

# **APPENDIX 8-I. LIFE-CYCLE COST ANALYSIS FOR SMALL AND LARGE VOLUME GAS-FIRED AND ELECTRIC STORAGE WATER HEATERS**

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## **APPENDIX 8-I. LIFE-CYCLE COST ANALYSIS FOR SMALL AND LARGE VOLUME GAS-FIRED AND ELECTRIC STORAGE WATER HEATERS**

### **8-I.1 INTRODUCTION**

As explained in chapter 10, DOE wanted to consider a pairing of efficiency levels that will promote the penetration of advanced technologies into the electric and gas-fired storage water heater markets and potentially save additional energy. Consequently, DOE is pairing an efficiency level requiring heat pump technology for large-volume electric storage water heaters with an efficiency level achievable using electric resistance technology for small-volume electric storage water heaters. In addition, DOE is pairing an efficiency level requiring condensing technology for large-volume gas storage water heaters with an efficiency level that can be achieved in atmospherically-vented gas-fired storage water heaters with increased insulation thickness for small storage volumes.

TSL 5 includes efficiency levels that require heat pump technology for electric storage water heaters with rated storage volumes at and above 56 gallons, and efficiency levels that require condensing technology for gas-fired storage water heaters with rated storage volumes at and above 56 gallons. Based on its market assessment, DOE estimated approximately 4 percent of gas-fired storage water heater shipments and 11 percent of models would be subject to the large-volume water heater requirements using the TSL 5 and 6 division. Similarly, DOE estimated approximately 9 percent of electric storage water heater shipments and 27 percent of models would be subject to the large volume water heater requirements using the TSL 5 and 6 division.

To derive the life-cycle cost (LCC) and payback period (PBP) results for TSL 5, DOE divided the results for gas and electric water heaters into two groups, one consisting of households with small-volume water heaters, and the other consisting of households with large-volume water heaters.

### **8-I.2 INPUTS TO LCC AND PBP ANALYSIS**

DOE divided the gas and electric storage water heater subsets (see chapter 7 for description) into two further subsets designed to include households that use either small-volume or large-volume water heaters using RECS 2001 and 2005.<sup>1, 2</sup> Table 8-I.2.1 and Table 8-I.2.2 show the details of the assignment of sample households to these two subgroups. Note that some households fall into both samples. For these households, their weights are divided appropriately based on Table 8-I.2.2 so that the total number of households in the national sample and “small-volume” plus “large-volume” is the same.

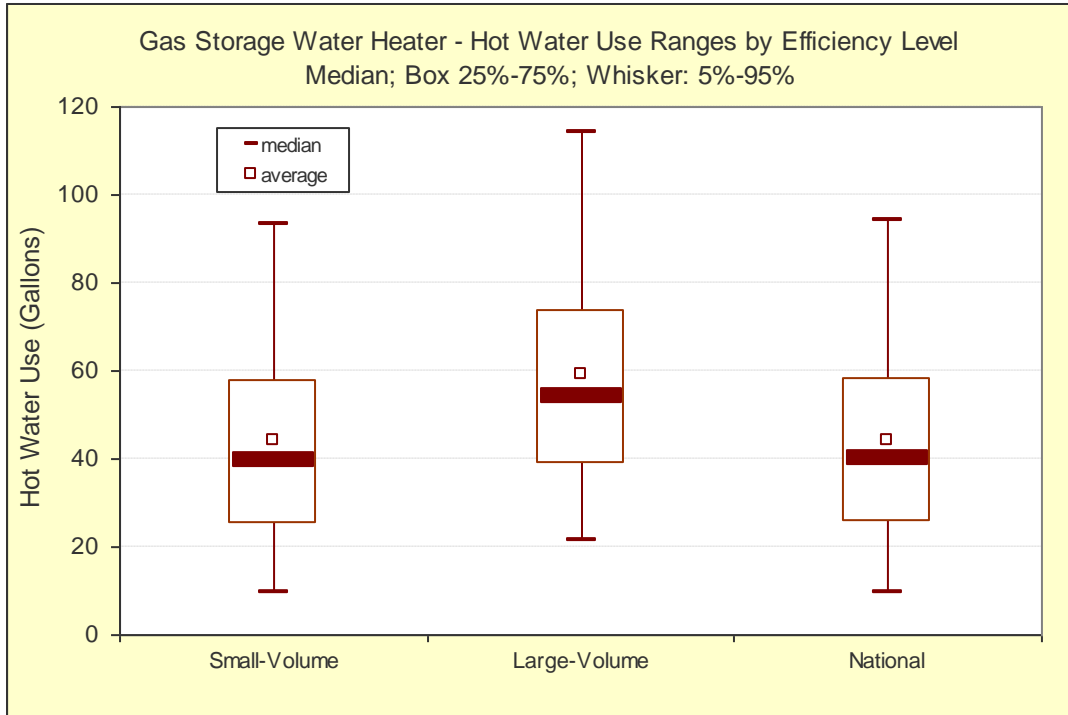
**Table 8-I.2.1 Selection of RECS 2005 Records for Water Heaters**

| Product Class               | Algorithm  | Sample       | No. of Records | No. of U.S. Households Represented<br>(million) |
|-----------------------------|--|--------------|----------------|---|
| Natural Gas and LPG Storage | Storage Water Heater = Yes<br>Fuel Type = Natural Gas or LPG<br>Shared Water Heater = No | Small-Volume | 2166           | 53.1  |
|                             |  | Large-Volume | 144            | 2.1   |
| Electric Storage            | Storage Water Heater = Yes<br>Fuel Type = Electricity<br>Shared Water Heater = No        | Small-Volume | 1465           | 35.9  |
|                             |  | Large-Volume | 261            | 3.6   |

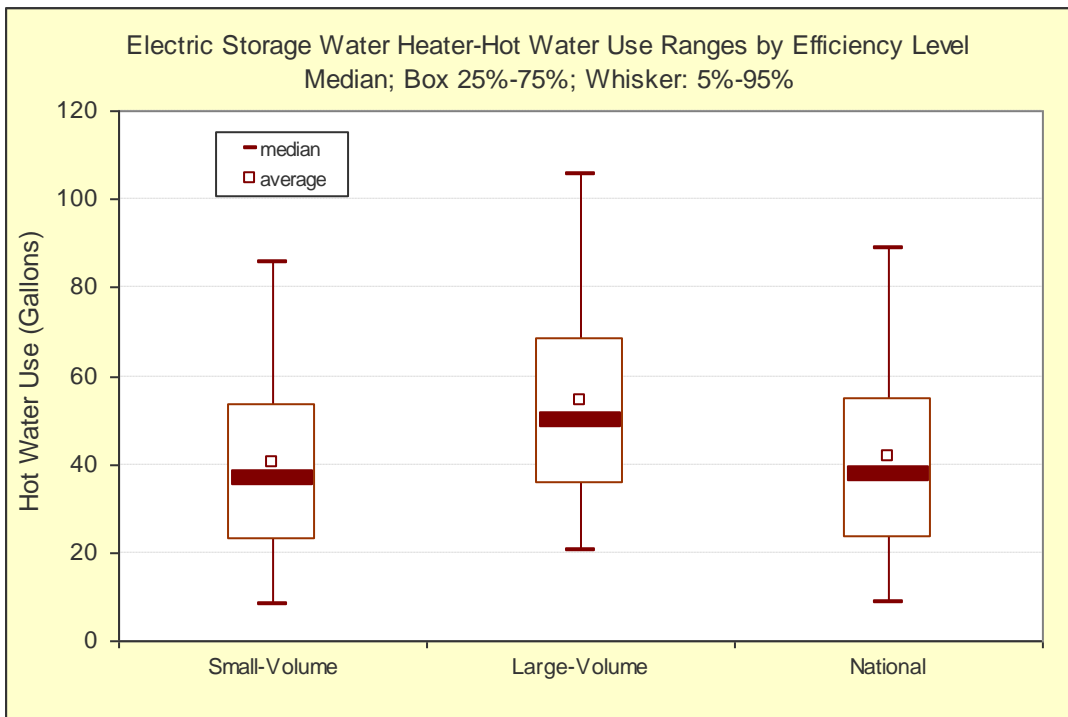
**Table 8-I.2.2 Water Heater Tank Sizes Selected for Sample Households**

| Fuel Type          | RECS Size Class | No. of Bathrooms | Water Heater Tank Size (gal) | Percent Assigned to Size Class | Subset       |
|--------------------|-----------------|------------------|------------------------------|--------------------------------|--------------|
| Natural Gas or LPG | Small           | Any # BR         | 30                           | 100%                           | Small-Volume |
|                    | Medium          | Any # BR         | 40                           | 77.9%                          |              |
|                    |                 |                  | 50                           | 22.1%                          |              |
|                    | Large           | 2 BR             | 50                           | 100%                           |              |
|                    |                 | $\geq 3$ BR      | 50                           | 45.5%                          | Large-Volume |
|                    |                 |                  | 65                           | 27.2%                          |              |
| Electric           | Medium          | Any # BR         | 75                           | 27.2%                          | Large-Volume |
|                    |                 |                  |                              |                                |              |
|                    |                 |                  |                              |                                |              |
|                    | Large           | $< 2$ BR         | 50                           | 100%                           | Small-Volume |
|                    |                 |                  | 50                           | 64.6%                          |              |
|                    |                 |                  | 65                           | 24.6%                          |              |
|                    |                 | 2 BR             | 80                           | 10.8%                          | Large-Volume |
|                    |                 |                  | 80                           | 65.3%                          |              |
|                    |                 |                  | 119                          | 34.7%                          |              |
|                    |                 | $\geq 3$ BR      |                              |                                |              |

Figure 8-I.2.1 and Figure 8-I.2.2 show the range in hot water use among sample households in each subgroup. The households with large-volume water heaters have higher median hot water use. [UPDATE CHARTS]



**Figure 8-I.2.2 Range of Daily Hot Water Use in Sample Households for Gas Storage Water Heaters**



**Figure 8-I.2.3 Range of Daily Hot Water Use in Sample Households for Electric Storage Water Heaters**

Table 8-I.2.3 lists the average annual energy use for gas-fired storage water heaters in each subgroup.

**Table 8-I.2.3 Annual Energy Consumption for Gas-Fired Storage Water Heaters**

| <b>Energy Efficiency Level<br/>(<i>EF</i>)</b> | <b>Average Energy Consumption</b> |   |                                  |   |                                  |   |
|--|-----------------------------------|---|----------------------------------|---|----------------------------------|---|
|  | <b>Small-Volume</b>               |   | <b>Large-Volume</b>              |   | <b>All</b>                       |   |
|  | <b>Gas<br/>(<i>MMBtu/yr</i>)</b>  | <b><i>Electricity</i><br/>(<i>kWh/yr</i>)</b> | <b>Gas<br/>(<i>MMBtu/yr</i>)</b> | <b><i>Electricity</i><br/>(<i>kWh/yr</i>)</b> | <b>Gas<br/>(<i>MMBtu/yr</i>)</b> | <b><i>Electricity</i><br/>(<i>kWh/yr</i>)</b> |
| 0.59 (baseline)                                | 16.3                              | 0   | 22.2                             | 0   | 16.7                             | 0   |
| 0.62   | 15.5                              | 0   | 21.0                             | 0   | 15.9                             | 0   |
| 0.63   | 15.0                              | 6   | 20.6                             | 6   | 15.5                             | 0   |
| 0.64   | 14.5                              | 69  | 19.6                             | 63  | 14.8                             | 83  |
| 0.65   | 14.1                              | 67  | 18.9                             | 62  | 14.5                             | 82  |
| 0.67   | 13.5                              | 66  | 18.4                             | 61  | 14.0                             | 80  |
| 0.77   | 11.8                              | 61  | 15.7                             | 56  | 12.2                             | 73  |

Table 8-I.2.4 lists average annual energy use for electric storage water heaters in each subgroup.

**Table 8-I.2.4 Annual Energy Consumption for Electric Storage Water Heaters**

| <b>Energy Efficiency Level<br/>(<i>EF</i>)</b> | <b>Average Energy Consumption<br/>(<i>kWh/yr</i>)</b> |                     |            |
|--|---|---------------------|------------|
|  | <b>Small-Volume</b>                                   | <b>Large-Volume</b> | <b>All</b> |
| 0.90 (baseline)                                | 2,502   | 3,660               | 2,604      |
| 0.91   | 2,473   | 3,565               | 2,569      |
| 0.92   | 2,439   | 3,534               | 2,535      |
| 0.93   | 2,421   | 3,485               | 2,515      |
| 0.94   | 2,377   | 3,397               | 2,467      |
| 0.95   | 2,345   | 3,331               | 2,431      |
| 2.00   | 1,348   | 1,927               | 1,399      |
| 2.35   | 1,172   | 1,677               | 1,216      |

Table 8-I.2.5 and Table 8-I.2.6 show the average installation cost by efficiency level for each subgroup.

**Table 8-I.2.5 Average Installation Cost for Gas-Fired Storage Water Heaters**

| Energy Efficiency Level | EF   | Average Installation Cost (2009\$)* |              |       |
|-------------------------|------|-------------------------------------|--------------|-------|
|                         |      | Small-Volume                        | Large-Volume | All   |
| 0                       | 0.59 | \$628                               | \$670        | \$630 |
| 1                       | 0.62 | \$702                               | \$740        | \$703 |
| 2                       | 0.63 | \$735                               | \$766        | \$736 |
| 3                       | 0.64 | \$853                               | \$876        | \$854 |
| 4                       | 0.65 | \$867                               | \$884        | \$868 |
| 5                       | 0.67 | \$884                               | \$904        | \$885 |
| 6                       | 0.77 | \$904                               | \$921        | \$905 |

\*Average installation cost represents the weighted average cost for replacement and new construction applications.

**Table 8-I.2.6 Average Installation Cost for Electric Storage Water Heaters**

| Energy Efficiency Level | EF   | Average Installation Cost (2009\$)* |              |       |
|-------------------------|------|-------------------------------------|--------------|-------|
|                         |      | Small-Volume                        | Large-Volume | All   |
| 0                       | 0.90 | \$283                               | \$333        | \$288 |
| 1                       | 0.91 | \$306                               | \$360        | \$311 |
| 2                       | 0.92 | \$318                               | \$360        | \$322 |
| 3                       | 0.93 | \$325                               | \$385        | \$330 |
| 4                       | 0.94 | \$345                               | \$391        | \$349 |
| 5                       | 0.95 | \$345                               | \$391        | \$349 |
| 6                       | 2.00 | \$534                               | \$553        | \$535 |
| 7                       | 2.35 | \$537                               | \$564        | \$539 |

\*Average installation cost represents the weighted average cost for replacement and new construction applications.

### **8-I.2.2 Base Case Energy Efficiency Distribution**

Table 8-I.2.7 and Table 8-I.2.8 present the market shares of the energy efficiency levels in the base case for the gas-fired and electric storage water heater product classes by rated volume.

**Table 8-I.2.7 Gas-Storage Water Heaters: Base Case Energy Efficiency Market Shares in 2015 by Rated Volume**

| Energy Efficiency Level | 30 Gallon |                  | 40 Gallon |                  | 50 Gallon |                  | 65 Gallon |                  | 75 Gallon |                  |
|-------------------------|-----------|------------------|-----------|------------------|-----------|------------------|-----------|------------------|-----------|------------------|
|                         | EF        | Market Share (%) | EF        | Market Share (%) | EF        | Market Share (%) | EF        | Market Share (%) | EF        | Market Share (%) |
| Baseline                | 0.61      | 92.01%           | 0.59      | 63.92%           | 0.58      | 57.29%           | 0.55      | 58.93%           | 0.53      | 41.67%           |
| 1                       | 0.63      | 1.74%            | 0.62      | 23.44%           | 0.60      | 4.56%            | 0.58      | 13.39%           | 0.56      | 26.04%           |
| 2                       | 0.64      | 0.00%            | 0.63      | 1.60%            | 0.62      | 24.09%           | 0.59      | 8.04%            | 0.57      | 20.83%           |
| 3                       | 0.65      | 0.00%            | 0.64      | 4.79%            | 0.63      | 7.81%            | 0.61      | 13.39%           | 0.59      | 0.00%            |
| 4                       | 0.66      | 0.00%            | 0.65      | 0.00%            | 0.65      | 0.00%            | 0.63      | 0.00%            | 0.61      | 5.21%            |
| 5                       | 0.68      | 5.25%            | 0.67      | 5.25%            | 0.66      | 5.25%            | 0.64      | 5.25%            | 0.62      | 5.25%            |
| 6                       | 0.78      | 1.00%            | 0.77      | 1.00%            | 0.76      | 1.00%            | 0.75      | 1.00%            | 0.74      | 1.00%            |

**Table 8-I.2.8 Electric-Storage Water Heaters: Base Case Energy Efficiency Market Shares in 2015 by Rated Volume**

| Energy Efficiency Level | 30 Gallon |                  | 40 Gallon |                  | 50 Gallon |                  | 65 Gallon |                  | 80 Gallon |                  | 119 Gallon |                  |
|-------------------------|-----------|------------------|-----------|------------------|-----------|------------------|-----------|------------------|-----------|------------------|------------|------------------|
|                         | EF        | Market Share (%) | EF        | Market Share (%) | EF        | Market Share (%) | EF        | Market Share (%) | EF        | Market Share (%) | EF         | Market Share (%) |
| Baseline                | 0.93      | 80.16%           | 0.92      | 7.31%            | 0.90      | 29.80%           | 0.88      | 30.23%           | 0.86      | 42.59%           | 0.80       | 12.67%           |
| 1                       | 0.94      | 0.00%            | 0.92      | 51.15%           | 0.91      | 16.76%           | 0.90      | 8.64%            | 0.88      | 0.00%            | 0.82       | 25.33%           |
| 2                       | 0.94      | 0.00%            | 0.93      | 0.00%            | 0.92      | 11.18%           | 0.90      | 8.64%            | 0.89      | 0.00%            | 0.83       | 12.67%           |
| 3                       | 0.94      | 11.88%           | 0.93      | 23.75%           | 0.93      | 26.08%           | 0.91      | 34.55%           | 0.90      | 26.21%           | 0.84       | 6.33%            |
| 4                       | 0.95      | 0.00%            | 0.94      | 7.31%            | 0.94      | 7.45%            | 0.93      | 4.32%            | 0.92      | 19.66%           | 0.85       | 38.00%           |
| 5                       | 0.95      | 2.97%            | 0.95      | 5.48%            | 0.95      | 3.73%            | 0.94      | 8.64%            | 0.94      | 6.55%            | 0.86       | 0.00%            |
| 6                       | 2.02      | 4.00%            | 2.01      | 4.00%            | 2.00      | 4.00%            | 1.98      | 4.00%            | 1.97      | 4.00%            | 1.92       | 4.00%            |
| 7                       | 2.37      | 1.00%            | 2.36      | 1.00%            | 2.35      | 1.00%            | 2.33      | 1.00%            | 2.32      | 1.00%            | 2.27       | 1.00%            |

### 8-I.3 RESULTS

Table 8-I.3.1 through Table 8-I.3.4 present the LCC and PBP results for each of the small- and large-volume subgroups. Refer to chapter 8 for an overview of the results categories. The efficiency levels that correspond to TSL 5 are highlighted in bold font.

**Table 8-I.3.1 Gas-Fired Storage Water Heaters (Small-Volume): LCC and PBP Results**

| Efficiency Level ID | Energy Factor | Life-Cycle Cost (2009\$) |                                 |                | Life-Cycle Cost Savings  |                 |            |             | Payback Period (years) |             |
|---------------------|---------------|--------------------------|---------------------------------|----------------|--------------------------|-----------------|------------|-------------|------------------------|-------------|
|                     |               | Average Installed Price  | Average Lifetime Operating Cost | Average LCC    | Average Savings (2009\$) | Households with |            |             | Median                 | Average     |
|                     |               |                          |                                 |                |                          | Net Cost        | No Impact  | Net Benefit |                        |             |
| Baseline            | 0.59          | \$1,072                  | \$2,440                         | \$3,512        |                          |                 |            |             |                        |             |
| <b>1</b>            | <b>0.62</b>   | <b>\$1,164</b>           | <b>\$2,327</b>                  | <b>\$3,491</b> | <b>\$15</b>              | <b>26%</b>      | <b>34%</b> | <b>40%</b>  | <b>2.0</b>             | <b>17.2</b> |
| <b>2</b>            | <b>0.63</b>   | <b>\$1,238</b>           | <b>\$2,262</b>                  | <b>\$3,499</b> | <b>\$6</b>               | <b>33%</b>      | <b>22%</b> | <b>46%</b>  | <b>4.5</b>             | <b>18.6</b> |
| 3                   | 0.64          | \$1,553                  | \$2,258                         | \$3,811        | -\$271                   | 73%             | 11%        | 16%         | 35.7                   | 57.5        |
| 4                   | 0.65          | \$1,585                  | \$2,193                         | \$3,779        | -\$241                   | 71%             | 6%         | 23%         | 26.5                   | 40.1        |
| 5                   | 0.67          | \$1,650                  | \$2,111                         | \$3,761        | -\$224                   | 71%             | 6%         | 23%         | 21.8                   | 27.5        |
| 6                   | 0.77          | \$1,886                  | \$1,857                         | \$3,743        | -\$206                   | 71%             | 1%         | 28%         | 15.9                   | 17.0        |

**Table 8-I.3.2 Gas-Fired Storage Water Heaters (Large-Volume): LCC and PBP Results**

| Efficiency Level ID | Energy Factor | Life-Cycle Cost (2009\$) |                                 |                | Life-Cycle Cost Savings  |                 |           |             | Payback Period (years) |             |
|---------------------|---------------|--------------------------|---------------------------------|----------------|--------------------------|-----------------|-----------|-------------|------------------------|-------------|
|                     |               | Average Installed Price  | Average Lifetime Operating Cost | Average LCC    | Average Savings (2009\$) | Households with |           |             | Median                 | Average     |
|                     |               |                          |                                 |                |                          | Net Cost        | No Impact | Net Benefit |                        |             |
| Baseline            | 0.59          | \$1,261                  | \$3,297                         | \$4,558        |                          |                 |           |             |                        |             |
| 1                   | 0.62          | \$1,355                  | \$3,117                         | \$4,472        | \$19                     | 8%              | 79%       | 13%         | 1.6                    | 7.1         |
| 2                   | 0.63          | \$1,418                  | \$3,062                         | \$4,480        | \$18                     | 19%             | 40%       | 41%         | 4.5                    | 17.7        |
| 3                   | 0.64          | \$1,714                  | \$2,991                         | \$4,705        | -\$147                   | 57%             | 27%       | 16%         | 26.4                   | 42.8        |
| 4                   | 0.65          | \$1,745                  | \$2,889                         | \$4,633        | -\$83                    | 52%             | 11%       | 36%         | 14.1                   | 19.9        |
| 5                   | 0.67          | \$1,810                  | \$2,804                         | \$4,614        | -\$65                    | 58%             | 5%        | 37%         | 13.2                   | 16.7        |
| <b>6</b>            | <b>0.77</b>   | <b>\$2,066</b>           | <b>\$2,404</b>                  | <b>\$4,470</b> | <b>\$77</b>              | <b>49%</b>      | <b>2%</b> | <b>49%</b>  | <b>9.8</b>             | <b>10.3</b> |



**Table 8-I.3.3 Electric Storage Water Heaters (Small-Volume): LCC and PBP Results**

| Efficiency Level ID | Energy Factor | Life-Cycle Cost (2009\$) |                                 |                | Life-Cycle Cost Savings  |                 |           |             | Payback Period (years) |             |
|---------------------|---------------|--------------------------|---------------------------------|----------------|--------------------------|-----------------|-----------|-------------|------------------------|-------------|
|                     |               | Average Installed Price  | Average Lifetime Operating Cost | Average LCC    | Average Savings (2009\$) | Households with |           |             | Median                 | Average     |
|                     |               |                          |                                 |                |                          | Net Cost        | No Impact | Net Benefit |                        |             |
| Baseline            | 0.90          | \$554                    | \$2,604                         | \$3,157        |                          |                 |           |             |                        |             |
| 1                   | 0.91          | \$585                    | \$2,573                         | \$3,158        | -\$2                     | 7%              | 68%       | 25%         | 3.8                    | 12.4        |
| 2                   | 0.92          | \$607                    | \$2,538                         | \$3,145        | \$3                      | 12%             | 42%       | 46%         | 4.0                    | 10.5        |
| 3                   | 0.93          | \$616                    | \$2,520                         | \$3,136        | \$9                      | 13%             | 38%       | 49%         | 4.0                    | 10.3        |
| 4                   | 0.94          | \$657                    | \$2,474                         | \$3,131        | \$13                     | 23%             | 15%       | 62%         | 5.2                    | 9.6         |
| <b>5</b>            | <b>0.95</b>   | <b>\$693</b>             | <b>\$2,440</b>                  | <b>\$3,134</b> | <b>\$10</b>              | <b>34%</b>      | <b>9%</b> | <b>57%</b>  | <b>6.9</b>             | <b>10.3</b> |
| 6                   | 2.00          | \$1,562                  | \$1,515                         | \$3,077        | \$62                     | 52%             | 5%        | 43%         | 9.8                    | 27.9        |
| 7                   | 2.35          | \$1,687                  | \$1,333                         | \$3,020        | \$118                    | 52%             | 1%        | 47%         | 9.4                    | 21.2        |

**Table 8-I.3.4 Electric Storage Water Heaters (Large-Volume): LCC and PBP Results**

| Efficiency Level ID | Energy Factor | Life-Cycle Cost (2009\$) |                                 |                | Life-Cycle Cost Savings  |                 |           |             | Payback Period (years) |            |
|---------------------|---------------|--------------------------|---------------------------------|----------------|--------------------------|-----------------|-----------|-------------|------------------------|------------|
|                     |               | Average Installed Price  | Average Lifetime Operating Cost | Average LCC    | Average Savings (2009\$) | Households with |           |             | Median                 | Average    |
|                     |               |                          |                                 |                |                          | Net Cost        | No Impact | Net Benefit |                        |            |
| Baseline            | 0.90          | \$729                    | \$3,742                         | \$4,471        |                          |                 |           |             |                        |            |
| 1                   | 0.91          | \$778                    | \$3,647                         | \$4,424        | \$15                     | 5%              | 67%       | 28%         | 3.2                    | 5.5        |
| 2                   | 0.92          | \$786                    | \$3,616                         | \$4,402        | \$24                     | 4%              | 63%       | 33%         | 3.0                    | 4.7        |
| 3                   | 0.93          | \$820                    | \$3,566                         | \$4,386        | \$31                     | 6%              | 57%       | 37%         | 3.7                    | 5.6        |
| 4                   | 0.94          | \$852                    | \$3,477                         | \$4,330        | \$72                     | 6%              | 28%       | 65%         | 3.3                    | 4.5        |
| 5                   | 0.95          | \$889                    | \$3,410                         | \$4,299        | \$98                     | 9%              | 13%       | 78%         | 4.3                    | 5.2        |
| <b>6</b>            | <b>2.00</b>   | <b>\$1,703</b>           | <b>\$2,046</b>                  | <b>\$3,749</b> | <b>\$626</b>             | <b>26%</b>      | <b>6%</b> | <b>68%</b>  | <b>6.0</b>             | <b>8.5</b> |
| 7                   | 2.35          | \$1,864                  | \$1,793                         | \$3,657        | \$717                    | 26%             | 1%        | 72%         | 6.3                    | 8.2        |

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