The Energy+ Household:

a consumer's perspective on sustainable energy

Indradeep Ghosh, PhD
Cupertino, CA, USA

The Energy+ Household is the 25th home to officially meet the 1000 Home Challenge.

The Energy+ Household

- **Imagine**
  - A single family house in the suburbs, about 2,200 sq ft (US median: 2,160)
  - 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

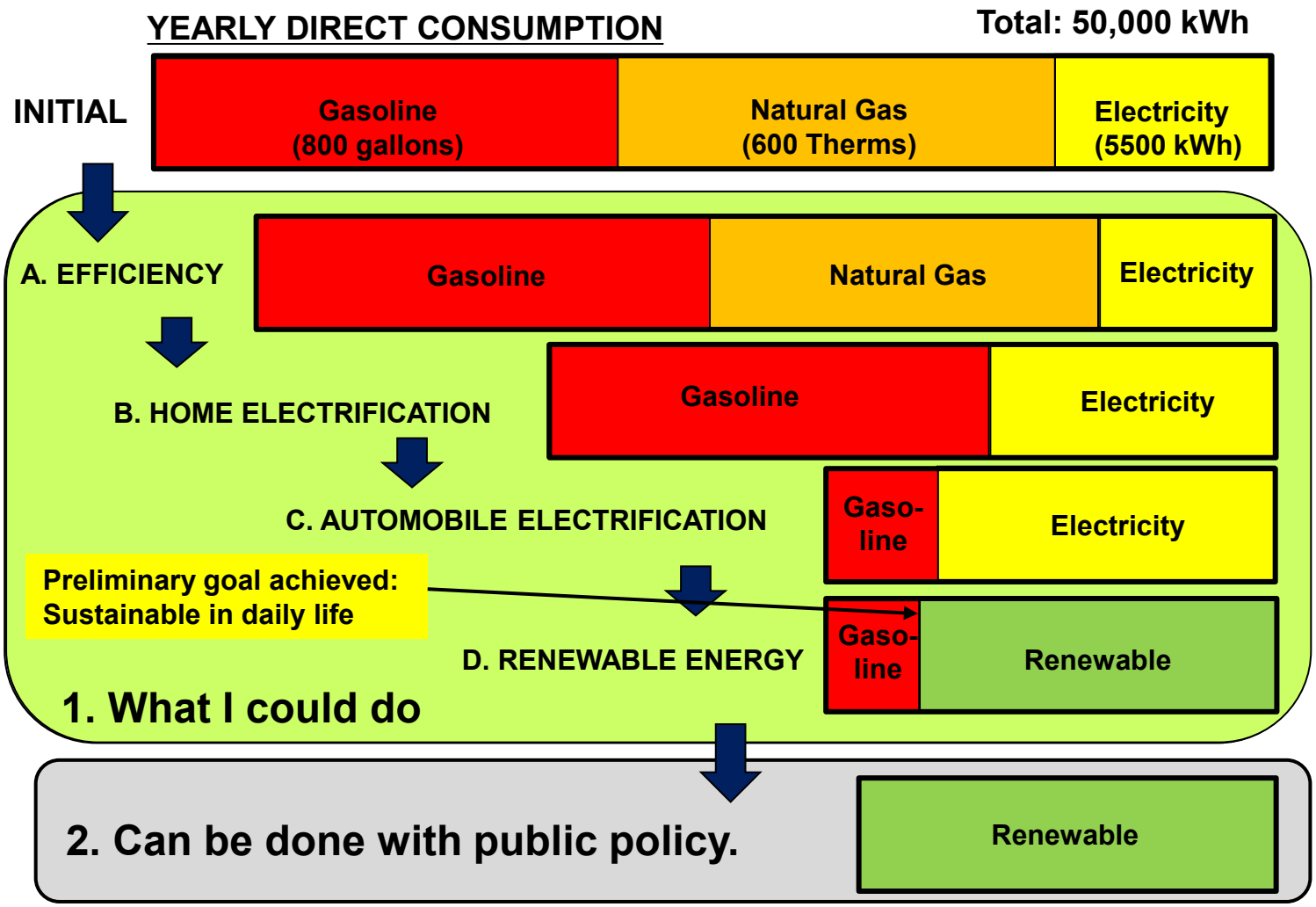
- **Now Imagine**
  - **ZERO** yearly energy bills (in fact, negative!)
    - ***i.e.,*** **zero electricity, zero natural gas, zero gas in daily life**
  - Completely sustainable & carbon free with renewable energy

- **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**
- **Amazed by the amount of energy wasted by phantom loads**

Utility Meter

Kill-a-Watt Meter

Whole-house phantom 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 70˚F in winter, 80˚F in summer**
  - **In summer ceiling/stand fans can help up to about 88˚F**
  - **Set back when house unoccupied**
  - **Use curtains and shades**
- **Low flow faucets/shower heads conserve water & heat**
- **Wash in cold water with high efficiency detergent**
- **Weatherstrip 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

- **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 (R-15 walls, R-30 attic)
  - Double pane windows

- **Programmable thermostat**

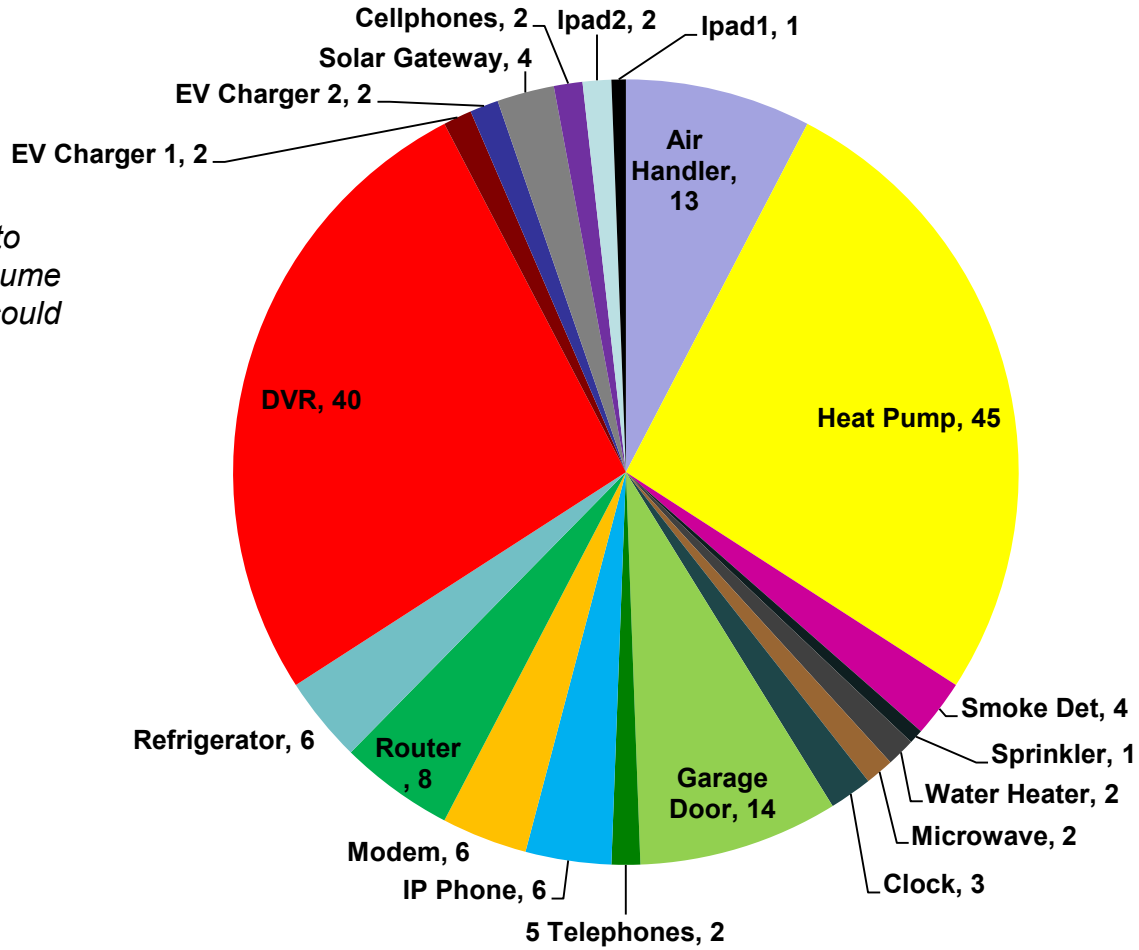
OR

NEST Thermostat

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

Phantom 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 NATURAL GAS USE

Water Heating

Gas
Water heater
Efficiency: 58%

$2,000

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	$9,000	$7,000
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

$8,500

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

Air Source Heat pump
Efficiency: ~300% average

- 1 week project
- Requires city permit
- 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

$1,000

- 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

$2,000

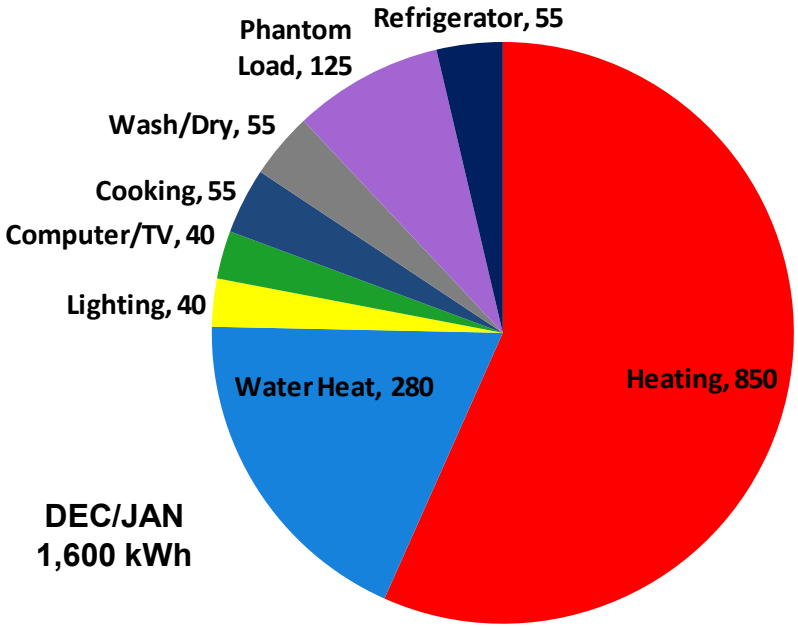
~40% efficient
Gas cooktop

~85% efficient
Induction cooktop

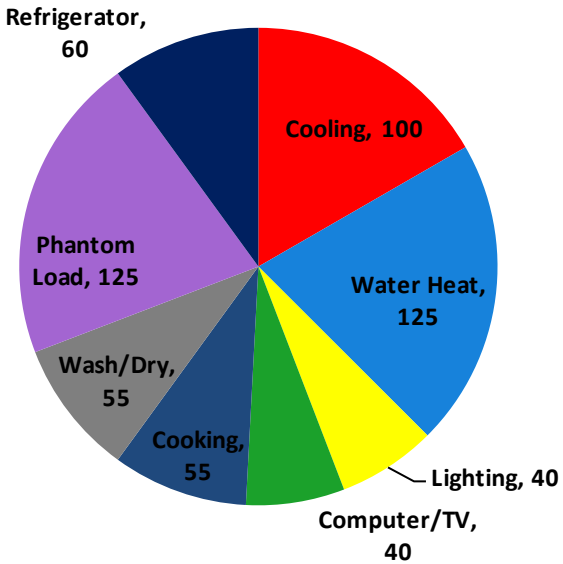
- Requires 240V cooktop line in kitchen
- Induction cooktops warm and cool very fast
- Requires iron/stainless steel utensils
- Only flat bottom utensils

Total 66% energy saved switching to electric

Monitored Monthly Consumption

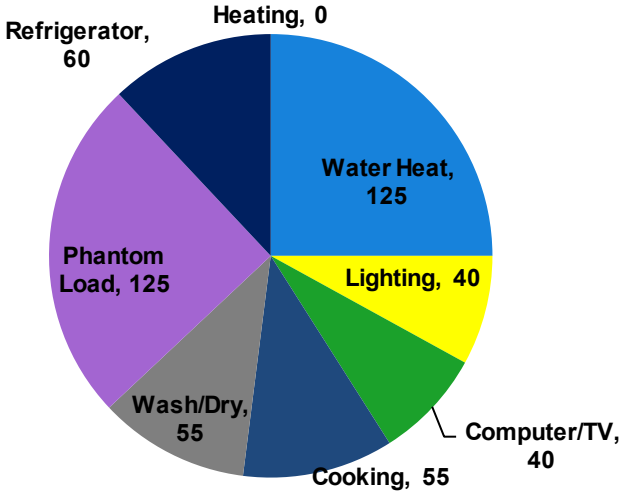


DEC/JAN
1,600 kWh

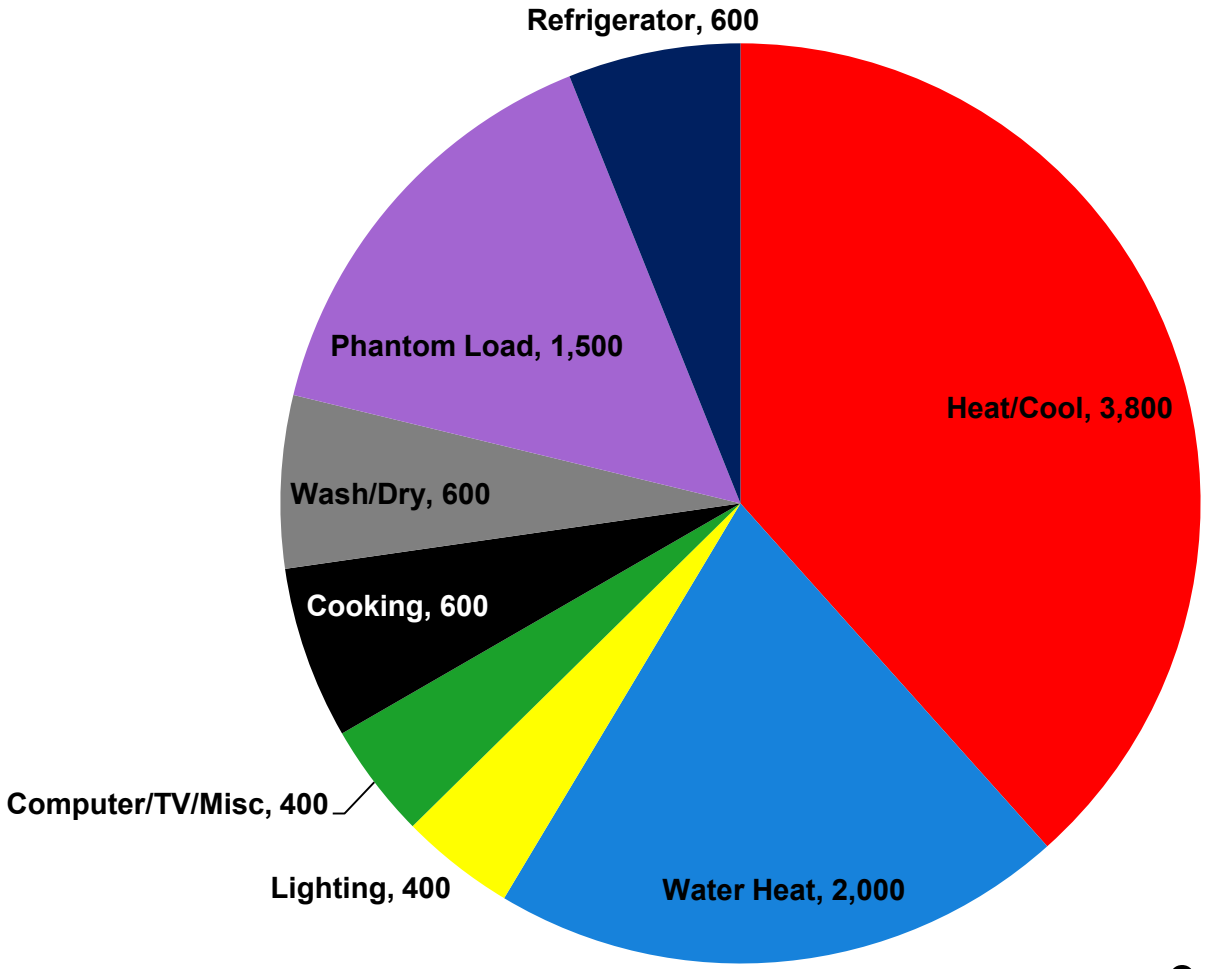


JULY/AUG
600 kWh

MAY/SEPT
500 kWh



Monitored Total for the Year



9,900 kWh

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

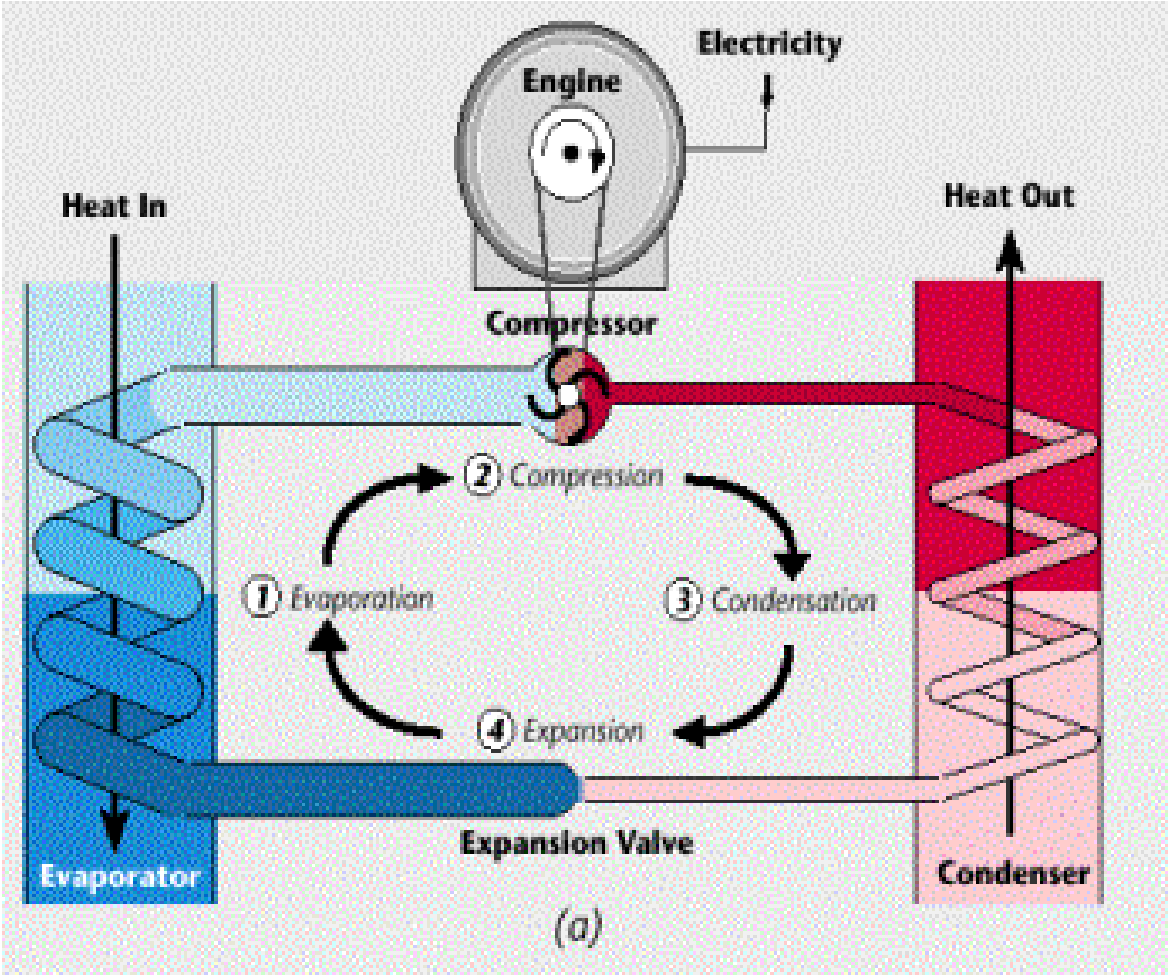
4.5 kWh/sq ft per year

Efficient Heating/Cooling: Heat Pumps

SUMMER
AC

HOME

OUTSIDE



WINTER
Heat Pump

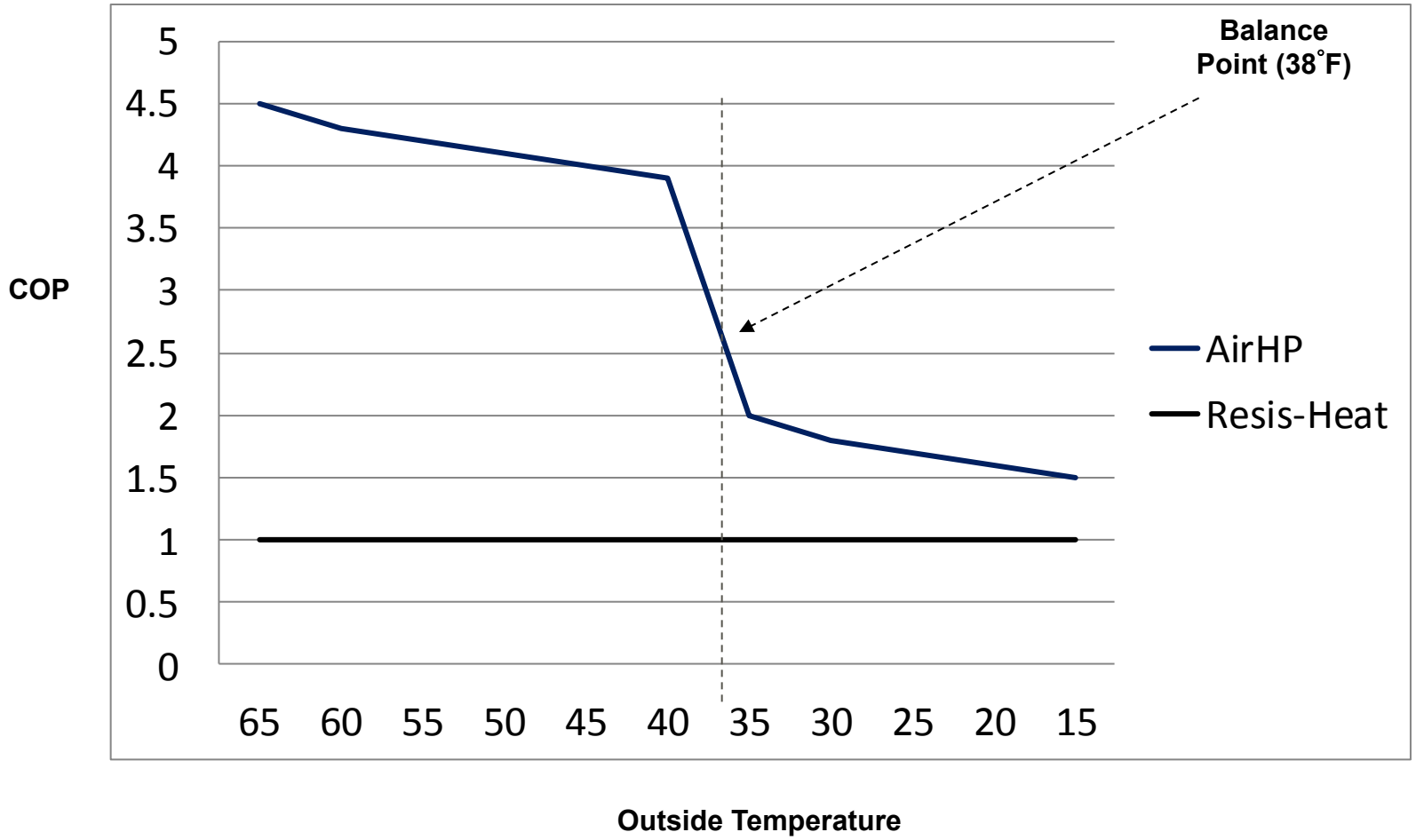
OUTSIDE

HOME

Efficiency degrades with temperature difference; Lower heating rate.

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

Our Heat Pump Performance



Average yearly COP in our climate - 3

THIRD STEP: ELIMINATE GASOLINE FROM DAILY LIFE

Automobile Electrification

Nissan Altima Hybrid (33 mpg)

$26,000

Chevy Volt (33kWh/100 miles)

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

Yearly requirement – 3,000 kWh

Toyota Highlander Hybrid (25 mpg) *

$25,000

Ford Focus Electric (31kWh/100 miles)

** 80 miles on electric, no gas

Yearly requirement – 1,700 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 :**
  - 9,900 kWh (home) + 4,700 kWh (cars) = 14,600 kWh (total/year)
  - 10 KW ideal tilt system facing south is sufficient (no shade)
  - If time-of-use rates are used, 8.5 KW 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 monocrystalline Canadian Solar modules
11.4 KW Fronius IG Plus V Inverter
(mono crystalline panels need 10% less area)

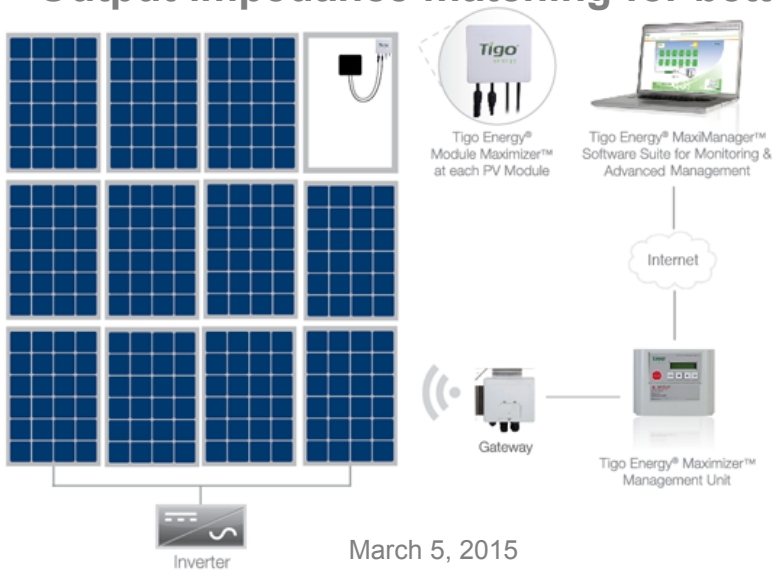
Expected output 16,400 kWh yearly
Some extra for 10% output degradation with time
(about 0.5% loss every year)

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 9¢/kWh (7¢/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)



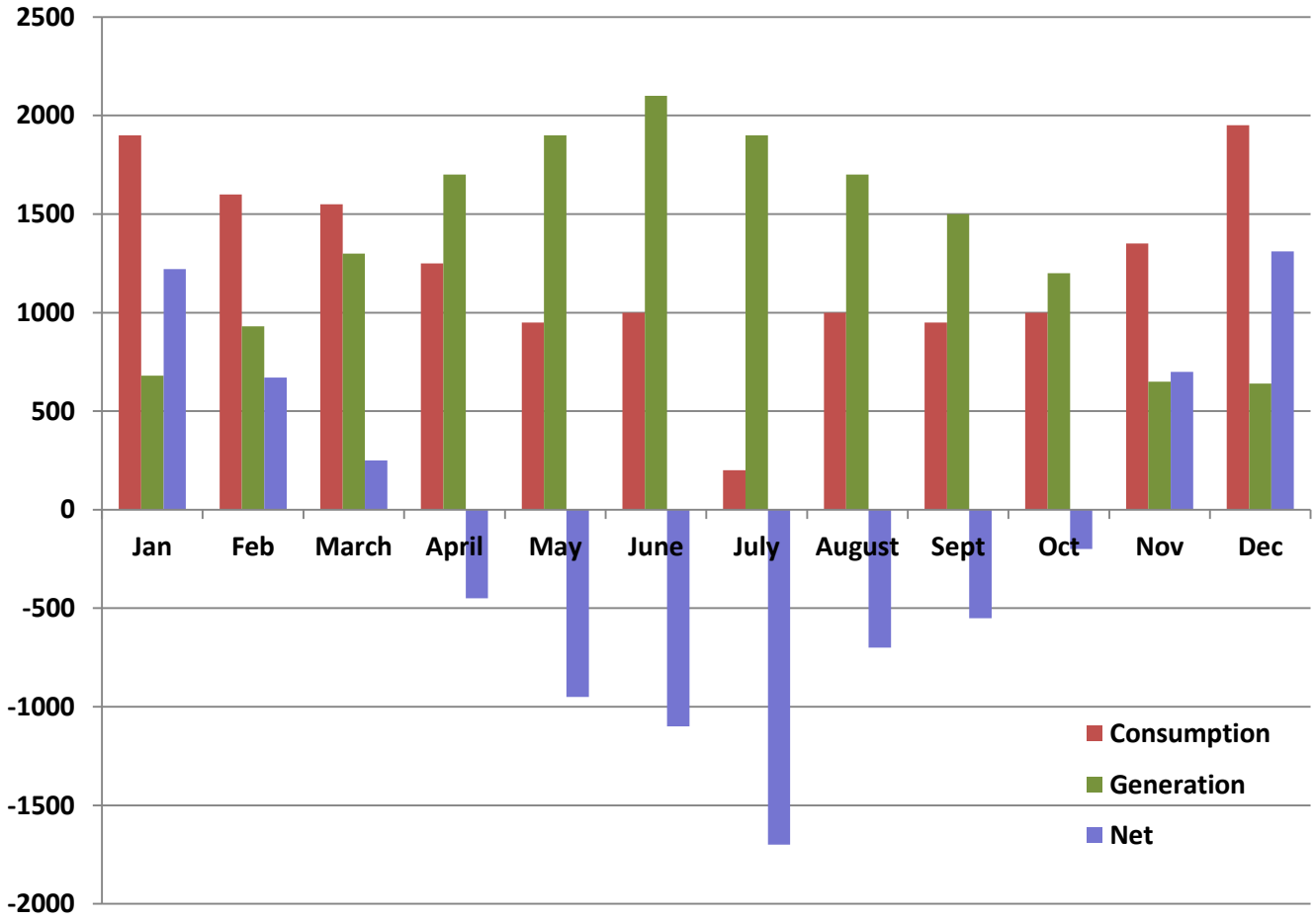
- Increases string output by up to 20%
- Especially good for shade and mismatched orientations
- Actual difference – about 10%
  - More noticeable in winter

Solar Installation Choices

My Approach

	DYI	Purchase Components + Solar Installer	Solar Company 20-year upfront pay lease
System Costs after Rebates	$1.2/watt; 5¢/kWh	$2/watt; 7¢/kWh	$2.5/watt; 9¢/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 – 1,800 kWh net extra generation
Can handle 10% output degradation over 25 years

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

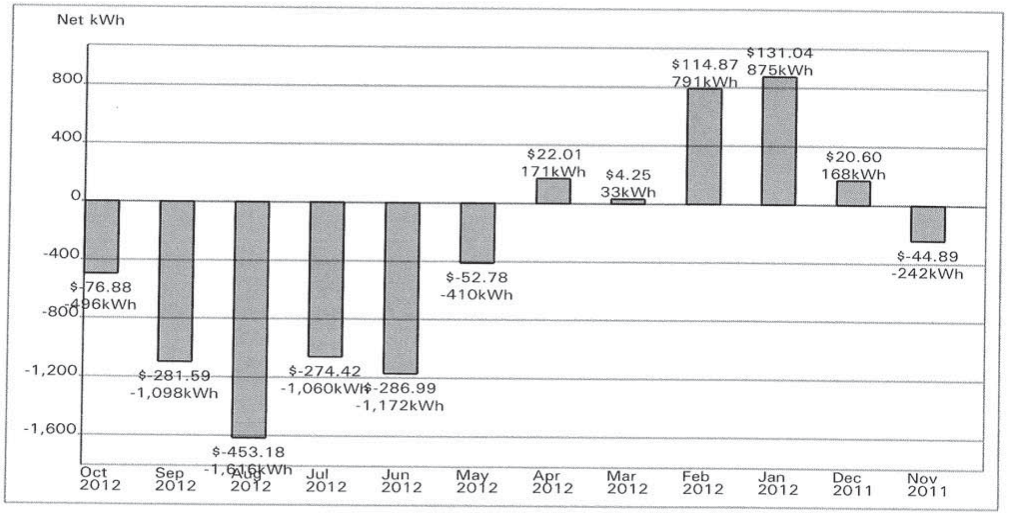
Rate Schedule: E 1XH/NEMS
Account ID: 3749760353
Service ID: 3749760335

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

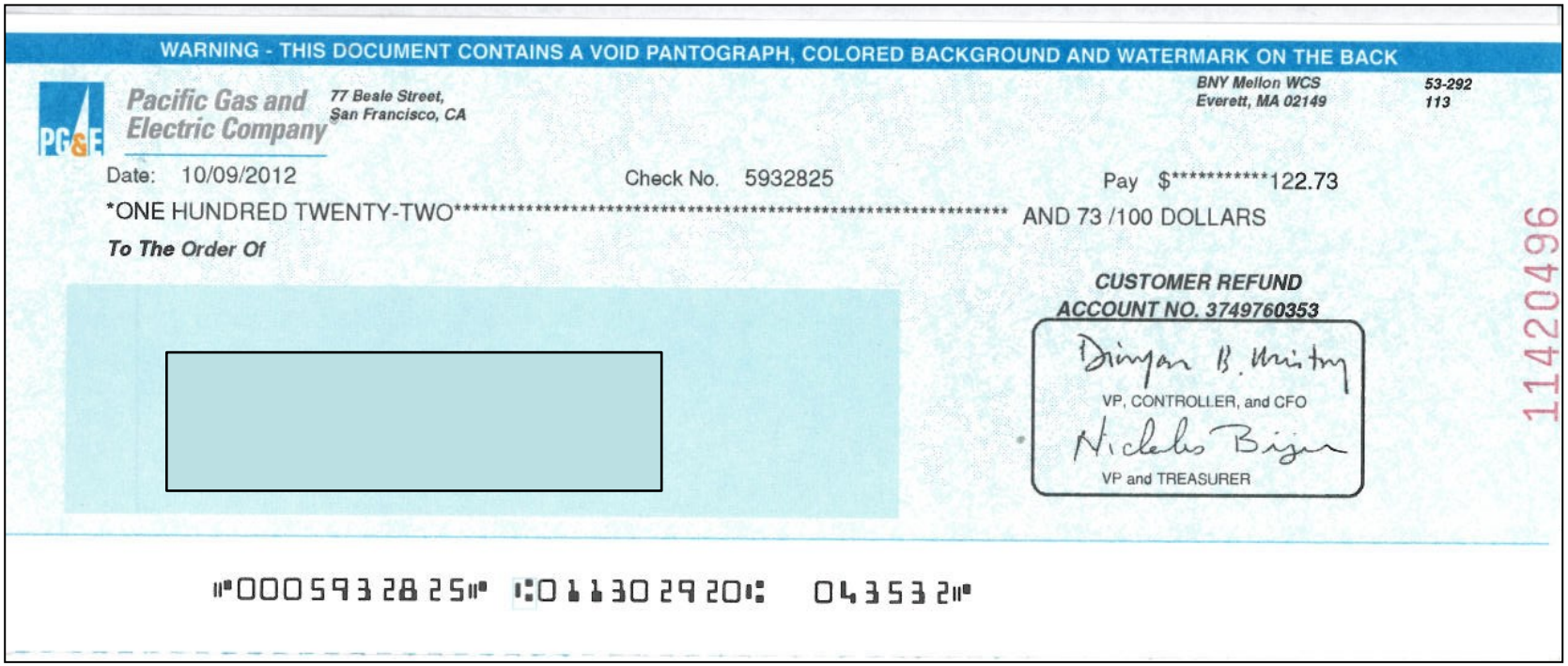
**Energy Charges/Credits (-) include all energy related amounts and taxes. Any negative amounts shown in the "TOTALS" row will not be applied to your next true-up period. This is because the net metering program was designed by the legislature for systems sized to customer usage on an annual basis. Currently 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.



- ***4,056** 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

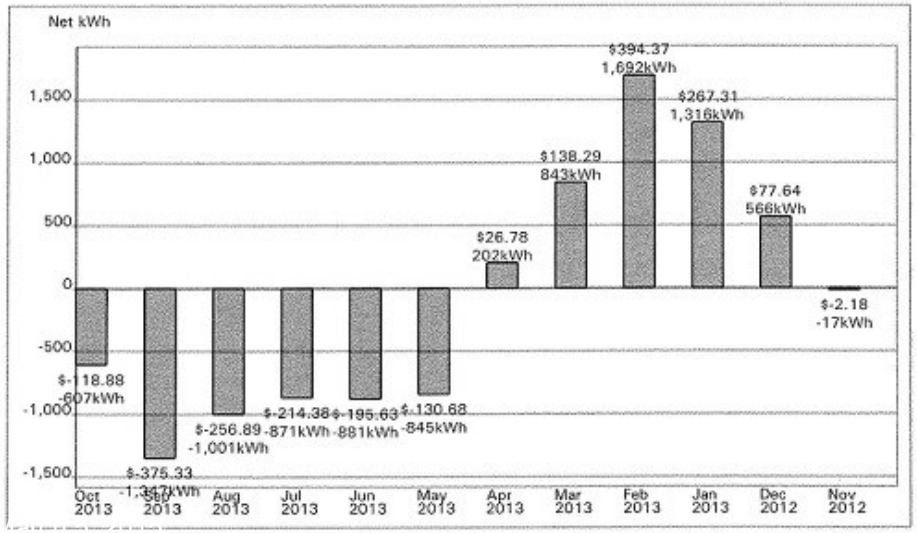
Rate Schedule: E 1XH/NEMS
Account ID: 3749760353
Service ID: 3749760335

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 energy related adjustments 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

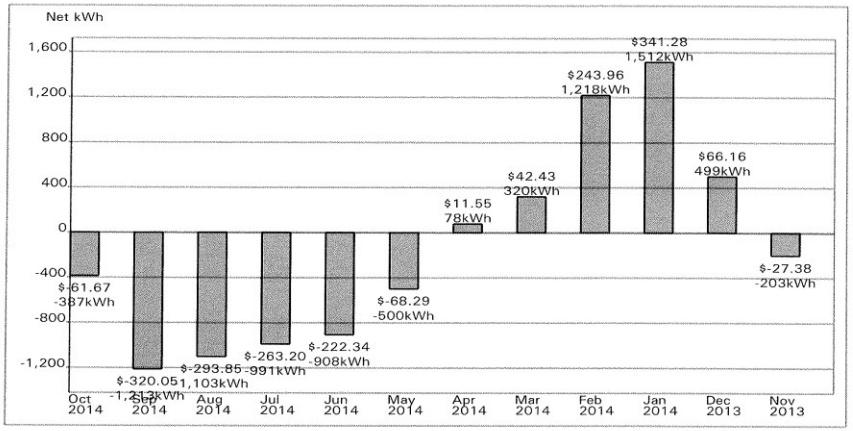
Rate Schedule: E 1XH/NEMS
Account ID: 3749760353
Service ID: 3749760335

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.



- ***1,678** kWh excess almost as estimated*

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

Article in San Jose Mercury News

COMMUNITY

Ghosh family invests in home, yielding energy surplus

By MATT WILSON

The Ghosh family home in Cupertino does not appear unusual in the least from the outside or inside. The tidy one-story home is roughly 2,200 square feet and is home to Indradeep Ghosh, his wife, Aninta, and their two small children.

"We are very typical of the average American household," he says.

To understand the home's uniqueness, one needs to look in the family mailbox to see what isn't there: The family has no electrical bills.

Over the past two years, Ghosh has successfully converted his Cupertino home into an energy-neutral household, meaning the family generates all of the energy it needs for day-to-day living for an entire year.

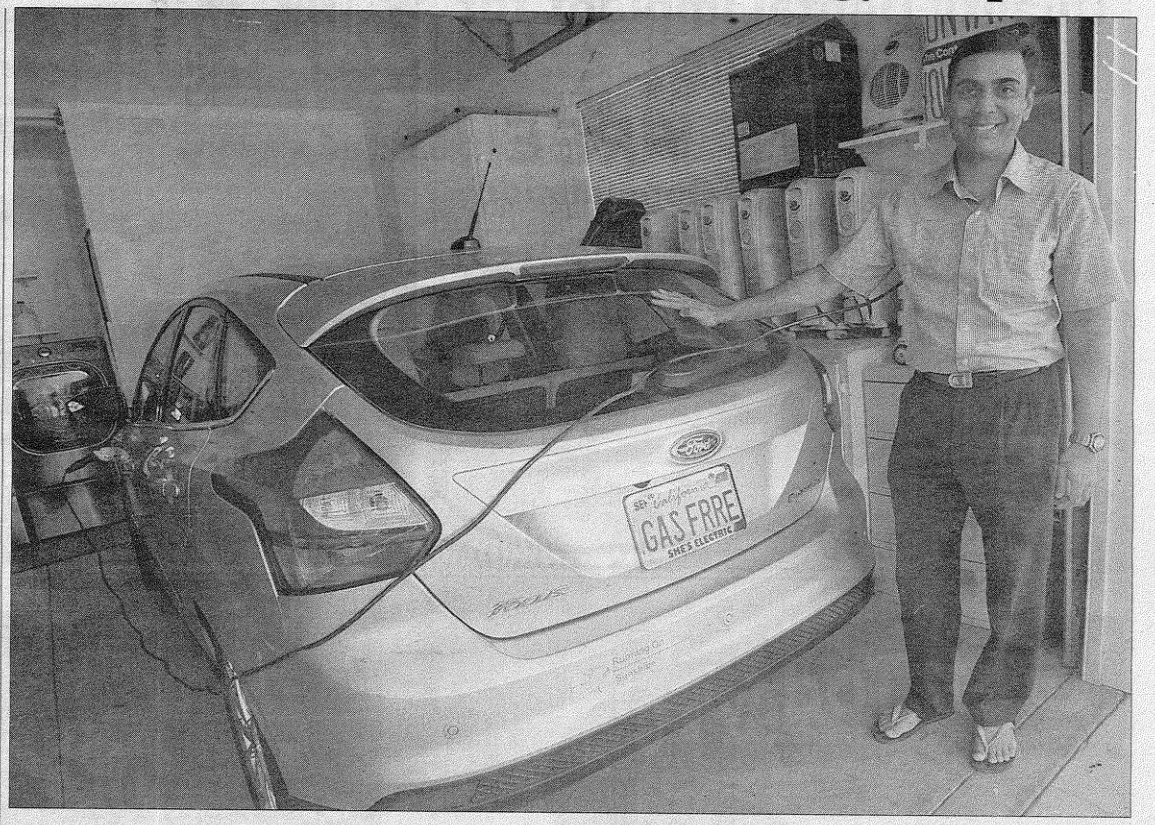
Throughout 2010 and 2011, the Ghoshs retrofitted their home with various devices and technology to greatly reduce their energy consumption, while also generating their own energy.

The first year was a smashing success as Pacific Gas and Electric sent the family money for generating more energy than it used. Based on wholesale prices, the Ghosh family pocketed $122.73.

"Don't try and do what I did if you're trying to make money out of this," Ghosh says. "Just try to balance out what you need."

Over the course of a year, he performed an energy audit using a wattmeter and a digital smart-meter installed by the utility company.

Ghosh found that the annual energy requirement for the family is roughly 14,400 kWh. A number



PHOTOGRAPHS BY JACQUELINE RAMSEYER

Indradeep Ghosh stands by his Ford Focus electric car with the license plate 'gas frre.'

sures were taken. All 50 lights in the home were replaced with LED bulbs, which reduced lighting load from 900 watts to 150

ing to get his wife to agree to give up the gas cooktop.

The gas-burning hot water heater was replaced with an en-

Indradeep Ghosh shows the air source heat pump he had installed while converting his Cupertino

Economics

*** In $1,000**

	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%

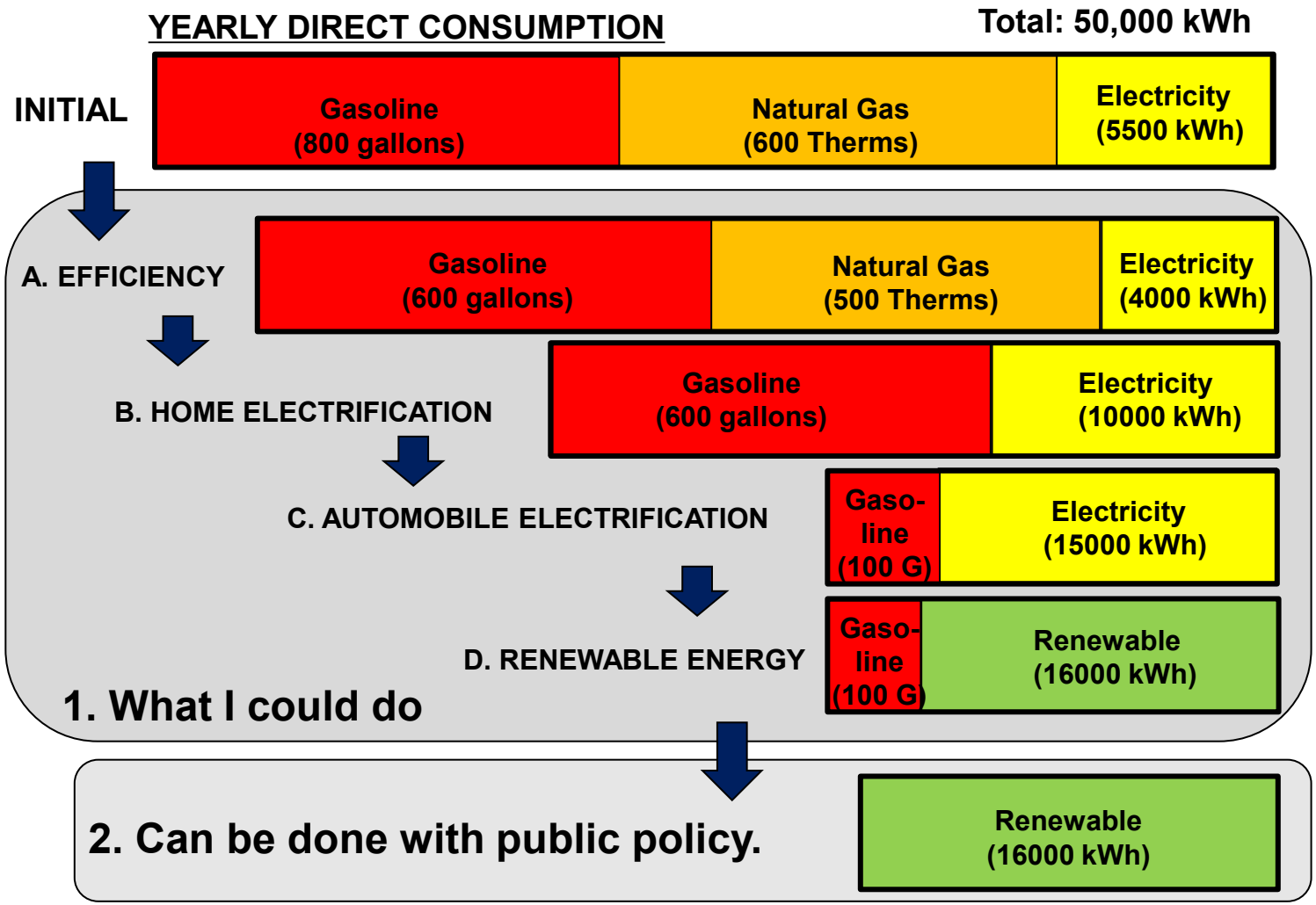
Main reasons:

No home retrofit: $15K reduction

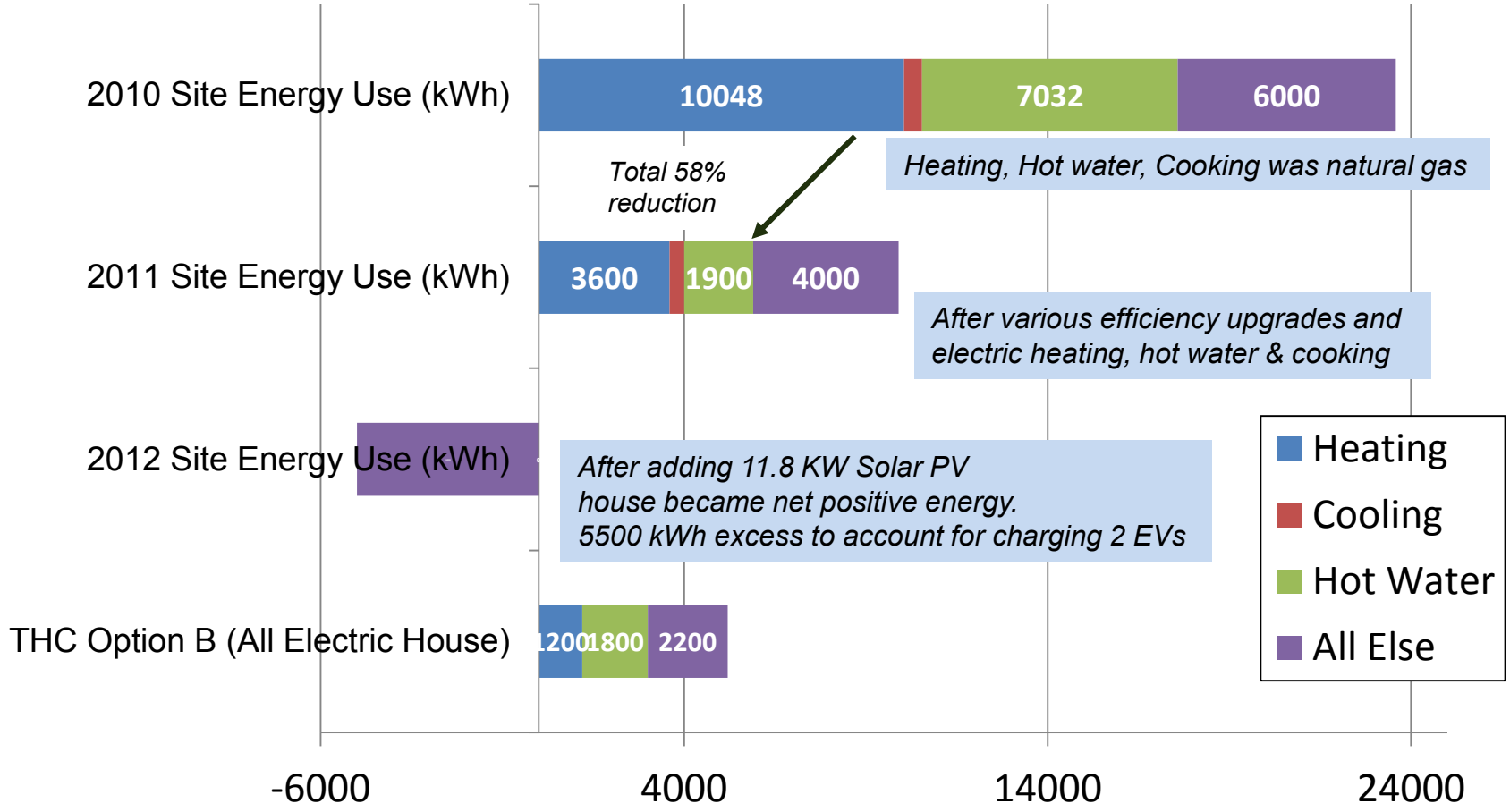
Smaller solar system possible for better constructed home: $6K

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

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)

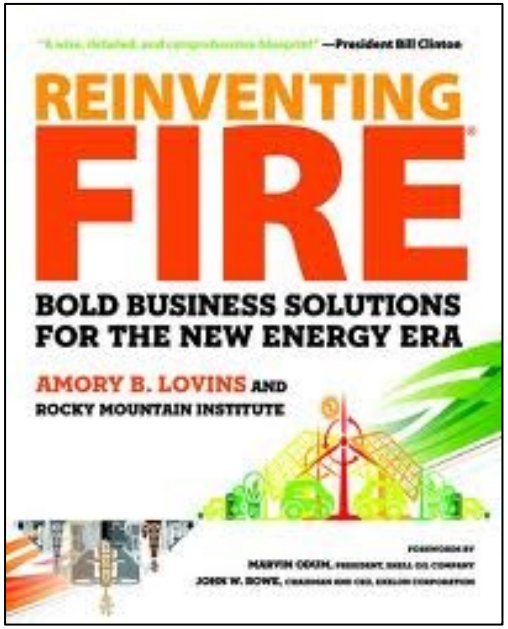
1000 Home Challenge: Pre & Post Annual Energy Use Compared with THC OPTION B



OPTION B 1000 Home Challenge Assumptions: 2,170 FFA; ZIP Code: 95014; 4 in household; all-electric home

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