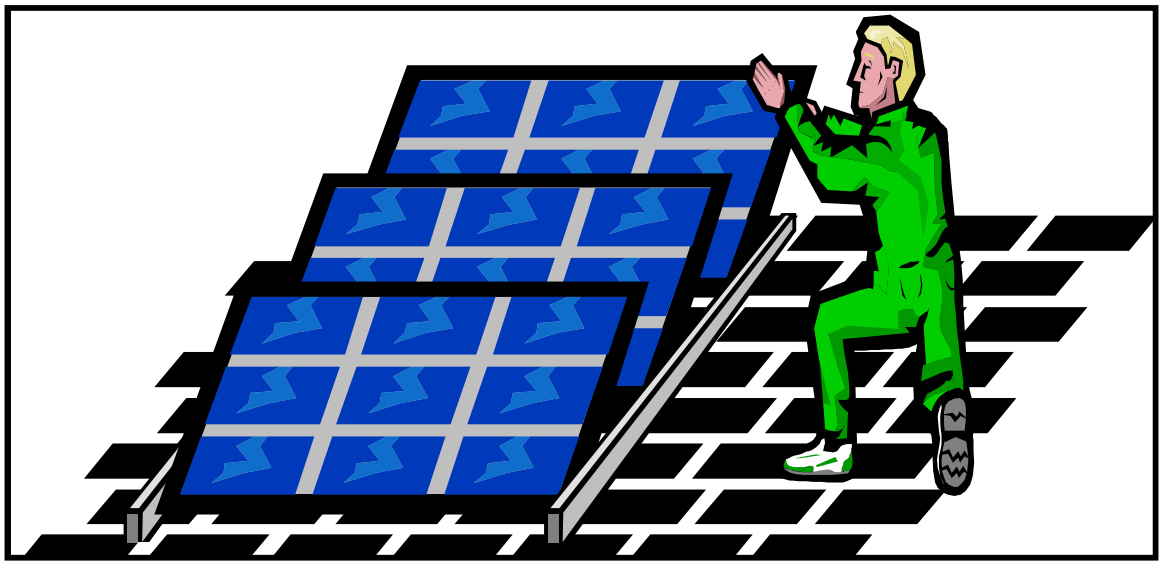
Designing PV system for Chris' House



Andy Chuang
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DE ANZA COLLEGE ESCI 61 FINAL PORJECT

Spring 2010 • 3:30 – 6:15PM • Ridha Hamidi, Bill Roeder

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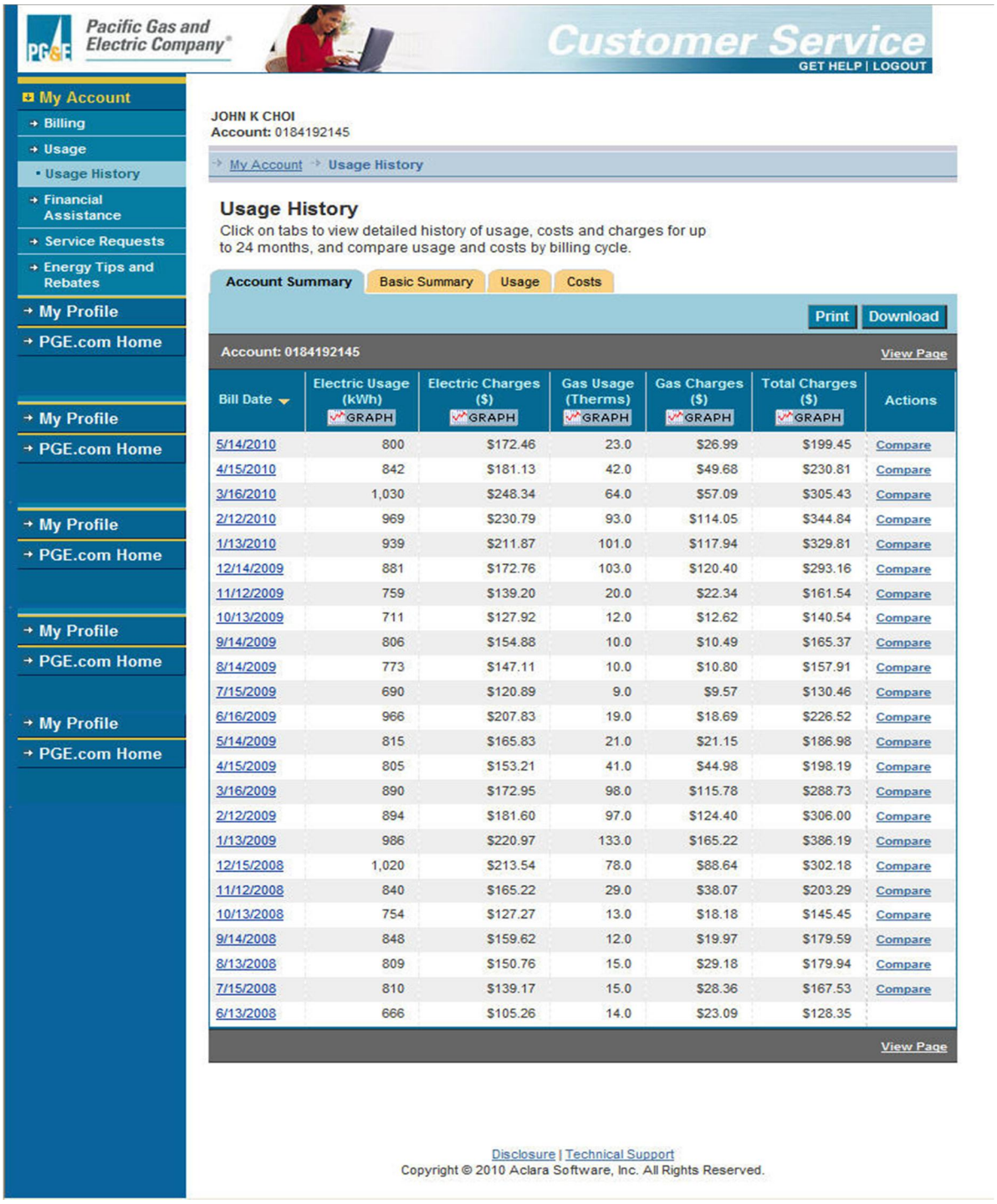
1. Performance of Chris' PV system



Pacific Gas and Electric Company

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JOHN K CHOI
Account: 0184192145

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Usage History

Click on tabs to view detailed history of usage, costs and charges for up to 24 months, and compare usage and costs by billing cycle.

Account Summary | Basic Summary | Usage | Costs

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Bill Date	Electric Usage (kWh) GRAPH	Electric Charges ($) GRAPH	Gas Usage (Therms) GRAPH	Gas Charges ($) GRAPH	Total Charges ($) GRAPH	Actions
5/14/2010	800	$172.46	23.0	$26.99	$199.45	Compare
4/15/2010	842	$181.13	42.0	$49.68	$230.81	Compare
3/16/2010	1,030	$248.34	64.0	$57.09	$305.43	Compare
2/12/2010	969	$230.79	93.0	$114.05	$344.84	Compare
1/13/2010	939	$211.87	101.0	$117.94	$329.81	Compare
12/14/2009	881	$172.76	103.0	$120.40	$293.16	Compare
11/12/2009	759	$139.20	20.0	$22.34	$161.54	Compare
10/13/2009	711	$127.92	12.0	$12.62	$140.54	Compare
9/14/2009	806	$154.88	10.0	$10.49	$165.37	Compare
8/14/2009	773	$147.11	10.0	$10.80	$157.91	Compare
7/15/2009	690	$120.89	9.0	$9.57	$130.46	Compare
6/16/2009	966	$207.83	19.0	$18.69	$226.52	Compare
5/14/2009	815	$165.83	21.0	$21.15	$186.98	Compare
4/15/2009	805	$153.21	41.0	$44.98	$198.19	Compare
3/16/2009	890	$172.95	98.0	$115.78	$288.73	Compare
2/12/2009	894	$181.60	97.0	$124.40	$306.00	Compare
1/13/2009	986	$220.97	133.0	$165.22	$386.19	Compare
12/15/2008	1,020	$213.54	78.0	$88.64	$302.18	Compare
11/12/2008	840	$165.22	29.0	$38.07	$203.29	Compare
10/13/2008	754	$127.27	13.0	$18.18	$145.45	Compare
9/14/2008	848	$159.62	12.0	$19.97	$179.59	Compare
8/13/2008	809	$150.76	15.0	$29.18	$179.94	Compare
7/15/2008	810	$139.17	15.0	$28.36	$167.53	Compare
6/13/2008	666	$105.26	14.0	$23.09	$128.35	

View Page

Disclosure | Technical Support

The average electricity usage of the Choi Family house:
The annual average electricity usage is 10,151.4 kWh / year.
The average monthly electricity use is 845.95 KWh / Month.
The average daily electricity use is 27.8 kWh / Day.

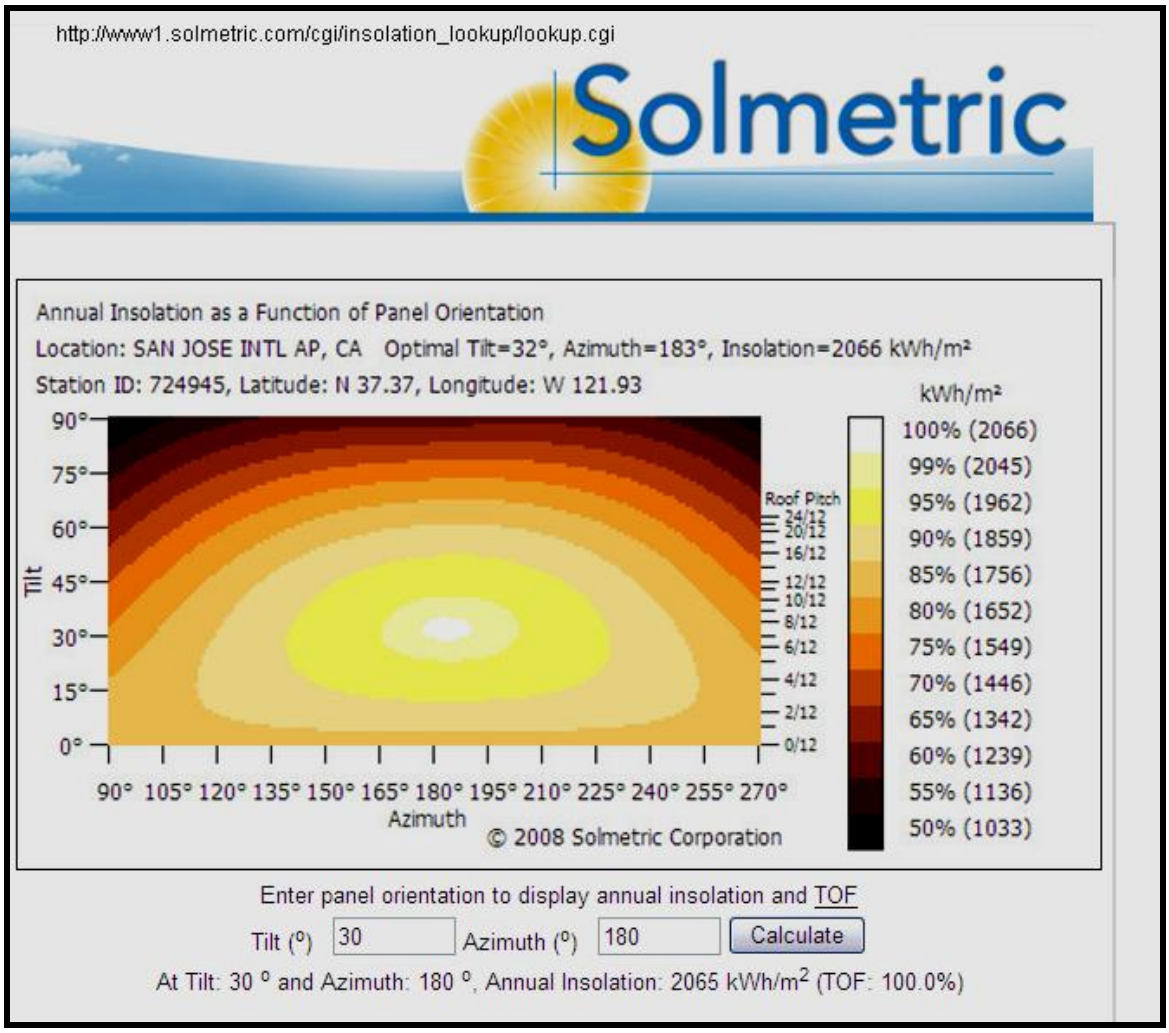
After energy efficiency measures:
To reduce the Chris' energy loads we will eliminate phantom loads by utilizing power strips to turn off when not in use, and replace old bulbs with CFLs. This way, we can reduce the family's daily electricity load to 25 kWh / Day. This will result in a annual load of 9,125 kWh / year, or 760kWh/month.

How much electricity do we want to generate per year from the PV System?
Chris' electric bill is $2028.50, and they think this is way too expensive! Thus, Chris wants to cut their annual electric bill by around 80%, so she wants 80% of her electricity to be generated by her PV system. In other words, she wants her future PV system to generate at least 7,300 kWh / year, which is 80% of 9,125 kWh / year.

2. Sun Resources

Using http://www1.solmetric.com/tools/RoofAzimTool.htm, we determine for Chris' house, the roof angle is 30°, and the azimuth angle of her roof is 180° due south.

After doing this, we go to http://www1.solmetric.com/cgi/insolation_lookup/go.cgi to help determine the average "sun hours/day" in the area of Chris' house. Since her house is in the city of San Jose, we select "SAN JOSE INTL AP" from a list of weather stations. Below is the screenshot of the result:



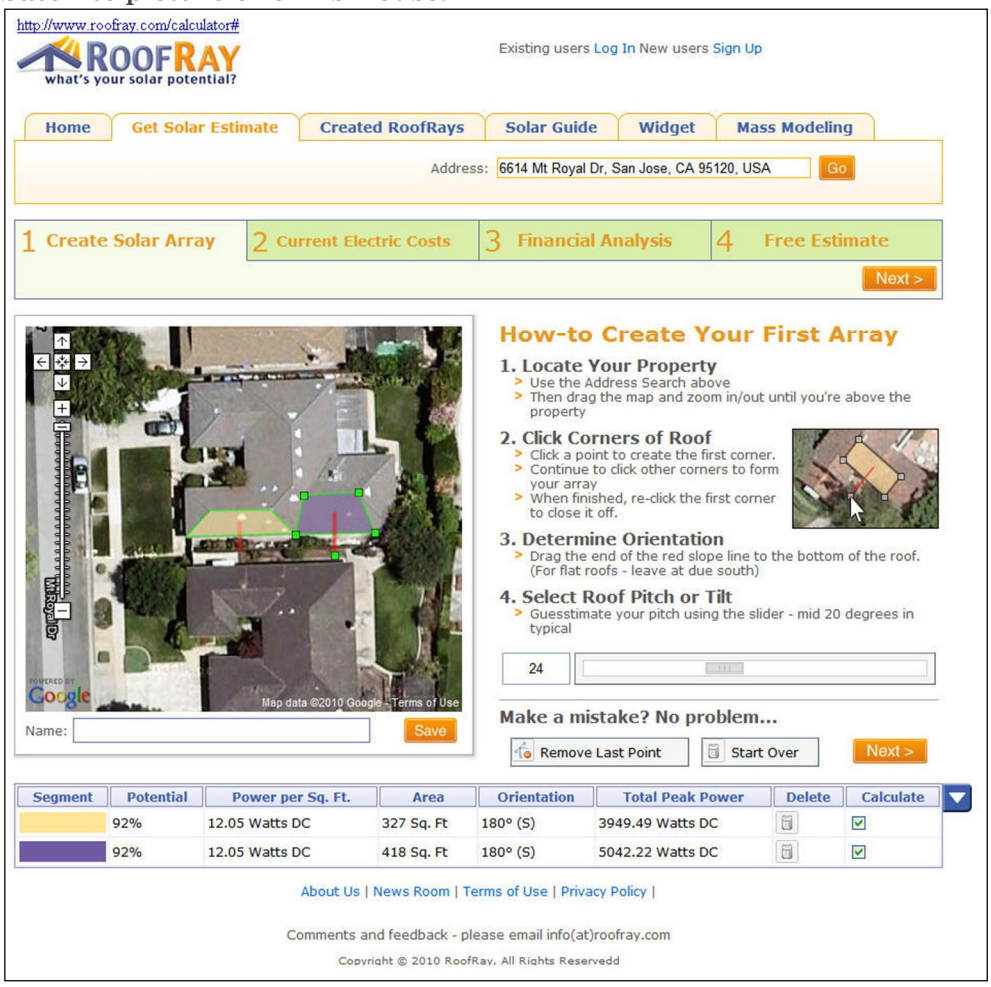
http://www1.solmetric.com/cgi/insolation_lookup/lookup.cgi

The annual insolation near Chris' residence is 2065 kWh/m²/year with TOF = 100%. In other words, the "PV module tilt and orientation" derate factor is 1, and the annual insolation is 2065 sun hours / year. Divide the annual insolation by 365 days, we got **5.66 sun hours / day**.

3. Site evaluation

Address of Chris' residence:
6614 Mount Royal Dr. San Jose, CA 95120

Satellite picture of Chris' house:



Roof condition of Chris' house:
Composite Roof, Installed 5years ago. There are two accessible roof areas. The one on the west side is 327 sq.ft. with a 180 degree orientation and 24 degree tilt. The east side roof has 418 sq.ft. and also 180 degree orientation and 24 degree tilt.

Shading analysis:
There is a tree on the south east side of the house which is bout 4 feet high from the roof and it would interfere with the collection of solar power on the east side, so we will construct on the west side roof.

Location of utility meter and main panel:
The utility meter and main panel are on the north side of the house.

4a. Design and Sizing PV system (I)

<table>
<tr><td>PV module tilt and orientation derate factor</td><td>For Chris' home in San Jose, the derate factor is TOF = 100%.
So, the PV module tilt and orientation derate factor = 1.</td></tr>
<tr><td>Sun hours per day</td><td>5.66 sun hours / day</td></tr>
<tr><td>AC power of Chris' PV system

If provide 100% of electricity needs for her house</td><td>To calculate the AC power of her PV system, use the equation:
<table><tr><td>Power
= Energy / Time</td><td>Energy = daily average energy consumption kWh / day

Time = "Sun hours / day" or kWh/m²/day

Power = Power of PV system</td></tr></table>
For her home in San Jose:
Time = 5.66 sun hours/day
Energy = (25 kWh / day)

Now solve for Power:
Power = Energy / Time
Power = (25 kWh / day) / (5.66 sun hours / day)
Power = 4.41 kW

The AC power of Chris' PV system should be at least 4.41 kW, if the PV system provides 100% of electricity needs for her house.</td></tr>
<tr><td>AC power of Chris' PV system

If provide 80% of electricity needs for her house</td><td>Chris want to cut her annual electricity bill by around 80%, so she wants 80% of her electricity to be generated by her PV system. So multiply 4.41 kW with 80%, and the AC power of Chris' PV system should be 3.528 kW.

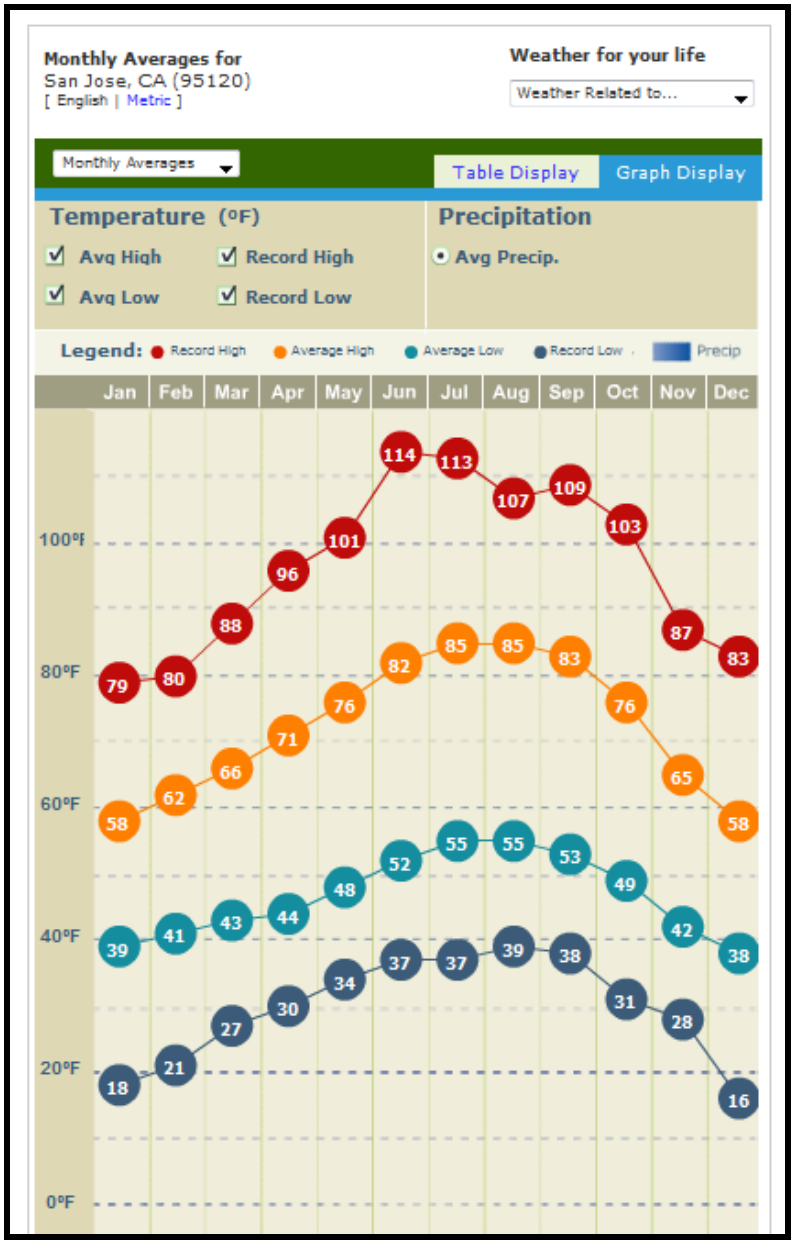
The AC power of Chris' PV system should be at least 3.528 kW.</td></tr>
</table>

4b. Design and Sizing PV system (II)

Step1 – record high and low temperature

Before using http://www.pvselect.com/index.php#sizer to help select inverters, PV modules, and number of strings for the PV system, the team needs to get the record high and low temperature of Chris' residence.

In 95120 at San Jose, the zip code of Chris' residence, average high temperature is 109 °F and raverage low temperature is 20 °F. Below is a screenshot of weather.com on temperatures in 95120.



http://www.weather.com/outlook/health/allergies/wxclimatology/monthly/graph/95120?role=

Step 2 – Modules, inverters, string, square footage

AC power of PV system

From previous results, we determine that the AC power of Chris' PV system should be at least 3.528 kW, or 3528 watts.

Modules

Since we want to minimize the number of modules for Chris' PV systems, we determine it is best to have each module to have a power rating of between 200 watts and 300 watts. After trial and error on www.pvselect.com/index.php#sizer, we selected ET-P672270 modules from ET solar, with each module having a rating of 270 watts.

Divide 3528 watts by 270 watts, we got 13.07 panels – we round that up to be 14 modules. Thus, the combined power rating of Chris' PV system should be 3.78 kW – calculated from multiplying (270 watts / modules) with (14 modules).

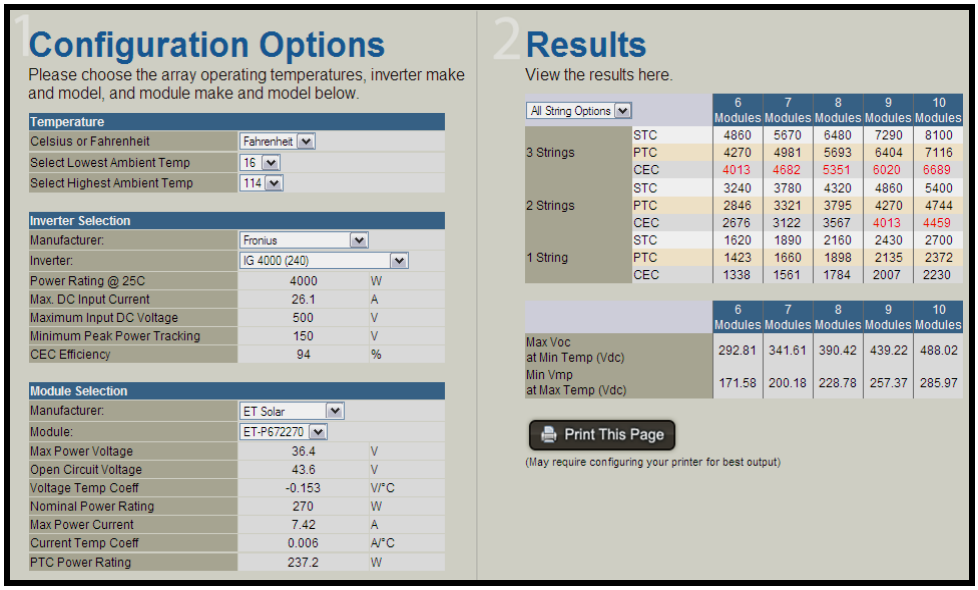
Inverter + derate factor

Since Chris' PV system so far will have a combined power rating of 3.78 kW or 3780 watts, we might need an Inverter with a 25C° power rating of around 4000 watts. The team then on www.pvselect.com/index.php#sizer selects IG 4000 (240) inverter from Fronius, in which the power rating at 25C° is 4000 watts.

The CEC efficiency of the inverter is 94%. So the CEC inverter derate factor is 0.94.

String Number

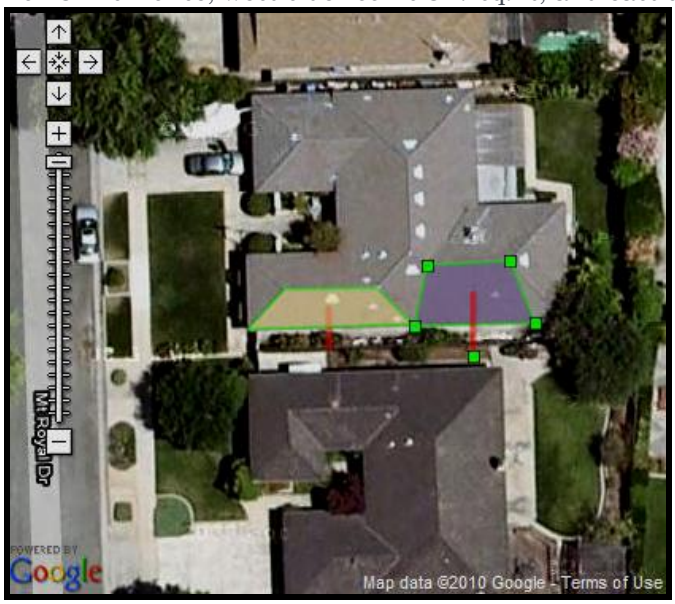
At "Results" of the screenshot below, by looking at the wattages of the PV system under 3 derate factors (STC, PTC, CEC), we decide her PV system should be a 2 string system with 7 PV modules / string. So, Chris' PV system should be a 2-string system with a total of 14 PV modules.



http://www.pvselect.com/index.php#sizer

Square-footage occupied by PV

For Chris' house, west side roof is 327 sq. ft, and east side roof is 418 sq ft.



http://www.roofray.com/calculator#

As for the dimension, each ET-P672270 module is 77in by 39.1in, or 20.9 sq. ft in area, according to http://www.solardesigntool.com/components/module-panel-solar/ET%20Solar%20Group%20/ET-P672270/specification-data-sheet.html;jsessionid=F7B68448267A02050642254247395214

Since Chris' 2-string system will have 14 of the ET-P672270 PV modules, the PV system will occupy an area of 292.6 sq. ft (14 * 20.9 sq. ft). To avoid shading from the tree at the south east side of the house, the best configuration is putting all 14 modules on the west side roof with 327 sq. ft in area.

Derate Factors

As we try to know the sun resources using http://www1.solmetric.com/cgi/insolation_lookup/lookup.cgi, we found for Chris' house, the "PV module and tilt" derate factor is 1. For the inverter model we selected, the CEC inverter derate factor is 0.94.

PV system Specification

- Use an IG 4000 240v inverter from Fronius for Chris' PV system, which has a "Power Rating @ 25C" rating of 4000 watts.
- It is a 2-string system with 7 PV modules/string by ET solar – a total of 14 PV modules. The modules are ET-P672270 modules, with 270 watts/module.
- Chris' PV system's power rating is 3.78 kW (2-strings * 7 modules/string * 270 watts/module), to compensate for all the derate factors under STC, PTC, and CEC that can decrease PV power production.
- Chris' PV system occupies 292.6 sq. ft on the roof. To avoid shading from the tree at the southeast side of the house, the best configuration is putting all 14 modules on the west side roof with 327 sq. ft in area.

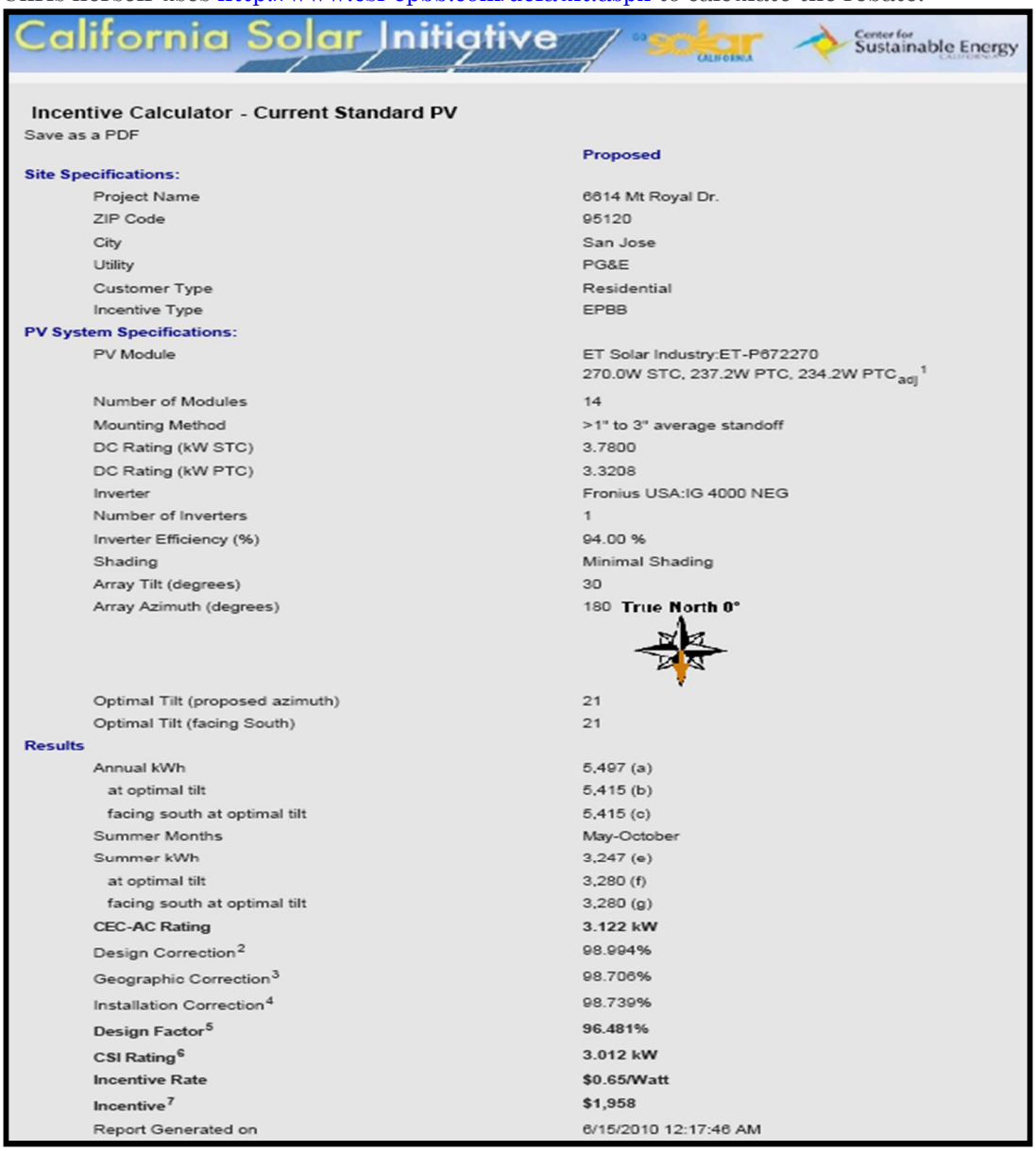
5. Cost of Chris' PV system

14 PV modules	From http://www.altersystems.com/catalog/et-solar-200-watt-solar-panel-etp654200-p-2148.html, each ET-P654200 PV module costs $620 with a power rating of 200 watts. Also, from http://www.thefind.com/search?query=ET-solar, each ET Solar 170 watts PV module costs $520. The ET-P654200 module costs $3.1/watt ($620 / 200 watts), and the ET Solar's 170 watts module also costs $3.1/watt ($520 / 170 watts). Based on this, the ET-P672270 module with a power rating of 270 watts costs $837 / module ($3.1 / module * 270 watts). Multiply 14 modules with $837 / module, and the total cost of the 14 "ET-P672270" modules is $11718. ***Cost of 14 "ET-P672270" modules = $11718***
Inverter	From http://www.ecodirect.com/ProductDetails.asp?ProductCode=Fronius-IG-4000&site=google_base, the price of the Fronius IG4000 inverter cost about $2400. ***Cost of "Fronius IG4000" inverter = $2400***
Labor	Labor cost for PV installation: 1.) Installing rack on the roof. 2.) Bolting PV to the rack. 3.) Installing inverter. We hang inverters on the walls, as conduit to PV and to Load Panel. 4.) Wiring: Combining junction boxes, fuses, and connections to inverter. 5.) Inspections of fire protection, building, electrical and utility before finalizing the installation. According to http://www.solarpowerforum.net/forumVB/showthread.php?t=2818, The labor rate is between $1/Watt and $1.25/Watt. So, If we hire workers to install the 3780-Watts PV system for Chris' house, the cost is between $3780 and $4725. ***Best Case cost of labor = $3780*** ***Worst Case cost of labor =$4725***

City Permit and Inspection	According to http://calseia.org/local-permits.html, permit fees for PV system in the City of San Jose is about $236. Also, the inspection cost is included in the permit fees. ***Permit fees for PV system in the city of San Jose = $236***
Balance of system	Chris' PV has a power rating of 3.78 kW, or 3780 watts **Balance of System cost:** Racking cost + Miscellaneous cost = (3780 watts * $0.45/Watt) + (3780 watts * $0.15/Watt) = $2268 ***Balance of System cost = $2268***

California Solar Initiative rebate

According to http://www.gosolarcalifornia.org/csi/rebates.html, under California Solar Initiative or CSI, if one owns a PV system of less than 50kW, one may apply for a cash rebate under EPBB or "Expected Performance Based Buydown." Since Chris' PV system is only 3.78 kW, she can get the CSI rebate from her utility compnay, and Chris herself uses http://www.csi-epbb.com/default.aspx to calculate the rebate:



California Solar Initiative

Incentive Calculator - Current Standard PV

Save as a PDF

	Proposed
Site Specifications:	
Project Name	6614 Mt Royal Dr.
ZIP Code	95120
City	San Jose
Utility	PG&E
Customer Type	Residential
Incentive Type	EPBB
PV System Specifications:	
PV Module	ET Solar Industry:ET-P672270 270.0W STC, 237.2W PTC, 234.2W PTC_{adj} [1]
Number of Modules	14
Mounting Method	>1" to 3" average standoff
DC Rating (kW STC)	3.7800
DC Rating (kW PTC)	3.3208
Inverter	Fronius USA:IG 4000 NEG
Number of Inverters	1
Inverter Efficiency (%)	94.00 %
Shading	Minimal Shading
Array Tilt (degrees)	30
Array Azimuth (degrees)	180 **True North 0°**
Optimal Tilt (proposed azimuth)	21
Optimal Tilt (facing South)	21
Results	
Annual kWh	5,497 (a)
at optimal tilt	5,415 (b)
facing south at optimal tilt	5,415 (c)
Summer Months	May-October
Summer kWh	3,247 (e)
at optimal tilt	3,280 (f)
facing south at optimal tilt	3,280 (g)
CEC-AC Rating	**3.122 kW**
Design Correction [2]	98.994%
Geographic Correction [3]	98.706%
Installation Correction [4]	98.739%
Design Factor [5]	**96.481%**
CSI Rating [6]	**3.012 kW**
Incentive Rate	**$0.65/Watt**
Incentive [7]	**$1,958**
Report Generated on	6/15/2010 12:17:46 AM

Under STC, Chris' PV system is 3.78kW. But under CSI rating, Chris' PV system is only 3.012 kW, and CSI requires PG&E to pays rebates according to CSI rating of one's PV system. Currently, the incentive rate is $0.65/Watt, and a CSI power rating of 3.012kW will give Chris a $1958 incentive rebates ($1958 = 3012 Watts * $0.65/Watt).

So PG&E will pay an incentive rebate of $1958 for Chris' 3.78 kW PV system.

Federal Tax Credit Incentive

The Net cost after CSI rebate:

post CSI net cost low estimate
=
(14 PV modules + inverter + labor best case + city permit + balance of system) – CSI rebate
= ($11718 + $2400 + $3780 + $236 + $2268) – $1958
= $18444

post CSI net cost high estimate
=
(14 PV modules + inverter + labor worst case + city permit + balance of system) – CSI rebate
= ($11718 + $2400 + $4725 + $236 + $2268) – $1958
= $19389

According to http://blogs.consumerreports.org/home/2008/12/energy-credits.html, an owner of a PV system can get a 30% tax credit. The "post CSI net cost low estimate" is $18444, and in this case she can get a $5533.2 federal tax credit ($18444 multiply by 30%). The "post CSI net cost high estimate" is $19389, and in this case she can get a $5816.7 federal tax credit ($19389 multiply by 30%).

Low estimate of Federal Tax Credit = $5533.20
High estimate of Federal Tax Credit = $5816.70

Net Cost

Net cost low estimate
= post CSI net cost low estimate – low estimate of federal tax credit
= $18444 – $5533.20 = $12910.80

Net cost high estimate
= post CSI net cost high estimate – high estimate of Fed tax credit
= $19389 – $5816.70 = $13572.30

Net up-front cost of Chris' PV system could be between $12910.8 and $13572.3

Chris' PV System Summary

PV Modules
14 of the ET-P672270 PV modules, with 270 watts/module

Inverter Model
Fronius IG 4000 240v inverter, with a "Power Rating @ 25C" rating of 4000 watts

String Number
A 2-strings system with 7 PV modules/string

PV power rating
The power rating of Chris' PV system is 3.78 kW under STC and 3.012 kW Under CSI

PV square footage
Chris' PV system occupies 292.6 sq. ft on the roof

Net-Cost
For Chris' PV system, the net up-front cost is between $12910.8 and $13572.3

Work Cited

Online tools

http://www.pvselect.com/index.php#sizer

http://www1.solmetric.com/tools/RoofAzimTool.htm

http://www.roofray.com/calculator#

http://www1.solmetric.com/cgi/insolation_lookup/go.cgi

http://www.csi-epbb.com/default.aspx

Temperatures of San Jose

http://www.weather.com/outlook/health/allergies/wxclimatology/monthly/graph/95120?role=

PV system hardware specifications and costs

http://www.solardesigntool.com/components/module-panel-solar/ET%20Solar%20Group%20/ET-P672270/specification-data-sheet.html;jsessionid=F7B68448267A02050642254247395214

http://www.altersystems.com/catalog/et-solar-200-watt-solar-panel-etp654200-p-2148.html

http://www.thefind.com/search?query=ET-solar

http://www.ecodirect.com/ProductDetails.asp?ProductCode=Fronius-IG-4000&site=google_base

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Other PV system costs

http://www.solarpowerforum.net/forumVB/showthread.php?t=2818

http://calseia.org/local-permits.html

Rebates and incentives

http://www.gosolarcalifornia.org/csi/rebates.html

http://blogs.consumerreports.org/home/2008/12/energy-credits.html