Seminar 56 – Urban-scale Building Energy Modeling, Part 6

Agent Based Modeling to Estimate the Adoption of Energy Efficient Building Technologies

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Learning Objectives

- Understand how one can estimate the actual rate of adoption of energy efficient building technologies at the urban, state and even national level
- Name at least three non-energy or non-economic measures that influence the adoption of energy efficient building technologies
- Describe how UBEM can be used to make well-informed utility planning decisions
- Recognize key structural and operating requirements for an urban-scale energy modeling platform
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Outline

• Technology Adoption Modeling
• Agent Based Modeling
• Commercial Building Agent Model
• Examples
• Conclusions
Why Model Technology Adoption?

Policy makers, Utility Program Designers, and Manufacturers (among others) all have a need to be able to estimate the adoption of new technologies in the marketplace

• Meeting sustainability and economic goals
• Maximizing performance of investments and incentives
• Understanding the needs of the marketplace
Who Models Technology Adoption?

Policy Makers
- Sustainability and Economic Planning

Utility Programs
- Maximizing Incentives

Manufacturers
- Understanding the Marketplace
Models for Technology Adoption

• Diffusion Models
  • Adoption as a diffusion process

• Technology Acceptance Model
  • Information systems theory model

• Agent Based Models

\[ \frac{dF}{dT} = p + (q - p)F - q F^2 \]
Agent Based Models (ABMs)

Agent Based Modeling (ABM) is a highly disaggregated – bottom up – approach to modeling grounded in computational, biological and social sciences.

- ABMs provide a framework to describe the interactions of complex systems using easily identifiable and understandable pieces — agents which represent individual decision makers.
Advantages of an ABM

• Endogenous (Self-directed)
• Simple Logic
• Natural Evolution
• Fewer Assumptions Required
• Fewer Explanatory Variables for Calibration and Validation
• Dependencies Do Not Need to Be Fully Understood
• Highly Adaptable and Extensible
• Flexible Disaggregation
Disadvantages of an ABM

• May Be Challenging to Collect Data to Inform Decision Logic
• Challenge in Identifying and Modeling Entities Who Seem to Make Illogical Decisions
• Can Be Computationally Demanding
• Difficult to Calibrate and Validate
• Tradeoff Between Temporal Granularity, Level of Disaggregation, and Number of Agents
A Commercial Building Agent Model

Inflow to Stock (Construction Rate)

Outflow from Stock (Demolition Rate)

Commercial Buildings Stock Status

Available Technologies

Technology Costs

Available Capital

Energy-efficiency Programs

Energy Costs

Changes to Existing Commercial Buildings Stock
(Refurbishing, Retrofitting, and Renovation Rates)

Owners

Available
Technologies

Commercial Buildings
Stock Status

Supermarket
Healthcare
Hotels
Apartments
Services

Retail

Hotels

Schools

Restaurants

Apartments

Services
Building Aggregation in ABM

Impact Level:
Aggregated Indices

Agent Level:
Aggregated Building Stocks

Building Level:
Individual Buildings

Component Level:
Building Systems
Commercial Building Stock

• When an ABM uses aggregation then representative models should be used.

- High- and Mid-Rise Apartments
- Large and Small Hotel
- Small, Medium, and Large Office
- Primary and Secondary School
- Warehouse and Supermarket
- Hospital and Outpatient Clinic
- Stand-alone Retail and Strip Mall
- Quick and Full Service Restaurants
Detailed simulations for an ABM may be too slow so a reduced order energy model might be needed.
Modeling Technology

- Economics
  - Discount Rate
  - First Costs
  - O&M Costs
  - Fuel Costs

- Energy
  - Energy Use
  - Embedded Energy
  - Life Cycle Energy

- Non-Energy
  - Design/Install Skill
  - Procurement/Install Time
  - Durability/Serviceability
  - Non-Energy Performance
Modeling Owners/Decision Makers

Owner Type
- Government
- Leader
- Follower
- Laggard

Tech Switch
- Same Tech Only
- Same Fuel
- Any Tech

Risk Preference
- Aggressive
- Average
- Risk Averse

Economic Focus
- Capital Only
- Capital + Energy
- Capital + O&M
- Cap + O&M + Energy
Decision Model

Non-Energy Benefits

$C_1$, $C_2$, ..., $C_N$

$W_1$, $W_2$, ..., $W_N$

Technology Adoption Factor
Changes Hurdle
Weights

Compute Normalized Costs based on hurdle factor/discount rate

Technology Costs

Cap.

$W_C$

O&M

$W_O$

Fuel

$W_E$

Financial Score

$W_{FS}$

Energy Score

$W_{ES}$

Weighted Score
Example Study: LED Lighting Adoption Savings

Total Energy Savings

2013-2015 used for calibration

- ABM with HVAC Effects
- ABM without any HVAC Effects
- Reference Model
Example Study: Hot Water Heating Energy Use

Comparison of ABM to a Reference Model from the DOE Energy Information Administration

Entire US Total

Annual Consumption (TBU)

Ref

ABM
Example Study: Technology Adoption Estimation

- ABM yearly estimation and diffusion model fitting to ABM output

Fit for Retrofit: All,
Decision Type: retrofit, Tech Index: 60,
Building Vintage: All, Building Type: All,
Census Region: All, Tech Vintage: All, Years 2004-2040

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Conclusions

• A CoBAM can be used to understand technology adoption based on costs, energy use, and non-energy benefits

• Argonne has validated a CoBAM through comparison to EIA energy predictions when using the same input data

• A CoBAM can be used to estimate Bass Diffusion Coefficients in order to get an adoption diffusion curve for a technology
QUESTIONS?

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