Policy Recommendations for the HERS Community to Consider regarding HERS point credit for Waste Water Heat Recovery Devices

Executive Summary

The performance of a waste water heat recovery device[1] in a typical residential water heating installation was analyzed[2] and **Energy factor (EF) enhancement** coefficients determined as a function of fuel (electricity or gas), GAMA Directory/DOE EF[3], volume of hot water use, water main inlet temperature, proportion of hot water use that is "batch" vs. "continuous"[4], heat exchanger effectiveness of the device, and waste water stream

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[1]Waste Water Heat Recovery's operating principle is the pre-heating of incoming main water on its way to the water heater with heat recaptured from warm outgoing drain water. An on-the-market device that utilizes this technology and was the subject of this analysis was the Gravity-Film-Heat Exchanger (GFX) device developed by WaterFilm Energy, Inc. http://gfxtechnology.com/

[2]A residential installation was modeled with a waste water heat recovery device installed between the water main and the water heater inlet. A set of linked steady-state energy balance equations was solved in a spreadsheet-based simulation to predict the energy factor enhancement of a 52-gallon electric & a 40-gallon gas water heater (the most-commonly-encountered sizes). The enhancement factor does not depend on the size water heater since the effect of that parameter is already "encapsulated" in the value of the GAMA/DOE energy factor.

[3]GAMA directory: http://www.gamanet.org/publist/publist.htm

DOE water heater test procedure:

http://www.eere.energy.gov/buildings/appliance_standards/residential/pdfs/D-2.pdf

http://www.bfrl.nist.gov/863/heat_transfer_group/appliance.htm

http://www.eere.energy.gov/buildings/appliance_standards/residential/waterheaters_051198.html

http://www.eere.energy.gov/buildings/appliance_standards/residential/pdfs/water_heater_fr.pdf

[4]**"Continuous" (Simultaneous) Draws of Hot Water** (for showers, hand washing, dishwashing by hand, etc.), warm (~100 F) waste water ("gray water") *simultaneously* flows down the drain (and through the hot side of the waste water heat recovery device heat exchanger) and transfers heat to the incoming water main water on its way to the water heater (via the cold side of the device's heat exchanger). **"Batch" Draws of Hot Water** (for baths, dishwasher cycles, clothes washer cycles, etc.), where hot water draw is not simultaneous with warm waste water

temperature. **To transpose to a HERS score the GAMA Directory DOE EF of a water heater should be multiplied by this enhancement coefficient, and the resulting modified EF input into the HERS scoring algorithm/software.**
The enhancement coefficients are valid for the following ranges of conditions (and are easily interpolated between any of these values):

DOE EF (energy factor) of conventional water heater (from GAMA Directory)

- gas water heater: 0.54 to 0.68 (w/recovery efficiencies ranging from 0.74 to 0.85)
- electric water heater: 0.8 to 0.94 (w/0.98 recovery efficiency)

Volume of hot water use per day (proxy = number of bedrooms)

- 50 gallons of hot water use per day (2-bedrooms)
- 60 gallons of hot water use per day (3-bedrooms)
- 70 gallons of hot water use per day (4-bedrooms)
- 80 gallons of hot water use per day (5-bedrooms)

(Note: In HERS assumptions, gpd of water use = 30 + 10 * number of bedrooms).

Water Main Inlet Temperature (proxy = average annual ambient air temperature)[5]

The following set of climatic conditions are correlated to **water main inlet temperature**

- 45 F average annual inlet water/avg.annual ambient temperature - "cold" climate
- 55 F average annual inlet water/avg.annual ambient temperature - "mixed" climate
- 65 F average annual inlet water/avg.annual ambient temperature - "mild" climate
- 75 F average annual inlet water/avg.annual ambient temperature - "hot" climate

Allocation of Hot Water Use Between "Batch" and "Continuous" Modes[6]

Use	% of total	Mode
Dishwasher	10.8%	batch
Clothes Washer	12.6%	batch
Baths	8.0%	batch
	31.4%	**<--subtotal**
Shower	41.6%	continuous
Other (mostly sinks)	27.0%	continuous
	68.6%	**<--subtotal**
	100.0%	**<---TOTAL**

Heat Exchanger Effectiveness: 0.4 to 0.6

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draining, does not offer the same potential for heat exchange, since for the most part flow through the hot and cold sides of the heat exchanger does not occur at the same time.

[5] A good approximation of **annual average water main temperature** in a particular location is the **average annual ambient air temperature** for that location. See NOAA isotherm map at http://lwf.ncdc.noaa.gov/img/documentlibrary/clim81supp3/tempnormal_hires.jpg

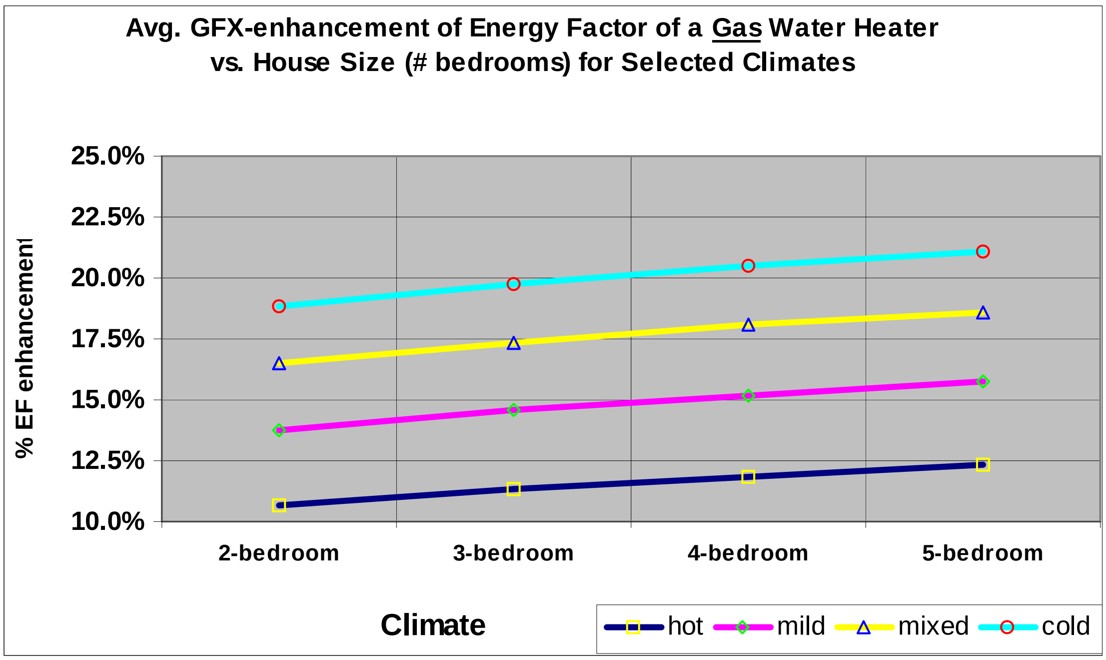
[6] from Hiller, Carl C. & Andrew Lowenstein, *Disaggregating Residential Hot Water Use*, ASHRAE Transactions: Symposia AT-96-18-1; and Hiller, Carl C. & Andrew Lowenstein, *Disaggregating Residential Hot Water Use – Part II*, ASHRAE Transactions: Symposia SF-98-31-2

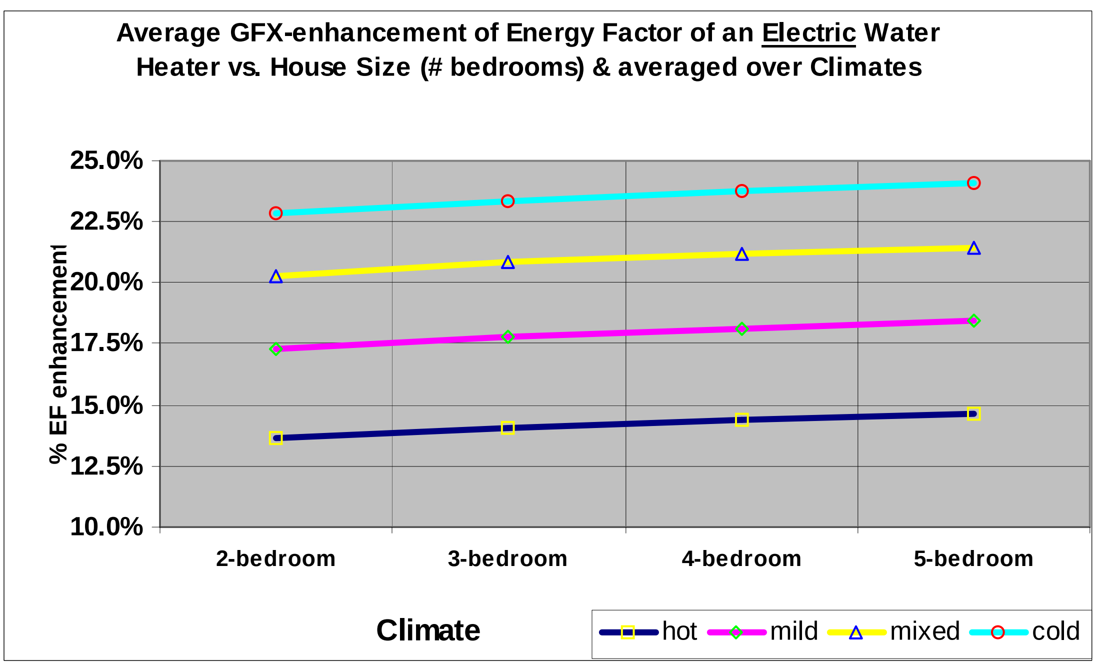
Waste Water Stream Temperature: 100 F

Water Heater Tank Size: independent of this variable (effect accounted for in GAMA/DOE EF)

Energy Factor Enhancement Coefficients

The following two graphs illustrate the energy factor performance enhancement for a typical 52-gallon electric and an 40-gallon gas water heater - as a function of hot water use volume (i.e., number of bedrooms) and water main temperature (i.e., climate) due to the installation of a waste water heat recovery device. In these graphs a device heat exchanger effectiveness of 0.5 was assumed, along with a 100 F waste water stream temperature. Exact regression equations are delineated below.





Regression Equations

For the simulations performed for this study the % energy factor enhancement coefficients are predicted by the following curve-fit equations, where,

HXeff = waste water heat recovery device heat exchanger effectiveness [dimensionless] for any particular installation

EF_{DOE} = the DOE energy factor rating of a water heater [dimensionless]

RE = the DOE recovery efficiency rating of a water heater [dimensionless]

gpd = average gallons per day of hot water use [gallons per day]

T_{main} = avg. water main inlet temperature [F] (i.e., avg. annual ambient air temperature)

Note: although these simulations were for water heaters of particular specified sizes, the analysis the equations are valid for other sizes since the thermal losses due to different sizes are embodied in the GAMA/DOE EF value.

The curve fits of the regression equations to the actual EF enhancement coefficient and energy cost savings data are shown graphically in the Results section above.

Electric: 52-gallon tank, EF_{DOE} ranging from 0.80 to 0.94

EF enhancement factor = (HXeff/0.5)^1.15 *
$(1.35 + 0.285 * Ln\{ EF_{DOE}^{0.8} * gpd^{0.06} / [(T_{main}+453)/453)]^{5.6} \})$

- So, GFX-enhanced new energy factor = old energy factor * EF enhancement factor
- <u>How to use in HERS Calculations</u>: Multiply the water heater's EF_{DOE} by the EF enhancement factor and enter this new value as the EF_{DOE} in the HERS rating algorithm (i.e., as a HERS rating software input). ($R^{2>}$=0.95)

Gas: 40-gallon tank, EF_{DOE} ranging from 0.54 to 0.68

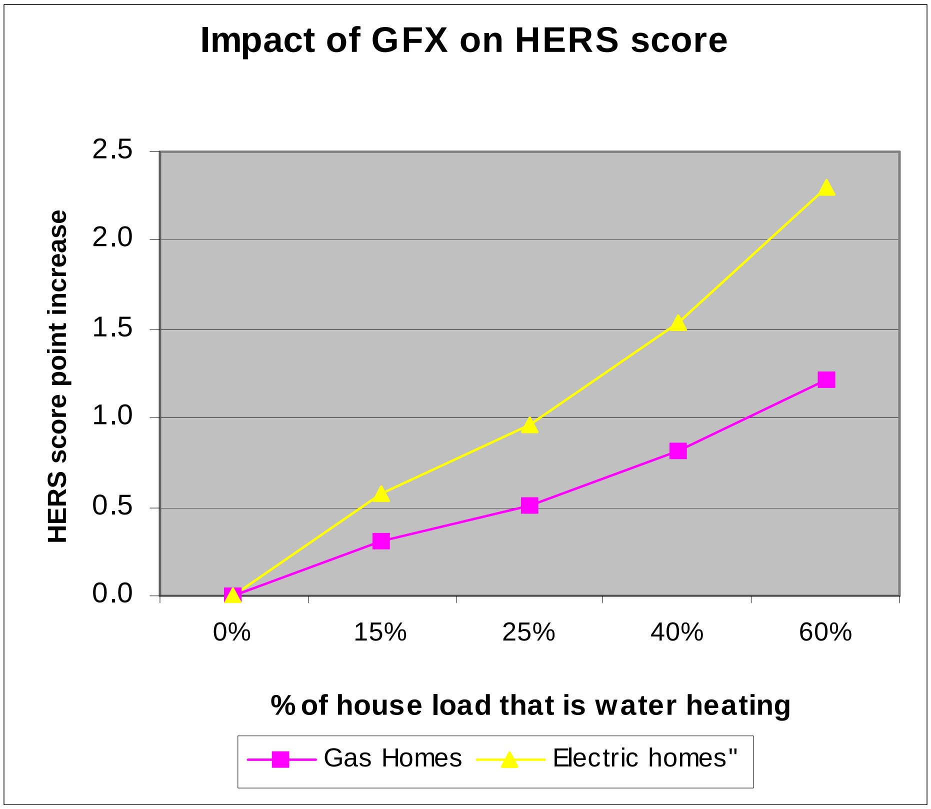
EF enhancement factor = (HXeff/0.5)^1.18 *
$(1.3015 + 0.284 * Ln\{ EF_{DOE}^{0.86} / RE^{0.8} * gpd^{0.095} * [(T_{main}+453)/453)]^{5.18} \})$

- So, GFX-enhanced new energy factor = old energy factor * EF enhancement factor
- <u>How to use in HERS Calculations</u>: Multiply the water heater's EF_{DOE} by the EF enhancement factor and enter this new value as the EF_{DOE} in the HERS rating algorithm (i.e., as a HERS rating software input). ($R^{2>}$=0.95)

Further Comments on HERS Score Impacts

This analysis concentrated on impacts on the **energy factor (EF)** parameter. The EF is an input to a HERS algorithm, which is used to calculate a **HERS score**. A higher EF will contribute to a higher HERS score; however, it is not possible to predict an exact general numerical correlation between the two, since the HERS score depends on the different proportions of heating, cooling and water heating energy use a house experiences in different climate regions and with different house geometrical design, orientation & size, and thermal envelope & HVAC equipment efficiency specifications.

An example of the impact that a waste water heat recovery device has on the HERS score of a typical residence in a mixed climate, as a function of the proportion of the house energy use that is water heating is illustrated in the graph below:



Recommendations

This analysis was performed to provide guidance to engineers and HERS raters for incorporating the installation of waste water heat recovery devices into HERS scoring algorithms. Of course for any particular installation the results of a custom engineering analysis could supplant these general equations.

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