Flexibility for the Design of a Residential Heat Pump System

Application Portfolio for ESD.71
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Motivation

• New emphasis on research to increase home energy efficiency
• Benefits of research not available for several years
• Heat Pumps are installed when needed
• Efficiency may be considered over a system’s lifecycle, but replacing whole system is too expensive.
Uncertainties

- Energy Prices
  - Recent Volatility has increased focus on energy use
- Performance Improvement
  - Benefits of R&D projects are uncertain
- Government Policy
  - Incentives for energy efficiency may change over time. Currently $1500 for high efficiency systems

Approach

- Model Performance of Heat Pump System
- Model Future Energy Prices
  - High, Average, or Low Trends with Decision Analysis
  - Binomial Lattice Analysis With Dynamic Programming
- Estimate Initial Cost of Flexibility
- Estimate Cost of Future Upgrades
Heat Pump System Model

- Simplified Model
- Use Degree Day data and BTU/DD to determine building energy flow
- SEER Rating is used to determine energy use
- Model for Cost of

Modeling Price Uncertainty

- Historical Data
  - Exponential Fit of Data since 1960
  - Average growth of 3.7%/year
  - Variance of 20%/year
  (Source: Energy Information Administration)

- Future Predictions
  - Parameters Based on Historical Data
  - Random Walk Model
• Considers Original Installation of Fixed Design vs. Flexible Design.
• Considers 3 possible price trends.
  - High (Increase of 7.4%/year)
  - Average (Increase of 3.7%/year)
  - Low (No Change)
• 2nd Period Trend Probabilities Change depending on initial trend.

**Decision Analysis Results**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Inflexible System</th>
<th>Flexible System</th>
<th>Choice</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENPV</td>
<td>($11,520)</td>
<td>($11,609)</td>
<td>Flexible</td>
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<tr>
<td>VAR, P10</td>
<td>($14,564)</td>
<td>($13,831)</td>
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<tr>
<td>CAPEX</td>
<td>($2,300)</td>
<td>($2,430)</td>
<td>Inflexible</td>
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</tbody>
</table>
Results of Binomial Lattice Analysis

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</tr>
</thead>
<tbody>
<tr>
<td>ENPV</td>
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<td>($11,182)</td>
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<tr>
<td>P10</td>
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<tr>
<td>CAPEX</td>
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Conclusions

- A Flexible Heat Pump System provides protection against high increases in future energy costs.
- Allows for economic installation of a typical system when purchased by homeowner.
- Allows for future upgrades when economic conditions, government incentives, or other motivations are present.
- Provides a larger potential market for some new technologies by allowing installation into existing systems.
Future Work

- Further study of technology development trends.
- Consideration of other uncertainties (incentives, weather) in valuation models.
- Expand models to include multiple energy sources and more realistic models.
- More accurate determination of costs and limits of flexibility.
- Identify specific technologies and plan for implementation.