Specific heat of water $1.00 \text{ Btu/(lbm °F)}$
1 U.S. gal $3.785 \text{ L}$
1 kg $2.2046 \text{ lbm}$
Density of water $1000 \text{ kg/m}^3$
1 gal $3.785 \text{ L}$
1 kg $2.2046 \text{ lbm}$
Density of water $1000 \text{ kg/m}^3$
1 gal $8.34 \text{ lbm}$
Heater efficiency, $\eta$ $0.75$
1 yr $52 \text{ wk}$
Shower $25 \text{ per wk}$
Min/shower $10 \text{ min}$
Heater inlet T $60 \text{ °F}$
Heater outlet T $100 \text{ °F}$
Initial capital cost per unit $10.00 \text{ per shower head}$
Number of shower heads $3$
Initial capital cost (IC) $30.00 \text{ (or cost difference between two options)}$
Energy price (natural gas) (Pr) $1.00 \text{ per therm}$
1 therm $1E+05 \text{ Btu}$

<table>
<thead>
<tr>
<th>Flow rate (gal/min)</th>
<th>Energy for high flow</th>
<th>Energy for low flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>$2.17E+07$</td>
<td>$8.68E+06$</td>
</tr>
<tr>
<td>Flow time (min/yr)</td>
<td>13000</td>
<td>13000</td>
</tr>
<tr>
<td>Hot water flow (gal/yr)</td>
<td>65000</td>
<td>26000</td>
</tr>
<tr>
<td>Energy flow (Btu/yr)</td>
<td>$2.89E+07$</td>
<td>$1.16E+07$</td>
</tr>
</tbody>
</table>

Annual Energy Savings (AES) $1.74E+07 \text{ Btu/yr}$
Simple Payback Period (SPP) $0.173 \text{ yr}$
Return on Investment (ROI) $579 \% \text{ per year}$

Cost of Conserved Energy Calculation
Interest rate, $i$ 0.06
Inflation rate for energy prices, $r$ 0.03
Discount rate, $d = i - r$ 0.03
Lifetime of shower head, $n$ 20 years
Operation and maintenance cost (O&M) $0.00 \text{ $/yr}$
Capital Recovery Factor (CRF) 0.0672
Cost of conserved energy (CCE) $0.0116 \text{ $/therm}$
Uniform Present Value Factor (UPVF) 14.9
Present Value Life-Cycle Savings (PVS) $2,582$
Net Present Value over Life-Cycle (NPS) $2,552$
Benefit-Cost Ratio (B/C) 86.1

AES = energy_{old} - energy_{new}$

SPP = \frac{IC}{AES \times Pr}$

ROI = \frac{100}{SPP}$

CRF = \frac{d(1 + d)^n}{(1 + d)^n - 1}$

CCE = \frac{IC \times CRF + O&M}{AES}$

UPVF = \frac{1}{CRF}$

PVS = (AES \times Pr - O&M) \times UPVF$

NPS = PVS - IC$

B/C = \frac{B}{C} = \frac{PVS}{IC}$