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LTPP Solar PV

Potential and Levelized Cost of Energy (LCOE)

June 28, 2010

Goals of Potential Analysis

- Develop PV Potential estimates
  - Identify 'Easy to connect' and 'harder to connect'
  - 4 size and configuration categories
    - 0.5 – 2 MW Roof, 0.5 – 2 MW Ground, 2 – 5 MW Ground, 5 – 20 MW Ground
  - 4 locations across California
    - Desert, Central Valley, North Coast, South Coast

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PV Potential Estimation

- Adjusted the 33% RPS Implementation Analysis potential study approach
  - Same underlying proprietary utility substation loadings and locations as used previously
  - Same large rooftop potential with satellite imagery
- Key changes
  - Added small roofs in rural areas
  - “Set aside” potential for current programs

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Screening Assumptions

- 'Easy' Interconnection
  - Nameplate PV system is less than or equal to 30% of peak load at point of interconnection to avoid reverse flow
- Participation
  - 33% of large roof owners will participate
- Penetration
  - 33% of feeders accommodate ground-mounted systems up to the 'easy' interconnection limits
  - 33% of RETI identified large PV sites can be interconnected with a moderate transmission interconnection cost
  - 10% of rural 'easy' interconnection potential in small roofs

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Distributed Solar PV

- 20 MW sites near non-urban 69 kV substations
- Smaller projects on rooftops, large commercial rooftops with 0.25 MW potential
- Limited by 30% peak load at a given substation

Illustrative Example of Distributed Solar PV

- 20 MW near substations
- Large commercial rooftops
- Residential rooftops

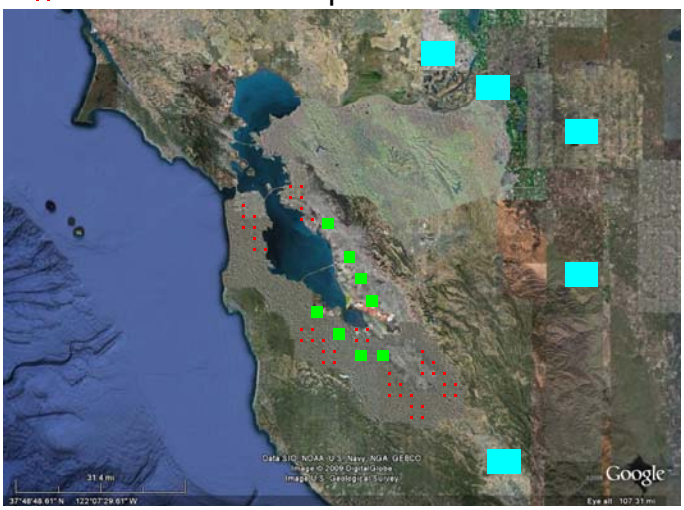

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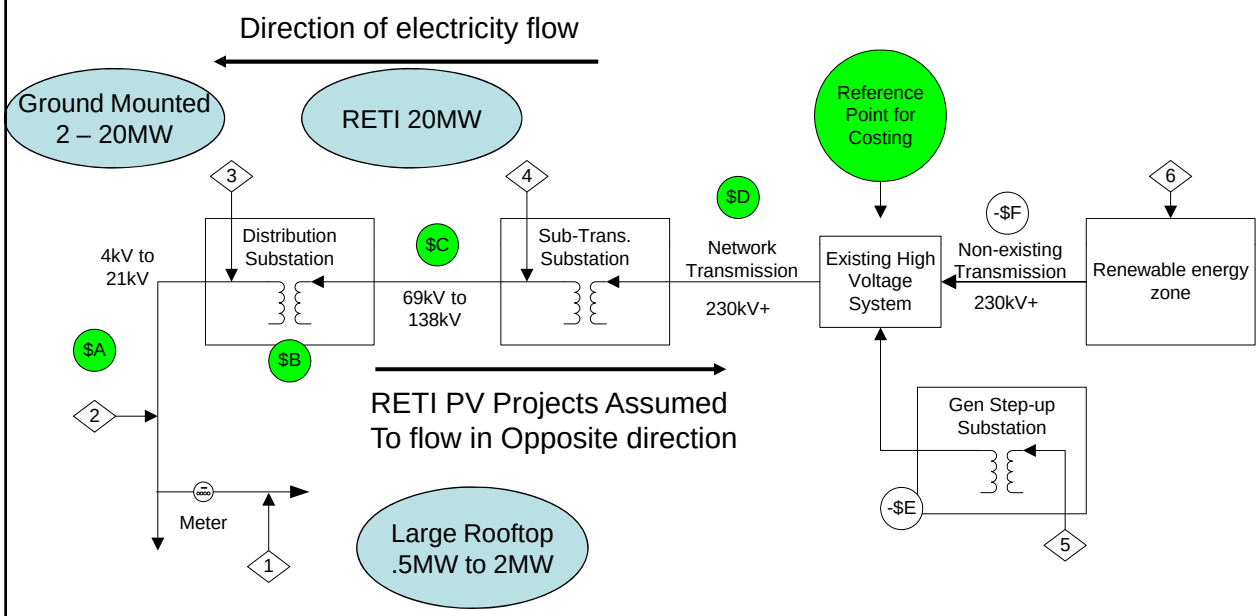
Diagram of Interconnection Points



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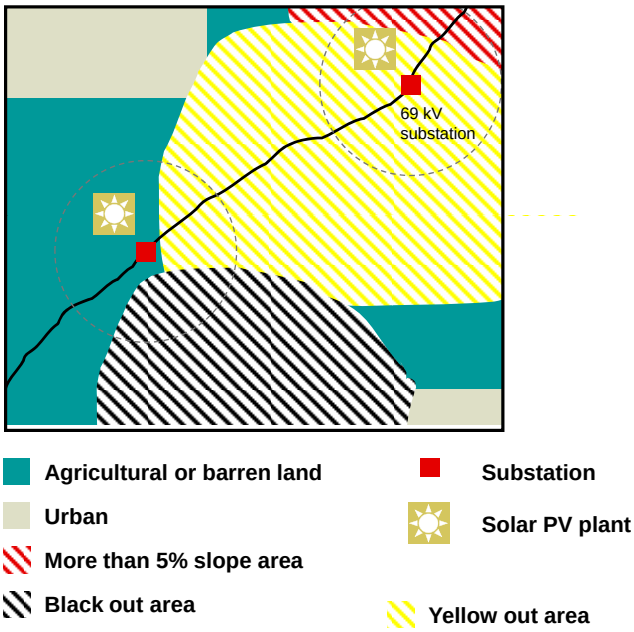
RETI Ground Mounted PV

- Initial criteria
  - near sub stations equal or less than 69 kV
  - agricultural or barren land
  - less than 5% slope
- Environmental screen
  - Black out areas
  - Yellow out areas
- Land parcel
  - a continuous 160 acre plot (20 MWp)
  - within 20 miles

Example B&V Map for Solar PV Non-Urban Projects



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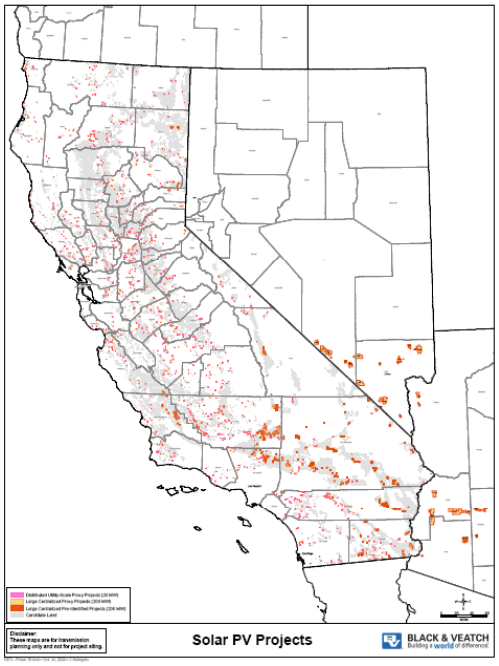
RETI Results on 20 MW Sites

- 27,500 MW nameplate PV sites identified
- ~1300 sites identified
- Filters Applied
  - 160 acres + for 20 MW
  - No sites within 2 miles of urban zones
  - Near substations, most are 2 to 3 miles of the distribution subs with 69kV+ high-side voltage
  - Land slope < 5%
- 20 MW on substations with high side voltage of 69kV
- 40 MW on substations with higher voltage than 69kV
- Assumed not to be Rule 21 compliant



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Black and Veatch Rooftop Analysis

- GIS used to identify large roofs in CA and count available large roof area
- Criteria
  - ‘Urban’ areas with little available land
  - Flat roofs larger than ~1/3 acre
  - Assumes 65% usable space on roof
  - Within 3 miles of distribution substation

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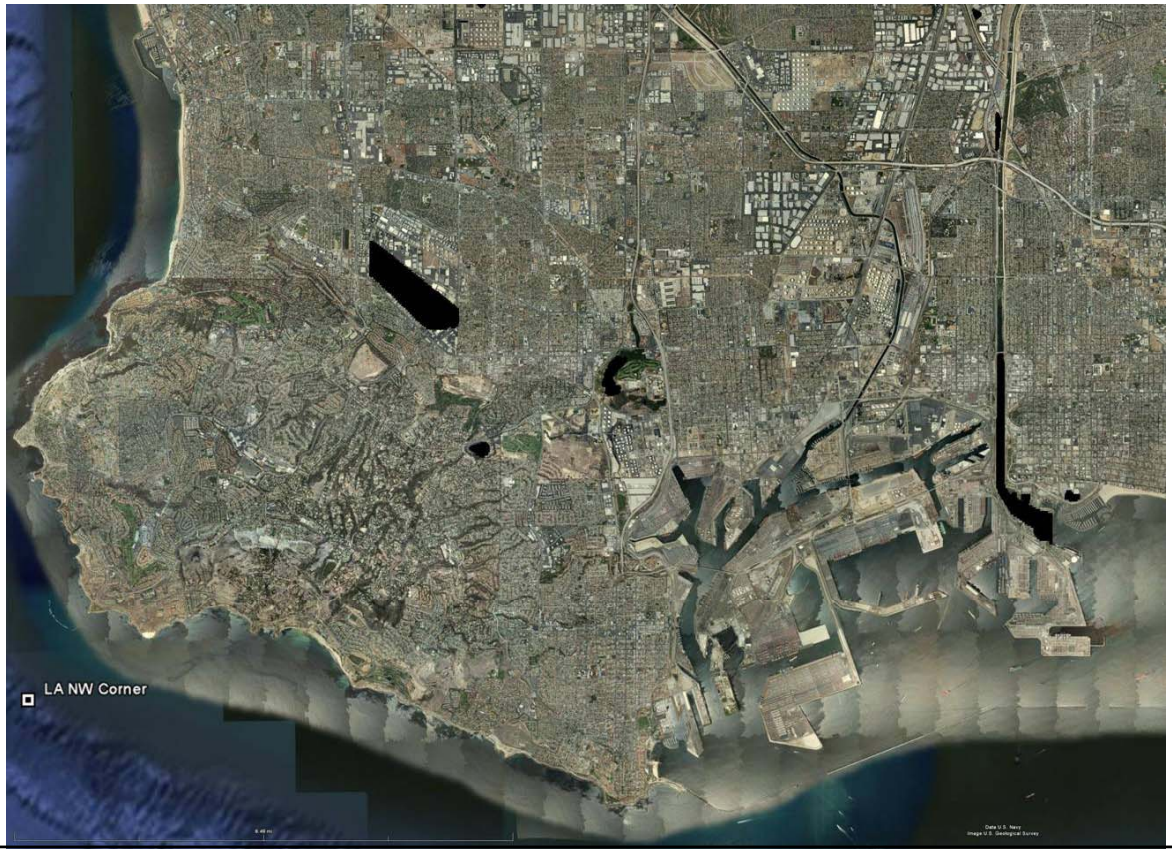
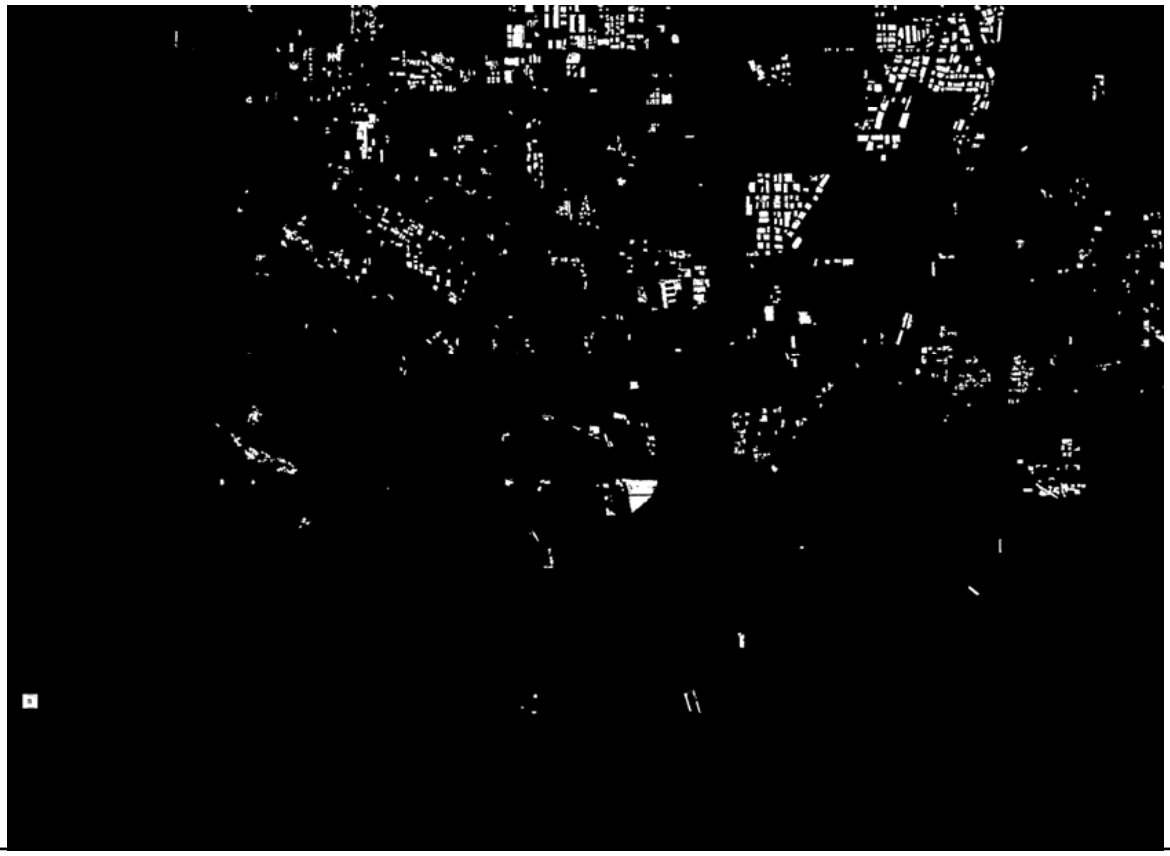
Solar Photovoltaic Rooftop Identification



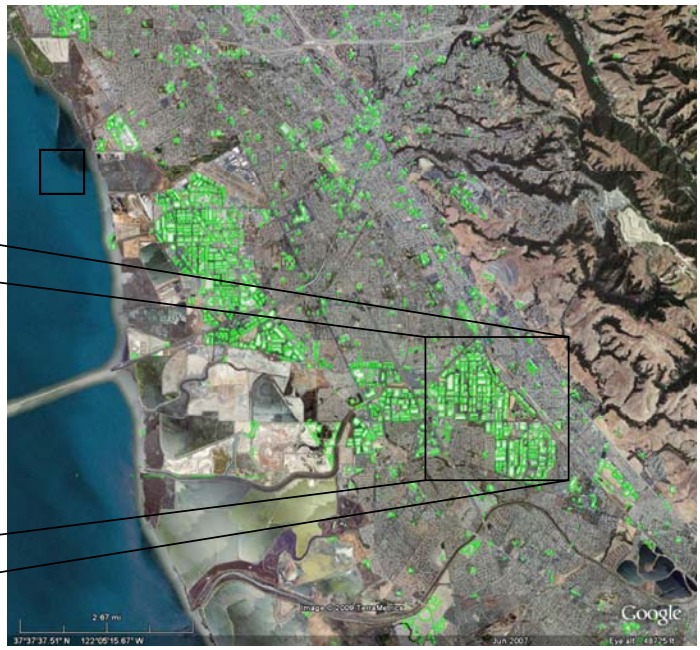
Solar Rooftop Identification

Solar Rooftop Identification



East Bay Area Example

Analysis automates the counting of roof space and tallies total acreage of large roof space. Also checks proximity to distribution substation (not shown due to confidentiality).



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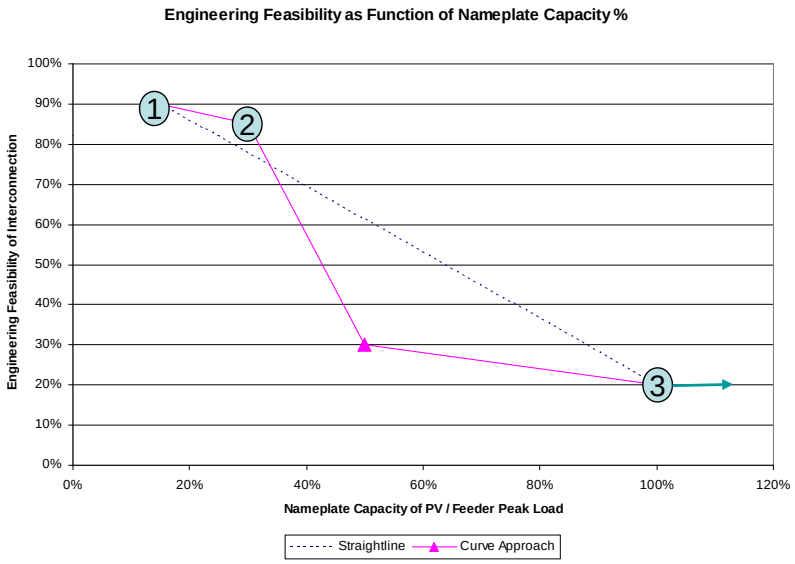
July 31, 2009

Technical Feasibility of PV Connections that are >15% & <100% of Peak Load

- Assumption on PV engineering feasibility

Caveat
These numbers are based on an educated guess not on any engineering analysis.



1 15% Peak Load 50% of in area PV

2 30% Peak Load 50% of in area PV

3 100+% Peak Load RETI projects

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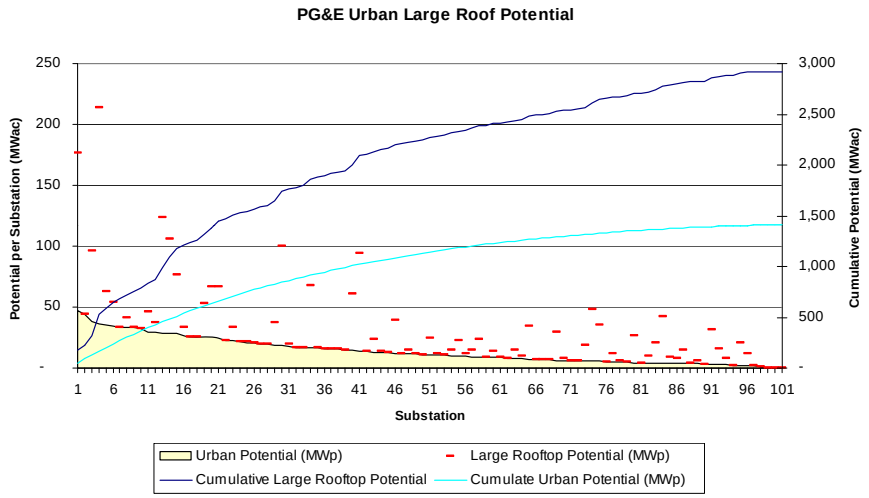
PG&E Example – Bay Area



Clusters of large roofs make it impossible to do every roof and be below the 30% peak load.

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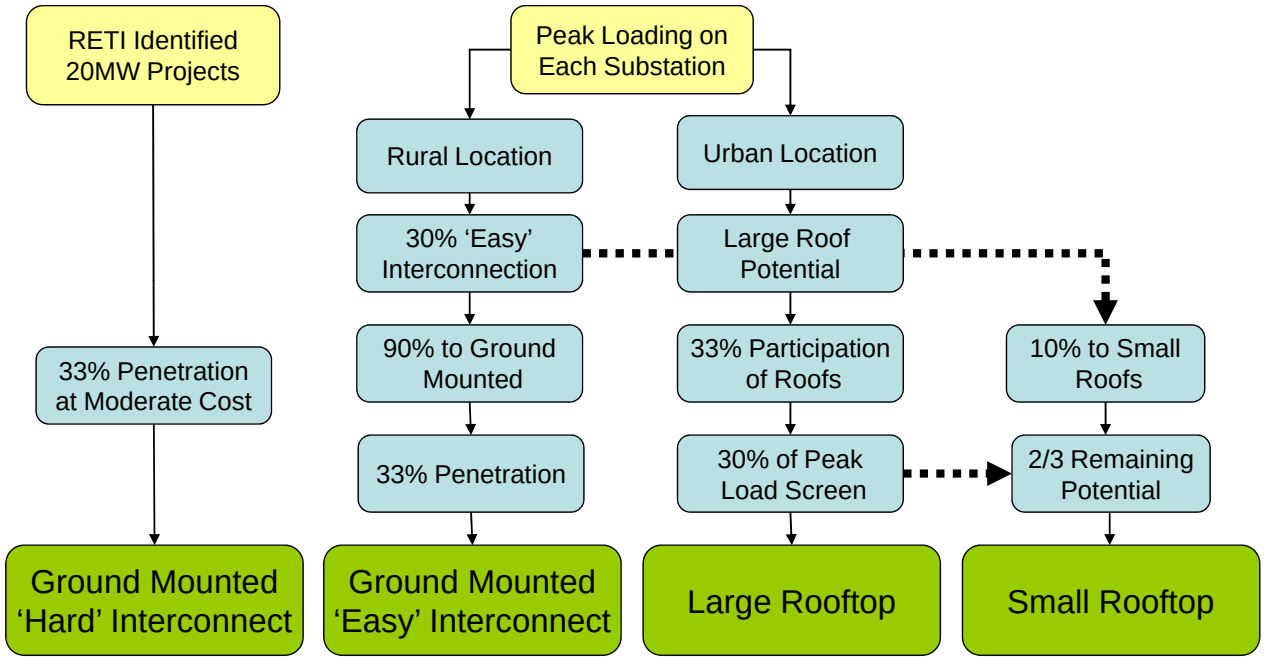
PV Potential Screening Method



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Screening Steps

- Raw Potential (MWs):

RETI Identified Sites
27,500

Substation Load Total
39,323

- After Screening (MWs):

Hard-to-Interconnect	Easy-to-Interconnect				TOTAL
Ground Mounted (>30% of peak load)	Ground Mounted (<30% of peak load)	Large Rooftop	Small Rooftop	Easy-to-Interconnect Total	
9167	2350	3671	3235	**9257**	**18424**

- After Removing Existing Programs (MWs):

Hard-to-Interconnect	Easy-to-Interconnect				TOTAL
Ground Mounted (>30% of peak load)	Ground Mounted (<30% of peak load)	Large Rooftop	Small Rooftop	Easy-to-Interconnect Total	
9167	1728	3241	977	**5947**	**15113**

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Modeled PV Potential (MW)

		Easy to Interconnect					Harder to Interconnect	TOTAL
		Ground Mounted (5-20MW)	Ground Mounted (2-5MW)	Ground Mounted (0.5-2MW)	Large Rooftop	Small Rooftop	RETI projects (>30%)	
PG&E	North Coast	151	46	13	779	18	1260	2266
	Central Valley	136	110	23	0	3	4267	4539
	TOTAL	**287**	**156**	**36**	**779**	**21**	**5527**	**6805**
SCE	Mojave Desert	55	9	2	0	14	947	1027
	Central Valley	99	14	2	0	420	467	1002
	South Coast	672	4	1	986	8	280	1951
	TOTAL	**827**	**27**	**5**	**986**	**442**	**1693**	**3981**
SDG&E	South Coast	86	2	0	138	103	153	483
	Mojave Desert	45	1	0	72	54	80	252
	TOTAL	**131**	**4**	**1**	**210**	**157**	**233**	**736**
Other	Central Valley	138	4	1	710	200	960	2013
	North Coast	26	1	0	133	38	180	377
	Mojave Desert	82	2	0	424	120	573	1202
	TOTAL	**246**	**7**	**1**	**1267**	**357**	**1713**	**3592**
TOTAL		**1492**	**193**	**43**	**3241**	**977**	**9167**	**15113**

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Goals of PV LCOE Analysis

- Create a publicly available pro-forma tool that calculates a levelized cost (LCOE)
- Develop model inputs
  - Capital Costs and Operating Costs
  - Performance parameters
  - Financing assumptions
- Calculate levelized cost of solar PV
- Standardize the LCOE presentation

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PV Financial Pro Forma Tool

- Balance complexity vs. applicability for a broad range of projects
- Some of the features:
  - Debt Service Coverage Ratio (DSCR) limit
  - Inverter replacement fund
  - Debt service reserve fund
- Available on E3 website for download;
  - http://www.ethree.com/public_projects/cpuc6.html

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Example – Model Inputs

Location: Desert
Technology: 5-20 MW Ground Mounted

System Cost & Performance Inputs:

	Inputs
System Size (DC) (MW)	20
System Cost ($/watt DC)	$3.700
Annual DC Capacity Factor	21.3%
System lifetime (Years)	25
Degradation Factor (%/yr)	1.00%
O&M Costs ($/kW)	$20.0
O&M Cost Escalator (%/yr)	2.0%
Inverter replacement cost ($/W)	$0.250
Inverter replacement time (Years)	10
Insurance Expense ($/kW)	$20.0
Insurance Escalator (%/yr)	2.0%

Financing Inputs:

	Inputs
Percent Financed with Equity	60%
After-Tax WACC	8.25%
Debt Interest Rate	7.50%
Cost of Equity	*10.79%*
Target minimum DSCR	1.40
Debt Period in Years	20
Federal Tax Rate	35%
State Tax Rate	9%
Tax Credit Rate	30%
MACRS Term	5
Escalator	0%

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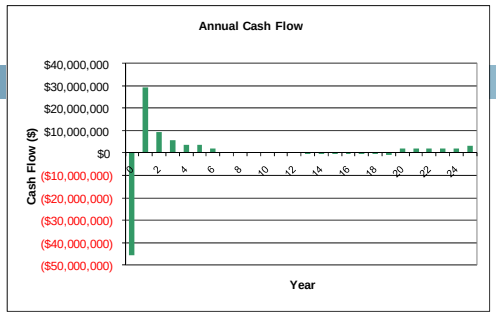
Example - Cashflow

Location: Desert
Technology: 5-20 MW Ground Mounted



- Screenshot of cash flow:

Year	0	1	2	3	4	5	6	7
Energy Production (MWh)		**37,398**	**37,024**	**36,654**	**36,288**	**35,925**	**35,565**	**35,210**
Cost of Generation ($/MWh)		$167.8186	$167.8186	$167.8186	$167.8186	$167.8186	$167.8186	$167.8186
Operating Revenue		$6,276,144	$6,213,383	$6,151,249	$6,089,737	$6,028,839	$5,968,551	$5,908,865
Total Revenue		**$6,276,144**	**$6,213,383**	**$6,151,249**	**$6,089,737**	**$6,028,839**	**$5,968,551**	**$5,908,865**
O&M Costs		($408,000)	($416,160)	($424,483)	($432,973)	($441,632)	($450,465)	($459,474)
Inverter Replacement Cost		($500,000)	($481,250)	($462,500)	($443,750)	($425,000)	($406,250)	($387,500)
Insurance Costs		($408,000)	($416,160)	($424,483)	($432,973)	($441,632)	($450,465)	($459,474)
Total Costs		**($1,316,000)**	**($1,313,570)**	**($1,311,466)**	**($1,309,696)**	**($1,308,265)**	**($1,307,180)**	**($1,306,449)**
Operating Profit		**$4,960,144**	**$4,899,813**	**$4,839,783**	**$4,780,041**	**$4,720,575**	**$4,661,371**	**$4,602,417**
Interest Expense		($2,352,336)	($2,298,015)	($2,239,620)	($2,176,846)	($2,109,364)	($2,036,820)	($1,958,836)
Loan Repayment Expense (Principal)		($724,274)	($778,595)	($836,990)	($899,764)	($967,246)	($1,039,790)	($1,117,774)
Debt Service Reserve		$0	$0	$0	$0	$0	$0	$0
Interest earned on DSRF		$110,938	$110,938	$110,938	$110,938	$110,938	$110,938	$110,938
Net Finance Costs		**($2,965,672)**	**($2,965,672)**	**($2,965,672)**	**($2,965,672)**	**($2,965,672)**	**($2,965,672)**	**($2,965,672)**
State tax refund/(paid)		$1,067,983	$1,853,506	$1,016,326	$513,663	$512,954	$134,979	($243,499)
Federal tax refund (paid)		$26,165,147	$5,446,615	$2,922,281	$1,406,400	$1,403,842	$263,400	($878,857)
Taxes Saved/(Paid)		**$27,233,130**	**$7,300,121**	**$3,938,607**	**$1,920,063**	**$1,916,796**	**$398,379**	**($1,122,356)**
Equity Investment	($45,593,868)							
After Tax Equity Cash Flow	**($45,593,868)**	**$29,227,602**	**$9,234,262**	**$5,812,717**	**$3,734,431**	**$3,671,699**	**$2,094,078**	**$512,389**

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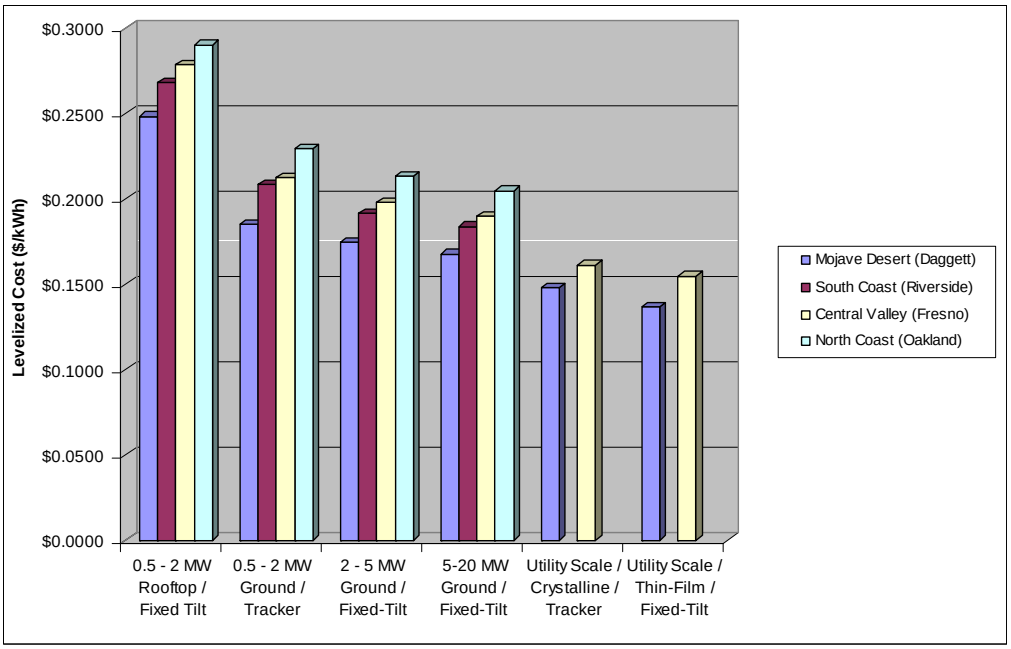
Levelized Cost of Energy from PV



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Results – Post-TOD Nominal LCOE

(Nominal $/kWh)

	0.5 - 2 MW Rooftop / Fixed Tilt	0.5 - 2 MW Ground / Tracker	2 - 5 MW Ground / Fixed-Tilt	5-20 MW Ground / Fixed-Tilt	150 MW Utility-Scale / Tracker	150 MW Utility-Scale / Fixed-Tilt
Mojave Desert (Daggett)	$0.2483	$0.1852	$0.1748	$0.1678	$0.1482	$0.1366
South Coast (Riverside)	$0.2683	$0.2085	$0.1916	$0.1840	N/A	N/A
Central Valley (Fresno)	$0.2788	$0.2127	$0.1979	$0.1900	$0.1612	$0.1548
North Coast (Oakland)	$0.2904	$0.2294	$0.2132	$0.2048	N/A	N/A

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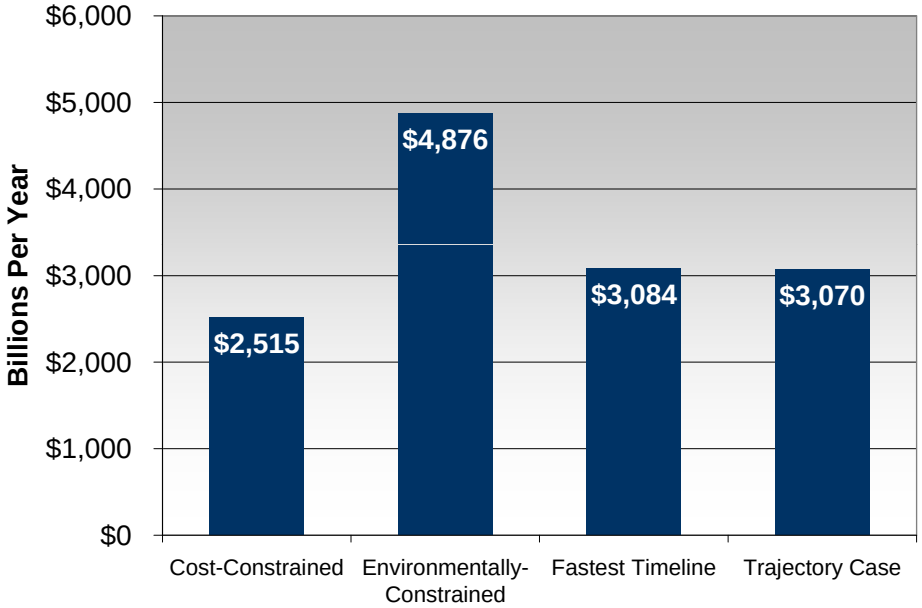
Total Net Cost* by Scenario



* Sum of each resource's net cost, not the same as the portfolio cost calculated in 2009

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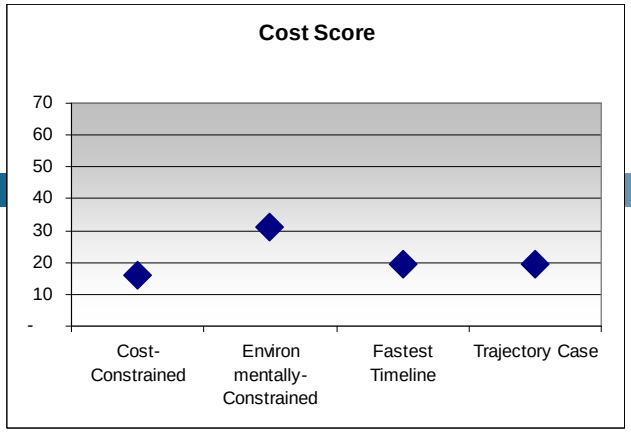

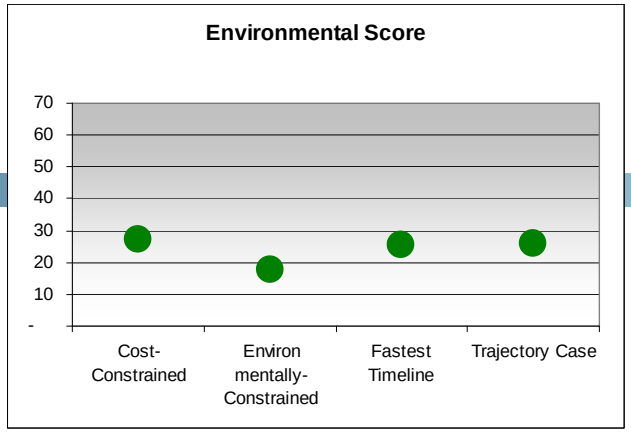

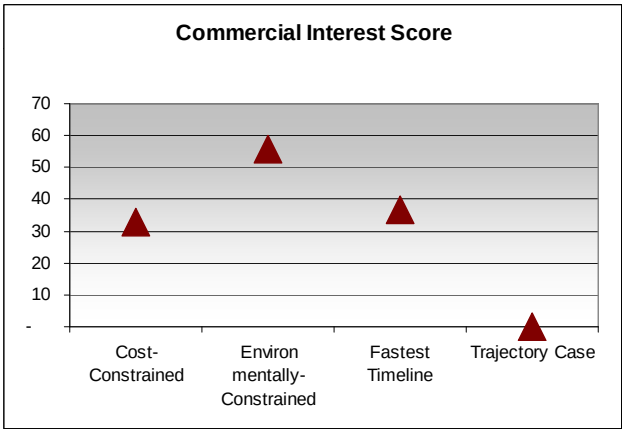

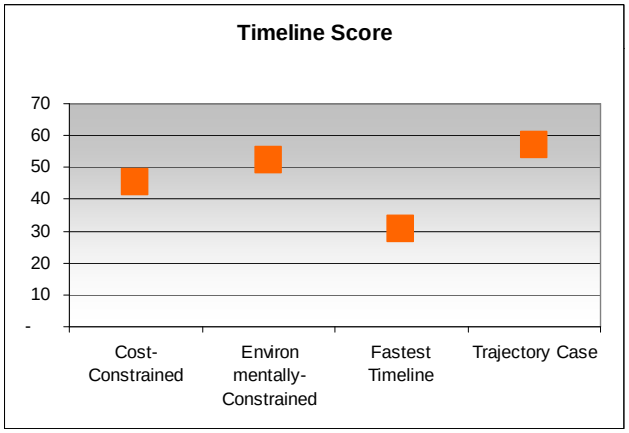

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Appendix

Avoided Capacity Cost Assumption

- **Distribution: $34/kW-yr**
  - Used average of EE avoided costs
- **Subtransmission: $34/kW-yr**
  - Used average of EE avoided costs
- **Transmission: $0/kW-yr**
  - Network is more difficult
  - Set to zero for 33% RPS analysis

Issues

- Timeframe vs. geographic specificity – must use long time frame for avoided cost value
- Cost of non-Rule 21 RETI 20MW PV Installations not studied
  - Network transmission costs of $65/kW-year assumed for these resources

See EE avoided costs, R.04-04-025

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PV Bid Pricing vs. LCOE

- The same $/kWh price can be presented in several different ways
- PV bids typically reflect the price *before* Time of Day (TOD) factors are applied
- Developers see the post-TOD value, which is the true cost of the PV system
- Escalators can skew costs when compared to flat levelized costs
- Results herein are post-TOD, flat nominal levelized

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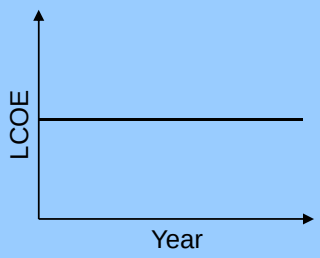
Comparison: PV LCOE metrics

Post-TOD flat nominal levelized used to show results

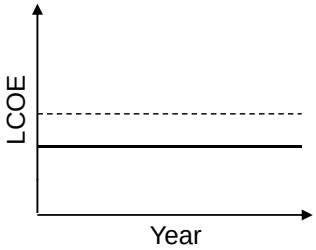
Post Time-Of-Delivery (TOD) Flat nominal levelized:

$0.1678/kWh



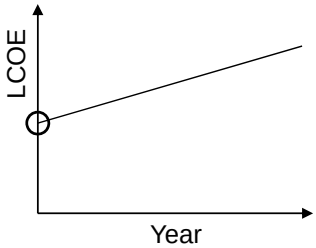
Pre-TOD Flat nominal levelized*:

$0.1266/kWh



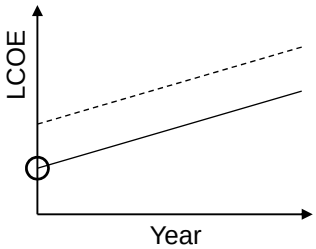
Post-TOD Year-1 cost with escalator:

$0.1441/kWh



Pre-TOD Year-1 cost with escalator* :

$0.1087/kWh



Note: Costs shown correspond to a project in the 5-20MW ground mounted category in the desert.
*Using a TOD factor of 1.3257 (SCE TOD schedule using TMY3 output data from Daggett with a ground mounted 25°fixed tilt system)

PV LCOE Input Assumptions

- Capital Costs
- Capacity Factors
- Financing Assumptions
- Operating Costs

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Black & Veatch Cost Estimates

1 MW rooftop	$5.00/watt dc
1 MW tracking	$4.75/watt dc
5 MW ground	$3.90/watt dc
20 MW ground	$3.70/watt dc

Based on configurations identified in B&V presentation
As stated previously, typical cost uncertainty is +/- 25%

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Performance Estimates

Type	Location	DC Capacity Factor
1 MW Rooftop	Daggett	18.3%
	Fresno	16.3%
	Oakland	15.6%
	Riverside	16.9%
1 MW Tracking	Daggett	23.5%
	Fresno	20.5%
	Oakland	19.0%
	Riverside	20.9%
5 MW, 20 MW Fixed Tilt	Daggett	21.3%
	Fresno	18.8%
	Oakland	17.5%
	Riverside	19.5%

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Financing Assumptions

- The following financing assumptions are used:

After-Tax WACC	8.25%
Debt Interest Rate	7.50%
Target DSCR	1.40
Debt Period in Years	20
Federal Tax Rate	35%
State Tax Rate	8.84%
Tax Credit Rate	30%
MACRS Term	5
Escalator	0%

- The model minimizes the % equity constrained to a target average DSCR of 1.40. This results in ~60% equity which slightly varies by technology and location.

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Operating Costs

- Operating costs for the LTPP study are broken down into O&M, insurance and inverter replacement costs:

LTPP	O&M Costs ($/kWdc)	O&M Cost Escalator (%/yr)	Inverter replacement cost ($/Wdc)	Inverter replacement time (Years)	Insurance Expense ($/kWdc)	Insurance Escalator (%/yr)
Fixed Tilt	$20.0	2.0%	$0.250	10	$20.0	2.0%
Tracker	$25.0	2.0%	$0.250	10	$20.0	2.0%

- As a reference, operating costs in RETI are presented into a single O&M cost that includes all ongoing capital expenditures:

RETI (converted to $/kWdc)	O&M Costs ($/kWdc)	O&M Cost Escalator (%/yr)
Fixed Tilt	$32.0	0%
Tracker	$44.0	0%

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Environmentally-Constrained Case: Resources by Location

Environmental Case	Score	Rank
Cost Score	31	4
Environmental Score	18	1
Commercial Interest Score	56	3
Timing Score	52	3
Total Net Cost	$ 4,876	4

Delivery Type	GWh	MW
Existing Transmisssion	25,052	11,020
Minor Upgrades	3,046	1,400
New Corridors	20,296	8,666
Out-of-State RECs	5,865	2,256
Total	**54,259**	**23,342**

	Resources Selected (GWh)	Environmental Score (0-100)
Total (GWh and Average Score)	***54,259***	***17.83***
Distributed Solar - Other	2,852	1.77
Distributed Solar - SDGE	785	3.62
Distributed Solar - SCE	4,596	4.54
Distributed Solar - PG&E	3,280	5.79
Westlands	7,163	10.53
Riverside East	11,192	20.65
Pisgah	7,260	21.22
Remote DG - SCE	348	21.62
Remote DG - Other	283	21.62
Remote DG - PG&E	929	21.62
Remote DG - SDGE	40	21.62
Tehachapi	5,516	23.46
Arizona RECs	737	24.10
Carrizo South	2,092	25.08
Alberta RECs	1,230	26.76
Northwest RECs	1,376	26.76
Montana RECs	820	26.76
Utah-Southern Idaho RECs	191	28.02
Palm Springs	222	29.14
San Bernardino - Lucerne	121	31.91
NonCREZ	1,333	33.71
San Diego South	156	34.08
Nevada N RECs	212	35.26
Round Mountain	226	35.37
New Mexico RECs	238	36.70
Nevada C RECs	1,062	40.79

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Environmentally-Constrained Case: Resources by Type

Project Status	GWh	MW
Discounted Core	21,162	8,146
Commercial Non-Core	2,805	1,154
Theoretical	30,292	14,042
Total	**54,259**	**23,342**

- Key Indicators:
  - Total Solar MW: 19,500 (16,800 PV)
  - Out-of-State RECs: 10%
  - Earliest compliance year: 2020
- Large-scale remote solar requires new transmission corridors
- Remote small-scale PV is the marginal resource – not all is picked

	All Resources (GWh)		
	In-State	Out-of-State	Total
Biogas	84	0	84
Biomass	938	238	1,176
Geothermal	0	212	212
Hydro	0	0	0
Large Scale Solar PV	22,701	864	23,564
Small Solar PV	13,112	0	13,112
Solar Thermal	5,474	935	6,409
Wind	6,085	3,616	9,701
Total	**48,394**	**5,865**	**54,259**
Out-of-State Share of 33% Target:		10%	

	All Resources (MW)		
	In-State	Out-of-State	Total
Biogas	12	0	12
Biomass	126	32	158
Geothermal	0	30	30
Hydro	0	0	0
Large Scale Solar PV	9,696	340	10,036
Small Solar PV	6,828	0	6,828
Solar Thermal	2,333	400	2,733
Wind	2,091	1,454	3,545
Total	**21,086**	**2,256**	**23,342**

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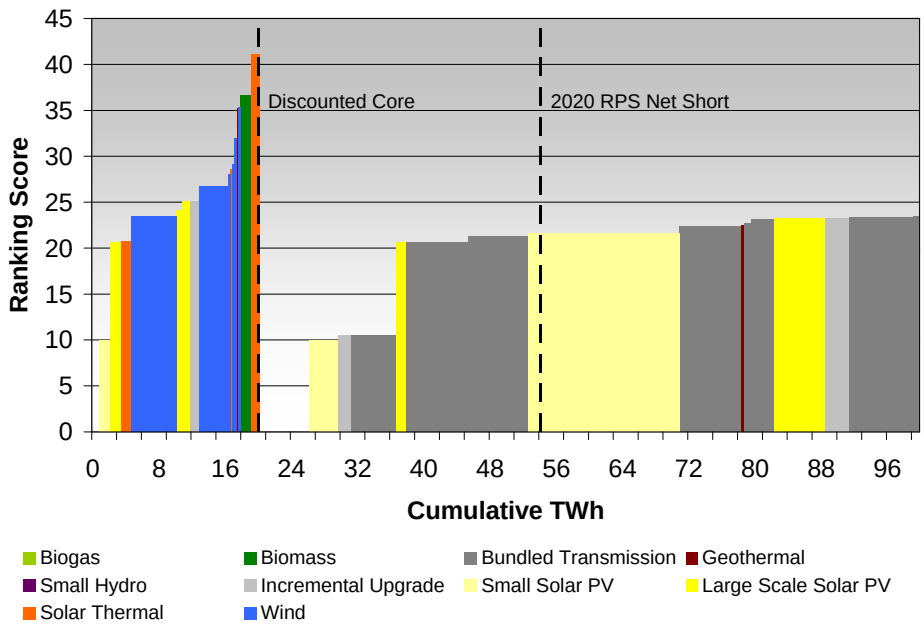
Environmentally-Constrained Supply Curve



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