Laboratory of Urban Complexity And Sustainability (LUCAS)
Faculty of Engineering, University of Nottingham, UK.

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# Stochastic modelling of occupants' presence, activities and electrical appliance use: No-MASS


- Jacob Chapman
- Peer-Olaf Siebers
- Darren Robinson

- The University of Nottingham


# The Performance Gap

- Deviations between predicted and real world performance
  - Uncertainties of model/ algorithms
  - Climate
  - Occupants
- Lead to stochastic models of behaviour
- Generic method integrating them
- Coupled with performance building simulation

# Stochasticity in peoples' behaviours

- Peoples' decisions depend on both deterministic and random responses to stimuli: they are **stochastic** in nature.
- The same occupant may respond differently, on different occasions, even in response to identical stimuli.
- We may also encounter considerable differences in response between individuals to identical stimuli.
- This randomness can have significant implications for comfort and for buildings' **energy** and other resource demands.

# **Stochastic** simulation

We want **stochastic** models that will account for:

- the **variety of behaviours** (investments, occupants' presence and activities, appliance use, comfort adaptations: personal & envelope)
- the **variation over time** of these behaviours,
- the **variation between individuals** of these behaviours.

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To provide more precise **inputs** to our simulations.

- More **robust** renovation and design solutions.
- Better **load profiles** for the **sizing and control** of energy conversion systems and supply networks: building-embedded and district-wide.
- Better **energy use** and **comfort** prediction.

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# Current approaches to behavioural modelling

Deterministic representions:

- Time schedules (e.g. for occupation and use of lights & appliances)
- Simple rules (e.g. for blinds and windows)

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These methods lack generality and extensibility

# Aims

- Improve simulated building performance in response to agents' stochastic decisions

# Objectives

- Present a framework for the integration of stochastic models
- Be able to assign archetypes to an agent template
- Integrate framework within a building simulation environment

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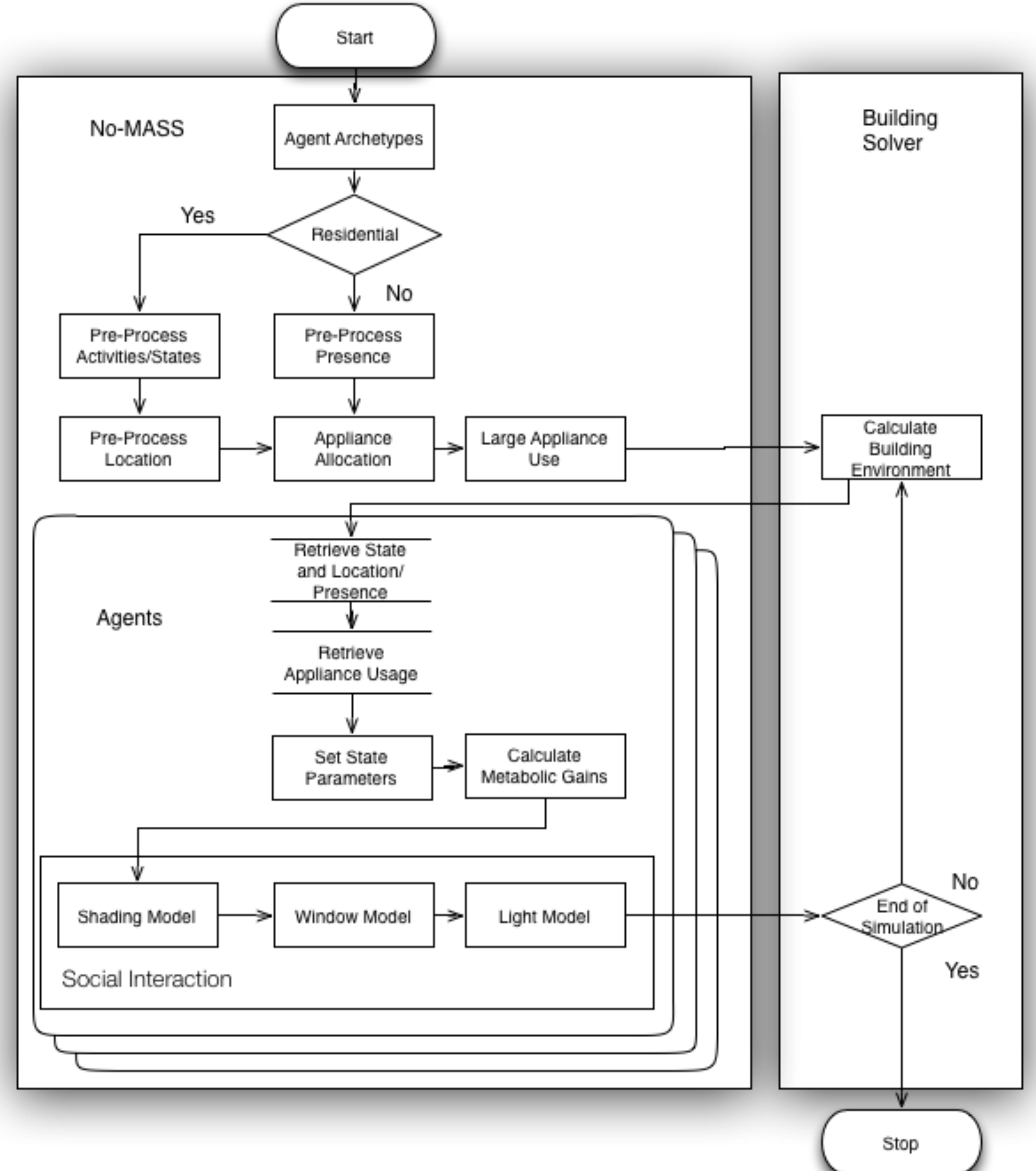
# Framework

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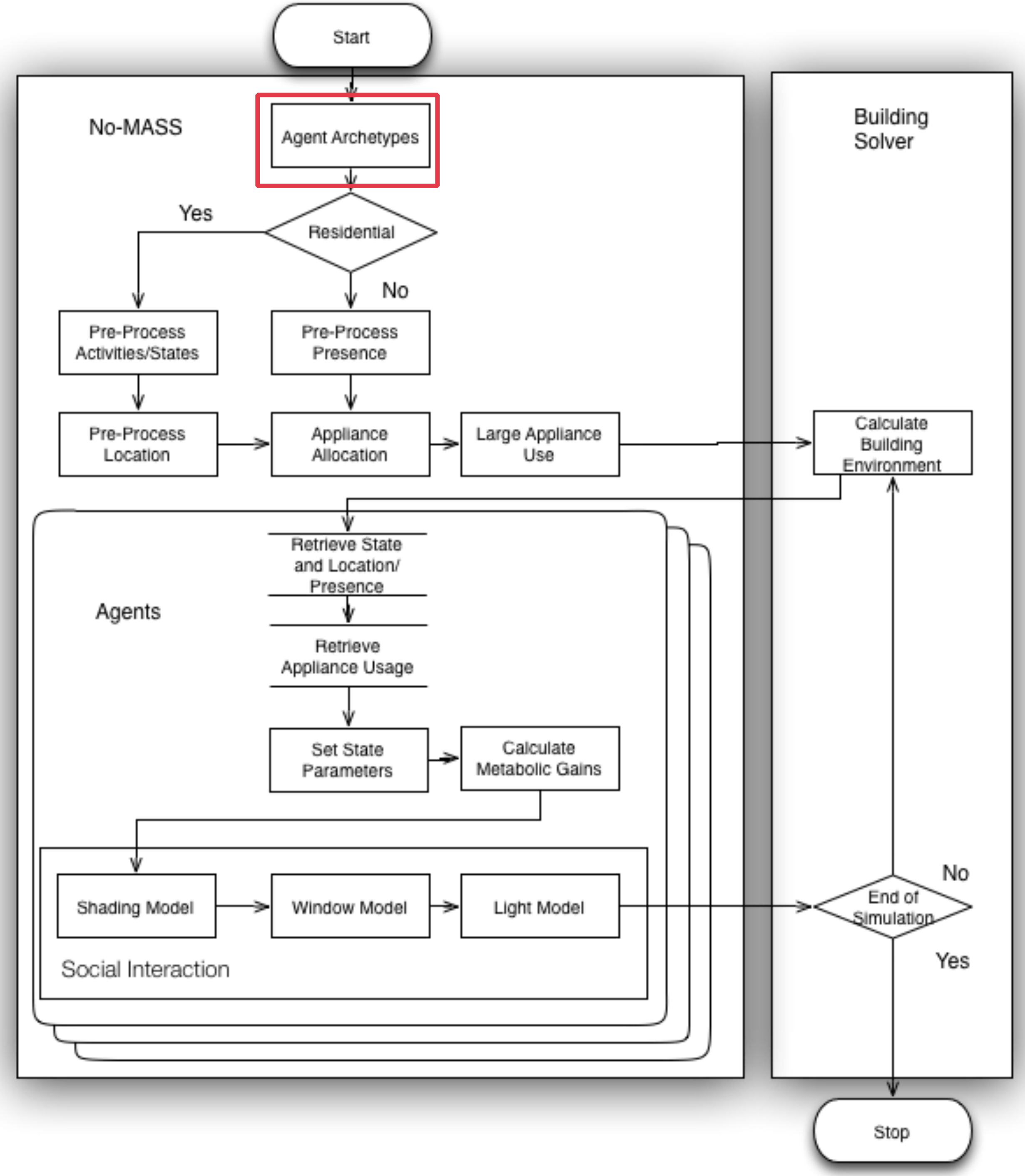
# Diversity Between Agents

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# Diversity Between Agents

| | | | |
|---|---|---|---|
| *age* | ***<36*** | ***36-59*** | ***>=59*** |
| *family* | ***with child*** | ***with teenager*** | ***…*** |
| *married* | ***TRUE*** | ***FALSE*** | |
| *day* | ***Monday*** | ***Tuesday*** | ***…*** |
| *season* | ***Summer*** | ***Spring*** | ***…*** |
| *gender* | ***male*** | ***female*** | |
| *employed* | ***TRUE*** | ***FALSE*** | |
| *computer* | ***TRUE*** | ***FALSE*** | |
| *retired* | ***TRUE*** | ***FALSE*** | |
| *education* | ***<*** | ***middel school*** | ***<*** |

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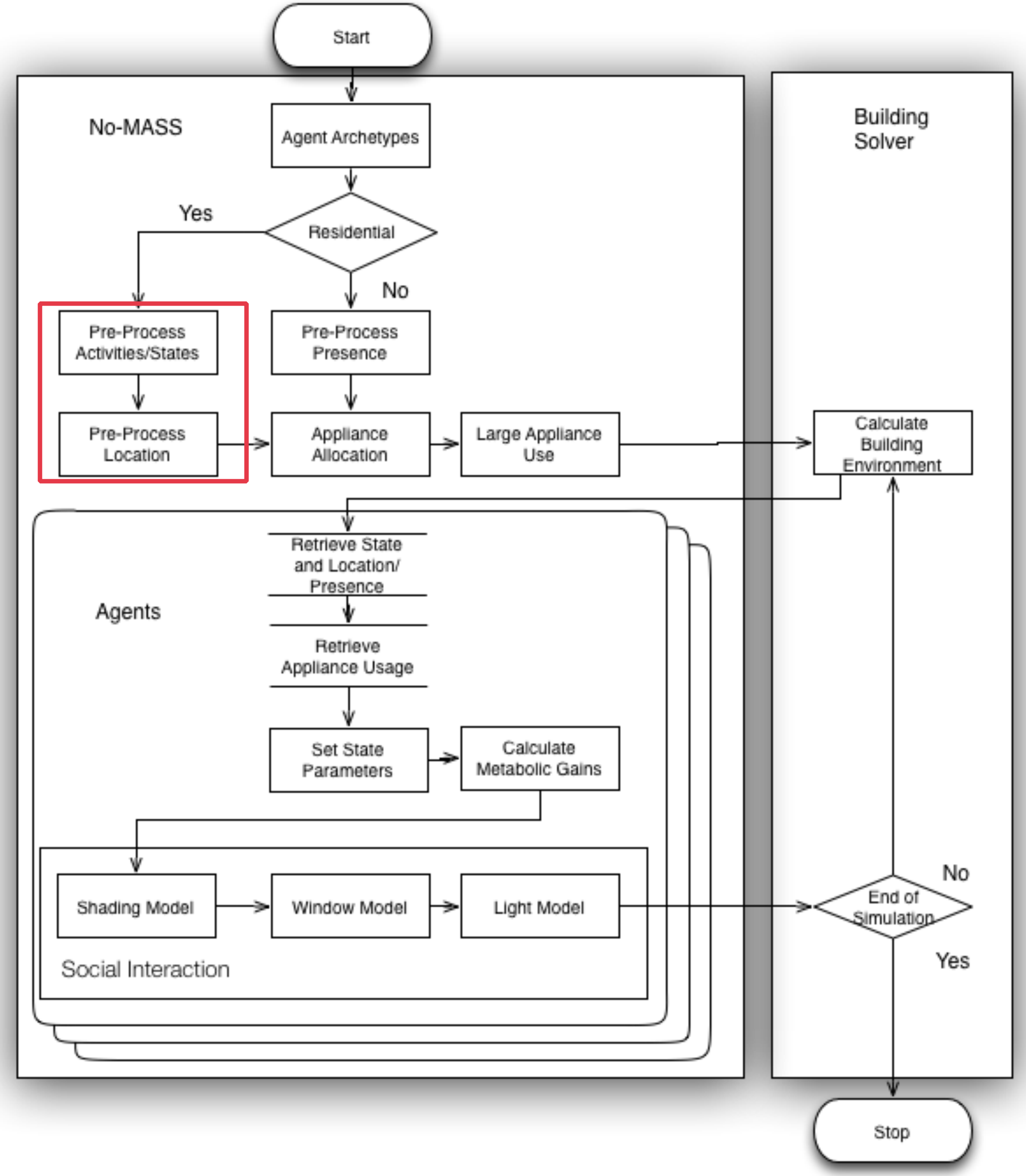
# Activities

- Agent State
- Location

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# Diversity Between Agents


Retired

Not Retired

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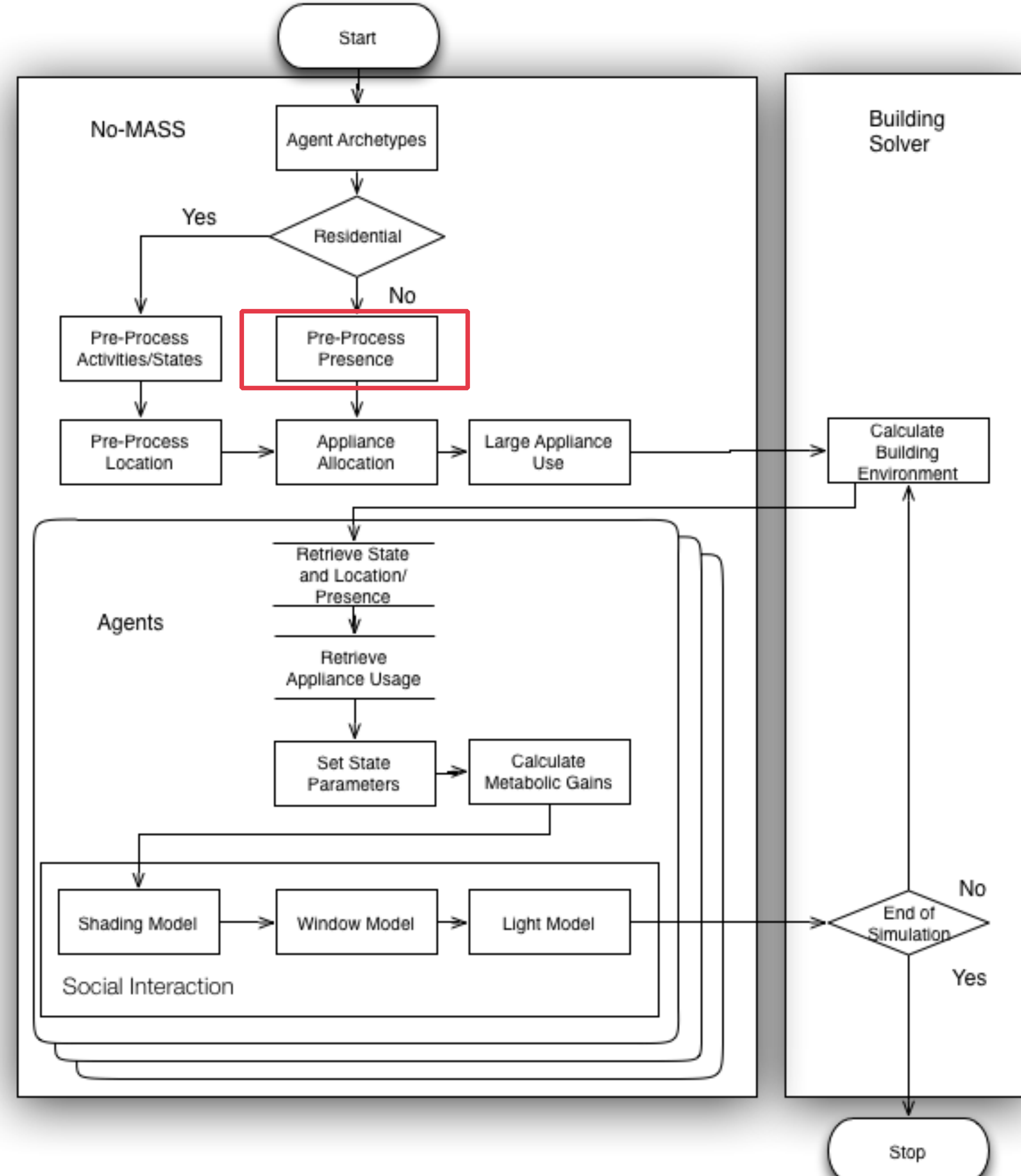
# Presence





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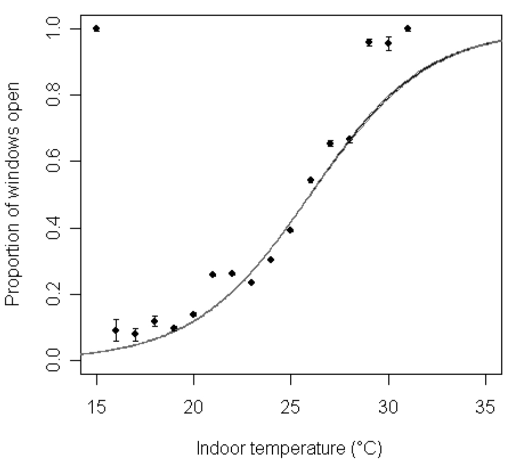
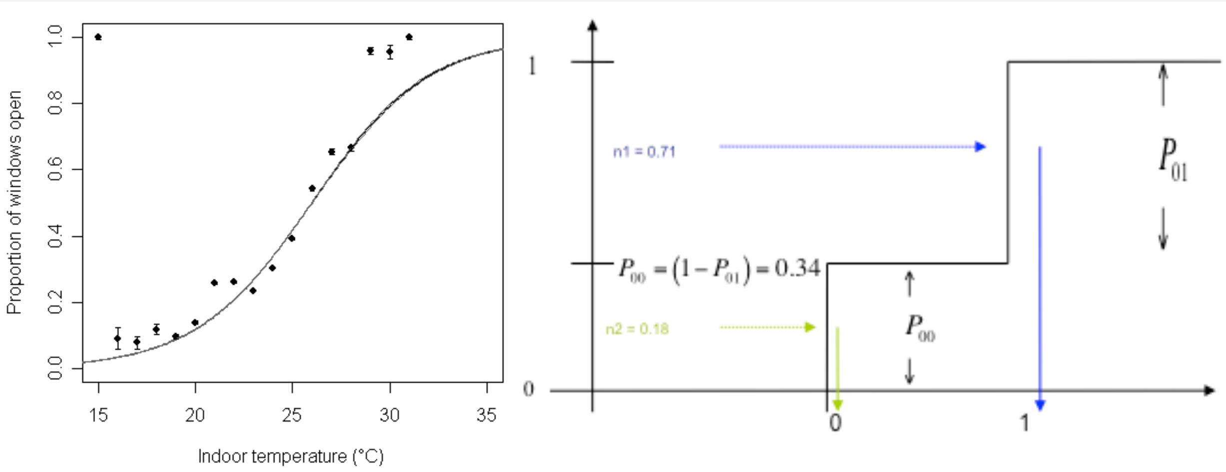
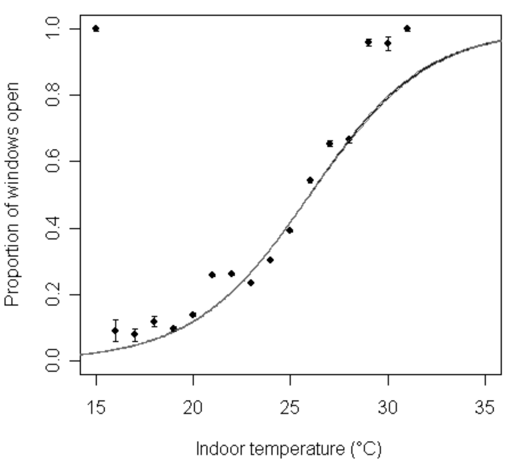
- Three modelling tools:
  - **Bernoulli process**

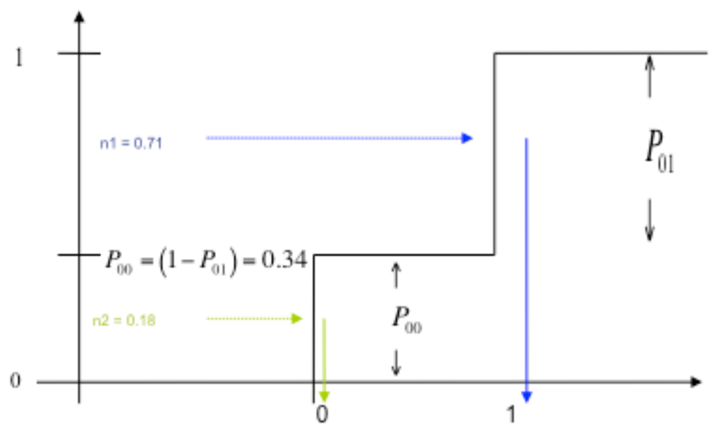


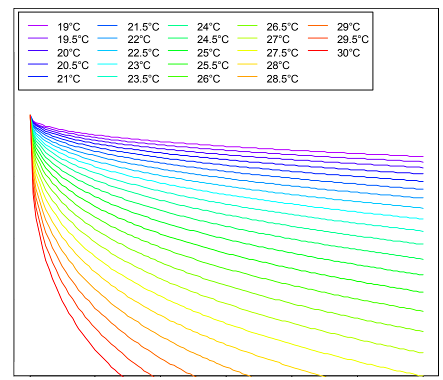
- Three modelling tools:
  - **Bernoulli process**
  - Discrete time random process: **Markov chain**



- Three modelling tools:
  - **Bernoulli process**
  - Discrete time random process: **Markov chain**
  - Continuous time random process: **Survival analysis**

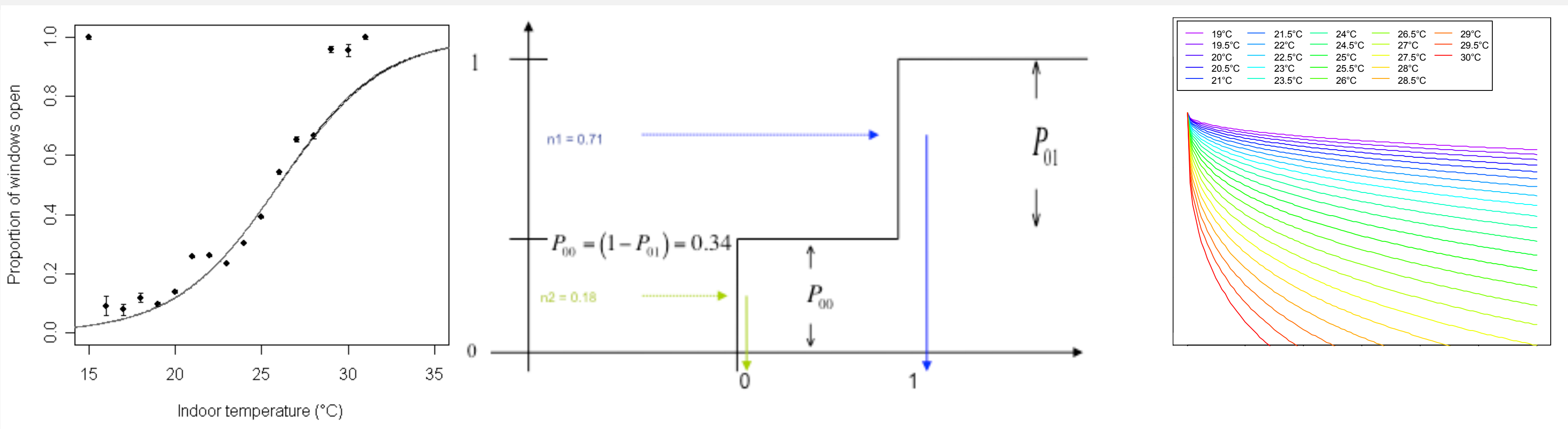



- Applying:

- Three modelling tools:
  - **Bernoulli process**
  - Discrete time random process: **Markov chain**
  - Continuous time random process: **Survival analysis**




- Applying:
  - **Cluster analysis** and/or **Forward selection**
  - k-fold **cross validation**

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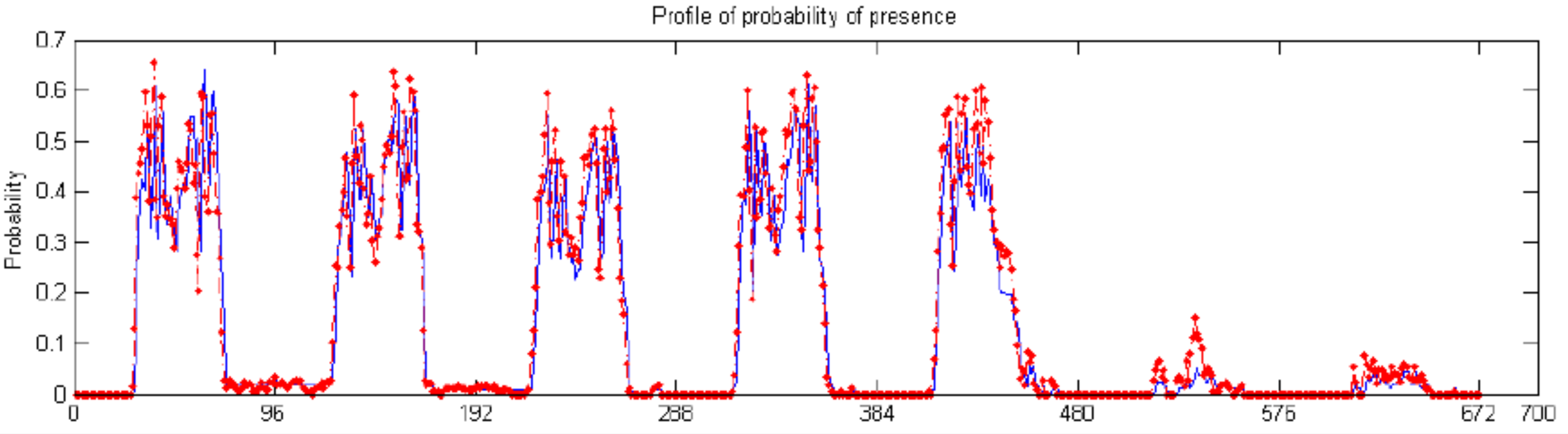
# Short-term **Presence** profile: $P_{ij}(t)$




*Page, Robinson, Morel and Scartezzini, Energy & Buildings 40(2), 2008*
*(5th most cited paper: 2008-13)*

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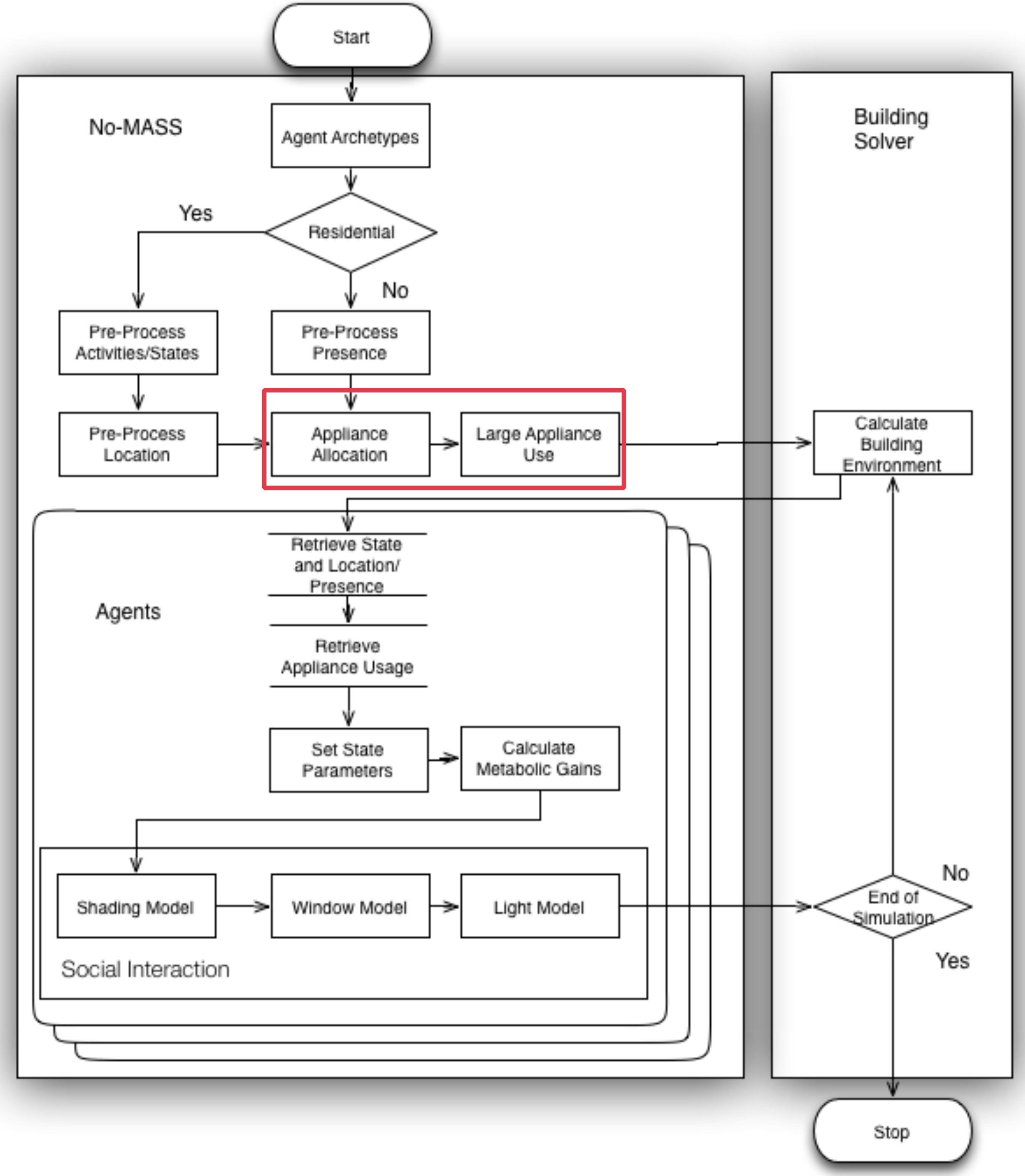
# Appliance

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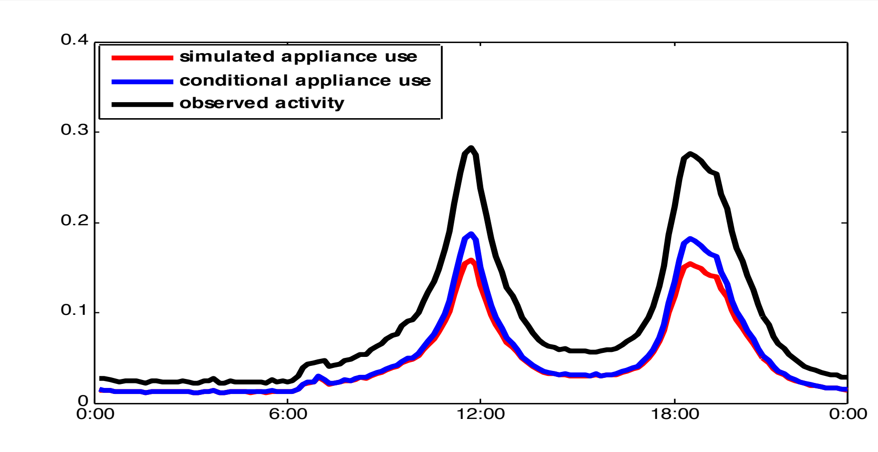
# Electrical appliances **ownership**

| | Model | TPR | FPR | ACC | AUC | Dxy |
|---|---|---|---|---|---|---|
| 1 | w'machine | 0.890 | 0.738 | 0.881 | 0.819 | 0.638 |
| 2 | t'dryer | 0.917 | 0.711 | 0.720 | 0.717 | 0.434 |
| 3 | dishwasher | 0.879 | 0.540 | 0.743 | 0.785 | 0.570 |
| 4 | s'instant | 0.845 | 0.625 | 0.702 | 0.609 | 0.218 |
| 5 | s'pumped | 0.273 | 0.115 | 0.704 | 0.607 | 0.214 |
| 6 | c'relectric | 0.919 | 0.742 | 0.762 | 0.621 | 0.242 |
| 7 | el'heater | 0.134 | 0.041 | 0.710 | 0.663 | 0.326 |
| 8 | freezer | 0.615 | 0.393 | 0.611 | 0.650 | 0.300 |
| 9 | w'pump | 0.270 | 0.065 | 0.805 | 0.678 | 0.356 |
| 10 | immersion | 0.918 | 0.721 | 0.772 | 0.614 | 0.228 |
| 11 | tvless21 | 0.906 | 0.813 | 0.660 | 0.593 | 0.186 |
| 12 | tvmore21 | 0.914 | 0.530 | 0.846 | 0.721 | 0.442 |
| 13 | desktop | 0.801 | 0.386 | 0.703 | 0.773 | 0.546 |
| 14 | laptop | 0.827 | 0.314 | 0.763 | 0.820 | 0.640 |
| 15 | g'console | 0.614 | 0.132 | 0.781 | 0.701 | 0.402 |

# Activity-dependent **appliance** modelling

***Following appliance assignment*, model its use:**

$$logit(P_a(t)) = \alpha_{a0} + \beta_{aj}\, logit(P_j(t))$$



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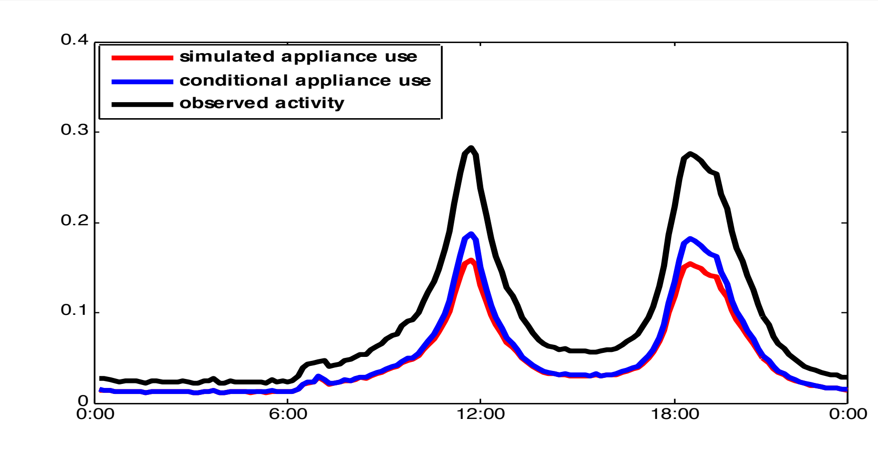


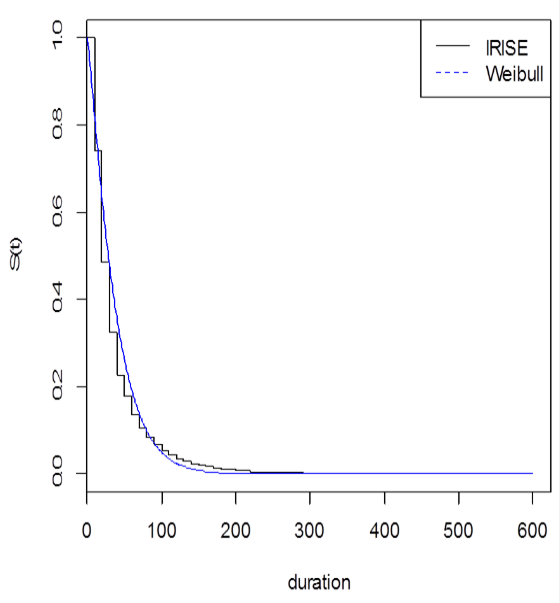

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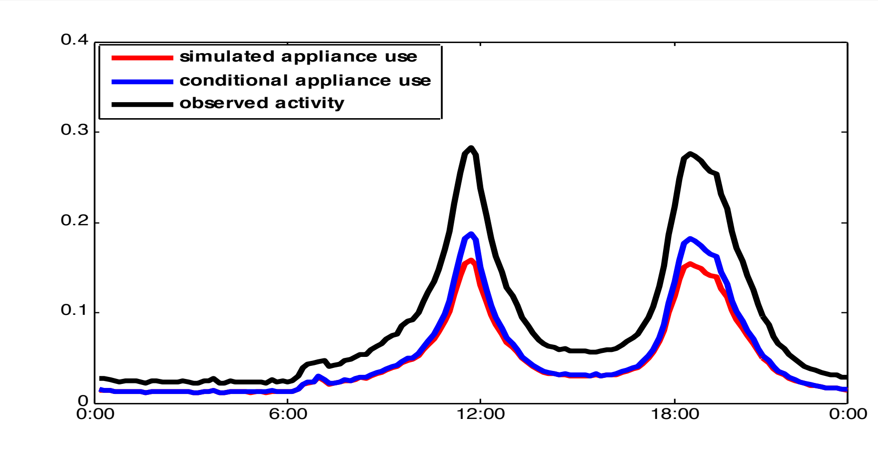


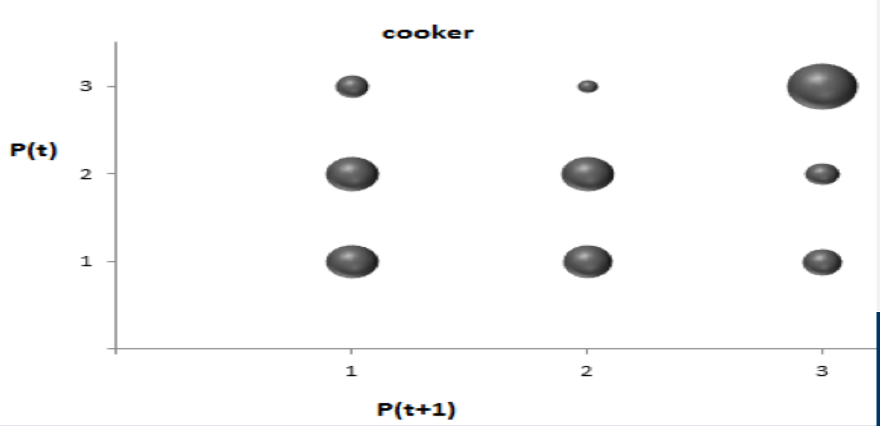


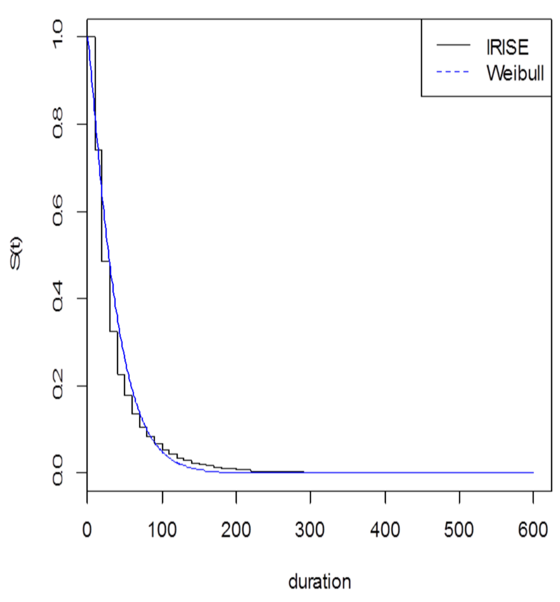

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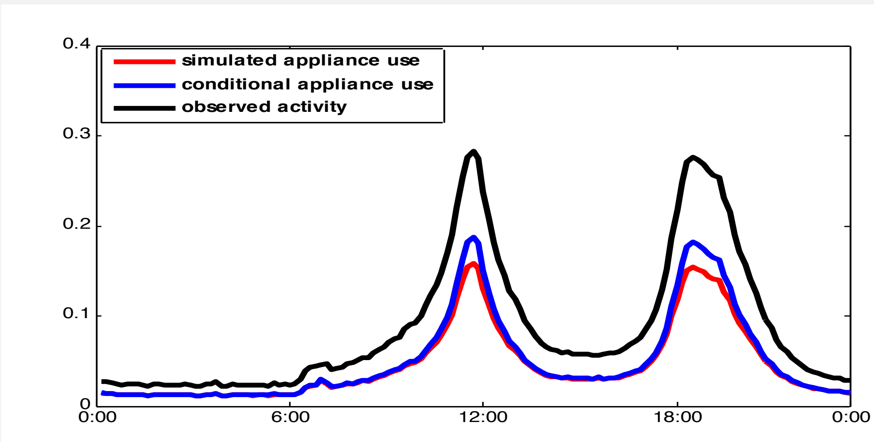
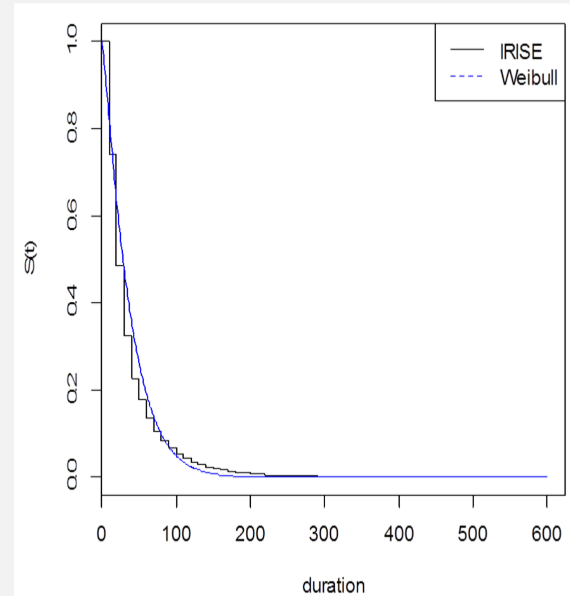
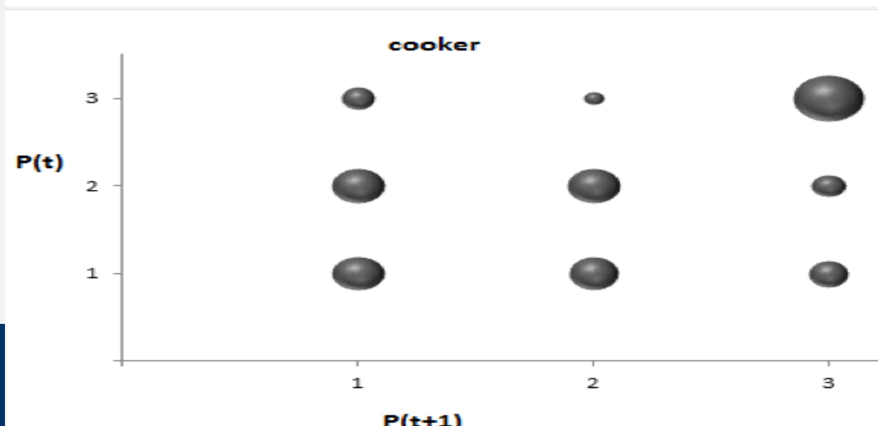
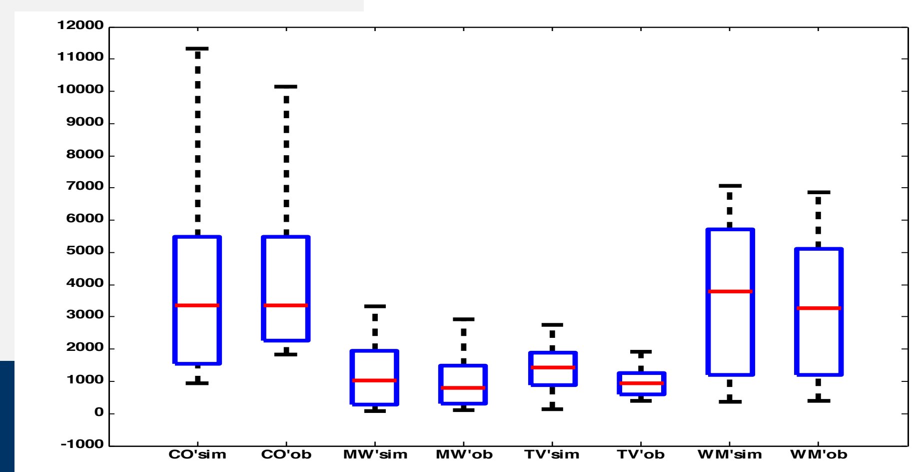


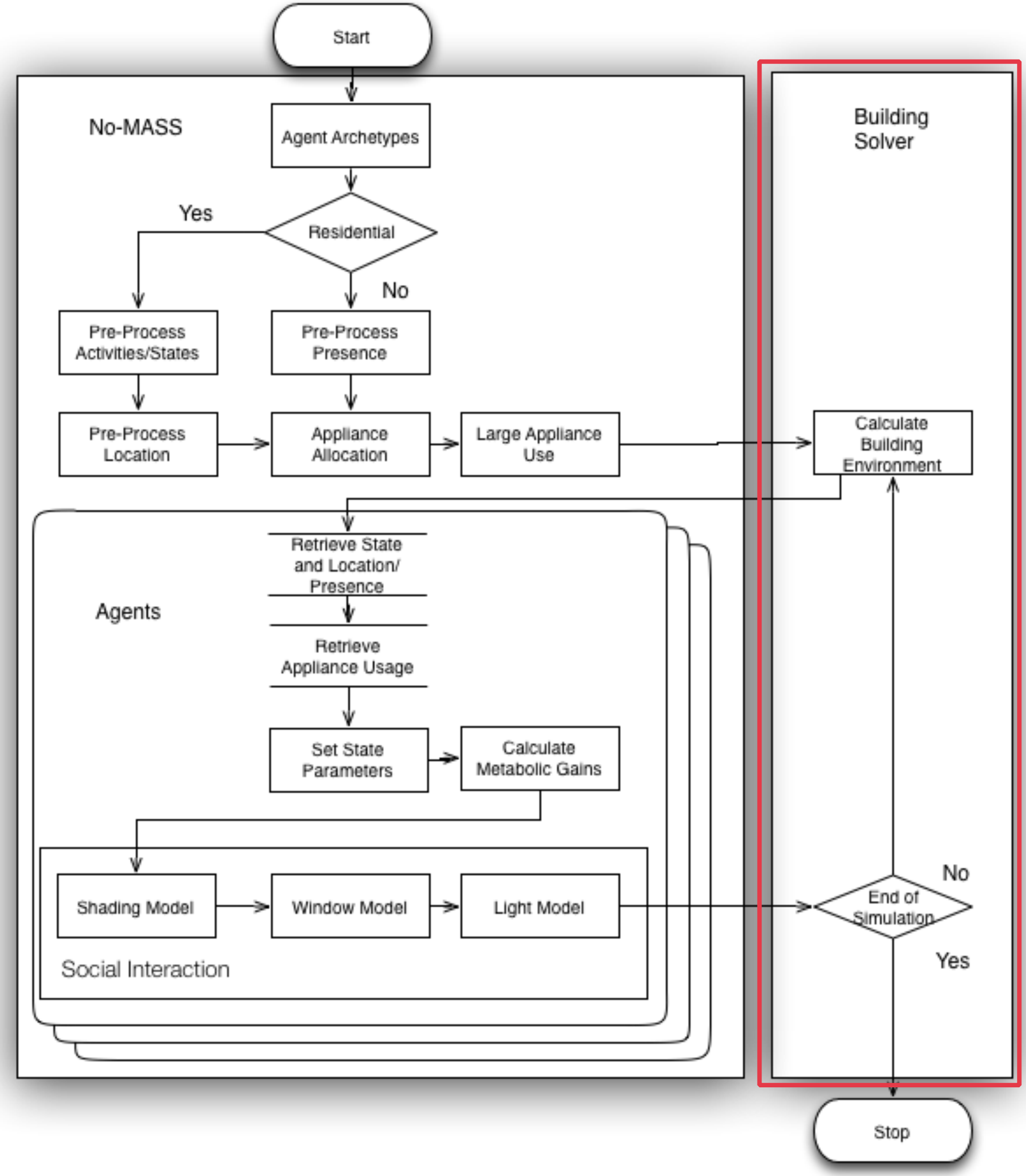



# Building Environment

- EnergyPlus
- Uses FMI
- Can be coupled with other tools

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# FMI - Functional Mockup Interface

- Generic programming interface
- Allows for a Co-Simulation environment
- XML defines the schema of coupling
- C++ arrays to pass data
- Timestep intervals
- Readily Available in EnergyPlus and other simulation tools
- Portable

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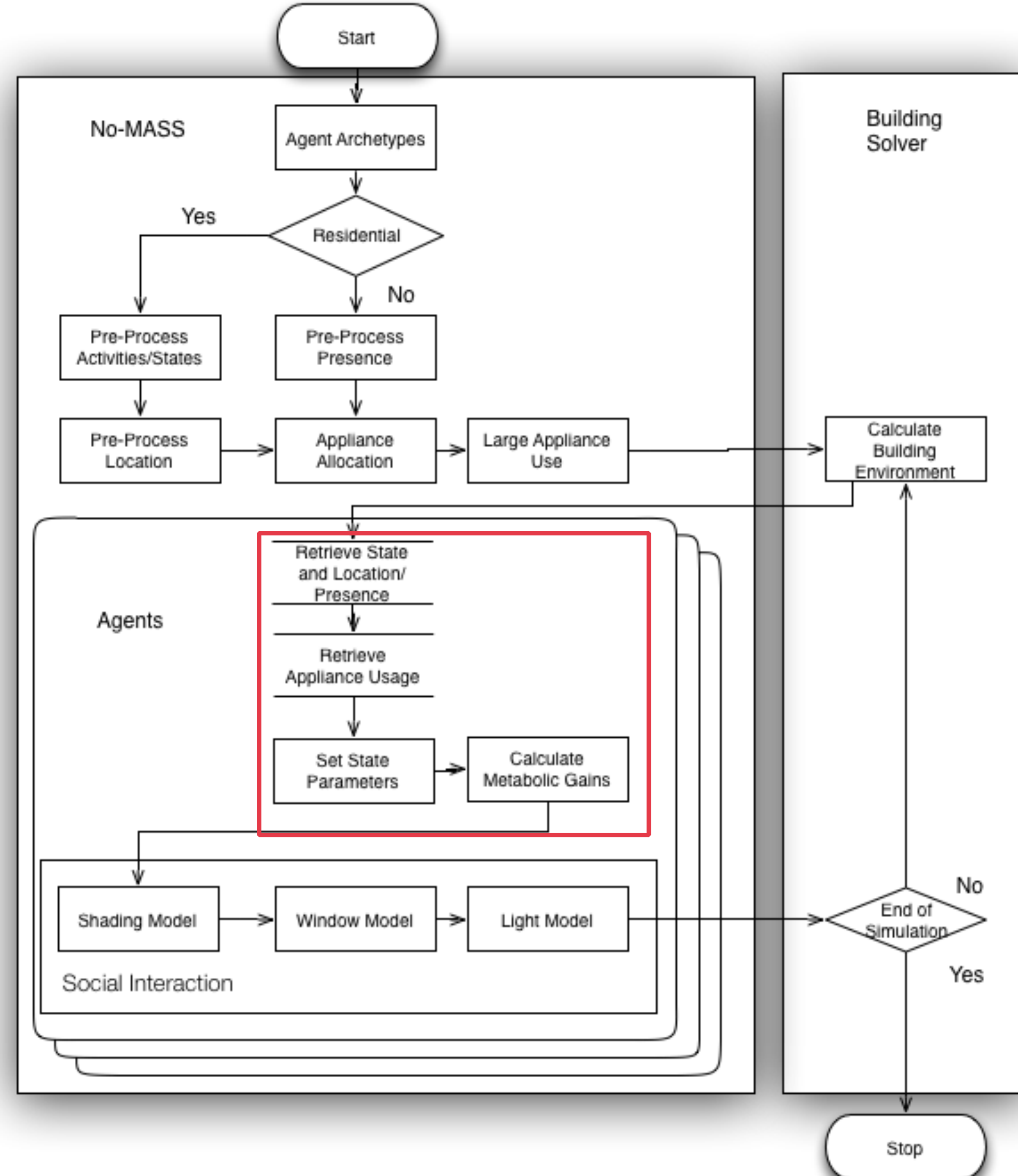
# States

- Timestep
- Set parameters

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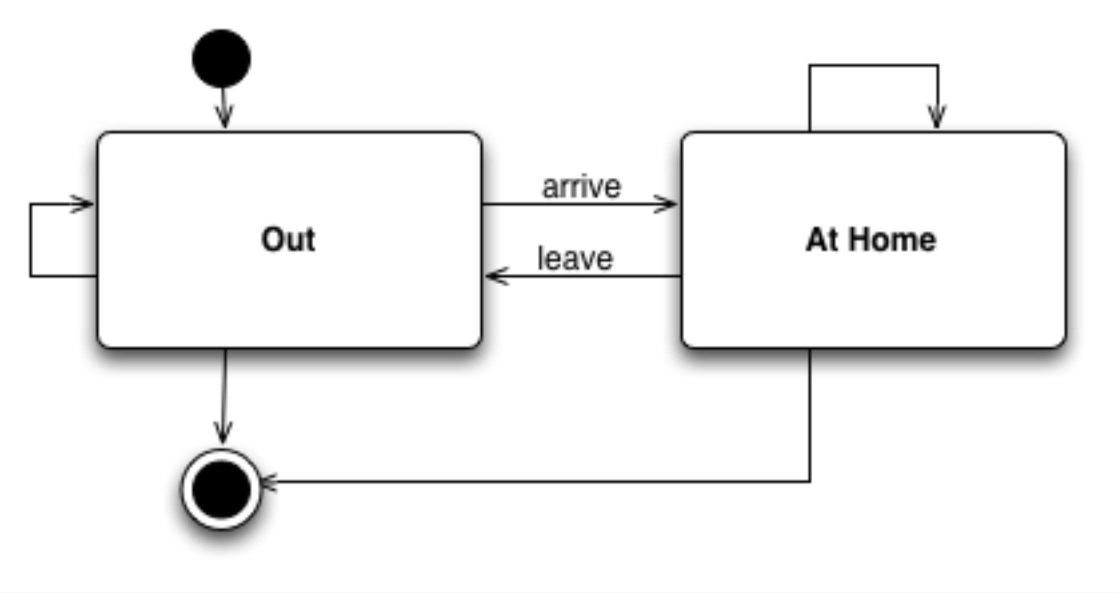
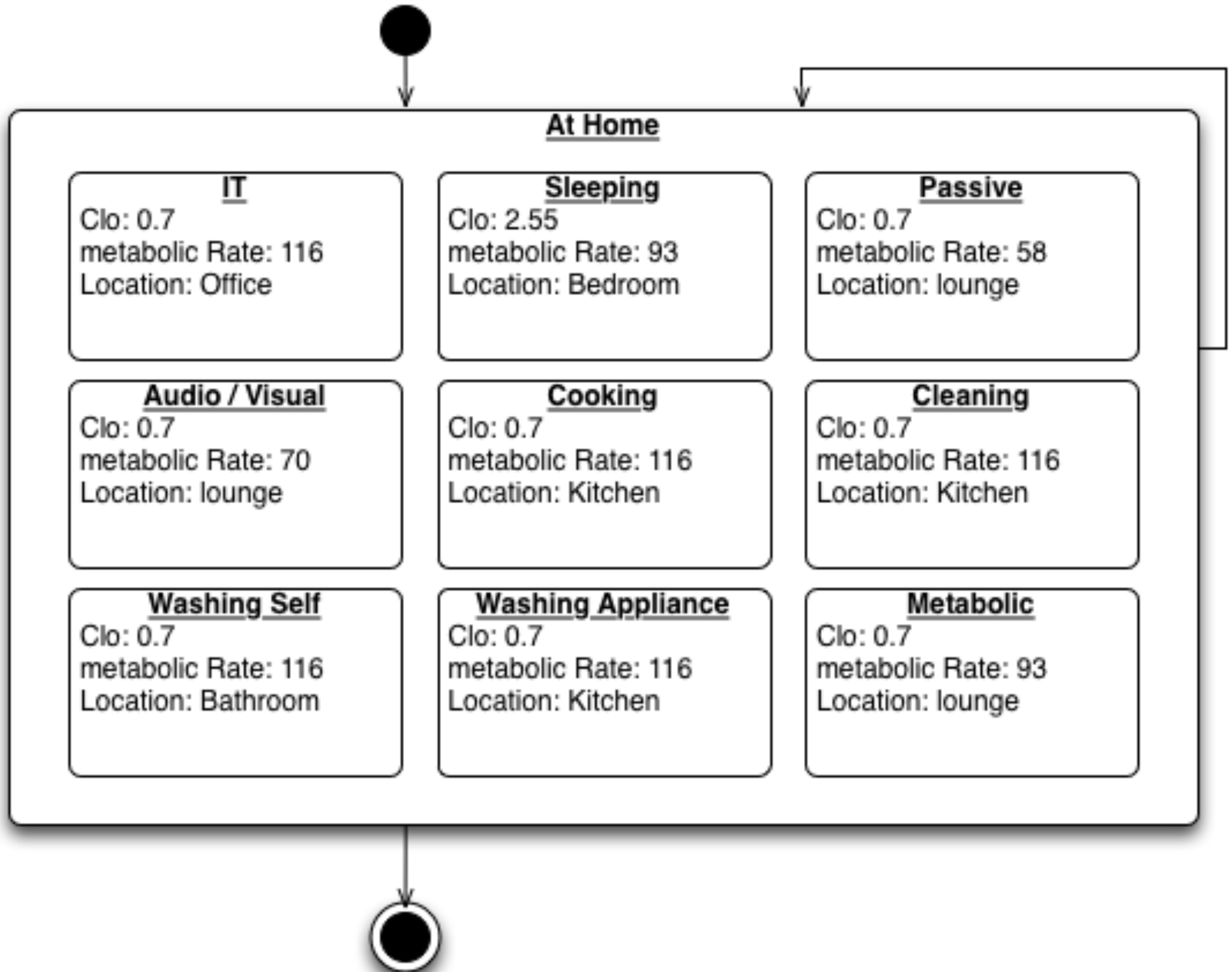
# Occupant States - House

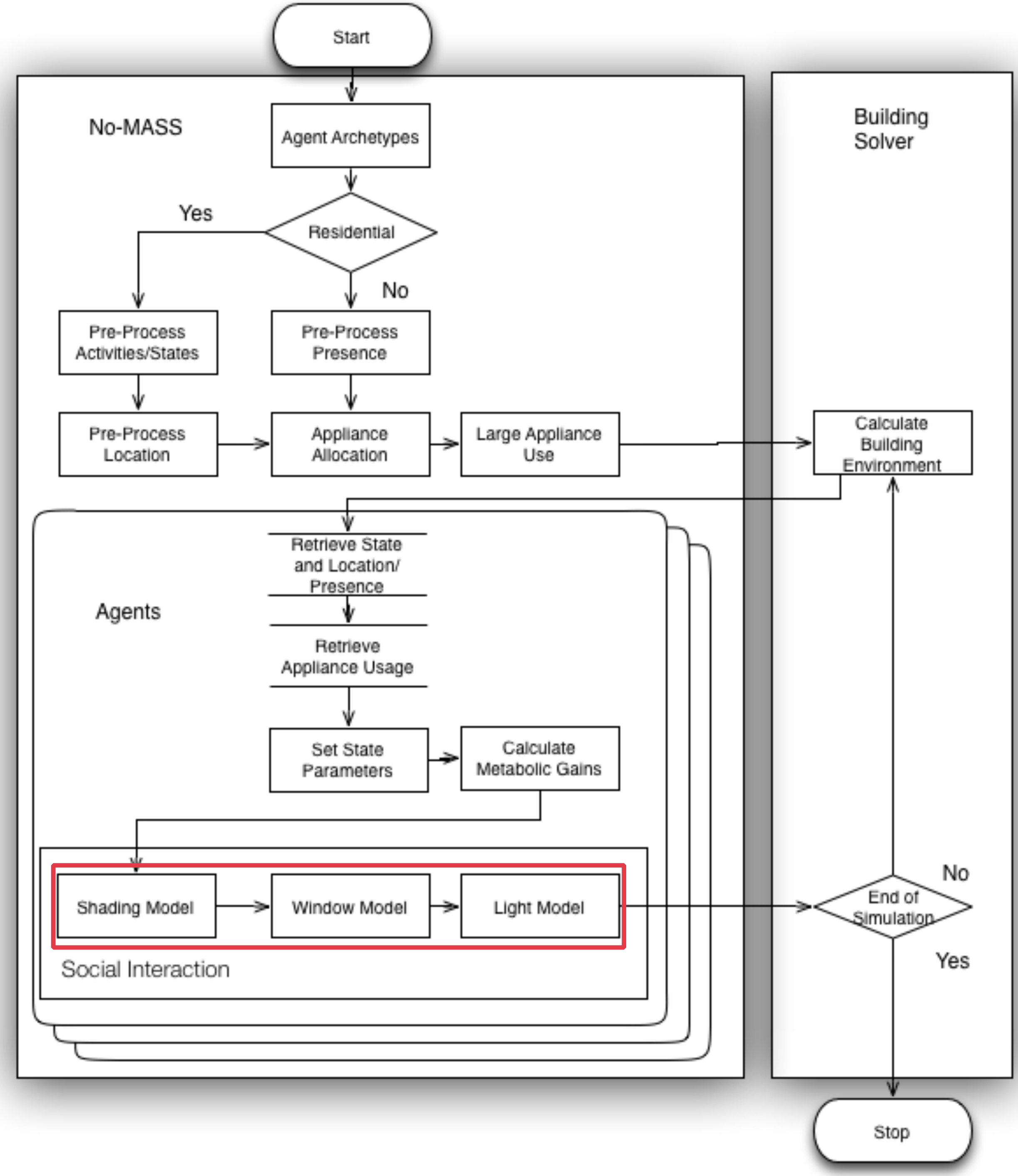


# Occupant States - House Sub States



# Interactions

- Shades
- Windows
- Lights

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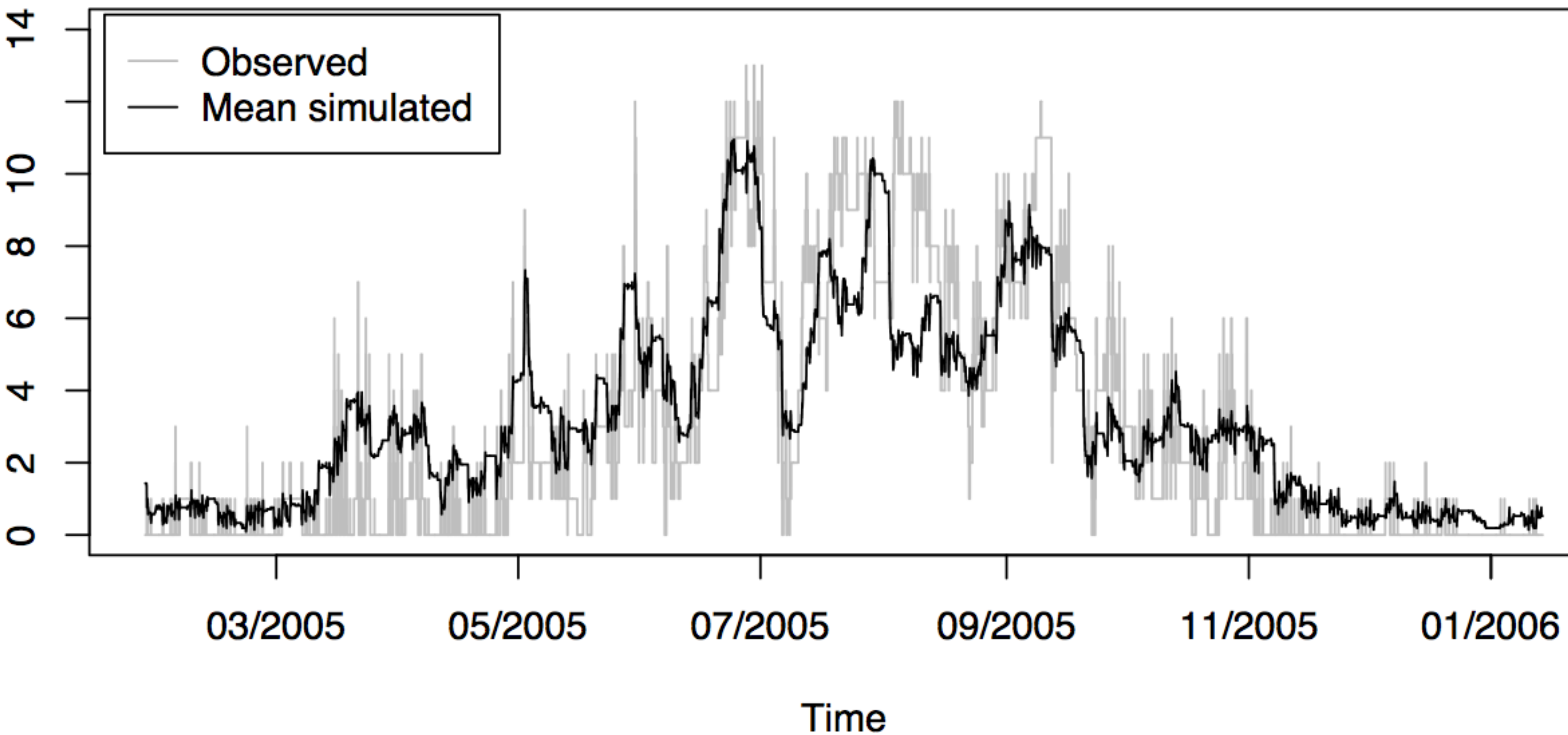
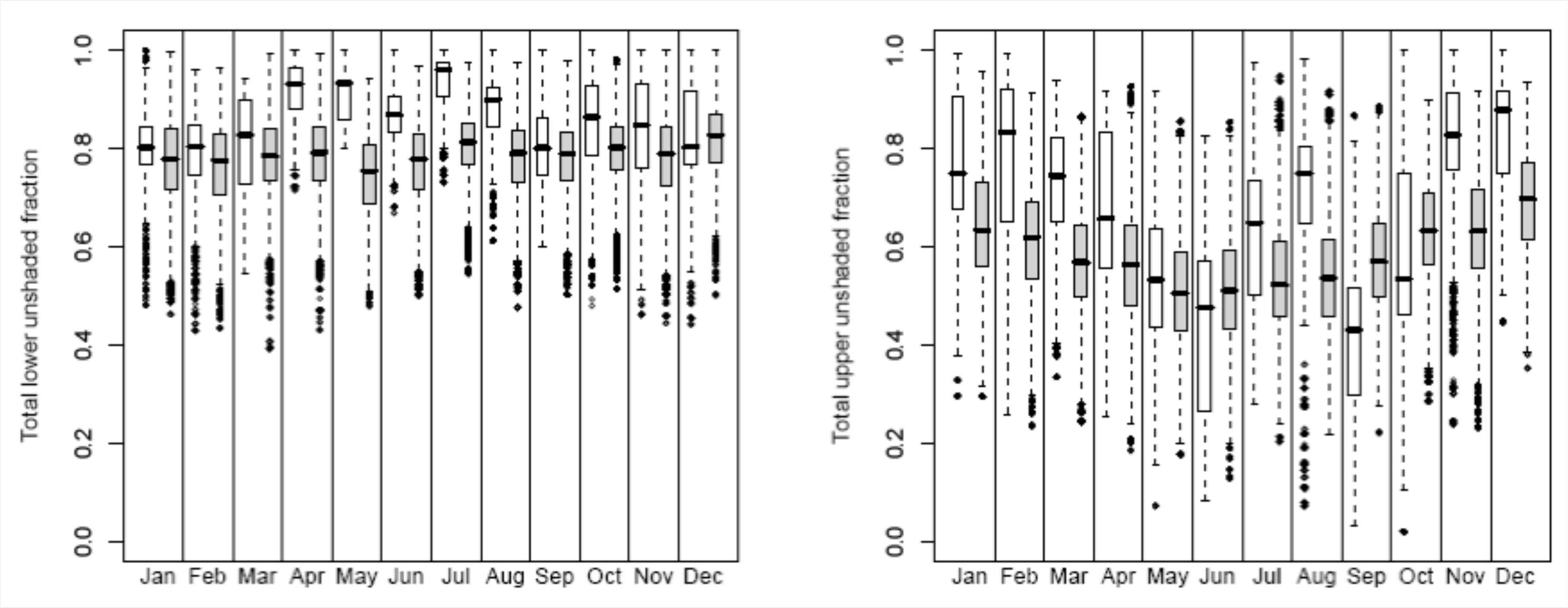
# **Window** openings: $P_{ij}(occ)$, $D_i|P(t)=1$

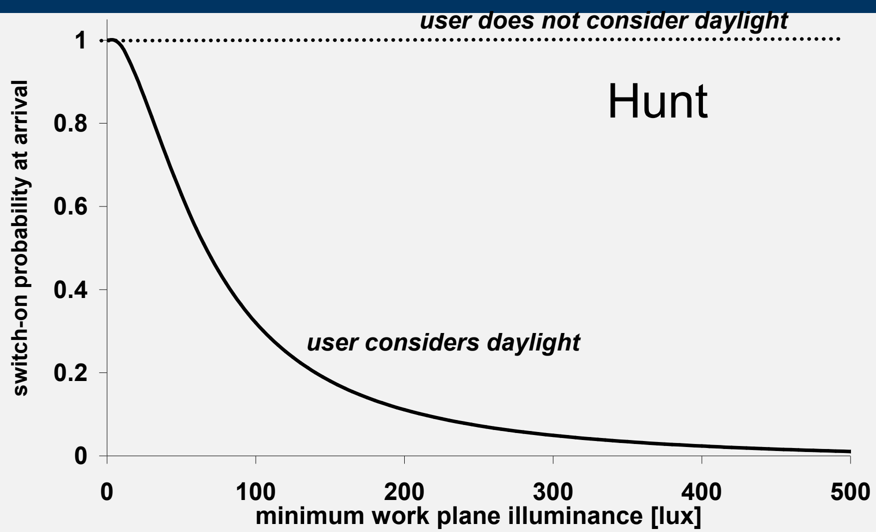



*Haldi and Robinson, Building and Environment : 44(12), 2009*
***Best Paper Prize: 2009***

# **Blind** position: $P_{ij}(t)$…




*Haldi and Robinson, JBPS : 3(2), 2010*
***Best Paper Prize: 2010-2011***



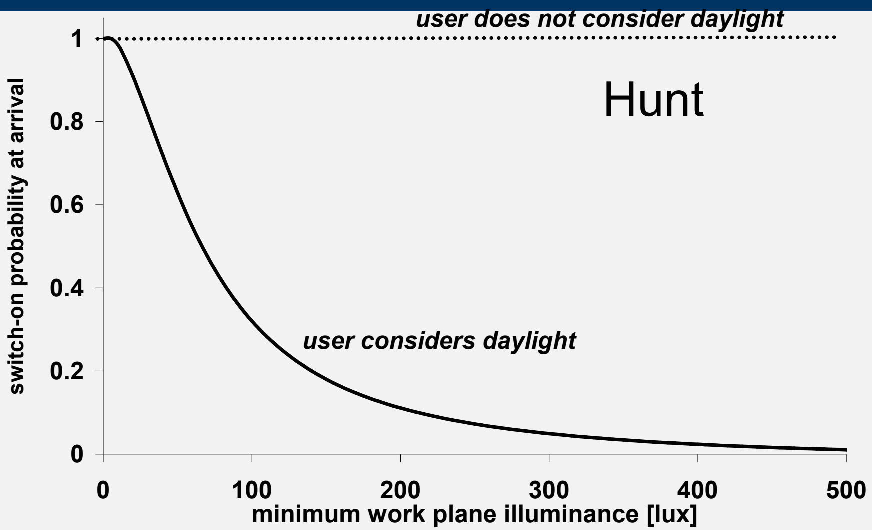

On arrival switch-on probabilities

# Lights

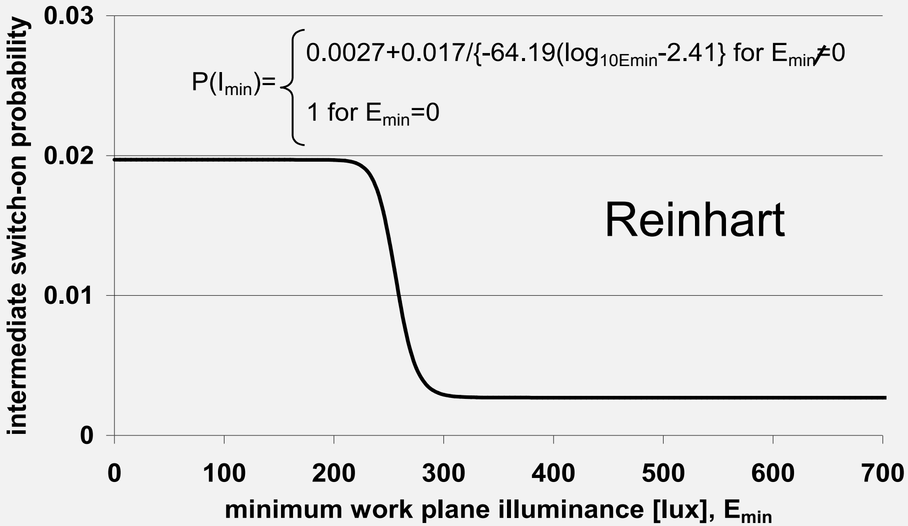
(Lightswitch 2002): $P_i(t)$…

# Lights

## (Lightswitch 2002): $P_i(t)$…



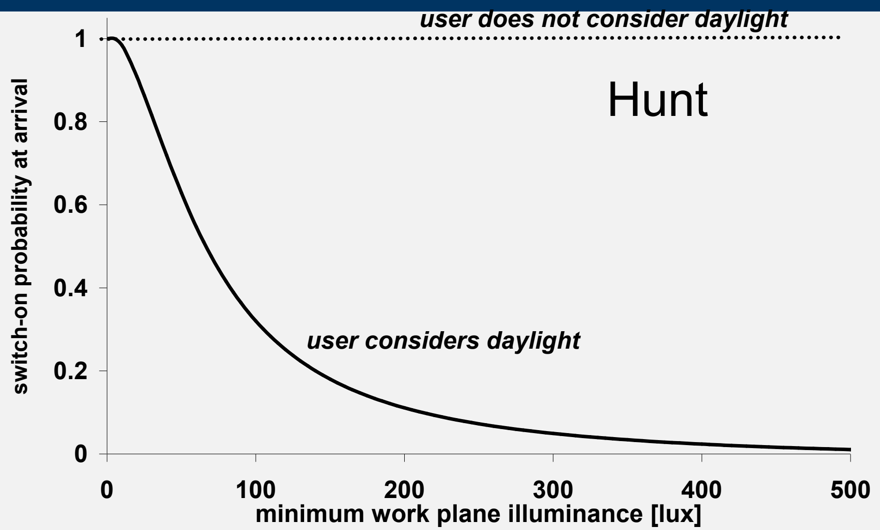

On arrival switch-on probabilities



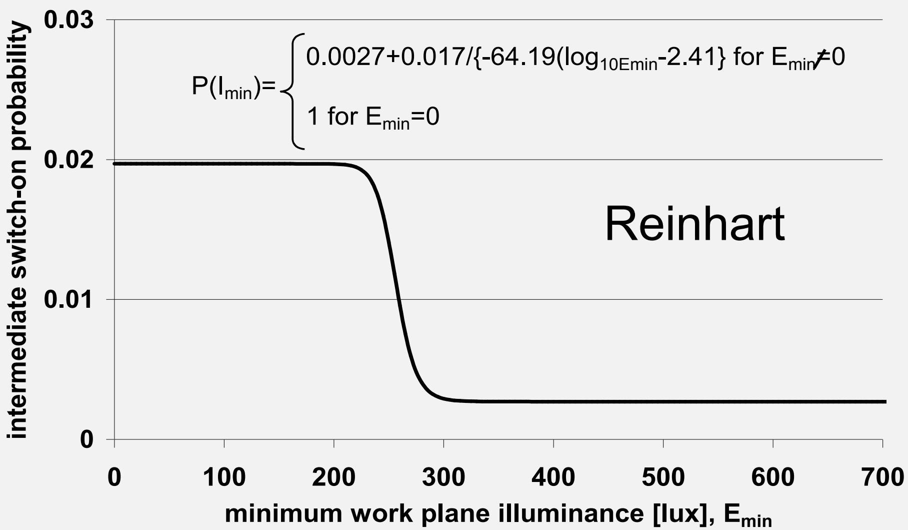

Within-day switch-on probabilities

# Lights

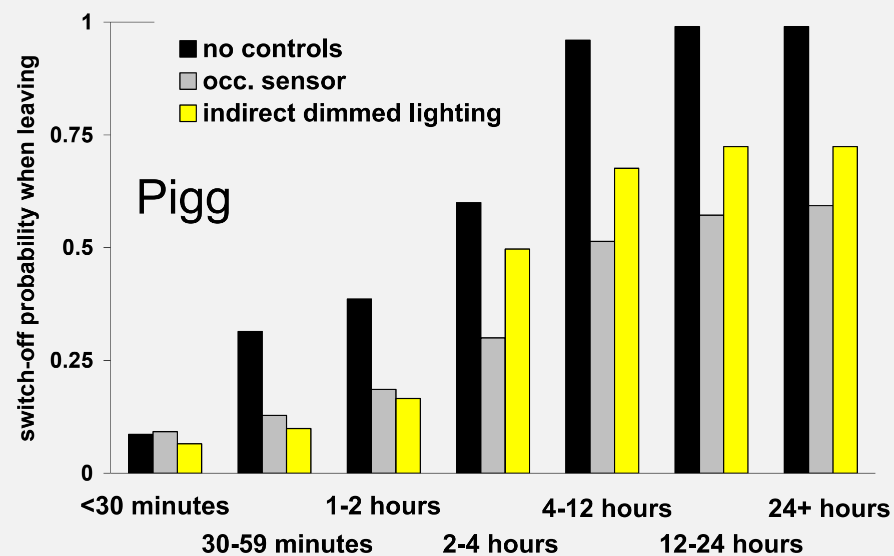
## (Lightswitch 2002): $P_i(t)$…




On arrival switch-on probabilities

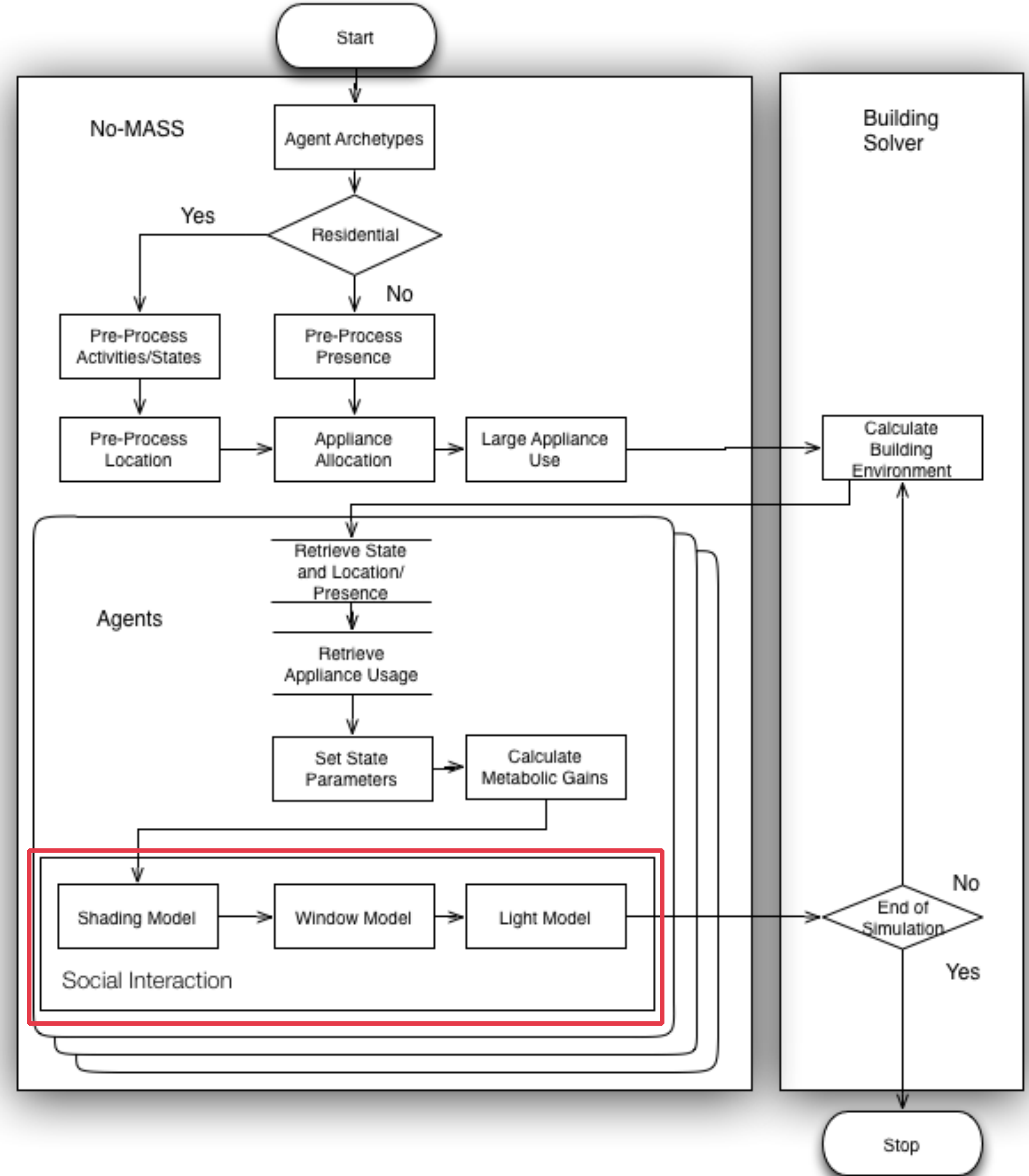



Within-day switch-on probabilities




Measured switch-off probabilities as a function of absence duration

# Social Interactions

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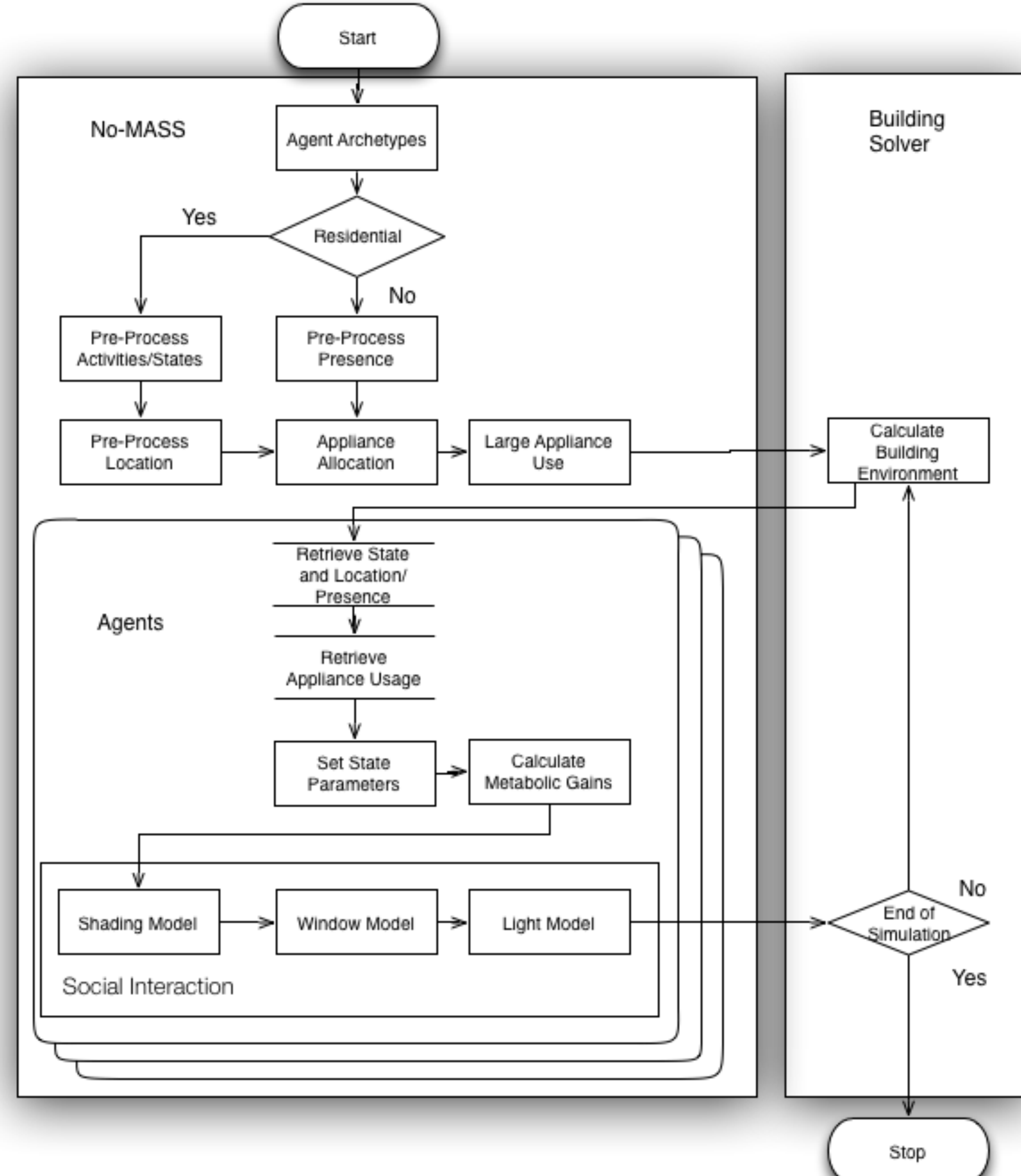
# Social Interactions

- Assign each agent with a power
- Each agent makes a vote for the action that they want to perform
- The action with the most votes is performed
  - Authoritarian Boss/ Family member
  - Everyone with equal voting power

# No-MASS

» Interactive / reactive occupants
» Empirically informed
» Diverse population

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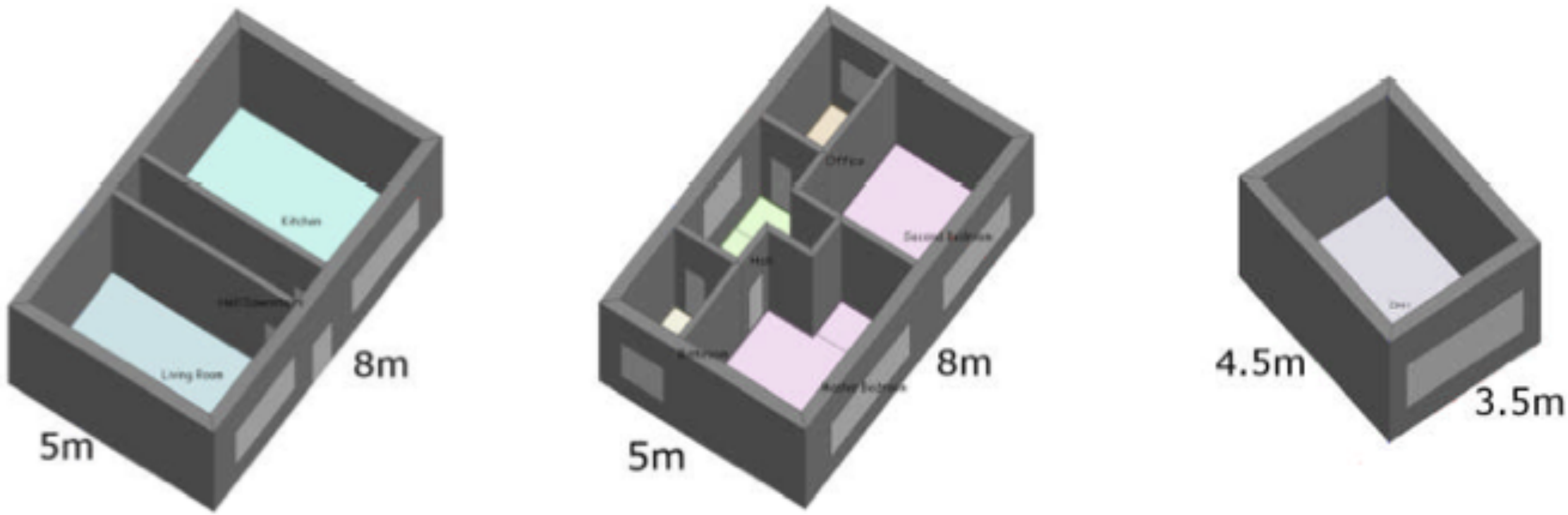
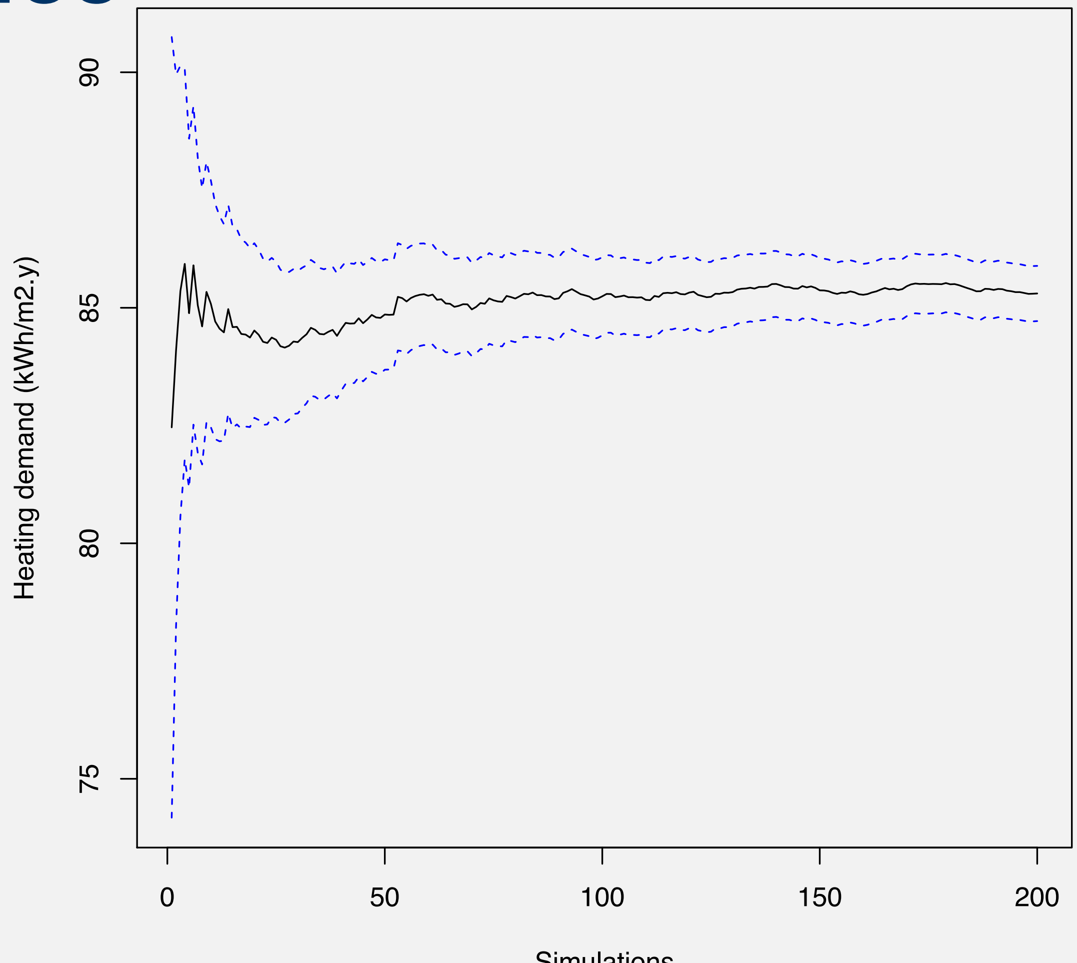
# Case Study

- House and office
- Based in Nottingham, UK and Geneva, Switzerland
- Two agents, profile of adults no children



# Mean Convergence

- Convergence at 80 simulations



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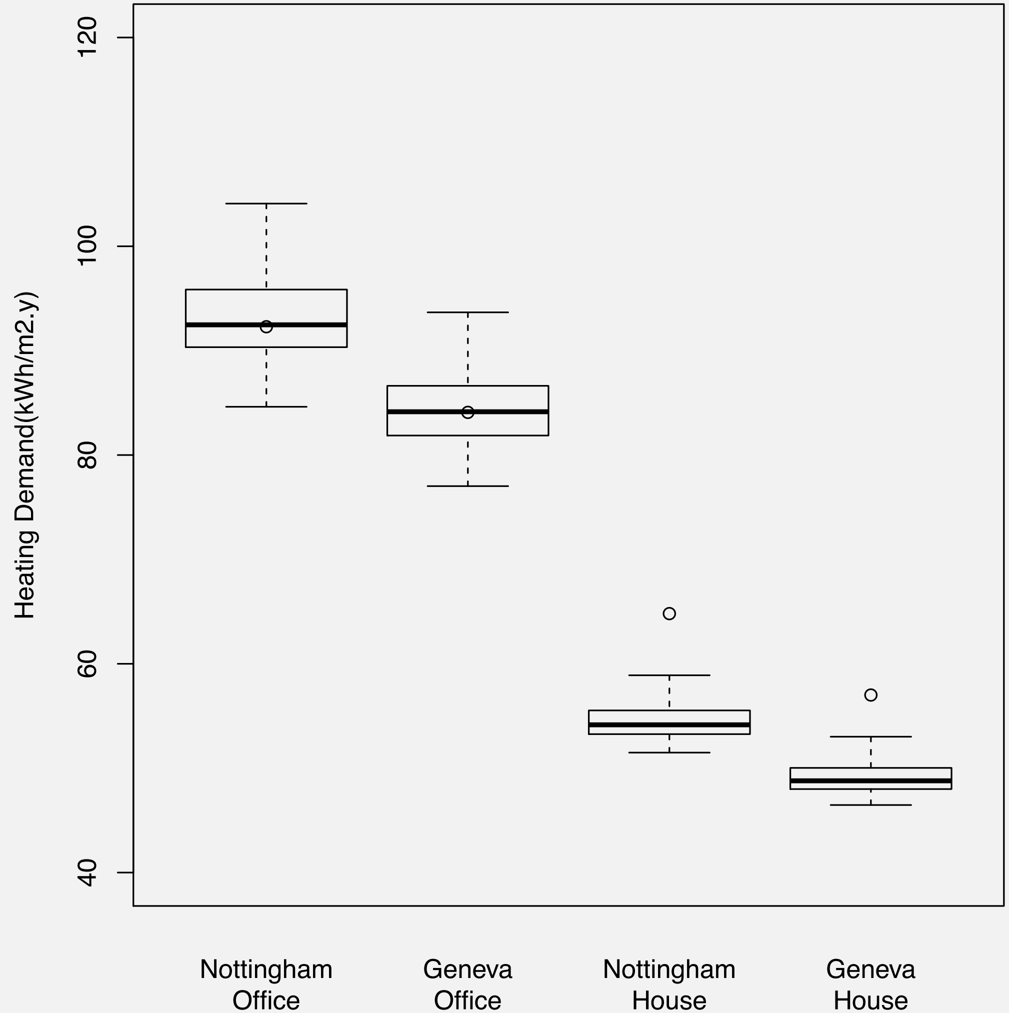
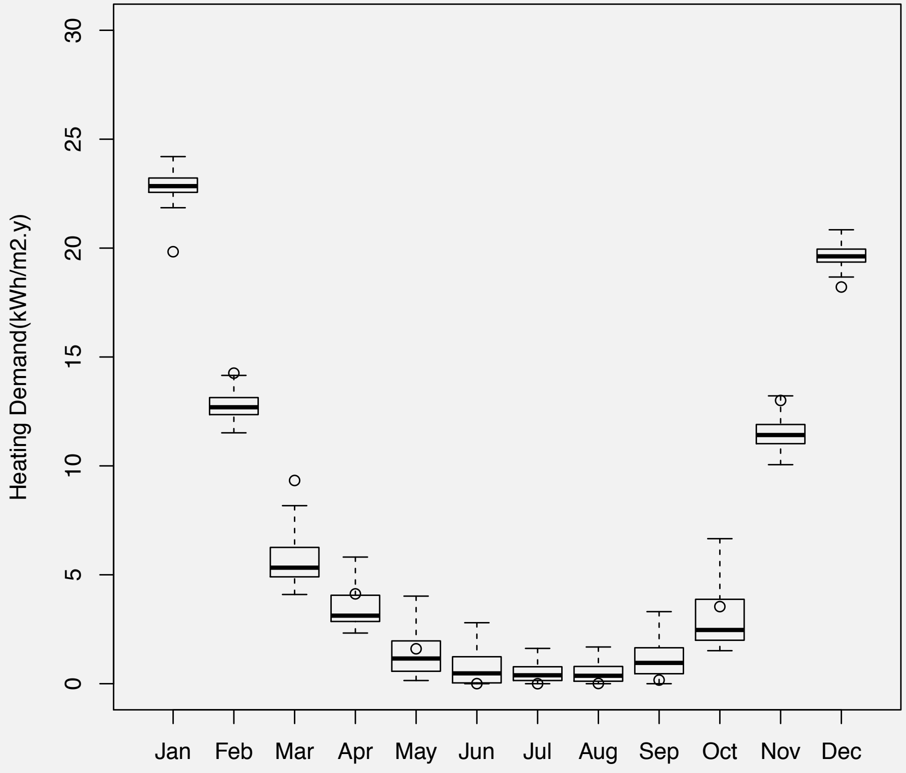
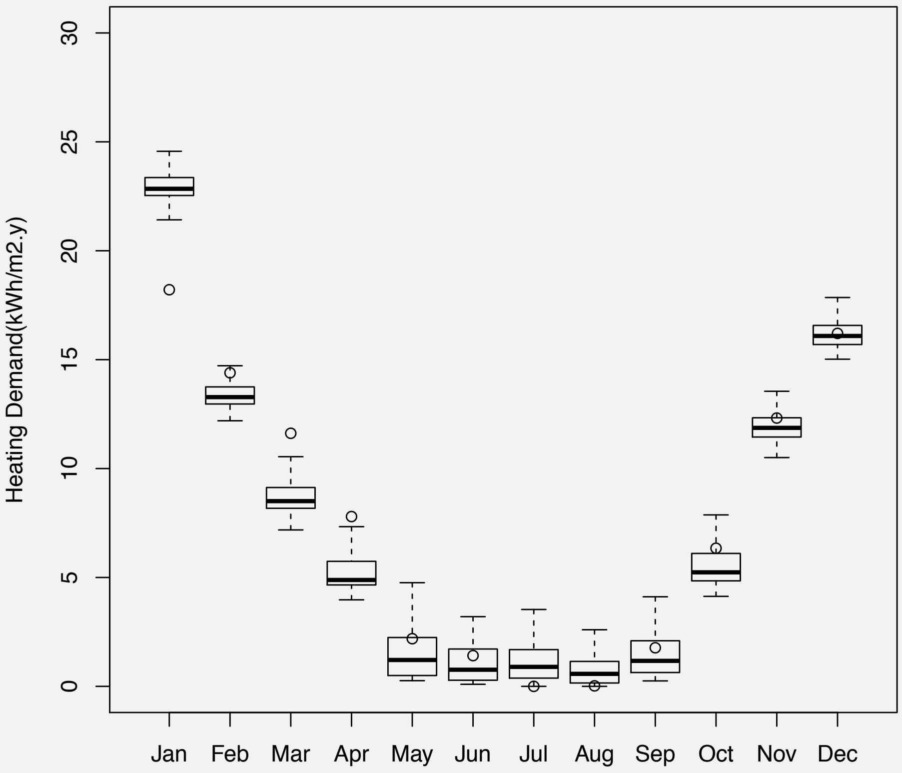
# Results



# Results - Office




Nottingham




Geneva

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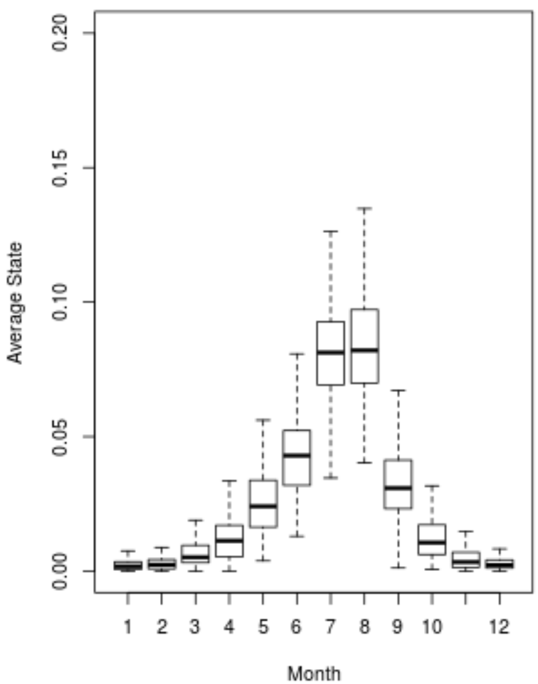
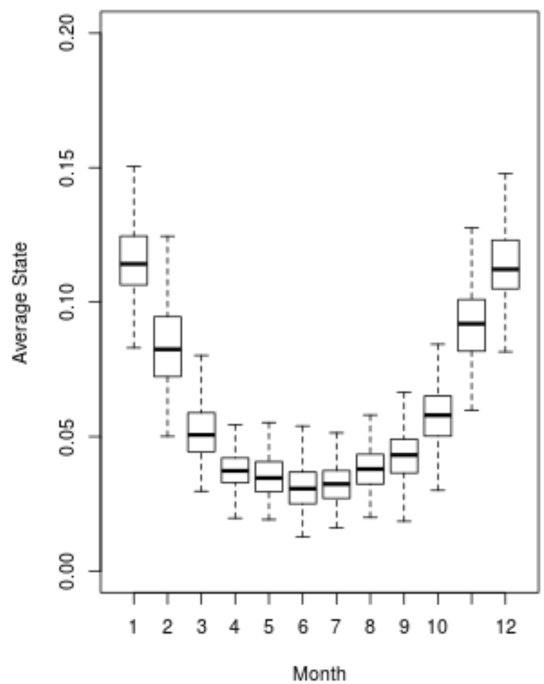
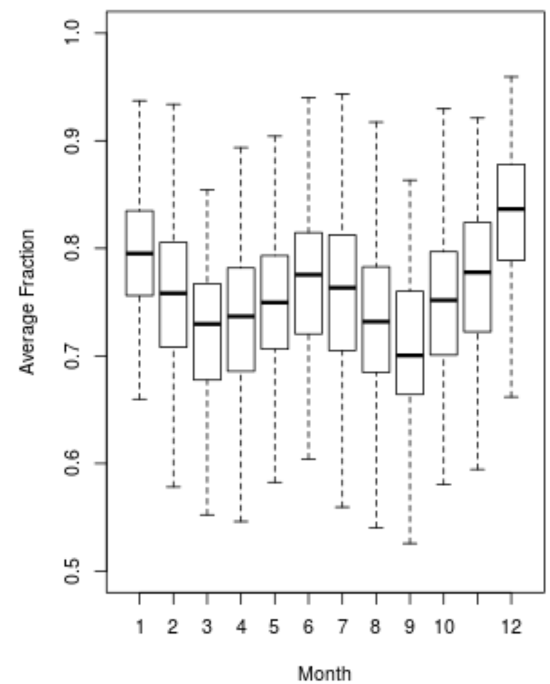
# Results - Geneva States




Windows




Lights




Shading

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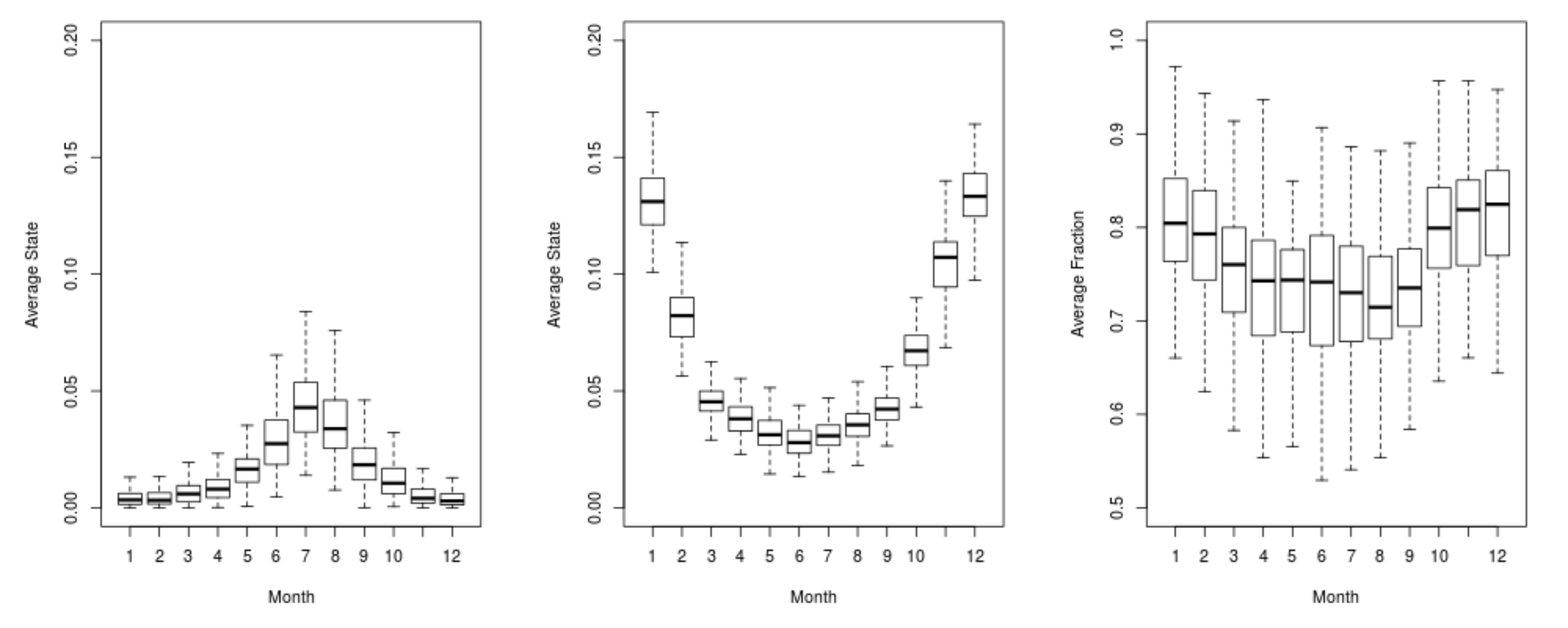
# Results - Nottingham States




Windows Lights Shading

# DesignBuilder

- Internship
- To integrate the No-MASS platform into design builder
- Allow practitioners to use the new representation of occupants to make informed decisions about how occupants actually use buildings

# Laboratory of Urban Complexity And Sustainability (LUCAS)

**Faculty of Engineering, University of Nottingham, UK.**

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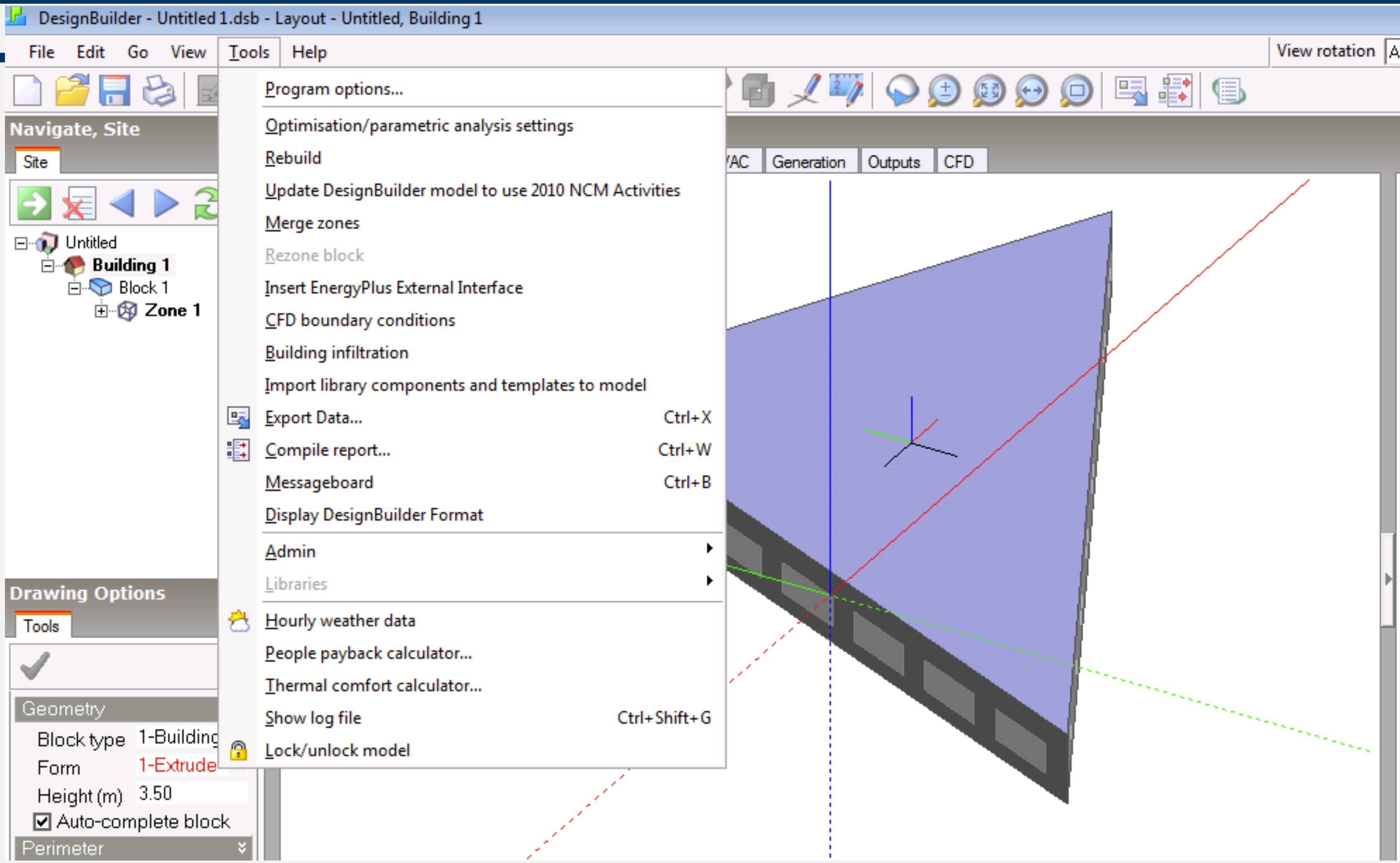



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27th October 2015

# Workshop

- Office construction
- Setting up parameters
- Setup agent simulation
- Analyse results
- House construction
- Setting up parameters
- Setup agent simulation
- Analyse results

# Thank You

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