Drain Water Heat Recovery Systems
and Introduction of a Proposed Method
for Site-Specific Water Heating EF

Presented by:
Rod Buchalter

www.renewability.com
In residential, DWHR works by using the outgoing **warm drain water** (typically the shower) to HEAT the incoming **cold fresh water**
Picture taken at a site in Traverse City, Michigan
Demonstrability: It is one of the most obvious and visible energy saving technologies that a builder can showcase. People can even feel the heat pickup on the DWHR unit when hot water runs down the drain.

Low-cost technology for credits in energy efficiency labeling programs (e.g. Energy Star for New Homes V2 & Canada, LEED for Homes)

Saves customers up to 35% on water heating costs (for 54% eff unit)

Positions builder as innovative and environmentally aware

Strengthens reputation as a leading edge builder

Substantially increases water heating systems effective capacity

Reduces greenhouse gas emissions

Maintenance free with no moving parts

Will increase the life of the water heater

Easy to install
Why all the excitement about DWHR? Tradeoff-Benefit is Great!

- This table is based upon Government Data for achieving similar performance to Canadian ESNH Versions 3&4 level.
- DWHR is about 3x less costly for the credit vs. upgrading walls from R19 to R24.
- This analysis has not yet been done for the US but similar numbers are expected. Note that DWHR saves less in a mild climate but there is also less space conditioning load.
Well over 100 builders include DWHR as a standard in all their homes

Another 200 builders offer the DWHR as an option in their homes

Over 6,000 new homes had DWHR installed in 2011 which is almost 20% of the housing starts

Over 15,000 DWHR units installed in Ontario to date
Hot Water Energy Consumption

- Water heating loads have been ignored in past
- Water heating is second largest energy load among many building types
- Expect higher percentage for new construction without DWHR
- This load is too large to ignore!!

According to the US DOE:

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Typical Hot Water Energy Load (% of total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homes - Detached</td>
<td>20.0%</td>
</tr>
<tr>
<td>Homes - Attached</td>
<td>21.3%</td>
</tr>
<tr>
<td>Multi-Res (2-4 apart's)</td>
<td>18.4%</td>
</tr>
<tr>
<td>Multi-Res (&gt;= 5 apart's)</td>
<td>22.4%</td>
</tr>
<tr>
<td>Lodging (dorms, hotels, etc.)</td>
<td>31.4%</td>
</tr>
<tr>
<td>Foodservice (e.g. Restaurants, Cafeterias, etc.)</td>
<td>15.6%</td>
</tr>
<tr>
<td>Hospitals - Inpatient</td>
<td>19.4%</td>
</tr>
<tr>
<td>Education (Locker Rooms in High School &amp; Colleges)</td>
<td>7.0%</td>
</tr>
</tbody>
</table>

SOURCE: U.S. DOE Website
For existing U.S. Building Stock.

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Residential Water Heating in the U.S. and Canada

Breakdown of Energy Consumption in Homes

- **Space Heating**: 59.3%
- **Lighting**: 4.4%
- **Appliances**: 14.0%
- **Water Heating**: 21.7%
- **Other**: 8.7%
- **Showering**: 13.0% of Total Energy Consumption

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Common Heat Exchangers

- found in cars, refrigerators, industrial applications

- work well when both fluids are clean

- cannot pass large solids and foul quickly

- not double-walled and vented - cannot be used for potable water
Falling Film Heat Exchangers

- **surface tension:**
  - as water falls through a version drain pipe, it clings to the inner surface

- **center section**
  - open pipe
  - large solids

- **high-efficiency,**
- **non-fouling**
- **maintenance-free**
Falling Film Heat Exchangers

- **Heat transfer:**
  - contact time is not essential
  - intimate contact fluid / wall is important

- **Drain water:**
  - very thin, turbulent film
  - < 1 mm thick

- **Result:**
  - Drain water
  - Heat Transfers to
  - Fresh water
1- Potable Water Safety
- double-walled and vented
- two walls of separation
dirty drain water // fresh water

2- Water Pressure Loss
- pressure loss is necessary but it must be minimized so that it is not noticed

3- Counter-Flow
- necessary for high efficiency
4- Efficient and Low Maintenance
   excellent contact between the two walls
   long service life
   maintenance-free
   do not foul over time

5- Variety of Sizes
   Freshwater connection: ¾in or 1in

Drain diameters: 2in, 3in, 4in, 6in
Drain length: 2ft to 10ft
Three Generations of DWHR Design

1st Generation:

- single coil
  - ½in diameter
  - arranged on inner drain pipe
  - for homes, does not comply to building code in many jurisdictions for Equal Flow and to Water Heater Only

- efficient
- high pressure loss in freshwater supply line
Three Generations of DWHR Design

2nd Generation:

- 2 or more 1st generation units stacked in series
- lower pressure loss
- lower efficiency
  - not a “counter-flow” heat exchanger
Three Generations of DWHR Design

3rd Generation

- multiple coils arranged in parallel on inner drain pipe
- optimized design:
  - highest efficiency
  - low pressure loss
- Currently 4 or 6 tubes
- patented and patents pending
NRCan Study: July 2007

Reported Pressure Loss of Drain Water Heat Recovery units from the Ministry of Natural Resources Canada Testing

- 60" Power-Pipe
- 60" GFX
- 60" Retherm
- 58" Watercycles (Lo-Copper)

1st Generation units cause VERY high water pressure loss
Standard Canadian Low Flow Showerhead
Insignificant water pressure loss with 2nd Generation Units and the Power-Pipe

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Reported Efficiency of Drain Water Heat Recovery units from the Ministry of Natural Resources Canada Testing*

- 60” Power-Pipe
- 60” GFX
- 60” Retherm
- 58” Watercycles (Lo-Copper)

The Power-Pipe multi-parallel coil design has the Highest Efficiency among ALL units

Efficiency

Shower Flowrate [USgal/min]

1st Generation Single Coil Units
2nd Generation Duo Coil Unit
Standard American Low Flow Showerhead
Standard Canadian Low Flow Showerhead

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# Hot Water Energy Savings Technology Comparisons

<table>
<thead>
<tr>
<th></th>
<th><strong>COST &amp; ENERGY SAVINGS</strong></th>
<th><strong>RETURN ON INVESTMENT</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SINGLE RESIDENTIAL</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Falling-Film DWHR with rated eff of 53.9%</td>
<td>25-35%</td>
<td>10-50%</td>
</tr>
<tr>
<td>• Standard On-Demand (tankless)</td>
<td>6-18%*</td>
<td>5-15%</td>
</tr>
<tr>
<td>• Freeze Protected Solar Water Heating</td>
<td>35-55%</td>
<td>0.1-5%</td>
</tr>
</tbody>
</table>

*NOTE: The California State Energy Commission de-rates the EF of On-Demand Water Heaters with a factor of 0.92. Also based upon incremental cost of $600 and On-Demand do not save energy during space heating season. The savings are about 6% for MN, WI, MI, NY, etc to about 12% for SC, UT, CA, etc to 18% in South FL.

<table>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>MULTI-UNIT RESIDENTIAL</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Falling-Film DWHR with rated eff of 55.7%</td>
<td>16-39%</td>
<td>20-40%</td>
</tr>
<tr>
<td>• Solar Water Heating (freeze protected)</td>
<td>10-50%</td>
<td>3-15%</td>
</tr>
</tbody>
</table>

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</thead>
<tbody>
<tr>
<td><strong>COMMERCIAL &amp; INDUSTRIAL</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Falling-Film DWHR Multi-Pipe System</td>
<td>40-60%</td>
<td>50-300%</td>
</tr>
<tr>
<td>• Other Heat Exchangers (not often possible)</td>
<td>5-20%</td>
<td>30-400%</td>
</tr>
</tbody>
</table>

*Falling-Film DWHR Technology Can Provide:*

* • High % savings impact  
  • Excellent Return on Investment,  
  • Long Maintenance-Free Operation, and  
  • NO negative impact on lifestyle (or process for commercial & industrial)*
Drain Water Heat Recovery recovers approximately 50% of the valuable heat energy that goes down the drain when you shower.

This recovered heat energy will allow you to reduce your water heating costs by up to 35%.

DWHR unit(s) must be installed vertically.
How % Energy Savings is Calculated in the following slides

% Energy Savings for DWHR

\[ \% \text{ Energy Savings} = \% \text{ Contribution of Domestic Hot Water} \times \] 

Maximum Possible DWHR Savings

(if unit is 100% efficient)

Rated Efficiency at Rated Flowrate

Limitation / Be Aware:

-Most accurate and generally applicable but does not provide the actual energy savings

Advantage:

-% Savings is useful for LEED

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• divert entire freshwater supply through DWHR unit immediately after it passes through water meter

• up to .5 ton of CO₂ savings per year per home with gas water heating

*Please NOTE: The LEED Points listed here are subject to project specific approval and are provided for illustration purposes only
Equal Flow with Slab-on-Grade

- install drain water heat recovery unit in wall of main floor
- 2 inch or 3 inch units commonly used

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Design Variation</th>
<th>Typical Hot Water Energy Load (% of total) A</th>
<th>Typical Reduction in Hot Water Load B</th>
<th>Typical Potential Savings of Total Energy Load (% of total) A*B</th>
<th>Typical LEED Points Achievable in IECC Climate Zones 6-8 - North</th>
<th>Typical LEED Points Achievable in IECC Climate Zones 1-5 - South</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homes - Detached</td>
<td>1-2 Washrooms</td>
<td>20.0%</td>
<td>35.0%</td>
<td>7.0%</td>
<td>7.4</td>
<td>7.6</td>
</tr>
<tr>
<td>Homes - Attached</td>
<td>(WC) in home</td>
<td>21.3%</td>
<td>35.0%</td>
<td>7.5%</td>
<td>7.7</td>
<td>8.0</td>
</tr>
</tbody>
</table>

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Equal Flow with Basement

- Equal Flow Configuration - plumbing fresh water from DWHR unit to water heater and fixtures
- maximizes heat exchanger's ability to extract heat from outgoing warm drain water

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Unequal Flow to Water Heater

- connect fresh water from DWHR unit to water heater only
- unequal flow application results in about 25% lower energy savings

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<tbody>
<tr>
<td>Homes - Detached</td>
<td>1-2 Washrooms</td>
<td>20.0%</td>
<td>26.3%</td>
<td>5.3%</td>
<td>6.0</td>
<td>6.1</td>
</tr>
<tr>
<td>Homes - Attached</td>
<td>(WC) in home</td>
<td>21.3%</td>
<td>26.3%</td>
<td>5.6%</td>
<td>6.3</td>
<td>6.4</td>
</tr>
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Unequal Flow to Shower

- preheated water connected to the cold side of shower only

- unequal flow application results in about 25% lower energy savings

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Home Installation

1

2

3

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Drain Water Heat Recovery for Single Homes

Home Installation

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When to Insulate DWHR Units

- virtually no heat loss from drain water heat recovery unit installed in room kept at 70°

- insulate DWHR unit to prevent condensation when bottom half of unit can be below dew point temperature during operation (enclosed in a wall)

- insulate when temperature of drain water exceeds 120F
Temperature Rise on 49.2 eff @ 2.5 gpm

Fresh Inlet ~ 46°F: 79°F
Drain Inlet ~ 101°F: 38.5°F
Fresh Outlet ~ 75°F: 23.7°F
- **Utility rebates**: Union Gas, Enbridge, Gaz Metro, Minnesota Power, Virginia Public Utilities and others

- **Energy Efficiency Programs**: Energy Star For New Homes in United States & Canada, LEED, state grant programs
- Minnesota Power
  $ 400 rebate (website)

- Virgina Public Utilities
  $ 400 rebate (review application form)
Water Heating: Simply Save Energy, Save Water and Stop Wasting Money

Drain Water Heat Recovery (DWHR)

Water heating is one of the largest energy expenses in the home, accounting for about 15–25 percent of residential energy costs. Yet, 90 percent of that heat goes right down the drain, costing you energy and money. Drain Water Heat Recovery (DWHR) technology can reduce water heating costs by up to 40 percent. This electric energy savings in turn translates into a reduction in greenhouse gas emissions by up to one ton per year.

“Drain Water Heat Recovery units are relatively easy to install. You know they work right after you put them in. Turn on the shower and you can feel nice tempered water going to the hot water tank. They reduce wear and tear on the water heater and there are no moving parts, so they are virtually maintenance free. I feel they are a worthwhile investment.”

Carol Nortz, Plumber, Carlson Duluth Company

Click here to read the Building Up Newsletter on Drain Water Heat Recovery
Power-Pipe™ Drain
Water Heat Recovery
Power-Pipe™

Power-Pipe - 3 In. Diam, 48 In. Long
(Price includes drain connectors)

Model: R3-48
Internet/Cat #: 938835
Saves up to 30 percent on water heating.
Return on investment of 15 to 50 percent - one of the highest for energy saving products!
Reduces greenhouse gas emissions in one home by up to 1 tonne/year
Easy, do-it-yourself installation
Maintenance-free

Price: $690.00

Add to Cart

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Some Other References

Government of France:

Government of Canada:
http://oee.nrcan.gc.ca/residential/personal/retrofit-homes/drain.cfm?attr=4

Minnesota Power:
http://www.mnpower.com/powerofone/one_home/waterheating/dwhr/

U.S. DOE:
http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13040

Sears Canada
http://www.sears.ca/stores/shop/search?langId=1&storeId=10051&catalogId=10001&N=0&Ntk=level1&Ntt=drain+water+heat+recovery&Nty=1&D=drain+water+heat+recovery&Ntx=mode+matchall&Dx=mode+matchall&initialquery=true&internalSearch=true

Home Depot Canada:
http://www.homedepot.ca/catalog/drain-water-heat-recovery/173006
Energy Factor (EF) Enhancement

e.g. 0.67 EF gas water heater without DWHR to 0.93 EF with DWHR Efficiency of 57% at 2.25gpm

Limitation / Be Aware:
- Does not give actual energy savings
- Ensure that home energy simulation software does not reduce space heating with increased input Water Heating EF

Advantage:
- On a level playing field with other water heating technologies (e.g. Tankless)
  - Easy to compare technologies
- Is widely applicable for Residential labeling programs (e.g. Energy Star)
Falling Film Heat Exchangers - How they Work, Design and Background

NOTE:
-GFX is the tradename of a specific proprietary DWHR
-Wast Water Heat Recovery is not the “industry accepted term”
Regression Equations

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

\[ HX_{\text{eff}} \] = waste water heat recovery device heat exchanger effectiveness [dimensionless]

for any particular installation

\[ EF_{\text{DOE}} \] = 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]

\[ T_{\text{in}} \] = 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,**

\[ EF_{\text{DOE}} \] ranging from 0.80 to 0.94

\[ EF_{\text{enhancement factor}} = (HX_{\text{eff}}/0.5)^{1.15} \times (1.35 + 0.285 \times \ln (EF_{\text{DOE}}^{0.8} \times gpd^{0.06} / ((T_{\text{in}} + 453)/453)^{5.6} )) \]

- So, GFA-enhanced new energy factor = old energy factor \* EF enhancement factor
- How to use in HERS Calculations: 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

\[ EF_{\text{enhancement factor}} = (HX_{\text{eff}}/0.5)^{1.18} \times (1.3015 + 0.284 \times \ln (EF_{\text{DOE}}^{0.86} / RE^{0.8} \times gpd^{0.95} / ((T_{\text{in}} + 453)/453)^{5.18} )) \]

- So, GFA-enhanced new energy factor = old energy factor \* EF enhancement factor
- How to use in HERS Calculations: 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). (\( R^2 = 0.95 \))
Example: **Natural Gas Water Heating and DWHR**

<table>
<thead>
<tr>
<th>DWHR Rated Effectiveness</th>
<th>Gas Tank Mixed Climate 2 bedrooms</th>
<th>Gas Tank Mixed Climate 3 bedrooms</th>
<th>Gas Tank Mixed Climate 4 bedrooms</th>
<th>Gas Tank Mixed Climate 5 bedrooms</th>
</tr>
</thead>
<tbody>
<tr>
<td>42.0%</td>
<td>0.960</td>
<td>0.964</td>
<td>0.967</td>
<td>0.970</td>
</tr>
<tr>
<td>44.0%</td>
<td>1.014</td>
<td>1.018</td>
<td>1.022</td>
<td>1.025</td>
</tr>
<tr>
<td>46.0%</td>
<td>1.069</td>
<td>1.073</td>
<td>1.077</td>
<td>1.080</td>
</tr>
<tr>
<td>48.0%</td>
<td>1.124</td>
<td>1.128</td>
<td>1.132</td>
<td>1.136</td>
</tr>
<tr>
<td>50.0%</td>
<td>1.179</td>
<td>1.184</td>
<td>1.188</td>
<td>1.192</td>
</tr>
<tr>
<td>52.0%</td>
<td>1.235</td>
<td>1.240</td>
<td>1.244</td>
<td>1.248</td>
</tr>
<tr>
<td>54.0%</td>
<td>1.291</td>
<td>1.297</td>
<td>1.301</td>
<td>1.305</td>
</tr>
<tr>
<td>56.0%</td>
<td>1.348</td>
<td>1.353</td>
<td>1.358</td>
<td>1.362</td>
</tr>
<tr>
<td>57.0%</td>
<td>1.376</td>
<td>1.382</td>
<td>1.387</td>
<td>1.391</td>
</tr>
<tr>
<td>58.0%</td>
<td>1.405</td>
<td>1.411</td>
<td>1.416</td>
<td>1.420</td>
</tr>
<tr>
<td>60.0%</td>
<td>1.462</td>
<td>1.468</td>
<td>1.473</td>
<td>1.478</td>
</tr>
<tr>
<td>62.0%</td>
<td>1.520</td>
<td>1.526</td>
<td>1.531</td>
<td>1.536</td>
</tr>
<tr>
<td>64.0%</td>
<td>1.578</td>
<td>1.584</td>
<td>1.590</td>
<td>1.595</td>
</tr>
<tr>
<td>66.0%</td>
<td>1.636</td>
<td>1.643</td>
<td>1.649</td>
<td>1.654</td>
</tr>
<tr>
<td>68.0%</td>
<td>1.695</td>
<td>1.702</td>
<td>1.708</td>
<td>1.713</td>
</tr>
<tr>
<td>70.0%</td>
<td>1.754</td>
<td>1.761</td>
<td>1.767</td>
<td>1.773</td>
</tr>
<tr>
<td>72.0%</td>
<td>1.813</td>
<td>1.821</td>
<td>1.827</td>
<td>1.833</td>
</tr>
</tbody>
</table>

For example, DWHR (57% efficiency at 2.25gpm) and with a Gas Water Heater having an EF=0.67, the “EF for Water Heating” is now **EF=0.93** (which is 0.67*1.387) according to EPA methodology for a 4 Bedroom Home on Gas Water Heating in a mixed climate zone.
**Example: Electric Water Heating and DWHR**

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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>42.0%</td>
<td>0.996</td>
<td>0.999</td>
<td>1.001</td>
<td>1.003</td>
</tr>
<tr>
<td>44.0%</td>
<td>1.051</td>
<td>1.054</td>
<td>1.056</td>
<td>1.058</td>
</tr>
<tr>
<td>46.0%</td>
<td>1.106</td>
<td>1.109</td>
<td>1.111</td>
<td>1.113</td>
</tr>
<tr>
<td>48.0%</td>
<td>1.162</td>
<td>1.165</td>
<td>1.167</td>
<td>1.169</td>
</tr>
<tr>
<td>50.0%</td>
<td>1.217</td>
<td>1.221</td>
<td>1.223</td>
<td>1.226</td>
</tr>
<tr>
<td>52.0%</td>
<td>1.274</td>
<td>1.277</td>
<td>1.280</td>
<td>1.282</td>
</tr>
<tr>
<td>54.0%</td>
<td>1.330</td>
<td>1.334</td>
<td>1.336</td>
<td>1.339</td>
</tr>
<tr>
<td>56.0%</td>
<td>1.387</td>
<td>1.390</td>
<td>1.393</td>
<td>1.396</td>
</tr>
<tr>
<td><strong>57.0%</strong></td>
<td><strong>1.415</strong></td>
<td><strong>1.419</strong></td>
<td><strong>1.422</strong></td>
<td><strong>1.425</strong></td>
</tr>
<tr>
<td>58.0%</td>
<td>1.444</td>
<td>1.448</td>
<td>1.451</td>
<td>1.454</td>
</tr>
<tr>
<td>60.0%</td>
<td>1.501</td>
<td>1.505</td>
<td>1.509</td>
<td>1.511</td>
</tr>
<tr>
<td>62.0%</td>
<td>1.559</td>
<td>1.563</td>
<td>1.567</td>
<td>1.569</td>
</tr>
<tr>
<td>64.0%</td>
<td>1.617</td>
<td>1.621</td>
<td>1.625</td>
<td>1.628</td>
</tr>
<tr>
<td>66.0%</td>
<td>1.675</td>
<td>1.680</td>
<td>1.683</td>
<td>1.686</td>
</tr>
<tr>
<td>68.0%</td>
<td>1.734</td>
<td>1.738</td>
<td>1.742</td>
<td>1.745</td>
</tr>
<tr>
<td>70.0%</td>
<td>1.793</td>
<td>1.797</td>
<td>1.801</td>
<td>1.805</td>
</tr>
<tr>
<td>72.0%</td>
<td>1.852</td>
<td>1.856</td>
<td>1.860</td>
<td>1.864</td>
</tr>
</tbody>
</table>

For example, a DWHR (57% efficiency at 2.25gpm) and with an Electric Water Heater having an EF=0.92, the “EF for Water Heating” is now **EF=1.31** (which is 0.92*1.422) according to EPA methodology for a 4 Bedroom Home on Electric Water Heating in a mixed climate zone.
3.10.2. Drainwater Heat Recovery (DHR)

(1) Drainwater Heat Recovery (DHR) technology has demonstrated a significant potential to reduce energy use and peak loads for water heating and is eligible for credits in ENERGY STAR qualified new homes using one of the options below:
(a) Under Section 3.11 Electrical and Appliances Savings Requirements, or under Section 3.12 Fuel Savings Credits.
(b) Using a combined energy factor (EF) with a hot water heater, it may meet the EF requirements for water heaters in the Alternative Building Packages described in Section 4.
(c) Using a combined EF with a hot water heater, or as an Energy Credit, it may be part of alternate compliance using EGNH software as described in Section 5.1.

(2) The combined EF may be calculated as shown in the paper “Drainwater Heat Recovery Credits for ENERGY STAR Qualified New Homes”, Energy Building Group Ltd., 21 March, 2006.
(3) The product must be labeled: “Approved for Potable Water”. The product must be certified by a Canadian licensed certification company such as ULC, CSA, ETL, etc.
(4) The product must be tested for heat exchange effectiveness at 9.5 lpm flow using hot water drain at 41.0C and entering water supply no greater than 9.5C.
(5) The product must be installed according to the manufacturer’s instructions.
(6) Where a single DHR unit is installed in a house with two or more stacks the credit must be reduced by 1/3 if not connected to all the showers in the house.
Falling Film Heat Exchangers - How they Work, Design and Background

**Calculation of the Combined Energy Factor**

It is recommended that the credits be based upon the determination of a “Combined Energy Factor”, \( Ef_{\text{combined}} \), which is a reformulation of the US DOE method (ref 2) for testing and rating of water heaters with consideration to addition of a DHR unit to the home. This \( Ef_{\text{combined}} \) for a water heating combines both DHR and any primary water heater which has been rated and is listed by GAMA: Gas Appliance Manufacturers Association (www.gamanet.org). This method is general enough to include combinations of all primary energy consuming water heaters and all accepted DHR units as described above; it also considers standby losses separate from recovery efficiency. This method was recently proposed by Gerald Van Decker, P.Eng., M.A.Sc. of RenewABILITY Energy Inc., manufacturer of the Power-Pipe line of DHR products (ref 3).

\[
Ef_{\text{combined}} = \frac{Q_{\text{load}}}{Q'_{\text{TotalFuel}}}
\]

Where,

\[
Q'_{\text{TotalFuel}} = \frac{Q_{\text{stby}}}{N_r + \frac{Q_{\text{load}} * (1 - \text{DHRMaxFactor} \times N_{\text{DHR}} \times \text{PF})}{N_r}}
\]

\[
Q_{\text{load}} = 15,894.46 \text{ MJ/year (ref 2)}
\]

\[
Q_{\text{stby}} = Q_{\text{load}} \times (\frac{N_r}{Ef} - 1)
\]

Note: These Equations were developed based upon Energy Balances with the EF Test Methodology.

DHRMaxFactor=.599 was determined from testing by NRCan. \( N_{\text{DHR}} \) is the DWHR rated efficiency, \( \text{PF} \) is 1 for equal flow and 0.75 for unequal flow and \( N_r \) is the water heater Recovery Efficiency.

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These Numbers are based upon the “Combined Energy Factor” Calculations and Independent Performance Testing according to an NRCan Protocol

A CSA Performance Testing Standard may be released in late 2012 / all Manufacturers are expected to have their units by July 2013

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Comparison of DWHR Methods and Moving Forward...

-Both Methods were developed Independently
-Both Methods have the same Purpose
-The U.S. Method Includes Climate Zone
-The Canadian Method is based upon Energy Balance, Results in a Simpler Equation(s) and works for all water heaters and all DWHR Efficiencies

NOTE:
-EF for Water Heaters is fairly good but it is based upon an Average US Climate and an Average US Load
-EF itself does not provide a means to accurately model/predict actual Hot Water Energy Consumption for any site
Comparison of Methods and Moving Forward...

What is Needed:
- We Propose a Method for Calculating “Site Specific EF” based upon: Rated EF, Climate Zone, Load, and use of DWHR (and/or Solar Water Heating)

- This Site Specific EF would also make it simple to account for the energy savings from having Efficient Water Distribution Systems because a Reduced Load would easily be considered

- This Site Specific EF has been developed and is under Preliminary Review
  - It is based upon a big, yet straightforward equation
  - Some results shall now be presented....
# Site Specific EF Examples - One Case

<table>
<thead>
<tr>
<th>Water Heater EF Test Conditions</th>
<th>Water Heater Site Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rated Energy Factor</strong></td>
<td><strong>Site Energy Factor</strong></td>
</tr>
<tr>
<td><strong>EF</strong></td>
<td><strong>EF</strong></td>
</tr>
<tr>
<td>0.67</td>
<td>TBD</td>
</tr>
<tr>
<td><strong>Recovery Efficiency</strong></td>
<td><strong>Recovery Efficiency</strong></td>
</tr>
<tr>
<td>$\eta_r$</td>
<td>$\eta_r$</td>
</tr>
<tr>
<td>79%</td>
<td>82%</td>
</tr>
<tr>
<td><strong>Water Heater Temperature</strong></td>
<td><strong>Water Heater Temperature</strong></td>
</tr>
<tr>
<td>$T_{\text{test,del}}$</td>
<td>$T_{\text{test,del}}$</td>
</tr>
<tr>
<td>135°F</td>
<td>120°F</td>
</tr>
<tr>
<td><strong>Cold Water Temperature</strong></td>
<td><strong>Annual Ave Cold Water Temp.</strong></td>
</tr>
<tr>
<td>$T_{\text{test,in}}$</td>
<td>$T_{\text{test,in}}$</td>
</tr>
<tr>
<td>58°F</td>
<td>45°F</td>
</tr>
<tr>
<td><strong>Room Temperature</strong></td>
<td><strong>Room Temperature</strong></td>
</tr>
<tr>
<td>$T_{\text{room}}$</td>
<td>$T_{\text{room}}$</td>
</tr>
<tr>
<td>67.5°F</td>
<td>67.5°F</td>
</tr>
<tr>
<td><strong>Volume Per Day</strong></td>
<td><strong>Volume Per Day</strong></td>
</tr>
<tr>
<td>$V_{\text{test}}$</td>
<td>$V_{\text{test}}$</td>
</tr>
<tr>
<td>64.3 gal</td>
<td>50 gal</td>
</tr>
<tr>
<td><strong>Site EF without DWHR</strong></td>
<td><strong>Site EF with DWHR</strong></td>
</tr>
<tr>
<td>EF*</td>
<td>EF&quot;</td>
</tr>
<tr>
<td>0.613</td>
<td>0.834</td>
</tr>
<tr>
<td><strong>DWHR Rated Efficiency</strong></td>
<td><strong>Energy Factor Modifier</strong></td>
</tr>
<tr>
<td>57.0%</td>
<td>EF&quot;/EF</td>
</tr>
<tr>
<td><strong>Plumbing Factor</strong></td>
<td>1.245</td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>
Site Specific EF Examples - Cold Climate

### Site Specific Water Heating EF with and without Drain Water Heat Recovery

<table>
<thead>
<tr>
<th>Zone: &quot;Cold&quot; Climate</th>
<th>Average Annual Water Mains Temperature: 45 °F</th>
<th>Recovery Efficiency: η_r = 82%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated Energy Factor:</td>
<td>EF = 0.67</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>House Detail:</th>
<th>1 Bedroom</th>
<th>2 Bedrooms</th>
<th>3 Bedrooms</th>
<th>4 Bedrooms</th>
<th>5 Bedrooms</th>
<th>6 Bedrooms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Water Load [gal/day]</td>
<td>40</td>
<td>50</td>
<td>60</td>
<td>70</td>
<td>80</td>
<td>90</td>
</tr>
<tr>
<td>DWHR Efficiency</td>
<td>None</td>
<td>0.581</td>
<td>0.613</td>
<td>0.637</td>
<td>0.655</td>
<td>0.669</td>
</tr>
<tr>
<td></td>
<td>40%</td>
<td>0.705</td>
<td>0.753</td>
<td>0.789</td>
<td>0.817</td>
<td>0.840</td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>0.745</td>
<td>0.799</td>
<td>0.840</td>
<td>0.871</td>
<td>0.897</td>
</tr>
<tr>
<td></td>
<td>60%</td>
<td>0.789</td>
<td>0.850</td>
<td>0.897</td>
<td>0.933</td>
<td>0.962</td>
</tr>
</tbody>
</table>

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### Site Specific Water Heating EF with and without Drain Water Heat Recovery

<table>
<thead>
<tr>
<th>House Detail:</th>
<th>1 Bedroom</th>
<th>2 Bedrooms</th>
<th>3 Bedrooms</th>
<th>4 Bedrooms</th>
<th>5 Bedrooms</th>
<th>6 Bedrooms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Water Load [gal/day]</td>
<td>40</td>
<td>50</td>
<td>60</td>
<td>70</td>
<td>80</td>
<td>90</td>
</tr>
<tr>
<td><strong>DWHR Efficiency</strong></td>
<td>None</td>
<td>0.602</td>
<td>0.632</td>
<td>0.654</td>
<td>0.670</td>
<td>0.683</td>
</tr>
<tr>
<td></td>
<td>40%</td>
<td>0.736</td>
<td>0.782</td>
<td>0.816</td>
<td>0.841</td>
<td>0.862</td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>0.780</td>
<td>0.831</td>
<td>0.869</td>
<td>0.899</td>
<td>0.922</td>
</tr>
<tr>
<td></td>
<td>60%</td>
<td>0.829</td>
<td>0.887</td>
<td>0.931</td>
<td>0.964</td>
<td>0.991</td>
</tr>
</tbody>
</table>

*Zone: "Mixed" Climate*

- Average Annual Water Mains Temperature: 55°F
- Rated Energy Factor: EF = 0.67
- Recovery Efficiency: \( \eta_r = 82\% \)
### Site Specific Water Heating EF with and without Drain Water Heat Recovery

#### Zone: "Mild" Climate

<table>
<thead>
<tr>
<th>Average Annual Water Mains Temperature:</th>
<th>65 °F</th>
<th>Recovery Efficiency:</th>
<th>( \eta_r = 82% )</th>
</tr>
</thead>
</table>

#### Rated Energy Factor:

\( EF = 0.67 \)

<table>
<thead>
<tr>
<th>House Detail:</th>
<th>1 Bedroom</th>
<th>2 Bedrooms</th>
<th>3 Bedrooms</th>
<th>4 Bedrooms</th>
<th>5 Bedrooms</th>
<th>6 Bedrooms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Water Load [gal/day]</td>
<td>40</td>
<td>50</td>
<td>60</td>
<td>70</td>
<td>80</td>
<td>90</td>
</tr>
<tr>
<td>DWHR Efficiency</td>
<td>None</td>
<td>0.625</td>
<td>0.652</td>
<td>0.672</td>
<td>0.686</td>
<td>0.698</td>
</tr>
<tr>
<td></td>
<td>40%</td>
<td>0.771</td>
<td>0.813</td>
<td>0.843</td>
<td>0.867</td>
<td>0.885</td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>0.819</td>
<td>0.866</td>
<td>0.901</td>
<td>0.928</td>
<td>0.949</td>
</tr>
<tr>
<td></td>
<td>60%</td>
<td>0.873</td>
<td>0.927</td>
<td>0.967</td>
<td>0.998</td>
<td>1.022</td>
</tr>
</tbody>
</table>

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### Site Specific Water Heating EF with and without Drain Water Heat Recovery

<table>
<thead>
<tr>
<th>Zone: &quot;Hot&quot; Climate</th>
<th>Average Annual Water Mains Temperature: 75°F</th>
<th>Recovery Efficiency: η_r = 82%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated Energy Factor: EF = 0.67</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>House Detail:</th>
<th>1 Bedroom</th>
<th>2 Bedrooms</th>
<th>3 Bedrooms</th>
<th>4 Bedrooms</th>
<th>5 Bedrooms</th>
<th>6 Bedrooms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Water Load [gal/day]</td>
<td>40</td>
<td>50</td>
<td>60</td>
<td>70</td>
<td>80</td>
<td>90</td>
</tr>
<tr>
<td>DWHR Efficiency</td>
<td>None</td>
<td>0.649</td>
<td>0.673</td>
<td>0.690</td>
<td>0.703</td>
<td>0.713</td>
</tr>
<tr>
<td></td>
<td>40%</td>
<td>0.809</td>
<td>0.846</td>
<td>0.873</td>
<td>0.894</td>
<td>0.910</td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>0.862</td>
<td>0.904</td>
<td>0.935</td>
<td>0.959</td>
<td>0.977</td>
</tr>
<tr>
<td></td>
<td>60%</td>
<td>0.922</td>
<td>0.971</td>
<td>1.007</td>
<td>1.034</td>
<td>1.055</td>
</tr>
</tbody>
</table>

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So in Summary....

A Water Heater with Rated EF=.67:
Will have a Site Specific EF ranging from:
0.613 (cold climate 2 bedroom home)
  to
0.713 (hot climate 5 bedroom home)

A Water Heater with Rated EF=.67 and **DWHR Rated Efficiency=60%:**
Will have a Site Specific EF ranging from:
0.850 (cold climate 2 bedroom home)
  to
1.055 (hot climate 5 bedroom home)

BUT, of course, the Energy Consumption for Water Heating would then be accurately Calculated Directly in software by LOAD and Cold Mains Temperature but with a Site Specific EF
Site Specific EF Examples Without DWHR

Site Specific EF with Water Heater Rated EF=0.67 and no DWHR

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Hot Water Load Bias Error by Assuming Constant EF....
Site Specific EF Examples With DWHR

![Graph showing site specific EF with water heater rated EF=0.67 and DWHR Eff=60%]

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Water Distribution Efficiency

--Gary Klein to discuss--

Efficient Water Distribution will result in a % Reduction in the Volume of Hot Water Load

With the Site Specific EF Model, one can simply take a reduced load for a given Bedroom Count (e.g. for 5 Bedroom from 80 gal/day to 70 gal/day) and use the EF at the lower volume.

Again, with actual load inputs and site conditions entered into software, one will now have an accurate calculation for Hot Water Load with or without Efficient Water Distribution

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Multi Unit Residential Buildings (MURB)

Contact Manufacturer for assistance on proper sizing.

Typical installation: up to 4 washrooms with 1 DWHR unit
MURBS and Lodging Design

- install DWHR units throughout building to preheat cold water for up to 4 washrooms above each unit.

- multi-unit residential and lodging buildings - common design to preheat cold water for 2 or more washrooms above.
Cold Water Preheating is Used in this Scenario

Central Water Heating
- DWHR unit placed in main drain stack with back-to-back washrooms or stacked vertically 1 to 4 washrooms/unit
- The annual savings will depend partly upon how many washrooms are connected to each DWHR unit

Apartment Buildings, Condos, and Dormitories
- water from DWHR unit supplies cold water to showers, lavatory and toilet

Hotels
- pre-heated water from DWHR unit supplies cold water line to showers and toilet, where desired. Not to the lavatory.
## 3-4 Washrooms per DWHR Unit

<table>
<thead>
<tr>
<th>Application (Building Type)</th>
<th>Variation</th>
<th>Plumbing Configuration / Comments</th>
<th>Typical Hot Water Energy Load (% of total)</th>
<th>Typical Reduction in Hot Water Load</th>
<th>Typical Potential Savings of Total Energy Load (% of total)</th>
<th>Typical LEED Points Achievable for High-Rise (NC and Major Retrofit) Multi-Residential</th>
<th>Typical LEED Points Achievable for Mid-Rise (HMR) Multi-Residential</th>
<th>Budgetary Total Cost Per Housing Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multi-Res (2-4 apart’s) w/ Central Water Heating</td>
<td>1-2 WC per DWHR Unit</td>
<td>CW Pre-Heating Only</td>
<td>18.4%</td>
<td>29.4%</td>
<td>5.4%</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td></td>
<td>3-4 WC per DWHR Unit</td>
<td>CW Pre-Heating Only</td>
<td>22.4%</td>
<td>23.5%</td>
<td>4.3%</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Multi-Res (&gt;= 5 apart’s) w/ Central Water Heating</td>
<td>1-2 WC per DWHR Unit</td>
<td>CW Pre-Heating Only</td>
<td>22.4%</td>
<td>23.5%</td>
<td>5.3%</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td></td>
<td>3-4 WC per DWHR Unit</td>
<td>CW Pre-Heating Only</td>
<td>22.4%</td>
<td>23.5%</td>
<td>5.3%</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td></td>
<td>5-6 WC per DWHR Unit</td>
<td>CW Pre-Heating with 1.5gpm Showerheads</td>
<td></td>
<td>22.4%</td>
<td>23.5%</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td></td>
<td>&gt;=7 WC per DWHR Unit</td>
<td>recirc. loop / custom engineered</td>
<td></td>
<td>22.4%</td>
<td>23.5%</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Lodging (dorms, hotels, etc.) / always Central Water Heating</td>
<td>1-2 WC per DWHR Unit</td>
<td>CW Pre-Heating Only</td>
<td>31.4%</td>
<td>23.5%</td>
<td>7.4%</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td></td>
<td>3-4 WC per DWHR Unit</td>
<td>CW Pre-Heating Only</td>
<td></td>
<td>31.4%</td>
<td>23.5%</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td></td>
<td>5-6 WC per DWHR Unit</td>
<td>CW Pre-Heating with 1.5gpm Showerheads</td>
<td></td>
<td>31.4%</td>
<td>23.5%</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td></td>
<td>&gt;=7 WC per DWHR Unit</td>
<td>recirc. loop / custom engineered</td>
<td></td>
<td>31.4%</td>
<td>23.5%</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>

**Typical Energy Savings:** 4% to 7%

**Typical Budgetary Cost:** $310 per suite

**Typical Payback Range:** 3 to 4 years
Questions & Discussion

Thank You for Attending!

www.RenewABILITY.com