Measured Performance of Natural Gas Tankless and Storage Water Heaters

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Full report:

Or

googl/TuFsJ

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Minnesota Statutes § 216B.241, subd. 1e
and
Center for Energy and Environment
Field Study overview

+ Objectives
  + To determine installed performance of TWH
  + To monitor hot water consumption behavior

+ Methodology
  + 10 sites
  + 25 water heaters
    + 8 Tank Water Heaters (TANK)
    + 9 Non-Condensing Tankless Water Heaters (TWHs)
    + 7 Condensing Tankless Water Heaters (CTWHs)
  + 4 week alternating mode test
  + Extensive data logging
  + Homeowner surveys
How Do Water Heaters Work?
Tank Type Water Heaters
Tank Water Heater Blanket

<table>
<thead>
<tr>
<th></th>
<th>Gas Consumption per Year, therms/year</th>
<th>Savings, therms/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>W/ Blanket Tset=120</td>
<td>210.0</td>
<td>5.5</td>
</tr>
<tr>
<td>W/ Blanket Tset=130</td>
<td>198.3</td>
<td>11.4</td>
</tr>
<tr>
<td>W/ Blanket Tset=140</td>
<td>201.8</td>
<td>14.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Cost</th>
<th>Payback, yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contractor</td>
<td>$18</td>
<td>1.2 - 3.3</td>
</tr>
<tr>
<td>Home-Owner</td>
<td>$22</td>
<td>1.5 - 4.0</td>
</tr>
</tbody>
</table>
Turn Down of the Temperature Setting on Storage Water Heaters

<table>
<thead>
<tr>
<th>Tset Setback °F</th>
<th>Savings therm/dy</th>
<th>Savings therm/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.02</td>
<td>7.3</td>
</tr>
<tr>
<td>10</td>
<td>0.04</td>
<td>14.6</td>
</tr>
<tr>
<td>15</td>
<td>0.06</td>
<td>21.9</td>
</tr>
<tr>
<td>20</td>
<td>0.08</td>
<td>29.2</td>
</tr>
<tr>
<td>25</td>
<td>0.1</td>
<td>36.5</td>
</tr>
</tbody>
</table>

Can assume costs of approximately $1/therm
• Gas value temperature setting should be used as the primary
• Hot water tap temperature measurement can be used to for check extreme errors
Water heater dead band and time between firing
Tankless Water Heaters
Issues Facing Tankless Water Heaters

+ Hot water quality
  + Delayed delivery time
  + Cold water sandwich
  + Consistent Supply temperature
  + Minimum flow rate for firing
  + Performance for multiple simultaneous uses
+ Higher installation costs
+ Maintenance costs
Home Owner Surveys

- Occupants were asked about how hot water quality would effect their decision to purchase each water heater.

- Surveys were given to home owners at the end of each operating period and asked to review the last four weeks

- Hot water quality indicators homeowners were asked about
  - Delay time until hot water arrives at the fixture
  - Necessity to increase flow when low flow is desired
  - Continuous hot water production without running out
  - Consistent temperature for a single use
  - Consistent temperature for multiple simultaneous uses
  - Flow rate reduction when using multiple simultaneous uses
Site Average

Standard Tank
Non-Condensing Tankless
Condensing Tankless

Delay until hot water arrives at fixtures

Outer circle represents definitely would buy this product with decreasing desire to buy towards the center.

Flow Rate reduction when using multi simultaneous uses

Necessity to increase flow when low flow is desired

Steady temp for multi simultaneous uses

Steady temp for a single use

Continuous production of hot water w/out running out
Delayed Delivery Time

Water Heater Start Up Output Temperatures

Outlet Temperature vs Seconds

- Navien w/ Buffer
- Tank
- TWH
- CTWH

Draw Spec: gpmh=1, Tset=120
Cold Sandwich for a TWH - Bosch 715
Site Average
Standard Tank
Non-Condensing Tankless
Condensing Tankless

Delay until hot water arrives at fixtures

Flow Rate reduction when using multi simultaneous uses

Steady temp for multi simultaneous uses

Steady temp for a single use

Continuous production of hot water w/out running out

Outer circle represents definitely would buy this product with decreasing desire to buy towards the center.
Site Average
Standard Tank
Non-Condensing Tankless
Condensing Tankless

Delay until hot water arrives at fixtures
Outer circle represents definitely would buy this product with decreasing desire to buy towards the center

Flow Rate reduction when using multi simultaneous uses

Steady temp for multi simultaneous uses

Steady temp for a single use

Continuous production of hot water w/out running out

Necessity to increase flow when low flow is desired
Min. Flow Rate for THWs to Start

- Minimum flow rate to start is 0.4 GPM (Max. is 0.66 GPM)
- 40% of THW require between 0.40 and 0.50 GPM
- 60% of THW require between 0.60 and 0.64 GPM

<table>
<thead>
<tr>
<th>Manuf.</th>
<th>Model</th>
<th>Input Rate kBtu/hr</th>
<th>Min GPM (to start)</th>
<th>Max GPM at ΔT 70°F</th>
<th>Max GPM at ΔT 35°F</th>
<th>EF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rinnai</td>
<td>RC98HPI</td>
<td>9.5-199</td>
<td>0.40</td>
<td>5.4</td>
<td>9.8</td>
<td>0.94</td>
</tr>
<tr>
<td>Takagi</td>
<td>T-K3</td>
<td>11-199</td>
<td>0.50</td>
<td>5.0</td>
<td>7.0</td>
<td>0.84</td>
</tr>
<tr>
<td>Rheem</td>
<td>RTG 66 DV</td>
<td>11-180</td>
<td>0.50 0.63</td>
<td>4.2</td>
<td>8.4</td>
<td>0.82</td>
</tr>
<tr>
<td>Noritz</td>
<td>N-0631S-DVMC</td>
<td>25-180</td>
<td>0.50</td>
<td>4.1</td>
<td>7.1</td>
<td>0.83</td>
</tr>
<tr>
<td>Navien</td>
<td>CR-210</td>
<td>17-175</td>
<td>0.50</td>
<td>5.1</td>
<td>9.8</td>
<td>0.95</td>
</tr>
<tr>
<td>Takagi</td>
<td>T-H2-DV</td>
<td>13-199</td>
<td>0.50</td>
<td>5.2</td>
<td>8.0</td>
<td>0.93</td>
</tr>
<tr>
<td>Noritz</td>
<td>N-0841-DVMC</td>
<td>11-199.9</td>
<td>0.50 0.49</td>
<td>5.3</td>
<td>10.2</td>
<td>0.91</td>
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<tr>
<td>Rinnai</td>
<td>R75Lsi</td>
<td>15-180</td>
<td>0.60</td>
<td>4.2</td>
<td>7.5</td>
<td>0.82</td>
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<tr>
<td>Rinnai</td>
<td>R94Lsi</td>
<td>15-199</td>
<td>0.60</td>
<td>4.8</td>
<td>9.4</td>
<td>0.82</td>
</tr>
<tr>
<td>Bradford White</td>
<td>TG-180I-N</td>
<td>15-180</td>
<td>0.60</td>
<td>3.8</td>
<td>7.5</td>
<td>0.82</td>
</tr>
<tr>
<td>Bradford White</td>
<td>TG-199I-N</td>
<td>15-199</td>
<td>0.60</td>
<td>4.7</td>
<td>9.4</td>
<td>0.82</td>
</tr>
<tr>
<td>GE</td>
<td>GN94DNSRSA</td>
<td>??-199</td>
<td>0.64</td>
<td>4.7</td>
<td>9.4</td>
<td>0.82</td>
</tr>
<tr>
<td>GE</td>
<td>GN75DNSRSA</td>
<td>??-180</td>
<td>0.64</td>
<td>3.8</td>
<td>7.5</td>
<td>0.82</td>
</tr>
<tr>
<td>Bosch</td>
<td>GWH-715 ES</td>
<td>19-199.9</td>
<td>0.65</td>
<td>4.7</td>
<td>9.2</td>
<td>0.81</td>
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<tr>
<td>Bosch</td>
<td>GWH-c800 ES</td>
<td>19.9-199</td>
<td>0.65</td>
<td>5.1</td>
<td>10.1</td>
<td>0.89</td>
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<tr>
<td>Noritz</td>
<td>N-0751-DVMC</td>
<td>12-199.9</td>
<td>0.66</td>
<td>4.8</td>
<td>9.8</td>
<td>0.82</td>
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<td>Paloma</td>
<td>PH-28R DVSN</td>
<td>19-199.9</td>
<td>0.66</td>
<td>4.9</td>
<td>9.7</td>
<td>0.82</td>
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<tr>
<td>Navien</td>
<td>CR-240A</td>
<td>17-199</td>
<td>None</td>
<td>5.8</td>
<td>11.1</td>
<td>0.95</td>
</tr>
</tbody>
</table>
Gas Line Upgrades

+ 0 of 10 sites in our study required street side or meter upgrades

+ 4 of 10 sites required a increased size gas line from the water heater to the gas meter
Venting

- Concentric
- Two Pipe
- Non-sealed
- Non-Condensing
Locating terminations

Vertical Exhaust
Efficiency, Energy Use, and Energy Costs
Input Output Curve For 3 WHs

Graph showing the relationship between daily natural gas input [kBtu/day] and daily hot water energy output [kBtu/day]. The graph includes three lines with the following equations:

1. \( y = 1.3023x + 20.508 \) with \( R^2 = 0.9524 \)
2. \( y = 1.3143x + 1.8761 \) with \( R^2 = 0.991 \)
3. \( y = 1.1163x + 1.4052 \) with \( R^2 = 0.997 \)

Graph legend includes symbols for CTWH, TANK, and TWH.
DOE Energy Factor Rating

- 24 hour simulated use test
- EF rating is similar to an efficiency but not meant to represent actual performance
- Used to estimate annual energy use and compare different water heaters

- Simulated use profile does not represent actual house hold use
- Assumed daily hot water usage is higher than the amount measured in real homes
- Differences in EF profile and real work profile favors some water heaters
Typical Hot Water Usage at Site #1

- **Weekdays**
- **Weekends**

Gallons of Hot Water

0:00 - 23:30

0 - 25 gallons
EF Rating vs Measures Efficiencies

<table>
<thead>
<tr>
<th></th>
<th>StWH</th>
<th>NTWH</th>
<th>CTWH</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>actual measured efficiency reductions</strong></td>
<td><strong>at 64 GPD</strong></td>
<td><strong>at 36 GPD</strong></td>
<td></td>
</tr>
<tr>
<td>STWH</td>
<td>0.04</td>
<td>0.11</td>
<td></td>
</tr>
<tr>
<td>NTWH</td>
<td>0.06</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td>CTWH</td>
<td>0.06</td>
<td>0.09</td>
<td></td>
</tr>
</tbody>
</table>
Typical Electrical Consumption for an IWH

Range of Consumption [Watts]

<table>
<thead>
<tr>
<th></th>
<th>Standby</th>
<th></th>
<th>Firing</th>
<th></th>
<th>Running</th>
<th></th>
<th>Post Purge [Whrs]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>4</td>
<td></td>
<td>Min</td>
<td>35</td>
<td></td>
<td></td>
<td>Min</td>
</tr>
<tr>
<td>Typical</td>
<td>8</td>
<td></td>
<td>Typical</td>
<td>70</td>
<td></td>
<td></td>
<td>Typical</td>
</tr>
<tr>
<td>Max</td>
<td>11</td>
<td></td>
<td>Max</td>
<td>110</td>
<td></td>
<td></td>
<td>Max</td>
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<td></td>
<td></td>
<td></td>
<td>Min</td>
<td>30</td>
<td></td>
<td></td>
<td>Min</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Typical</td>
<td>50</td>
<td></td>
<td></td>
<td>Typical</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Max</td>
<td>80</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>0.1</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.8</td>
</tr>
</tbody>
</table>
Electric Consumption by Average Outdoor Air Temperature

Electric Consumption [KWhr/day]

Average Outdoor Air Temperature

- Freeze Days
- Non Freeze Days
## Estimated Electrical Consumption for each Tankless Water Heater

<table>
<thead>
<tr>
<th></th>
<th>Electric Consumption</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HW + Standby</td>
<td>Freeze Protect</td>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>kWhr/day</td>
<td>kWhr/yr</td>
<td>kWhr/day</td>
<td>kWhr/yr</td>
<td>kWhr/yr</td>
</tr>
<tr>
<td><strong>Rheem RTG 66DV</strong></td>
<td>0.10</td>
<td>38</td>
<td>0.05</td>
<td>3</td>
<td>41</td>
</tr>
<tr>
<td><strong>Rinnai R75Lsi</strong></td>
<td>0.10</td>
<td>37</td>
<td>0.27</td>
<td>23</td>
<td>61</td>
</tr>
<tr>
<td><strong>Bosch GWH-715ES</strong></td>
<td>0.20</td>
<td>72</td>
<td></td>
<td></td>
<td>72</td>
</tr>
<tr>
<td><strong>Takagi TK-1</strong></td>
<td>0.21</td>
<td>78</td>
<td></td>
<td></td>
<td>78</td>
</tr>
<tr>
<td><strong>Nortiz N-0751-MCDV</strong></td>
<td>0.35</td>
<td>126</td>
<td>0.38</td>
<td>4</td>
<td>130</td>
</tr>
<tr>
<td><strong>Navien CR210</strong></td>
<td>0.13</td>
<td>46</td>
<td></td>
<td></td>
<td>46</td>
</tr>
<tr>
<td><strong>Navien CR240A</strong></td>
<td>0.30</td>
<td>111</td>
<td></td>
<td></td>
<td>111</td>
</tr>
<tr>
<td><strong>Bosch GWH-c800ES</strong></td>
<td>0.41</td>
<td>148</td>
<td></td>
<td></td>
<td>148</td>
</tr>
<tr>
<td><strong>Noritz N-0814-DVMC</strong></td>
<td>0.30</td>
<td>111</td>
<td>1.37</td>
<td>140</td>
<td>251</td>
</tr>
</tbody>
</table>

*Only one of two sites had freeze protection
## Estimated Simple Payback

- TWH+CTHW installed costs: $2500-$5000
- TANK Installed costs: $1000
- Average Savings from TWH + CTWH

<table>
<thead>
<tr>
<th></th>
<th>1-2 Occup</th>
<th>3-4 Occup</th>
<th>5+ Occup</th>
<th>DOE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CTWH Savings, $/yr</strong></td>
<td>$ 49</td>
<td>$ 68</td>
<td>$ 73</td>
<td>$ 80</td>
</tr>
<tr>
<td><strong>Payback, yrs</strong></td>
<td>30 to 80</td>
<td>22 to 59</td>
<td>21 to 55</td>
<td>19 to 50</td>
</tr>
<tr>
<td><strong>TWH Savings, $/yr</strong></td>
<td>$ 48</td>
<td>$ 58</td>
<td>$ 61</td>
<td>$ 65</td>
</tr>
<tr>
<td><strong>Payback, yrs</strong></td>
<td>31 to 82</td>
<td>26 to 69</td>
<td>25 to 66</td>
<td>23 to 62</td>
</tr>
</tbody>
</table>
Hot Water Use
Difference in Hot Water Use

+ 0 of 10 sites in our study – no significant difference in water use between tank and tankless heaters

+ 1 of 10 sites – slight increase in hot water energy demand
Annual Average Hot Water Usage for Each Heater Type

![Bar chart showing annual average hot water usage for different heater types across various site numbers. The x-axis represents site numbers from 1 to 10, and the y-axis represents average daily hot water volume in GPD. The chart compares StWH, NTWH, and CTWH types.]
Median GPDs for Ten Homes

Project Average
36 GPD
26 DpD
Seasonality of Water Heating Demand

![Graph showing the seasonality of hot water demand with a linear regression line and equation: \( y = -0.8393x + 98.688 \) with an R² value of 0.6187.](image-url)
Draw Categories

+ Less than 5 seconds (LT5) – All draws that are less than 5 seconds
  + Large number, small volume, small energy
  + Some of these draws are not necessarily actual hot water events, just water/pressure shifts in the plumbing system
+ No temp rise at water heater outlet (No_WH_Rise)
  + Much more common with TWH and StWH type
+ No temp rise at end use (No_End_Rise)
  + Water heater outlet was hot but fixture never received hot water
+ Single end use draw (Single_End)
  + One fixture got hot water
+ Multiple end use draw (Multi_End)
  + Two or more fixtures had hot water
Single End Use Draws by Fixture

*Only averaged over the 4 sites that had dishwashers*
Percentage of Total Daily Volume for Single End Use Fixtures

- Showers and tubs
- Bath sinks
- Kitchen sinks
- Laundry sinks
- Clothes washers
- Dishwashers

Sites:
- Site 1
- Site 2
- Site 3
- Site 4
- Site 5
- Site 6
- Site 7
- Site 8
- Site 9
- Site 10
Energy Consumption by Draw Type

<table>
<thead>
<tr>
<th>Draw Type</th>
<th>% of total Energy Input</th>
<th>% of total Energy Output</th>
<th>% of total Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lt5 draws</td>
<td>6%</td>
<td>1%</td>
<td>7%</td>
</tr>
<tr>
<td>No Rise Draws - No_WH_Rise, No_End_Rise</td>
<td>6%</td>
<td>6%</td>
<td>6%</td>
</tr>
<tr>
<td>End Use Draws - Single_End, Multi_End</td>
<td>89%</td>
<td>93%</td>
<td>87%</td>
</tr>
</tbody>
</table>

Efficiency of Tankless Water Heater Draws by Length

- Site 1
- Site 2
- Site 3
- Site 4
- Site 5
- Site 6
- Site 7
- Site 8
- Site 9
- Site 10
### Average Draw Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Site 1</th>
<th>Site 2</th>
<th>Site 3</th>
<th>Site 4</th>
<th>Site 5</th>
<th>Site 6</th>
<th>Site 7</th>
<th>Site 8</th>
<th>Site 9</th>
<th>Site 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Draws per day (no LT5)</td>
<td>47.8</td>
<td>34.6</td>
<td>8.5</td>
<td>16.2</td>
<td>27.7</td>
<td>36.8</td>
<td></td>
<td></td>
<td>19.6</td>
<td>16.5</td>
</tr>
<tr>
<td>Volume, gal</td>
<td>0.4</td>
<td>1.4</td>
<td>2.6</td>
<td>1.2</td>
<td>1.9</td>
<td>1.0</td>
<td></td>
<td></td>
<td>0.9</td>
<td>2.1</td>
</tr>
<tr>
<td>Length, Sec</td>
<td>13.4</td>
<td>59.2</td>
<td>98.6</td>
<td>49.0</td>
<td>81.8</td>
<td>40.4</td>
<td></td>
<td></td>
<td>38.6</td>
<td>103.9</td>
</tr>
<tr>
<td>Flowrate, GPM</td>
<td>0.8</td>
<td>1.3</td>
<td>1.8</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td></td>
<td></td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Idle periods greater than 17 hrs</td>
<td>0.1%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.2%</td>
<td>0.1%</td>
<td>0.1%</td>
<td>0.1%</td>
<td></td>
<td>0.4%</td>
<td>0.4%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Ave</th>
<th>EF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Draws per day (no LT5)</td>
<td>26.0</td>
<td>6</td>
</tr>
<tr>
<td>Volume, gal</td>
<td>1.4</td>
<td>10.7</td>
</tr>
<tr>
<td>Length, Sec</td>
<td>60.6</td>
<td>214.3</td>
</tr>
<tr>
<td>Flowrate, GPM</td>
<td>1.2</td>
<td>3</td>
</tr>
<tr>
<td>Idle periods greater than 17 hrs</td>
<td>0.2%</td>
<td>17%</td>
</tr>
</tbody>
</table>

See full report for this project to see how this difference effects WH ratings.
Typical hot water flow rates

![Graph showing the frequency of hot water draws by flow rate. The x-axis represents flow rate bins in gallons per minute (GPM), and the y-axis represents frequency in percentage. The graph indicates that most water draws occur between 1.5 and 2 GPM.]
Summary

+ Low flow (1 gpm) response time vary by model and is a drawback for tankless.

+ Tankless “endless” water draw is a positive and they operate at setpoint more consistently.

+ Tankless need to increase flow slight drawback
Summary - continued

+ Actual efficiency typically 3 – 5% lower than rated for all heaters
+ Efficiency varies by water demand. Savings are fairly consistent
+ Electric use varies (37 – 148 kWhr/yr) is not insignificant – freeze protection high for some
+ No observed difference in water use
Questions?

Full report:
Or
goo.gl/TuFsJ

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