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Seminar 43 Urban-Scale Energy Modeling, Part 3

Urban Energy

Learning Objectives

- Learn how urban-scale building modeling can be used to make more well-informed energy decisions
- Learn challenges of big data and computing for city scale building energy modeling
- Understand why metropolitan planning agencies are starting to become more interested in building energy use
- Understand the interactions between data collected in the SEED Platform through energy disclosure laws and city scale modeling with DECAF

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Outline/Agenda

- Motivation
- Real Estate Model
- Building Energy Model
- Coupling the two models
- Example Use

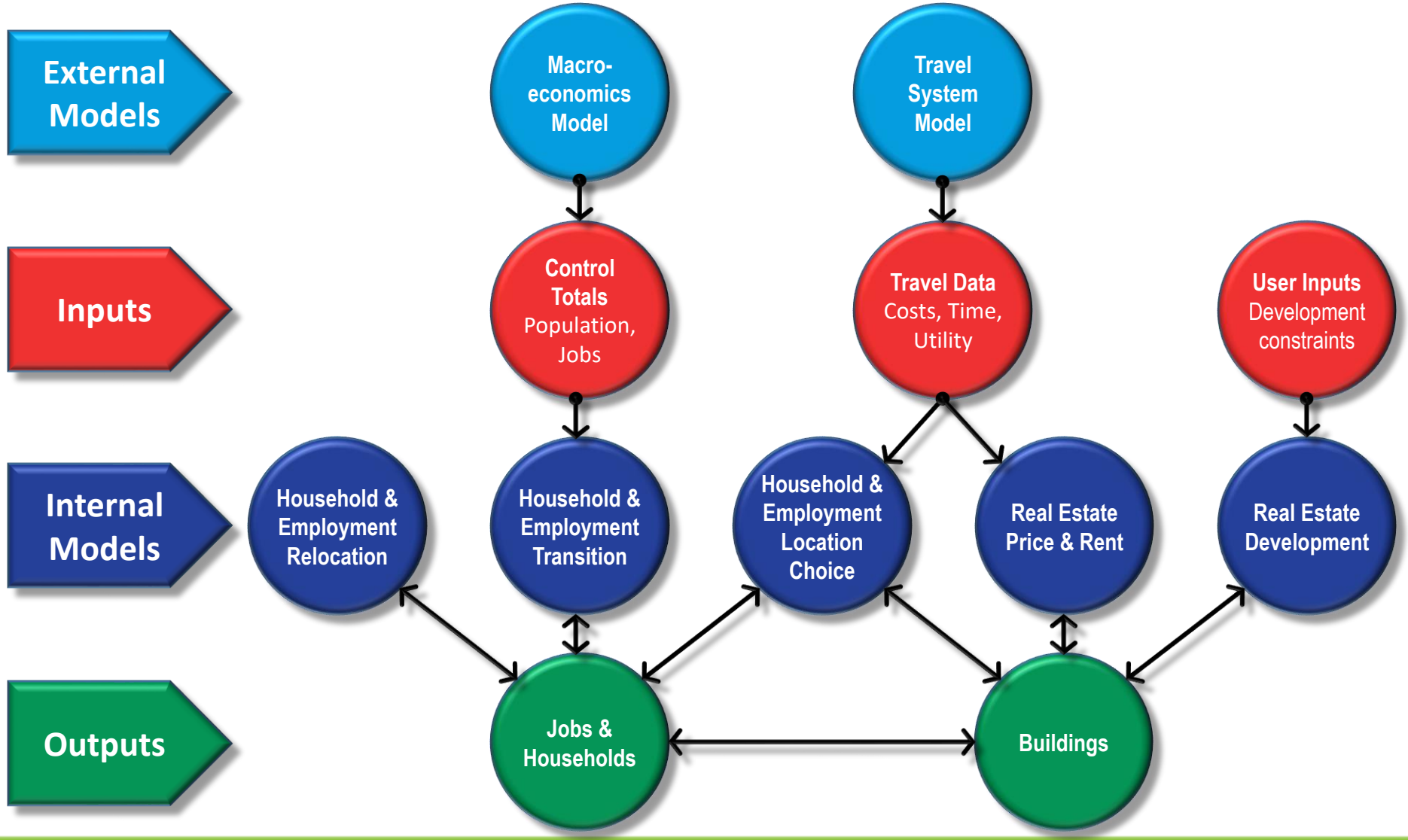
Motivation

- Urban Planners often run real estate simulations to understand the effects of policy on changes in the type and value of building stock and demographics
  - Building energy use could be a factor in those changes so should be incorporated if possible
  - Changes in building stock and demographics will result in changes in building energy use
- Coupling of a building energy model (BEM) to a real-estate model will allow planners to understand the coupled effects of policy changes on urban growth and building energy use

Real Estate Simulation Models

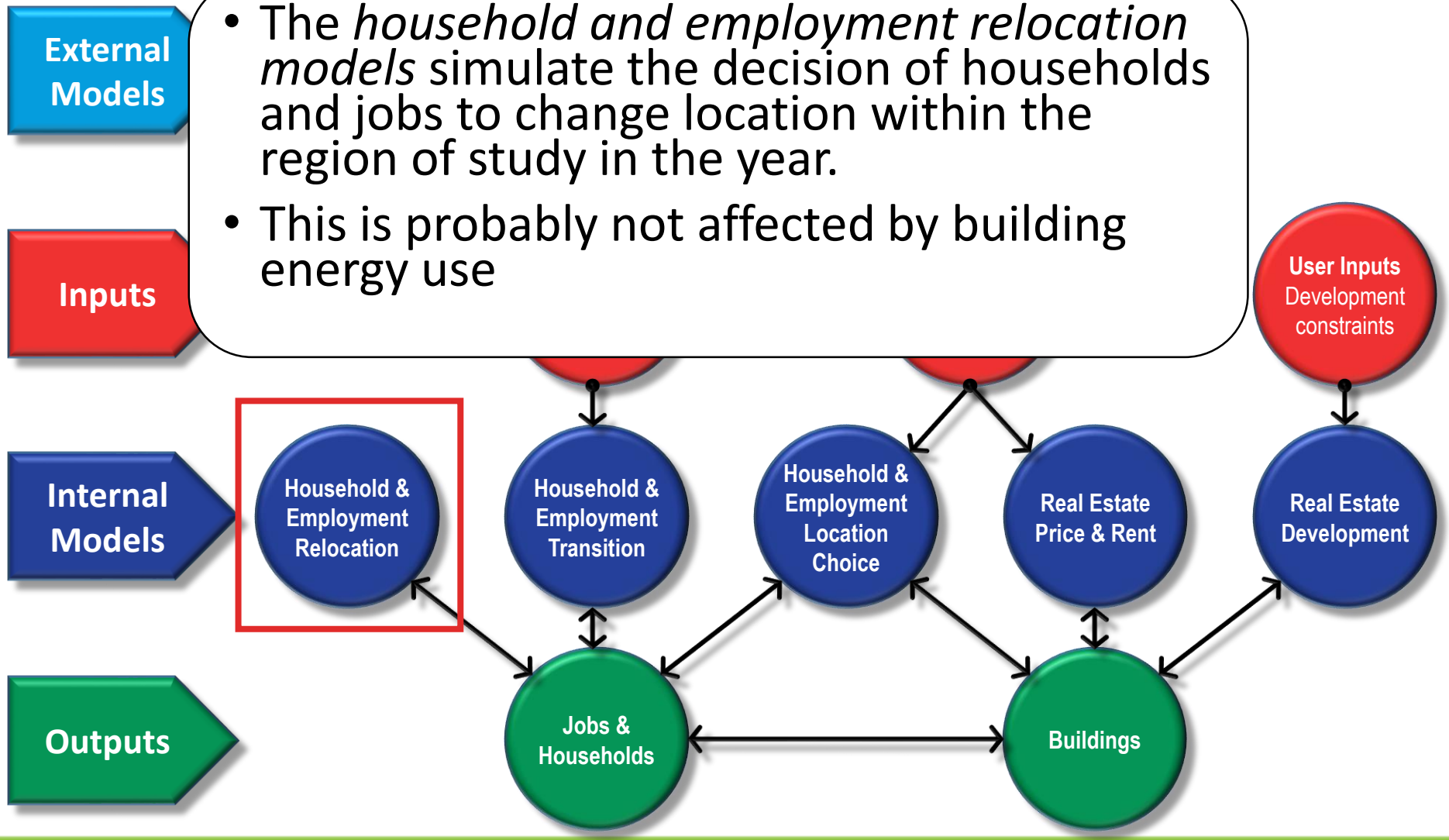
- Real estate simulation models attempt to estimate the changes in the value and type of buildings along with the shift in demographics
  - Models can include zoning, code, taxes and other policy decisions that impact real estate development
- These data are typically used with input/output economic models to predict economic impacts in addition to the change of the real estate market
- These models typically rely on external traffic / mobility simulation models as inputs to the move of people and jobs in the real estate simulation

Real Estate Simulation Model



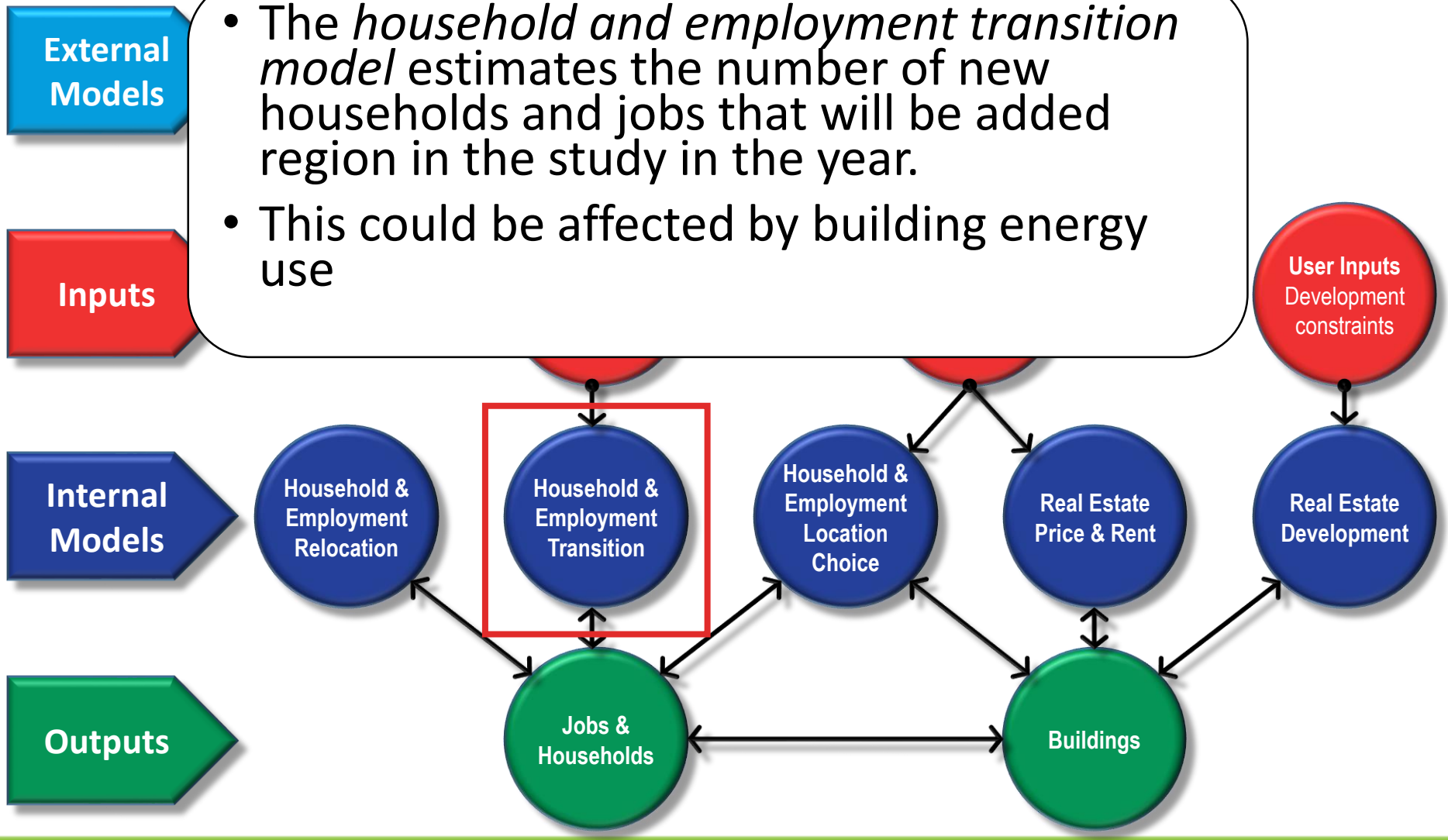
Household and Employment Relocation Model

- The *household and employment relocation models* simulate the decision of households and jobs to change location within the region of study in the year.
- This is probably not affected by building energy use



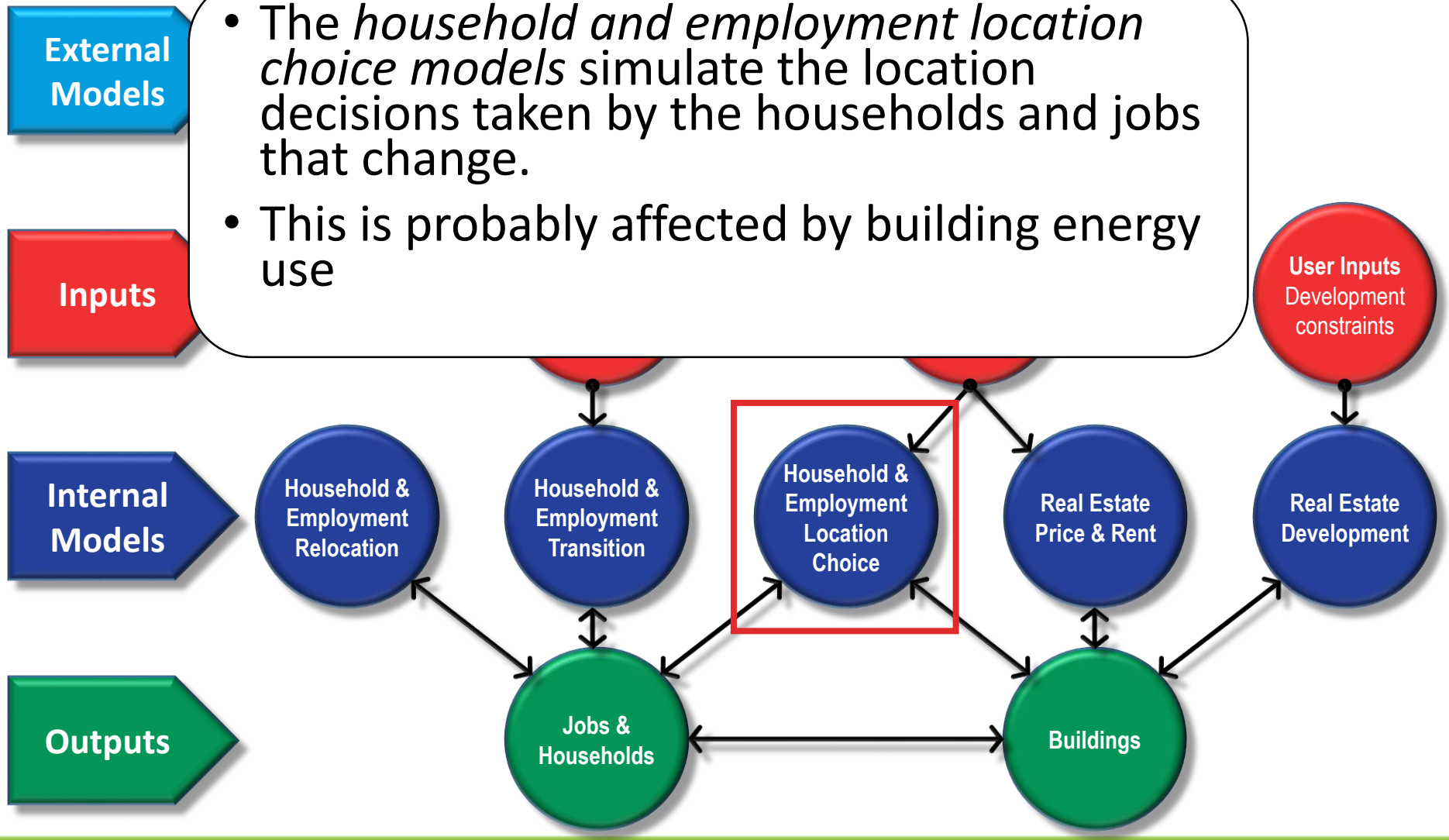
Household and Employment Transition Model

- The *household and employment transition model* estimates the number of new households and jobs that will be added region in the study in the year.
- This could be affected by building energy use



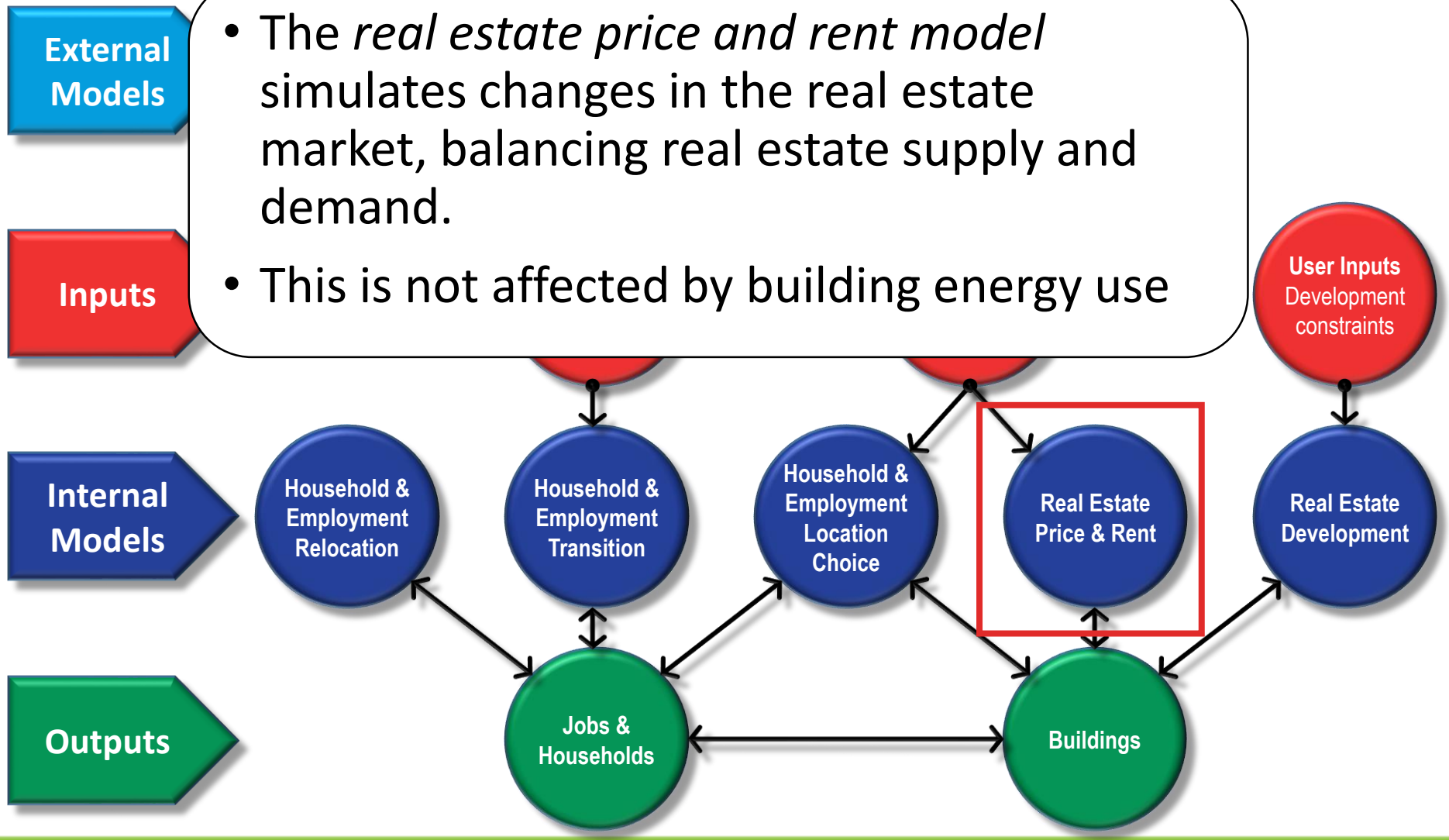
Household and Employment Location Choice Model

- The *household and employment location choice models* simulate the location decisions taken by the households and jobs that change.
- This is probably affected by building energy use



Real Estate Price and Rent Model

- The *real estate price and rent model* simulates changes in the real estate market, balancing real estate supply and demand.
- This is not affected by building energy use



Real Estate Development Model

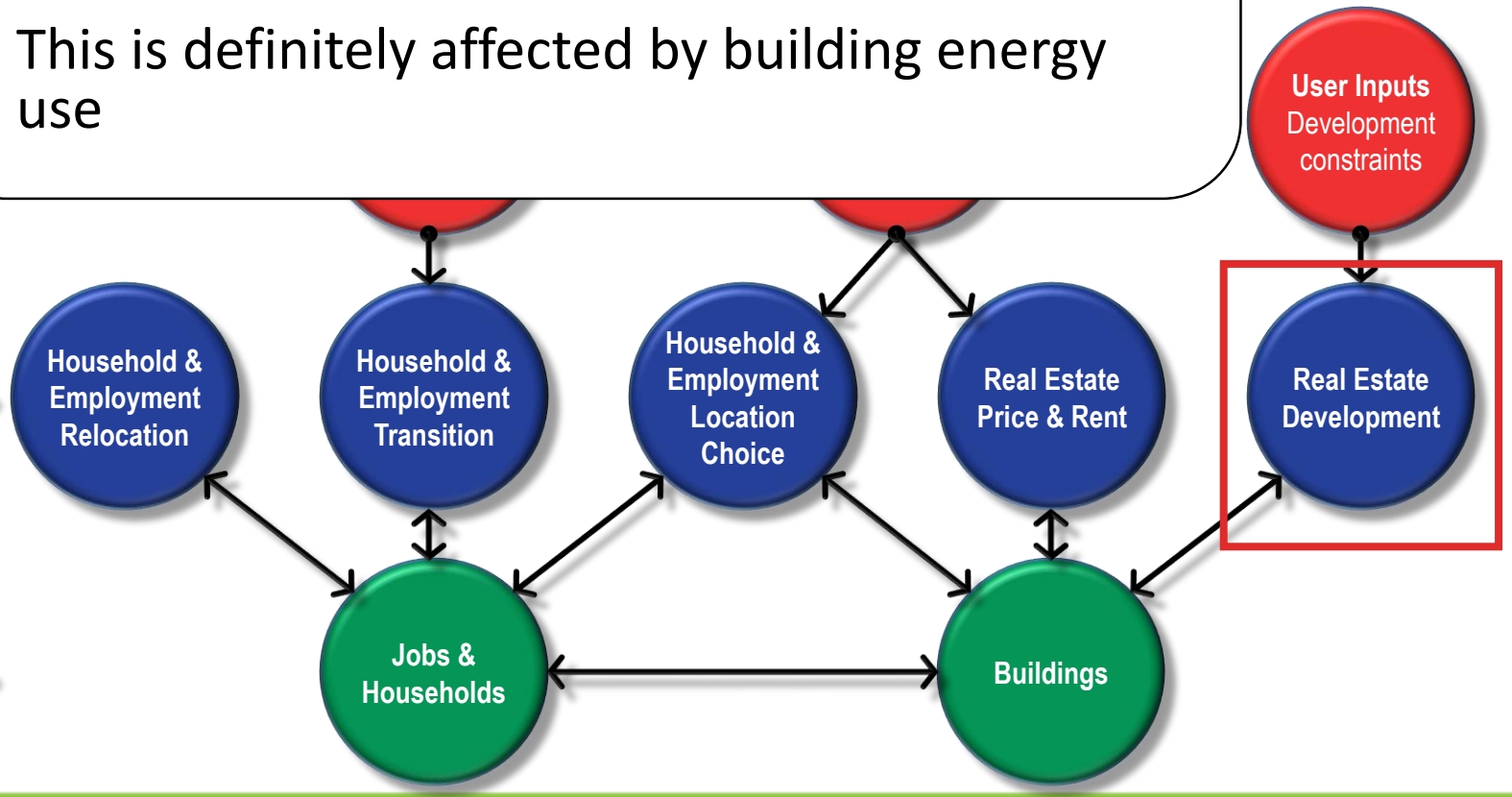
External Models

Inputs

Internal Models

Outputs

- The *real estate development model* simulates the actions of real estate developers to develop sections of the city including location and the type of development
- This is definitely affected by building energy use



How Does Building Energy Affect Real Estate Growth?

Building energy use and costs affect:

- Building operating costs which affects choice to develop and price a building and the decision to add or eliminate jobs
- Building value which affects choice to development and price a building
- Choice of whether or not to move to a new building and where one might want to move

Selecting a Building Energy Model

Considerations for selecting a building energy model (BEM) for coupling to the real-estate model include:

- Only monthly or annual energy and costs are needed
  - Extremely detailed simulation is unnecessary
- Building information is quite limited
  - Must use building templates that get modified
- Model must run fast
  - The real-estate and traffic simulations don’t need cloud or HPC so the BEM shouldn’t either

Selecting a Building Energy Model

Considerations for coupling the real-estate model to a building energy model (BEM):

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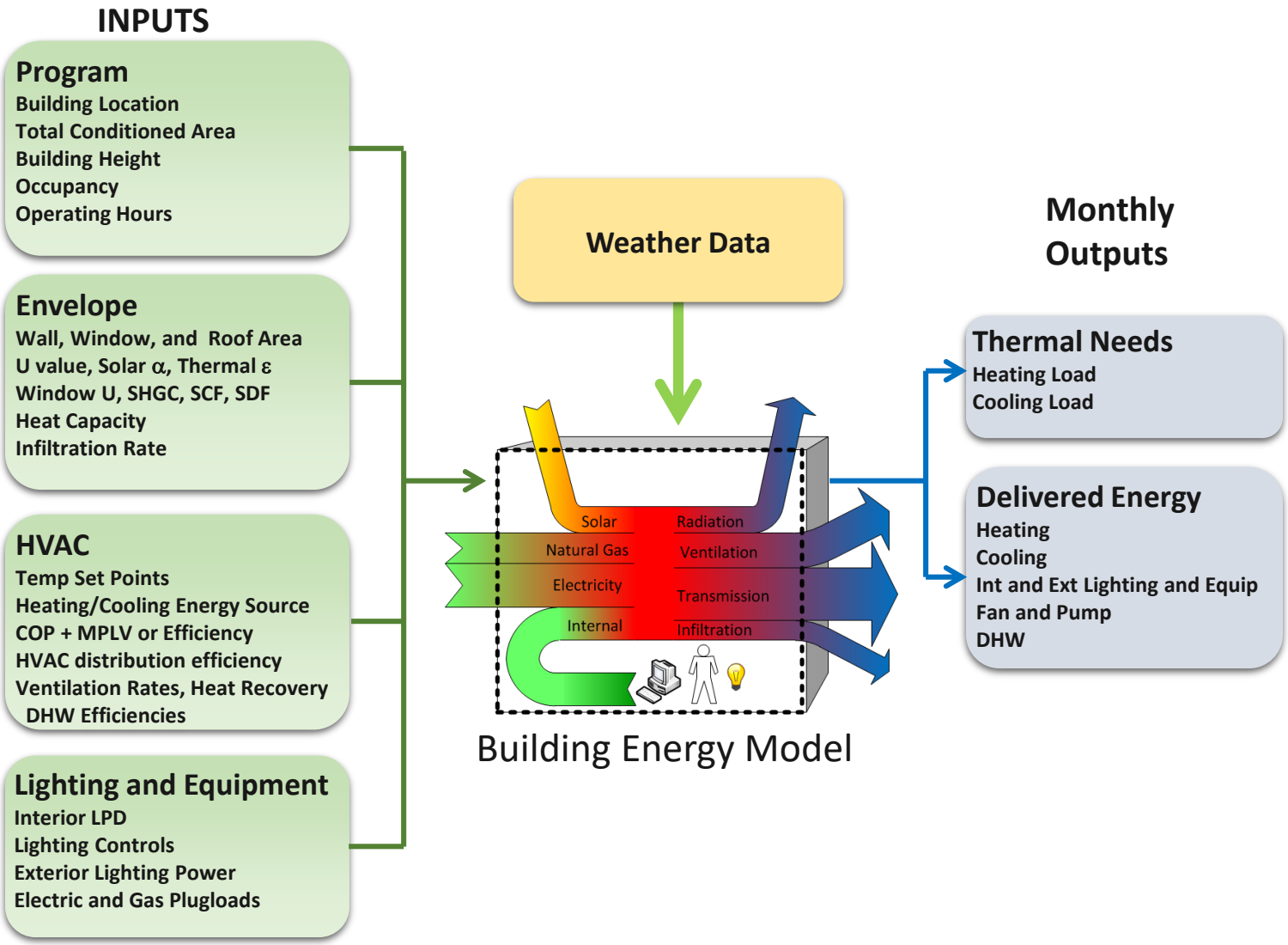
One model that fits these criterion is the Reduced Order Model based on ISO 13790

ISO 13790 Reduced Order Model



Coupling to the Models

The BEM can be coupled into the real-estate model through simple python scripts. At the end of each year scripts will

- Extract building and demographic data
- Generate input models for the BEM
- Run the BEM (utilizing multi-cores if available)
- Parse the BEM output files
- Analyze the BEM output
- Feed the BEM data back into the real-estate simulation

Using Data Frames

We used data frame structures in our implementation

- Data frames are the python equivalent of pivot tables in excel

One of the popular data frame packages has a large number of pre-defined data analysis operations that ease coding including:

- Counting, Sorting, Extracting, Merging
- Statistical Analysis
- Plot and Histogram Generation

Example Use: San Francisco

A very popular real-estate simulation program has an example data set based on San Francisco

- Over 150,000 residential and commercial buildings
- Information includes building type, size (stories and floor area), and household size

The real estate software is

- Coded in Python using a data frame structure which makes data analysis very simple
- Natively uses HDF5 for data exchange (much faster than CSV for reading/writing)

Example Stat Analysis

```
print bldg_yr_eui.describe(percentiles =
[0.05, 0.25,0.5, 0.75 ,0.95])
```

```
count    113918.000000
mean        304.318489
std          92.111982
min          72.212252
5%          175.491735
25%         241.801795
50%         294.069972
75%         354.338944
95%         464.747881
max         998.586553
```

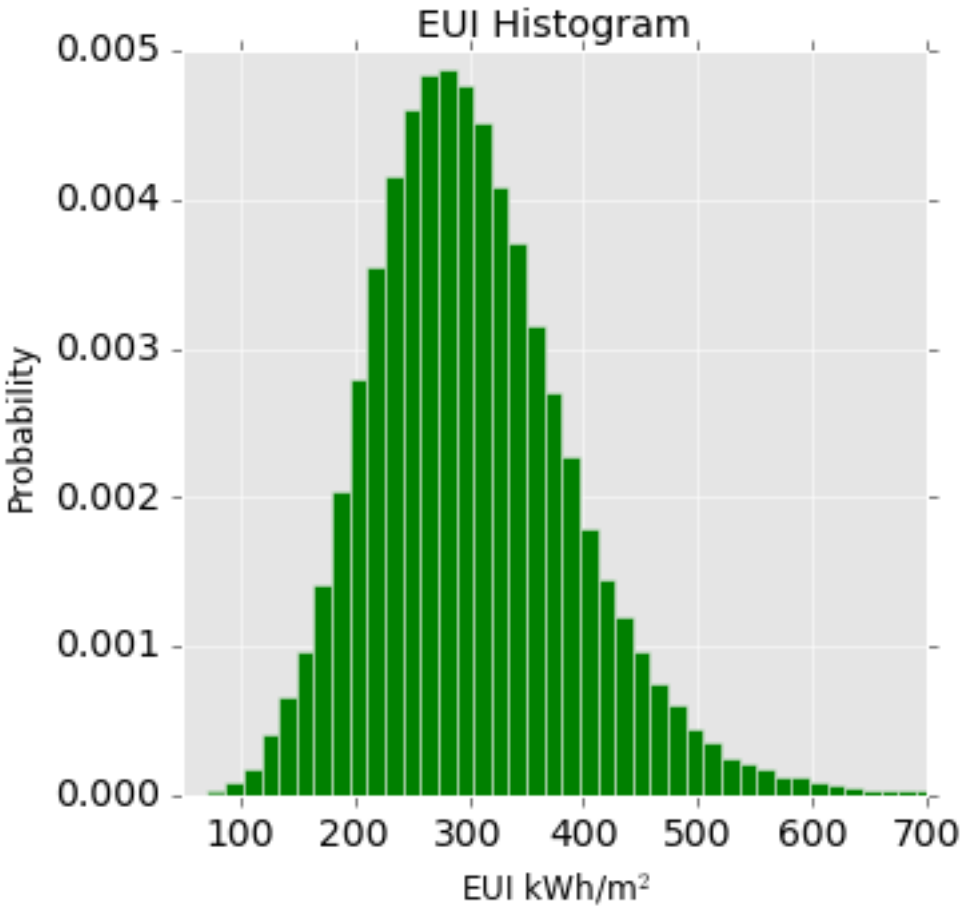
One line of python code can create a fairly complete statistical analysis of the building EUI

Units are kWh/m2

Example Histogram Generation

```
bldg_yr_eui.plot(kind='hist',color='g',alpha=1, bins=60,
normed=True)

plt.xlabel(r'EUI kWh/m$^2$')
plt.ylabel('Probability')
plt.title('EUI Histogram')
plt.axis([50,700,0,0.005])
```



Example Data Visualization

- 3D graphics can be used to visualize the data as false color plots on the buildings

Computation Time

- Real estate simulation takes about 12 seconds per year on an 8 core machine
- Buildings simulation (over 100,000 BEM runs on the residential buildings) takes about 50 min on the same 8 core machine
  - Cloud or HPC could be used to look at many scenarios with various assumptions and input data that drive differing amounts of real estate growth

Conclusions

- A BEM coupled to a real-estate / urban planning model allows one to affects of growth and policy on building energy use
- Use of Python with data frame structures allows for powerful data analysis with compact and readable code
- Computation time is dominated by BEM hence the need for a very fast BEM

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QUESTIONS?

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