RESIDENTIAL ENERGY AND WATER USE REDUCTION CALCULATIONS

Lighting

Quantity	Location	Original Watts	CFL Watts	Watts saved	Hours/day	KW-h Savings/year
7	Kitchen	100	20	560	4	817

Assuming 12 Cents/KW-h = $98/year

$$Simple\ Payback: \frac{Cost\ of\ Fixtures}{\frac{Savings}{year}} = \frac{7 \times \$16.00}{\frac{\$98}{year}} = 1.14\ years$$

$$Return\ on\ Investment: \frac{Annual\ Cost\ Savings}{Installed\ Cost\ of\ the\ Appliance} = \frac{\$98}{\$112} \times 100 = 87.5\%\ (Tax\ Free)$$

Water Heating

Showers:

Quantity of Shower per Day	Number of Heads	Old Flow Rate (GPM)	New Flow Rate (GPM)	Hot Water Saved (GPM)	Duration (Minutes)	Gallons saved per day	Gallons saved per year
2	2	2.5	1.2	1.3	15	78	28,470

To Heat 28,470 Gallons of water from 50°F to 120°F requires…

$$Gallons \times {}^{8.34\ lbs}/_{gallon} \times specific\ heat\ of\ water \times Change\ in\ Temperature$$

$$28{,}470\ Gallons \times \frac{8.34\ lbs}{Gallon} \times 1.0\ \frac{BTU}{F - lbm} \times (120^0F - 50^0F) = 16{,}620{,}786\ BTU$$

Dollars Saved:

For Propane:

$$\frac{\$3.22}{100{,}000\ BTU} \times 16{,}620{,}786\ BTU = \frac{\$535.00}{year}$$

$$Simple\ Payback: \frac{Cost\ of\ Shower\ Heads}{\frac{Savings}{Year}} = \frac{2 \times \$59.00}{\$535.00} = .22 years\ or\ 2.6\ months$$

$$Return\ on\ Investment: \frac{Annual\ Cost\ Savings}{Installation\ Cost\ of\ Shower\ Heads} \times 100 = \frac{\$535.00}{\$118.00} \times 100 = 453\%$$

Water Heating

Water Heater Wrap (Radiant Barrier):

- Reduces heat transfer by about 40%
- Saves about 9% on your water heating bill
- Since water heating represents about 21% of a typical home utility bill and the typical homes utility bills are about $2,000/year:

$$\frac{\$2{,}000}{year} \times 21\% = \frac{\$420}{year} \times 9\%\ savings = \frac{\$37.80}{savings/year}$$

$$Simple\ Payback: \frac{Cost\ of\ Wrap}{\frac{Savings}{Year}} = \frac{\$19.98}{\$37.80} = .52 years\ or\ 6\ months$$

$$Return\ on\ Investment: \frac{Annual\ Cost\ Savings}{Installation\ Cost\ of\ Wrap} \times 100 = \frac{\$37.80}{\$19.98} \times 100 = 189\%$$

Domestic Re-Circ

# of cold starts per day	Flow Rate of Cold start (GPM)	Duration (minutes)	Gallons saved Per day	Gallons saved Per year
2	2.5	3	15	5,475

In this case, the calculations need to reflect the difference between heating water from 40°F - 120°F and 75°F - 120°F. This is due to the fact that the water is at room temperature with the ON DEMAND.

$$Gallons \times {}^{8.34\ lbs}/_{gallon} \times specific\ heat\ of\ water \times Change\ in\ Temperature$$

$$5{,}475\ Gallons \times \frac{8.34\ lbs}{Gallon} \times 1.0\ \frac{BTU}{F - lbm} \times (75^0F - 40^0F) = 1{,}598{,}152\ BTU$$

For Propane:

$$\frac{\$3.22}{100{,}000\ BTU} \times 1{,}598{,}152\ BTU = \frac{\$51.46}{year}$$

$$Simple\ Payback: \frac{Cost\ of\ ON\ DEMAND}{\frac{Savings}{Year}} = \frac{\$167}{\$51.46} = 3.24\ years$$

$$Return\ on\ Investment: \frac{Annual\ Cost\ Savings}{Installation\ Cost\ of\ ON\ DEMAND} \times 100 = \frac{\$51.46}{\$167} \times 100 = 30.8\%$$

Plug Loads

- Typical entertainment station with DVD, T.V. satellite, gaming console, etc…
- Measured actual use with everything “turned off” but still connected to house power.
- This was measured with a “Kill-a-Watt” meter to be 15 watts.

Energy Saved:

$$15\ Watts \times \frac{8{,}760\ hours}{year} \times \frac{1\ KW}{1{,}000\ watts} = 131.4\ KWh$$

Dollars Saved:

$$131.4\ KWh\ \times \frac{12\ cents}{KWh} = \$15.76/_{year}$$

$$Simple\ Payback:\ \frac{Cost\ of\ Smart\ Strip}{\frac{Savings}{Year}} = \frac{\$20}{\$15.76} = 1.26\ years$$

$$Return\ on\ Investment:\ \frac{Annual\ Cost\ Savings}{Installation\ Cost\ of\ Smart\ Strip} \times 100 = \frac{\$15.76}{\$20} \times 100 = 78.8\%$$

Clothes Drying

<u>Clothes Hanger:</u>

- Typically would do 5 loads of laundry per week

$$\frac{5\ loads}{week} \times \frac{52\ weeks}{year} = \frac{260\ loads}{year}$$

- With clothes hanger we would be able to reduce this amount by approximately 75% by air drying in the summer, spring and fall.

$$\frac{Loads\ saved}{year} = 75\% \times \frac{260\ loads}{year} = \frac{195\ loads}{year}$$

$$\frac{Average\ energy\ used}{load} = \frac{2.5\ KWh}{load}$$

$$Energy\ Saved\ = \frac{2.5\ KWh}{load} \times \frac{195\ loads}{year} = \frac{487.5\ KWh}{year}$$

Dollars saved:

$$\frac{487.5\ KWh}{year} \times \frac{12\ cents}{KWh} = \frac{\$58.5}{year}$$

$$Simple\ Payback:\ \frac{Cost\ of\ Clothes\ hanger}{\frac{Savings}{Year}} = \frac{\$53}{\$58.5} = .9\ years = 10.87\ months$$

$$Return\ on\ Investment:\ \frac{Annual\ Cost\ Savings}{First\ Cost\ of\ Clothes\ Hanger} \times 100 = \frac{\$58.5}{\$53} \times 100 = 110.3\%$$

Ventless/Condensing Dryer:

Total Loads per year = 260

Conventional Dryer Energy use = 2.5KWh per load

Condensing Ventless dryer energy use = 1.0 KWh per load

$$\frac{Energy\ Savings}{Load} = \frac{2.5\ KWh}{load} - \frac{1.0\ KWh}{load} = \frac{1.5\ KWh}{load}$$

$$Energy\ Saved = \frac{260\ loads}{year} \times \frac{1.5\ KWh}{load} = \frac{390\ KWh}{year}$$

$$Electric\ Energy\ Saved = \frac{390\ KWh}{year} \times \frac{12\ cents}{KWh} = \frac{\$46.8}{year}$$

Avoidance of make-up air due to being ventless:

$$\frac{BTU}{Hr} = Dryer\ CFM \times 1.08 \times Change\ in\ Air\ Temperature$$

$$\frac{BTU}{Hr} = 190\ CFM \times 1.08 \times (75°F - 40°F)$$

$$\frac{BTU}{Hr} = 7{,}182\frac{BTU}{Hr} \times \frac{70\ minutes}{load} \times \frac{1\ hour}{60\ minutes} = 8{,}379\frac{BTU}{Load}$$

Assuming total loads/year is 260 loads:

$$8{,}379\frac{BTU}{load} \times \frac{260\ loads}{year} = 2{,}178{,}540\frac{BTU}{year}$$

For Propane:

$$\frac{\$3.22}{100{,}000\ BTU} \times 2{,}178{,}540\ BTU = \frac{\$70.00}{year}$$

Total Dollars Saved:

$$\$46.8\ (Condensing\ Dryer) + \$70.00\ (Avoidance\ of\ Makeup\ air) = \frac{\$116.00}{year}$$

$$Simple\ Payback: \ \frac{Cost\ of\ Dryer}{\frac{Savings}{Year}} = \frac{\$500}{\$116} = 4.3\ years$$

$$Return\ on\ Investment: \ \frac{Annual\ Cost\ Savings}{First\ Cost\ of\ Dryer} \times 100 = \frac{\$116}{\$500} \times 100 = 23.2\%$$

Energy Star Appliances

Energy Calculation to know when to replace an appliance with an Energy Star Appliance

Refrigerator Example:

- Old existing refrigerator used approximately 1,800 KWh/year
- A new Energy Star replacement refrigerator would only use 400 KWh/year
- The net energy savings per year would be 1,400 KWh/year.

Dollars Saved:

$$\frac{1{,}400\ KWh}{year} \times \frac{12\ cents}{KWh} = \frac{\$168}{year}$$

$$Simple\ Payback: \ \frac{Cost\ of\ Refrigerator}{\frac{Savings}{Year}} = \frac{\$800}{\$168} = 4.76\ years$$

$$Return\ on\ Investment: \ \frac{Annual\ Cost\ Savings}{First\ Cost\ of\ Refrigerator} \times 100 = \frac{\$168}{\$800} \times 100 = 21\%$$

Insulating a Garage Door

- From testing in the winter months the garage temperature was maintained 10°F higher previous years without the insulation.
- (Please remember that the garage is a well insulated, sealed, but not heated space)
- Energy savings will only apply in winter since we keep the garage door open in the summer.

Heat Transfer:

$$Q = U \times A \times \Delta T$$

$$where: U = Overall\ heat\ transfer\ coefficient\ \left(\frac{BTU}{Hr \cdot Ft^2 \cdot {}^\circ\mathrm{F}}\right)$$

$$A = Area\ of\ Conditioned\ wall\ between\ house\ and\ garage$$

$$\Delta T = Average\ Temperature\ difference\ between\ conditioned\ house\ and\ garage$$

$$Q = \frac{BTU}{Hr}\,saved\ due\ to\ 10°\text{F}\ increase\ in\ average\ temperature\ of\ garage$$

For our house:

$$Q = \frac{.09\ BTU}{Hr \cdot Ft^2 \cdot °\text{F}} \times (20Ft \times 12Ft) \times 10°\text{F} = 216\frac{BTU}{Hr}$$

*Note: 20 ft x 12 ft is the area of the wall separating conditioned house from garage, not the area of the garage door.

Fuel Required:

$$F = \frac{24 \cdot DD \cdot Q}{\eta(T_i - T_o)H} \times C_d$$

$$where:\ F = The\ quantity\ of\ Fuel\ saved, the\ units\ depend\ on\ H$$

$$DD = the\ degree\ days\ for\ period$$

$$Q = the\ calculated\ heat\ loss\ reduction\ in\frac{BTU}{Hr}$$

$$\eta = efficiency\ of\ fuel\ source\ equipment$$

$$H = Heating\ Value\ of\ Fuel\ in\ BTU\ per\ units$$

$$C_d = Correction\ Factor\ for\ degree\ days = .65\ for\ Maryland$$

$$F = \frac{24 \times 4500 \times 216\ BTU/Hr}{.80(10°\text{F}) \times 92{,}000\ BTU/Gallon} \times .65 = 20.6\ Gallons\ of\ Propane$$

Cost of Propane per Gallon = $2.52 per Gallon

Dollars Saved:

$$20.6\ Gallons \times \frac{\$2.52}{Gallon} = \frac{\$51}{Year}$$

First cost of material = $.36/sq.ft.

Assume Garage Door = 128 sq.ft.

$$\frac{Cost}{Area} \times Area = \frac{\$.36}{Ft^2} \times 128Ft^2 = \$46.08$$

$$Simple\ Payback:\ \frac{Cost\ of\ Material}{\frac{Savings}{Year}} = \frac{\$46.08}{\$51} = .903\ years = 10.8\ months$$

$$Return\ on\ Investment\colon\ \frac{Annual\ Cost\ Savings}{Cost\ of\ Product} \times 100 = \frac{\$51}{\$46.08} \times 100 = 110\%$$

Solar Photovoltaic System

First cost for a 4 KW system = approximately $30,000

Federal Tax Credit = 30% X 30,000 = $9,000

Maryland State Tax Credit = $10,000 (at time of my installation) (current MD Tax Credit is now $4,000)

Net First Cost = $11,000 ($30,000 - $9,000 - $10,000)

Based on current monitoring:

$$\frac{6{,}000\ KWh}{year} \times \frac{12\ cents}{KWh} = \$720$$

$$\frac{Renewable\ energy\ credits}{year} = \frac{Average}{year} = \$1{,}200$$

Dollars Saved:

$$\$1{,}200 + \$700 = \$1{,}920/year$$

$$Simple\ Payback\colon\ \frac{Net\ First\ Cost}{\frac{Energy\ Savings + Renewable\ Energy\ Credits}{Year}} = \frac{\$11{,}000}{\$1{,}920} = 5.72\ years$$

$$Return\ on\ Investment\colon\ \frac{Annual\ Cost\ Savings}{Net\ First\ year\ Cost} \times 100 = \frac{\$1{,}920}{\$11{,}000} \times 100 = 17.45\%$$

Spray Foam Insulation

*Until further experience this winter, I will estimate energy savings based on expected percentage reduction.

Typical household total energy use = $2,000

Assume total heating/cooling cost = 53% per U.S. Department of Energy consumption estimates.

Actual Heating/Cooling Costs = $2,000 X 53% = $1,060

Actual spray foam insulation savings per manufacturer’s monitoring/testing of homes = 38%

Net Energy Savings = 38% X $1,060 = $402/year

<u>First Cost</u>

Approximately $7,000 for a very large attic with 12/12 pitch

Federal Tax Credit = 30% X $7,000 = $2,100

Reduced to $1,500, Maximum Net Federal Tax Credit = $1,500

Net First Cost = $7,000 - $1,500 = $5,500

$$Simple\ Payback{:}\ \ \frac{Net\ First\ Cost}{\frac{Savings}{Year}} = \frac{\$5{,}500}{\$402} = 13.6\ years$$

$$Return\ on\ Investment{:}\ \ \frac{Annual\ Cost\ Savings}{Net\ First\ year\ Cost} \times 100 = \frac{\$402}{\$5{,}500} \times 100 = 7.3\%$$

Please note that if ductwork is located in Attic and existing insulation is in poor condition the payback will be much quicker. Also, note that the simple payback will be much lower if actual utility costs are higher.

Variable Speed Pumping

Original Pool Pump Power = 1.5 Horsepower

$$Power\ in\ KW = 1.5HP \times \frac{745\ Watts}{HP} = 1117.5\ Watts = 1.1175\ KWatts$$

Hours of Operation per year:

$$6\ months \times \frac{30\ days}{month} \times \frac{8\ hours}{day} = 1{,}440\,\frac{hours}{year}$$

$$\frac{Total\ Original\ Energy}{year} = 1.1175KW \times \frac{1{,}440\ Hours}{year} = \frac{1{,}609\ KWh}{year}$$

With Variable speed pump we can reduce flow in half

Therefore the new power per the pump affinity laws would be:

$$KW_2 = KW_1 \times (.5)^3 = 1.1175 \times .125 = .1396\ KW$$

Total revised energy per year will be calculated first by doubling the hours of operation.

Total Variable Speed (Double Operating Time):

$$\frac{Energy}{year}(Double\ operating\ time) = .1396\ KW \times \frac{1{,}440\ hours}{year} \times 2 = 402\,\frac{KWh}{year}$$

$$Minimum\ Energy\ Savings\ per\ year = 1609\ KWh - 402\ KWh = 1{,}207\ KWh$$

$$Minimum\ Dollars\ saved\ per\ year = 1207\ KWh \times \frac{12\ cents}{KWh} = \frac{\$144}{year}$$

$$Simple\ Payback\ (Max):\ \frac{Net\ First\ Cost}{\frac{Savings}{Year}} = \frac{\$800}{\$144} = 5.5\ years$$

$$Return\ on\ Investment\ (Min):\ \frac{Annual\ Cost\ Savings}{Net\ First\ year\ Cost} \times 100 = \frac{\$144}{\$800} \times 100 = 18\%$$

Total Variable Speed (Same Hours of Operation):

$$\frac{Energy}{year}(same\ hours\ of\ operation) = .1396\ KW \times \frac{1{,}440\ hours}{year} = 201\frac{KWh}{year}$$

$$Maximum\ Energy\ Savings\ per\ year = 1609\ KWh - 201\ KWh = 1{,}408\ KWh$$

$$Maximum\ Dollars\ saved\ per\ year = 1408\ KWh \times \frac{12\ cents}{KWh} = \frac{\$168}{year}$$

$$Simple\ Payback\ (Min):\ \frac{Net\ First\ Cost}{\frac{Savings}{Year}} = \frac{\$800}{\$168} = 4.76\ years$$

$$Return\ on\ Investment\ (Max):\ \frac{Annual\ Cost\ Savings}{Net\ First\ year\ Cost} \times 100 = \frac{\$168}{\$800} \times 100 = 21\%$$

Therefore, Savings increase with hours of operation and energy use of original pump.

Domestic Hot Water Use – Hoffman House

I. Original Hot Water Load:

A. Dad Shower = 2.5gpm x 5 minutes = 12.5 gallons/day x 7 days/week x 52 weeks/year = 4,550 gallons

Mom Shower = 2.5gpm x 5 minutes = 12.5 gallons/day x 7 days/week x 52 weeks/year = 4,550 gallons

Jessie Shower = 2.5gpm x 15 minutes = 37.5 gallons/day x 7 days/week x 52 weeks/year = 9,750 gallons

Abby Shower = 2.5gpm x 15 minutes = 37.5 gallons/day x 7 days/week x 52 weeks/year = 9,750 gallons

Dishwasher = 6.8 gallons per load x 4 loads/week x 52 weeks/year = 1,414 gallons

Clotheswasher = 18.4 gallons per load x 5 loads/week x 52 weeks/year = 4,784 gallons

Lav-Washing = 2.0 gpm x 1minute/day = 2gallons per day x 5days per week x 52weeks per year = 520 gallons

Miscellaneous Hot Water Use = 10 gallons per week x 52 weeks per year = 520 gallons

Total Hot Water Use = 35,838 gallons per year

$$Average\ per\ Person\ Per\ Day\ =\ 35{,}838\ gallons\ per\ year\ x \frac{1}{365\ days}\ x\ \frac{1}{4\ people}$$
$$= 24.5\ gallons\ per\ person\ per\ day$$

B. Energy Use Originally = Energy to Heat Hot Water, Energy Loss of Water Heater Jacket, Flue Losses, and Pipe Losses:

1. $Tank\ Losses\ = 100\ watts\ x\ \frac{3.413BTU}{watt} = 341.3BTUs$

$$Per\ Year = 341.3\ BTU\ x\ \frac{24\ hours}{day} x \frac{20\ days}{month}\ x \frac{12months}{year} = 2{,}948{,}832\ BTUs\ per\ year$$

2. Energy to Heat Water

Gallons x specific Heat x 8.34 lbs per gallons x ΔT.

$$= 35{,}838\ gallons\ per\ year\ x \frac{1.0BTU}{lbs\ x\ °\mathrm{F}}\ x\ 8.34\ lbs\ per\ gallons\ x\ (120°\mathrm{F} - 55°\mathrm{F})$$
$$= 19427779.8BTUs\ per\ year$$

Total Energy Use =
$\frac{Energy\ to\ Heat\ Water + Energy\ Losses\ at\ tank\ and\ piping}{Heat\ Content\ of\ Fuel\ x\ Average\ Efficiency\ of\ Equipment} = \frac{19{,}427{,}779.8BTUs\ + 2{,}948{,}832\ BTUs\ per\ year}{92{,}000BTU\ per\ gallon\ x\ .75} =$
$324\ gallons\ per\ year$

3. $Cost = Fuel\ Use\ x\ Cost\ per\ unit = 324\ gallons\ per\ year\ x\ \$2.75\ gallons\ =$ $\$891.00\ per\ year$

II. Current hot water use after installing low flow shower heads, low flow aerator, and radiant barrier at water heater.

C. Dad Shower = 1.3gpm x 5 minutes = 6.5 gallons/day x 7 days/week x 52 weeks/year = 2,366 gallons

Mom Shower = 1.3gpm x 5 minutes = 6.5 gallons/day x 7 days/week x 52 weeks/year = 2,366 gallons

Jessie Shower = 1.3gpm x 15 minutes = 19.5 gallons/day x 7 days/week x 52 weeks/year = 5,050 gallons

Abby Shower = 1.3gpm x 15 minutes = 19.5 gallons/day x 7 days/week x 52 weeks/year = 5,050 gallons

Dishwasher = 6.8 gallons per load x 4 loads/week x 52 weeks/year = 1,414 gallons

Clotheswasher = 18.4 gallons per load x 5 loads/week x 52 weeks/year = 4,784 gallons

Lav-Washing = .75gpm x 1minute/day = .75gallons per day x 5days per week x 52weeks per year = 195 gallons

Miscellaneous Hot Water Use = 10 gallons per week x 52 weeks per year = 520 gallons

Total Hot Water Use = 21,785 gallons per year

$$Average\ per\ Person\ Per\ Day\ =\ 21{,}785\ gallons\ per\ year\ x\frac{1}{365\ days}\ x\ \frac{1}{4\ people}$$
$$=14.92\ gallons\ per\ person\ per\ day$$

B. Energy Use (After upgrade of showers, aerators, etc…)

= Energy to heat hot water + energy loss of water heater jacket + flue losses + pipe losses

1. Tank losses = 75% x 100 watts (25% reduction due to addition of radiant barrier)

$$=\ 75\ watts\ \mathrm{x}\frac{3.413\mathrm{BTU}}{\mathrm{watt}}\ =\ \ 255\mathrm{BTU}$$

$$Per\ Year = 255\ BTU\ x \frac{24 hours}{day} x\ \frac{30\ days}{month}\ x \frac{12\ months}{year} = 2{,}211{,}624\ BTUs\ per\ year$$

2. <u>Energy to Heat Hot Water</u>

$$Energy = Gallons\ x\ specific\ heat\ x\ 8.34 lbs\ per\ gallon\ x\ \Delta T$$

$$= 21{,}785\ gallons\ x \frac{1.0 BTU}{16°\mathrm{F}}\ x\ 8.34 lbs\ per\ gallon\ x\ (120°\mathrm{F} - 55°\mathrm{F}) = 11{,}809{,}648 BTU's\ per\ year$$

$$Total\ Energy\ Use\ = \frac{Energy\ to\ Heat\ Water + Energy\ Losses\ at\ tank\ and\ piping}{Heating\ Content\ of\ Fuel\ x\ Average\ Efficiency\ of\ Equipment}$$

$$= \frac{11{,}809{,}648 + 2{,}211{,}624\ BTUs\ per\ year}{92{,}000\ BTU's\ per\ Gallon\ x\ .75} = 203\ Gallons\ Per\ Year$$

3. $Cost = Fuel\ Use\ x\ cost\ per\ unit = 203\ gallons\ per\ year\ x\ \$2.75\ per\ gallon = \$558.00\ per\ year$

The simple pay back for the aerators, low flow heads and radiant barrier is, as follows:

$$Simple\ Payback = \frac{Shower\ Heads\ (2\ x\ \$59.00)\ +\ Aerators\ (3\ x\ \$49.00)\ +\ radiant\ barrier\ (\$50.00)}{Savings\ per\ year = \$891.00 - \$558.00}$$

$$Simple\ Payback\ = \frac{\$225.00}{\$333.00\ per\ year} =\ .67\ years = 8\ months$$

If you include well pump energy and lift pump savings then payback period will really be much less.

Also, this analysis does not include energy savings due to less water heater blower fan operation.

Solar Domestic Hot Water

From previous analysis including current hot water use, tank losses etc… the estimated yearly cost for domestic hot water is approximately = 203 gallons of propane at $2.75 per gallon

= $558.00 per year

Assume we can save 85% per year = $474.00 per year

Assume the first cost = $3,750.00 material

$2,500.00 labor

$6,250.00 total

Net cost after federal tax = $6,250.00 – (.30 x 6,250.00) = $4,375.00 (Federal Tax Credit is 30% of Total Cost)

Net cost after state grant = $4,375.00 – 2,000.00 = $2,375.00 (State Incentive is $2,000)

$$Simple\ Pay\ Back\ = \frac{\$2{,}375.00}{\$474.00\ per\ year} = 5\ years$$

This is not a bad payback and it does not include cost to operate solar pump nor does it escalate energy costs. This is a decent return on investment.

Return on Investment = $\frac{Annual\ Cost\ Savings}{Installation\ Cost\ After\ Rebates} x\ 100 = \frac{\$474.00}{\$2{,}375.00} x\ 100 = 20\%$