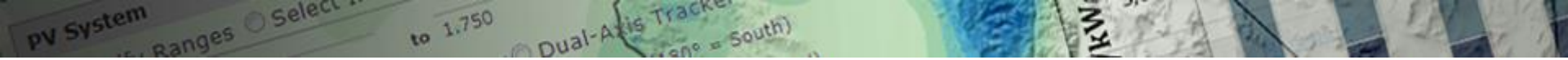
Value of Solar Tariff in Minnesota: Overview

April 14, 2014

Prepared for
Washington UTC

Prepared by
Clean Power Research



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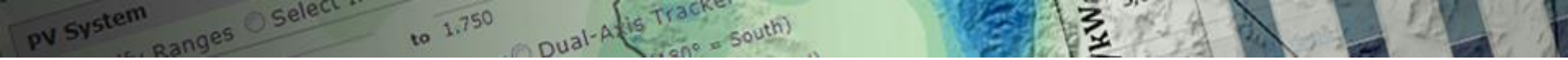
- Introduction
- Transparency Elements and Assumptions
- Technical Analysis
- Economic Analysis
- Final VOS Calculation



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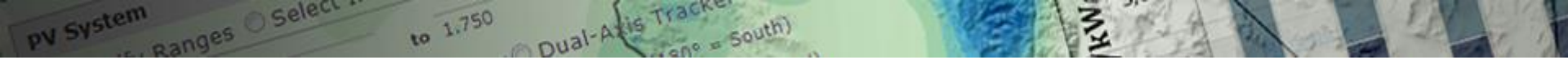
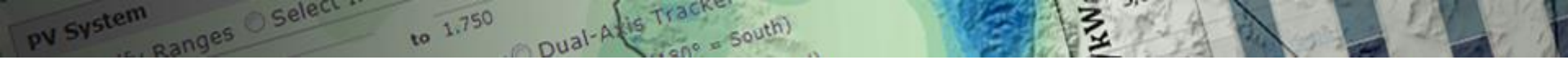


Minnesota's VOS Calculation Methodology

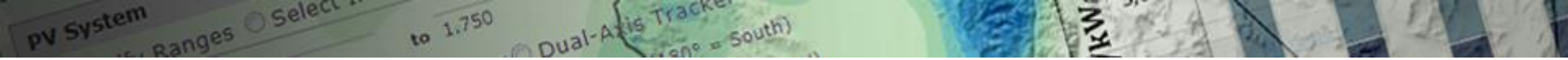
25 Year Levelized Value

	Gross Value ($/kWh)	×	Load Match Factor (%)	× (1 +	Loss Savings Factor (%)	) =	Distributed PV Value ($/kWh)
Avoided Fuel Cost	GV1				LSF-Energy		V1
Avoided Plant O&M - Fixed	GV2		ELCC		LSF-Energy		V2
Avoided Plant O&M - Variable	GV3				LSF-Energy		V3
Avoided Gen Capacity Cost	GV4		ELCC		LSF-ELCC		V4
Avoided Reserve Capacity Cost	GV5		ELCC		LSF-ELCC		V5
Avoided Trans. Capacity Cost	GV6		ELCC		LSF-ELCC		V6
Avoided Dist. Capacity Cost	GV7		PLR		LSF-PLR		V7
Avoided Environmental Cost	GV8				LSF-Energy		V8
Avoided Voltage Control Cost							
Solar Integration Cost							
							Value of Solar



What is a VOS tariff?

- It is the rate that represents utility-specific long term value of distributed solar generation.
- It is not an incentive program, but it does not preclude a (supplemental) incentive program.
- It includes both utility avoided costs and societal benefits.
- Societal benefits are a public policy decision. These are paid for by all ratepayers (solar and non-solar) to allow the utility to recover costs.
- It is based on marginal (not average) costs.
- It may be based on either gross generation or net energy exported to grid.
- It is an identical rate for all rate classes.
- It is recalculated annually for new customers.



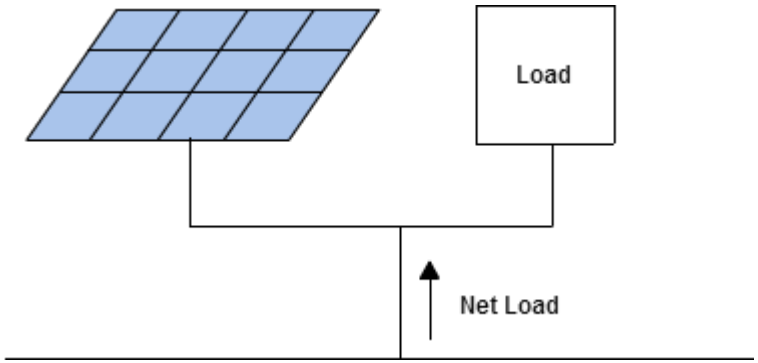
MN Legislative Background

- Minnesota passed legislation* in 2013 that allows IOUs to apply to the PUC for a Value of Solar (VOS) tariff as an alternative to net metering.
- The methodology must meet certain requirements contained in the legislation (details to follow).
- Commerce selected Clean Power Research to support process of developing the methodology. Commerce guided the process and made key policy decisions.
- Excellent stakeholder process: Four workshops, draft methodology posted for comment. Process included active engagement of all three IOUs, local and national solar organizations, public agencies, and individuals.
- Commerce submitted the methodology to the PUC for approval (1/31). Adopted (3/12).

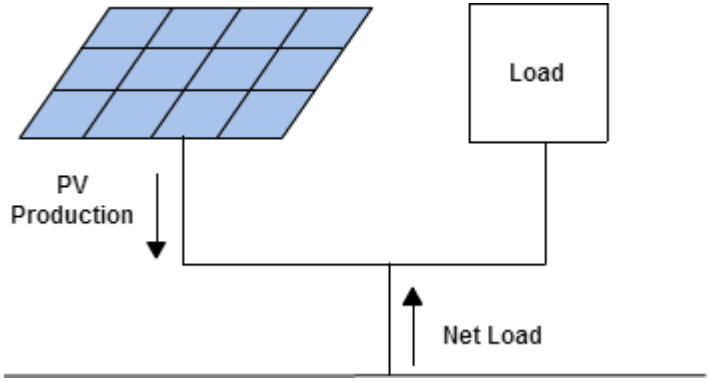
* MN Laws 2013, Chapter 85 HF 729, Article 9, Section 10

Charges and Credits

NET LOAD



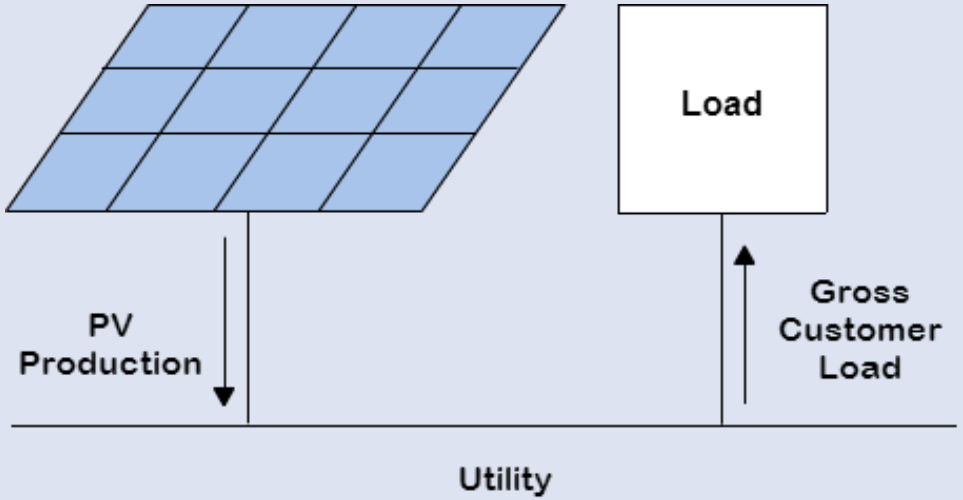
PV AND NET LOAD

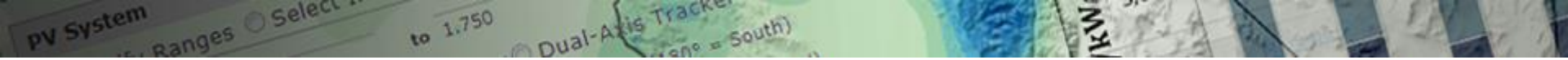


MN VOS FRAMEWORK:

Separates charges and credits

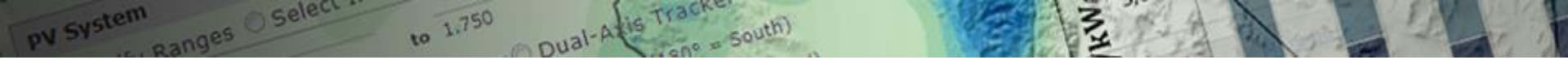
- **VOS Credit** applies to gross PV production
- **Charges** apply to gross Customer Load (at applicable rate schedule)





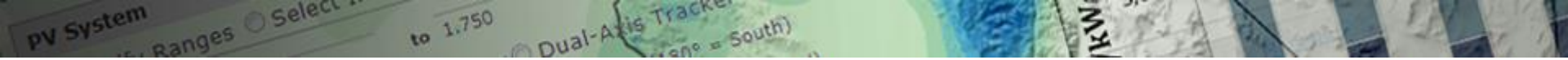
Key MN Legislative Requirements

- Allow recovery of cost to serve customer-participants.
- Account for “the value of energy and its delivery, generation capacity, transmission capacity, transmission and distribution line losses, and environmental value.”
- May incorporate other values “based on known and measurable evidence of the cost or benefit of solar operation to the utility.” (e.g., local manufacturing, high-value locations).
- Annually updated.
- Credit to “represent the present value of the future revenue streams of the value components”, minimum 20 year contract.



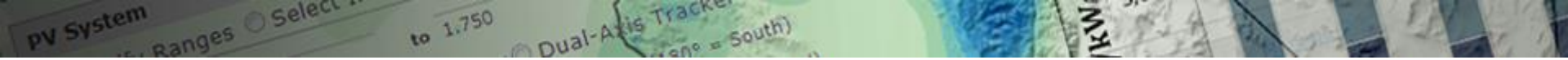
VOS components included

Value Component	Basis	Legislative Guidance	Notes
Avoided Fuel Cost	Energy market costs (portion attributed to fuel).	Required (energy)	Includes cost of long-term price risk
Avoided Plant O&M Cost	Energy market costs (portion attributed to O&M).	Required (energy)	
Avoided Generation Capacity Cost	Capital cost of generation to meet peak load.	Required (capacity)	
Avoided Reserve Capacity Cost	Capital cost of generation to meet planning margins and ensure reliability.	Required (capacity)	
Avoided Transmission Capacity Cost	Capital cost of transmission.	Required (transmission capacity)	
Avoided Distribution Capacity Cost	Capital cost of distribution.	Required (delivery)	
Avoided Environmental Cost	Externality costs.	Required (environmental)	



VOS components included as placeholders

Value Component	Basis	Legislative Guidance	Notes
Voltage Control	Cost to regulate distribution (future inverter designs)		Future (TBD)
Integration Cost	Added cost to regulate system frequency with variable solar.		Future (TBD)



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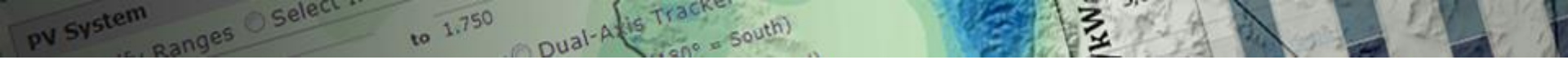


Fixed assumptions, part 1

Common to all utilities

Fuel Prices						
Guaranteed NG fuel prices				**Environmental Externalities**		
2014	$3.93	$ per MMBtu		Environmental discount rate	3.00%	per year
2015	$4.12	$ per MMBtu		Environmental costs	(shown in separate table)	
2016	$4.25	$ per MMBtu				
2017	$4.36	$ per MMBtu		**Economic Assumptions**		
2018	$4.50	$ per MMBtu		General escalation rate	2.37%	per year
2019	$4.73	$ per MMBtu				
2020	$5.01	$ per MMBtu				
2021	$5.33	$ per MMBtu		**Treasury Yields**		
2022	$5.67	$ per MMBtu		1 Year	0.13%	
2023	$6.02	$ per MMBtu		2 Year	0.29%	
2024	$6.39	$ per MMBtu		3 Year	0.48%	
2025	$6.77	$ per MMBtu		5 Year	1.01%	
				7 Year	1.53%	
Guaranteed NG fuel price escalation	4.75%			10 Year	2.14%	
				20 Year	2.92%	
PV Assumptions				30 Year	3.27%	
PV degradation rate	0.50%	per year				
PV life	25	years				

Fixed assumptions, part 2

Environmental costs, common to all utilities

Derived from EPA Social Cost of Carbon

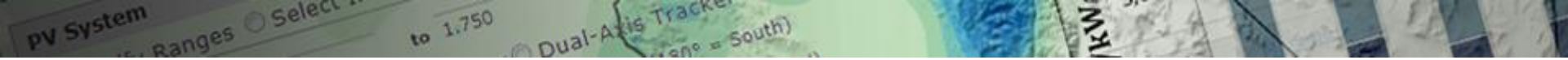
Year	Analysis Year	CO_2 Cost ($/MMBtu)	PM10 Cost ($/MMBtu)	CO Cost ($/MMBtu)	NO_x Cost ($/MMBtu)	Pb Cost ($/MMBtu)	Total Cost ($/MMBtu)
2014	0	1.939	0.066	0.000	0.012	0.000	2.017
2015	1	2.039	0.067	0.000	0.013	0.000	2.119
2016	2	2.142	0.069	0.000	0.013	0.000	2.224
2017	3	2.249	0.070	0.000	0.013	0.000	2.333
2018	4	2.360	0.072	0.000	0.014	0.000	2.446
2019	5	2.475	0.074	0.000	0.014	0.000	2.562
2020	6	2.594	0.076	0.000	0.014	0.000	2.684
2021	7	2.717	0.077	0.000	0.015	0.000	2.809
2022	8	2.844	0.079	0.000	0.015	0.000	2.939
2023	9	2.976	0.081	0.000	0.015	0.000	3.073
2024	10	3.113	0.083	0.000	0.016	0.000	3.212
2025	11	3.255	0.085	0.000	0.016	0.000	3.356
2026	12	3.401	0.087	0.000	0.016	0.000	3.505
2027	13	3.482	0.089	0.000	0.017	0.000	3.588
2028	14	3.637	0.091	0.000	0.017	0.000	3.746
2029	15	0.745	0.093	0.000	0.018	0.000	0.856
2030	16	3.888	0.096	0.000	0.018	0.000	4.002
2031	17	4.136	0.098	0.000	0.018	0.000	4.252
2032	18	4.314	0.100	0.000	0.019	0.000	4.433
2033	19	4.498	0.103	0.000	0.019	0.000	4.620
2034	20	4.688	0.105	0.000	0.020	0.000	4.813
2035	21	4.885	0.107	0.000	0.020	0.000	5.013
2036	22	5.089	0.110	0.000	0.021	0.000	5.219
2037	23	5.299	0.113	0.000	0.021	0.000	5.433
2038	24	5.517	0.115	0.000	0.022	0.000	5.654

EXAMPLE: VOS Data Table (required), Part 1

	Input Data	Units
Economic Factors		
Start Year for VOS applicability	2014	
Discount rate (WACC)	8.00%	per year
Load Match Analysis (see calculation method)		
ELCC (no loss)	40%	% of rating
PLR (no loss)	30%	% of rating
Loss Savings - Energy	8%	% of PV output
Loss Savings - PLR	5%	% of PV output
Loss Savings - ELCC	9%	% of PV output
PV Energy		
First year annual energy (see calc. method)	1800	kWh per kW-AC
Transmission		
Capacity-related transmission capital cost	$200	$ per kW
Years until new transmission capacity is needed	0	years
Transmission life	60	years
Transmission capital cost escalation	2.00%	per year

EXAMPLE: VOS Data Table (required), Part 2

	Input Data	Units
Power Generation		
Peaking CT, simple cycle		
Installed cost	900	$/kW
Heat rate	9,500	BTU/kWh
Intermediate peaking CCGT		
Installed cost	1,200	$/kW
Heat rate	6,500	BTU/kWh
Other		
Solar-weighted heat rate (see calc. method)	8000	BTU per kWh
Fuel Price Overhead	$0.50	$ per MMBtu
Generation life	50	years
Heat rate degradation	0.100%	per year
O&M cost (first Year) - Fixed	$5.00	per kW-yr
O&M cost (first Year) - Variable	$0.0010	$ per kWh
O&M cost escalation rate	2.00%	per year
Reserve planning margin	15%	
Distribution		
Capacity-related distribution capital cost	$200	$ per kW
Distribution capital cost escalation	2.00%	per year
Peak load	5000	MW
Peak load growth rate	1.00%	per year



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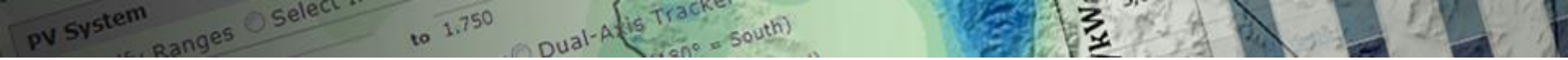
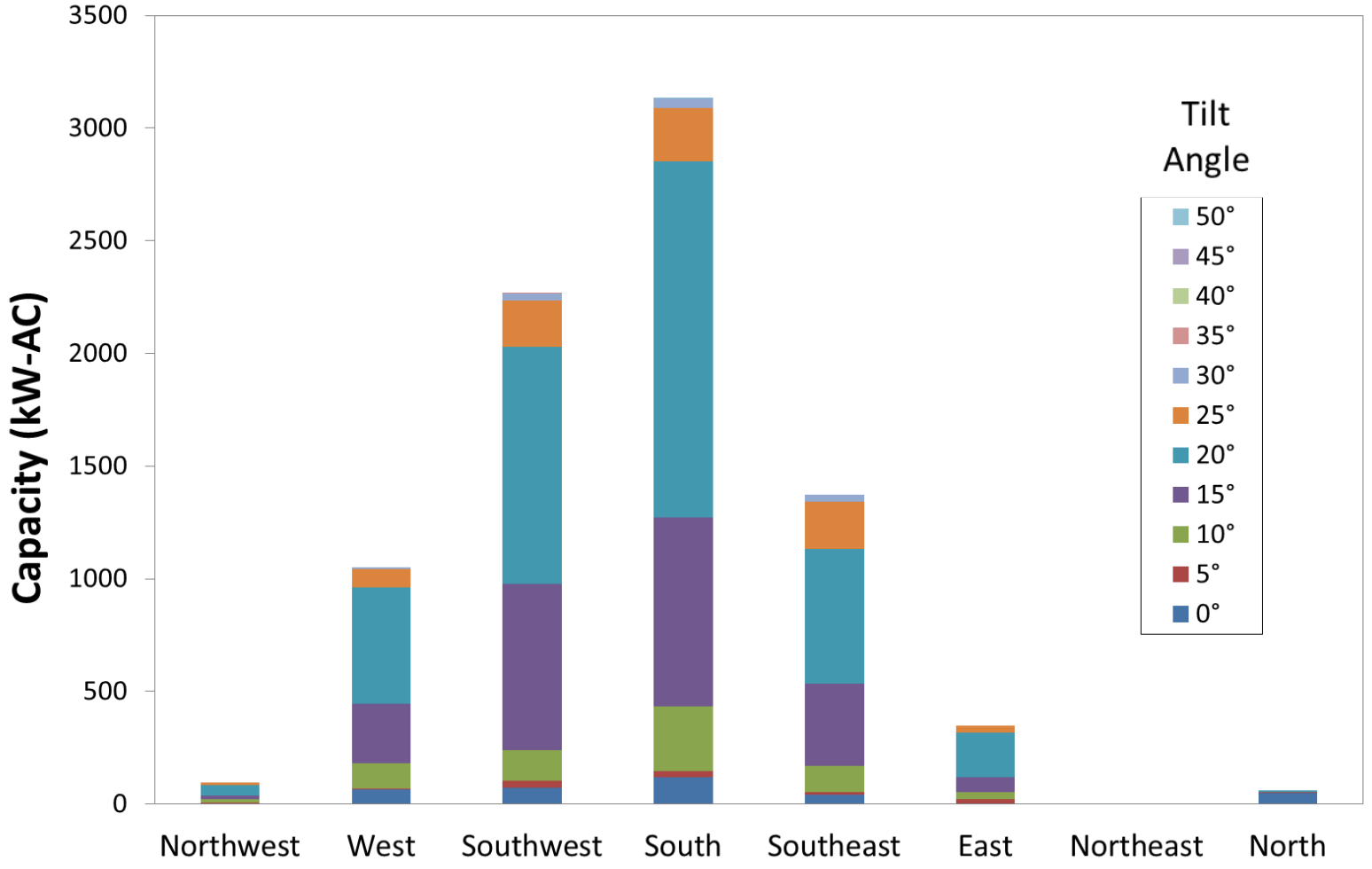


Fleet Production Shape

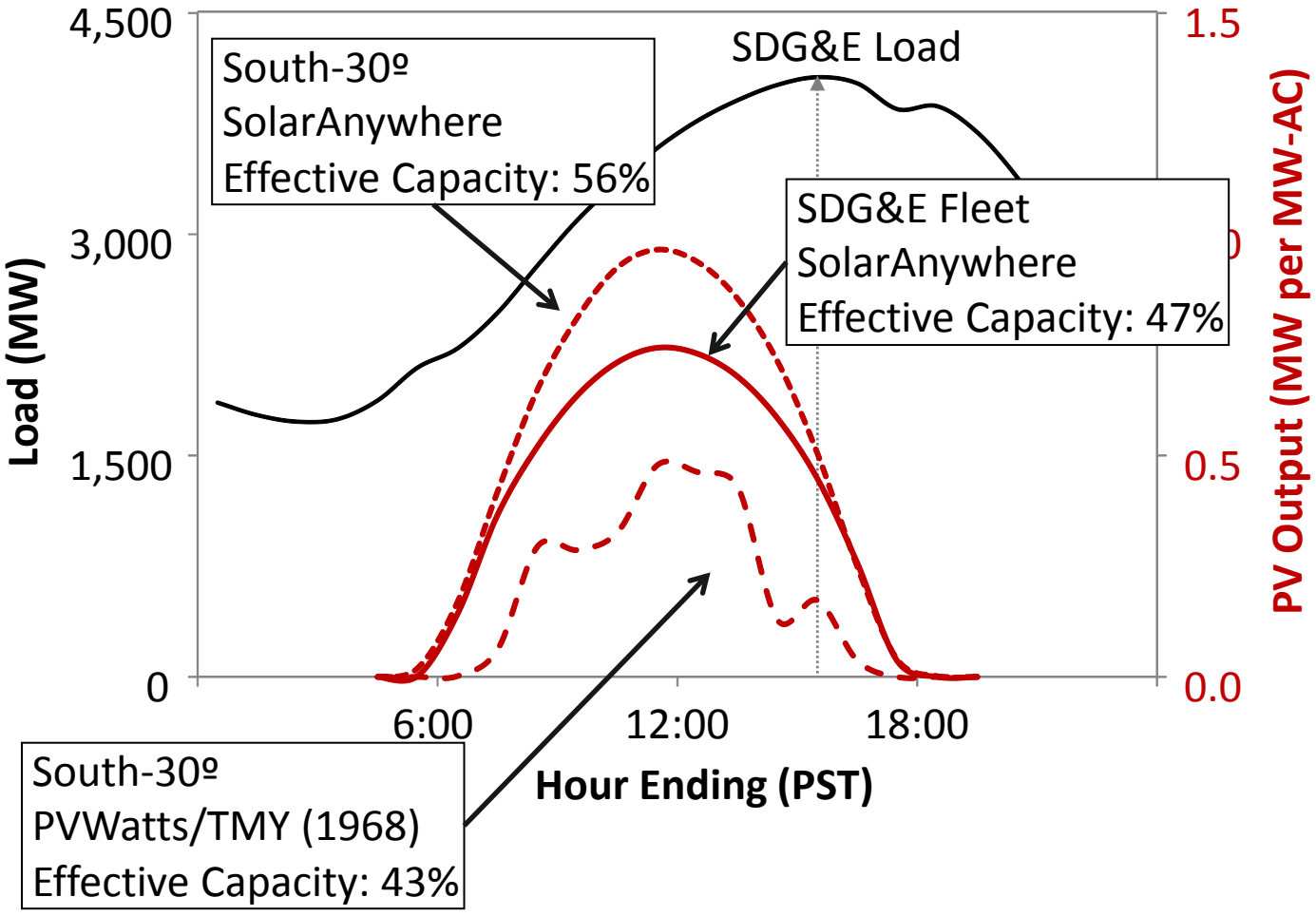
"Why not just use a single, representative PV system, for the solar profile?"

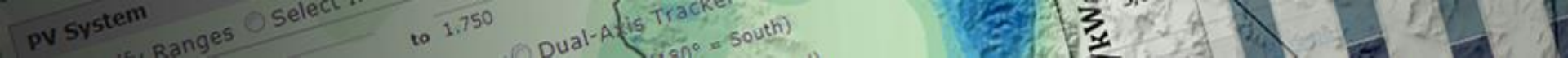
Fleet Orientations

Austin Energy 2013



VOS rates are based on the Fleet Production Shape, time-synched with utility load





Fleet Production Shape

The Fleet Production Shape…

- is the hourly output of the marginal PV resource , 1 kW-AC
- has units of kW per kW-AC
- has the same shape as the aggregate fleet, but scaled to size

Three options to obtain this:

- Actual Fleet - Metered Production
- Actual Fleet - Simulated Production
- Load-based Fleet - Simulated Production

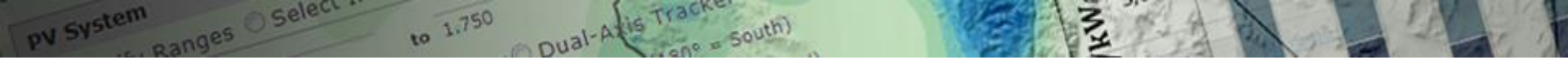
Three different loss savings factors

	Losses Avoided	Key hours of Load Analysis Period	Weighting
Loss Savings$_{ELCC}$	T&D	All	Exponential by load
Loss Savings$_{PLR}$	D Only	Peak	None
Loss Savings$_{AvoidedEnergy}$	T&D	All	None

$$ELCC_{WithLosses} = ELCC_{WithoutLosses}(1 + LossSavings_{ELCC})$$

Calculated twice
(with and w/o losses)

Displayed in Levelized Calculation Chart



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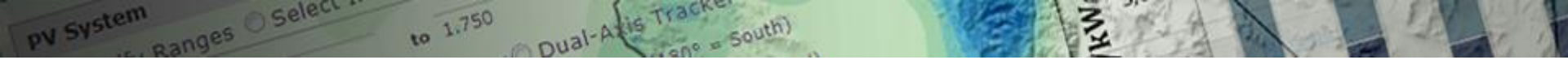
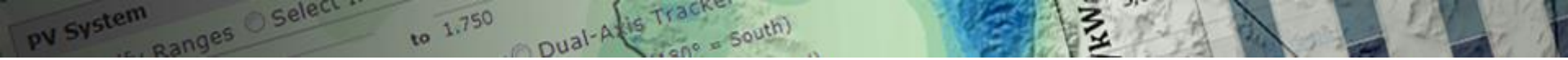


Example Component Calculation

Avoided Fuel Costs

				Prices			Costs			Disc. Costs	
Year	**Guaranteed NG Price**	**Burnertip NG Price**	**Heat Rate**	**Utility**	**VOS**	**p.u. PV Production**	**Utility**	**VOS**	**Discount Factor**	**Utility**	**VOS**
	($/MMBtu)	($/MMBtu)	(Btu/kWh)	($/kWh)	($/kWh)	(kWh)	($)	($)	**(risk free)**	($)	($)
2014	$3.93	$4.43	8000	$0.035	$0.061	1,800	$64	$110	1.000	$64	$110
2015	$4.12	$4.65	8008	$0.037	$0.061	1,791	$67	$110	0.999	$67	$110
2016	$4.25	$4.79	8016	$0.038	$0.061	1,782	$68	$109	0.994	$68	$109
…											
2036	$11.30	$12.70	8178	$0.104	$0.061	1,612	$167	$99	0.523	$88	$52
2037	$11.84	$13.30	8186	$0.109	$0.061	1,604	$175	$98	0.504	$88	$50
2038	$12.41	$13.94	8194	$0.114	$0.061	1,596	$182	$98	0.485	$88	$48

Validation: Present Value	**$1,999**	**$1,999**



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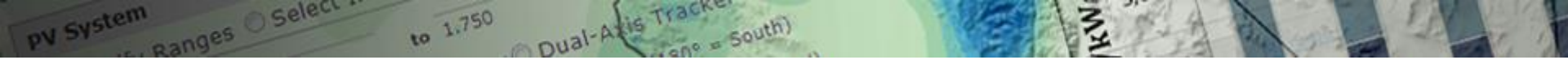


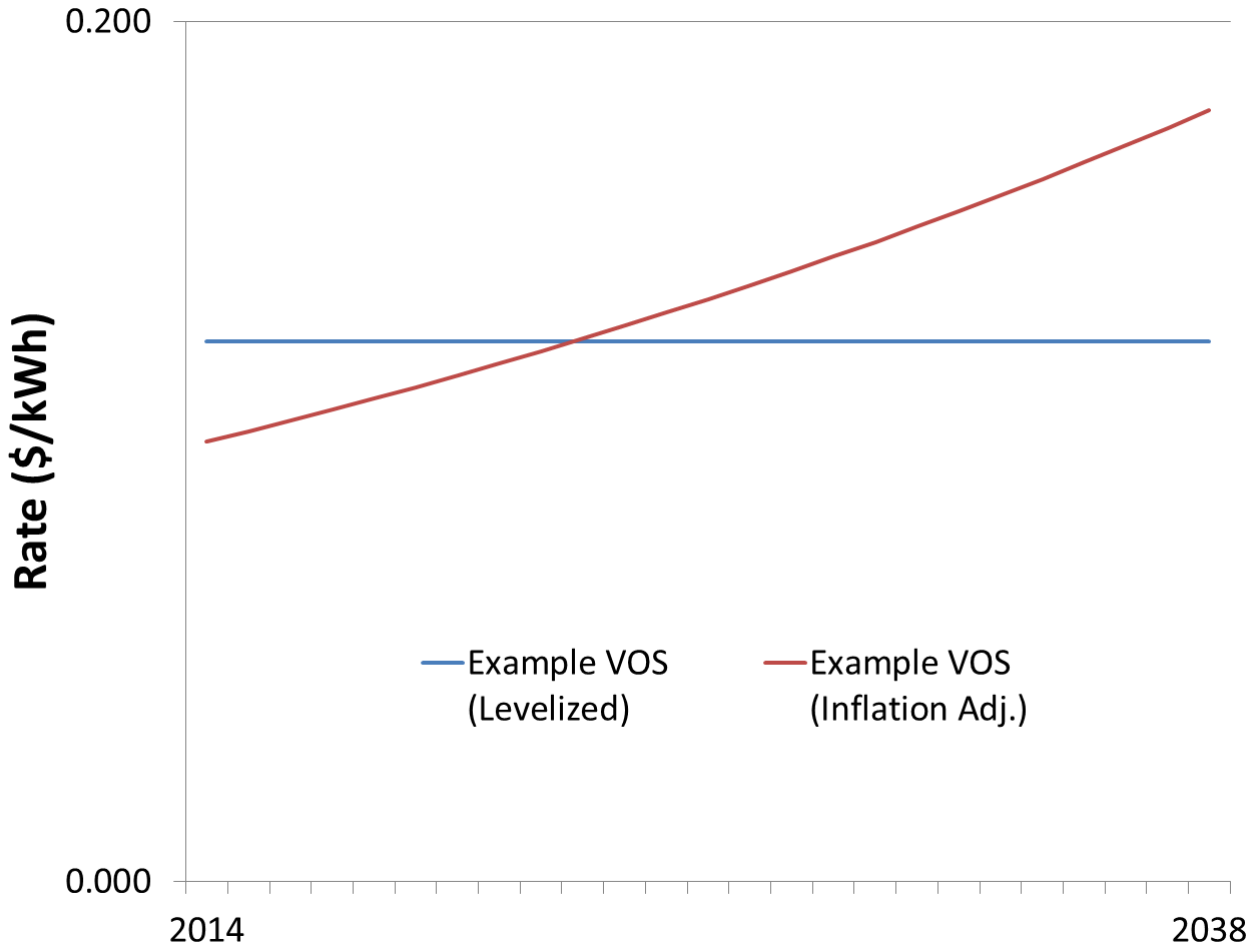
VOS levelized calculation chart (required)

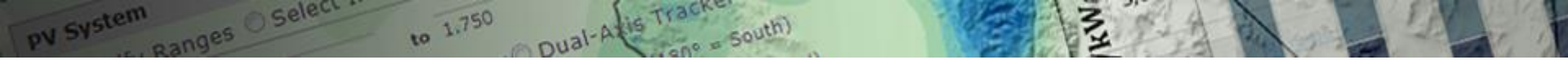
25 Year Levelized Value

	Economic Value ($/kWh)	X	Load Match (No Losses) (%)	X	(1 +	Distributed Loss Savings (%)	) =	Distributed PV Value ($/kWh)
Avoided Fuel Cost	E1					DLS-Energy		V1
Avoided Plant O&M - Fixed	E2		ELCC			DLS-ELCC		V2
Avoided Plant O&M - Variable	E3					DLS-Energy		V3
Avoided Gen Capacity Cost	E4		ELCC			DLS-ELCC		V4
Avoided Reserve Capacity Cost	E5		ELCC			DLS-ELCC		V5
Avoided Trans. Capacity Cost	E6		ELCC			DLS-ELCC		V6
Avoided Dist. Capacity Cost	E7		PLR			DLS-PLR		V7
Avoided Environmental Cost	E8					DLS-Energy		V8
Avoided Voltage Control Cost								
Solar Integration Cost								
								Lev. VOS

Example Results

Inflation-adjusted VOS schedule calculated from levelized VOS





MN Reference Documents

Minnesota Department of Commerce VOS page:

https://mn.gov/commerce/energy/topics/resources/energy-legislation-initiatives/value-of-solar-tariff-methodology%20.jsp

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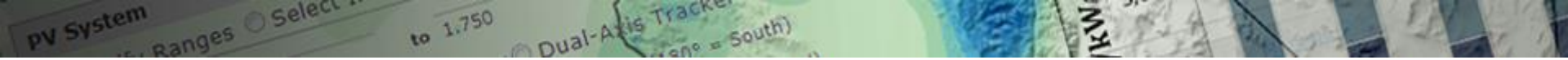
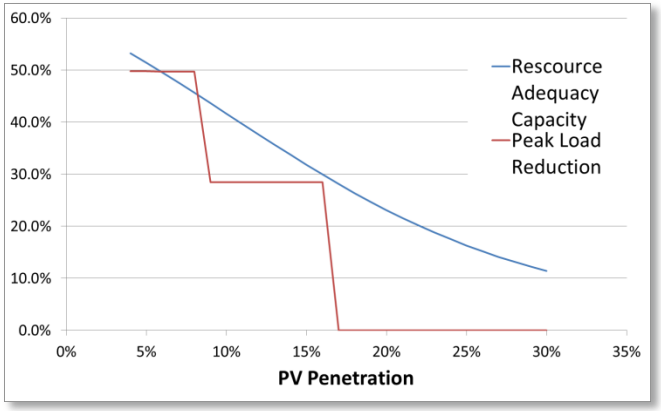
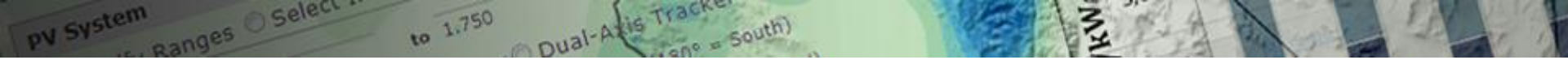


Appendix

Effective Capacity



- Two measures of “effective capacity” are used:
  - Effective Load Carrying Capability (ELCC)
  - Peak Load Reduction (PLR)
- Both measures depend upon penetration level
- VOS is based on current penetration level:
  - “Built in” to load shape used in load analysis
  - Current VOS participants compensated at current penetration level
  - Future VOS participants compensated at future penetration level

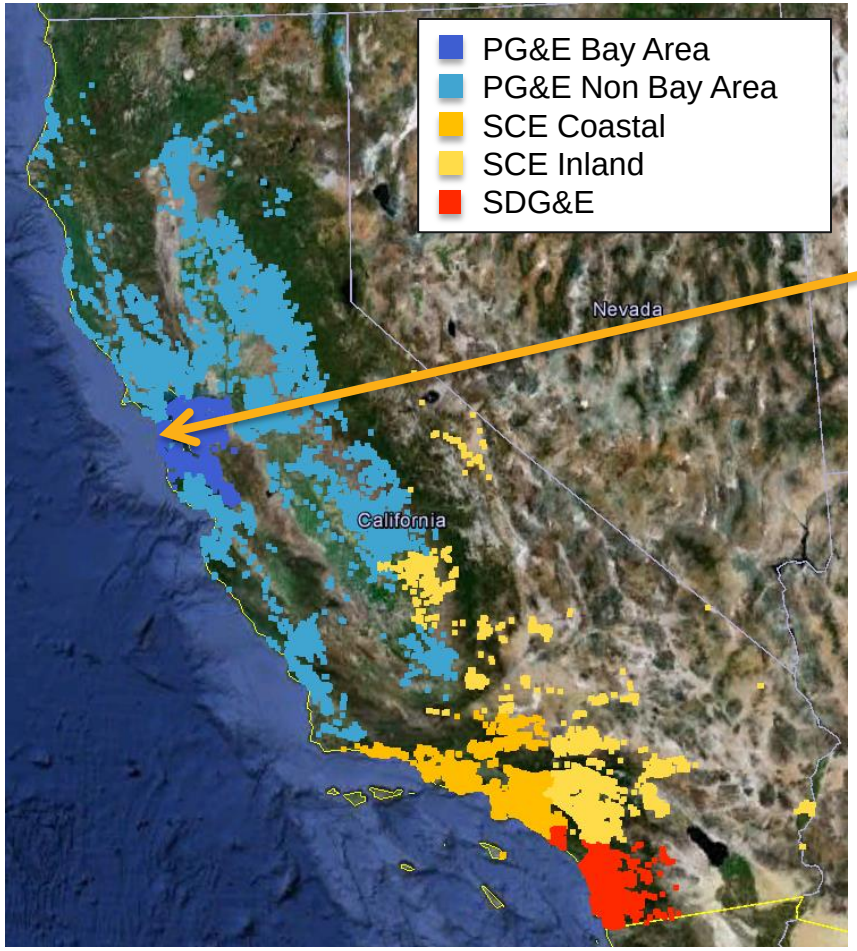


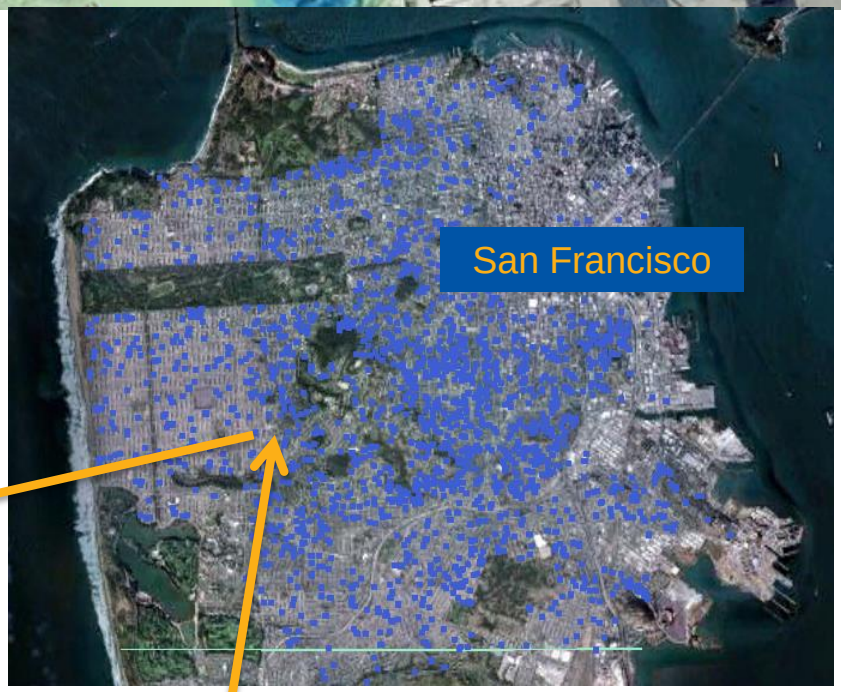
Marginal fuel

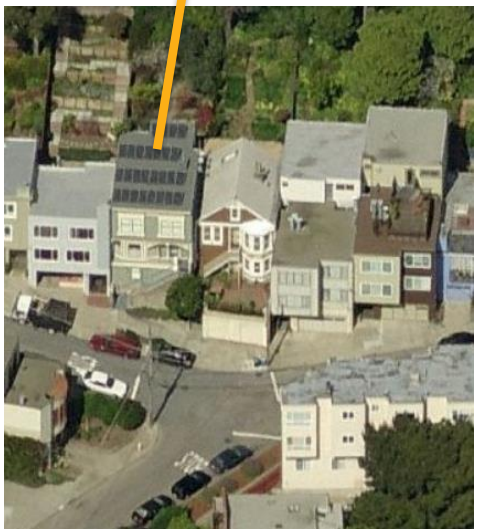
- Methodology assumes that PV displaces natural gas during solar operating hours
- Consistent with MISO market experience
- During some hours of year, other fuels (e.g., coal) may be on margin
  - Assumes that these occur in non-solar hours; or that
  - Overall impact of coal displacement is small

Fleet Simulation

California ISO 2012





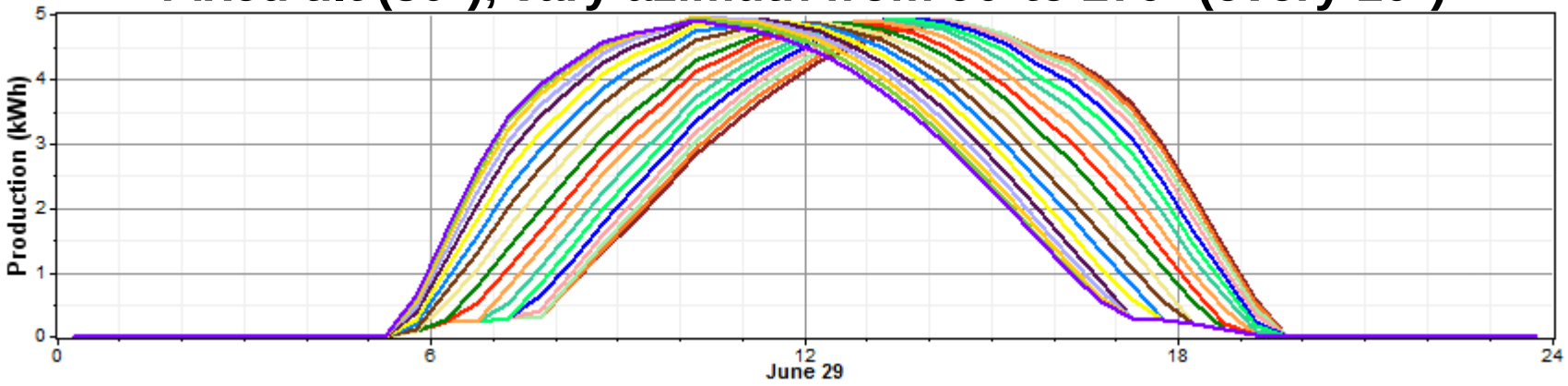


- 4.49 kW-AC
- SunPower Inverter (SPR-5000X, 240V)
- 27 Modules (SunPower 210 W, SPR-210-WHT)
- 37.76281º N, 122.44313º W
- South, 10 degree tilt
- Commissioned April 2008

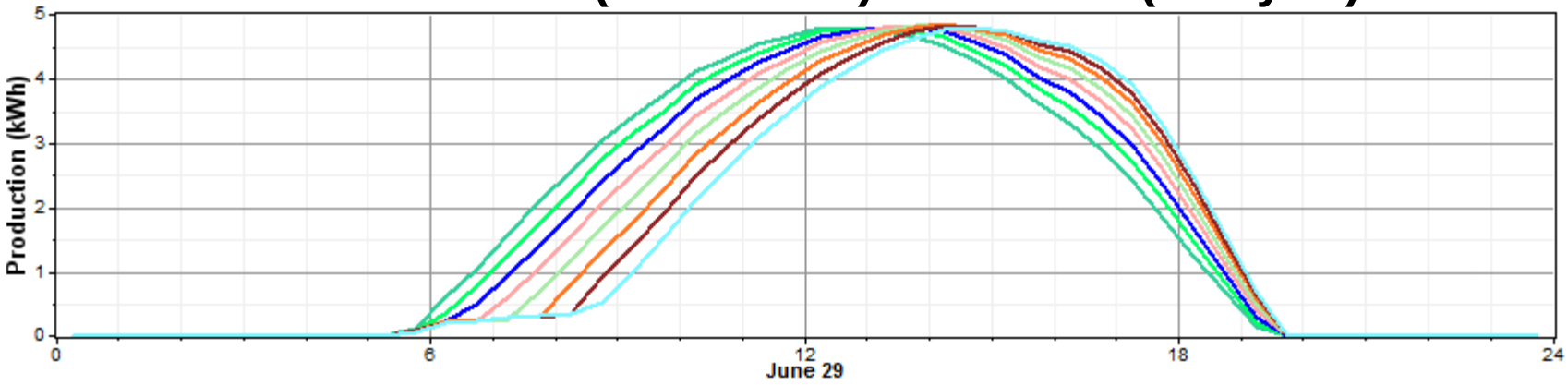
Example solar shapes by configuration

Duke Energy, 2013

Fixed tilt (30°), vary azimuth from 90°to 270° (every 10°)



Fixed Azimuth (270°- West) Tilt 5°- 40° (every 5°)



VOS rating convention: kW-AC (*with losses*)

kW-AC = kW-DC_{STC} x Module Derate x Inv Efficiency x Loss Factor

Example:

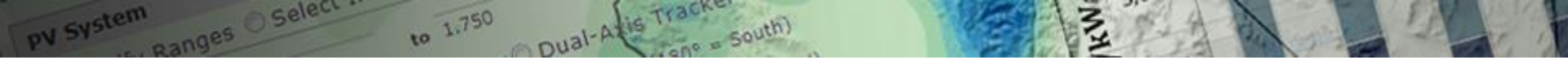
10 kW DC_{STC}

X 90% module derate factor

X 95% inverter load-weighted efficiency

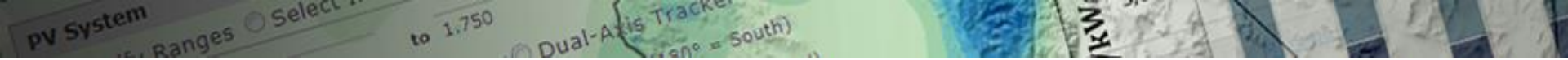
X 85% other loss factor

7.27 kW-AC



Load Analysis Period

- Used for hourly loss calculations, ELCC calculation, PLR calculation, annual energy calculation
- Must be at least one year
- Must be made up of complete, full years (not partial years)



Load Analysis Data

Includes:

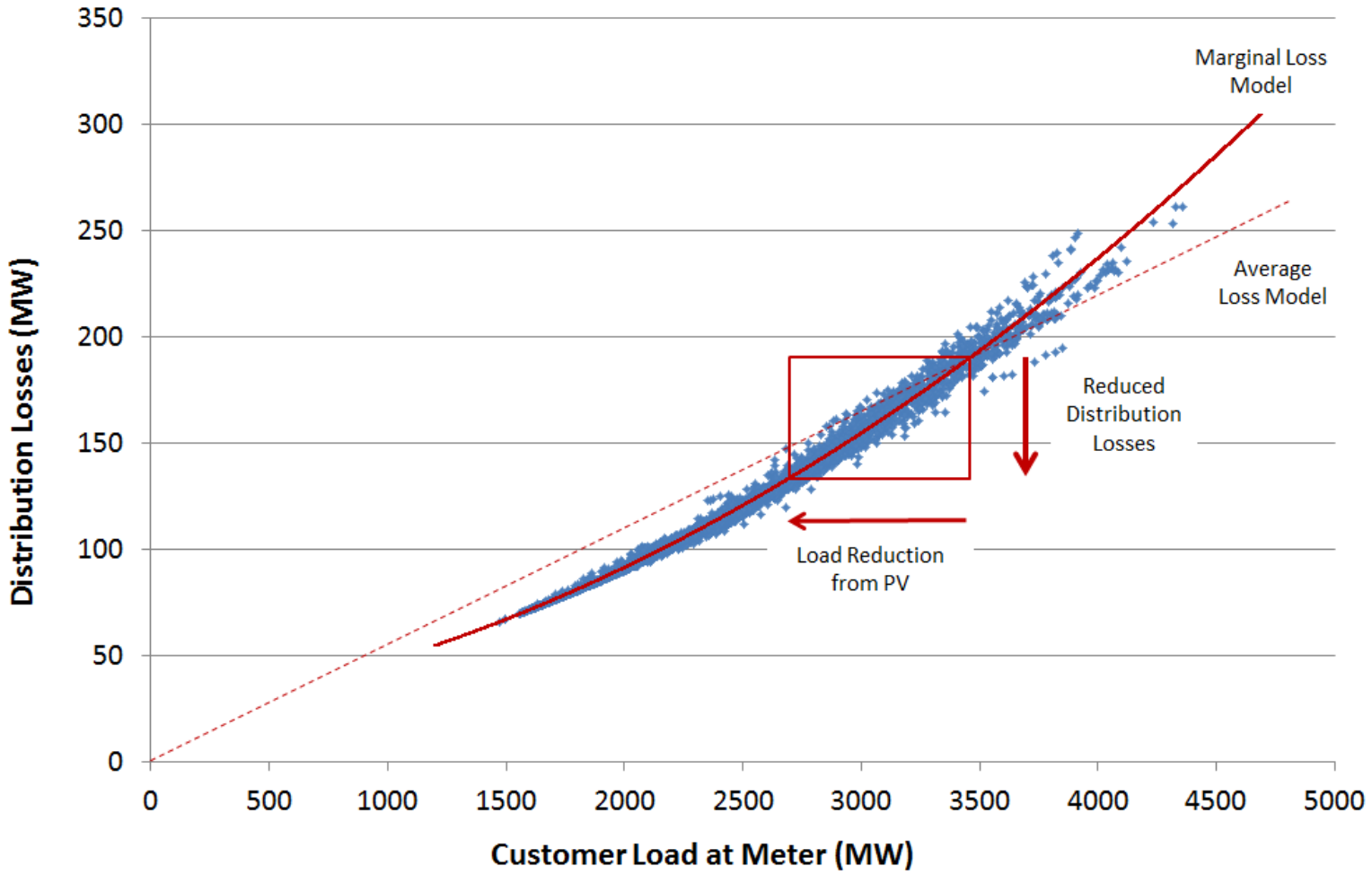
- Utility loads (hourly)
- Distribution loads (hourly)
- Fleet Production Shape

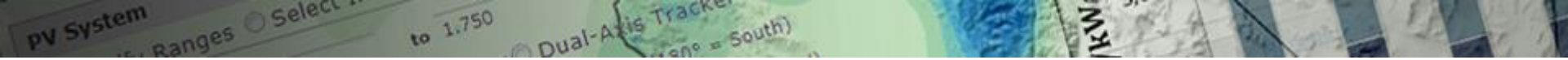
Requirements:

- Time synchronized
- Cleaned

Non-linear loss model example

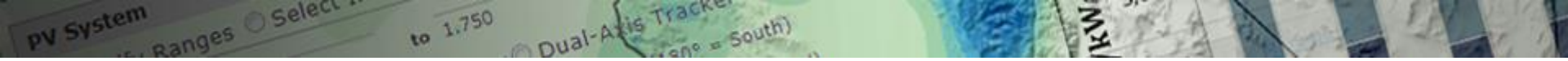
Based on SDG&E secondary loss factors, 2012





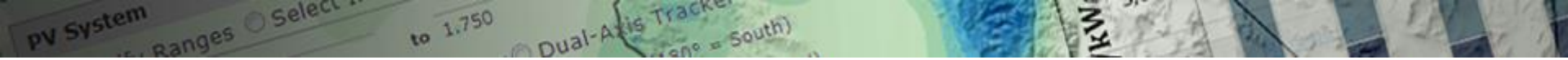
Requirements for loss savings calculations

1. Losses calculated for each hour of the Load Analysis Period.
2. The marginal PV resource is used (Fleet Production Shape), time-synched with utility generation load.
3. Transmission and distribution losses calculated separately using distinct loss study data.
4. Calculated on marginal basis (e.g., if load is 1000 kW and PV produces 1 kW, then the marginal loss savings are losses at 1000 kW minus losses at 999 kW.
5. Distribution losses should be based on the power entering the distribution system, after transmission losses.



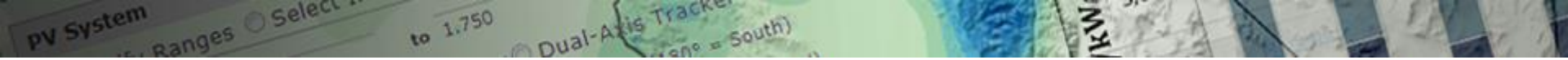
Requirements for loss savings calculations (continued…)

6. Avoided transmission losses should take into account both the avoided load due to marginal PV and the avoided distribution losses.
7. Calculations of avoided losses should not include no-load losses (e.g., corona, leakage current).
8. Calculations of avoided losses in any hour should take into account the non-linear relationship between losses and load.



Three different discount rates

Discount Rate	Purpose	Source
Risk-free discount rate	Discounting and levelizing avoided fuel costs	U.S. Treasury yields of various terms
Environmental discount rate	Discounting and levelizing environmental costs	EPA (corresponds to future CO_2 costs)
Utility discount rate	Discounting and levelizing all other costs	Utility weighted average cost of capital (WACC)



Avoided Fuel Costs

Fuel price volatility

- Fuel costs are subject to high and unknown volatility. Fluctuations in fuel costs are passed on to customers through a fuel adjustment charge. Therefore, the cost of fuel volatility is borne by customers.
- PV energy is delivered into the grid at a fixed, long-term rate, not subject to fuel price volatility.
- To account for this difference, long term, guaranteed fuel prices are used, and discounting/levelizing is done using risk-free rates.

Avoided Fuel Costs

Three options for obtaining guaranteed fuel prices:

- Futures Market
  - Based on NYMEX futures, 4.75% escalation after 12 years
  - Details provided in methodology
- Long Term Price Quotation
  - Same, except utility obtains 25-year quotation from AA-rated supplier of natural gas
- Utility-guaranteed Price
  - Utilities include in their rate filing a mechanism for removing the fuel adjustment charges for the solar customer over the 25 year term

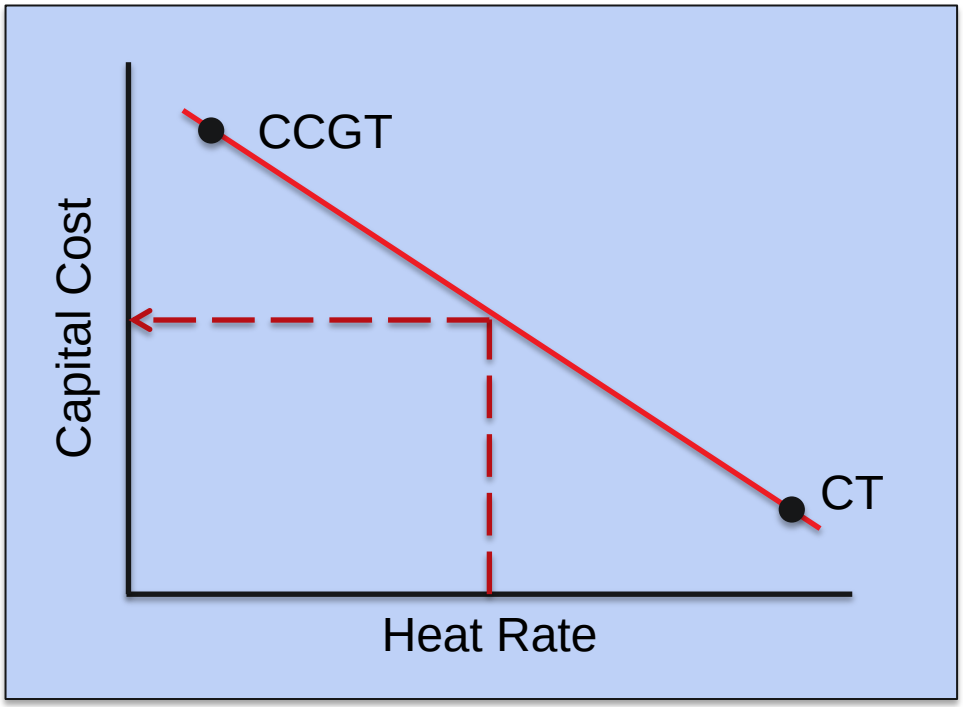
Solar weighted heat rate

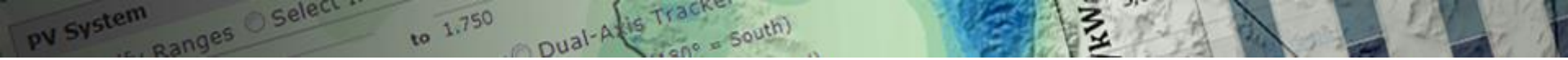
$$HeatRate_0 = \frac{\sum HeatRate_j \times FleetProduction_j}{\sum FleetProduction_j}$$

- Gives heat rate input value
- Used for the first year
- Evaluated over hours of Load Analysis Period
- Use actual marginal heat rates, Fleet Production Shape

Avoided Gen. Capacity Cost

- Based on costs of two technologies: peaking CT and intermediate CCGT
  - CT has high heat rate, low cost
  - CCGT has low heat rate, high cost
- The “displaced capacity” must be consistent with the “displaced fuel” (i.e., from the same “displaced resource”)
- Therefore, the capital cost of the displaced resource is assumed to be between the CT and CCGT, using the Solar Weighted Heat Rate to interpolate

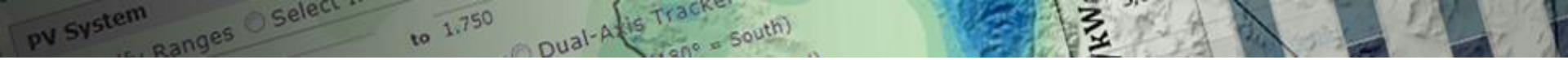




Avoided Dist. Capacity Cost

Two Options

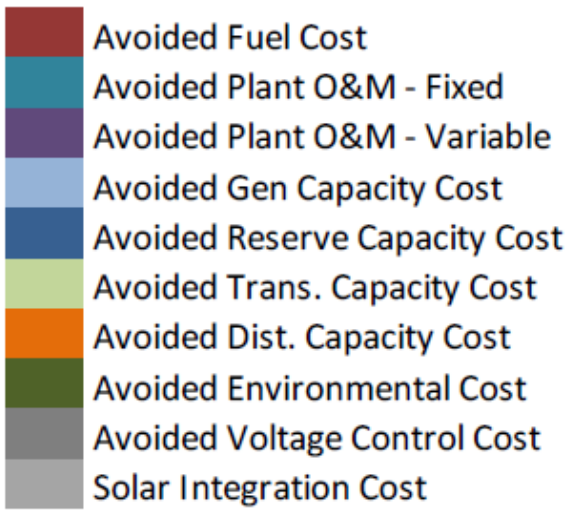
	Data Sources	VOS
System-wide Avoided Costs	System-wide data is used	Single result, applies to all locations
Location-specific Avoided Costs	Local costs, growth rates, etc	Multiple VOS results, allows “targeting” of high-value areas



(Example) Deferrable Dist. Cost Evaluation

Account	Account Name	Additions ($) [A]	Retirements ($) [R]	Net Additions ($) = [A] - [R]	Capacity Related?	Deferrable ($)
	DISTRIBUTION PLANT					
360	Land and Land Rights	13,931,928	233,588	13,698,340	**100%**	13,698,340
361	Structures and Improvements	35,910,551	279,744	35,630,807	**100%**	35,630,807
362	Station Equipment	478,389,052	20,808,913	457,580,139	**100%**	457,580,139
363	Storage Battery Equipment					
364	Poles, Towers, and Fixtures	310,476,864	9,489,470	300,987,394		
365	Overhead Conductors and Devices	349,818,997	22,090,380	327,728,617	**25%**	81,932,154
366	Underground Conduit	210,115,953	10,512,018	199,603,935	**25%**	49,900,984
367	Underground Conductors and Devices	902,527,963	32,232,966	870,294,997	**25%**	217,573,749
368	Line Transformers	389,984,149	19,941,075	370,043,074		
369	Services	267,451,206	5,014,559	262,436,647		
370	Meters	118,461,196	4,371,827	114,089,369		
371	Installations on Customer Premises	22,705,193		22,705,193		
372	Leased Property on Customer Premises					
373	Street Lighting and Signal Systems	53,413,993	3,022,447	50,391,546		
374	Asset Retirement Costs for Distribution Plant	15,474,098	2,432,400	13,041,698		
TOTAL		3,168,661,143	130,429,387	3,038,231,756		**$ 856,316,173**

MN Example Calculation (illustrative only)



	Economic Value	Load Match (No Losses)	Distributed Loss Savings	Distributed PV Value
	($/kWh)	(%)	(%)	($/kWh)
Avoided Fuel Cost	$0.056		8%	$0.061
Avoided Plant O&M - Fixed	$0.003	40%	9%	$0.001
Avoided Plant O&M - Variable	$0.001	40%	8%	$0.001
Avoided Gen Capacity Cost	$0.048	40%	9%	$0.021
Avoided Reserve Capacity Cost	$0.007	40%	9%	$0.003
Avoided Trans. Capacity Cost	$0.018	40%	9%	$0.008
Avoided Dist. Capacity Cost	$0.008	30%	5%	$0.003
Avoided Environmental Cost	$0.027		8%	$0.029
Avoided Voltage Control Cost				
Solar Integration Cost				
				$0.127

Example