Responding to Climate Change:
Worksheets

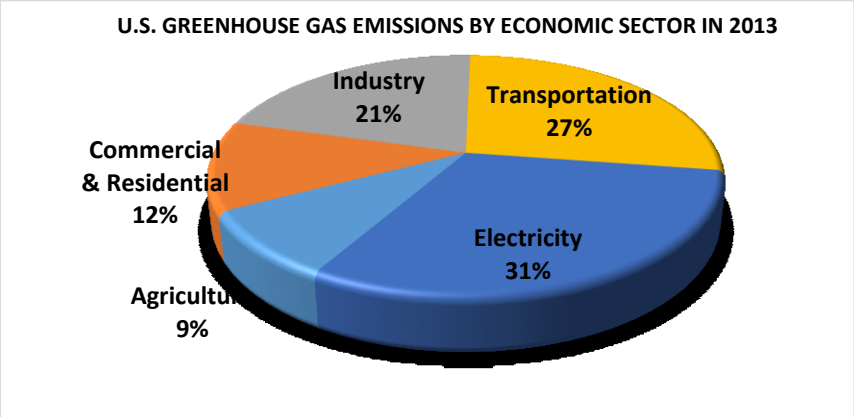
GREEN FIRST TASK FORCE

Preface:

Global Climate Change affects all Life and is a moral issue requiring an ethical response by all people.

Climate Change is real and humans are causing it by altering the amount of greenhouse gases in our common atmosphere. Human activities are responsible for almost all of the increase in greenhouse gases in the atmosphere over the last 150 years. [1] Total emissions by Americans in 2013 came to a total of 6,673 Million Metric Tons of CO_2 equivalent. [2,3] **U.S. emissions increased by 2.0 percent from 2012 to 2013.**

Greenhouse gases trap heat and make the planet warmer. The largest source of greenhouse gas emissions from human activities in the United States is linked to burning fossil fuels for electricity, heat, and transportation. There are viable alternatives to fossil fuels for our energy needs.



All emission estimates from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013*

http://www.epa.gov/climatechange/ghgemissions/sources.html

April 2015

[1] IPCC (2007). Summary for Policymakers. In: *Climate Change 2007: The Physical Science Basis*. *Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[2] U.S. Energy Information Administration (2014). *Electricity Explained – Basics*.

[3] *Kahn Ribeiro, S., S. Kobayashi, M. Beuthe, J. Gasca, D. Greene, D. S. Lee, Y. Muromachi, P. J. Newton, S. Plotkin, D. Sperling, R. Wit, P. J. Zhou (2007). Transport and its infrastructure. In Climate Change 2007: Mitigation*. *Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds.)], Cambridge University Press, Cambridge, United Kingdom.

Worksheets for Preparing a Comprehensive "Response to Climate Change" Plan

The best way to predict the future is to create it…..Abraham Lincoln

Our national energy policy must change from "All of the Above" to "Any of the Sustainable Options." And further burning of ancient hydrocarbons is not among those sustainable options. These worksheets are intended to help transition from fossil fuel to inexhaustible energy (renewable energy). The following worksheets are intended to help evaluate today's options and select those that are best for my personal circumstances.

There are as many reasons for envisioning and constructing a personal plan to "Respond to Climate Change" as there are people. These worksheets are for my unique plan – something I believe I can accomplish under my unique circumstances. Although my plan is unique, I draw strength from knowing it is fundamentally the same as all others who respect Life and are concerned about their children and their children and all future generations – human and non-human.

Motivation

Often the source of motivation to act can be traced back to one's spiritual core – an inner knowing.
Often the motivation to act can be traced to one's rational self – it makes sense logically.
Often the motivation to act can be traced to an observation of those around us – others have found a better way.
And when these fundamental sources of energy align, fasten your seat belt, because something new is about to emerge.

The opening and closing worksheets can help you focus on this motivation to plan and implement your plan.

Solar PV. If you are concerned about GHG emissions from electric generating plants that burn ancient hydrocarbons as a fuel, and you are concerned about your utility company's failure to consider the urgency of the issue. If you are considering generating your own electrical power sustainably by putting solar panels on your roof or in investing a community solar garden, you may find the Solar PV worksheet helpful.

Transportation. If you are concerned about risky offshore deep-ocean drilling particularly in the artic and would like to stop burning gasoline, check out the Transportation worksheet.

Heating & Cooling. If you are concerned about fracking, about ground water contamination, about methane leakage and carbon pollution from natural gas and you are interested in learning more about other sources of thermal energy for heating your home including exchanging free thermal energy with Earth for heating and cooling or If you want to stop buying natural gas to heat your home and hot water, you may find the Geothermal Heat Pump worksheet useful.

General Lifestyle.

If you are concerned about consumerism and waste and other unsustainable human behavior, there is general Lifestyle worksheet.

Food.

If you are concerned about the quality of food available today and the methods of producing processing and distributing this essential need for humans and all living beings in the interdependent web of Life, see the Food worksheet.

Investing & Saving.

If you are concerned about how your savings are being used, you may find the Divesting/Investing worksheet useful.

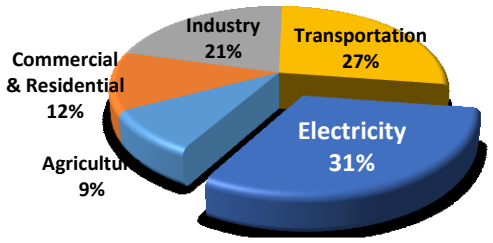
Responding to Climate Change:

Solar Photovoltaic (PV) System Worksheet

GREEN FIRST TASK FORCE

Current Electrical Power Usage

Let's assume that you want to consider producing your own electrical power with zero emissions without contributing further to climate change. What would a solar PV system look like? What would it cost?



The following worksheet can help you envision a solar PV system that provides the sustainable electrical power you currently buy from a utility company – a company that generates 80% of this energy unsustainably by burning ancient hydrocarbons (fossil fuel) thereby further contributing to climate change.

To get started, all you need is knowledge of your current annual electric bill (This does not include the cost of natural gas that is generally on the same monthly statement). You may already know how much electrical power you used over the course of a year. If you did not retain these monthly records, your utility company will send out the information upon request.

If you know your annual electric bill (i.e. the sum of the last 12 months electric usage), start on line (1). If you know your annual electrical usage in terms of kWh (kilowatt hours), you can start on line (3). The numbers in the far right column represent an "Example" case where the annual electric bill is $1000.

		MY INFO	EXAMPLE
(1)	**What is your annual (sum of last 12 months) electric bill?**	$_____	**$1000**
(2)	**What is the unit cost ($/kWh) of your electrical power?** [If unknown, use 11 cents per kilowatt hour or $0.11 per KWh]	$ ____ / kWh	**$0.11 /kWh**
(3)	**How much power did you use last year?** [If unknown, divide line (1) by Line (2)]	_____ kWh	**9090 kWh**
(4)	**How much will you be spending on electricity over the next 20 years?** [The average increase in cost of electricity historically has averaged between 4% and 5% per year. Let's assume 4.5% per year.] The "compounding factor" (CF) for 20 years is then 1.57. The 20 year cost estimate is then: 20 Year Cost = 20 x Annual Cost (line 1) x 1.57 (A 20 year time frame is used because generally the solar system performance is warranted for that long or longer.)	$ _____	**$31,371**

Example: The annual cost of electricity in this case is $1000. To determine how much power you consumed expressed in kWh, divide line (1) by Line (2): or 1000/0.11 = 9090 kWh of electrical energy used last year. Write 9090 into line (3). The cost over 20 years is simply 20 times your annual cost multiplied by a factor to account for rising energy costs in the future.

Estimate the Size of the Solar PV System Needed

Next you can estimate how large your solar PV system must be to harvest enough sunlight to generate that amount of electrical power you need to meet your energy needs.

Using information from the National Renewable Energy Laboratory (NREL) in Golden, CO (actually a computer model available to the public called PVWATTS. Go to http://pvwatts.nrel.gov/pvwatts.php), you learn that a 1 kW rated system mounted on your south-facing roof in Denver, CO (at a 20 degree tilt) is expected to generate 1510 kWh of power annually. (For this computer model, south-facing is 180 degrees azimuth, East facing is 90 degrees azimuth). Let's now determine approximately how large a south- facing solar PV system must be to produce all of your own electrical power.

Use the number in line (3) and divide by 1510.

(5)	Approximate Size of Solar System You Need [Divide line (3) by 1510 kWh/kW (rated DC power)]	(3) / 1510 = _____ kW	9090/1510 = **6.0 kW**

But what if: you don't have any south facing roof? The PVWATT computer indicates if the orientation is changed to East-facing (Azimuth = 90 degrees), then a 1 KW solar PV is expected to generate about 1314 kWh annually (a 13% reduction in performance). So use 1314 instead of 1510.

In this example, we would need a 6.0 KW solar PV system that faces south. In English, we'd say, a six kilowatt south-facing system can harvest the energy you need for your life style. Please note that according to the current law in Colorado, the utility company (i.e. Xcel) limits you to a maximum of 10 kW system to qualify for a "small system." The current regulations also limit your PV system production to no more than 120% of your last 12 months usage – even if you "plan" to use more in the future (e.g. even if you plan to buy an electric car next month).

Estimate the Number of Solar PV Modules (Panels) Needed

Today, typical solar PV modules (often called panels) can produce 250 W (0.25 kW) to 300 W (0.3 kW) of electrical power per module. And the efficiency continues to improve slowly over time. Let's use 250 W modules; they require more available surface area than the 300 W modules.

(6)	Approximate Number of Solar Modules/Panels Needed [Divide line (5) by 0.25 kW / module]	(5) / 0.25 = _____ modules	6.0/0.25 = **24 modules**

Estimate How much Surface Area is Required to Install Your Solar PV System.

Each panel is about 18 ft^2 in area. (about 3' x 6').

(7)	Approximate Surface Area Needed for Your Solar System [Multiply line (6) by 18.	(6) x 18.0 = _____ft^2	24 x 18 = **432 ft^2**

Example: In this example case, we would need around 24 panels that will take up 432 ft^2 of the roof, in your back yard or in a local solar garden.

The amount of sun accessible area is a critical issue for some folks. Generally speaking, in the past and even today homes are not being designed or oriented to maximize the ability to harvest inexhaustible (free) energy. Or you may live in a condo or apartment and do not have any roof space you personally can use. Or there may be mature trees that shade your roof – not necessarily a bad thing from a systems perspective, but not so good for you. In these cases, you will want to investigate investing in solar panels located in a community solar garden.

Estimate Approximate Cost of Your Solar PV System.

How much can this solar system be expected to cost? You should be able to get a deal where the installation cost is less than $4/W ($4000/kW) before any rebates or tax credits are applied. (In Germany, a country that has made a national commitment to transition to renewable energy, the cost is now around $2/W.)

The cost of the solar modules/panels has dropped dramatically over the past decade. The hardware cost of a PV panel now appears to be leveling off a bit. China is the number one manufacturer today with plans to transition 30% of their population to renewable energy in the next 15 years – that's equivalent to having the entire United State transition to renewable energy by 2030. Europe is probably the next biggest producer of solar PV modules.

Between now and December 31, 2016, installing a solar PV system qualifies you for a 30% federal tax credit. You can then compare your net cost in line(10) with the cost of buying climate changing coal-generated electrical power from your local utility company.

(8)	Approximate Cost of Your Solar System before Rebates/Tax Credits [Multiply line (5) by 4000.]	(5) x $4,000 = _____$ft^2$	6 x $4,000 = $24,000
(9)	Estimate the Federal Tax Credit (30% of the installed cost) [multiply line(8) by 0.3	$ _____	$24,000 x 0.3= **$7,200**
(10)	Net Cost of Your Solar PV System (Estimated) [subtract line(9) from line (8)]	$ _____	**$16,800**
(11)	Recall the accumulated cost of buying coal-generated electric power for the next 20 years in line (4) to line (10). Which is bigger? ☺	$ _____	**$31,371**
(12)	And the cost difference (savings) by harvesting sunlight instead of burning coal/natural gas is? If a penny saved is a penny earned, then you can see how many pennies you	$ _____	**$14,571**

	earned. [Subtract line (11) from line (10).		
(13)	Some would consider this difference as "earnings" or a return on your investment (ROI), If you do, let's divide it by the original amount you invested in solar and call it a ROI. [divide line (12) by line(10)]	_____ %	$14,571/$16,800= 0.87= **87% "ROI"**
(14)	Average this "ROI" over a 20 year time frame. [divide line (13) by 20]	_____%	87% / 20 = **4.3% Annual "ROI"**
(15)	But line (10) seems like a lot of money to invest. Let's compare it to the market value of your home. [Insert an estimate of the market value of your home]	$ _____	**$250,000**
(16)	So what's the relative cost of this solar PV upgrade to the value of the property? [divide line (10) by line (15) and express as a percentage]	_____ %	16800/250000 = 0.067 = **6.7%**

Your investment risk is related to the probability that the Sun won't shine for 20 more years.

"But I don't know how long I'm going to live in this place that I'm investing in. It probably will be at lot less than 20 years." This is where each of us has to review our investing values and purposes as discussed in the "Divesting/Investing" section. Because rooftop solar is a relatively new item, the Real Estate community is still responding to how solar affects the market value of a home. According to the National Appraisal Institute, property value will increase $20,000 for every $1000 you reduce your electric bill per year. Ironically, that's the "example" case we are examining. A home that comes with prepaid electric for the next 20 years is a powerful selling point. Truth be told, every new home should be constructed with (or at least to accommodate) rooftop solar. When incorporated into the original build, the additional cost for a sustainable house would be less than 5% of the total cost.

There are several other resources to review that confirm that "Adding Solar PV to your home is a good investment."

1) "Going Solar in America" http://nccleantech.ncsu.edu/wp-content/uploads/Going-Solar-in-America-Ranking-Solars-Value-to-Customers_FINAL.pdf
   "Most Americans are unaware of the true financial value of solar today. Seen by many as a technological luxury, solar energy is not seriously considered as an option by most homeowners in the U.S. However, our analysis shows that, in 46 of America's 50 largest cities, a fully-financed, typically-sized solar PV system is a better investment than the stock market, and in 42 of these cities, the same system already costs less than energy from a residential customer's local utility."
   --- NC Clean Energy Technology Center (Formerly the NC Solar Center) NC State University

2) "U.S. Residential Solar Financing 2015-2020"
   http://www.greentechmedia.com/research/report/us-residential-solar-financing-2015-2020

   2014 was the third consecutive year that the U.S. residential solar market experienced more than 50% growth and the first year it exceeded installations in the non-residential market. This rapid growth can largely be attributed to the widespread availability and increasing diversity of financing solutions. The first wave of

growth in the residential market, from about 2010 to 2014, can be attributed to third-party financing for leases and PPAs that made solar affordable to the masses. More recently, the market has seen a resurgence of direct ownership, with a number of new players introducing a wide range of loan products.

Companies covered in the report include:

Admirals Bank | Amergy Solar | Astrum Solar | Brite Energy | Clean Power Finance | Credit Suisse | Dividend Solar | Enerbank | Google | GreenSky Credit | HERO | Kilowatt Financial | Kina'ole Capital | LightStream | Main Street Power | Mosaic | NRG Home Solar | OneRoof Energy | Patagonia | Renewable Funding | REPOWER by Solar Universe | RGS Energy | SolarCity | SunEdison | Sungage Financial | Sungevity | Sunlight Financial | Sunnova | SunPower | Sunrun | Verengo Solar | Vivint Solar

Conclusion: First order estimates indicate that investing solar PV has the potential to be a good investment for the owner of the system AND for the owners children and their children and future generations of all Life.

An expert financial consultant will probably recommend that you finance your solar system assuming you can enter into a loan at 5% you will actually be better off financially than if you buy the outright without financing – it has to do with NPV.

They are several scenarios that make the investment even better financially.

1) As EPA places more regulations on coal-fired plants the retail cost of electricity will go up faster than it has traditionally. This will increase the ROI for solar PV.
2) There is a growing movement to impose a "price on carbon pollution." If there a carbon burning fee becomes a reality, those who have invested in solar PV will benefit financially.
3) If Xcel takes less than 20 years to transition to 100% inexhaustible / renewable energy, those who invested early in solar PV will still have helped slow the rate of climate change.

BUT THERE IS MORE!

Estimate the amount of CO_2 pollution you can avoid by investing in Solar PV

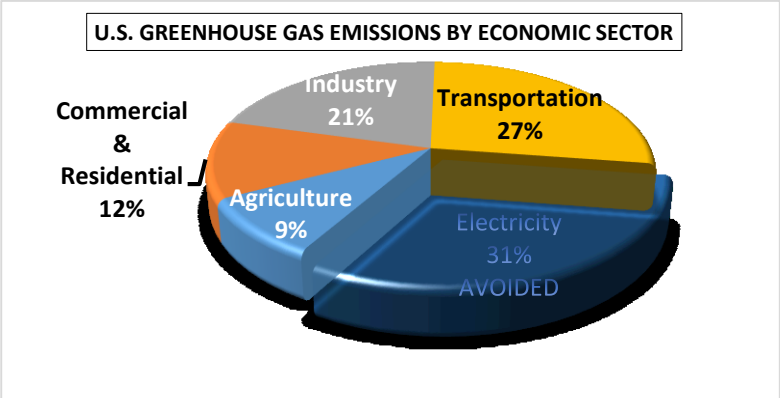
Fuel	Pounds of CO_2 per kWh
Coal	
Bituminous	2.07
Sub-bituminous	2.15
Lignite	2.17
Natural gas	1.21
Distillate oil (No. 2)	1.67
Last updated: March 30, 2015 Ref: http://www.eia.gov/tools/faqs/faq.cfm?id=74&t=11	

According to the EPA, approximately 2 lbs of CO_2 are created for each kWh of power generated by a coal-fired plant. As the table indicates, a natural gas-fired electrical generating plant will only produce 1.2 lbs of CO_2 for each kWh produced; however, this table does not address the contribution of methane leakage associated with natural gas. Natural gas (primarily methane, CH_4) is a much "worse" GHG. According to the IPCC, methane has a Climate Change Potential that is 86 times higher than CO_2 when averaged over 20 years. The lifetime of methane

molecule is between 10 & 20 years when released into the atmosphere and the carbon eventually ends up as CO_2 after about a century.

We can also estimate the amount fresh water that your solar PV system conserved also using NREL information: [http://www.nrel.gov/docs/fy04osti/33905.pdf] that indicates 2 gallons of water are needed by a typical power plant to produce 1 kWh of power. For Colorado and other Western states water consumption is significant consideration.

(17)	Estimate the amount of CO2 your solar PV system will avoid by generating your energy from sunlight. [multiple line (3) by 2 lbs/kWh	(3) x 2 = _____lbs / year	9090 x 2 x = **18,180 lbs of CO_2 avoided annually**
(18)	Over its 20 year life, your Solar PV system will also lower GHG emission [multiple line(17) by 20.0	_____ lbs	18180 x 20 /2200 = **165 metric tons of CO_2 avoided.**
(19)	AND your solar PV system will conserve 2 gallons of water for each kWh generated. [multiply line (3) by 2]	_____ gallons	9090 x 2= **18,180 gallons of water conserved annually**
(20)	Over the 20 year life of the system the amount of water conserved is also significant.	_____ gallons	18180 x 20= **363,600 gallons**



Over the 20 year warranted life of the solar system, our "example" solar PV system 163,620 kWh of power @ .11 / kWh = $18,000 of emission free energy – and you didn't burn any coal, require any fracking for a gas-fired generating plant and you didn't consume 2 gallons / kWh or 363,600 gallons of water. That's 18,180 gallons / year (If you normally use 60,000 -70,000 gallons / year, that's 25-30% of your annual usage that should be credited to your water bill.)

Your solar PV also avoided dumping more mercury and other heavy metals as well as NOx and fly ash into the atmosphere – as you know, these by-products of burning fossil fuel find their way into human and non-human beings through the food chain.

But What about Energy Storage?

Because of the nature of solar PV, the amount of energy available varies over the course of a day and over the course of a year. There are 2 million documented species alive today that have evolved to accommodate these seemingly "inconvenient" ground rules of life. Humans still have a lot to learn from their distant cousins (the non-human living systems) that co-habit our planet. Our autotroph cousins that look directly to Sun for the energy they need to live (e.g. a tree) harvest sunlight during the day, store

some energy for growth during the night and in the winter when there is less sunlight available. The Tesla Corporation (and SolarCity a close associate) announced earlier in the year that they planned to provide a new product for homeowners – an affordable electrical energy storage system that fits in a garage. This battery pack basically uses the lithium battery technology developed for electric cars and repackages the cells to fit along the wall of a typical garage. A 7kWh battery was priced at $3000 and a 10 kWh battery at $3500.

Energy storage for power generated from wind and solar is a challenging but not insurmountable problem. There are several dozen "Storage Solutions" currently being evaluated. The U.S. Department is conducting research on a half dozen promising solutions. Wikipedia lists a broader range of Energy Storage possibilities. NREL and Germany have developed and are testing prototype hydrogen fuel-cell powered electric cars. Pumping water uphill to storage reservoirs, compressing gas and using excess electricity to electrolyze water and generate hydrogen for long term storage are just a few of the current Energy Storage options being evaluated seriously. Australia has started marketing a "flow battery" alternative to Lithium Ion batteries. So it is an exciting future for folks who like to solve solvable problem. Learning to live sustainable is one of those solvable problem.

So Do You Buy or lease?

Everyone's financial situation is different. Only you can decide. As shown in the graph below, the trend is away from leasing and toward ownership. A 50-50 split is expected in 5 years.

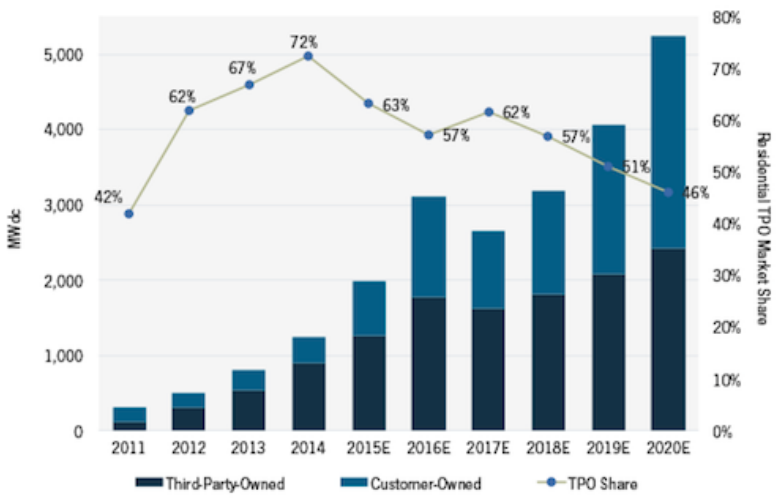


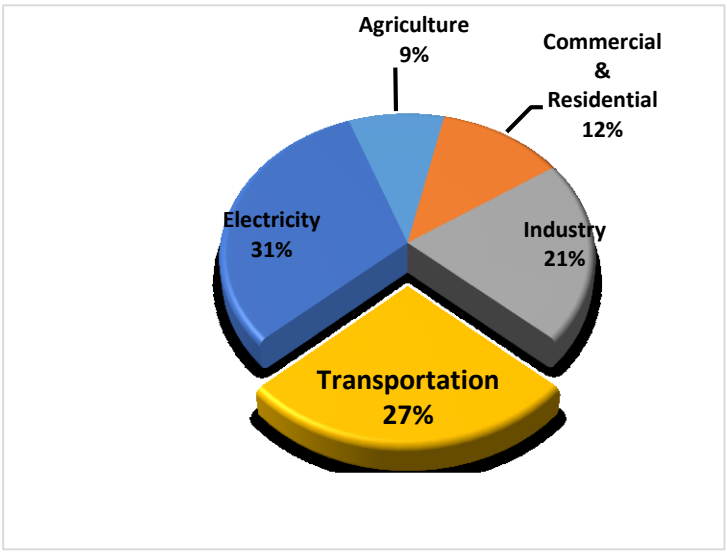
FIGURE: Residential Third-Party Ownership Penetration and Installations by Ownership Type

Ref: U.S. Residential Solar Financing 2015-2020
http://www.greentechmedia.com/research/report/us-residential-solar-financing-2015-2020

The North Carolina Solar Center cited above seems to suggest that financing your solar system (i.e. owning it) is a better investment than Wall Street investments.

Transportation

Electric vehicles provide a pathway to sustainable transportation—particularly when the electrical power used to operate the vehicle is derived from an inexhaustible/renewable source such as the rooftop solar or wind.

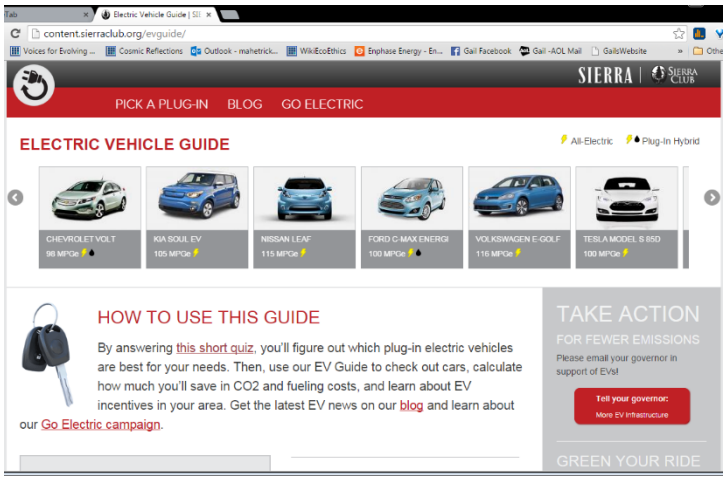


According to the EPA, total Greenhouse Gas (GHG) emissions in 2013 were 6.7 Billion Metric Tons of CO_2 equivalent. As shown in the pie chart, nearly 30% of these emissions were in the transportation sector.

Path to Zero Emissions

Electric vehicles produce zero tailpipe emissions. Plug-in hybrid vehicles use no fossil fuel and have zero tailpipe emissions while driving within their all-electric range. If the batteries of these vehicles are charged directly from renewable sources (e.g. rooftop solar PV), then the greenhouse gas emissions are essentially zero. Traditional hybrid vehicles and other high MPG cars that still burn gasoline do have lower emissions than most older cars – but not zero emissions as do electric vehicles.

The good news is that in 2012 there were only two all-electric vehicles available (Tesla, Nissan Leaf) and one plug-in hybrid (Chevrolet Volt), but in 2015 there are at least 13 all-electric and 10 plug-in hybrids on the market for you to choose from. If fact the problem becomes, which of the 23 options are best for your unique transportation needs.



The Sierra Club, wanting to promote zero emission vehicles, has come to the rescue with an Electric Vehicle Guide website. http://content.sierraclub.org/evguide/pick-a-plugin

Let's see how this "Guide" works. By clicking on "How to use this Guide" and new window appears with several questions to answer as shown.

When you have answered these questions, you "Submit" your response and a new windows appears displaying options (in this case 6 possibilities) that meet your driving needs **AND** when combined with your rooftop solar PV eliminates your emissions for personal transportation.

PICK A PLUG-IN

There are so many terrific plug-in cars on the market. By answering this short quiz, you'll figure out which plug-in electric vehicles (EVs), if any, are best for your lifestyle. There is no overall best EV. It all depends on how many miles a day you drive, whether you take frequent long trips, whether you have a place to plug in the car, how much money you're prepared to spend, etc. Answer the questions below, and get started on your journey to pick a plug-in car.

How many miles total do you drive in a typical day?

0-50 -- I mostly keep it local. ▾

For long trips, would you consider using another car in household, renting, car-sharing, carpooling, or taking bus/train/plane?

No -- I want to buy a road trip car. ▾

Do you have access to an electrical outlet in a garage or driveway at home or at work?

Yes -- I'm good to go! ▾

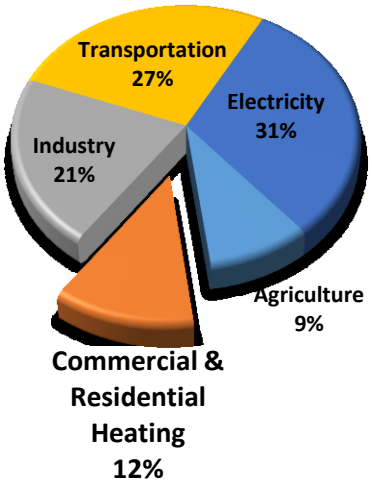
Minimum number of seats needed?

4 -- I want room for family and friends. ▾

 CHEVROLET VOLT	38 mi	4	Nationwide	$27,510 (after $7,500 federal tax credit). Price includes MSRP plus destination charge.	Plug-In Hybrid
 FORD C-MAX ENERGI	21 mi	5	Nationwide	$28,463 (after $4,007 federal tax credit). Price includes MSRP plus destination charge.	Plug-In Hybrid
 FORD FUSION ENERGI	21 mi	5	Nationwide	$30,835 (after $4,007 federal tax credit). Price includes MSRP plus destination charge.	Plug-In Hybrid
 HONDA ACCORD PLUG-IN	13 mi	5	CA, NY	$36,944 (after $3,626 federal tax credit). Price includes MSRP plus destination charge.	Plug-In Hybrid
 TOYOTA PRIUS PLUG-IN	11 mi	5	Nationwide	$28,358 (after $2,500 federal tax credit). Price includes MSRP plus destination charge.	Plug-In Hybrid
 BMW i3 WITH RANGE EXTENDER	72 mi	4	Nationwide	$39,700 (after $7,500 federal tax credit). Price includes MSRP plus destination charge.	Plug-In Hybrid

Heating & Cooling without Burning – Geothermal / GeoExchange Heat Pumps

Geothermal heat pumps are among the most efficient and comfortable heating and cooling technologies available because they use the earth's natural heat to provide heating, cooling, and hot water—**no fossil fuel is required.**



About Geothermal Heat Pumps

While many parts of the country experience seasonal temperature extremes – from scorching heat in the summer to sub-zero cold in the winter – a few feet below the earth's surface the ground remains a relatively constant temperature. The natural ground temperature is cooler than the natural air temperature in summer, and warmer than the natural air temperature in winter. While the margin of variation is small, seasonal changes in ground temperature give geothermal heat pumps a dependable and permanent wintertime heat source and summertime heat sink.

Geothermal heat pumps, also known as 'ground source', GeoExchange, earth-coupled, and earth energy heat pumps, take advantage of this resource and represent one of the most efficient and durable options on the market to heat and cool your home.

How Geothermal Heat Pumps Work

Using a heat exchanger, a geothermal heat pump can move heat from one space to another. In summer, the geothermal heat pump extracts heat from a building and transfers it to the ground for cooling. In winter, the geothermal heat pump takes natural heat from the ground and transfers it to the home or building for heating. Although the heat pump vary somewhat, typically one unit of energy (electrical) can exchange 4-5 units of thermal energy between the Earth and a home. Although the homeowner buys or provides the 1 unit of power from rooftop solar, the owner is not charged for the 4-5 units of thermal energy transferred from the house in the summer to cool it or the 4-5 units of ground heat into the house to warm it. Although the technology is as old refrigerators, ground source heat pumps has not thrived, because our current broken economic system riddled with externalities indicates sustainable geothermal heat pumps are more expensive than unsustainable fossil fuel burning furnaces.

Installing a geothermal heat pump system can be the most cost-effective and energy efficient home heating and cooling option. Geothermal heat pumps are a particularly good option if you are building a new home or planning a major renovation to an existing home by re-placing, for example, an HVAC system. For more information please see the following resources:

DOE Energy Savers: Geothermal Heat Pumps, www.energysavers.gov/ geothermal_heat_pumps
Energy 101: Geothermal Heat Pumps, www.eere.energy.gov/multimedia/ vid-eo_geothermal_heat_pumps.html

Estimating the size of Geothermal/Geoexchange Heat Pump

Actual sizing should be done by a professional installer because there are so many factors to consider. However for the sake of illustration we will provide one real example. If your circumstances are somewhat similar, the example will serve to illustrate what a geothermal looks like.

If you know your annual natural gas bill (i.e. the sum of the last 12 months natural gas usage), start on line (1). If you know your annual electrical usage in terms of "therms" (1 therm = 100,000 BTU), you can start on line (3). The numbers in the far right column represent an "Example" case where the annual gas bill is about $800.

		MY INFO	EXAMPLE
(1)	**What is your annual (sum of last 12 months) gas bill?**	$_____	**$800**
(2)	**What is the unit cost ($/therm) of your natural gas?** [If unknown, use 80 cents per therm or $0.80 per therm]	$ ____ / therm	**$0.80 / therm**
(3)	**How much natural gas did you use last year?** [If unknown, divide line (1) by Line (2)]	_____ therm	**1000 therms**
(4)	**How much will you be spending on natural gas (heating) over the next 20 years?** [The average historical increase in the cost of utilities has averaged between 4% and 5% per year. Let's assume 4.5% per year.] The "compounding factor" (CF) for 20 years is then 1.57. The 20 year cost estimate is then: 20 Year Cost = 20 x Annual Cost (line 1) x 1.57 (A 20 year time frame is used because generally the geothermal heat pump system performance is often warranted for that long or longer.)	$ _____	20 x 800 x 1.57= **$25,120**

Example: The annual cost of natural gas in this case is $800. To determine how much thermal energy you consumed expressed in therms, divide line (1) by Line (2): or 800/0.8 = 1000 therm of natural gas used last year. Write 1000 into line (3). The cost over 20 years is simply 20 times your annual cost multiplied by a compounding factor to account for rising energy costs in the future.

Estimate the Size of the Geothermal System Needed

Sizing a heating and cooling system is complex and best performed by a professional HVAC installer. However for this example, we will assume we are retrofitting an existing home that already has a history of natural gas usage using a forced-air gas furnace. In this case it is relatively simple to transition from fossil fuel to inexhaustible energy (geothermal/ground source thermal energy) – you simply pull out the gas furnace and slide in a geothermal heat pump furnace. The air ducting remains the same. In this case the 2000 ft^2 home is relatively old (built in 1074 with meager insulation in the walls and attic and has leaky windows). Generally for a newly constructed home of this size, a 3 Ton rated unit might be adequate; however in this case, being an older home with less insulation, a 4 T rated unit will be used as the example.

(5)	Approximate Size of System You Need [For retrofitting use the rating of the existing natural gas furnace or if you have made significant energy saving upgrades to the home, have a HVAC contractor re-size your heating and cooling requirements]	_____ Ton Rating	**4.0 Ton Rating**

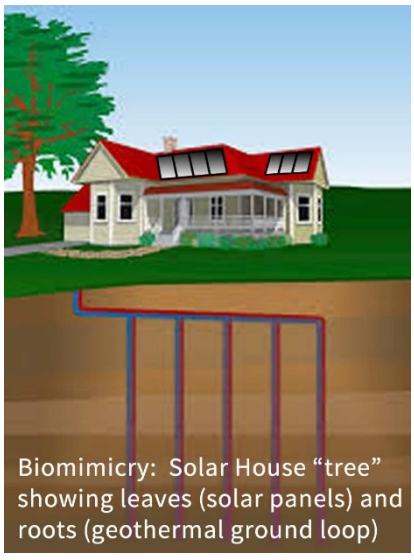
Next let's estimate the size of the "ground loop" required for this size heat pump. If this is a new home without landscaping, a horizontal ground loop would be a consideration. For most people who are changing out their natural gas furnace with a geoexchange heat pump, using a vertical ground loop is the only practical option. A rough rule is that you need about 150 – 200 feet of "bore" per ton, so a 4 Ton unit needs at least 600 of "bore." Generally two boreholes 300 feet deep will be drilled instead of one 600 feet deep. The borehole used is typically about 4-5 inches in diameter. The drilling and installation of the black plastic pipe into the borehole for closed loop water circulation costs about $15 / foot of bore.

(6)	Approximate Size of the Ground Loop [150 – 200 ft of per ton] [multiple line(5) 150]	(5) x 150 = _____ feet or bore	4 x 150 = **600 feet**
(7)	Approximate Cost of the Ground Loop [$15 / foot of bore] [multiple line(6) by 15	(6)x 15 $_____	600 x 15 = **$9000**

The cost of the geothermal heat pump furnace is more expensive than a natural gas furnace but the air conditioning function is included in the single system. For rough estimating purposes, you might use $2500 / ton. Until December 31, 2016, this system qualifies for a 30% federal tax credit.

(8)	Approximate cost of the heat pump furnace [rough estimate is $2500 / ton]	(5) x 2500 = $_____	4x2500= **$10,000**
(9)	Total cost estimate	(7) + (8) = $_____	9000+ 10000= **$19000**
(10)	Figure the Federal Tax Credit on the total installed cost [multiple line (9) by 0.3	(9) x 0.3= $_____	19000 x 0.3= **$5700**
(11)	Net Cost of Zero Emission heating and cooling (assumes the electric power to operate the heat pump is generated by the solar PV system you installed earlier)		**$13300**
(12)	Compare the net cost to the expected cost using natural gas [Subtract line (11) from Line(4)]	(4)-(11)= $_____	25120-13300= **$11820**

The net **gain** is $11820. Considering this example is using an "oversized" system, it still appears that between 10 & 15 years the system pays for itself and starts making money for the owner. And perhaps MORE importantly, during its 20 plus years of warranted operation, the owner is not contributing to further climate change – while living quite comfortably.



Biomimicry: Solar House "tree" showing leaves (solar panels) and roots (geothermal ground loop)