Flexibility for the Design of a Residential Heat Pump System

Application Portfolio for ESD.71

Kevin Ferrigno

Professor: Richard de Neufville
TA: Michel-Alexandre Cardin

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

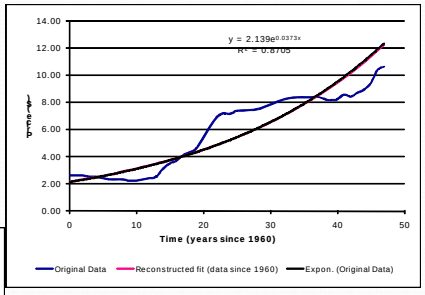
Heat Pump System Model

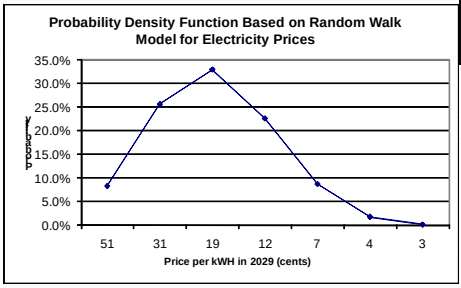
- Simplified Model
- Use Degree Day data and BTU/DD to determine building energy flow
- SEER Rating is used to determine energy use
- Model for Cost of

Modeling Price Uncertainty

- Historical Data
  - Exponential Fit of Data since 1960
  - Average growth of 3.7%/year
  - Variance of 20%/year

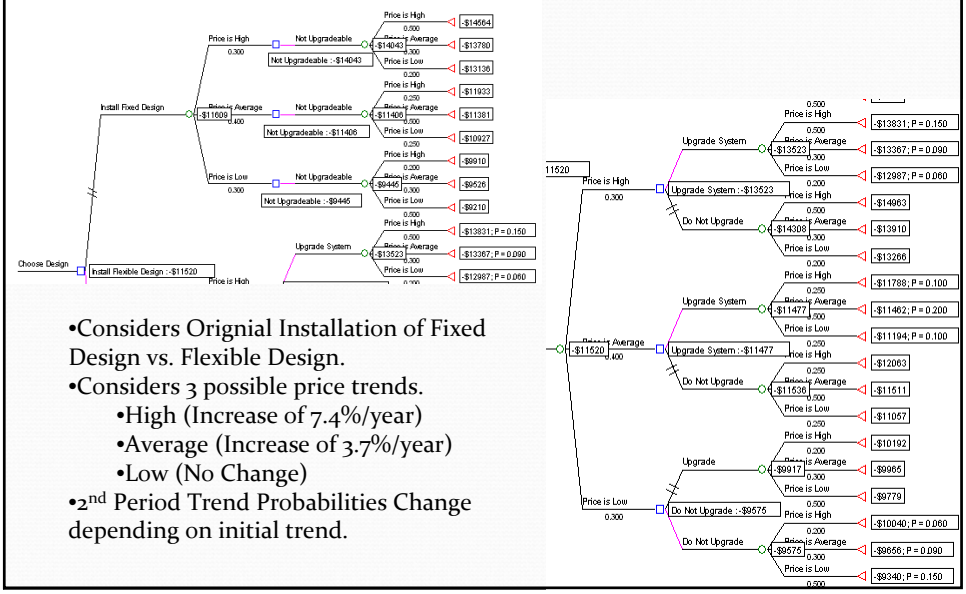
(Source: Energy Information Administration)





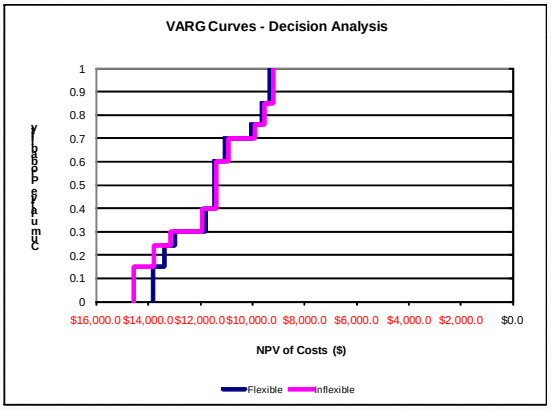
- Future Predictions
  - Parameters Based on Historical Data
  - Random Walk Model

Decision Analysis



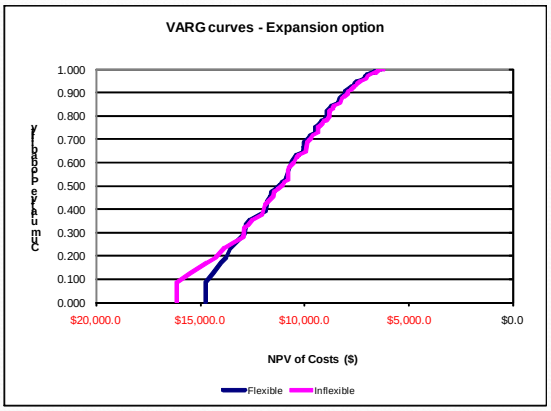
- Considers Orignial Installation of Fixed Design vs. Flexible Design.
- Considers 3 possible price trends.
  - High (Increase of 7.4%/year)
  - Average (Increase of 3.7%/year)
  - Low (No Change)
- 2nd Period Trend Probabilities Change depending on initial trend.

Decision Analysis Results



Criteria	Inflexible System	Flexible System	Choice
ENPV	($11,520)	($11,609)	Flexible
VAR, P10	($14,564)	($13,831)	Flexible
CAPEX	($2,300)	($2,430)	Inflexible

Results of Binomial Lattice Analysis



Criteria	Inflexible System	Flexible System	Choice
ENPV	($11,332)	($11,182)	Flexible
P10	($15,446)	($14,384)	Flexible
CAPEX	($2,300)	($2,430)	Inflexible

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.