A Very, Very Fine House: Saving Energy in Residential Buildings

Residential savings may be the best known, and are certainly the most mature renewable energy technologies.

Climate control in new homes can easily be reduced from the average U.S. standard through high levels of insulation without thermal bridges, tight seals, high-quality single pass ventilation, and high efficiency windows. In Germany, Jürgen Schnieders conducted a study of various "Passivhuas" (passive house) buildings[213] in Germany, documenting that on average they saved 90% of heating and cooling costs compared to U.S. averages, while adding about 10% to construction costs. That is easily recovered (with interest) over the course of a 15 year mortgage or by slightly higher rents that will still save tenants money in lower utility bills.

In existing homes we can save less, around 60%, by weather sealing to one air change per hour, insulating attics, floors, and ducting, and installing modest window forms of window insulation – such as window insulation kits, tinting or insulated drapes.

On average in the U.S. a 60% reduction would save about $400 per year[214] . Capital costs for the saving will run between $1,000 and $3,000. So energy savings provide an eight year simple (interest free) payback; add interest to provide a 6.5% real rate of return, and this stretches out to twelve years. You can shave a bit off this by timing such remodeling close to the time you have to replace your furnace, (and air conditioner if you use one). After insulation, you can buy a 30% to 50% smaller furnace[i], at 15% to 20% less -another $200 savings; price differences between larger and smaller air conditioners will result in similar savings.

You can go further, retrofitting anything you would install in a new home, but while it may improve your home air quality, and show social responsibility, it won't pay for itself in money.

This is not just something that can be done; it is something that has been done.

The NAHB Research Center, Inc. did a study for the National Renewable Energy Laboratory documenting a gut rehab that saved over 80% of heating and cooling energy cost effectively[215].

When it comes to new homes, more than 5,000 such homes have been built in the EU - including some in areas of Finland well north of Alaska.

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[i]You have to size your furnace for peak not average usage –so can't cut by as much as your total energy savings.

Professor Soontorn Boonyatikarn in hot humid Bangkok, Thailand built a home that uses 1/15th the overall energy of a normal upper middle class Thai home[216]. Its air conditioner is one quarter the tonnage of a normal Bangkok air conditioner for a home this size. This home cost about $124,000 to build, normal for a Thai home of it's size in his neighborhood. Amory Lovins claims that total cooling requirements are about 10% of average[217].

In the same book, Amory and Hunter Lovins and Paul Hawken suggest the headquarters/residence of the organization the Lovins run and live in as an example:

Rocky Mountain Institute headquarters in Colorado is at an elevation of 7,100 feet. It gets as cold as -47 degrees F in this location. Amory Lovins claims they saved 99% of space heating energy, and used 92 percent efficient heat recovering ventilators, and that they saved construction costs over conventional techniques.

We can demonstrate similar savings for domestic water-heating - after climate control the next largest energy consumer in the home - 17.28% of residential use[218], adding $207 per to the average yearly bill[219]. A systems approach to water energy savings will include water savings as well; in 2002, the average annual price of water and other public services was $326[220]. Estimating $25 a month of this as trash removal cost means that water & sewer charges ran about $300 per year. So, combined water, sewage, and water-heating dollars total around $507 annually.

To improve efficiency in both water use and water heating, we might do the following:

Expense Description	*Cost*	*Savings/Comment*
Non-emergency scheduled plumbing labor	$210	Quote from local plumber.
Find & repair all leaks - additional materials	$25	100%
2 bathroom tap aerators to lower flow from 2.6 Gallons per Minute (GPM) to .5 GPM	$7[221]	80% savings over 2.6 GPM average
1 kitchen tap aerator to lower flow from 2.6 GPM kitchen sink to 1.1 GPM	$1.50[222]	~58% savings over 2.6 GPM kitchen sink average
2 Stepflow kick pedal sinks controllers	$270[223]	50% savings
2 Aqua Helix low flow showerhead nozzles to lower shower flow from 2.5 GPM to .5 GPM	$60.00[224]	80% savings
2 Microphor 2 quart (1/2 gallon) compared to 2.6 standard "low flow" toilet in most homes (note: new toilets in U.S. cannot exceed 1.6 gallon flush - but a lot of existing ones are 2.6 and even five gallons - so a 2.6 gallon average is a LOW estimate.)	$1,078[225]	80% savings
Whole house drain heat recovery system - recovers heat from discarded hot water to raise temperature of cold water fed to water heater.	$240[226]	55% energy savings only
Difference between energy efficient dishwasher (ASKO D3350[227])and standard[228] at normal replacement time (ISO certified for 15 year lifespan[229]	$333[230]	45%
Difference between energy efficient washing machine(GWL11[231]) and standard[228] at normal replacement time	$220	78%[232]
Landscape water conservation (drip or micro-sprinkler irrigation system) combined with more efficient landscaping. (Watering at right time, rain gauge to avoid over-watering, building soil to reduce runoff, plants with same water requirements in same place, avoid watering sidewalks, driveway etc.)	$400[233]	50%
SubTotal	**$2,844.50**	

So now we can figure our heat and water savings. Note that while most of the savings apply to a particular appliance or sector of household water/hot water use, the whole house drain heat recovery system apply to all water heating.

How much do these savings total?

Given the distribution of water use, the measures we outlined would reduce hot water consumption[234] (and therefore hot water energy) as follows:

Means	Savings as % of source	Savings as % total consumption
Faucet - 34.3%	Assuming kitchen sink uses 75% hot water, we save 58% of kitchen sink hot water, and 85% in other two sinks for a total savings of 64.75% of sink hot water use.	22.21%
Dishwasher - 3.6%	45%	1.62%
Clothes washer – 15.5%	78%	12.09%
Bath - 16.7%	No savings	
Shower - 25.1%	80%	20.01%
Subtotal		**55.93%**
Leak Repair – 4.08% of remaining 44.07%	100% - We fix all leaks	2.12%
Subtotal	**Hot water savings**	**58.05%**
Subtotal - hot water energy savings	**Standby losses (due to water heater running even when no hot water used) means energy net savings are lower.**	**46.40%**
Drain Recovery System	Gross savings 55%	Less than 18.5% net[i]
Subtotal (energy)		**Less than 65%**
Tankless water heater heats water only on demand – when hot water is used.	Saves almost all remaining energy use. Tankless water heater are more expensive than conventional, but thanks to reduced demand, when current heater wears out you can buy a small tankless for the same as the old storage heater it replaces[235,236]	
Total Energy Savings		**~85%**

The same measures reduce water use as follows[72]:

Category	**Percent use**	**Percent savings**	**Total**
toilet flushing	20.91%	80.00%	16.73%
Bathing	17.95%	48.00%	8.62%
Cleaning	9.28%	70.00%	6.50%
Sinks	3.06%	64.75%	1.98%
Outdoor	32%	50.00%	16.00%
Subtotal			**49.82%**
Leak repair then saves 4.8% of remaining use			2.41%
Total			**52.23%**

[i] From 55% to 18.4% is a big drop. Remember we have already reduced hot water consumption by 46.4% - so it can only recover heat from ~53.6% remaining. A GFX heat exchanger can't do anything about standby consumption –which remains about 20% of original (not reduced) consumption; so that leaves slightly under 33.6% available to actually apply that 55% recovery to. 55% of 33.6% is slightly under 18.5%.

So we save 52.23% of water inflow and sewage outflow, and 85% of water heating energy use. Given the values we looked at for costs ($207 for heating, $300 for water and sewer), at a 6.5% discount rate, the present value of these savings over a thirteen year period is around ~$2,860 - a trivial gain over $2,845. Thus, we can save ~85% of hot water cost, and around half of water consumption at around zero costs, or a very miniscule gain. Aside from the social benefits we do have some additional personal benefits as well. Water saving dishwashers and washing machines also save soap. Ultra low flush toilets actually tend to have fewer jams, need fewer double flushes, and have fewer plumbing problems in general than standard low flush ones. Tankless water heaters occupy less space than standard ones, last longer, and are easier to repair. Kick pedal sink controls help slow disease transmission within the home, and also provide convenience when your hands are full. (In fact most kick pedal sink controls installed within homes are installed for these reasons and not for the purposes of water savings.)

The following table lists the climate control and water heating savings above, along with potential savings from other water appliances:

Residential Savings	**% Total Consumption**	**% We Save of This Type**	**Net % Savings**	**Average Net Present Value (NPV) of savings**
Heating, Cooling, and Ventilation	53.05%	New -90% Existing-60% Total-70%	New-47.7% Existing-31.8% Total-37.1%	New-$2,870 Existing -$1,903
Water Heating	17.28%	85%	14.68%	$20
Refrigeration (Wuppertal refrigerator[85]) – as described in section on material intensity a built in refrigerator freezers, constructed on the spot rather than shipped may incorporate more insulation and more efficient heat pumps and motors – greatly increasing operating efficiency.	5.69%	78.10%	4.44%	$128
Other Appliances, Lighting, and Phantom Loads (Compact fluorescent lamps [237], Washers with better spin dry cycles to reduce drying[238], Gas/Propane rather than electric dryers[239], moisture sensors[240], most efficient cooking appliances, turning computers off when not in use, LCD monitors, turning on energy saving feature, power strips on appliances to cut off phantom loads)	24.07%	51.85%	12.48%	$345
Total			New 79.36% Existing 63.44% Total 68.75%	New $3,370 Existing $2,405 Total $2,860

If you look at amount of energy consumption remaining and the NPV of the savings, you will note that after these investments are made homeowners and renters will break even buying renewables at around double the price of fossil fuels. In other words, the price we pay per amount of energy would increase – but because we would use so much less, our total energy bill (including payments on more slightly more expensive homes and appliances) will be less than at present.

End Notes

[213]Jürgen Schnieders, *CEPHEUS - Measurement Results from More Than 100 Dwelling Units in Passive Houses.* May 2003. *Passive House Institute*, 23/Dec/2003 <http://www.passiv.de/07_eng/news/CEPHEUS_ECEEE.pdf>.

(Note: he documented an 80% reduction compared to German standards. But Germans use about half the energy per capita as the U.S.

States Census Bureau, "Section 19 - Energy and Utilities," *Statistical Abstract of the United States 2002*. December 2002. *United States Census Bureau* <http://www.census.gov/prod/2003pubs/02statab/energy.pdf>.p847
Table No. 1350. Energy Consumption and Production by Country: 1990 and 2000

So this is a 90% savings, compared to U.S. standards. Actually it is a bit more, because the 80% savings compares to tougher requirements for new German homes, not average use.

[214]U.S. Department of Energy - Energy Information Administration, "2001 Consumption and Expenditures Tables - Space-Heating Expenditures Tables," *A Look at Residential Energy Consumption in 2001*. 23/October 2003, 23/Dec/2003 <ftp://ftp.eia.doe.gov/pub/consumption/residential/2001ce_tables/spaceheat_expend.pdf>

Table CE2-9e. Space-Heating Energy Expenditures in U.S. Households by Northeast Census Region, 2001 - Preliminary Data

Table CE2-12e. Space-Heating Energy Expenditures in U.S. Households by West Census Region, 2001 - Preliminary Data

U.S. Department of Energy - Energy Information Administration, "2001 Consumption and Expenditures Tables - Electric Air-Conditioning Expenditures Tables," *A Look at Residential Energy Consumption in 2001*. 23/October 2003, 23/Dec/2003 <ftp://ftp.eia.doe.gov/pub/consumption/residential/2001ce_tables/ac_expend.pdf>.

Table CE3-9e. Electric Air-Conditioning Energy Expenditures in U.S. Households by Northeast Census Region, 2001 - Preliminary Data

Table CE3-12e. Electric Air-Conditioning Energy Expenditures in U.S. Households by West Census Region, 2001 - Preliminary Data

[215]Joe Wiehagen and Craig Drumhelle, *Strategies for Energy Efficient Remodeling | Seer 2003 |Case Study Report*, 2004). 30/Mar 2004. *National Renewable Energy Laboratory*, 1/Oct/2005 <http://www.toolbase.org/docs/MainNav/Remodeling/4564_SEERCaseStudyReport.pdf>.

[216] Agence France-Presse, *Thai Architect Hits on Blueprint for Sustainable Living in the Tropics*. 28/September 2003, Terra Daily, 06/Jul/2005 <http://www.terradaily.com/2003/030928033742.6azaxajn.html>.

Maria Cheng and Julian Gearing, "Green Seeds,". *Asia Week* 27-18 11/May 2001, Asia Week, 05/Jul/2005 <http://www.asiaweek.com/asiaweek/magazine/nations/0,8782,108626,00.html>.

[217]And according to Amory Lovins this was larger than he needed.
Paul Hawken, Amory Lovins, and L.Hunter Lovins, *Natural Capitalism: Creating the Next Industrial Revolution* (Boston: Little, Brown and Company/Back Bay, 2000).
Chapter 5:Building Blocks. p103.

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[218]U.S. Department of Energy - Energy Information Administration, "2001 Consumption and Expenditures Tables - Total Energy Consumption," *A Look at Residential Energy Consumption in 2001*. 23/October 2003, 23/Dec/2003 <ftp://ftp.eia.doe.gov/pub/consumption/residential/2001ce_tables/enduse_consump.pdf>.

Table CE1-9c. Total Energy Consumption in U.S. Households by Northeast Census Region, 2001 - Preliminary Data

U.S. Department of Energy - Energy Information Administration, "2001 Consumption and Expenditures Tables - Water-Heating Consumption Tables," *A Look at Residential Energy Consumption in 2001*. 23/October 2003, 23/Dec/2003 <ftp://ftp.eia.doe.gov/pub/consumption/residential/2001ce_tables/waterheat_consump.pdf>.

Table CE4-9c. Water-Heating Energy Consumption in U.S. Households by Northeast Census Region, 2001 - Preliminary

[219]U.S. Department of Energy - Energy Information Administration, "2001 Consumption and Expenditures Tables - Water-Heating Expenditures," *A Look at Residential Energy Consumption in 2001*. 23/October 2003, 23/Dec/2003 <ftp://ftp.eia.doe.gov/pub/consumption/residential/2001ce_tables/waterheat_expend.pdf>

Table CE4-9e. Water-Heating Energy Expenditures in U.S. Households by Northeast Census Region, 2001 - Preliminary Data

Table CE4-10e. Water-Heating Energy Expenditures in U.S. Households by Midwest Census Region, 2001 - Preliminary Data

[220]U.S. Department of Labor Bureau of Labor Statistics, "Table 8. Region of Residence: Average Annual Expenditures and Characteristics," *Consumer Expenditure Survey 2002*. 13/Nov 2003. *U.S. Department of Labor Bureau of Labor Statistics*, 06/Jul/2005 < http://www.bls.gov/cex/2002/Standard/region.pdf>.

Table 8. Region of residence: Average annual expenditures and characteristics, Consumer Expenditure Survey, 2002

[221]Whedon 0.5 GPM Ultra SaverAerator - US$3.50
Energy Federation Incorporated, *EFI Internet Division Residential Catalogue | Bath Faucet Aerators*. July 2005, Energy Federation Incorporated, 13/Jul/2005 <http://www.energyfederation.org/consumer/default.php/cPath/27_52>.

similar product to above for $2.15
Conserv-A-Store, *Conserv-A-Store :: Recycling Supplies, Solar Lighting, Electrical, Plumbing & Water Conservation Products-Economical & Eco-Friendly! Part Number: 01-0104*. July 2005, Conserv-A-Store, 13/Jul/2005 <http://www.conservastore.com/productdetail.php?p=23>.

[222]Conserv-A-Store, *Conserv-A-Store :: Recycling Supplies, Solar Lighting, Electrical, Plumbing & Water Conservation Products-Economical & Eco-Friendly!*. July 2005, Conserv-A-Store, 13/Jul/2005 <http://www.conservastore.com/index_plumbing.htm>.

[223]According to the Handyman Club the Stepflow Kick Pedal should be discounted to $129
Tom Sweeney, *Handyman Club of America - Hands Free - Pedal Valve Makes Sink Faucets Convenient and Clean.* February 1999, Handyman Club of America (Publishers of Handy Magazine), 13/Jul/2005 <http://www.handymanclub.com/document.asp?cID=57&dID=777>.

And here it is on-line for $120.00 with shipping and such probably around $129 .
Professional Piercing Information Systems, *Products: Step-Flow Operated Sink Valve*. 16/June 2005, Professional Piercing Information Systems, 13/Jul/2005 <http://www.propiercing.com/products.html>.

[224]Priced at $27.00 without shipping at sustainable village. Assuming six bucks in shipping charges total of $60. Since sustainable village ships this only to developing nations, I've given the URL of manufacturer who should be able to tell where we in the U.S. can actually buy it.

Sustainable Village, *Sustainable Village - Products - Aqua Helix*. 2005, Sustainable Village, 13/Jul/2005 <http://www.thesustainablevillage.com/servlet/display/product/detail/22602>.

Jet Blast Industrial Services, *Aqua Helix Home*. 18/Feb 1999, Jet Blast Industrial Services, 13/Jul/2005 <http://www.jetblast.net/ahhome.html>.

[225]Microphor LF-210 $539.00
Dean Petrich, *Toilet Prices*. 16/July 2005, Ultra-Low Water-Flush toilets, Aqua Alternatives, 20/Jul/2005 <http://www.enviroalternatives.com/toiletprices.html#ULTRA-LOW%20WATER-FLUSH>.

[226]WaterFilm Energy Inc., *GFX 40% Off.* GFX Heat Exchanger, 25/May 2005, WaterFilm Energy Inc., 20/Jul/2005 < http://www.gfxtechnology.com/sale.html>.

Carmine Dr. Vasile, *International Data on Successfully Demonstrated Energy Efficiency Projects - Residential Waste Water Heat-Recovery System: GFX.* April 2000, Centre for the Analysis and Dissemination of Demonstrated Energy Technologies, 20/Jul/2005 <http://gfxtechnology.com/CADDET.PDF>.

Note where showers are not the main hot water consumer in the household storage recovery systems are available in the same price range:

National Association of Home Builders Research Center, *Drainwater Heat Recovery.* 2004, National Association of Home Builders Research Center, 08/Aug/2005 <http://www.toolbase.org/tertiaryT.asp?DocumentID=2134&CategoryID=1402>.

[227]EnergyStar Dishwasher product rating - in this case 85% better than average new model (so divide by 185).
(Note: this does not quite double efficiency of what is currently for sale, which means it is probably double or better that currently in use - but we will use EnergyStar rating as conservative estimate of savings)

Energy Star Program of the EPA and DOE, *Energy Star Qualified Dishwashers*, List of Energy Star Dishwashers with Efficiency Ratings. 14/June 2004, Energy Start Program of the EPA and DOE, 10/Jul/2005 <http://www.energystar.gov/ia/products/prod_lists/dishwash_prod_list.pdf>.p1

[228]Average Energystar & regular appliance prices 2000

The NPD Group, Inc., *NPD INTELECT REPORTS SIGNIFICANT GROWTH FOR ENERGY-EFFICIENT APPLIANCES.* Average Appliance Prices: Energystar Vs. Non-Energystar, 18/October 2000, The NPD Group, Inc., 10/Jul/2005 < http://www.npd.com/press/releases/press_001018.htm>.

(Note: A market survey is a legitimate source for pricing information).

[229]ASKO, *D3350*. 204, ASKO, 05/Jul/2005 <http://www.asko.se/ASKO/brandsite/main.cfm?moduleID=10&productID=2814#>.

[230]Universal Appliance and Kitchen Center, *24" ASKO Dishwasher, D3121*. Quote July 10 for Asko D3121, July 2005, Universal Appliance and Kitchen Center, 10/Jul/2005 <http://store.universal-

akb.net/24asdid3.html>. (Note this was for a particular day – the key is that you can get a dishwasher that consumes around 250 kWh per year for around $333 more than a non-Energy Star model.)

[231]Liz Madison, *Kitchen Tools, Kitchen Electrics, Cookware, Tableware - LizMadison.Com -GWL11*. GWL11 Clothes Washer, July 2005, Liz Madison, 10/Ju <http://www.lizmadison.com/housewares/Product.asp_X_SKU_Y_GWL11_Z_REF_Y_SHLIZ>.

No doubt the particular page will have expired by the time you read this. The main point is that you can get a washing machine that saves nearly 80% of the energy a non-Energy Star model would use for about $220 more.

[232]Energy Star Program of the EPA and DOE, *ENERGY STAR® Qualified Clothes Washers*, ENERGY STAR® Qualified Clothes Washers with Effiiciencies and Projected Yearly KWh Consumption. 21/June 2004. *Energy Star Program of the EPA and DOE*, 11/Jul/2005 <http://www.energystar.gov/ia/products/prod_lists/clotheswash_prod_list.pdf>.

(Again this rates against average new available, so efficiency compared to installed home clothes washers is probably slightly better.)

[233]Mark Hutchinson, *Trickle Irrigation: Using and Conserving Water in the Home Garden - University of Maine Cooperative Extension Bulletin #2280*. April 2005, University of Maine Cooperative Extension, 13/Jul/2005 < http://www.umext.maine.edu/onlinepubs/htmpubs/2160.htm>.

[234]William B. DeOreo, David M. Lewis, and Peter W. Mayer, *Seattle Home Water Conservation Study: The Impacts of High Efficiency Plumbing Fixture Retrofits in Single-Family Homes*. December 2000. *Aquacraft, Inc. Water Engineering and Management*, 08/Aug/2005 <http://www.cuwcc.org/Uploads/product/Seattle-Final-Report.pdf>.p54.

[235]Madison Gas & Electric Company, *Water Heaters*. Feb/25 2005. *Madison Gas and Electric Company*, Madison Gas and Electric Company, 08/Aug/2005 <http://www.mge.com/images/PDF/Brochures/Residential/WaterHeaters.pdf>.p3.

[236]Low Energy Systems, Inc, *Infinion with Battery Spark Ignition*. August 2005, Low Energy Systems, Inc, 08/Aug/2005 <http://www.tanklesswaterheaters.com/infinion2.html>.

[237] U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, "Energy Savers: Compact Fluorescent Lamps," *Energy Savers: A Consumer Guide to Renewable Energy and Energy Efficiency*, 21/June 2004, 19/Aug/2005 <http://www.eere.energy.gov/consumerinfo/factsheets/ef2.html>.

[238]Fisher & Paykel, *Washers*. August 2005, Fisher & Paykel, 19/Aug/2005 <http://usa.fisherpaykel.com/laundry/washers/washers.cfm>.

[239]Secondary (end use) consumption is 4 kWh per load for the electric dryer, plus .23 kWh per load plus .22 therms per load for the gas dryer. If you convert therms to kWh at 100% efficiency this comes out the gas dryer actually using 67% more energy than an electric dryer.

Energy Star Program of the EPA and DOE, "About the HES Appliance Module," *The Home Energy Saver*, Table 3: Other Appliances and Miscellaneous Energy Usages, 06/June 2001, Energy Star Program of the EPA and DOE, 20/Aug/2005 < http://homeenergysaver.lbl.gov/hes/aboutapps.html>.

However, on average heat driven power plants convert only 36.47% of heat energy into electricity.

International Energy Agency, *Electricity Information 2002 Edition*, Electricity Information, vol. 2002 Edition, no. ISBN 9264197931 (Paris: OECD - Organisation for Economic Co-operation and Development, 2002).p.II.706

Part II Table 9 United State Electricity Production From Combustible Fuels in Electricity Plants"

So dividing the electricity consumption in both gas and electric dryers by 36.47, and then converting both to therms or both to kWh as you please, you end up with a 35.47% savings.

[240]California Energy Commission, "Dryers," *Consumer Energy Center - Inside Your Home*, August 2005, California Energy Commission, 20/Aug/2005 <http://www.consumerenergycenter.org/homeandwork/homes/inside/appliances/dryers.html>.