

Energy and Cost Savings Calculations

Introduction

The emissions and cost savings estimates that are a part of the MN Energy Challenge website represent our best efforts to provide users with reasonable estimates of the savings that they can expect from performing the suggested energy saving actions. Our goal in developing the website was to provide users with meaningful, accurate savings estimates that did not require a large amount of user input to generate. There is an inherent tension in these goals in the sense that a greater amount of detail allows for more accurate estimates of energy use and savings, however the time required to provide such detail may reduce the willingness of users to complete the Energy Challenge calculator and reduce the effectiveness of the website. Thus, a complete bottom up analysis of household energy use, such as that found at the Department of Energy's Home Energy Saver website (<http://hes.lbl.gov>), was deemed to be not compatible with the website's goals. However, we felt it important to provide users with more meaningful use and savings estimates than a single universal value would provide. We therefore attempted to provide users with the ability to obtain estimates of their energy use and potential energy savings that take into account those factors such as family size, home size, the efficiency of their vehicles, the length of their commute and number of miles driven in a year, that account for much of the variability in a family's energy use.

More accurate assessments of user's emissions and energy savings can be calculated at other websites. Two sites that perform in depth analyses of home energy use are www.energyguide.com and the Department of Energy's Home Energy Saver at <http://hes.lbl.gov>. These sites generate in depth analyses of home energy use and provide more accurate assessments of the energy savings that can be achieved from particular actions. If the user wishes to use the energy savings estimates from such websites they can be entered into the Energy Challenge Calculator by following the "Let me add my own actions..." link.

Energy Use (Footprint)

The user has the ability to base their Energy Challenge use estimates based upon the use of an average Minnesota household with typical vehicle and driving habits, or upon the user's annual utility bills, vehicular efficiency, and annual miles driven. The average use estimates were derived from resources such as the *Minnesota Utility Data Book* [1], the 2001 Residential Energy Consumption Survey (RECS) [2] and the Bureau of Transportation Statistic's *National Transportation Statistics 2005* [3].

Energy Savings

The cost savings for each of the Energy Challenge actions represents only the avoided energy costs of the user. The savings estimate is not a Net Savings that incorporates the costs of the measure, or any rebates available to those who carry out the measure. The

Net Savings for these actions may vary significantly from the avoided energy costs of the measures. Some of the Energy Challenge actions are no or low cost actions whose Net Savings will be very close to the savings estimates of the website. Other actions, such as insulating un-insulated walls, have significant up-front costs. Many of the higher cost actions are associated with rebates from utilities, low interest loans and/or federal tax credits.

The savings estimates are derived from a number of sources. Savings estimates for electronic appliances as well as some space conditioning actions are often derived from the *2005 Buildings Energy Data Book* and the 2001 RECS. Other savings estimates related to space conditioning were generated with the help of CEE's engineering staff. Savings estimates related to water use are often informed by AWWA Research Foundation's *Residential End Uses of Water* [4]. A more detailed record of the calculations used to estimate energy use and savings can be found in the following section.

Some savings estimates are those that could be expected for an average Minnesota household, while some estimates are based on the savings expected for atypical households. An example of the latter is the estimated savings for insulating un-insulated walls. That estimate is based on the expected savings for homes with very little or no wall insulation (which is atypical in Minnesota). This is because those families with even moderately insulated walls are not likely to increase their insulation level because of the much lower benefit/cost ratio of doing so. This is likely to lead to a high estimated percentage savings for those users that choose to base their calculations upon the consumption of an average Minnesota household.

It is important to note that the savings estimates of the Energy Challenge Calculator represent the savings expected for each single action. There are a number of instances in which performing certain actions will change the savings expected for other related actions. One example of this would be installing a low flow showerhead and a high efficiency water heater. The energy challenge calculator will overestimate the combined savings from these actions because it assumes the existence of an inefficient water heater when calculating the savings from a low flow showerhead.

Carbon Emissions Factors

The CO₂ emissions factors for natural gas, fuel oil, and electricity used by the website were provided by the Minnesota Pollution Control Agency. Other CO₂ emissions factors are from the Energy Information Administration. There is some variability in the various estimates of the emissions factor for electricity in Minnesota. The variability in these estimates arises in large part from different methods of accounting for the sources of the electricity consumed in the state. Some estimates consider only the electricity generated within Minnesota, while others attempt to account for the significant imports of CO₂ free hydro-electricity from Ontario.

Energy Prices

Energy prices have experienced considerable volatility over the past several years. Continued energy price volatility creates the possibility that any price chosen for use in the Energy Challenge Calculator will differ significantly from current retail prices. Retail gasoline prices for the months surrounding the launch of the MN Energy Challenge website provide an excellent example of this. From their peak in early August 2006 to the launch of the website in mid-October gasoline prices have fallen ~30%. The net result of this is that the price of \$2.34/gallon used in the Energy Challenge calculator has been transformed from an apparently conservative estimate of gasoline prices to an apparent over-estimation of gasoline prices.

To accommodate this volatility the Energy Challenge Calculator uses prices for gasoline, fuel oil, propane and natural gas that are three year averages of Minnesota prices during each fuel's high demand season [5], [6]. (The average January price for natural gas, propane and fuel oil, and the average July price for Gasoline). Prices from the high demand season were chosen because that is when much of each fuel is consumed, and therefore should approximate the price most often paid. The electricity price used is the average of the 2005 and 2006 year-to-date residential price in Minnesota [7].

Basic Assumptions

Fuel Emissions Factors and Prices

Fuel Source	CO₂ Content	CO₂ Content	Price
Natural Gas	11.07 lb CO ₂ /therm[8]	110.7 lb CO ₂ /MM Btu[9]	\$1.03/therm
Fuel Oil	22.13 lb CO ₂ /gallon[8]	159.6 lb CO ₂ /MM Btu[9]	\$1.73/gallon
Electricity	1.714 lb CO ₂ /kwh[8]	502.3 lb CO ₂ /MM Btu[9]	\$0.085/kwh
Gasoline	19.56 lb CO ₂ /gallon [9]	156.5 lb CO ₂ /MM Btu [9]	\$2.34/gallon
Propane	12.67 lb CO ₂ /gallon [9]	139.8 lb CO ₂ /MM Btu [9]	\$1.51.gallon

Average Minnesota Household's Energy Use

Average Household Natural Gas Use (MCF)	105[10]
Average Household Natural Gas (Btu)	107,835,000
Average Household Electricity Consumption (kWh)	10,000 [10]
Average Vehicles Owned per Household	2
Average Miles Traveled per Vehicle	12,500 [3]
Average Miles Traveled per Gallon	22 [3]
Average Gallons Consumed per Vehicle per Year	568 [3]

Equipment and Use Assumptions

Space Heating Use Assumptions

Heated Square Footage per Household	2,110[11]
Per Customer for Space Heating (Btu)	87,735,000
Per Square Foot (Space Heating) (Btu)	41,581
Per 250 Square Feet (Space Heating) (Btu)	10,395,142

Space Heating Equipment Assumptions[1]

<i>Equipment</i>	<i>AFUE</i>
Gas Furnace (Old)	74%
Gas Furnace (New)	94%
Gas Boiler (Old)	74%
Gas Boiler (New)	85%
Fuel Oil Furnace (Old)	79%
Fuel Oil Furnace (New)	86%
Fuel Oil Boiler (Old)	74%
Fuel Oil Boiler (New)	85%

Air Conditioning Use Assumptions

<i>Central AC</i>	
Average Cooled Square Feet/Household[11]	2261
Average Full Load Cooling Hours/year [12]	600

Average Central AC Unit Size	2.5 tons	30,000 Btu/hour
Btu/Year/ Average Household		18,000,000
Btu/year/Square Foot (average household)		7,961
Btu/Year/ 250 Square Feet (average household)		1,990,270

Room AC

Historical Average Capacity [1]		10,000 BTU/hr
Average Full Load Cooling Hours/Unit/year [12]		600
Average Btu/year		6,000,000

Air Conditioning Equipment Assumptions

Central AC

Central AC (Pre-1992 Average)		7 SEER
Central AC (Best Available in 2006)		18 SEER
Average Central AC Unit Size	2.5 tons	30,000 Btu/hour

Room AC

Room AC (1980's Average)		7 EER
Room AC (2006 Best Available)		12 EER
Average Room AC Unit Size		10,000 Btu/hour

Air Conditioning kWh Consumption Formula

$$\text{kWh} = (600 \text{ Full Load Cooling Hours} * X \text{ Btu/hour}) / (\text{SEER or EER}) * .001$$

Water Heater Use Assumptions

	Million (BTU)	BTU
Average Minnesota Household Natural Gas Use for Water Heating [13]	20.1	20,100,000
Average Minnesota Household Electricity use for Water Heating [13]	9.7	9,737,848

Household Size	Million BTU/ household (US Average)	% of Average	Minnesota Household Million BTU natural gas	Minnesota Household Million BTU of Electricity
Average (2.4)	15.8		20.1	9.7
1	9.6	64.00%	12.9	6.2
2	14.9	94.30%	19.0	9.1
3	17.8	112.66%	22.6	10.9

	4	20.6	130.38%	26.2	12.6
	5	23.6	149.37%	30.0	14.5
6 or more		25.5	161.39%	32.4	15.7

Per Customer Natural Gas use
for Water Heating (Btu)

20,100,000[13]

Water Heating Equipment Assumptions

	<u>Efficiency Factor (EF)</u>
Gas Fired Storage (Old) (2002 Stock Average) [1]	55%
Gas Fired Storage (New) (2004 Best Available)	65%
Electrical Storage (Old) (2002 Stock Average)	87%
Electrical Storage (New) (2004 Best Available)	95%

Hot Water Use Assumptions

Shower Consumption

Inlet Temp (F)	Shower Temp (F)	WH Outlet Temp (F)
57	104	130
57	104	130
	Energy Factor	0.5
	Showers/day	1
	Occupants	1

Low/No Cost Energy Saving Actions

Compact Fluorescent Lamps

Existing Bulb	70 watts
CFL Replacement	18 watts
Average Hours/day	4

Turn off Lights and Electronics

Average household consumption for lighting, color TV, PC and printer, and VCR/DVD [14].	1743 kwh
Assumed 10% savings	174.3 kwh

Unplug or Dispose of Extra Refrigerator or Freezer

Average Refrigerator Energy Consumption	1232 kwh/year[14]
Average Freezer Energy Consumption	1039 kwh/year
Average	1135.5 kwh/year

Programmable Heating Thermostat

$$\text{Annual Baseline}_{\text{Therms}} = \text{Household Area} * 41581_{\text{Btu/sf/year}}/100000$$

$$\% \text{ Savings for 5 Degree Setback for 8 Hours} = 4.8\%$$

$$\text{Annual Savings}_{\text{Therms}} = \text{Annual Baseline}_{\text{Therms}} * .048$$

AC Thermostat Up 2 Degrees

The percent savings for a series of 2 degree increases in AC Thermostat temperature were estimated using 2 RESNET simulations, as well as the savings estimates provided by the Energy Star cost estimator for programmable thermostats [15]. The average % savings for each 2 degree increment was 13%.

5 Minute Shower

See Above for basic assumptions.

Shower Flow (gpm)	Hot Water	
	Flow (gpm)	Energy (Btu/h)
2.20	1.42	50,940

Shower Time Reduction (min)	Energy Saved		
	Per Shower (Btu)	Per Day (Btu)	Annual (Mcf)
3.7	6,283	6,283	2.29

Furnace Thermostat Down 2 Degrees

Energy Star's Cost Estimator for Programmable Thermostats [15] was used to estimate the percent savings for a range of 2 degree decreases in thermostat setpoints. The Cost Estimator estimates a savings of ~0.9% savings for each two degree decrease in setpoint for each 4 hours. This was extrapolated to 5.5% savings for 24 hours.

Cold Water Wash

Laundry Consumption

Cold Temp (F)	Hot Temp (F)	Wash Vol (gal)	Type of Washes			Hot Water/(day*person)		Energy Use (Btu)	Ann ual (Mcf)
			Co ld %	Wa rm %	Ho t %	Vol (gal)	Energy Load (Btu)		
57	120	15.0	0%	50 %	50 %	11.25	5,835	11,669	4.26
57	120	15.0	75 %	20 %	5 %	2.25	1,167	2,334	0.85
								Energy Savings	3.41
	Energy Factor	0.5							
	Occupant	1							

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Low Flow Showerhead

Reduced Shower Flow (gpm)	Hot Water		
	Flow (gpm)	Energy (Btu/h)	
0.60	0.39	13,893	
	Energy Saved		
Shower Time (min)	Per Shower (Btu)	Per Day (Btu)	Annual (Mcf)
8.2	3,797	3,797	1.39

Water Heater Down 1/8

5% savings on water heating fuel use. ACEEE estimates a 3% to 5% savings per each 10 degree decrease in thermostat temperature [16].

Utility Load Control

Savings estimates were based on Xcel Energy’s Saver’s Switch program which offers a 15% savings on electricity use during the months of June through September. We have proprietary information that suggests that 41% of annual residential electricity use occurs during those months, so the cost savings estimated for this measure are 15% of 41% of the estimated annual electricity bill. Xcel Energy’s CIP filings estimate 13 kWh/year/customer savings.

Close Doors and Windows w/ Room and Central AC

It is CEE’s experience from its fieldwork that many homeowners do not fully seal their homes or apartments when running the air conditioner. The website calculates that a savings of 10% is achievable by closing all doors and windows. This is probably a conservative estimate, however without studying the question in greater detail we did not wish to provide a higher estimate.

Central Air Off at Night

The goal of this action is to have people turn off their AC unit and open their windows on those evenings when the outside air temperature is cool. For the purposes of this analysis we assume that people will do so when the outside air temperature is below 75 degrees at 8 pm. It was assumed that on those evenings when the AC was turned off that it would remain off until 8 am. The Minneapolis/St. Paul data from the Typical Meteorological Year 2 [17] was used to estimate this. A reference point of 65 degrees was assumed. The total degree hours for the year, the total degree hours between 8pm and 8am and the total degree hours between 8pm and 8am for evenings with a temperature above 75 degrees at 8pm were calculated. The following formula was used to estimate that 16.87% of air conditioning energy use can be avoided by not using the AC when it is cool outside at night.

$$\% \text{ AC Use avoided} = (\text{DH } 8\text{pm to } 8\text{am} - >75 \text{ degree at } 8\text{pm}) / \text{Total Degree Hours} * 100$$

Vehicle Actions

Drive Sensibly

The EPA and DOE's website www.fueleconomy.gov estimates that 5% to 33% and 7% to 23% of fuel use can be avoided by driving sensibly and driving the speed limit respectively. We chose to use a conservative estimate of 10% for the combination of the two actions.

Heating Actions

Seal Bypasses

We have assumed a 5% space heating savings for sealing bypasses.

Close Damper

Open area of chimney with a damper = 5 square inches
3"x12" chimney opening with a 1/6" crack around perimeter of the damper.
ASHRAE estimates that 5 sq in equals 75 cfm50 or 7.5 therms/year.

Insulate Walls

Average House

2000 square feet
Square Footprint

8' walls
15% of external area is windows and doors
2x4 construction w/ empty walls
80% AFUE furnace

Savings 0.36 therms/sf/year

Calculation Fuel Savings = $\text{Area}_{\text{wall}} * 0.36$

Insulate Attic

Average House Existing insulation - R15 (4" to 5" of insulation)
Increased to - R44
80% AFUE furnace
Attic Area = 75% of Floor Area

Savings 0.05 therms/sf

Calculation Fuel Savings = $\text{Area}_{\text{roof}} * 0.05$

Major Appliance Actions

Replace Refrigerator

1990 Rated Maximum Electricity Uses (average)[1]	1,152 kwh/year
2006 Average Energy Star Annual Electricity Use[18]	514 kwh/year

Replace Water Heater

Households are assumed to replace a furnace with the equivalent efficiency of the stock average for 2002 with a furnace with the equivalent efficiency of the best available models in 2004 (see Water Heating Equipment Assumptions above). Household hot water use is based on the information under Water Heating Use Assumptions above.

Replace Central/Room Air Conditioner

Savings are based on Air Conditioning Use Assumptions and Air Conditioning Equipment Assumptions above.

Bibliography

1. *2005 Buildings Energy Data Book. 2005*, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, Washington, D.C.
2. *2001 Residential Energy Consumption Survey*. Energy Information Agency, Washington, D.C. Available at: <http://www.eia.doe.gov/emeu/recs/contents.html>
3. *National Transportation Statistics 2005. 2005*, U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics,, Washington, D.C. Available at: http://www.bts.gov/publications/national_transportation_statistics/2005
4. Mayer, P.W. and DeOreo, W.B., *Residential End Uses of Water*. 1999: AWWA Research Foundation.
5. *Petroleum Navigator. 2006*, Energy Information Administration. Available at: http://tonto.eia.doe.gov/dnav/pet/pet_pri_gnd_dcus_nus_w.htm
6. *Natural Gas Navigator. 2006*, Energy Information Administration. Available at: http://tonto.eia.doe.gov/dnav/ng/ng_pri_sum_dcu_nus_m.htm
7. *Average Retail Price of Electricity to Ultimate Customers by End-Use Sector, by State. 2006*, Energy Information Administration, Washington, D.C. Available at: http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_b.html
8. Butcher, Keith, e-mail from Peter Ciborowski. (8/24/06) Minnesota Pollution Control Agency, Minneapolis, MN
9. *Fuel and Energy Source Codes and Emission Coefficients*. Voluntary Reporting of Greenhouse Gases Program [cited 2006 8/29/06]; Available from: <http://www.eia.doe.gov/oiaf/1605/coefficients.html>.
10. *Energy Policy and Conservation Report. 2004*, Minnesota Department of Commerce,, St. Paul. Available at: http://www.state.mn.us/mn/externalDocs/Commerce/Quadrennial_Report_2004_071404102049_2004-QuadReport.pdf
11. *Residential Energy Consumption Survey 2001*. Energy Information Administration, Available at: <http://www.eia.doe.gov/emeu/recs/recs2001/detailcetbls/html>

12. *Life Cycle Cost Estimate for 1 Energy Star Qualified Central Air Conditioner*. 2005, U.S. Department of Energy, U.S. Environmental Protection Agency.
13. *Residential Energy Consumption Survey 2001*. Available at:
<http://www.eia.doe.gov/emeu/recs/recs2001/detailcetbls/html>
14. *Residential Energy Consumption Survey 2001 Special Topics: End Use Consumption of Electricity*. Energy Information Administration, Available at:
<http://www.eia.doe.gov/emeu/recs/recs2001/enduse2001/enduse2001.html>
15. *Life Cycle Cost Estimate for 1 Energy Star Qualified Programmable Thermostat*. U.S. Environmental Protection Agency, U.S. Department of Energy, Washington, D.C. Available at:
http://www.energystar.gov/index.cfm?c=thermostats.pr_thermostats
16. Wilson, Alex, Thorne, Jennifer, and Morrill, John, *Consumer Guide to Home Energy Savings*. 8th ed. 2003, Washington, D.C.: American Council for an Energy-Efficient Economy.
17. *Typical Meteorological Year 2 for Minneapolis/St. Paul*. 1995, National Renewable Energy Laboratory. Available at:
http://rredc.nrel.gov/solar/old_data/snrdb/tmy2/state/html
18. *Energy Star Qualified Refrigerators and Freezers*. 2006