The Energy+ Household:

a consumer's perspective on sustainable energy

Indradeep Ghosh, PhD

Cupertino, CA, USA

The Energy+ Household

- **Imagine**
  - A single family house in the suburbs about 2200 sq ft (US median: 2160)
  - Household of 2 adults, 2 kids (US avg: 3)
  - 2 commuting cars in household with 2 working adults
  - Weekend chores, visits to nearby family/friends, entertainment

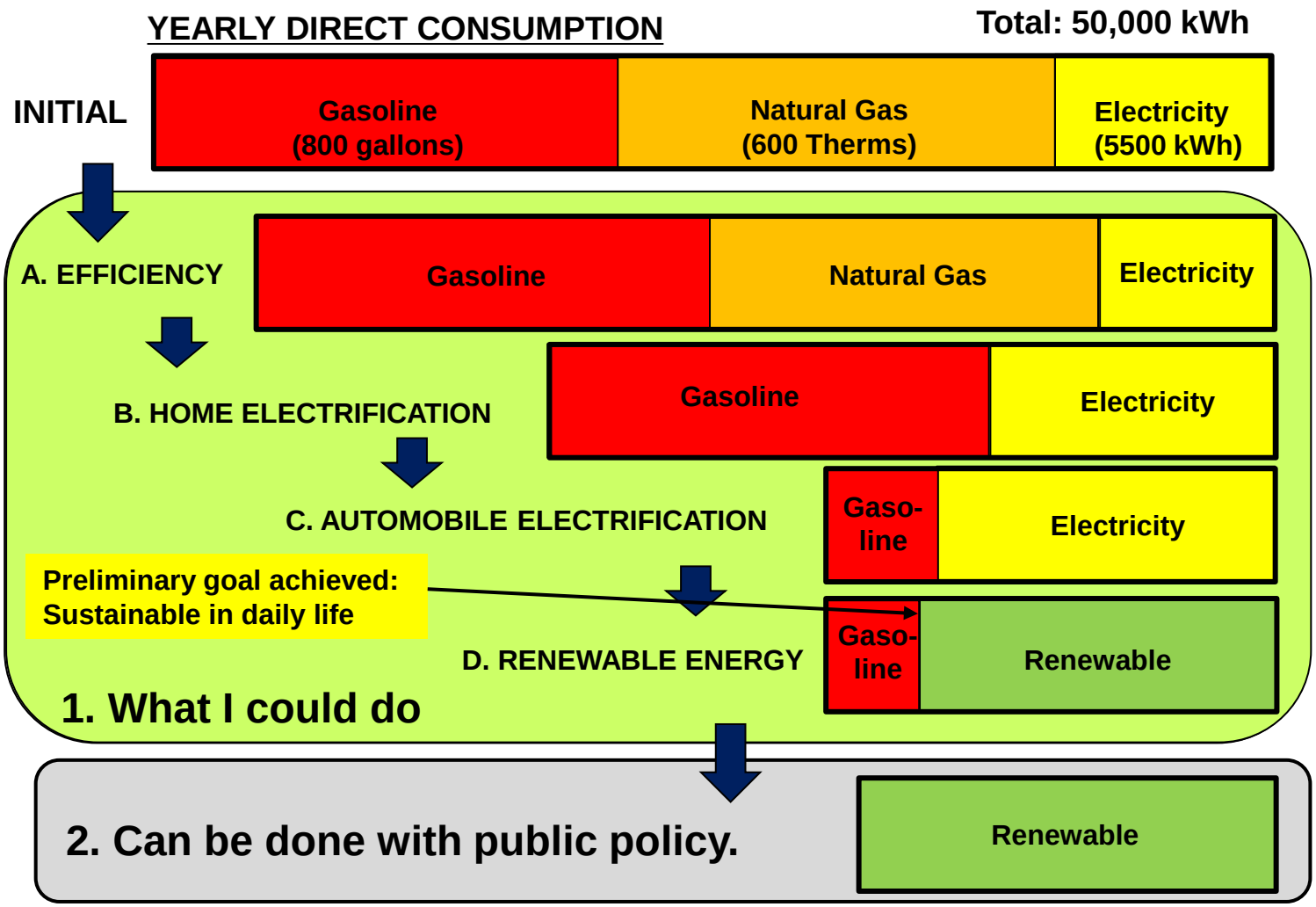
- **Now Imagine**
  - **ZERO** yearly energy bills (in fact negative!)
    - ***i.e.*** **zero electricity, zero natural gas, zero gas in daily life**
  - Completely sustainable & carbon free with renewable energy

- **This presentation describes how?**

Primary Goal of this Project

- **Create a Sustainable and Carbon Neutral household**
- **90% of household direct carbon footprint is fossil fuel based energy consumption**
- **First step**
  - **Create a *net-zero energy* household**
  - **Eliminate all direct fossil fuel use in daily life**
  - **Use renewable energy for all day to day energy needs**
- **Byproduct**
  - **Energy cost savings**

Overview & Outline

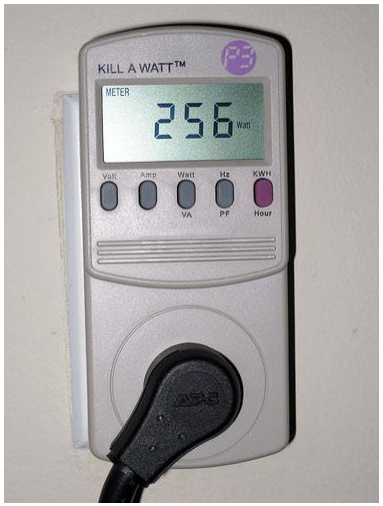


FIRST STEP:
ENERGY AUDIT & REDUCING CONSUMPTION

Whole House Energy Audit

- **Used utility meter, utility bill, and kill-a-watt meter to analyze energy consumption of different systems in house**
- **Amazed by the amount of energy wasted by plug loads**

Utility Meter



Kill-a-Watt Meter

Whole house plug load – 220 W

Efficiency: Universal Practices

- **Switch off unnecessary lights**
- **Switch off computers, TVs, appliances after use**
  - **Newer ones have good sleep modes**
- **Full loads in dishwasher, washer, dryer**
  - **Clothes line in backyard if you have time**
- **Thermostat set to 70F in winter, 80F in summer**
  - **In summer ceiling/stand fans can help up to about 88F**
  - **Setback when house unoccupied**
  - **Use curtains and shades**
- **Low flow faucets/shower heads conserve water & heat**
- **Wash in cold water with high efficiency detergent**
- **Weather-strip and caulk windows, doors, leaks**

Increase Efficiency

30% Reduction

- **LED lighting & Motion sensors**
  - Costs coming down ($5 for 40W equivalent)
  - Replaced 50 [avg. lighting load 900W -> 230W (CFL) -> 150W (LED)]

- **Energy star appliances**
  - dishwasher, refrigerator, washer

ENERGY STAR

- **Reduce plug loads**
  - Energy efficient DVR minor improvement (62W -> 40W)
  - plug load cut-off remote (40W or 350 kWh/yr saved)

- **Insulation: Attic, Walls, Floor (retrofit expensive)**
  - Newer house ('97) somewhat insulated (R15 walls, R30 attic)
  - Double pane windows

- **Programmable thermostat**

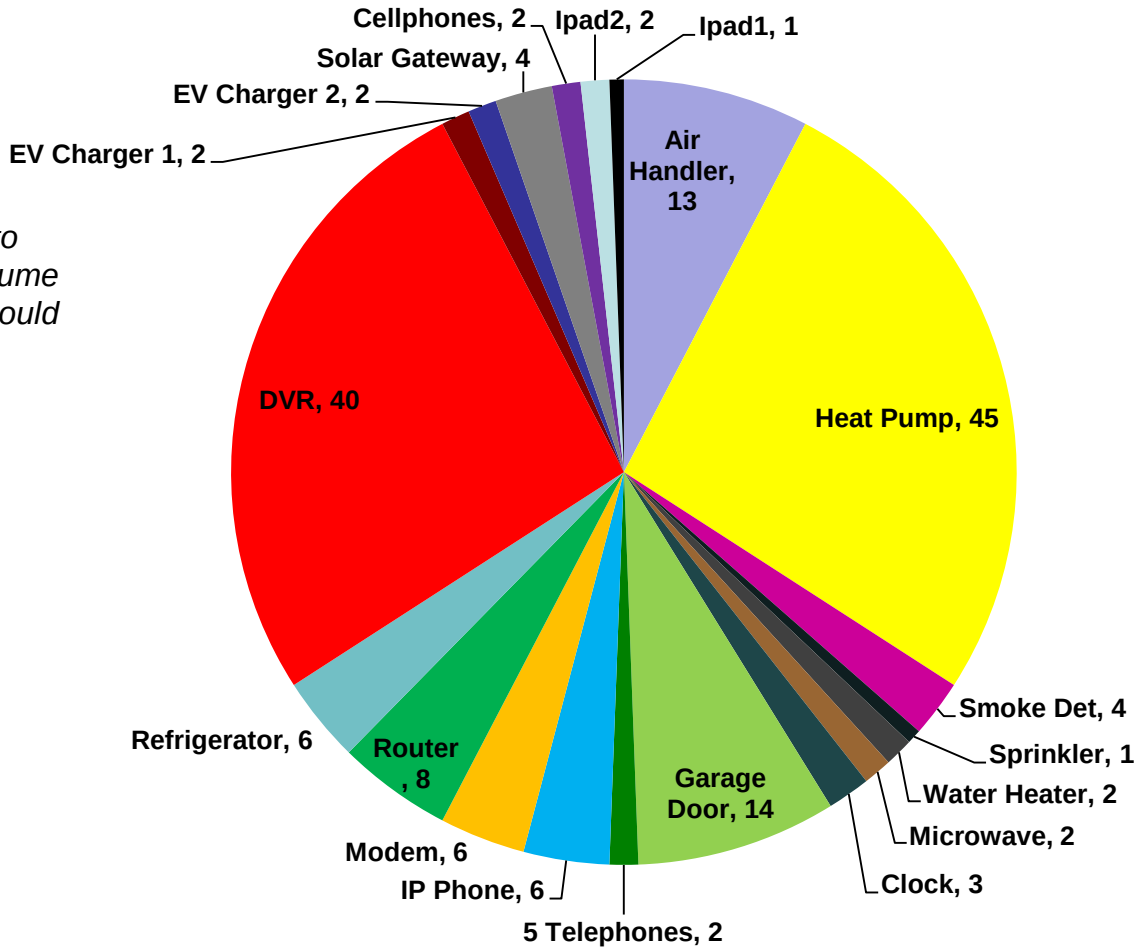
OR

NEST Thermostat

- **Efficient heating/cooling and water heating equipment**

Plug Load Analysis

65 items connected to power lines, 35 consume constant power, 20 could not be cut off.



1 Watt = 8.7 kWh / year

Total Wasted Power: 170W, 1500 kWh/year

Water Conservation

$75

- **Faucets**
  - 1 GPM
  - Special aerators

$75

- **Shower heads**
  - 1.5 GPM

$150

- **Toilets**
  - 1.3 G per flush
  - Dual Flush

$100s to $1000s

- **Native plants**
  - minimize lawn irrigation

- Installed new aerators
- Replaced shower heads
- Replaced toilets
- Replaced front and back lawns

SECOND STEP: ELIMINATE NATRUAL GAS USE

Water Heating

Gas
Water heater
Efficiency: 58%

$2000

GE GeoSpring,
50 gallon,
Energy Factor: 2.4

Electric Heat Pump
Water heater
Efficiency: 240% avg.

- Available in Lowes/Home Depot
- Requires new 240V connection
- May require permit
- Some noise and cold air → garage or basement
- *Tip: The new heat pump water heaters in the market have reached 300% efficiency*

Water Heater:
Solar Thermal *vs* (PV + Heat Pump)

	Solar Thermal	PV + Heat Pump Water Heater
Net Efficiency	50%	40%
Total Cost Before Rebates	$9000	$7000
Installation	Quite Complicated	Simple
Excess Solar	Wasted	Banked
Running Costs		Slightly Lower
Maintenance	Higher Many moving parts Leaks in plumbing	Few Moving parts Inverter at 15 yrs

Space Heating

200% efficient
AC

+

80% efficient
Gas furnace

$8500

Rheem, 3 Ton
16 SEER
HSPF 10
5KW, Aux

Air Source Heat pump
Efficiency: 300% average

- 1 week project
- Requires city permit
- Current heat pumps are 400% efficient – slightly more expensive
- Extra 240V line for air handler, new thermostat line
- Air handler placed in attic
- *Tip: Use electric space heaters sparingly as they are expensive to run*
- *Tip: Potentially better performance may be obtained by ductless mini-split heat pumps.*

Drying

$1000

80% efficiency

97% efficiency

- Electric dryers are usually cheaper to buy
- Replacement is usually straightforward
- In my case, we already had an electric dryer
- *Tip: Recently heat pump dryers have become available. Those can cut energy use by half*

Cooking

$2000

40% efficient
Gas cooktop

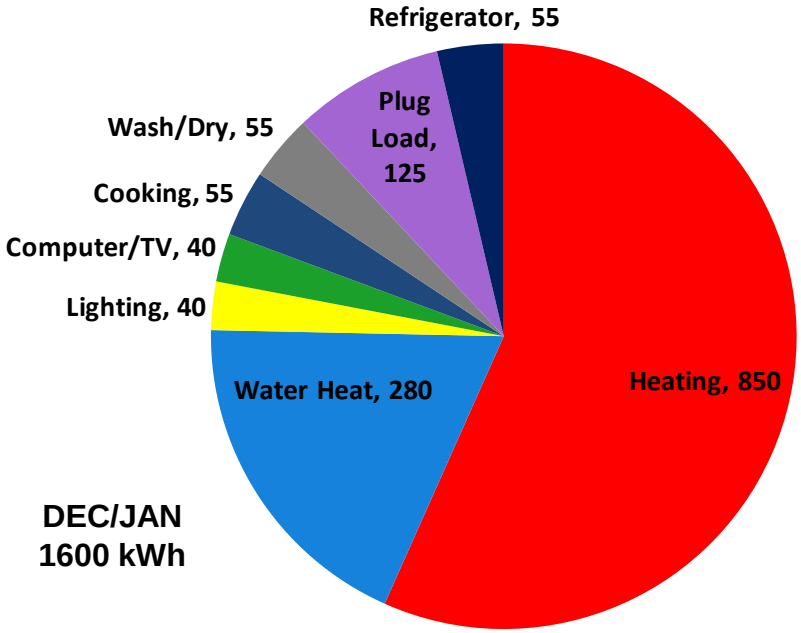
85% efficient
Induction cooktop

2X

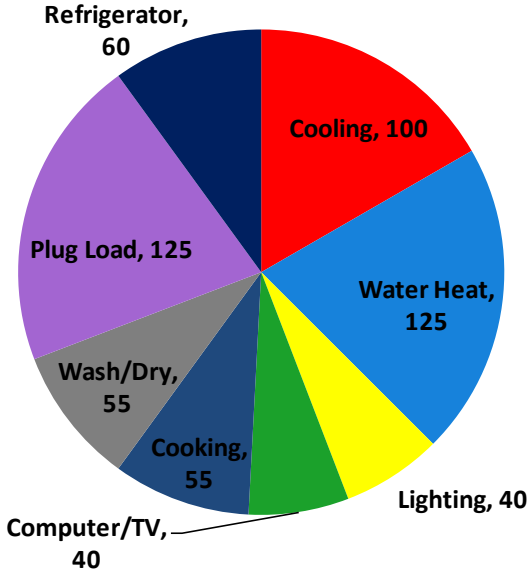
- Requires 240V cooktop line in kitchen
- Induction cooktops warm and cool very fast
- Requires iron/stainless steel utensils
- Only flat bottom utensils

Total 66% energy saved switching to electric.

Monitored Monthly Consumption

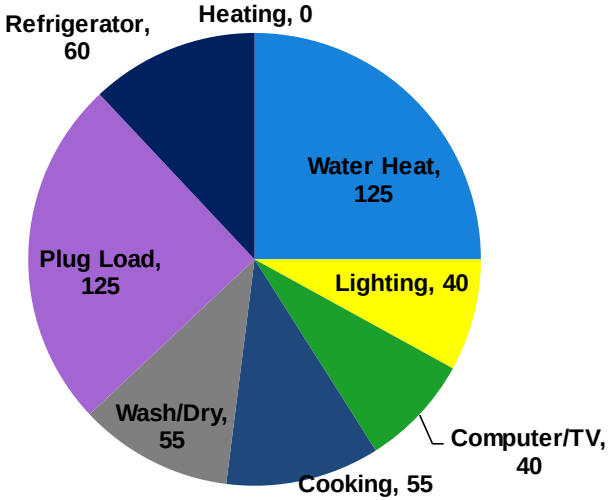


DEC/JAN
1600 kWh

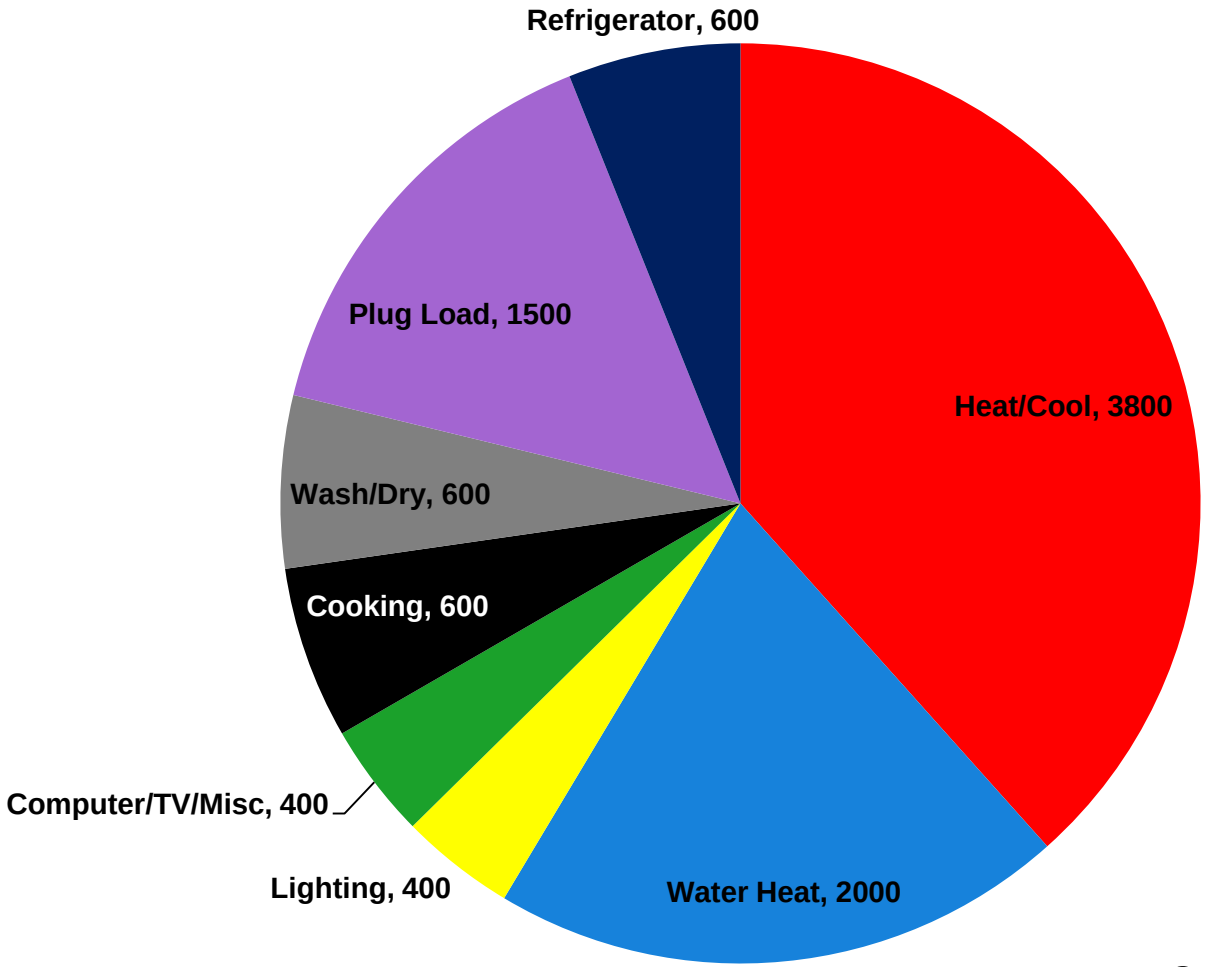


JULY/AUG
600 kWh

MAY/SEPT
500 kWh



Total for the Year



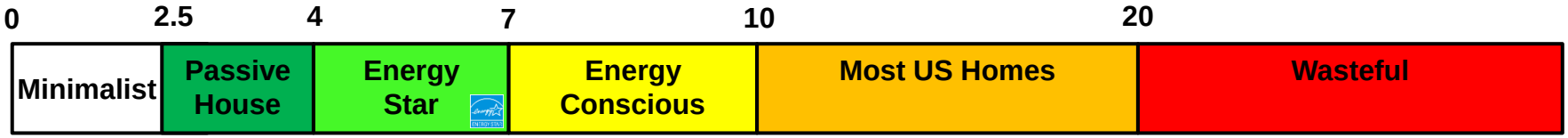
9900 kWh

(50% of US Average)
(All electric home)

4.5 kWh/sq ft per year

kWh/SqFt/Yr: the MPG of your house

- **Energy Use Intensity: Lower is better**
- **Add up 12 month electricity use from utility bills: X kWh**
- **For electricity not offset by renewables multiply by grid factor**
  - **(Primary energy/End use energy): about 2 for CA**
  - **Add all kWh produced by renewables**
- **Add up all natural gas use for 12 months: Y Therms**
  - **Multiply by transmission factor: 1.05 in CA**
  - **Multiply by 29.3 to convert to kWh**
- **Add the two and divide by sq ft of home: kWh/sq ft per year**



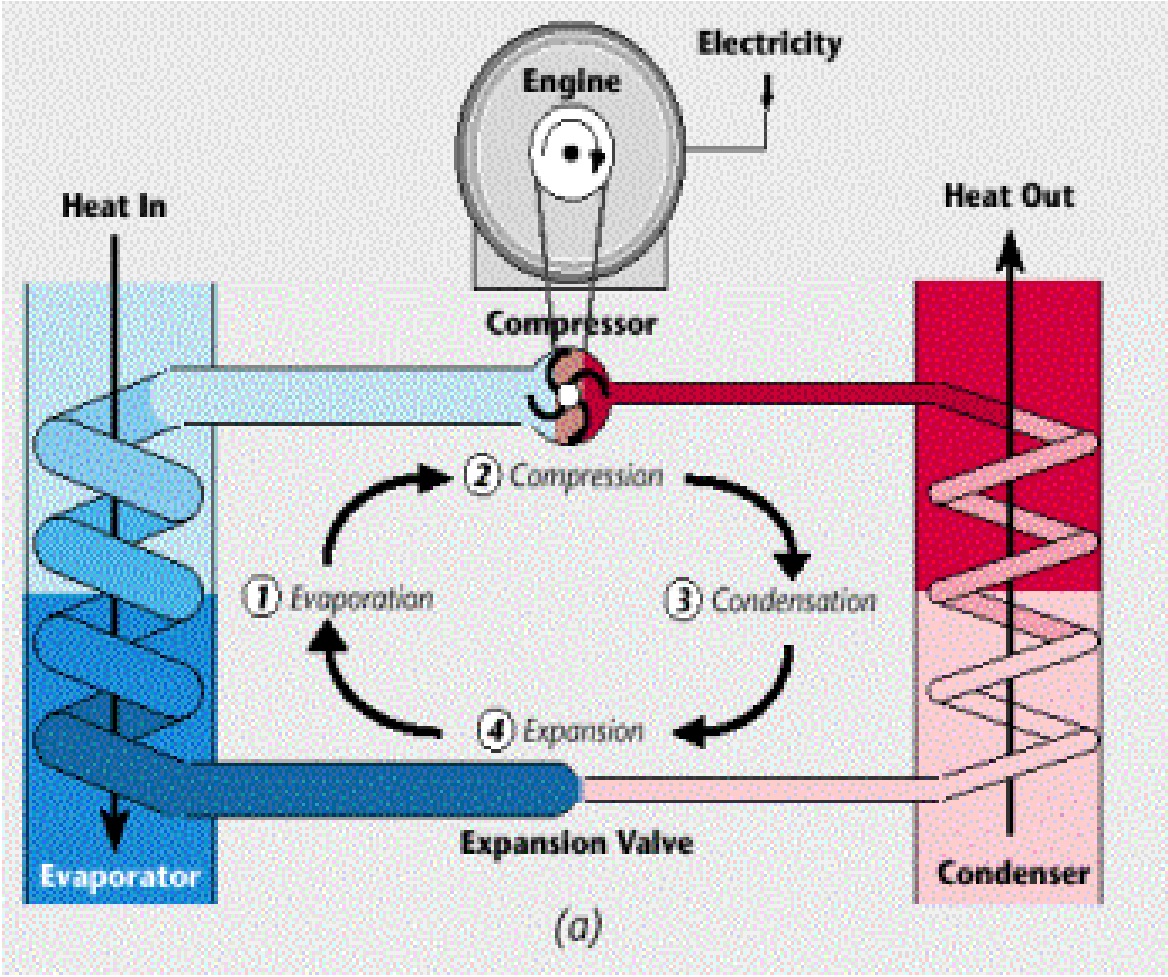
* Standard house without pool or hot tub

Efficient Heating/Cooling: Heat Pumps

SUMMER
AC

HOME

OUTSIDE



WINTER
Heat Pump

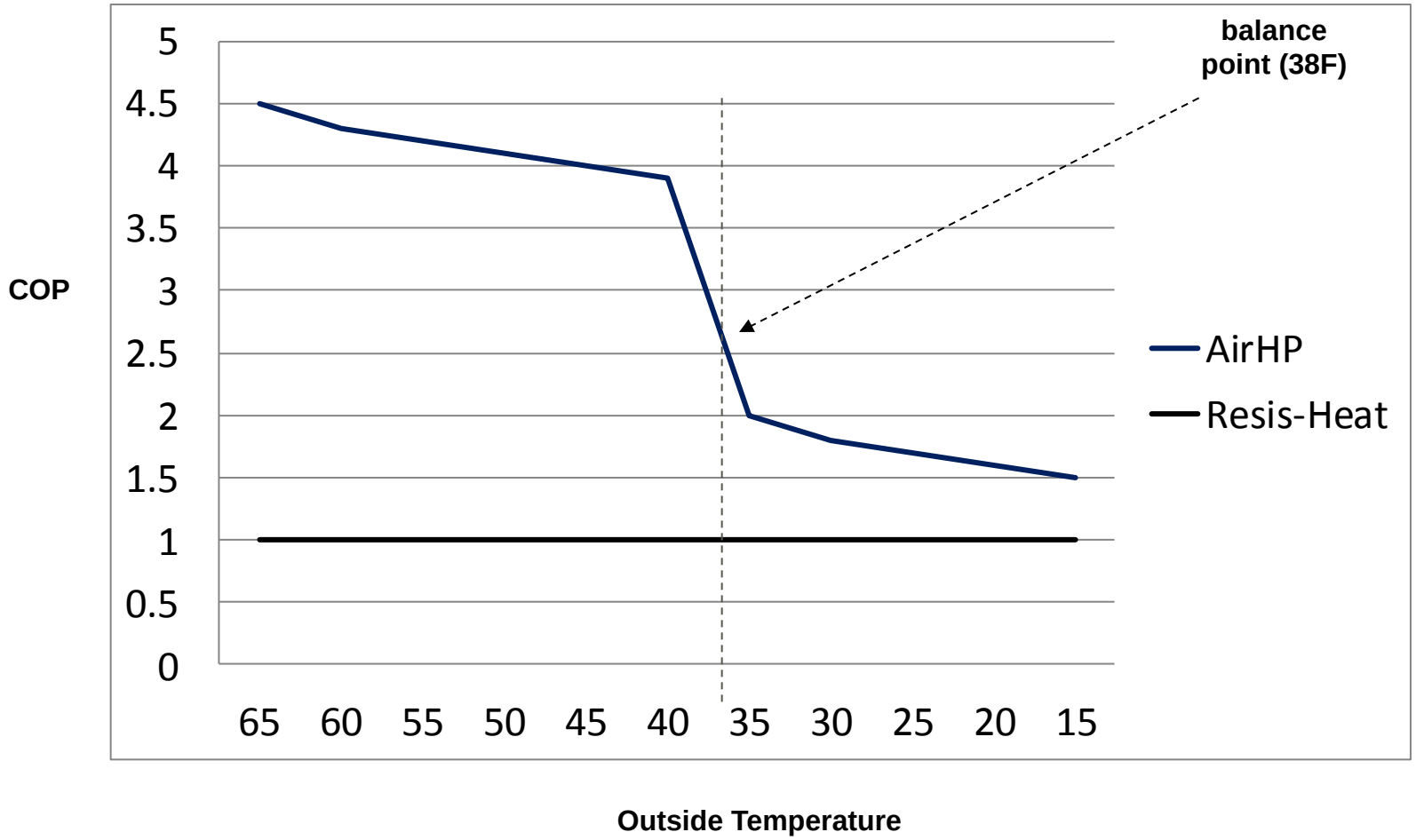
OUTSIDE

HOME

Efficiency degrades with temperature difference; Lower heating rate.

Coefficient of Performance (COP) = Heat Energy Pumped into Home/Electrical Energy Spent in Device

Heat Pump Performance



Average Yearly COP - 3

THIRD STEP: ELIMINATE GASOLINE from DAILY LIFE

Automobile Electrification

$26,000

Nissan Altima Hybrid (33 mpg)

Chevy Volt (33kWh/100 miles)

** 40 miles on electric, then gas
95% in EV mode. Uses 1 gallon per month

Yearly requirement – 3000 kWh

$25,000

Toyota Highlander Hybrid (25 mpg) *

Ford Focus Electric (31kWh/100 miles)

** 80 miles on electric, no gas

Yearly requirement – 1700 kWh

- Retained as the long trip, extended family, and large item hauler

70% Energy Reduction

FOURTH STEP: GENERATE YOUR OWN ENERGY

Renewable Energy Generation

- **Grid Tied Rooftop Solar System**
- **Total Need :**
  - 9900 kWh(home) + 4700 kWh (cars) = 14600 kWh (total/year)
  - 10 KW ideal tilt system facing south is sufficient (no shade)
  - If time-of-use rates are used 8.5KW would be enough

<u>AIM:</u> ***Generate ALL energy used in day to day life through renewables. Energy cost offset is secondary aim.***

Installed Solar System

10 KW DC Solar Panel can do this
Ideal south orientation and tilt

I needed 12 KW, about 850 sq ft of roof
Used US, DOE, Solar Output Calculator

Installed system 9/2011
Online on 10/14/2011

11.8 KW DC
About 10 KW AC

40, 295W mono-crystalline Canadian Solar Modules
11.4 KW Fronius IG Plus V Inverter
(mono crystalline panels need 10% less area)

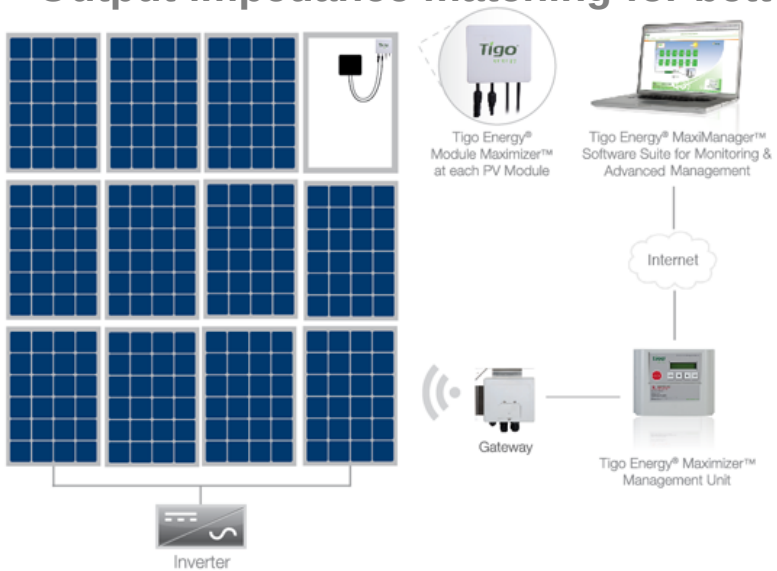
Expected output 16,400 kWh yearly
Some extra for 10% output degradation with time
(about 0.5% loss every year)

S

SOLAR INSTALLER:
InteliSolar, Santa Clara

Solar Energy: Recent Advances

- **Costs dropping like a rock**
  - Panels as low as $0.75/watt
  - Installed cost $3/watt, $2/watt after rebates
    - **$0.7 panel, $0.25 inverter, $0.5 (rest), $1.3 (install & permits)**
  - Assuming 25 year life, cost is 9c/kWh (7c/kWh after rebates)
    - **Solar has achieved Grid Parity even without rebates.**
- **Micro Inverters** ***$0.60/watt***
  - Costs more than string inverters, could not handle > 250W panels
- **Performance optimizers** ***$0.20/watt***
  - Output impedance matching for better performance (MPPT)



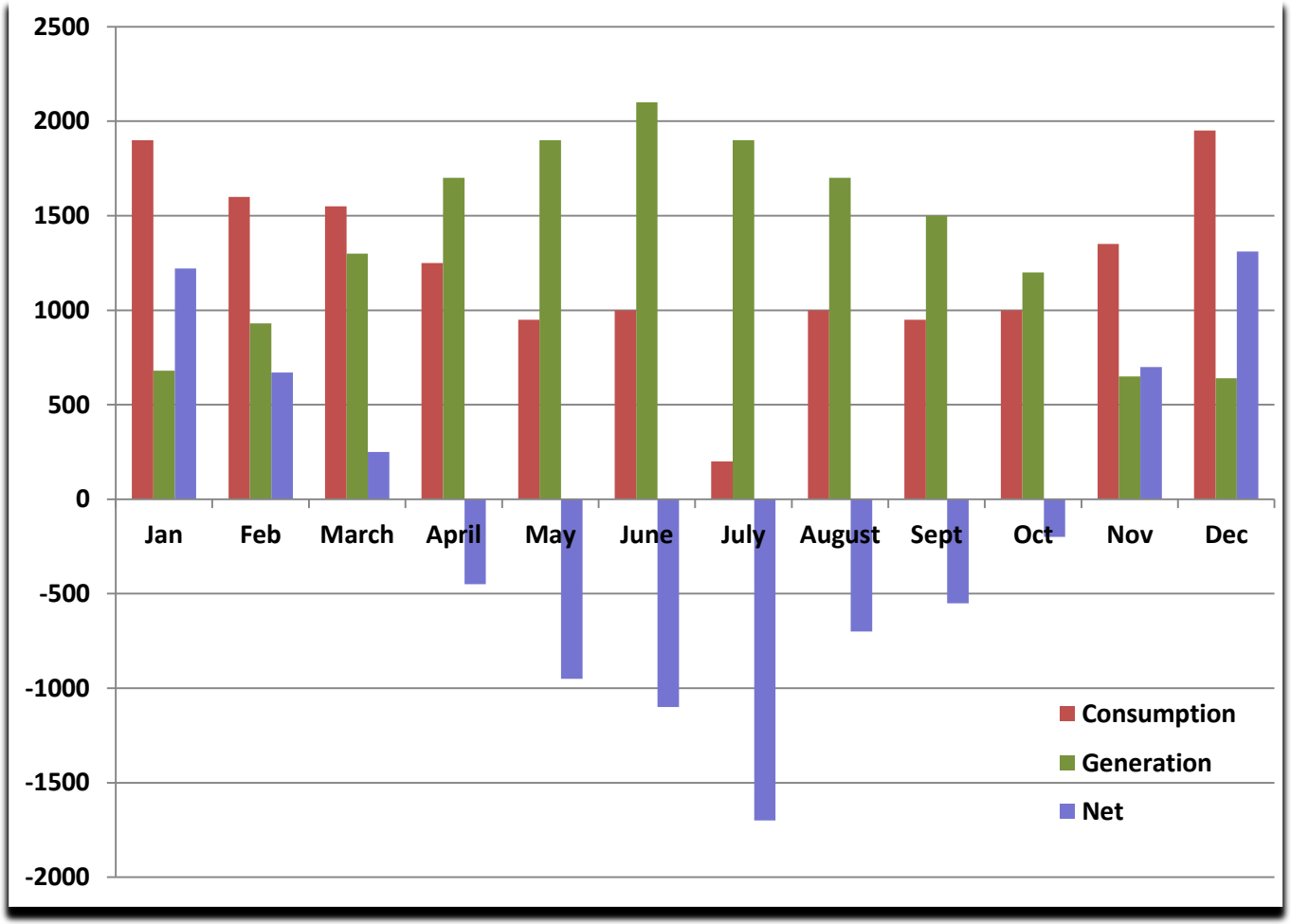
- Increases string output by up to 20%
- Specially good for shade and mismatched orientations
- Actual difference – about 10%
  - More noticeable in winter

Solar Installation Choices

My Approach

	DYI	Purchase Components + Solar Installer	Solar Company 20 year upfront pay lease
System Costs after Rebates	$1.2/watt; 5c/kWh	$2/watt; 7c/kWh	$2.5/watt; 9c/kWh
Steps Required	Estimation System Design Pull Permit Purchase parts Install City Inspection PG&E Connection Rebate Paperwork	Estimation System Design Purchase parts PG&E Connection Rebate Paperwork	Call Solar Company Pay Solar Company
Running Steps	Clean Repair Monitor	Clean Monitor	Clean Monitor
Running Costs	Equipment Replace Installation Replace Insurance	Equipment Replace Insurance	Solar Company Pays

Estimated Year Round Performance



Estimate for the year – 1800 kWh net extra Generation
Can handle 10% output degradation over 25 years

RESULTS

After First Year

Pacific Gas and Electric Company

PACIFIC GAS AND ELECTRIC COMPANY
NET ENERGY METERING ELECTRIC STATEMENT
THIS IS NOT A BILL
Service Dates: August 24,2012 to September 25,2012

Includes True-up period from Nov 2011 to Oct 2012

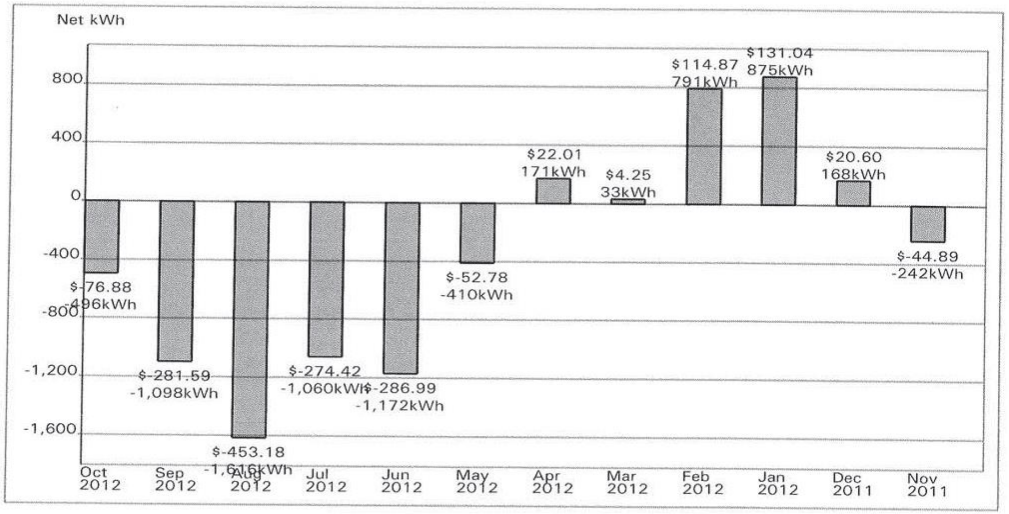
Rate Schedule: E 1XH/NEMS
Account ID: 3749760353
Service ID: 3749760335

PAGE 3

ENERGY TRUE-UP HISTORY:

BILLING MONTH	BILL TO DATE	ENERGY (kWh)	ENERGY CHARGES/ CREDITS
Oct 2012	09/25/12	-496	$-76.88
Sep 2012	08/24/12	-1,098	$-281.59
Aug 2012	07/26/12	-1,616	$-453.18
Jul 2012	06/26/12	-1,060	$-274.42
Jun 2012	05/29/12	-1,172	$-286.99
May 2012	04/26/12	-410	$-52.78
Apr 2012	03/27/12	171	$22.01
Mar 2012	02/27/12	33	$4.25
Feb 2012	01/26/12	791	$114.87
Jan 2012	12/28/11	875	$131.04
Dec 2011	11/28/11	168	$20.60
Nov 2011	10/26/11	[illegible]	[illegible]
TOTALS		-4,056	$-1,177.96

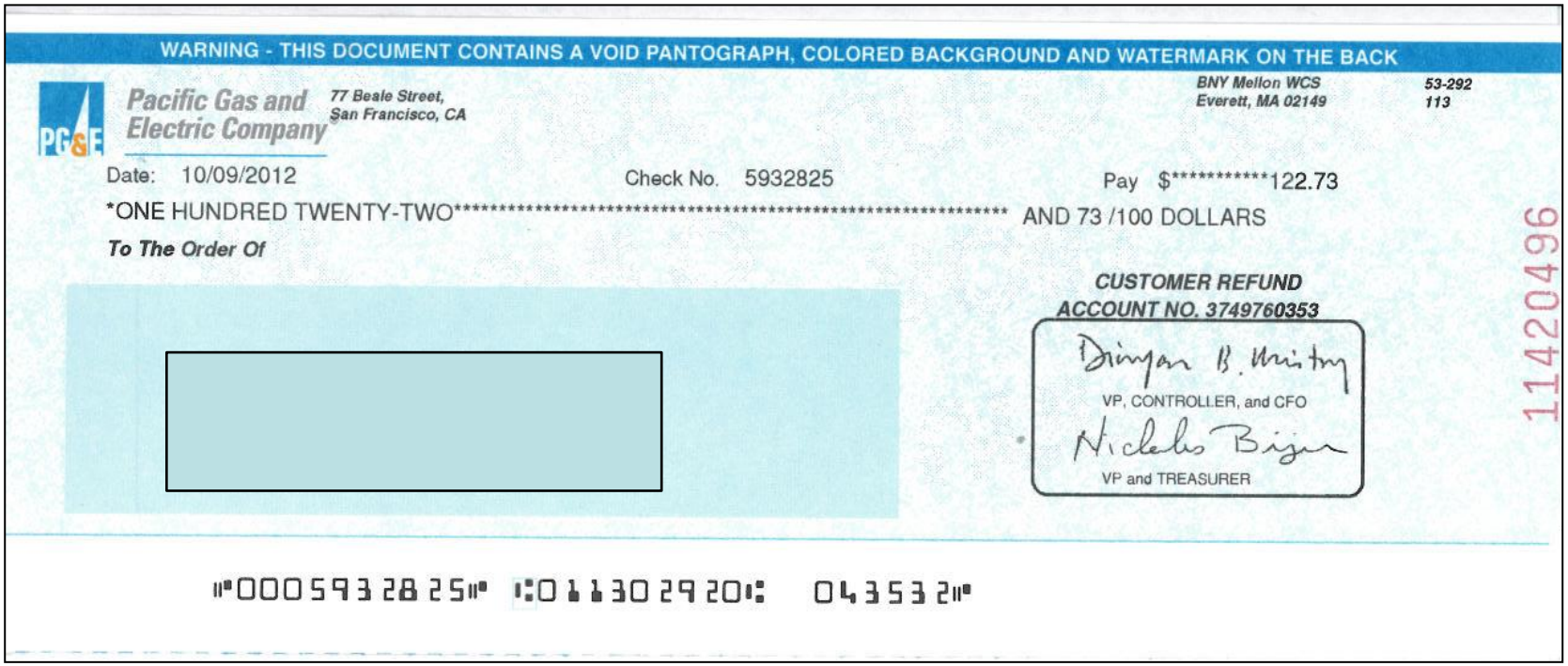
**Energy Charges/Credits (-) include all energy related amounts and taxes. Any negative amounts shown in the "TOTALS" row will not be applied to your next true-up period. This is because the net metering program was designed by the legislature for systems sized to customer usage on an annual basis. Currently approved tariffs and legislation provide that any financial credit associated with the program be used to offset current year bills, but neither result in a negative annual bill, nor be carried forward from one year to the next.



- ***4056*** *kWh excess higher than estimated as EVs were not there for whole year.*

Generation: *16,200 kWh*
- *Volt – 7 months*
- *FFE – 1 month*

PG&E sends a Check!



WARNING - THIS DOCUMENT CONTAINS A VOID PANTOGRAPH, COLORED BACKGROUND AND WATERMARK ON THE BACK

Pacific Gas and Electric Company
77 Beale Street, San Francisco, CA

BNY Mellon WCS
Everett, MA 02149

53-292
113

Date: 10/09/2012 Check No. 5932825 Pay $**********122.73

*ONE HUNDRED TWENTY-TWO********** AND 73 /100 DOLLARS

To The Order Of

CUSTOMER REFUND
ACCOUNT NO. 3749760353

VP, CONTROLLER, and CFO

VP and TREASURER

11420496

⑈0005932825⑈ ⑆011302920⑆ 043532⑈

This amount is much lower than previous final bill as PG&E pays customers wholesale rates only for any extra electricity generated.

After Second Year

Pacific Gas and Electric Company

PACIFIC GAS AND ELECTRIC COMPANY
NET ENERGY METERING ELECTRIC STATEMENT
THIS IS NOT A BILL
Service Dates: August 25,2013 to September 24,2013
Includes True-up period from Nov 2012 to Oct 2013

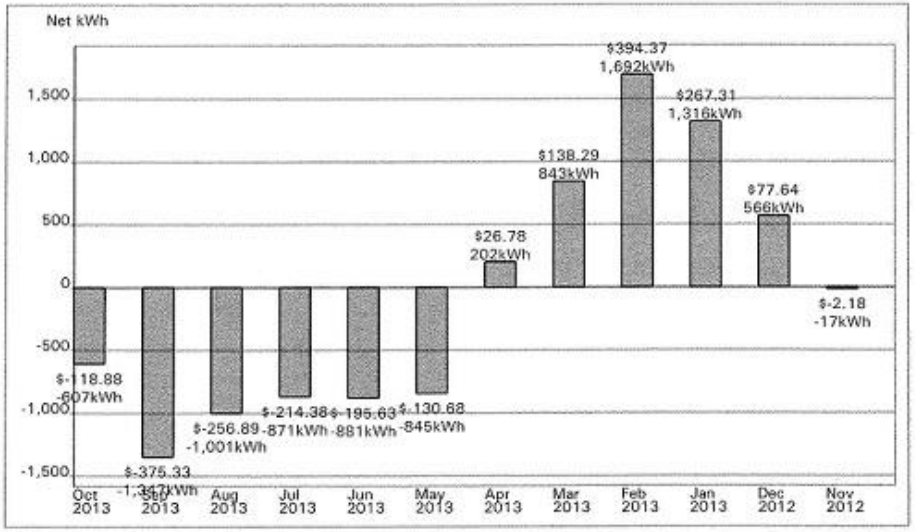
Rate Schedule: E 1XH/NEMS
Account ID: 3749760353
Service ID: 3749760335

PAGE 3

ENERGY TRUE-UP HISTORY:

BILLING MONTH	BILL TO DATE	ENERGY (kWh)	ENERGY CHARGES/ CREDITS
Oct 2013	09/24/13	-607	$-118.88
Sep 2013	08/25/13	-1,347	$-375.33
Aug 2013	07/25/13	-1,001	$-256.89
Jul 2013	06/25/13	-871	$-214.38
Jun 2013	05/27/13	-881	$-195.63
May 2013	04/25/13	-845	$-130.68
Apr 2013	03/26/13	202	$26.78
Mar 2013	02/25/13	843	$138.29
Feb 2013	01/28/13	1,692	$394.37
Jan 2013	12/27/12	1,316	$267.31
Dec 2012	11/26/12	566	$77.64
Nov 2012	10/24/12	-17	$-2.18
TOTALS		-950	$-389.58

**Energy Charges/Credits (-) include all charges related and taxes. Any negative amounts shown in the "TOTALS" row will not be applied to your next true-up period. This is because the net metering program was designed by the legislature for systems sized to customer usage on an annual basis. Currently approved tariffs and legislation provide that any financial credit associated with the program be used to offset current year bills, but neither result in a negative annual bill, nor be carried forward from one year to the next.



- ***950*** *kWh excess slightly lower than estimated*

Generation: *16,150 kWh*
Consumption: *15,200 kWh*
Higher consumption due to 2 months of guests.
Gasoline Consumption: *115 gallons*

After Third Year

Pacific Gas and Electric Company

PACIFIC GAS AND ELECTRIC COMPANY
NET ENERGY METERING ELECTRIC STATEMENT
THIS IS NOT A BILL
Service Dates: August 26,2014 to September 25,2014

Includes True-up period from Nov 2013 to Oct 2014

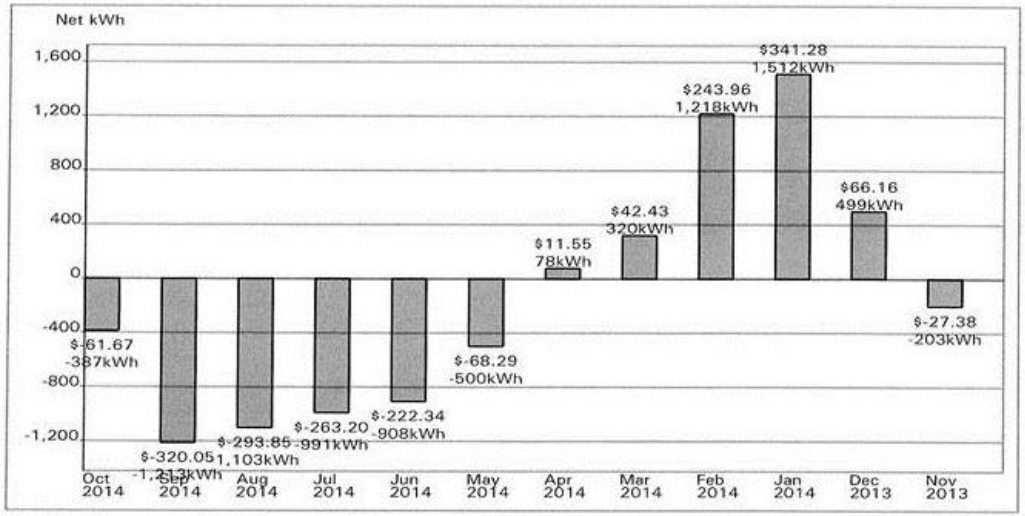
Rate Schedule: E 1XH/NEMS
Account ID: 3749760353
Service ID: 3749760335

PAGE 3

ENERGY TRUE-UP HISTORY:

BILLING MONTH	BILL TO DATE	ENERGY (kWh)	ENERGY CHARGES/ CREDITS
Oct 2014	09/25/14	-387	$-61.67
Sep 2014	08/26/14	-1,213	$-320.05
Aug 2014	07/27/14	-1,103	$-293.85
Jul 2014	06/25/14	-991	$-263.20
Jun 2014	05/27/14	-908	$-222.34
May 2014	04/27/14	-500	$-68.29
Apr 2014	03/26/14	78	$11.55
Mar 2014	02/25/14	320	$42.43
Feb 2014	01/26/14	1,218	$243.96
Jan 2014	12/25/13	1,512	$341.28
Dec 2013	11/22/13	499	$66.16
Nov 2013	10/23/13	-203	$-27.38
TOTALS		-1,678	$-551.40

**Energy Charges/Credits (-) include all energy related amounts and taxes. Any negative amounts shown in the "TOTALS" row will not be applied to your next true-up period. This is because the net metering program was designed by the legislature for systems sized to customer usage on an annual basis. Currently approved tariffs and legislation provide that any financial credit associated with the program be used to offset current year bills, but neither result in a negative annual bill, nor be carried forward from one year to the next.



- ***1678*** *kWh excess almost as estimated*

Generation: *15,700 kWh*
Consumption: *14,000 kWh*
Solar output degraded a bit.
Gasoline Consumption: *100 gals*

After Fourth Year

ENERGY STATEMENT
www.pge.com/MyEnergy

Account No: 3749760353-2
Statement Date: 09/25/2015
Due Date: 10/16/2015

Summary of Your NEM True-Up Period Charges

Summary of NEM Charges

Bill Period End Date	Net Usage (kWh)	NEM Charges Before Taxes	Estimated Taxes	Total NEM Charges
10/28/2014	-148	-$22.01	-$0.57	-$22.58
11/24/2014	377	57.68	1.49	59.17
12/25/2014	1085	219.57	5.56	224.13
01/26/2015	993	225.34	5.70	231.04
02/25/2015	326	52.79	1.36	54.15
03/26/2015	122	20.18	0.52	20.66
04/27/2015	-582	-96.35	-2.48	-98.83
05/27/2015	-721	-164.15	-4.15	-168.30
06/25/2015	971	255.73	3.47	259.19
07/26/2015	-1185	-322.32	-8.08	-330.40
08/26/2015	-600	-159.28	4.02	163.28
09/24/2015	[illegible]	-33.22	-0.86	[illegible]
TOTAL	-1591	-$478.75	-$[illegible].95	-$490.70

Differences in net usage may occur due to rounding

Electric Minimum Charges

Bill Period End Date	Minimum Charges
10/28/2014	$4.70
11/27/2014	4.28
12/25/2014	4.58
01/26/2015	4.73
02/25/2015	4.44
03/26/2015	4.28
04/27/2015	4.73
05/27/2015	4.40
06/25/2015	4.29
07/26/2015	4.58
08/25/2015	4.44
09/24/2015	8.77
TOTAL	$58.29

Explanation of Calculations

This is your True-Up statement. Since the total Electric Minimum Charges are greater than the total NEM Charges Before Taxes, your Service Period and any current month Electric Minimum Charges in addition to any applicable charges and taxes for the True-Up period.

Since this is your **True-Up statement**, all electric usage charges and credits are reset to zero starting with your next billing cycle.

Net Surplus Compensation (NSC). This credit occurs on the True-Up statement only if the **Net Usage (kWh)** of the system has generated more energy than consumed during the overall 12 month billing cycle. The NSC is based on that month's market price for energy (see current calculation under **Credit for Net Surplus Compensation (NSC)** below).

Based on your **Net Usage (kWh)**, the True-Up calculations are:

Total NEM Charges Before Taxes	-$478.75
Total Electric Minimum Charges	58.29
Total NEM Charges Due	**$0.00**
Credit for Net Surplus Compensation (NSC) (-1591 kWh x 20150 kWh @ $0.03754/kWh)	**-$59.66**

Summary of NEM Charges continued on next page →

Please contact the Solar Customer Service Center at 1-877-743-4112 for questions about your NEM charges.
Visit www.pge.com/nembilling for a detailed explanation of NEM billing

- ***1591*** *kWh excess almost as estimated*

Generation: *15,200 kWh*
Consumption: *13,600 kWh*
Solar output degraded bit more.
Gasoline Consumption: *100 gals*

After Fifth Year

ENERGY STATEMENT
www.pge.com/MyEnergy

Account No: 3749760353-2
Statement Date: 09/26/2016
Due Date: 10/17/2016

Summary of Your NEM True-Up Period Charges

Service Full: 19870 DARNHART AVE
Service Agreement ID: 3749760463
Rate Schedule: E1 X | Residential Service

Summary of NEM Charges

Bill Period End Date	Net Usage (kWh)	NEM Charges Before Taxes	Estimated Taxes	Total NEM Charges
10/25/2015	52	$8.67	$0.23	$8.90
11/23/2015	573	92.24	1.50	93.74
12/23/2015	1323	304.93	7.70	312.63
01/25/2016	1401	351.37	8.85	360.22
02/24/2016	565	104.68	2.67	107.35
03/24/2016	386	70.16	1.79	71.95
04/25/2016	-281	-51.16	1.31	52.47
05/24/2016	-381	-68.16	-1.73	-69.89
06/23/2016	958	276.35	-8.50	-284.85
07/25/2016	-1384	-441.23	-10.89	-452.22
08/24/2016	-1091	-331.27	-8.27	-339.54
09/25/2016	[illegible]	-104.43	2.66	[illegible]
TOTAL	-462	-$370.56	-$9.02	-$379.58

Differences in net usage may occur due to rounding

Explanation of Calculations

This is your True-Up statement. Since the total electric Minimum Delivery Charges are greater than the total NEM Charges Before Taxes, your balance owed are any current month electric Minimum Delivery Charges in addition to any applicable charges and taxes for the True-Up period.

Since this is your **True-Up statement,** all electric usage charges and credits are reset to zero starting with your next billing cycle.

The Minimum Delivery Charge is assessed monthly and credited at true-up if the total NEM Charges Before Taxes are greater than your cumulative Minimum Delivery Charges.

*Energy Charges are basic commodity costs related to energy usage. These charges will only be billed at True-up if they are a positive amount and when the total NEM Charges Before Taxes are less than your total Minimum Delivery Charges.

Net Surplus Compensation (NSC). This credit occurs on the True-Up statement only if the **Net Usage (kWh)** of the system has generated more energy than consumed during the overall 12-month billing cycle. The NSC is based on that month's market price for energy (see current calculation under **Credit for Net Surplus Compensation (NSC)** below).

Based on your Net Usage (kWh), the True-Up calculations are:

Total NEM Charges Before Taxes	-$370.56
Total Electric Minimum Delivery Charges	-$9.02
Total NEM Charges Due	**$0.00**

Please contact the Solar Customer Service Center at 1-877-743-4112 for questions about your NEM charges.

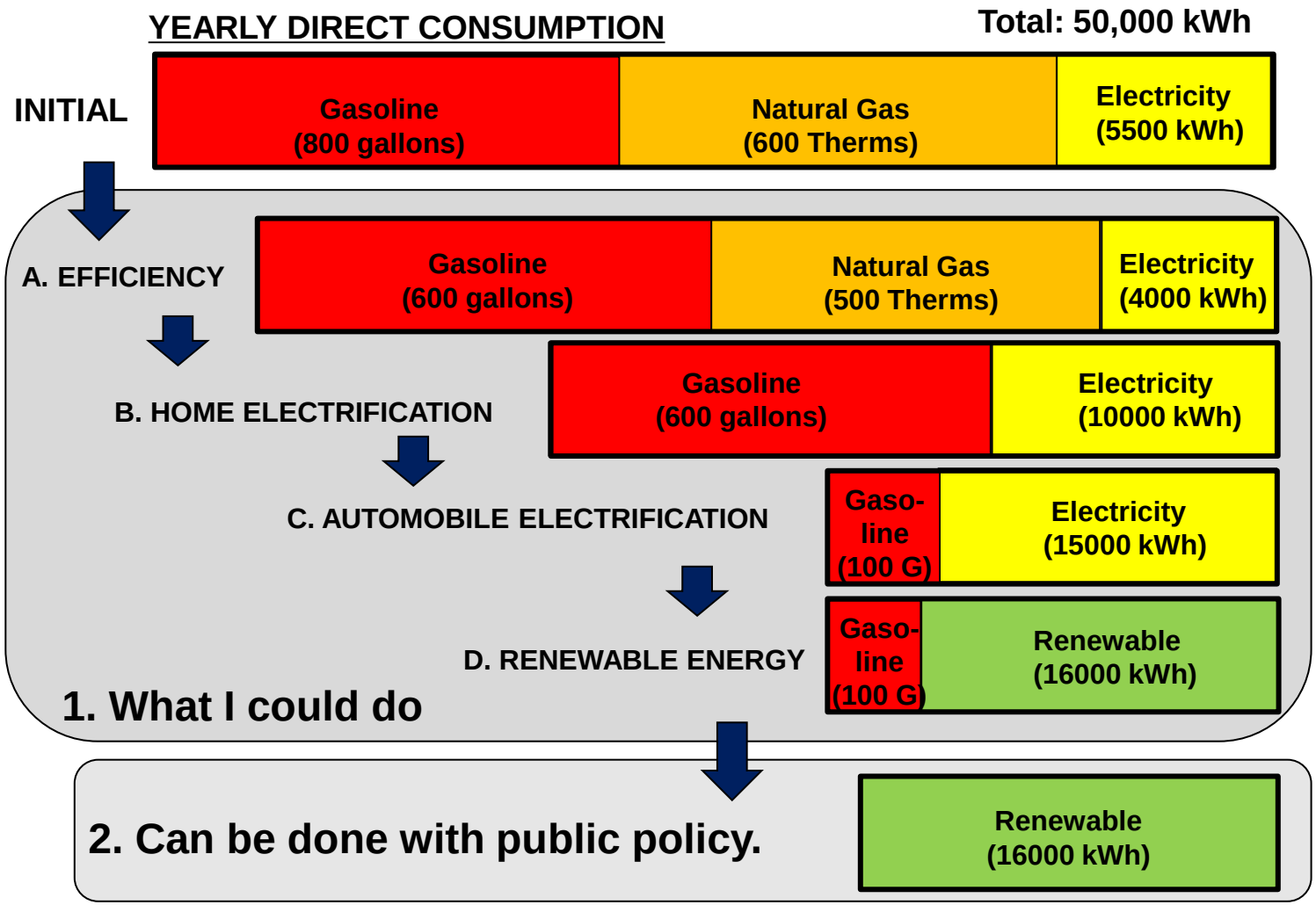
Visit **www.pge.com/nembilling** *for a detailed explanation of NEM billing*

Page 3 of 3

- ***462** kWh excess almost as estimated*

***Generation:** 14,900 kWh*
***Consumption:** 14,400 kWh*
Solar output hit a temporary snag.
***Gasoline Consumption:** 80 gals*

In the End


YEARLY DIRECT CONSUMPTION
Total: 50,000 kWh
INITIAL
Gasoline (800 gallons)
Natural Gas (600 Therms)
Electricity (5500 kWh)
A. EFFICIENCY
Gasoline (600 gallons)
Natural Gas (500 Therms)
Electricity (4000 kWh)
B. HOME ELECTRIFICATION
Gasoline (600 gallons)
Electricity (10000 kWh)
C. AUTOMOBILE ELECTRIFICATION
Gaso-line (100 G)
Electricity (15000 kWh)
D. RENEWABLE ENERGY
Gaso-line (100 G)
Renewable (16000 kWh)
1. What I could do
2. Can be done with public policy.
Renewable (16000 kWh)

FINANCES

Economics

*** In $1000**

	HOME RETROFIT	CARS (extra cost)	SOLAR GENERATOR	TOTAL
2013	15	20	36	71
Rebates	2	20	13	33
Net	13	0	23	36

Savings: 4,5K per year ; Payback: 8 years; Rate of return: 10%

Main reasons:

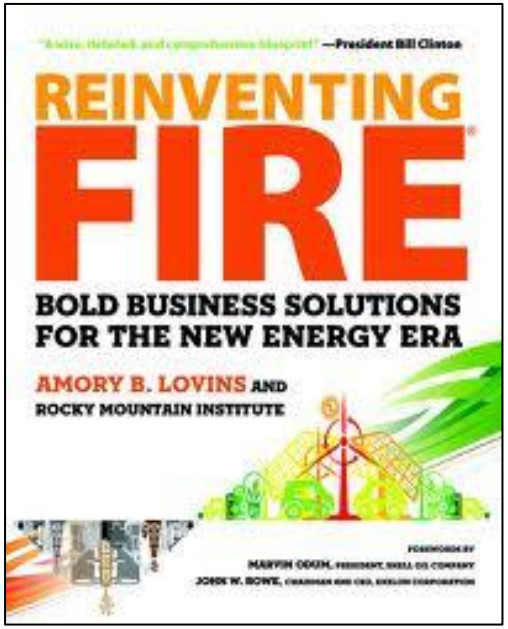
No home retrofit: $15K reduction

Smaller solar system possible for better constructed home: $6K

Lower battery cost + mass production in EVs: $20K reduction (no subsidy needed)

Contact & Questions

- **Indradeep Ghosh**
  - Cupertino, CA 95014, USA
- **Email:** indraghosh@hotmail.com
- **YouTube Video:** http://www.youtube.com/watch?v=W8OYK1pnxN8
- **Cost Analysis Spreadsheets:** http://carbonfreepaloalto.org/



Highly recommend reading this book

& this Web book:

http://www.withouthotair.com/

http://thesolutionsproject.org