**The Effects of a Drastic Reduction in Energy on the American Lifestyle**

**Abstract**

*We investigate the effects on the American lifestyle of a drastic reduction in remote site energy supply in two areas: operating residences and operating automobiles, which together consume more than one third of all the energy used in the United States. Specifically, we look at the effects of a 10-to-20 fold (more than 1000 per cent) reduction in energy coming from the electrical grid, natural gas, oil, and gasoline. We compare and contrast the costs (without any subsidies) and lifestyles of two families that live in average houses in American locations that get an average amount of sunlight: Family I lives in a conventional house that uses conventional energy and drives conventional automobiles, whereas Family II lives in a net-zero-energy house-and-electric-car combination powered by a large solar PV array. The data suggest that Family II lives a more comfortable and secure lifestyle than Family I, and experiences savings of thousands of dollars per year without any significant upfront cost. We also briefly discuss the cost differences in those parts of the contiguous United States that receive lesser or greater amounts of sunlight than the average. While we do not address the energy used in commercial, industrial, or agricultural operations, many of the same techniques used in the house and car design can be applied to these energy sectors. Future studies could include off-grid residences that are self sufficient in energy and water and have no pipe, wire, or cable connections to the outside world.*

We examine the effects on the American lifestyle of a radical reduction in remote site energy supply in operating residences and automobiles. This study is constrained by the following restrictions and assumptions:

* We only address the energy required to operate residences (houses, apartments, condos, etc.) and automobiles, plus the energy needed to create energy producing features such as solar PV. Our analysis only applies to new construction, and does not consider retrofits. It also does not address the time needed to convert the bulk of the American housing and transportation systems to the new energy scenario.
* No subsidies are used in the cost calculations, only costs provided by vendors
* We do not address the energy associated with infrastructure, commerce, industry, or agriculture.
* We assume a starting date of 2013 at a time when a fair number of electric cars should be on the market and the cost of solar PV is expected to decline by more than 30% [[ PV cost](http://www.unep.org/pdf/factsheet-Poznan.pdf) ]
* We assume a conservative economic climate with 30 year mortgage rates of 6% [ [current rates](http://www.hsh.com/today.html) are less than 5% ] and an average 3% annual inflation rate over 30 years. We also assume that grid-based electricity, natural gas, oil, and gasoline remain fixed near current values except for a 3% inflation rate.
* We assume that the long sides of newly constructed residences are oriented within +/- 30 degrees of due South in order to maximize solar radiation, and that houses are built in the absence of tall trees or other obstructions on the South side which would shadow the house or PV array.

We measure the effects of a drastic energy reduction by comparing the costs profiles of two families with different energy scenarios:

* Family I buys a new house of conventional design that uses conventional remote site energy (electricity form the grid, natural gas, or oil), and drives conventional gasoline engine automobiles.
* Family II buys a new house of the same size as Family I, and drives electric automobiles the same distance per year as Family I, and so enjoys a similar lifestyle, but lives in a net-zero energy house-and-electric car combination powered by a large solar PV array along with a storage battery. At times it draws electricity from the grid, but other times it produces an excess amount of electricity which is sent back to the grid, reducing the coal or gas needed to create electricity, while also driving the electric meter for the house backwards, so at the end of the year, the energy cost is zero or negative and remains so for 30 or more years.

Family II pays more for their house because it is built according to the most energy efficient standards (specifically, the European Passive House (EPH) standard), uses efficient lighting, appliances, and electronics throughout, and sports a large 8 KW solar PV system along with a 20 KWH battery for storage. Thus we compare the higher energy cost for the conventional house for Family I against the higher mortgage cost for Family II.

To compare these costs we must determine:

* The cost of energy over a 30 year period for Family I
* The cost of the energy saving and energy producing features of the house for Family II (note that the energy cost itself will be zero). To do this we need to determine (a) how much energy the house consumes in KWH/year, (b) how much energy the electric cars consume in KWH/year, (c) the cost of the solar PV array of sufficient size, (d) the cost of the energy saving features of the EPH design, and (e) the cost of the storage battery. These additional costs will determine the increase in mortgage costs for Family II.

We do this in several steps:

**Step 1:** Compute the energy cost over 30 years for Family I:

* The average American household spends $2350/year on energy for their residence (see below for the combined cost of electricity and space heating)
* The average American family drives 21,000 miles/year in their automobiles [ [miles](http://www.eia.doe.gov/emeu/rtecs/chapter3.html) ]
* The average cost of gasoline is set at $3/gallon, but grows at 3%/year (the current average is a bit below that but has been much higher recently [[ gas cost](http://www.eia.doe.gov/oil_gas/petroleum/data_publications/wrgp/mogas_home_page.html) ] )
* The average miles per gallon is set at 30 MPG, although the current average is much less [[ current mpg](http://www.google.org/recharge/dashboard/calculator) ]
* Therefore, the energy cost for gasoline in the first year is (21,000/30)\*3 = $2,100 and the total energy cost for the first year is $2350 + $2100 = **$4450**
* Assuming that the costs of gasoline, electricity, and natural gas remain fixed over the next 30 years except for a 3% inflation rate, the cost after 30 years is $4450 \* (exp(0.03\*30)) = $4450\*2.46 = $10947. So the average cost over 30 years is (4450 + 10947)/2 = $7698/year
* Thus the energy cost for Family I over 30 years is $7698\*30 **= $230,940**

**Step 2.** Compute the annual energy in KWH needed for the house for Family II:

* The average American household consumes about 11,000 KWH/year [ [electricity cost](http://tonto.eia.doe.gov/ask/electricity_faqs.asp#electricity_use_home) ] at an average cost of $0.115/KWH, which comes to $1250/year
* Most residences get their heat from natural gas or oil, so we must convert that energy into KWH. The average heating cost in the U.S. appears to be about $1100, looking at graphs of various types of heating [[ space heating costs](http://www.hydro.mb.ca/your_home/home_heating_comparisons.pdf) ].
* $1100 would translate to about 9,800 KWH/year if expressed in terms of electricity (which has a cost of $0.115/KWH), giving a total of 11,000 + 9,800 = 20,800 KWH/year ( by way of comparison, in Southern California, average total KWH/household is estimated at 18,000 KWH/year, a fairly close match [ [total California household energy](http://www.physics.uci.edu/~silverma/actions/HouseholdEnergy.html) ]). Therefore, the total energy cost of a typical household in the United States is about $1250 + $1100 = **$2350/year**
* The EPH design cuts energy cost by a factor of four [ [EPH](http://www.efcf.com/reports/E20.pdf) ], yielding 5200 KWH/year (as a reality check, a 1650 square foot house built in 2006 in Oklahoma [[ Oklahoma](http://www.zdnet.com/blog/emergingtech/a-zero-energy-home-in-oklahoma/239) ] achieved net-zero energy with a 5.3 KW solar PV array, which translate to about 5960 KWH/year, despite the fact that it was not built according to the strict EPH standards)
* However, more recent advances in energy efficiency, such as the heat pump water heater recently introduced by General Electric [ [GE heat pump](http://www.geappliances.com/heat-pump-hot-water-heater/) ], which cuts water heating energy in half, should reduce this. Water heating accounts for 18% of the electrical energy cost in a house [ [water heating costs](http://www.wapa.gov/es/pubs/fctsheet/WaterHeating.pdf) ], and 18% of 11,000 KWH is 1980 KWH, half of that is 990 KWH, so the energy cost of a EPH design should be 5200 – 990 = 4210 KWH. We round this up to **4300 KWH/year**

**Step 3:** Compute the amount of annual KWH energy used by the electric cars for Family II:

* We assume that Family II has three electric cars: a full-function 5-passenger, 90 MPH electric car similar to the Nissan Leaf, and two tiny micro cars limited to 35 MPH, and weighing perhaps less than 1000 lbs (note: electric micro cars should be much more acceptable to the American public than gasoline micro cars, not only because they remain quiet, smooth, clean, and efficient, unlike micro gasoline cars whose features become heavily compromised as they shrink, but also because electric micro cars have much more usable interior space, as the drive train takes up zero space in the car: the battery, controller, and charger can be shaped to fit under the floor of the vehicle, and the motor is replaced by four small motors embedded inside the wheels: hence zero space.)
* These cars travel the same combined 21,000 miles/year as for Family I. Since the larger car would often be reserved for more occasional use when faster speeds, greater passenger or cargo loads, or longer trips are required, we set 8000 miles/year as the distance travelled for the full performance car, and 13,000 miles/year combined for the two micro cars
* Since the full size car is similar to the Nissan Leaf which has a range of 100 miles using 24 KWH [ [Nissan battery](http://www.nissanusa.com/leaf-electric-car/index%22%20%5Cl%20%22/leaf-electric-car/specs-features/index) ] of batteries, it should get 4.166 miles/KWH. However, there is also a 10-12% charging loss from wall plug to battery [[ wall plug loss](http://www.evworld.com/article.cfm?storyid=1731) ] . We will assume the smaller 10% as this is an active area of research and should improve, which yields 3.75 miles/KWH, or 2133 KWH/year
* The two tiny micro cars, weighing less than 1000 lbs, and limited to 35 miles/hour, should easily get 6.5 miles/KWH, including wall plug-to-battery losses, and thus consume 13,000/6.5 = 2000 KWH/yr. This appears to be a very conservative estimate given that cutting the weight in half yields almost twice the MPG in a gasoline engine car [ [weight reduction in cars](http://www.statcrunch.com/5.0/viewreport.php?reportid=5572) ]. So the total for all three cars is 2133 + 2000 = **4133 KWH/year**

**Step 4:** Compute the cost of a solar PV array which provides the energy needed for both house and cars for Family II:

* The total KWH used by Family II for house and cars is 4300 + 4133 = **8433 KWH/year**
* In an average location in the U.S., a 1 KW PV array will start producing energy at a rate of about 1250 KWH/year [[ PV per state](http://rredc.nrel.gov/solar/calculators/PVWATTS/version1/) ] (note: this is a rough average computed by sampling a number of cities in the US, from a low of 970 KWH/year in Seattle, to a high of 1663 KWH/year in Tucson). The rate of decline is estimated at less than 0.75% so that after 30 years a solar PV array is still producing energy at 80% of the initial value or 1000 KHW/year [ [PV loss rate](http://www1.eere.energy.gov/solar/pv_basics.html) ]. So a 1 KW PV array should generate an average of **1125 KWH/year** over 30 years
* Thus an 8 KW solar PV array should produce an average of 8000 \* 1.125 = **9000 KWH/year**, for the next 30 years, well in excess of the 8433 KWH/year needed for the house and cars
* We calculate the cost of PV as follows: as of 2010, a large 8 KW PV array costs about $7/watt fully installed [[ current PV cost](http://www.unequalprotection.com/forum/2010/06/real-price-pv) in California or Colorado]. If we assume a 30% reduction in three years, to $5/watt, an 8 KW PV array should cost **$40,000** without subsidies. In fact, as of 2010, in some places, such as Arizona, non-subsidized PV arrays already sell fully installed for $5/watt [ [Arizona](http://sunpluggers.com/news/in-arizona-another-surge-for-solar-pv-prompts-plan-to-trim-incentive-0708) PV ]

**Step 5:** Compute the cost of the energy saving features of the European Passive House:

The median cost of a new house in the United States in 2009 is $217,000 [[ median cost](http://www.census.gov/const/uspriceann.pdf) ], which we round up to $220,000. The cost of the EPH design in Germany adds 5%-to-7% to the cost of the house [[ cost of EPH](http://www.fastcompany.com/blog/danielle-sacks/ad-verse-effect/green-architecture-alternative-leed) ]. Taking the upper limit of 7%, we get $15,400, which we round to $15,000

**Step 6:** Compute the cost of a battery

A battery is not a necessary part of this scenario, but not only reduces the need to draw energy from the grid, but can also serve as a buffer in case a cloud should suddenly cover a neighborhood, thus dramatically reducing the energy going to the house or back to the grid. We assume that a battery of 20 KWH should be sufficient (there are off-grid houses that get by with 20 KHW [ [off-grid battery](https://www.affordable-solar.com/solar-power-system-off-grid-3075-watt.htm) ] ).

Nissan claims their batteries will cost about $375/KWH [ [Nissan battery cost](http://gas2.org/2010/05/05/report-nissan-leafs-battery-costs-a-staggeringly-cheap-375kwh-to-produce/) ] in full production so their 24 KWH battery should cost $9000 and last 5-10 years[ [Nissan battery life](http://www.nissanusa.com/leaf-electric-car/faq/list/technology#/leaf-electric-car/faq/list/technology) ]. Since the environment inside a house is far more benign than in a car (no shock or vibration, near constant room temperature, and much lower charge/discharge rates), a 2nd hand battery should cost perhaps 2/3 as much and last twice as long, yielding a 15 year life at $6000, so a total of **$12,000** for 30 years

**Step 7:** Compute the cost difference over 30 years between Family I and Family II:

Except for maintenance, which should be much less for Family II than Family I, as the house for Family II is moisture sealed, lacks a central heating/cooling system, and electric cars require much less maintenance then gasoline engine cars, the additional cost of the house for Family II is the cost of the energy saving features, the cost of the solar PV array, and the battery which comes to $15,000 + $40,000 + $12,000 = **$67,000.**

If we assume no down payment, and a 6% mortgage rate, the monthly cost for the $220,000 house for Family I is $1319 [ [mortgage calculator](http://www.bankrate.com/calculators/mortgages/mortgage-calculator.aspx) ], whereas the monthly cost for Family II is $1721, a difference of $402/month, or $144,720 over 30 years. On the other hand, the energy cost for Family I is $230,940 over 30 years, so Family II saves **$86,220** over 30 years, or **$2874/year**.

**Step 8:** Compute the energy savings for Family II versus Family I:

The EPH cuts overall energy consumption by a factor of four, and electric cars cut energy consumption by a factor of four or five [ [electric car energy](http://www.inference.phy.cam.ac.uk/withouthotair/c20/page_127.shtml) ]. Given that solar PV generates 10-to-30 times as much energy [[ PV energy payback](http://www1.eere.energy.gov/solar/pv_basics.html) ] over their useful lifetime, theoretically Family II should reduce energy consumption by a factor of 40-to-120. However, Family II is still connected to the grid, and while this connection reduces the need of the grid to generate its own power, various losses should reduce this to perhaps a 10-to-20 fold reduction in energy for Family II.

In addition to the cost and energy benefits, Family II also is free from energy price spikes, has enough locally supplied energy to carry out basic functions even if the grid should go down, and enjoys a house and car combination that is more comfortable, quieter, cleaner, and requires much less maintenance

**Conclusion:** itappears possible to radically cut the energy needed to operate American residences and automobiles, while maintaining or even enhancing our standard of living. Since operating our residences consumes about 21% of the total energy used in the U.S.[ [residences](http://en.wikipedia.org/wiki/Energy_in_the_United_States#Current_consumption)], and automobiles consume about 14% [[ automobile energy](http://en.wikipedia.org/wiki/Energy_in_the_United_States#Current_consumption) is half of transportation energy], this virtually eliminates more than 1/3 of total U.S energy use. Of course, many of the same techniques can also be applied to the industrial and commercial use of energy.

We can extend the results to other parts of the contiguous United States by assuming that the major difference in cost would be the difference in the cost of the most expensive element, the solar PV array, due to differences in solar radiation. This differs by about +/- 30%, so we would expect that in Seattle [ [Seattle PV](http://rredc.nrel.gov/solar/calculators/PVWATTS/version1/US/Washington/Seattle.html) ], the solar PV array would cost about $52,000 whereas in Tucson [ [Tucson PV](http://rredc.nrel.gov/solar/calculators/PVWATTS/version1/US/Arizona/Tucson.html) ] it would cost about $28,000. In Seattle, this would add **$79,000** (instead of $67,000) to the house cost and yield a savings of **$2010/year**, whereas in Phoenix it would add **$55,000** (instead of $67,000) to the house cost and save **$5190/year.**