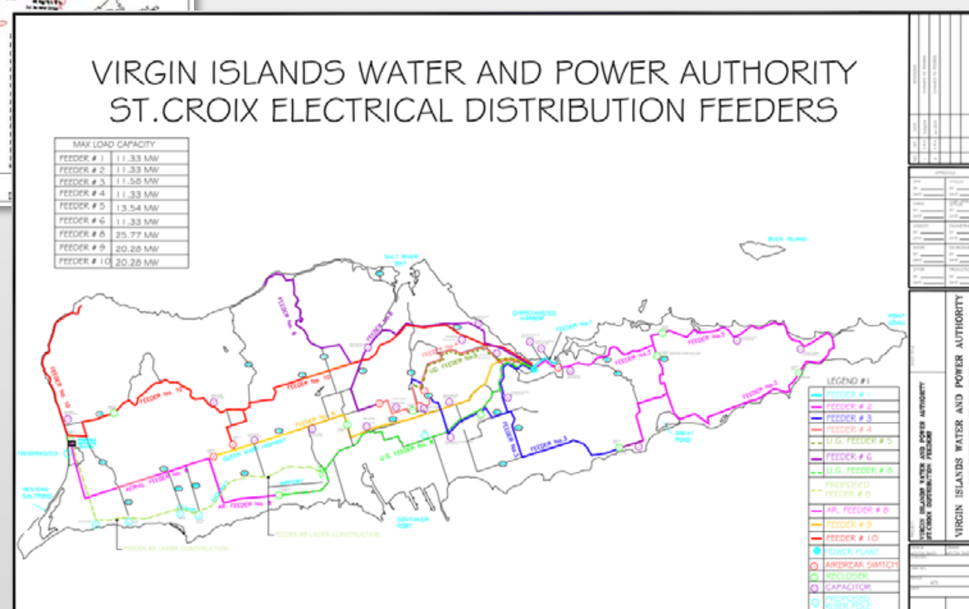
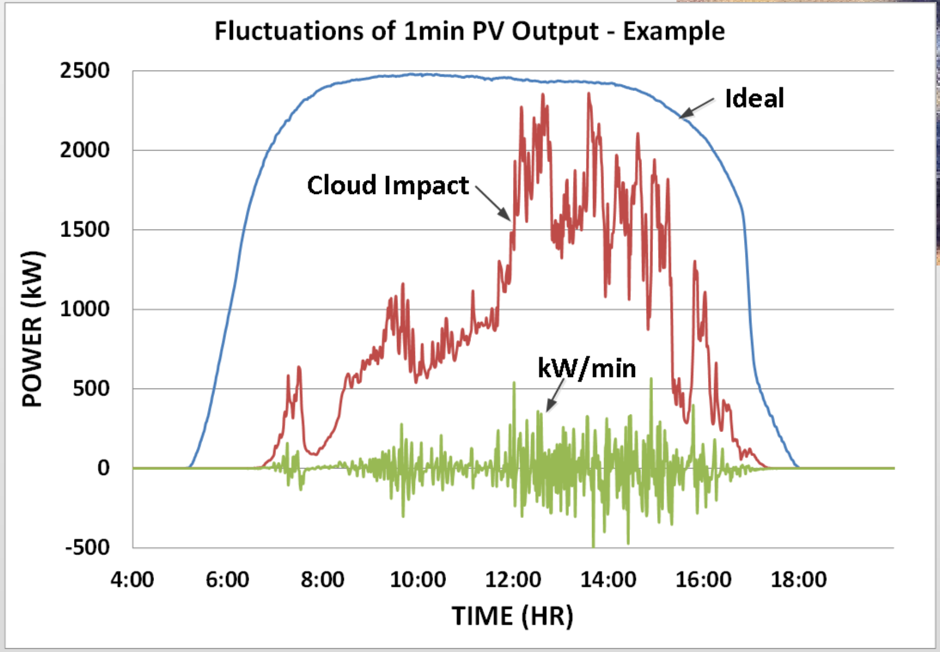
Integrating Renewables into WAPA's Distribution System





Why Can't We Go 100% Sun/Wind? Variability and Lack of Control



Integrating Renewable Energy Projects into the WAPA Distribution Systems

St. Thomas and St. Croix Electrical Load Information

Island	Average Daily Peak	Annual System Peak	Average Loads	Minimum Loads
St. Thomas	78 MW	88 MW	65 MW	50 MW
St. Croix	50 MW	55 MW	40 MW	35 MW

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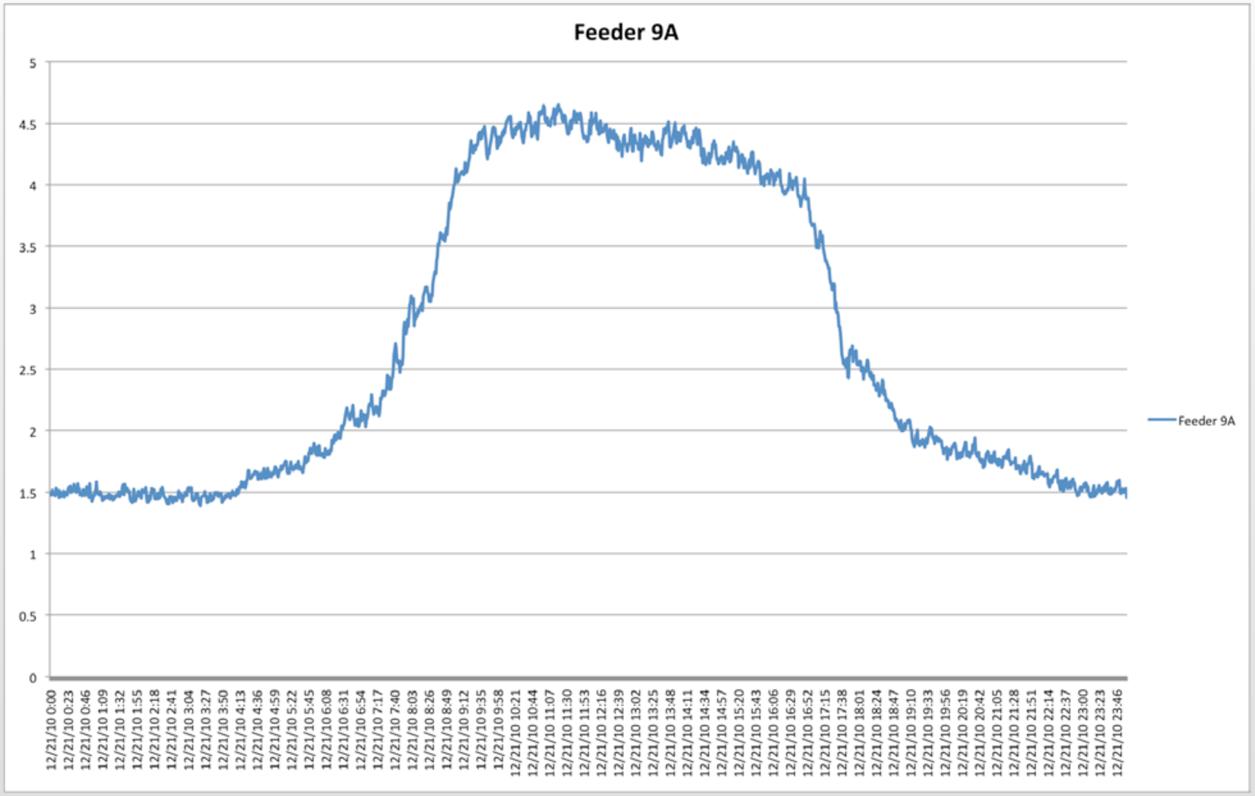
Typical Commercial/Industrial Daily Load Profile – STT Feeder 9A



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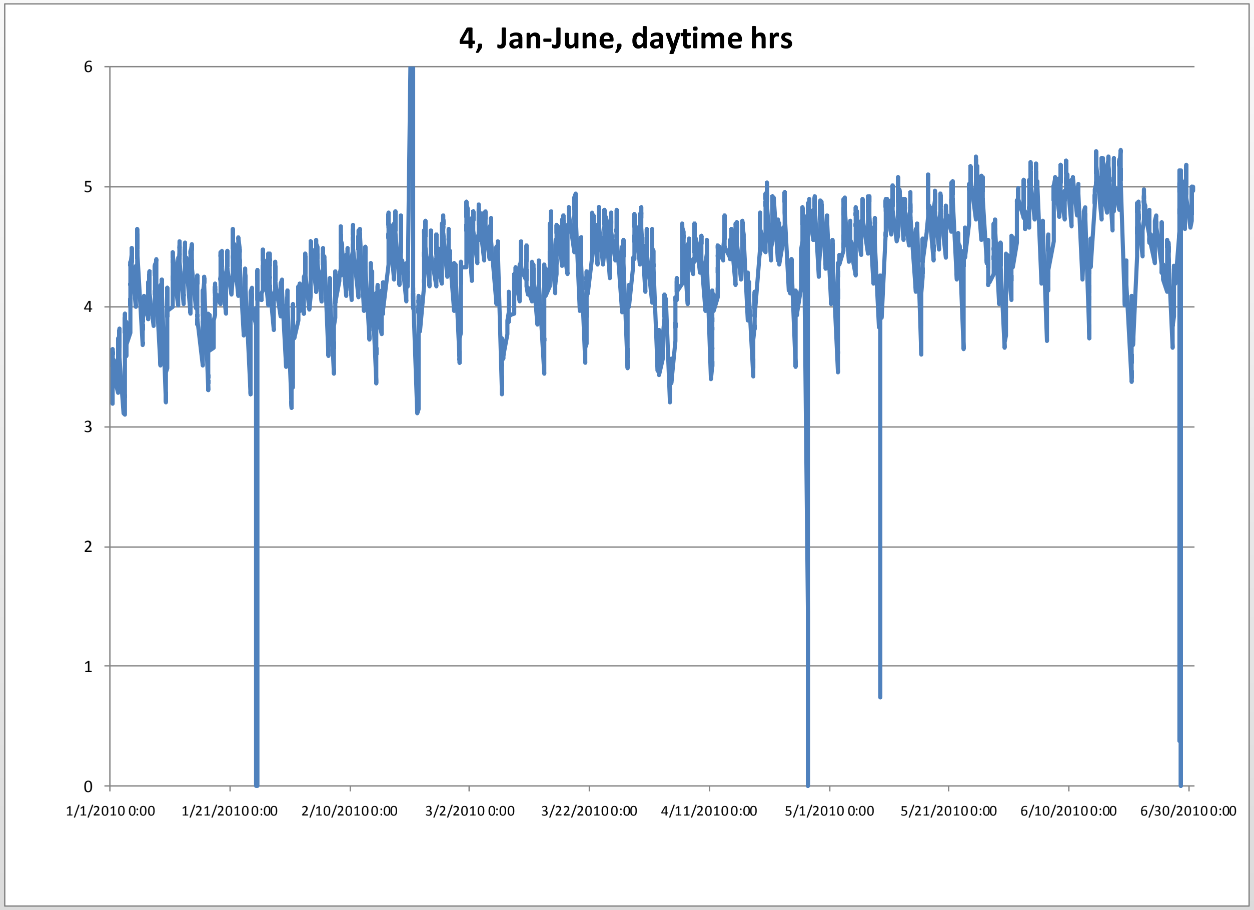
Six-Month Daytime Load Profile– STX Feeder 4



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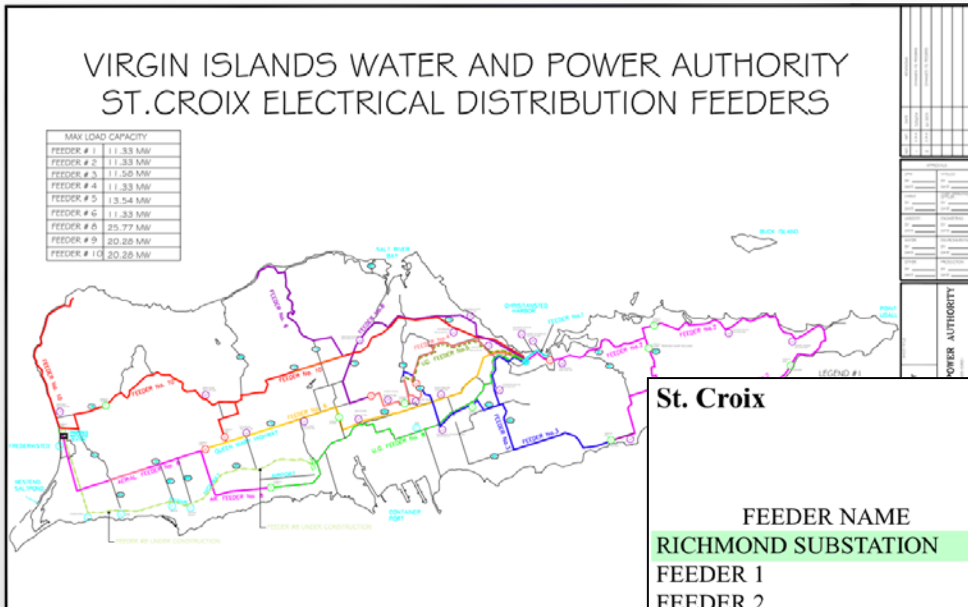
Loads Analyzed Feeder by Feeder

How Much Solar/Wind Can We Put on Each Feeder?



St. Croix

FEEDER NAME	Voltage (kV)	MIN LOAD (MW)	PEAK LOAD (MW)	10% Rule PV Capacity (MW)
RICHMOND SUBSTATION				
FEEDER 1	13.8	1.3	2.7	0.27
FEEDER 2	13.8			0.00
FEEDER 3	13.8	2.6	4.5	0.45
FEEDER 4	13.8	2.5	4.7	0.47
FEEDER 5	13.8	0.5	1.3	0.13
FEEDER 6	13.8	3.7	5.6	0.56
FEEDER 9A	24.9	2.3	3.9	0.39
FEEDER 10A	24.9	1.05	1.8	0.18
	Subtotal	13.95	24.50	2.5
NEW SPANISH TOWN SUBSTATION				
FEEDER 8	24.9	7.5	10.1	1.01
FEEDER 9B	24.9	2.3	3.9	0.39
FEEDER 10B	24.9	1.05	1.8	0.18
	Subtotal	10.9	15.8	1.6
	STX Total	**24.80**	**40.30**	**4.03**

Interconnection Process

A technical review of the system design and proposed equipment

Fast Track – projects may proceed without detailed system impact study

Standard – necessary to determine upgrades or modifications needed to maintain power quality

Fast Track Process – Screens

- Limit total PV generation on feeders to **10% of annual peak demand** to avoid voltage regulation issues (per IEEE 1547.2)
- Keep **total PV** generation on feeders to **less than annual minimum daytime load** on the feeder to prevent generation export
- Locate larger PV systems **close to large loads** or substations

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Next Steps

- Obtain updated and additional feeder load data to verify peaks, minimum loads, and load profiles
- Obtain fault currents and system ratings
- Identify potential sites for PV generation on St. Thomas

Thank You!

Credit: NREL

Questions or Comments?

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