40,000 Pound Carbon Diet

How a middle class American family reduced their carbon footprint by 75% (and made money doing it)

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Introduction

This is a story of one family's effort to reduce its carbon footprint. It starts with Solar Domestic Hot Water (DHW) in the early 1980s. This was followed by alternative communing, pool heat and more serious investments in generating electricity with the sun and the use of electric vehicles (boats and cars). The outcomes of our experiment: significant reductions in our carbon footprint and economic/financial benefits.

The purpose of this article is to share our experiences, motivations and the insights we gained.

Alternative to Auto Commuting

Transportation looms large in global warning/climate change. Old fashioned economics tells us to attack a problem where the marginal benefits will be greatest. That is why we started with replacing the use of a commuter car with a bike and public transportation.

If one wants to make an impact on carbon emissions, transportation is a good place to start. By some accounts transportation is responsible for 30% of greenhouse gas emissions.[1] In 2005, I invested about $500 in a folding bike (Figure 1), and began commuting to my teaching job. Before I bought the bike I borrowed a friend's fold up and experimented. Knowing this crazy idea (my wife's perspective) was feasible, I made the investment and sold our second car. I did not peddle the whole 30 miles to work. Instead, I biked a mile to the Long Island Rail Road (LIRR), folded her up, carried her onboard (not a tough task since the bike weighs only 27 lbs.), took the train to the station nearest to the campus, unfolded her, and then peddled to campus (another mile and a half).

My motivation for this initiative was purely ecological, but it made good sense economically too. My wife gave up her notion of having a wacko husband and actually liked not having the cost and parking issues with a second car. At today's prices, I would be saving almost $2,000 annually with this alternative commuting scheme. [2] Ecologically, this experiment was a great success. We were able to avoid the emission of about 6,000 lbs of CO^2 annually from my car. [3]

I enjoyed other benefits. I gained about 2 hours of productive time each day by working on the train. This translated to 2 hours a day to spend on important things (being with the family, playing with a boat, etc). Also I did not have to endure traffic jams or threats from road-raged motorists.

Figure 1 - Dahon Folding Bike

Many objections to ecological initiatives are based on perceptions of inconvenience. So I should disclose the downside of bike/train commuting. There are tradeoffs in terms of convenience. In foul weather, my bike ride could be challenging (snow suit, rain gear) or cause for calling a cab (I did this once in three years). Flat tires or other mechanical malfunctions are negligible risks, but no more than the risk of an auto breakdown. (I never had either in more than 20 years of teaching.)

From my perspective the benefits far exceeded the costs. By not emitting those $6,000 pounds of CO2, we were reducing our family's carbon footprint (which was about 60,000 pounds annually back then[4]) by about 10%, a small step for mankind. Meanwhile we were saving money, gaining productive work time, avoiding the aggravation of auto commuting, and I was getting fresh air and exercise.

Table 1 –Ecological, Financial and other Benefits of Alternative Commuting

Ecological Benefit: • 6,113 pound of carbon NOT emitted annually Financial Benefit: • Annual savings of $1,949 Other: • Productive commuting (2 hours/day) • No traffic jams/road rage exposure • Fresh air, exercise

Last Word on alternative commuting: The impact of altering one's behavior is very evident in this initiative. There is no new technology playing here. This is pure behavior modification: Get on a bike, and take a train instead of the old jump in the car routine. The environmental and financial benefits are enormous, with savings of over 6,000 pounds of carbon emissions and almost $2,000 in dollar costs avoided.

Solar Domestic Hot Water

Let's flash back to 1981, when energy prices were soaring. The family found our dream home in Rhode Island. We could afford the down payment, taxes and the mortgage, but not the oil bills –not without a plan to reduce heating oil consumption by two thirds. Enter solar domestic hot water (DHW).

The energy used for heating water for showers, laundry, cooking, dishwashing, etc. is a major part of a household electric, gas or oil bill. In fact the Department of Energy estimates the average American Family's hot water usage accounts for 25% of its energy bill. And solar DHW worked well for us. Even in the cold New England winter, two days of sun would make us enough hot water for our family of 5 to have free hot water for three days. Indeed, the drain-back[5] system we installed in 1981, together with significant conservations measures (insulation, storm windows, heat set-backs, etc), enabled us to reduce our oil usage from 1,800 to 600 gallons a year (which we could afford).

We learned several important lessons during this early venture into the use of renewable energy

- ***Behavioral changes must accompany investments in systems.*** If our family of 5 did not throttle back on our showers, our hot water usage would have overcome the solar DHW system's capacity to provide for us.
- To make sure one's investment is paying you back; one should ***monitor the system daily***. In the case of our solar DHW system this meant paying attention to the thermometers to assure the water coming back to the storage tank was hotter than what was sent to the roof. It is much better to read the gauges to discover a malfunction (and then troubleshoot to fix the problem) than to get a huge electric bill at the end of the month because your back up heating elements have kicked in while your investment sat idle.
- Making decision to invest in ***solar DHW is a no brainer***! The few thousand dollars it costs to install a solar DHW system are paid back very quickly.

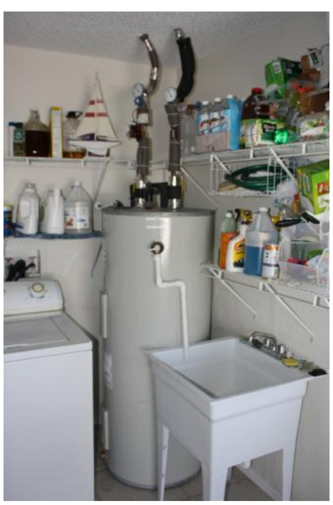
We installed a Solar DHW system in our Florida home as soon as it became our permanent residence in 2007. The single collector was elevated for maximum solar energy absorption. Figure 2 shows the DHW collector in the foreground. The horizontal modules in the background are part of our electrical generating system. The small Photovoltaic (PV) module on top of the DHW module provides the energy needed to power the only moving part in the system (a small pump). We renewed the roof before installing the solar system, and expect to get 25 years or more out of each of them.

Hot water is stored in an 80 gallon tank (Figure 3). Notice the system thermometers to help us assure the system is working property. You can also see the small motor on the left that pumps cold water from the bottom of the tank up to the collector, and returns hot water.

Figure 2- DHW Collector with PV module to run pump

The solar DHW system cost us about $2,300 ($4,000 to the contractor for installation, less $1,200 federal income tax rebate and $500 state rebate). We recovered that investment in 4 years and see a return on investment of at least 24%. [6] If we assume a 5% increase in energy prices, we will enjoy a 29% return on investment. No matter the exact financial details, we have been enjoying free hot water for several years, and will continue to have free hot water for decades to come.

Figure 3 - Solar DHW storage tank, pump, control valves, thermometers



Saving money is pleasing, but what really makes us happy is helping the planet while we make money. By allowing the sun to heat our DHW, we are avoiding the emission of almost 7,000 pounds of CO^2 annually. [7] This was more than 10% of our annual family carbon footprint.

Last Word on Solar DHW: Our experience, over 4 decades with solar DHW, is that human behavior is as important as the technology when it comes to making your solar DHW system work efficiently. If you take 20 minute showers and use excessive amounts of hot water in other ways, the system will not be able to keep your electric or gas bill way down, nor will it save much on carbon emissions. In addition to conserving hot water, it is wise to check your system often to monitor its performance. All your need to do is walk by the system every few days and glance at the thermometers to assure the water coming from the roof is hotter than the water on its way up to the collector. But altering your behavior this way, together with an investment in solar hot water can pay great environmental and dollar benefits – in our case we are avoiding almost 7,000 pounds of carbon emissions annually and enjoying a 20+ percent return on our investment. As I said earlier, the decision for Solar DHW is not a difficult one.

Table 2- Financial and Ecological Analysis Solar DHW

Ecological Benefit:

- 6,720 pounds of carbon NOT emitted annually

Financial Benefits:

- Return on investment of at least 24% (more if energy prices increase)
- Free hot water after 4 years (the payback period for the investment), for the rest of the system's 15 year life*

Other:

- Can produce hot water even if there is no power on the grid

* I expect mine will last longer than 15 years, as the Solar DHW system on my RI home has been in operation since 1981.

Solar Pool Heat

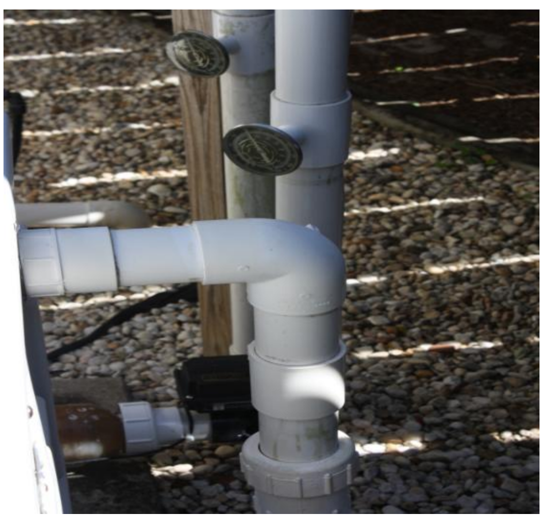
In the winter of 2007-2008, our attention turned to keeping our swimming pool warm in the winter. Our home came with a heat pump built into the pool filtering/circulating system. The heat pump did a good job of heating the pool, but at significant cost. Using the heat pump could add hundreds of dollars to our monthly electric bill, plus thousands of pounds of carbon emissions to the atmosphere.

The remedy was a simple solar heating system, one tied into the existing pool filtration system. We learned that a solar collector array equal in area to the pool's surface could maintain about 80 degrees in the pool. If you have a big pool (ours is about 18' x 40') that's a lot of space needed for your collectors. Since we were saving our roof space for a solar electric system, we mounted our pool solar array on a ground level rack (Figure 4).

Figure 4- Solar Array Pool Heat

Our pools solar heat works automatically, controlled by a simple device shown in Figure 5. When the temperature at the solar collectors is greater than the water coming from the pool, the controller sends the circulating filtration water to the collectors to gain solar heat before returning to the pool. The solar system will continue to heat the pool water until the maximum (selectable) temperature is reached, the circulating pump times off, or the water in the pool reaches the temperature at the collectors.

Figure 5 - Solar Pool Heat Controls



During the summer, this system can be run in reverse to cool the pool water. Instead of circulating pool water during the day to heat it, it is run at night. Then the (hot) pool water is sent to the collectors to lose heat to the evening air.

We have found that this system works nicely, maintaining our pool close to 80 degrees throughout the winter months. The system paid for itself in 5 years[8] freeing us from sending extra money to Florida Power and Light (FPL) in our electric bill. We are now getting free pool heat from the sun for the rest of the life of the system (15 years). And we enjoy a great return on investment (about 18%, or more if the price of electricity escalates). [9]

If we were building a new home, or installing a pool, we could have avoided the cost of the heat pump (almost $4,000), which would have more than paid for the Solar pool heating system (whose net cost was about $3,300).[10] Not using electricity to heat our pool translated into an avoidance of about 7,600 pounds of carbon emissions annually,[11] a significant benefit for the environment. The financial and ecological benefits of our pool heat are summarized in Table 3.

Table 3 - Financial and Ecological Analysis Solar Pool Heat

Ecological Benefit: • 7,637 pounds of carbon NOT emitted annually Financial Benefits: • Return on investment of at least 16% (more if energy prices increase) • Free pool heat after 5 ½ years (the payback period on the investment), for the rest of the system's 15 year life Other: • Can serve as a pool cooling system in the summer

Last Word on Solar Pool Heat: The most important pool heating behavior we discovered is to insulate the pool against heat loss. Unless we cover your pool each night, and during the days when it is really cold, there is no way the solar heater is going to keep temperatures near 80 degrees. Pool blankets cost a few hundred dollars and last for years. A roller mechanism (Figure 6) makes it relatively easy to deploy and retrieve the insulation blanket. The mechanism can be installed for about $500, and that price is included in our financial calculations.

Figure 6 - Pool Insulation Cover

In addition to covering your pool each night, we found it is wise to check the system often to monitor its performance. This is a simple matter of walking by, and noting the thermometers, making sure the water is hotter going to the pool than it is when it returns. Unless you make sure your system is working, your investment may not be returning you the savings you hoped for. These daily chores can help you achieve great benefits. In our case we are avoiding the emission of well over 7,000 pounds of carbon annually while enjoying more than a 16% return on our investment.

Photovoltaic (PV) Solar Electrical

At the end of 2009 we took the big plunge and installed a 5 kilowatt photovoltaic system. Imagine that 5 KW generator you see at Home Depot up on your roof, sending electricity down to your distribution box. But instead of making all that noise on your roof, and burning fossil fuel, it is totally quiet, meanwhile powering all your lights and appliances, cooling your home, running your pool, meanwhile spinning your electric meter backwards and earning you credit with your utility company. Some (11) of the 22 roof mounted modules are shown in Figure 6. We have these 11 panels on our south facing tile roof and another 11 on the flat roof over our Lanai. You can see the flat roof modules on the background of Figure 2.

We are often asked about putting a solar (hot water pool heat or PV) system on an old roof. My view is that if it is almost time to invest in a new roof, you might as well do it before installing your roof panels. On the other hand, it is not that big a deal to remove a solar system in 10 years or so, and then have it re-mounted after your new roof is installed.

Figure 7 – PV Modules

The PV system is very simple and reliable. Other than the electrons moving thru the wires, it has no moving parts. Direct Current (DC) power is created at the roof modules. An inverter (Figure 7) located in our garage, converts the DC to the Alternating Current (AC) used in the house. The inverter has a convenient readout of what's happening with our PV system (how much power it is currently generating as well as historical data). This makes it easy to monitor and record system performance to assure we are getting a good return on our investment.

Figure 8 – Inverter

If we are making more electricity than we are using (which is the norm during daylight hours), the system sends electricity back to the "grid" thru FPL's meter (Figure 9), causing the meter to run backwards. The meter keeps track of what comes in and what we send back to the grid. We have what is called a "net metering" agreement with FPL. The utility agrees to serve as our battery, taking our excess power and letting us recover it when the sun isn't shining.

Figure 9 - Meter and Junction Boxes

If we generate more electricity in a month than we take from the grid, we build up a reserve in our FPL account. If we use more electricity in a month than we send back to the grid (as can happen in the winter when the days are short), we pay for it out of our reserve- or if our reserve is empty, we actually pay money. At the end of the calendar year we settle up, with FPL paying us real money for our reserve (they pay us at the wholesale price).s

During the first two years of our PV/Net metering experience, we generated more electricity than we consumed. As a result we paid a monthly bill of about $6 (the administrative fee), and got a refund from FPL each January. Not paying an electric bill is a good feeling. Going into our retirement years without having to budget for this utility bill is a great financial advantage. For conservative investors like us, the PV system is paying a good return on investment. If we assume a 5% annual increase in utility prices over the 25 year life of our PV system, we will realize a 9% return on investment. [12]

There is even more good news for anyone interested in investing in a PV system now. Prices are way down from where they were in 2009 when we bought our system, which more than compensates for state rebates drying up. A 5 KW system like ours can be had for about $14,000 now. If electric prices increase at 5% on average, over the 25 year life of a PV system, the investment would pay a 9% return for a homeowner. [13] A business owner would get a higher return because of tax savings from accelerated depreciation of the asset.

Overall, our PV adventure as a very important accomplishment. As you can see in Table 4 summary, the PV system paid off in ecological as well as financial terms. A winner!

Last Word on PV: As with all renewable energy systems, human behavior trumps technology. I once visited friends who were proudly showing me their new PV system. We went down in their basement late in the day to see a bunch of blinking error signals, indicating the system had been malfunctioning at least for that whole day. A simple reset got things working again. It had been weeks since the couple had checked on their system, and for all they know, they could have gone weeks without the "free" source of power they paid for. I have heard other stories of people not noticing that their PV system was not working, and none of them involved serious malfunctions requiring service. They were all cases where a daily human check would have limited the loss of generating power to a few hours at most.

Table 4 - Financial and Ecological Analysis of PV System

Ecological Benefit:

- 7,832 pounds of carbon NOT emitted annually
- Home can achieve net zero carbon emissions with appropriate conservation/behavioral measures

Financial Benefits:

- Our return on investment: 9% (assumes 5% increase in annual price of electrical power over 25 year life of the PV system.
- Today's prices are lower, so you can achieve similar –or better- returns without relying on state rebates (which are drying up)
- Businesses achieve a higher ROI due to tax savings from accelerated depreciation

Other:

- General peace of mind knowing you do not have to pay an electric bill for the next 25 years.

Another important contribution from human behavior comes from energy conservation. For example, one of the reasons we are able to generate more power than we consume is by keeping the sun off our windows with Bahamas shutters. This limits the temperature indoors and reducing the days we have to employ our air conditioning. And when we do use our AC, we set our thermostat to 80 degrees. This is warmer than most of our family and friends maintain their homes, but we are comfortable at 80 degrees as long as we have a breeze coming thru the house, and/or we use ceiling fans. With the help of Stan Cox (*Losing Your Cool*, 2012 Cox Press) we learned that humans are actually comfortable and more healthy too, if they can adapt to higher indoor temperatures, during the summer months. We also hang our laundry most of the time instead of using the dryer, turn off lights when not in the room, etc. If we did not conserve energy, we would not be able to achieve net carbon zero emissions with our 5 KW PV system

These behavioral habits have become routine for us and no longer seem like inconveniences. They are a small price to pay for the net carbon zero emissions we achieved, almost 8,000 lbs. of carbon emissions we avoid, meanwhile enjoying a good, albeit conservative 8% return on our investment.

Electric Boat

After observing the actual performance of our PV system for a few months, we could see that our projections were pretty accurate, if not a bit understated. We were in fact, producing 15-20% more electricity than estimated. ***What to do with that surplus power***? We were not ready to commit to an electric car because production models were not yet readily available.

We were, however, ready for another boat. We took delivery on *Mangrove Queen*, a 21' Duffy Classis in the fall of 2010. Her surrey top and displacement hull form remind us of Humphrey Bogart's *African Queen* (Figure 10)

Figure 10 - Mangrove Queen

Mangrove Queen uses sixteen (16) six volt (golf cart) batteries to create 450 ampere hours (ah) of 48 volt power. The batteries are arranged in two banks under the port and starboard seats (Figure 11)

Figure 11 - Starboard Battery Bank

The "main engine" is a 7 ½ horsepower electric motor shown in Figure 12. We cruise quietly at a speed of 4-5 knots, with about 10 hours of endurance. [14]

Figure 12 - 7 1/2 HP Motor

Charging is a simple matter of "plugging in" to a 110 volt receptacle while dockside. For us, this means the batteries are charged from our PV system. We enjoy virtually free boating operations, as the power comes from the solar panels on our roof.[15] If we were to have a diesel powered boat of the same size, we would be paying about $243 dollars for fuel and adding about 1,300 pounds of CO_2 to the atmosphere annually. [16] While modest in comparison to alternative commuting (and as we will see in the next section, the use of an electric car), the electric boat does have notable financial and ecological benefits (Table 5).

Last Word on the Electric Boat: The decision to go with an electric boat (together with the solar DHW decision) was the simplest of all our energy initiatives. Living on the water, and having surplus energy for our boating made this another no-brainer. By not going with a fossil fuel burner, we save carbon emissions and money for fuel. Meanwhile we are on the water--quiet and free. We are limited to 5 knots of speed, which to ex-sailboat folks is no inconvenience at all. To the contrary, going slow allows us to enjoy the view.

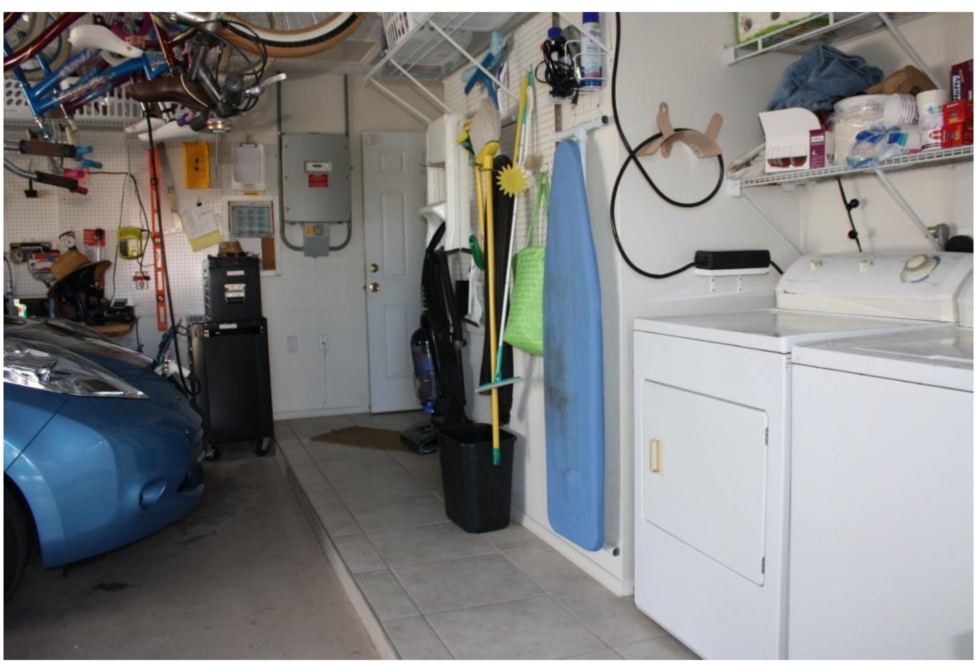
Table 5- Electric Boat Financial and Ecological Analysis

Ecological Benefit: • 1,300 pound of carbon NOT emitted annually Financial Benefit: • Annual savings of $243 on diesel operations Other: • Powered 100% by renewable energy • Quiet operation • Zero emissions of any kind

Electric Car

In December of 2011, we took delivery on our Nissan Leaf, and life has not been the same since. Instead of the trouble and expense of trips to the "gas station," we refuel in the comfort of our garage, drawing on the renewable solar power created on our roof. In Figure 13 you can see "EVie" (as we call her) taking a drink from the 220 volt drier receptacle. [17] That gray box in the background is the inverter for our PV system that is providing the "free" fuel for EVie. [18]

Figure 13 - EVie at Her Charging Station



We drive our 5 passenger car with all the bells and whistles (heated seats, Navigation, Bluetooth, satellite radio, etc.), enjoying almost all the benefits of a regular car without committing the sin of polluting the atmosphere – we emit virtually no emissions. Last year (2012), our Leaf saved over $1,500 in fuel cost and avoided the emission of 6,680 lbs of CO^2.[19]

The only shortcoming of the electric car is the need to plan our trips if going beyond the 80-100 mile range of our battery. For us, this need to "think" occurs about once every two weeks. This requires us to do some advance route planning (navigation), doing a search for a charging station near our destination, and/or making arrangements to plug in somewhere else (relative, friend, marina, restaurant). If it gets too far and/or too hard, we take our gas car.

During the first year with our Leaf, we have used the electric car for about 60% of our car trips. The majority of the miles in a gas car are to/from the airport (100 miles away) in our minivan (which also has space for 7 passengers and luggage) to pick up/drop off family. This means we need to have another car; a gas car in reserve (I suppose we could lease a gas car for our airport/long road trips, but it seem convenient to hold onto our old Honda cars – we have one at our Florida home and one in our NY home).

I am asked how much it costs to drive the electric car versus a regular gas car. My reply is that, if we did pay for electricity (which we don't, for the most part) we go 100 miles for $2.30. Then I ask how many miles per gallon do you get? If they say, for example, they achieve 30 miles per gallon; I do the calculation that shows they pay over $13 to go 100 miles. If you are lucky enough to get 30 miles per gallon, you could save over $10 for every 100 miles you drive – that's over $1,300 annually if you drive 12,000 miles a year - by driving an electric car.[20] Think about putting a dollar in your pocket every 10 miles you drive. That's as much fun as a honk and wave at every gas station you bypass. Of course, if you are getting your juice from solar power, you could be saving as much as $1,600 annually on fuel.[21]

Batteries are a concern with electric vehicles, just as they are with Boeings' new 787 aircraft. While I am not afraid our Leaf's lithium ion battery will catch fire, there is a risk with the uncertainty of the cost to replace it when it reaches the end of its life. I transferred this risk to Nissan by leasing instead of buying our Leaf. Our lease term is 4 years at 15,000 miles per year, so when the battery warrantee expires at 60,000 miles, the car will belong to Nissan.

Another (unfounded) concern with electric cars is the notion that they "replace tailpipes with smokestack." It simply is not true that the pollution caused by generating electricity is more harmful than mining, refining and burning gasoline. The Union for Concerned Scientist report, *State of Charge*, makes clear the climate benefits that electric cars have over conventional gas vehicles across the United States.[22] As pointed out by Peter Norby in the *Hidden Costs of Energy*, it takes about 6 kw of electricity just to refine a gallon of gasoline, and that doesn't begin to account for the damage that gallon of gasoline does when it is burned in the internal combustion engine. By contrast, my Leaf can travel about 28 miles on that 6 kwh of electricity, and do so without any emissions.[23] So much for this bunk of replacing a tailpipe with a smokestack!

Evaluating the total cost of the electric car versus a regular gas car should take into account the cost of ownership as well as the cost to maintain and operate the vehicles.[24] Our economic analysis compares our Leaf with a similarly equipped 5 passenger car. The Leaf cost more (perhaps $12,000 more, offset by a $7,500 federal tax credit), but it is less expensive to operate. Other than rotating tires there is virtually no maintenance owing to the lack of an internal combustion engine. And there is the savings from not buying gas. The equivalent annual cost (EAC) of the Leaf is just under $7,800 compared with almost $8,000 for a hypothetical gas car.[25] This assumes the price of gas remains constant. If gas prices increase, the advantage of the electric car becomes greater. Unless you have a PV system, the outcome of the financial analysis is pretty much a tie, and changing any of the assumptions can swing the analysis one way or the other. If you get your electricity from the sun, as we do, the Leaf's EAC is about $7,500, a $500 annual advantage over the gas car.

Final Word on the Electric Auto: As in all of our initiatives, convenience and behavior are significant factors in our use of the electric car. We do drive in the ECO mode, which stretches our range, and reduces the amount of electricity it takes to recharge our battery. It takes time and energy to plan longer trips. Emotionally these "inconveniences" are well worth the good feelings we get by running clean and passing gas stations by. The benefits of saving almost 7,000 lbs. of carbon emissions, together with the overall lower cost of owning/operating a vehicle that never stops at a gas station, far outweigh the inconveniences.

Table 6- Electric Car Financial and Ecological Analysis

Ecological Benefit:
- 6,680 pounds of carbon NOT emitted annually

Financial Benefits:
- EAC of our Leaf is about $500 less than an equivalent gas car
- As the price of gas increases, the advantage of the electric car becomes even greater.

Other:
- Quiet and Zero emission operation
- Avoid hassle of going to the gas station

Who cares?

Over the course of the past three decades, my family's motivation and commitment to ecological matters has evolved. At first, we were moved towards using renewable energy by economic/financial motives. The escalating cost of fossil fuel drove the decisions to conserve energy and invest in a solar hot water system. While the financial factors are still relevant (we are a family of limited resources), our concern for the environment has surfaced as a priority.

The Union of Concerned Scientists says we need to reduce carbon emissions by 80% if we are to have any hope of reversing global warming, climate change, and the rise of sea levels. We look at our grandchildren and wish they will not face increasingly severe weather events, which can threaten their life styles, if not their survival. We want them to experience the kind of coastal living that our ancestors have enjoyed. But unless we put a radical halt to our carbon emissions, our heirs will be screwed. It is frightening to see our present neighborhoods (in Florida and New York) under water –which is where they will be later this century unless climate change is reversed. [26]

Climate change is also increasingly recognized as a matter of national security. Intelligence and strategy assessments point out the possible outcomes from continued climate change, including:

- With 80 % of the world's population living within 20 miles of the coast, we have the real possibility of whole nations being displaced by rising sea level.
- Climate driven disasters, like typhoons and tsunamis can cause the displacement of hundreds of thousands, if not millions of people.
- Global security can degrade quickly with these sorts of massive population shifts. Providing a military prepared to deal with these kinds of threats will strain our already constrained resources.[27]

Conclusion

The threat to our heirs, as well as the world's population, has moved us over the past decade to try to reduce our share of carbon emissions. The sum of our efforts has been a reduction of almost 40,000 lbs in annual carbon emissions. Table 7 summarizes our initiatives and their results in terms of reducing our carbon footprint.

Table 7 - Overall Reduction in Carbon Emissions

Initiative	Reduction in Annual Carbon Emissions
Commuting by bike/public transportation	6,113 lbs
Solar DHW	6,720
Pool Heat	7,636
PV	10,965
Electric Boat	1,362
Electric Car	6,680
Total Annual Reduction	39,476 lbs
Baseline (Carbon Footprint before initiatives)	53,343 lbs[28]
Reduction	74%

We are pleased with the results, for a few reasons. We were able to achieve almost a 75% reduction in emissions, which is close to the goal of 80% set by the Union of Concerned Scientists as what mankind needs to do to save the planet. We feel that with continued improvements, we can achieve that 80%. Our near term strategy has us working in the transportation area (primarily by reducing carbon emissions from our gas car by more use of public transportations and our electric car) and adding capacity to our PV system (reducing the electricity we take from the grid to net zero).

Meanwhile, the investments that contributed to these emission reductions have also earned us money. A summary of our returns on investment are show in the following table. [29]

Table 8 - Summary of Investment Returns

Investment	Return
Commuting by bike/public transportation	Annual savings $1,950
Solar DHW	29% ROI
Pool Heat	21% ROI
PV	9% ROI
Electric Boat	Annual savings $243
Electric Car	Annual savings $500

The most expensive initiative (the PV system) is the most effective in that it reduces our carbon footprint more than 10,000 lbs annually. But this does not mean you have to spend a lot of money to make any progress. For example, using the $500 bike and public transportation as almost as effective as the $30,000 electric car. We found that it was the integration of all the initiatives that enabled us to reach our goal. We would not come close to the reduction needed to save the planet without investing in all of these system and, yes, altering our behavior.

Table 9 - Summary of Behaviors

- Got out of habit of jumping into the gas powered car to go anyplace
    - Use bike or public transportation as a first choice
    - Use the Electric Car, planning routes carefully for trips over 80-100 miles
    - Learn to enjoy the peace of not rushing everywhere in the car, fighting traffic and getting agitated.
- Conserve hot water
    - Limit duration of showers
    - Cover pool with insulating blanket at night.
- Conserve energy in general
    - Keep direct sun out of the house with shutters, etc. to reduce load on Air Conditioner (A/C)
    - Set A/C high and heat low, and Hang laundry for the sun to dry instead of using clothes drier
    - Regular stuff like turning off lights and fans when leaving a room
- Learn to enjoy going slow in the boat, enjoying the scenery, peace and quiet
- Monitor systems to make sure they are paying on your investments
    - Check thermometers on solar DHW and pool heat to assure the return is hotter than the supply
    - Daily log of PV power generated and what is sent to/from the grid

Behavior modification and establishing new paradigms has been an essential ingredient in our success in reducing our carbon footprint. Table 9 sums up our altered behaviors. We have, over the course of the past few years, learned to act differently than most of our friends, neighbors and family.

This is a story of one family's energy policy evolution. We started with revising our commuting routine, and then moved to simple domestic DHW and pool heat. Finally we took the plunge into more serious investments in PV and Electric vehicles. Along the way, we have adapted our behaviors and outlook on what we thought before to be conveniences. The result has been significant reduction in our carbon footprint and economic/financial benefits as well.

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About the Author

Coty Keller lives in Port Charlotte, Florida with his wife Marge. He is in his third career. Coty served for over 20 years in the US Navy. His favorite jobs in the Navy were Captain of ships (he got to do that twice) and teaching management at the Naval War College (that experience was a basis for his present work). Coty's second career was in industry, in both service (insurance) and manufacturing (yacht production). His third career - for the better part of two decades - has been college teaching. Almost all of Coty's teaching has been with graduate level professionals. Coty is an associate professor of management at St. Joseph's College in New York and adjunct professor of National Security Affairs at the Naval War College.

Coty has a bachelor's degree in Psychology from Colgate University, a master's in Financial Management from the Naval Postgraduate School and a PhD in Decision Science from Walden University.

Coty's personal interests are family, being on the water and ecological activities. You can see his complete resume from his homepage (http://faculty.sjcny.edu/~keller/)

End notes

[1] See the Executive Summary of *Climate 2030* by the Union of Concerned Scientists.

[2] Technically, the $1,949 cost savings is the Equivalent Annual Cost (EAC) difference between owning/operating our Honda Accord and owning/operating the folding bike and taking the train. EAC is the net present value of the life cycle cost divided by the years the asset is owned. The calculations are based on the following assumptions: cost of capital (5%), purchase price (Accord $20,000; Bike $500), price of gas ($4.25/gallon), train tickets ($12.90 round trip), annual maintenance ($500 for the Accord, $50 for the bike), and life span (Accord 10 years, Bike 15 years). The undiscounted costs would be $3,826 for commuting by car and $2,045 for the bike/train option (a difference of $1,780).

[3] 6,113 pound of CO2 is calculated as the result of 8,887 grams of CO2 emitted per gallon of gas, as per the EPA. I am estimating our Accord achieved 30 MPG.

[4] Carbon emissions were estimated using David Gershon's *Low Carbon Diet*.

[5] "Drain back" is one of the types of solar DHW system used in cold climates. When the sun heats the collector to a temperature that is higher than the coldest water in your storage tank, the system pumps water from a reservoir up to the collector to gain heat which is then transferred to the potable water in your storage tank. When the collector temperature is no longer hot enough to make hot water, all the water *drains back* to the reservoir. To learn more about different kinds of solar DHW systems, see *Solar Hot Water Systems* (Tom Lane) *and Solar Living Source Book* (John Schaeffer).

[6] The DOE estimates that a family of two will consume 4,600-5,000 Kilowatt Hours (kwh) of electricity annually to heat hot water. At 12 cents per kwh FPL's current fee), that's $528 annually we don't pay. Divide the $2,300 investment by $576 saved annually for a 4 year payback. Return on investment is calculated as Internal Return on Investment, using a 15 year economic life.

[7]4800 kwh of electricity (the average 2 person annual energy used to heat how water) at 1.4 pounds of carbon emitted per kwh generated by Florida Power and Light (FPL) yields a 6,720 pound saving annually. Calculated from FPL's fuel source information and statistics provided by the US Energy Information Agency.

[8] Payoff of 5.5 years is calculated by dividing the $3,298 investment by the $600 annual savings (5455 kwh at 11 cents). 5455 kwh annually comes from an estimate of running the heat pump for 4 months in winter at $150 monthly.

[9] 20% return on investment (ROI) is based on an investment of $3,298 with annual returns of $600 (the saving from $150/month on 4 months electric bills each year). An annual increase of 5% in utility costs would increase the ROI to 25%.

[10] The pool solar hot water system (collectors, controls, plumbing, and ground mounted rack) cost $4,140, less 30% federal income tax rebate and $100 Florida rebate. Adding an insulating blanket and roller storage system brought the total cost to $3,298.

[11] 5455 kwh avoided at 1.4 pounds CO^2 per kwh.

[12] Calculation of 9% return on investment is based on investment of $14,000, a useful life of 25 years, our PV system producing an average of 7,832 kwh annually, savings based on a current price of 12 cents/kwh escalating at an annual rate of 5%.

[13] Current prices are as low as $4 per watt for PV systems. For example, Sun Commercial Solar (www.suncommercialsolar.com) is a contractor who will design and install your PV System for this reasonable price. $4 per watt translates to an investment of $14,000 ($20,000 gross less 30% federal tax rebate) for a 5 KW system that should produce almost 8,000 kwh of electricity annually (saving you $861 worth of electricity at 11 cents/kwh).

[14] The motor consumes about 20-25 amps at cruising speed. The 450 ah battery capacity gives us 10 hours before we get to the 50% of reserve capacity we like to maintain.

[15] The first year after the Electric boat was put in service (2011), we still produced more than what we consumed, with a surplus of more than 300 ah. At 3-5 ah per charge, this surplus would have doubled had we not been charging the boat. Since FPL pays us about $.03 per kwh for surplus generated, you could say it cost us about $9 to charge our boat. Had we paid full price ($.11/kwh) it would have cost us a little over $33 for a year's boat operations.

[16] Fuel and carbon emission savings are bases on 121 hours of operation annually, with a diesel engine burning ½ gallon/ hour, diesel emissions of 22.4 lbs. $CO2$/gallon.

[17] The Leaf comes with the EVSE and able to plug into 110 volt receptacles. We had our EVSE modified to take 220 or 110 volts, and for an investment of less than $400, have avoided the need for a more costly charging station. Go to (http://evseupgrade.com) for info on the EVSE upgrade.

[18] Well, almost "free." Since we began fueling our Leaf at home, we no longer produce more electricity than we generate with our PV system. Our deficit the first in 2012 was just under 1,000 kwh, or about $110 worth of FPL power at $.11/kwh.

[19] These calculations are based on driving the Leaf 11,711 miles in 2012, assuming that gas costs $3.75/gallon and a gas car gets 28.5 mpg (the average of what we get on our Honda Civic and Odyssey). The carbon calculation allows for the "dirty" electricity we used (assumes the 981 kwh we purchased from FPL emits 1.4 pounds per kwh, assumes the charging station at our home in Freeport, New York is clean since 85% of the power there is supplied from renewable sources).

[20] Calculated by the difference in a gas car (assuming $4 per gallon, 30 mpg) and an EV driving 4.7 miles per kwh, with electricity costing $.11/kwh.

[21] Assumes 30 miles per gallon, $4/gallon, 12, 000 miles annually.

[22] The executive summary says, "In regions covering 45 percent of the nation's population, electricity is generated with a larger share of cleaner energy resources—such as renewable and natural gas—meaning that EVs produce lower global warming emissions than even the most efficient gasoline hybrids. But in regions where coal still makes up a large percentage of the electricity grid mix, the most efficient gasoline-powered hybrid vehicles will yield lower global warming emissions than an electric vehicle. Even then, however, electric vehicles slash oil consumption in nearly all regions."

[23] We have averaged 4.7 miles per kwh in our first 15,000 miles in the Leaf.

[24] The cost of ownership of our two old Honda gas cars (we keep an Odyssey at our Florida home and a Civic at our New York summer home) would not be a relevant cost in the comparison because we would have them whether we had an electric car or a new gas car.

[25] Equivalent Annual Cost (EAC) is cost of owning and operating an asset over its life span. This analysis is based on a 4 year life, 12,000 miles/year, and uses a 5% discount rate. The Leaf sells for $37,500 less the $7,500 tax credit and goes 4.7 miles per khw which cost $.11 each. The gas car price is $25,000, gets 30 mpg and gas costs $4/gallon. Annual maintenance for the Leaf is $50 annually; for the gas car maintenance will cost $200 each year.

[26] See interactive graphic at http://www.nytimes.com/interactive/2012/11/24/opinion/sunday/what-could-disappear.html?ref=sunday

[27] See *Global Trends 2030*. Also December 2012 speech by Pacific Commander Admiral Locklear to the Asia Society (http://www.pacom.mil/commander/06_dec_12-asia--pacific-rebalance.shtml)

[28] Carbon footprint is estimated by using the calculator in Gershon's *Low Carbon Diet: a 30 Day Program to Lose 5,000 Pounds.* Auto transportation, gas, electric and propane consumption, as well as garbage are used to arrive at annual family carbon footprints. For the purpose of this calculation, air miles were not included. The calculator can be found at http://www.empowermentinstitute.net/index.php/community/low-carbon-diet/household-co2-calculator.

[29] Returns on investment calculations assume 5% annual increase in the price of energy. If we assume the price of energy will not increase the ROIs are 24% on Solar DHW, 16% on Solar Pool Heat and 4% on the PV system.