REPORT

Title: **Occupant Behavior Module for EnergyPlus/OpenStudio**

Report Date: **April 29, 2016**

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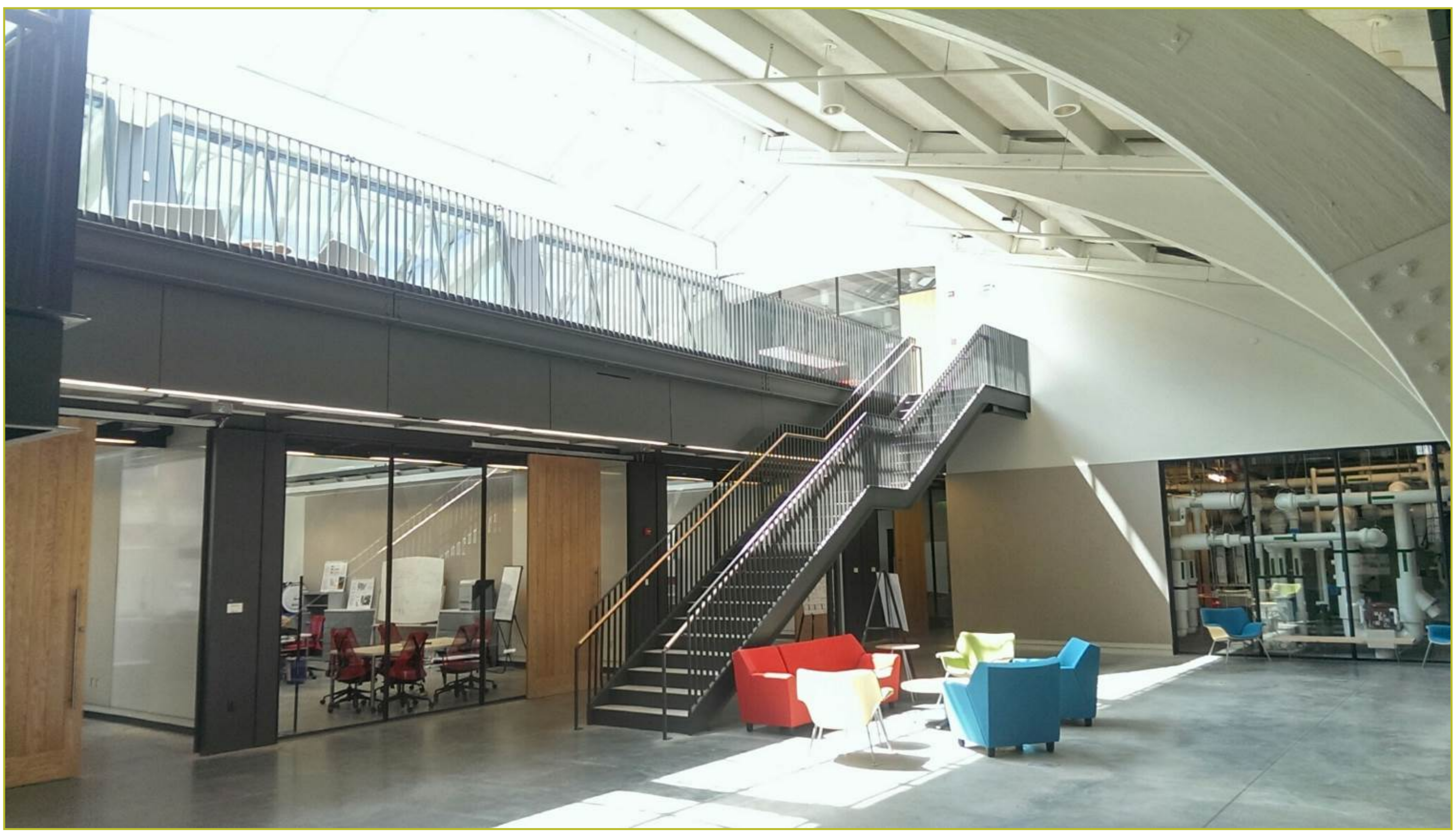

Funded by U.S. DOE

Report Abstract

Project objectives.

This project develops a calibrated occupant behavior module that aids building design & operation by simulating user impacts on energy use. Most building energy modelers ignore the effects of occupant behavior by assuming fixed comfort targets and ignoring "unregulated" loads. Yet researchers know that occupants influence building performance by their choice of setpoints, schedules, and adaptive behaviors, which are heterogeneous, often habitual, and sometimes maladaptive. Missing from practice are parsimonious and reliable representations of expected adaptive behaviors in small and medium sized commercial buildings, especially retrofits. This project builds upon a variety of fieldwork and modeling work conducted in 2013 (BP3) and prior years on occupant behavior in small & medium-sized commercial buildings. The team assembled previously collected data (physical measurements, observations, surveys, and interviews in several buildings) into a database of occupants and their adaptive behaviors in specific contexts. The database was partitioned into a training dataset and a testing dataset for purposes of validation. The occupant behavior simulation software module extended a previous agent-based model coded in Java for use in a co-simulation context by coding in obXM using obFMU and employing ExternalInterface to enable co-simulation with the EnergyPlus building energy modeling program, working closely with the LBNL team led by Tianzhen Hong. Through this project, Rutgers (1) developed a dataset of generic commercial building occupants incorporating their typical distribution of behavioral responses to thermal & lighting conditions; (2) assessed representativeness of the sample dataset against a reserved testing dataset using cross-validation techniques; (3) created a synthetic population database of building occupants, and (4) an agent-based model of occupant behavior that uses the synthetic data set, and solved the mechanics of co-simulation with EnergyPlus while (5) obtaining IEA Annex 66 leaders review and feedback our work. Included as final deliverable products are (6) a nested validation / calibration process at the building- and occupant-levels using standard RMSE metrics, a (7) synthetic population and co-simulation users' manual, and (8) a submitted journal manuscript. We have successfully created an occupant behavior model that utilizes the synthetic data set and can connect to EnergyPlus.

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Overview

Most building energy modelers ignore the effects of occupant behavior by assuming fixed comfort targets and ignoring "unregulated" loads. Yet researchers know that occupants influence building performance by their choice of setpoints, schedules, and adaptive behaviors, which are heterogeneous, often habitual, and sometimes maladaptive. Missing from practice are parsimonious and reliable representations of expected adaptive behaviors in small and medium sized commercial buildings, especially retrofits. This project made use of data collected by Rutgers in BP3 and from earlier non-DOE work, by the Building 101 data portal, and other sources, to develop a calibrated occupant behavior module for incorporation into EnergyPlus, the modeling engine underlying OpenStudio. Table 1 provides an overview of project milestones and deliverables.

Table 1. Milestones and Go/NoGo excerpt from CBEI PMP, 7/24/15

M/GN Number	Description	Verification Process
GN3.4.1	Deliver dataset of generic commercial building occupants incorporating typical distribution of behavioral responses to thermal & lighting conditions.	Assess representativeness against reserved testing dataset using cross- validation techniques; request expert review by IEA Annex 66 participants.
GN3.4.2	Deliver functional (but not yet calibrated or validated) occupant behavior simulation module for co-simulation with EnergyPlus.	Demonstrate functionality of module in co-simulations; seek expert review of code by IEA Annex 66 participants.
M3.4.a	Calibrated & validated occupant behavior simulation model (when run in co-simulation)	Nested validation process (building-level, occupant-level) with standard RMSE metrics
M3.4.b	Short technical manual & journal/conference paper submission	Delivery of manual & paper

Final Deliverable: A documented, functional, calibrated & validated occupant behavior simulation module enabling co-simulation with EnergyPlus (all files related to deliverables relevant to 3.4.1 may be found here http://en.openei.org/datasets/dataset/ob-commercial-building)

Our process began with pooling existing data generated a validated, anonymous, and representative **occupant behavior dataset** with common fields and a common coding system that could then be used to generate a synthetic population and offer modelers a robust dataset to inform building performance design practice.

Next, the **Co-Simulation of the Synthetic Population dataset with EnergyPlus** included writing co-simulation codes on obXML format by using a standardized occupant behavior modeling tool, obFMU and co-simulation with EnergyPlus using ExternalInterface.

Finally, **Agent Based Modeling** (ABM) of occupant behavior constructs what-if scenarios prior to retrofitting a building. The ABM approach shows adaptive actions made by individual occupants to building environment as well as occupant social interactions to come up with a collective adaptive action in regards to their environment

A **technical manual** is provided as a users' guide to the co-simulation process that offers a transparent overview to facilitate practice as well as advancement of the process. A **manuscript** entitled, "Using Synthetic Population Data for Prospective Modeling of Occupant Behavior during Design" has been submitted with revisions to Energy and Buildings.

Findings of BP5 Work

A number of overall findings summarize the work of BP5 while offering direction for advancing the efficiency of occupant behavior co-simulation for increased accuracy in building performance design:

- Assembling disparate data sets into a combined data set to provide an empirical basis for synthesis involves significant challenges. Building designers would benefit if researchers develop a common core protocol.
- As expected, the model based on the combined data set is most similar to that based on the largest data set contributed (ASHRAE RP-884). The models based on the smaller longitudinal and cross-sectional data sets lack as much explanatory power.
- Multivariate analysis is feasible with the combined data set. For example, the data support expected relationships between outdoor air temperature, indoor air temperature, age, sex, and the acquisition of local space heaters by occupants.
- Models using the synthetic data are very similar to those using the observed data, further building confidence that the synthetic data set closely matches the covariance structure of the combined observed data set.
- The synthetic data set supports multivariate relationships among dependent and explanatory variables that are very similar to those observed in the underlying combined data set.
- A well-calibrated synthetic data set represents a more highly transferable form of occupant behavior information than (1) standard distributions, (2) building performance models calibrated to occupied existing buildings, and (3) building performance models linked in co-simulations to occupant behavior models calibrated to existing occupied buildings. It incorporates contextual information and can support a variety of modeling approaches.

Occupant Behavior in Commercial Buildings: Synthetic Population, Co-Simulation with EnergyPlus and Agent Based Modeling

Acknowledgements & Disclaimer

This research was supported by the Consortium for Building Energy Innovation, sponsored by the U.S. Department of Energy under Award Number DE-EE0004261.

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Table of Contents

Summary

This technical manual serves as an outline of three separate research projects related to building energy performance modeling of occupant behavior, conducted at the Rutgers Center for Green Building (RCGB): a Synthetic Population project, a Co-Simulation of Synthetic Population with EnergyPlus project, and an Agent Based Modeling project. They all aim at improving interior building design through maximizing comfort, satisfaction, health and productivity of commercial-office building occupants.

- The first section of the manual is related to the Synthetic Population project. It first starts by explaining the process of gathering existing data on occupant behavior from RCGB studies, identifying similar datasets from other researchers, aggregating them to a large database and ultimately utilizing them as the basis to create a synthetic population. It then covers a step-by-step instruction of constructing cohorts from the synthethic dataset.
- The second section describes the steps involved in the Co-Simulation of Synthetic Population with EnergyPlus project. It includes writing co-simulation codes on obXML format by using a standardized occupant behavior modeling tool, obFMU and co-simulation with EnergyPlus using ExternalInterface.
- The last section presents the processes involved in the Agent Based Modeling (ABM) project. It first describes the characteristics of building occupant agents and their interactions with the building and each other. It also covers a step-by-step instruction of setting up and running an ABM model on NetLogo, an ABM modeling tool written in Java.

The increased amount of occupant behavior data contributes to construction of a reliable database that is later used to generate the synthetic population, which in turn ensures preserving confidentiality and allows transferability of findings. The process of setting up co-simulation with EnergyPlus using obFMU provides insights into the needs of standardized methods to better integrate multiple modeling tools. The cohort strategy, for example, enables modelers to utilize existing datasets on occupant behaviors for constructing an occupant behavior model. Finally, Agent Based Modeling (ABM) of occupant behavior contributes to construct what-if scenarios prior to retrofitting a building. The ABM approach does not only show adaptive actions made by individual occupants to building environment, but also their interactions among themselves to come up with a collective adaptive action in regards to their environment. The resulting outcomes help inform practice and contribute to the improvement of energy building performace models and simulations for the purpose of optimizing interior comfort and satisfaction.

1. Introduction

In the United States, residential and commercial buildings consume more than 40% of the national total energy and more than 70% of the electric energy. In 2013 alone, the national energy bill reached $410 billion (US EIA, 2014). Studies have indicated that building occupants and their activities contribute to building energy consumption and indoor environmental quality (IEQ) (Santin, Itard, Visscher, 2009). Occupants interact with the building systems and each other in multiple forms such as operating shades or blinds and electrical equipment, adjusting thermostats, opening and closing windows etc (Sonderegger, 1977-1998). Occupants' choice of setpoints, schedules, and adaptive behaviors are can be heterogeneous, often habitual, and sometimes maladaptive (IEA, 2013). However, in practice, building design modeling does not incorporate the dynamic nature of occupant behaviors, and considers instead, pre-fixed values for comfort. Thus, more robust representations of adaptive behaviors would significantly contribute toward well-informed building performance models. Ideally, they would utilize large amounts of data from existing buildings, would respect confidentiality and would promote trasnferability.

Traditionally, research efforts on building occupant behavior modeling have been using stochastic approaches to predict human decision-making. Complex occupant decision process is, then, translated into schedules that most Building Energy Modeling (BEM) programs understand. BEM programs use occupancy schedules, thermostat settings, lighting use, HVAC schedules, and plug-loads that do not capture the dynamics of occupant behavior (Feng, Yan & Hong, 2015; D'Oca & Hong, 2015). Integrating two simulation models, namely Occupant Behavior Models and BEM, can be challenging and the co-simulation approach is appropriate to perform this task. Co-simulation couples two or more simulation tools together, allowing a steamlined data exchange between sub-modeling systems. The Rutgers Center for Green Building (RCGB) has focused much of its recent work on this juxtaposition of building design modeling and advanced energy retrofits (AER), occupant responses to building conditions, and energy modeling co-simulation. The next generation of work in this area is the creation of a valid and reliable synthetic population database for the purposes of co-simulation modeling.

The following documentation serves as a short technical manual to support researchers' efforts to model building energy performance with the increased knowledged gained from information about how building occupants respond to their building environment's conditions to improve satisfaction, comfort, health status, and productivity. This work started by aggregating occupant behavior data from several RCGB studies of existing commercial office buildings. The data was gathered through post-occupancy evaluations that included field observations, quasi-experimental conditions, and archived data analysis to examine a variety of different parameters including thermal and lighting comfort and satisfaction. It then proceeded by assembling similar datasets (i.e., data on building descriptives, workspace features, occupant attributes, meterological information) from other researchers, for the purpose of creating a baseline database. This database contains an increased amount of occupant behavior data in an effort to provide an adequate foundation of building occupant characteristics and behaviors, which is eventually used to generate a representative population. In order to preserve confidentiality and to maintain replicability, we generate a synthetic dataset that attempts to capture the building occupants' interactions and covariation within a defined set of contextual parameters in commercial buildings. It successfully supports multivariate modeling to serve as a behaviorally-robust basis for building design and contributes to co-simulation for building energy performance design. Lastly, it is utilized in an occupant behavior model that co-simulates with the EnergyPlus building energy model. The dataset is then divided into cohorts and translated into .xml format by using obFMU. obFMU is a standardized occupant behavior modeling tool (developed by Hong, et.al. (2015)) at the Lawrence Berkeley National Laboratory, to model occupant behaviors. The team also developed an occupant behavior framework that described the organizational component among occupants and its interaction with building environment. However, because the current version of obXML does not support this capability, we separately modeled these phenomena within NetLogo, an Agent-Based Modeling (ABM) tool based in Java.

This manual is divided in three major sections. The first section briefly describes the methods for collecting preliminary occupant behavior data and provides an overview of the datasets aggregation process. It then discusses the creation of a synthetic data set of occupant behaviors compiled from a larger repository of work on post-occupancy evaluation projects (POE) at Rutgers Center for Green Building (RCGB), plus relevant works by other researchers. The second section explains the co-simulation process using obFMU. The next section provides a step-by-step tutorial of setting up co-simulation in EnergyPlus by using a real building energy model and a synthetic data set of occupant behaviors. The last section covers an Agent-Based Modeling (ABM) approach of occupant behaviors. Conclusions and future recommendations are highlighted at the end.

2. Creating a Synthetic Population

2.1 Rationale

The overall objective for combining disparate datasets is to better understand the qualitative context of occupant behaviors in response to building conditions, to obtain quantitative measures where possible, on those behaviors and the corresponding building conditions, and to eventually create a robust database that can serve as a reliable representation of expected adaptive behaviors for the sake of increased precision of building energy performance prediction. This section describes the process of assembling three diverse occupant behavior datasets, which later form the basis for generating a synthetic population of building occupants. They include data from cross-sectional, longitudinal and time-series studies, and a large-scale ASHRAE RP-884 dataset.

2.2 Descriptions of Datasets

2.2.1 Cross-Sectional Dataset

Data on occupant thermal and lighting comfort and satisfaction were collected by Rutgers researchers in 6 studies involving 16 low to mid-rise commercial office buildings in NJ and PA between the years 2009-2014. Two of the six studies included time-series analysis of occupants' responses to building conditions over time during actual and simulated demand response events (discussed elsewhere); the majority of the data was cross-sectional. The methods employed triangulated data from a number of sources to characterize building conditions as well as occupant behavior in response to those conditions. Building data included archived information on building systems and energy retrofits; visits/walk-throughs and observations of building conditions such as temperature, light readings, and occupant adaptive behaviors and person-environment modifications (e.g., use of portable fans, heaters, task lighting, or sun and glare blocks); photo documentation of person-environment settings; on-line building occupant surveys and questionnaires; one-on-one interviews with selected building owner and organizational representatives; focus groups; building performance-analysis; , and life-cycle cost (LCC) analysis. A total of 954 occupant records were collected. Key findings were summarized according to overall building design, HVAC-lighting-water-energy design, occupant behavior and building reactions to AER and demand response events (i.e., load shedding experiments when lighting and cooling energy systems were reduced for limited periods during a set number of workdays), and occupant perceptions of comfort, well-being, and productivity. Occupant behavior data revealed that better information about adaptive behaviors greatly improves energy model accuracy, that standard assumptions about occupant-behavior schedules are often wrong and that a more sophisticated representation is warranted, and that EnergyPlus needs additional hooks for incorporating occupant behavior (Figueroa, et. al, 2014).

2.2.2 Longitudinal Dataset

This dataset consists of records for 24 occupants focused on responses to questions about thermal comfort and related behavioral adaptations from a longitudinal case study of a single office building in Philadelphia. The collection methods included twice-daily online surveys for two-week periods in four seasons of one year for 2012 and 2013 and were accompanied by more frequent observations through datalogger measurements of indoor and outdoor temperatures and other environmental factors *(*Langevin, et.al, 2015*).* The study's findings informed the improved measurement, modeling, and anticipation of occupant behavior as part of future sustainable building design and operation practices. Preliminary data were deidentified and made publicly available for use through the Open Energy Information Organization.

2.2.3 ASHRAE-RP-884 Dataset

Raw data on thermal comfort were collected from multiple projects and various researchers of 160 buildings worldwide to assemble this mix of cross-sectional and longitudinal data recorded during 1982 to 1997. All projects were ASHRAE-funded and included the creation of a standard template that organized records in the following groups of variables: basic Identifiers, thermal questionnaire, indoor climate physical observations, calculated indices, personal environmental control, and outdoor meteorological observations. The resulting 20,215 occupant records incorporated quality control throughout an adaptive modeling method for the purpose of generating a variable temperature standard. Criteria for data screening focused on indoor climatic instruments, while standardization of questionnaires secured the database's internal consistency *(*de Dear, et. al, 1997*)*. Datasets were made publicly available for use through the University of Sydney, Architecture, Design and Planning website.

2.2.4 Final Database

The aforementioned datasets were created for different purposes, but share variables in common, as highlighted in Figure 1 below.

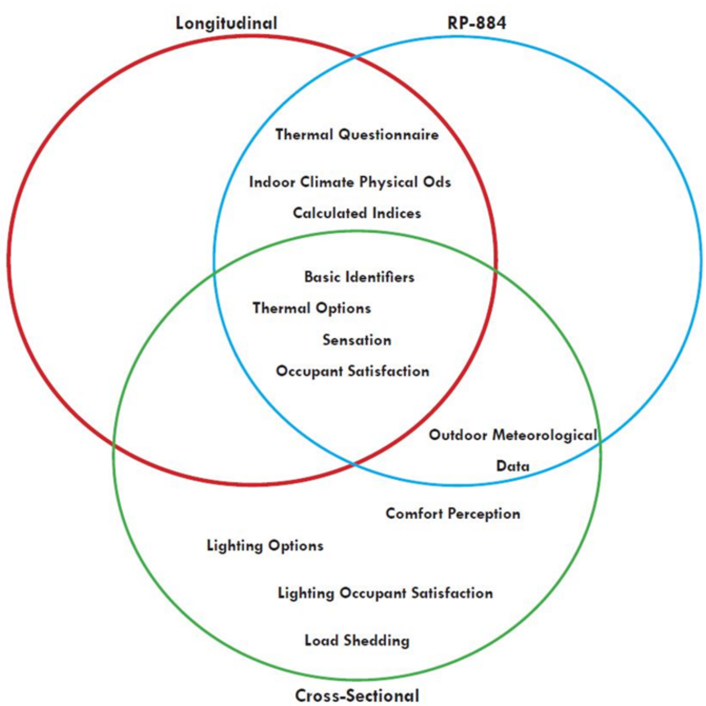

Figure 1: Overlapping data fields in cross-sectional, longitudinal and ASHRAE-RP-884 datasets

The process of creating the final baseline database towards the objective of a combined dataset to help increase building modeling precision is summarized in the following steps[1]:

1. Review of the literature and exploration of underlying assumptions for identifying variables of interest to understanding occupant adaptive behaviors.
2. Locate relevant and available datasets.
3. Identify studies that include, at minimum, objective measurements of outside air temperature, indoor air temperature, thermal sensation perceptions, and frequency of a set of adaptive behaviors such as adjusting a thermostat or using a local space heater.
4. Locate the data and coding for each study.
5. Identify common variables of interest in transferable fields. For fields to be transferable variables must have the same context even if they are coded differently.
6. Operationalize coding through developing an equivalence basis to convert the various data coding schemes to a common scheme, and to carry out data transformations.
7. Pool the data into one database.
8. Perform imputation of missing values to a reasonable extent.
9. Explore bivariate and multivariate relationships in the underlying datasets.
10. Reproduce these investigations using the final database.
11. Identify robust evidence whenever possible for specific bivariate and multivariate relationships in the final database.
12. Respect time frame and need for database iterations.

The three datasets are collected by different researchers and present variations in terms of the occupants, buildings, locations, and dates. More specifically, there is a wide variety in terms of occupant age, sex, daily average outdoor temperature, daily average outdoor relative humidity, indoor air temperature and others. However, all sets show some significantly consistent patterns, especially in regards to the variables of interest, such as availability of portable space heaters, availability of portable fans and the frequency of using portable fans.

The final database acquires characteristics of the three underlying datasets in proportion to the number of observations in each. As expected, the ASHRAE RP-884 dataset dominates the combined database, while the cross-sectional dataset, which is the smallest, has the least effect. The descriptive statistics of the final database show that it is very close to the ASHRAE RP-884 set, which has a high age mean, older dates, naturally ventilated buildings in its majority, and measurements from warmer climates than the smaller, more recent sets.

[1] For more information, please see Appendix A.

2.3 Generating a Synthetic Population

This section discusses the creation of a synthetic data set of occupant behaviors. There are three distinct steps to perform such task. As seen previously, the first is to collect relevant data sets on occupant behavior in commercial buildings (cross-sectional, longitudinal and ASHRAE-RP884). The second step is to integrate the three data sets that have three distinct properties, by running a table-join routine through **R** and **STATA**. Regression analysis is done in order to find common explanatory variables to predict occupant behaviors. The final step is to create a synthetic dataset out of the combined version of three data sets. The synthetic dataset is created deterministically by utilizing **synthpop** package for **R** and demonstrating that it successfully passes a goodness-of-fit test with the original combined data set (Nowok, et.al., 2016).

Like other synthetic data generation implementations, generating a synthetic version of data using **synthpop** fits the original dataset to the assumed distribution and obtains its parameters' estimates. Below are step-by step instructions to generate a synthetic population based on the three datases we previously collected. To learn available features of the package in greater detail, interested readers can directly consult to the package documentation (Nowok, et.al., 2016).

1. Re-name the collected dataset, in our case **obdataset.csv**, and put the file in your project folder.
2. Start your **R** and set the working directory to your project folder.
3. Call `R> library("synthpop)` to let **R** know that you will be using an add-on package **synthpop**.
4. Load your original dataset into the project and store it into a dataframe name **obdata,** by typing: `R> obdata <- read.csv("obdataset.csv")`. Notice that all missing data in the dataframe is recorded as "NA".
5. To make the whole process reproducible, use parameter **seed**:
   `R> my.seed <- 1234532`
6. After all required parameters are set, begin synthesizing process by calling the function **syn()**. Then, give a name to your resulting object of class **synds**, it is called **sobdata** in our case, where sobdata stands for "synthesized occupant behavior dataset." The parameter **m** indicating the number of synthesis instances is set to 5 in order to generate several versions of the synthetic data that are then averaged, and other arguments are left as default. The parameter **drop.not.used** is set to FALSE (otherwise the method and **predictor.matrix** will miss information on variables that are excluded from the model). By default, all variables are synthesized using the **ctree** implementation of **CART** models that can handle any type of data. The first variable is a random sample with replacement drawn from its observed value. You can also define the sequence of visits for all variables by including **visit.sequence.**
   `R> sobdata <- syn(obdata, m = 5, drop.not.used = FALSE, seed = my.seed)`

7. To compare the synthesized data with the original dataset, use the **compare.synds()** function of the **synthpop** package. The function takes arguments of a synthetic data object and a data frame with original data and compares relative frequency distributions of each variable. The function **compare.fit.synds()** allows the comparison of the estimates based on the synthesized datasets and those based on the original dataset. [2]

2.4 Dividing Synthetic Population with Cohorts

The next step is to use the synthetic data set for co-simulation work. We divided the data set into multiple cohorts and generated probability values of performing particular adaptive actions. Five significant independent variables are found from running ordered logit regression on the synthetic dataset. They are gender (male, female), age (0-29,30-49, 50-69), ventilation type (HVAC, Non-ventilated, Mixed), indoor air temperature (below or equal to22 degC, above 22 deg C), and outdoor air temperature (below or equal to 23 degC, above 23 degC). Figure 2 below shows that there are 72 combinations of the independent variables. A probability value is derived from each combination of these variables. Using a portable heater, for example, has probability values that vary from 0 to 0.991 across 72 combinations (median=0.044, mean=0.174) The probability values of using a portable fan have a minimum of 0.000, a maximum of 1.000, a median of 0.160, and a mean of 0.265.[3]

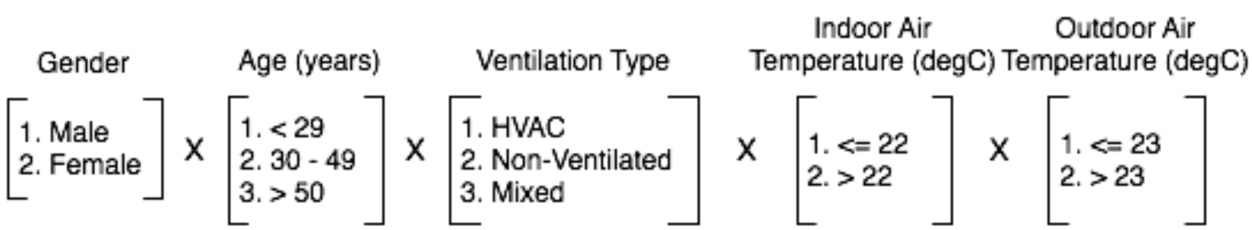

Figure 2: Cohorts construction framework (72 cohorts in total)

3. Co-simulating Synthetic Population with EnergyPlus BEM

3.1 Co-simulation Process with obFMU

An obFMU enables co-simulation in EnergyPlus by requiring an XML file to be generated based on occupant behavior characteristics and configuration with EnergyPlus. The architecture of the obFMU, described in Figure 3, consists of four main components, including a co-simulation interface, the interface description file in XML format, data model, and solvers. At each time

[2] For more information, please see Appendix B.

[3] For more information, please see Appendix C.

step, obFMU co-simulates the occupants' behavior described in the obXML schema and the building system conditions obtained from EnergyPlus run. The obXML schema describes the occupant behavior is generated separately based on a synthetic data set of occupant behavior. The obXML schema adopts four key elements of human cognitive process, Drivers, Needs, Actions, and Systems (DNAs) in interacting with the building environment (Hong, D'Oca, & Turner, 2015).

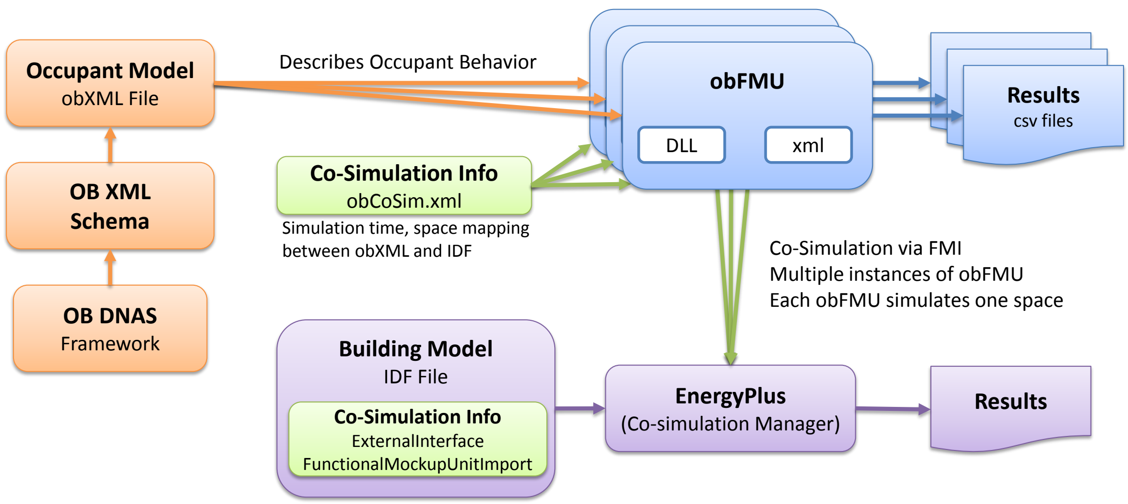

Figure 3: The obFMU architecture v1.2. (Hong et.al. 2015)

Table 1 describes the obFMU v1.2 release package that is necessary to conduct our co-simulation study. The building model used as a case study is based on Xu (2012) 's dissertation work on a highly-instrumented commercial building in Philadelphia, PA, USA. Xu (2012) provides a detailed, step-by-step account of the data collection, model preparation and calibration process used to create the baseline EnergyPlus building model.

Files	***Description***
obFMU.fmu	The obFMU v1.2 enables the on/off control of windows, lights, thermostat, and HVAC systems.
obXML v1.2.xsd	The obXML schema v1.2 associated with the obFMU v1.2.
obXML.xml	An example of obXML file generated based on obXML schema v1.2.
obCoSim.xml	An example file describing the simulation time step, and the space mapping between obXML and the IDF.
<buildingmodel>.idf	An example IDF file with co-simulation information defined in EnergyPlus IDD objects: ExternalInterface, ExternalInterface:FunctionalMockupUnitImport,

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
ExternalInterface:FunctionalMockupUnitImport:To:Schedule.

Table 1: obFMU file structures

3.2 Illustrative examples: Building 101

There are seven main steps to prepare EnergyPlus co-simulation process with ObXML.

3.2.1 EnergyPlus model of Building 101

The first step is to have a working EnergyPlus model of a building. The team studies Building 101 that is located in Philadelphia. The building has been renovated over the years to accommodate tenant turnover. It contains 75,156ft2 (6,982 m2) of gross building floor area with 61,000 ft2 (5,667 m2) of multi-tenanted conditioned space. The building has 3 floors and basement level, and is positioned on the north/south axis (Figure X). As of August 2013 the building was 70% occupied (Figure 4). Interested readers can refer to Xu (2012) for a full energy analysis of the building, including the development and calibration of the EnergyPlus model used as a baseline for this study.

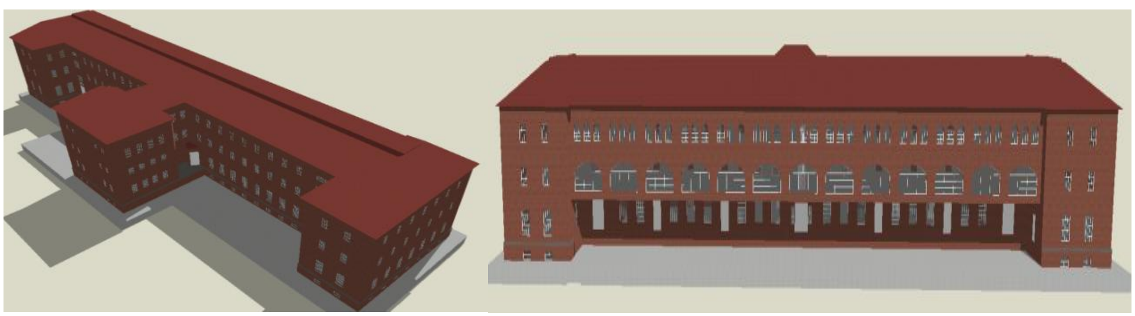

Figure 4: Building 101 model (Left: Building East Façade; Right: Building West Façade) (Xu, 2012)

The EnergyPlus model of Building 101 consists of 53 thermal zones. The model has both output variables and schedules needed to run co-simulation. Output variables that are available for co-simulation are Zone Mean Air Temperature, Zone Mean Air Temperature, Zone Air CO2 Concentration, Zone Lights Electric Power, Site Outdoor Air Drybulb Temperature, and Site Rain Status. In regards to schedules, the model has people schedule to simulate people movement in the building. Lighting schedule is also available for selected zones in the building. The lighting schedule applies to overhead lighting adjustment. Schedule for electric equipment controls the use of task light, portable heater, office equipment, and kitchen appliances. The model uses dual-setpoint thermostat to adjust temperature for selected zones. This has been modified for co-simulation with the current obXML, which only considers single-setpoint thermostat. Schedules for adjusting window blinds are also included in the co-simulation.

We selected only ten zones for the obXML co-simulation work since the current version of obXML only able to handle occupancy and occupant behaviors in at maximum ten zones. These zones are on the 2nd floor and highly instrumented. Table 2 lists zone names that are included in the obXML model. Figure 5 shows a layout of the 2nd floor Building 101 and the zones' locations.

No	***Thermal zones names***
1	2ndFloor_NTeleConfRoom
2	2ndFloor_NICONLab
3	2ndFloor_NMechRoom
4	2ndFloor_MPcCntrlOffc214
5	2ndFloor_SEndOffice201
6	2ndFloor_SWOffice206
7	2ndFloor_NWOffice222
8	2ndFloor_SStairwellsShallway
9	2ndFloor_SEOffice205
10	2ndFloor_NEOffice223

Table 2: Ten zones on the 2nd floor of Building 101 that are included in obXML

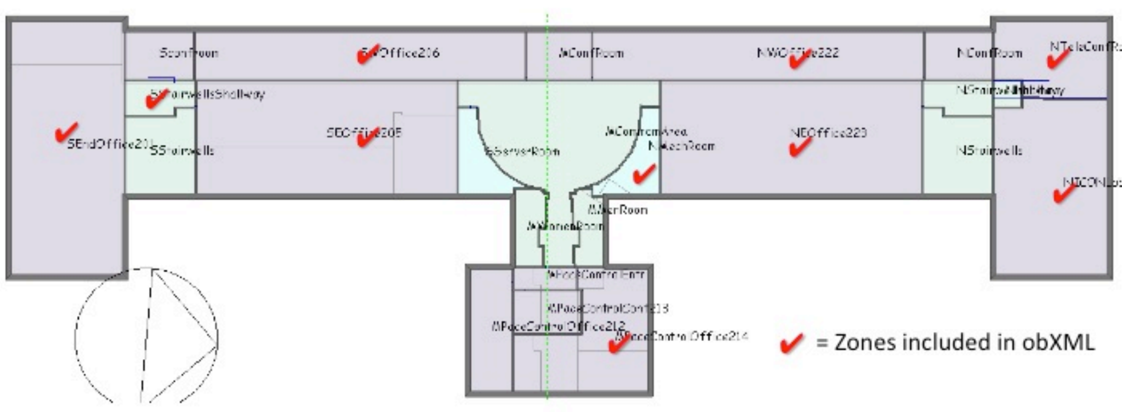

Figure 5: Ten zones on the 2nd floor of Building 101 that are included in obXML

3.2.2 Interface using ExternalInterface:FunctionalMockupUnitImport

The external interface can map to two EnergyPlus input objects called **ExternalInterface:FunctionalMockupUnitImport:From:Variable** and **ExternalInterface:FunctionalMockupUnitImport:To:Schedule**. Modellers have to pay careful attention in placing these objects in an orderly manner. All reference to schedules should be replaced with the new schedule declarations.

The **ExternalInterface:FunctionalMockupUnitImport:From:Variable** replaces the object **Ouput:Variable** of EnergyPlus. It consists of 5 inputs as the following: 1) the output variable index key name can be any thermal zone name; 2) the output variable name is the variable name of interest such as “Zone Mean Air Temperature”, “Zone Lights Electric Power”; 3) FMU File name is the default obFMU.fmu; 4) FMU instance name is a user-defined fmu instance name (i.e. obm_2ndFloor_NWOffice222); 5) FMU variable name relates to the output variable name.

The **ExternalInterface:FunctionalMockupUnitImport:To:Schedule** can be used to overwrite schedules. It consists of 6 input parameters as the following: 1) Schedule Name; 2) Schedule Type Limits Names (i.e. Any Number); 3) FMU File Name is the default **obFMU.fmu**; 4) FMU Instance Name is a user-define fmu name; 5) FMU variable name relates to the schedule name; 6) An optional field, called “initial value”. If a value is specified for this field, then this value will be used during the warm-up period and the system-sizing.

```
ExternalInterface:FunctionalMockupUnitImport:From:Variable,
<Output:Variable Index Key Name>,
<Output:Variable Name>,
<FMU File Name>,
<FMU Instance Name>,
<FMU Variable Name>;

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
<Schedule Name>,
<Schedule Type Limits Names>,
<FMU File Name>,
<FMU Instance Name>,
<FMU Variable Name>,
<Initial Value>;
```

3.2.3 obXML.xml file

The third step is to create an occupant behavior schema within the **obXML.xml** file. The file contains a schema of interactions between building spaces and occupants, written in **.xml** format. The definition of obxml starts with

```
<OccupantBehavior xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
ID="obXML" Version="1.2" xsi:noNamespaceSchemaLocation="obXML_v1.2.xsd">
```

The schema has four major parts to describe the interactions.

3.2.4 Building spaces

The code for building description is located within <spaces>… </spaces>. It includes information such as space id, space type, maximum number of occupants, occupant IDs, and all systems interacting with occupants such as HVAC, lighting, window opening, plug load, and thermostat. Below is a sample .xml schmea of building space **2ndFloor_NWOffice222** with its building system. The current obXML version allows for 9 space types, such as MeetingRoom, Corridor, Outdoor, Office, ResidentialOwn, ResidentialRent, OfficeShared, OfficePrivate, and Other. Six systems are now available. They are HVAC, Light, Window, PlugLoad, Thermostat, and ShadeAndBlind. There may also be occupancy in the space.

```
<Space ID="2ndFloor_NWOffice222">
   <Type>OfficeShared</Type>
   <MaxNumOccupants>3</MaxNumOccupants>
   <Systems>
      <HVAC><Type>ZoneOnOff</Type></HVAC>
      <Light><Type>OnOff</Type></Light>
      <Window><Type>Fixed</Type></Window>
      <PlugLoad><Type>ContinuousControl</Type></PlugLoad>
      <Thermostat><Type>Adjustable</Type></Thermostat>
   </Systems>
   <OccupantID>OC1</OccupantID>
   <OccupantID>OC2</OccupantID>
</Space>
```

3.2.5 Occupant behaviors definitions

The second part describes each occupant and behaviors performed by the occupant and its code located within <occupants>…</occupants>. An occupant has attributes of Occupant ID, Priority, Age, Gender, LifeStyle, JobType, and sets of behaviors. An occupant may perform more than one action on a system. For example, an occupant adjusts the room lighting under a dimmed or bright ambient lighting. The occupant may also adjust the lighting when he or she enters or leaves the room.

```
<Occupants>
   <Occupant ID="OC47" Name="Tenant of 2ndFloor_NWOffice222">
      <Priority>2</Priority>
      <Age>30</Age>
      <Gender>Female</Gender>
      <LifeStyle>Norm</LifeStyle>
      <JobType>Tenant</JobType>
      <BehaviorID>B_Movement</BehaviorID>
      <BehaviorID>B_Lighting</BehaviorID>
      <BehaviorID>B_PortHeater</BehaviorID>
      <BehaviorID>B_Thermostat</BehaviorID>
      <BehaviorID>B_AirCondition</BehaviorID>
      <BehaviorID>B_Windows</BehaviorID>
   </Occupant>
</Occupants>
```

3.2.6 Translating synthetic population database to behavior declarations

Each behavior is described by a probability distribution of performing the action. Code that describes the behaviors, is located within <behaviors>…</behaviors>. In this section of the **obXML** schema, the building occupant behavior is described in the DNAs framework, "an ontology to standardize the description of energy-related occupant behavior in buildings"

(Hong, 2015). Take for example an occupant using portable heater. **D-Drivers** describes the environmental conditions that trigger such action (i.e. Time of day and season). **N-Needs** describes occupant physical needs regarding, for example, thermal comfort. **A-Actions** describes the type of action (i.e. Turn On), and the probability distribution of performing the action.

This probability equation is derived from the analysis on our previously generated synthetic population of occupants and their behaviors. The current version of **obXML** has ten mathematical equations, whose coefficients can be adjusted by the users. For example, an occupant's turning on and off the room lighting upon entering and leaving the room relies on one constant probability equation with a value of 0.98. Another example is occupant's thermal adaptive behavior in using portable heater. This action relies on probability Weibull function that receives 3 coefficients and 1 parameter that is Room Air Temperature. These coefficients were results of running sets of logistic regressions of the previously generated synthetic dataset.[4]

3.2.7 obCoSim.xml file

The next step is to define the zones that are used for co-simulation, in **obCoSim.xml** file. This file defines a FMU (Functional Mockup Unit) instance for each space in obXML code. The file describes the space mapping between **obXML** and the **IDF**, time step, and other simulation settings.[5]

3.3 Results

The simulation from obXML produces three sets of results. They are occupant movement, occupant movement by rooms, and output variables for each room. In our case, the occupant movements are recorded in hourly basis. Table 3 describes the occupant location at each different location at a time. For example, an occupant with ID OC36 moves from room with an ID 1 (2ndFloor_NICONLab) to room ID 7 (2ndFloor_NWOffice222) at 9am to 10am on January 3rd. Around the same time, another person with ID OC40 also moves to the room from 2ndFloor_SEndOffice201 (Room ID 5). Table 4 shows the number of occupants in each room in Building 101. At 10am on January 3rd, 3 occupants occupy room with an ID 7. Table 5 shows the environmental condition in Room 2ndFloor_NWOffice222.

---

[4] For more information, please see Appendix D.

[5] For more information, please see Appendix E.

Room Numb		0	2	3	4	5	6	7	8	9	10
Room ID	Outdoor		2ndFloor_NI	2ndFloor_NN	2ndFloor_MI	2ndFloor_SE	2ndFloor_SW	2ndFloor_NV	2ndFloor_SS	2ndFloor_SE	2ndFloor_NE
Occupant Nu		0	2	3	4	5	6	7	8	9	10
Occupant ID	OC31		OC33	OC34	OC35	OC36	OC37	OC38	OC39	OC40	OC41
57	2015/1/3 9:0:00		1	1	1	1	2	2	2	5	5
58	2015/1/3 10:0:00		2	10	10	7	6	10	8	7	10
59	2015/1/3 11:0:00		1	1	0	1	1	2	1	1	1
60	2015/1/3 12:0:00		7	4	10	2	10	5	0	10	10
61	2015/1/3 13:0:00		1	1	1	1	2	2	2	5	5
62	2015/1/3 14:0:00		9	9	10	10	5	9	9	10	10
63	2015/1/3 15:0:00		1	1	1	0	2	1	1	0	1
64	2015/1/3 16:0:00		8	10	0	10	10	10	10	10	0
65	2015/1/3 17:0:00		1	1	10	1	2	2	1	1	10
66	2015/1/3 18:0:00		10	5	1	5	8	10	10	10	1
67	2015/1/3 19:0:00		0	0	0	0	1	0	1	0	0

Table 3: Occupant movements in Building 101.

step	time	0	1	2	3	4	5	6	7	8	9	10
57	2015/1/3 9:0:00	0	5	3	0	0	5	3	2	0	3	3
58	2015/1/3 10:0:00	1	2	1	1	0	1	3	3	2	2	8
59	2015/1/3 11:0:00	2	14	4	0	0	0	1	0	0	0	3
60	2015/1/3 12:0:00	1	5	2	0	1	1	0	1	0	1	12
61	2015/1/3 13:0:00	0	5	3	0	0	5	3	2	0	3	3
62	2015/1/3 14:0:00	0	3	0	1	0	2	1	2	0	6	9
63	2015/1/3 15:0:00	7	12	2	0	0	0	0	1	0	0	2
64	2015/1/3 16:0:00	2	3	0	0	0	0	0	0	1	3	15
65	2015/1/3 17:0:00	1	12	5	0	0	1	0	0	0	0	5
66	2015/1/3 18:0:00	3	5	0	0	0	2	0	0	2	0	12
67	2015/1/3 19:0:00	16	5	0	0	0	0	0	0	0	1	2

Table 4: Number of occupants in rooms.

Time	Temperature	Illuminance(l	CO2 (ppm)	LPD (w)	Ourdoor air t	AC Schedule	Lighting Sch	Infiltration S	Plug Load Scl
1/3/16 9:00	24.003329	24.003329	652.349256	3271.193	-9	0	1	0.06	0
1/3/16 10:00	24.007383	24.007383	632.681257	3271.193	-9	1	1	0.06	0
1/3/16 11:00	24.004584	24.004584	622.749835	3271.193	-9	1	1	0.06	0
1/3/16 12:00	24.005085	24.005085	655.263929	3271.193	-9	1	1	0.06	0
1/3/16 13:00	24.007921	24.007921	688.893415	3271.193	-8	1	1	0.06	0
1/3/16 14:00	24.004932	24.004932	665.612411	3271.193	-8.2	1	1	0.06	0
1/3/16 15:00	24.004185	24.004185	660.607305	3271.193	-8	1	1	0.06	0
1/3/16 16:00	24.002962	24.002962	711.989658	3271.193	-8	0	0	0.06	0
1/3/16 17:00	24.006796	24.006796	725.582391	3271.193	-8	0	1	0.06	0
1/3/16 18:00	24.006608	24.006608	717.331495	0	-8	0	1	0.06	0
1/3/16 19:00	24.005611	24.005611	666.162748	3271.193	-8	0	1	0.06	0

Table 5: Environmental conditions in Room 2ndFloor_NWOffice222.

4. Agent-Based Modeling of Occupant Behavior using NetLogo

In our research, we also employ an Agent-Based Modeling (ABM) approach to simulate autonomous agents and their interaction with other agents and their environment. The building occupant agents perform actions based on Belief, Desire, Intention (BDI) framework that characterizes human decision-making process. By relying on this framework, individual building occupants develop plans and make decisions to carry out particular plan of action (Rao and

Georgeff, 1998). The model is implemented in NetLogo (Wilensky and Rand, 2014). It extends the framework developed by (Andrews et.al., 2011, and Andrews et.al., 2012).

Programmed in NetLogo, a “multi-agent programmable modeling environment”, the ABM approach focuses on individual and shared decisions of occupants as they experience and react to changing environmental conditions based on information about the current state of controllable and uncontrollable building features. Building 101 is modeled and run. And, its results were broken down and used as a look-up table by the occupant behavior model. The occupant behavior model includes occupants’ adaptive behaviors regarding thermal comfort (e.g. adjusting thermostat set points, turning on/off space heaters, opening/closing windows and doors, and changing winter/summer clothes) and their influence on airflow rate entering their thermal zone by using set points and infiltration schedules. The ABM also models occupants’ lighting comfort adaptive behaviors (turning on/overhead lights, turning on/off task lights, opening/closing window blinds). Calibration is done using survey and interview data from individual building occupants, plus building-wide performance data for Building 101.

Figure 6 shows the layout interface for a modeler to set the simulation input parameters. Prior running the simulation, he or she needs to set the all required input parameters. From left to right columns in figure 5, below is the explanation of input parameters.

1. A modeler chooses simulation type of thermal, lighting, or combination of the two.
2. A modeler chooses to use a synthetic dataset to describe occupancy and occupant behaviors for the model.
3. A modeler chooses EnergyPlus output file to set a look-up table of building environment.
4. A modeler chooses a combination of simulation scenarios. The first is a communication level between a building manager, tenant representatives, and tenants on a scale from 0 (no-communication) to 100 (the best communication). The second is a building control level for all types of building occupants on a scale between 0 (no control) to 100 (full control). The third is clothing choice scenario as part of occupant thermal adaptive behaviors.

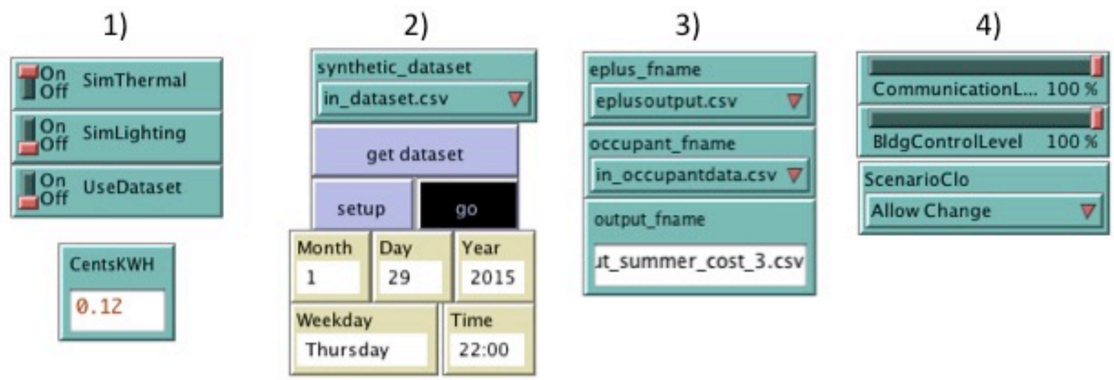

Figure 6: ABM model input interface in NetLogo

NetLogo also enable us to display outputs in real-time while running ABM simulation through a set of graphs. In our implementation, the simulation results also output into a file. For our experiment on occupant behavior, we displayed the following outputs:

- **KWH** – KiloWatt-Hours that is energy consumption taken directly from EnergyPlus results.
- **Predicted Mean Vote** – Average individual thermal comfort.
- **Discomfort** – Average individual discomfort level.
- **Effort** – Average individual effort level.
- **Tenant representative responsiveness** – Average tenant representative responsiveness to tenants' requests.
- **Building manager responsiveness** – Average building manager responsiveness to tenant representatives' requests.
- **Individual adaptive behavior** – Adaptive behaviors performed by tenants, tenant representatives, and building manager.

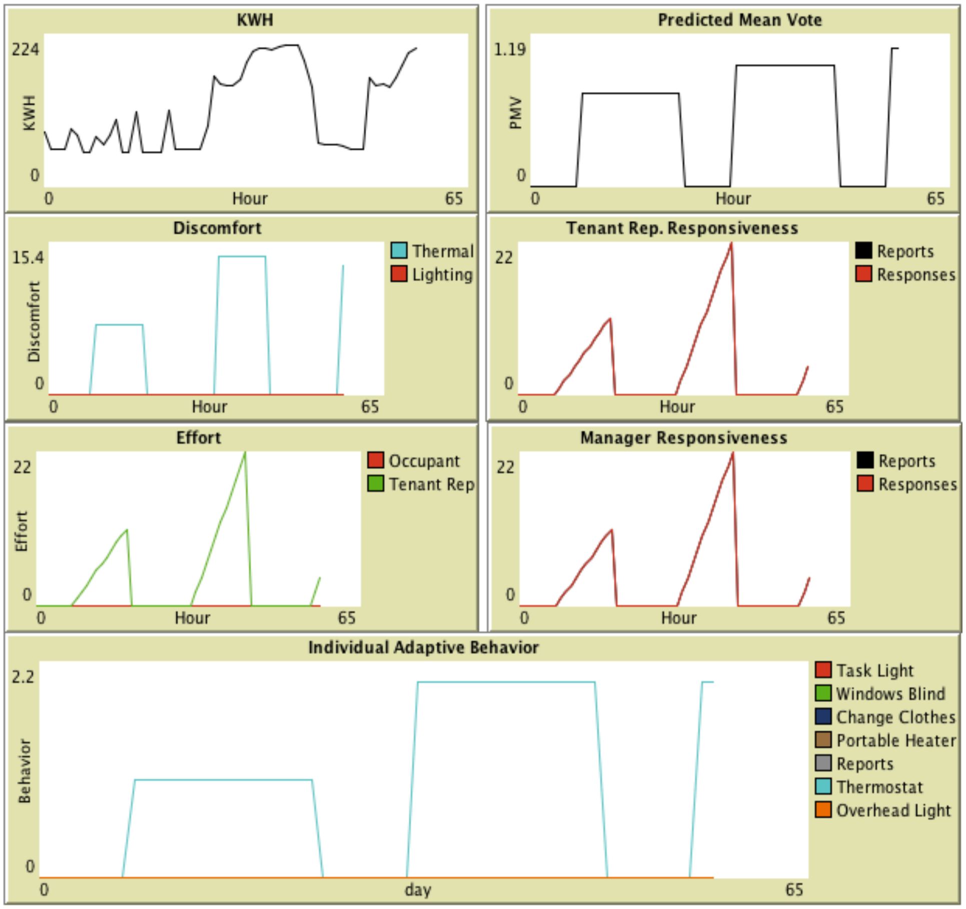

Figure 7: Output displays implemented in NetLogo.

5. Conclusions and Future Recommendations

In the present study, three individual research projects were documented for the purpose of informing future researchers in the area of occupant behavior building energy performance modeling and simulation: a Synthetic Population project, a Co-Simulation of Synthetic Population with EnergyPlus project, and an Agent Based Modeling project.

In the first project, we illustrated the process of aggregating disparate occupant behavior data from several studies in existing commercial office buildings. The resulting database formed the basis for generating a representative population. In the second project, we used the synthetic population to derive a co-simulation with EnergyPlus under obFMU. EnergyPlus is a building energy modeling (BEM) software and obFMU is a standardized building occupant behavior modeling tool. Both software platforms are developed by Lawrence Berkeley National Laboratory at Berkeley (LBNL). Lastly, we separately modeled the organizational component among occupants and its interaction with the building environment using NetLogo, an ABM tool based in Java.

Combined results of our analyses indicate that occupant behavior data collected in disparate contexts can be manipulated to serve as a valid basis for incorporating behavioral factors in building energy models.

Future recommendations include

- Collection of additional data from real occupants in existing commercial office buildings
- Exploration of alternative methods for generating synthetic populations
- Improvements in obFMU and EnergyPlus
- Applications/tests of findings to lighting and plug-loads
- Better co-simulation method to hot-link EnergyPlus with Agent Based Modeling of building occupant behavior

IE-EBC Annex-66 (http://www.annex66.org/) is an international group of which this team is a part, that is encouraging and documenting advances in incorporating occupant behavior into building energy performance modeling, by identifying best practices, preparing case studies and teaching materials, and coordinating special issues of several technical journals. The work introduced in this project will be advanced by the larger Annex 66 research community.

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Appendices

Appendix A: Datasets Aggregation

Cross-sectional Dataset

- 6 case studies
- 16 commercial office buildings
- # of floors: 3-5
- 2009-2014
- Locations: NJ and PA, USA
- 954 occupant records
- Researcher: Rutgers Center for Green Building
- Link : http://en.openei.org/datasets/dataset/one-year-behavior-environment-data-for-medium-office

Year	Location	Data Form	Building N	Occupant Record
2009	Union City, NJ Camden, NJ	Survey	2	49
2011	Phila Navy Yard	Survey	2	36
2012	Phila Region	Survey/interviews/observations	2	108
2013	Phila Region	Survey/interviews/observations	9	744
2014	Phila Navy Yard	Survey/interviews/observations	1	17
Total			**16**	**954**

Longitudinal Dataset

- 1 case study-1 building
- # of floors: 4
- Location: Friends Center office building, Philadelphia, PA, USA
- 2013-2014
- 24 occupant records-2503 responses
- Researcher: Jared Langevin (Langevin, et.al, 2015)
- Link: http://en.openei.org/datasets/dataset/one-year-behavior-environment-data-for-medium-office

ASHRAE RP-884 Dataset

- 160 case studies-buildings
- Locations: UK, Thailand, USA (CA, MI), Indonesia, Canada, Australia, Pakistan, Greece, Singapore
- 1982-1997
- 20,215 occupant records
- Researchers: Brown, Busch, Benton, Brager, Karyono, Donnini, de Dear, Newsham, Fergus, Baker, Ifitkhar, Rowe, Fountain, Williams, Foo, Leow, Bauman *(*de Dear, et. al, 1997)
- Link: http://sydney.edu.au/architecture/staff/homepage/richard_de_dear/ashrae_rp-884.shtml

Assembling the Datasets

The study datasets although diverse, shared a large number of variables in common-even if those fields were coded differently- and that formed the basis for the assembling process. There were also a number of fields that existed in some of the sets but could be easily reproduced in all. Lastly, there were a number of fields that were relevant to the research scope but did not have values in all sets. As seen below, variables that have responses in all the datasets are highlighted with yellow, variables that can be easily reproduced in all sets are highlighted with orange and variables important to remain but not easily reproduced in all, are highlighted with light blue.

		Final Database		**Longitudinal**	**Corss-Sectional**	**ASHRAE RP-884**
	Category	**Variable**	**Description**			
1	Basic Identifiers	Researcher	researcher's name			x
2		Location	building location			x
3		Climzone	based on the Koppen climate classification			x
4		Season	heating or cooling season			x
5		Bldgtype	the type of building (office, commercial, residential, academic, municipal)			x
6		Ventype	type of ventilation			x
7		Datasource	the source of the data (types of interviews, questionaires etc)	x	x	
8		Bldgcode	each building is assigned a unique identifier-number		x	x
9		Bldgname	name of building		x	

10		OcNumber	each respondent is assigned a unique number	x		
11		Age	the age of each respondent	x	x	x
12		Sex	The gender of the respondent	x	x	x
13		Health	chronic or recurring health condition reported by respondent		x	
14		Year	year of survey		x	x
15		Day	day of year of survey		x	x
16		Time	time of survey		x	x
17		Weather	weather during the day of the survey			x
18		Wksp	respondent's office type	x	x	
19		Floor	floor number	x	x	
20		Office Location	location in core or periphery	x	x	
21		Exposure	orientation of a peripheral workspace		x	
22		Lux	Spot value of illuminance taken during site visit observation using Konica Minolta T-10 37126130/57136049. Measurements were taken on desk surface (30" AFF) at or near work area taken in accordance with NREL guidelines.		x	
23	Outdoor Meteorological Data	day15_ta	outdoor max air temperature on day of survey			x
24		day06_ta	outdoor min air temperature on day of survey			x
25		dayav_ta	outdoor average air temperature on day of survey	x		x
26		day15_rh	outdoor max rel humidity on day of survey			x
27		day06_rh	outdoor min rel humidity on day of survey			x
28		dayav_rh	outdoor average rel humidity on day of survey	x		x
29		day15_et	outdoor max ET (Ta and rh at time of daymx_ta)			x
30		day06_et	outdoor min ET (Ta and rh at time of daymn_ta)			x
31		dayav_et	outdoor average ET on day of survey			x
32		airvelocity	outdoor air velocity on day of survey	x		
33	Indoor Climate Physical Ods	TA_H	air temperature at 1.1 m above floor			x
34		TA_M	air temperature at 0.6 m above floor	x	x	x
35		TA_L	air temperature at 0.1 m above floor			x

36		DEWPT	dewpoint temperature			x
37		PRTAB	plane radiant asymmetry temperature			x
38		TG_H	globe temperature at 1.1 m above floor			x
39		TG_M	globe temperature at 0.6 m above floor			x
40		TG_L	globe temperature at 0.1 m above floor			x
41		VEL_H	air speed 1.1 m above floor			x
42		VEL_M	air speed 0.6 m above floor	x		x
43		VEL_L	air speed 0.1 m above floor			x
44		TURB_H	turbulence intensity at 1.1 m above floor			x
45		TURB_M	turbulence intensity at 0.6 m above floor			x
46		TURB_L	turbulence intensity at 0.1 m above floor			x
47		INDOOR Lumens	Logged via HOBO U12	x		
48		INDOOR CO2	Logged via HOBO Telair 7001 sensor	x		
49	Calculated Indices (n.b. combined chair+clothing)	TAAV	average of three heights' air temperature			x
50		TRAV	average of three heights' mean radiant temperature	x		x
51		TOP	average of TAAV and TRAV			x
52		VELAV	average of three heights' air speed			x
53		VELMAX	maximum of three heights' air speeds			x
54		TUAV	average of three heights' turbulence			x
55		PA	vapor pressure			x
56		RH	relative humidity	x		x
57		ET	new effective temperature index et*			x
58		SET	new standard effective temperature index set*			x
59		TSENS	two-node tsens index [-1.5, +2.0]			x
60		DISC	two-node disc index [-4, +4]			x
61		PMV	predicted mean vote, Fanger's model [-3, +3]	x		x
62		PPD	predicted percentage dissatisfied, Fanger's model			x
63		PD_H	percentage dissatisfied due to draft at 1.1 m height Fanger et.al			x
64		PD_M	percentage dissatisfied due to draft at 0.6 m height Fanger et.al			x
65		PD_L	percentage dissatisfied due to draft at 0.1 m height Fanger et.al			x
66		PD_MAX	percentage dissatisfied due to draft max of all 3 heights Fanger et.al			x
67	Sensation	LightingSens	respondent's light perception		x	
68		ThermalSens	respondent's thermal perception	x		x

69	Lighting Options	Hblinds	respondent's access to blinds		x	
70		HOHLt	respondent's access to overhead light on/off switch		x	
71		HOHLtD	respondent's access to overhead light dimmer switch		x	
72		HtaskLt	respondent's access to task or cabinet light		x	
73		Hnotify	respondent's access to management for lighting control		x	
74		Hother	respondent's access to other options for lighting control		x	
75		Fblinds	how often respondent adjusts blinds		x	
76		FOHLt	how often respondent adjusts overhead lights on/off switch		x	
77		FOHLtD	how often respondent adjusts overhead light dimmer		x	
78		FtaskLt	how often respondent adjusts task light		x	
79		Fnotify	how often respondent notifies management for lighting comfort		x	
80		Fother	how often respondent takes other actions for lighting comfort		x	
81	Lighting Occupant Satisfaction	SatElLt	satisfaction with workspace electric light		x	
82		SatLtAll	satisfaction with overall workspace lighting		x	
83	Thermal Questionnaire	PRXY_TSA	thermal acceptability			x
84		TSA	thermal acceptability question			x
85		MCI	thermal preference	x		x
86		VENT	air movement acceptability			x
87		AVM	air movement preference			x
88		COMF	general thermal comfort right now	x		x
89		ACT10	metabolic activity in last 10 min			x
90		ACT20	metabolic activity between 20 and 10 min ago	x		x
91		ACT30	metabolic activity between 30 and 20 min ago			x
92		ACT60	metabolic activity between 60 and 30 min ago	x		x
93		MET	average metabolic activity of subject	x		x
94		CLO	ensemble clothing insulation	x		x
95		UPHOLST	insulation of the subject's chair	x		x
96		INSUL	clothing plus upholstery insulation	x		x
97	Additional Comfort Perception	AClHot			x	
98		FCLHot	Respondents' frequency of hot feeling during cold season		x	
99		AClCold			x	

100		FClCold	Respondents' frequency of cold feeling during hot season		x	
101		AHtHot			x	
102		FHtHot	Respondents' frequency of hot feeling during hot season		x	
103		AHtCold			x	
104		FHtCold	Respondents' frequency of cold feeling during hot season		x	
105	Thermal Options	HOpWin	respondent's access on operable windows	x	x	x
106		HExDoors	respondent's access on exterior doors			x
107		HInDoors	respondent's access on interior doors	x	x	x
108		Htstat	respondent's access on thermostat	x	x	x
109		Hblinds	respondent's access on blinds	x	x	x
110		Hheater	respondent's access on heater	x	x	x
111		Hportfan	respondent's access on portable fan	x	x	x
112		Hvent	respondent's access on air ventilation		x	
113		HRmAC	respondent's access on adjustable AC		x	
114		Hdehumid	respondent's access on humidifier		x	
115		HClFan	respondent's access on ceiling fan		x	
116		Hcloth	respondent's access on clothing	x	x	
117		Hdrinks	respondent's access on drinks	x		
118		Hnotify	respondent's access on management for thermal control	x	x	
119		HotherTH	respondent's access on other actions for thermal control		x	
120		FOpWin	how often respondent adjusts windows	x	x	x
121		FExDoors	how often respondent adjusts exterior doors			x
122		FInDoors	how often respondent adjusts interior doors	x	x	x
123		Ftstat	how often respondent adjusts thermostat	x	x	x
124		Fblinds	how often respondent adjusts blinds	x	x	x
125		Fheater	how often respondent adjusts heater	x	x	x
126		Fportfan	how often respondent adjusts portable fan	x	x	x
127		Fvent	how often respondent adjusts air ventilation		x	
128		FRmAC	how often respondent adjusts room AC		x	
129		Fdehumid	how often respondent adjusts humidifier		x	
130		FClFan	how often respondent adjusts ceiling fan		x	
131		Fcloth	how often respondent adjusts clothing	x	x	
132		Fdrinks	how often respondent adjusts drink options			
133		Fnotify	how often respondent notifies management for thermal comfort		x	

134		Fother	how often respondent takes other actions for thermal comfort		x	
135		PCC	perceived control over thermal environment			x
136		PCC_AG	aggregate perceived control			x
137	Occupant Satisfaction	SATEMP	satisfaction with workspace temperature	x	x	x
138		SATWKSP	satisfaction with workspace	x	x	
139	Load Shedding	Load Shed Day	data collected during a demand response event		x	
140		Shed HVAC	level of demand response for HVAC		x	
141		Shed light	level of demand response for light reduction		x	

First, there was a need to create a standard template that the final database would rely on. This included all common fields from the 3 sets, but also the number of fields that could be easily reproduced, as well as those that were incomplete, but still relevant to the scope of the research project and valuable for future use. The larger ASHRAE RP-884 dataset carried out the majority of the template due to its disproportionally large sample size (20,215 records vs 2503-longitudinal and 955-cross-sectional). The resulting template included all 137 different variables/columns that were classified into 12 major categories:

1. Basic identifiers (22 variables)
2. Outdoor Meteorological Data (10 variables)
3. Indoor Climate Physical Ods (16 variables)
4. Calculated Indices (18 variables)
5. Sensation (2 variables)
6. Lighting Options (12 variables)
7. Lighting Occupant Satisfaction (2 variables)
8. Thermal Questionnaire (14 variables)
9. Additional Comfort Perception (4 variables)
10. Thermal Options (32 variables)
11. Occupant Satisfaction (2 variables)
12. Load Shedding (3 variables)

Fields/variables for each category, as well as the coding and units used for each field of the final database are illustrated below:

	Category	Name	Description	Units	Coding
1	Basic Identifiers	Researcher	Researcher's name	-	-
2		Location	Building location	-	-
3		Climzone	Based on the Koppen climate classification	-	-

4		Season	Heating or cooling season	-	-
5		Bldgtype	The type of building (office, commercial, residential, academic, municipal)	-	-
6		Ventype	Type of ventilation	-	HVAC, NV=Naturally Ventilated, Mixed
7		Datasource	The source of the data (types of interviews, questionaires etc)	-	-
8		Bldgcode	Each building of RCGB is assigned a unique identifier-number	-	-
9		Bldgname	Name of building	-	-
10		OcNumber	Each respondent is assigned a unique number in longitudinal database	-	-
11		Age	The age of each respondent	-	1=0-19, 2=20-29, 3=30-39, 4=40-49, 5=50-59, 6=60-69, 7=70-79
12		Sex	The gender of the respondent	-	1=male, 2=female
13		Health	Any chronic or recurring health condition reported by respondent	-	-
14		Year	Year of survey	-	-
15		Day	Day of year of survey	-	-
16		Time	Time of survey	-	-
17		Weather	Weather during the day of the survey	-	-
18		Wksp	Respondent's office type	-	1=enclosed pvt office, 2=shared pvt, 3=shared cube high parts 4=pvt cube high part (DEFAULT), 5=shared cube low parts, 6=pvt cube low part (INC GLASS PANEL), 7=open wkspace, 8=other
19		Floor	Floor number	-	0=basement
20		Office Location	Location in core or periphery	-	1=core, 2=perimeter
21		Exposure	Orientation of a peripheral workspace	-	1=NE, 2= NW, 3=SE, 4=SW, 5=Oth, 6=DK, 7=S, 8=N, 9=E, 10=W

22		Lux	Spot value of illuminance taken during site visit observation using Konica Minolta T-10 37126130/57136049. Measurements were taken on desk surface (30" AFF) at or near work area taken in accordance with NREL guidelines.	-	-
23	Outdoor Meteorological Data	day15_ta	Outdoor max air temperature on day of survey	C	-
24		day06_ta	Outdoor min air temperature on day of survey	C	-
25		dayav_ta	Outdoor average air temperature on day of survey	C	-
26		day15_rh	Outdoor max rel humidity on day of survey	%	-
27		day06_rh	Outdoor min rel humidity on day of survey	%	-
28		dayav_rh	Outdoor average rel humidity on day of survey	%	-
29		day15_et	Outdoor max ET (Ta and rh at time of daymx_ta)	C	
30		day06_et	Outdoor min ET (Ta and rh at time of daymn_ta)	C	
31		dayav_et	Outdoor average ET on day of survey	C	
32		airvelocity	Outdoor air velocity on day of survey	m/s	
33	Indoor Climate Physical Ods	TA_H	Air temperature at 1.1 m above floor	C	-
34		TA_M	Air temperature at 0.6 m above floor	C	-
35		TA_L	Air temperature at 0.1 m above floor	C	-
36		DEWPT	Dewpoint temperature	C	-
37		PRTAB	Plane radiant asymmetry temperature	C	
38		TG_H	Globe temperature at 1.1 m above floor	C	-
39		TG_M	Globe temperature at 0.6 m above floor	C	-
40		TG_L	Globe temeprature at 0.1 m above floor	C	-
41		VEL_H	Air speed 1.1 m above floor	m/s	-
42		VEL_M	Air speed 0.6 m above floor	m/s	-
43		VEL_L	Air speed 0.1 m above floor	m/s	-
44		TURB_H	Turbulence intensity at 1.1 m above floor	frac	-

45		TURB_M	Turbulence intensity at 0.6 m above floor	frac	-
46		TURB_L	Turbulence intensity at 0.1 m above floor	frac	-
47		INDOOR Lumens	Logged via HOBO U12	lumens/m2 *REGENERATE	-
48		INDOOR CO2	Logged via HOBO Telair 7001 sensor	ppm	-
49	Calculated Indices (n.b. combined chair+clothing)	TAAV	Average of three heights' air temperature	C	-
50		TRAV	Average of three heights' mean radiant temperature	C	-
51		TOP	Average of TAAV and TRAV	C	-
52		VELAV	Average of three heights' air speed	m/s	-
53		VELMAX	Maximum of three heights' air speeds	m/s	-
54		TUAV	Average of three heights' turbulence	frac	-
55		PA	Vapor pressure	kPa	-
56		RH	Relative humidity	%	-
57		ET	New effective temperature index et*	C	-
58		SET	New standard effective temperature index set*	C	-
59		TSENS	Two-node tsens index [-1.5, +2.0]	-	-
60		DISC	Two-node disc index [-4, +4]	-	-
61		PMV	Predicted mean vote, Fanger's model [-3, +3]	-	-
62		PPD	Predicted percentage dissatisfied, Fanger's model	frac	-
63		PD_H	Percentage dissatisfied due to draft at 1.1 m height Fanger et.al	frac	-
64		PD_M	Percentage dissatisfied due to draft at 0.6 m height Fanger et.al	frac	-
65		PD_L	Percentage dissatisfied due to draft at 0.1 m height Fanger et.al	frac	-
66		PD_MAX	Percentage dissatisfied due to draft max of all 3 heights Fanger et.al	frac	-
67	Sensation	LightingSens	Respondent's light perception	-	ASHRAE -3=dark, -2=dim, -1= slightly dim, 0=neutral, 1=slightly bright, 2=bright, 3=very bright

68		ThermalSens	Respondent's thermal perception	-	ASHRAE -3= cold, -2= cool, -1= slightly cool, 0=neutral 1=slightly warm, 2=warm, 3=cool
69	Lighting Options	Hblinds	Respondent's access to blinds	-	1=has access, 0=doesn't have access
70		HOHLt	Respondent's access to overhead light on/off switch	-	1=has access, 0=doesn't have access
71		HOHLtD	Respondent's access to overhead light dimmer switch	-	1=has access, 0=doesn't have access
72		HtaskLt	Respondent's access to task or cabinet light	-	1=has access, 0=doesn't have access
73		Hnotify	Respondent's access to management for lighting control	-	1=has access, 0=doesn't have access
74		Hother	Respondent's access to other options for lighting control	-	1=has access, 0=doesn't have access
75		Fblinds	How often respondent adjusts blinds	-	1=na, 2=never, 3=rarely, 4=sometimes, 5=often, 6=always
76		FOHLt	How often respondent adjusts overhead lights on/off switch	-	1=na, 2=never, 3=rarely, 4=sometimes, 5=often, 6=always
77		FOHLtD	How often respondent adjusts overhead light dimmer	-	1=na, 2=never, 3=rarely, 4=sometimes, 5=often, 6=always
78		FtaskLt	How often respondent adjusts task light	-	1=na, 2=never, 3=rarely, 4=sometimes, 5=often, 6=always
79		Fnotify	How often respondent notifies management for lighting comfort	-	1=na, 2=never, 3=rarely, 4=sometimes, 5=often, 6=always
80		Fother	How often respondent takes other actions for lighting comfort	-	1=na, 2=never, 3=rarely, 4=sometimes, 5=often, 6=always
81	Lighting Occupant Satisfaction	SatElLt	Satisfaction with workspace electric light	-	1=low to 7=high
82		SatLtAll	Satisfaction with overall workspace lighting	-	0-100 scale
83	Thermal Questionnaire	PRXY_TSA	Thermal acceptability	-	1.5<=ASH<=1.5 [1=unacc, 2=acc]
84		TSA	Thermal acceptability question	-	[1=unacc, 2=acc]
85		MCI	Thermal preference	-	1=want cooler, 2=no change, 3=want warmer
86		VENT	Air movement acceptability	-	1=very unacc. to 6=very acc.
87		AVM	Air movement preference	-	1=less, 2no change, 3=more

88		COMF	General thermal comfort right now	-	1=very uncomf to 6=very comf
89		ACT10	Metabolic activity in last 10 min	met	-
90		ACT20	Metabolic activity between 20 and 10 min ago	met	-
91		ACT30	Metabolic activity between 30 and 20 min ago	met	-
92		ACT60	Metabolic activity between 60 and 30 min ago	met	-
93		MET	Average metabolic activity of subject	met	-
94		CLO	Ensemble clothing insulation	clo	-
95		UPHOLST	Insulation of the subject's chair	clo	-
96		INSUL	Clothing plus upholstery insulation	clo	-
97	Additional Comfort Perception	FCLHot	Respondents' frequency of hot feeling during cold season	-	1=never, 2=infrequently, 3=not in last month 4=1-3d/month, 5=1-3d/week, 6=daily, 7=hourly
98		FClCold	Respondents' frequency of cold feeling during hot season	-	1=never, 2=infrequently, 3=not in last month 4=1-3d/month, 5=1-3d/week, 6=daily, 7=hourly
99		FHtHot	Respondents' frequency of hot feeling during hot season	-	1=never, 2=infrequently, 3=not in last month 4=1-3d/month, 5=1-3d/week, 6=daily, 7=hourly
100		FHtCold	Respondents' frequency of cold feeling during hot season	-	1=never, 2=infrequently, 3=not in last month 4=1-3d/month, 5=1-3d/week, 6=daily, 7=hourly
101	Thermal Options	HOpWin	Respondent's access on operable windows	-	1=has access, 0=doesn't have access
102		HExDoors	Respondent's access on exterior doors	-	1=has access, 0=doesn't have access
103		HInDoors	Respondent's access on interior doors	-	1=has access, 0=doesn't have access
104		Htstat	Respondent's access on thermostat	-	1=has access, 0=doesn't have access
105		Hblinds	Respondent's access on blinds	-	1=has access, 0=doesn't have access
106		Hheater	Respondent's access on heater	-	1=has access, 0=doesn't have access
107		Hportfan	Respondent's access on portable fan	-	1=has access, 0=doesn't have access
108		Hvent	Respondent's access on air ventilation	-	1=has access, 0=doesn't have access
109		HRmAC	Respondent's access on adjustable AC	-	1=has access, 0=doesn't have access
110		Hdehumid	Respondent's access on humidifier	-	1=has access, 0=doesn't have access

111		HCIFan	Respondent's access on ceiling fan	-	1=has access, 0=doesn't have access
112		Hcloth	Respondent's access on clothing	-	1=has access, 0=doesn't have access
113		Hdrinks	Respondent's access on drinks	-	1=has access, 0=doesn't have access
114		Hnotify	Respondent's access on management for thermal control	-	1=has access, 0=doesn't have access
115		HotherTH	Respondent's access on other actions for thermal control	-	1=has access, 0=doesn't have access
116		FOpWin	How often respondent adjusts windows	-	1=na, 2=never, 3=rarely, 4=sometimes, 5=often, 6=always
117		FExDoors	How often respondent adjusts exterior doors	-	1=na, 2=never, 3=rarely, 4=sometimes, 5=often, 6=always
118		FInDoors	How often respondent adjusts interior doors	-	1=na, 2=never, 3=rarely, 4=sometimes, 5=often, 6=always
119		Ftstat	How often respondent adjusts thermostat	-	1=na, 2=never, 3=rarely, 4=sometimes, 5=often, 6=always
120		Fblinds	How often respondent adjusts blinds	-	1=na, 2=never, 3=rarely, 4=sometimes, 5=often, 6=always
121		Fheater	How often respondent adjusts heater	-	1=na, 2=never, 3=rarely, 4=sometimes, 5=often, 6=always
122		Fportfan	How often respondent adjusts portable fan	-	1=na, 2=never, 3=rarely, 4=sometimes, 5=often, 6=always
123		Fvent	How often respondent adjusts air ventilation	-	1=na, 2=never, 3=rarely, 4=sometimes, 5=often, 6=always
124		FRmAC	How often respondent adjusts room AC	-	1=na, 2=never, 3=rarely, 4=sometimes, 5=often, 6=always
125		Fdehumid	How often respondent adjusts humidifier	-	1=na, 2=never, 3=rarely, 4=sometimes, 5=often, 6=always
126		FCIFan	How often respondent adjusts ceiling fan	-	1=na, 2=never, 3=rarely, 4=sometimes, 5=often, 6=always
127		Fcloth	How often respondent adjusts clothing	-	1=na, 2=never, 3=rarely, 4=sometimes, 5=often, 6=always
128		Fdrinks	How often respondent adjusts drink options	-	1=na, 2=never, 3=rarely, 4=sometimes, 5=often, 6=always
129		Fnotify	How often respondent notifies management for thermal comfort	-	1=na, 2=never, 3=rarely, 4=sometimes, 5=often, 6=always
130		Fother	How often respondent takes other actions	-	1=na, 2=never, 3=rarely, 4=sometimes, 5=often,

			for thermal comfort		6=always
131		PCC	Perceived control over thermal environment	-	1=no control to 5=complete control
132		PCC_AG	Aggregate perceived control	-	-
133	Occupant Satisfaction	SATEMP	Satisfaction with workspace temperature. Based upon estimates of respondent in current season of temperature at midday v preference	-	57-95
134		SATWKSP	Overall satisfaction with workspace	-	1=low to 7=high
135	Load Shedding	Load Shed Day	Data collected during a demand response event		1=yes, 0-no
136		Shed HVAC	Level of demand response for HVAC	-	0= no reduction, 1=level 1(2.5 degree reduction), 2= level 2 (3.5 degree reduction), 3=level 3 (4.5 degree reduction)
137		Shed light	Level of demand response for light reduction		0= no reduction, 1=level 1(10% reduction), 2= level 2 (20% reduction), 3=level 3 (30% reduction)

Cross-sectional dataset transformation

In order to comply with the final database template, units and coding, the cross-sectional dataset was modified as follows:

❖ **Basic Identifiers**

- 7 fields were added
    1. Researcher: the name of the researcher (RCGB for all studies)
    2. Location: the location of the study building (see corresponding table in the previous section-NJ and PA)
    3. Climatic zone: data taken from Koppen climate classification (humid subtropical and humid continental)
    4. Season: cooling vs heating where cooling=4/1 to 10/31 and heating: 11/1 to 3/31 based on the field of the data collection dates
    5. Building Type: office commercial for all study buildings
    6. Ventilation Type: HVAC, NV (naturally ventilated) or mixed, based on the background information collected by the researchers of the Center
    7. Occupant Number: Each respondent was assigned a unique identification number

- Day field was modified to reflect the format of ASHRAE RP-884. Day was added as a number of the day of year of survey and not as a date as it was previously
- Exposure field: values that were not numbers were replaced by blank.

❖ **Outdoor Meteorological Data**

- Air temperature min, max and average on day of survey fields: Some data existed from site visits. They were transformed from Fahrenheit to Celsius. When not available, they were taken from the National Oceanic and Atmospheric Administration (NOAA: http://www.noaa.gov/ -> Mercer County Airport, Wings Field Airport, Philadelphia International Airport and Newark International Airport)
- Relative Humidity min, max and average on day of survey fields: Some data existed from site visits. When not available, they were taken from the National Oceanic and Atmospheric Administration (NOAA: http://www.noaa.gov/ -> Mercer County Airport, Wings Field Airport, Philadelphia International Airport and Newark International Airport)

❖ **Indoor Climate Physical Obs**

- Air temperature measurements were taken approximately 2 feet above floor or else 0.6 meters which corresponds to the Air temperature column of ASHRAE RP-884

❖ **Lighting Options**

- All Access fields were transformed to reflect the coding 1=has access, 0=doesn't have access. Previously, coding was 1=has access, 2=doesn’t have access.
- All Frequency fields were transformed to reflect the coding: 1=na, 2=never, 3=rarely, 4=sometimes, 5=often, 6=always. Previously, coding was: 1= always, 2=often, 3=sometimes, 4=rarely, 5=never, 6=na

❖ **Thermal Options**

Thermal adaptive action fans and doors were renamed as portable fans and interior doors respectively to reflect the names of the corresponding columns in the ASHRAE RP-884 dataset.

- All Access fields were transformed to reflect the coding 1=has access, 0=doesn't have access. Previously, coding was 1=has access, 2=doesn’t have access.
- All Frequency fields were transformed to reflect the coding: 1=na, 2=never, 3=rarely, 4=sometimes, 5=often, 6=always. Previously, coding was: 1= always, 2=often, 3=sometimes, 4=rarely, 5=never, 6=na

Longitudinal dataset transformation

In order to comply with the final database template, units and coding, the longitudinal dataset was modified as follows:

There were a number of categories/fields that were deleted since they were not directly relevant to the scope of this work. Those were:

- Behavior/Reason
- Behavior/State of fan/heater/window
- Behavior/Thermostat point

- Behavior/Drinks
- Personal values/Choose set points
- Business/Productivity and Privacy
- Comfort/Productivity/Satisfaction/Satisfaction with perceived control

❖ **Basic Identifiers**

- Office type field was renamed to workspace since the content was almost identical

❖ **Outdoor Meteorological Data**

- Outdoor ambient temperature field was renamed to average daily temperature on day of survey
- Outdoor relative humidity field was renamed to average daily relative humidity on day of survey

❖ **Indoor Climate Physical Obs**

- Indoor ambient temperature field was renamed to indoor air temperature at 0.6 m above floor
- Indoor air velocity field was renamed to air speed at 0.6 m above floor

❖ **Sensation**

- Thermal sensation right now became thermal sensation. It was also recoded to reflect the ASHRAE RP-884 coding as: 1=want cooler, 2=no change, 3=want warmer. Values related to -3, -2 and -1 were nonexistent

❖ **Thermal Questionnaire**

- Thermal preference right now field was renamed to thermal preference
- Metabolic rate (last 15 mins) was renamed to metabolic activity between 20 and 10 min ago to comply with ASHRAE RP-884
- Metabolic rate (last 1 hour) was renamed to metabolic activity between 60 and 30 min ago to comply with ASHRAE RP-884
- The average of those two fields was then calculated to be added to the field: average metabolic activity of subject
- Clothing level field was renamed to ensemble clothing insulation
- A new field was created that was the insulation of the subject's chair, similarly to the ASHRAE RP-884 dataset, where chair=0.1 clo
- A field named clothing level was renamed to clothing plus upholstery insulation

❖ **Thermal Options**

- A fan/heater class field was broken into two different columns: access on heater and access on portable fan

- Availability columns were renamed to access columns
- Access columns were then recoded to: 1=have access, 0=don't have access. The previous coding was from 0 to 4, where: 0 = Don't Know ; 1 = Not Allowed / Possible ; 2 = I Can Do This, But Choose Not To; 3 = I Do This But Generally Need to Consult Others First ; 4 = I Do This Without Consulting Others. So, 0, 1, 2, and 3 were coded to 0 and 4 cells were coded to 1.
- Reported discomfort to management field was renamed to respondent's access on management for thermal control. NaN values were replaced with 0 and 2 values were replaced with 1 (for simplification purposes and since only 1 value of 2 existed)
- Net clothing change field was renamed to how often respondent adjusts clothing. It was also recoded as: 1=na, 2=never or minor change, 3=rarely or small change, 4=sometimes or moderate change, 5=often or large change, 6=always or largest change

❖ **Occupant Satisfaction**

- General satisfaction with temperature field was renamed to satisfaction with workspace temperature
- General satisfaction with the amount of space field was renamed as satisfaction with workspace

ASHRAE RP-884 dataset transformation

In order to comply with the final database template, units and coding, the ASHRAE RP-884 dataset was modified as follows:

First, all individual RP-884 datasets were merged together.

❖ **Basic Identifiers**

- 5 fields were added
    i. Researcher: the name of the researcher (relevant information was given in each individual set)
    ii. Location: the location of the study building (relevant information was given in each individual set)
    iii. Climatic zone: data taken from Koppen climate classification (relevant information was given in each individual set)
    iv. Building Type: (office commercial, academic, residential etc)
    v. Ventilation Type: HVAC, NV (naturally ventilated) or mixed

- Season field was recoded from summer-winter to cooling-heating
- Sex field was recoded as 1=female, 2=male

- Age field was recoded as: 1=0-19, 2=20-29, 3=30-39, 4=40-49, 5=50-59, 6=60-69, 7=70-79

❖ **Sensation**

- ASHRAE thermal sensation field (ASH) was renamed to thermal sensation

❖ **Occupant Satisfaction**

- How satisfied are you with perceived control over thermal environment field (PCS) was renamed to satisfaction with workspace temperature

❖ **Thermal Options**

- Local fan field was renamed to portable fan to reflect the cross-sectional dataset classification
- Similarly, all thermal adaptive actions columns were renamed to reflect the cross-sectional dataset's names

Appendix B : R routines

```
## author : Handi Chandra Putra
## version : 1.0

library("synthpop")

dataAll = read.csv("OriginalDataset.csv")

my.seed <- 17914709
#sds <- syn(dataAll, m = 1, drop.not.used = FALSE, visit.sequence =
c(27,30,36,13,14), seed = my.seed)
#write.syn(sdataAll, "sdataAll", filetype = c("csv"), convert.factors =
"numeric", data.labels = NULL, save.complete = TRUE, extended.info = TRUE)

############# FITTING MODELS ##############
modelFheater.sds <- glm.synds(Fheater ~ Age + Sex + dayav_ta + dayav_rh +
TA_M, family = "binomial", data = sds)
modelFheater.dataAll <- glm(Fheater ~ Age + Sex + dayav_ta + dayav_rh + TA_M,
family = "binomial", data = dataAll)
compare.fit.synds(modelFheater.sds, dataAll)
```

Appendix C: Cohort Analysis

Adaptive Action: Portable Heater

Gender	Age (years)	Vent Type	Indoor Air Temp (degC)	Outdoor Air Temp (degC)	Probability
Male	0-29	HVAC	<= 22	<= 23	0.161
				> 23	0.000

			> 22	<= 23	0.060
				> 23	0.045
		Non-Ventilated	<= 22	<= 23	0.675
				> 23	0.000
			> 22	<= 23	0.713
				> 23	0.000
		Mixed	<= 22	<= 23	0.000
				> 23	0.000
			> 22	<= 23	0.000
				> 23	0.000
	30-49	HVAC	<= 22	<= 23	0.292
				> 23	0.214
			> 22	<= 23	0.102
				> 23	0.090
		Non-Ventilated	<= 22	<= 23	0.414
				> 23	0.000
			> 22	<= 23	0.201
				> 23	0.000
		Mixed	<= 22	<= 23	0.000
				> 23	0.000
			> 22	<= 23	0.292
				> 23	0.000
	50-69	HVAC	<= 22	<= 23	0.278
				> 23	0.267
			> 22	<= 23	0.098
				> 23	0.043
		Non-Ventilated	<= 22	<= 23	0.000
				> 23	0.000
			> 22	<= 23	0.000
				> 23	0.000

		Mixed	<= 22	<= 23	0.000
				> 23	0.000
			> 22	<= 23	0.000
				> 23	0.000
Female	0-29	HVAC	<= 22	<= 23	0.275
				> 23	0.000
			> 22	<= 23	0.149
				> 23	0.063
		Non-Ventilated	<= 22	<= 23	0.926
				> 23	0.000
			> 22	<= 23	0.610
				> 23	0.000
		Mixed	<= 22	<= 23	0.000
				> 23	0.000
			> 22	<= 23	0.030
				> 23	0.000
	30-49	HVAC	<= 22	<= 23	0.375
				> 23	0.185
			> 22	<= 23	0.125
				> 23	0.064
		Non-Ventilated	<= 22	<= 23	0.650
				> 23	0.000
			> 22	<= 23	0.582
				> 23	0.000
		Mixed	<= 22	<= 23	0.353
				> 23	0.000
			> 22	<= 23	0.598
				> 23	0.587
		HVAC	<= 22	<= 23	0.316
				> 23	0.000
			> 22	<= 23	0.066
				> 23	0.041
	50-69	Non-Ventilated	<= 22	<= 23	0.991
				> 23	0.000

			> 22	<= 23	0.744
				> 23	0.000
		Mixed	<= 22	<= 23	0.268
				> 23	0.000
			> 22	<= 23	0.280
				> 23	0.289

Adaptive Action: Portable Fan

Gender	Age (years)	Vent Type	Indoor Air Temp (degC)	Outdoor Air Temp (degC)	Probability
Male	0-29	HVAC	<= 22	<= 23	0.151
				> 23	0.116
			> 22	<= 23	0.193
				> 23	0.227
		Non-Ventilated	<= 22	<= 23	0.099
				> 23	1.000
			> 22	<= 23	0.219
				> 23	0.974
		Mixed	<= 22	<= 23	0.000
				> 23	0.000
			> 22	<= 23	0.007
				> 23	0.000
	30-49	HVAC	<= 22	<= 23	0.207
				> 23	0.356
			> 22	<= 23	0.140
				> 23	0.216
		Non-Ventilated	<= 22	<= 23	0.165
				> 23	0.000
			> 22	<= 23	0.326
				> 23	0.930
		Mixed	<= 22	<= 23	0.438

				> 23	1.000
			> 22	<= 23	0.207
				> 23	0.500
	50-69	HVAC	<= 22	<= 23	0.250
				> 23	0.500
			> 22	<= 23	0.202
				> 23	0.070
		Non-Ventilated	<= 22	<= 23	0.000
				> 23	0.000
			> 22	<= 23	0.000
				> 23	0.667
		Mixed	<= 22	<= 23	0.000
				> 23	0.000
			> 22	<= 23	0.000
				> 23	0.000
Female	0-29	HVAC	<= 22	<= 23	0.141
				> 23	0.000
			> 22	<= 23	0.162
				> 23	0.158
		Non-Ventilated	<= 22	<= 23	0.070
				> 23	1.000
			> 22	<= 23	0.448
				> 23	0.982
		Mixed	<= 22	<= 23	0.000
				> 23	0.000
			> 22	<= 23	0.060
				> 23	0.000
	30-49	HVAC	<= 22	<= 23	0.155
				> 23	0.200
			> 22	<= 23	0.136
				> 23	0.151
		Non-Ventilated	<= 22	<= 23	0.085

				> 23	0.000
			> 22	<= 23	0.408
				> 23	0.946
		Mixed	<= 22	<= 23	0.000
				> 23	0.000
			> 22	<= 23	0.032
				> 23	0.000
	50-69	HVAC	<= 22	<= 23	0.227
				> 23	0.250
			> 22	<= 23	0.071
				> 23	0.236
		Non-Ventilated	<= 22	<= 23	0.017
				> 23	1.000
			> 22	<= 23	0.307
				> 23	0.961
		Mixed	<= 22	<= 23	0.257
				> 23	0.500
			> 22	<= 23	0.529
				> 23	0.466

Appendix D

ObCoSim.xml

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	</SpaceNameMapping>
	<SpaceNameMapping>
		<obXML_SpaceID>2ndFloor_NICONLab</obXML_SpaceID>
		<FMU_InstanceName>obm_2ndFloor_NICONLab</FMU_InstanceName>
	</SpaceNameMapping>
	<SpaceNameMapping>
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		<FMU_InstanceName>obm_2ndFloor_NMechRoom</FMU_InstanceName>
	</SpaceNameMapping>
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		<FMU_InstanceName>obm_2ndFloor_SEOffice205</FMU_InstanceName>
	</SpaceNameMapping>
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    <SimulationSettings>
		<IsLeapYear>No</IsLeapYear><!-- Yes or No. Default No.-->
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		<DoMovementCalculation>Yes</DoMovementCalculation>
		<IsDebugMode>No</IsDebugMode>

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esultFilename>
		<!-- Start at 00:00:00 -->
		<StartMonth>1</StartMonth>
		<StartDay>1</StartDay>
		<!-- End at 24:00:00 -->
		<EndMonth>1</EndMonth>
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    </SimulationSettings>
</CoSimulationParameters>
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ObXML.xml


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<Description>This code is authored by Handi Chandra Putra </Description>
<OccupantBehavior xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
ID="obXML" Version="1.1" xsi:noNamespaceSchemaLocation="obXML_v1.1.xsd">
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 <Building ID="Building_101">
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<Window><Type>Fixed</Type></Window>
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<Thermostat><Type>Adjustable</Type></Thermostat>
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<Description>Unplug Portable Heater when left</Description>
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<Description>Portable heater On when room it's cold </Description>
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```xml
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&lt;DayofWeek&gt;Weekday&lt;/DayofWeek&gt;
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<Description>Leave Window Close</Description>
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 <Holiday Name="Columbus Day"><Date>2015-10-02</Date></Holiday>
 <Holiday Name="Veterans Day"><Date>2015-11-11</Date></Holiday>
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EnergyPlus : ExternalInterface

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ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_NTeleConfRoom,  !- Output:Variable Index Key Name
    Zone Mean Air Temperature,  !- Output:Variable Name
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_NTeleConfRoom,  !- FMU Instance Name
    Zone_Temperature;        !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_NTeleConfRoom,  !- Output:Variable Index Key Name
    Zone Mean Air Temperature,  !- Output:Variable Name,
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_NTeleConfRoom,  !- FMU Instance Name
    Zone_illum;              !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_NTeleConfRoom,  !- Output:Variable Index Key Name
    Zone Air CO2 Concentration,  !- Output:Variable Name
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_NTeleConfRoom,  !- FMU Instance Name
    Zone_co2;                !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_NTeleConfRoom,       !- Output:Variable Index Key Name
    Zone Lights Electric Power,  !- Output:Variable Name
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_NTeleConfRoom,   !- FMU Instance Name
    Zone_Light_Power;        !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    Environment,  !- Output:Variable Index Key Name
    Site Outdoor Air Drybulb Temperature,  !- Output:Variable Name
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_NTeleConfRoom,  !- FMU Instance Name
    OutdoorAir_Drybulb_Temperature;  !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    Environment,             !- Output:Variable Index Key Name
    Site Rain Status,        !- Output:Variable Name
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_NTeleConfRoom,  !- FMU Instance Name
    Outdoor_Rain_Indicator;  !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_NICONLab,  !- Output:Variable Index Key Name
    Zone Mean Air Temperature,  !- Output:Variable Name
```

```
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NICONLab,  !- FMU Instance Name
    Zone_Temperature;         !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_NICONLab,  !- Output:Variable Index Key Name
    Zone Mean Air Temperature,  !- Output:Variable Name
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NICONLab,  !- FMU Instance Name
    Zone_illum;               !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_NICONLab,  !- Output:Variable Index Key Name
    Zone Air CO2 Concentration,  !- Output:Variable Name
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NICONLab,  !- FMU Instance Name
    Zone_co2;                 !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_NICONLab,        !- Output:Variable Index Key Name
    Zone Lights Electric Power,  !- Output:Variable Name
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NICONLab,    !- FMU Instance Name
    Zone_Light_Power;         !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    Environment,  !- Output:Variable Index Key Name
    Site Outdoor Air Drybulb Temperature,  !- Output:Variable Name
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NICONLab,  !- FMU Instance Name
    OutdoorAir_Drybulb_Temperature;  !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    Environment,              !- Output:Variable Index Key Name
    Site Rain Status,         !- Output:Variable Name
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NICONLab,  !- FMU Instance Name
    Outdoor_Rain_Indicator;  !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_NMechRoom,  !- Output:Variable Index Key Name
    Zone Mean Air Temperature,  !- Output:Variable Name
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NMechRoom,  !- FMU Instance Name
    Zone_Temperature;         !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_NMechRoom,  !- Output:Variable Index Key Name
    Zone Mean Air Temperature,  !- Output:Variable Name
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NMechRoom,  !- FMU Instance Name
    Zone_illum;               !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_NMechRoom,  !- Output:Variable Index Key Name
    Zone Air CO2 Concentration,  !- Output:Variable Name
    obFMU.fmu,                !- FMU File Name
```

```
    obm_2ndFloor_NMechRoom,  !- FMU Instance Name
    Zone_co2;                !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_NMechRoom,       !- Output:Variable Index Key Name
    Zone Lights Electric Power,  !- Output:Variable Name
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_NMechRoom,   !- FMU Instance Name
    Zone_Light_Power;        !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    Environment,  !- Output:Variable Index Key Name
    Site Outdoor Air Drybulb Temperature,  !- Output:Variable Name
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_NMechRoom,  !- FMU Instance Name
    OutdoorAir_Drybulb_Temperature;  !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    Environment,             !- Output:Variable Index Key Name
    Site Rain Status,        !- Output:Variable Name
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_NMechRoom,  !- FMU Instance Name
    Outdoor_Rain_Indicator;  !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_MPcCntrlOffc214,  !- Output:Variable Index Key Name
    Zone Mean Air Temperature,  !- Output:Variable Name
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_MPcCntrlOffc214,  !- FMU Instance Name
    Zone_Temperature;        !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_MPcCntrlOffc214,  !- Output:Variable Index Key Name
    Zone Mean Air Temperature,  !- Output:Variable Name
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_MPcCntrlOffc214,  !- FMU Instance Name
    Zone_illum;              !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_MPcCntrlOffc214,  !- Output:Variable Index Key Name
    Zone Air CO2 Concentration,  !- Output:Variable Name
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_MPcCntrlOffc214,  !- FMU Instance Name
    Zone_co2;                !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_MPcCntrlOffc214,       !- Output:Variable Index Key Name
    Zone Lights Electric Power,  !- Output:Variable Name
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_MPcCntrlOffc214,   !- FMU Instance Name
    Zone_Light_Power;        !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    Environment,  !- Output:Variable Index Key Name
    Site Outdoor Air Drybulb Temperature,  !- Output:Variable Name
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_MPcCntrlOffc214,  !- FMU Instance Name
```

```
    OutdoorAir_Drybulb_Temperature;  !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    Environment,               !- Output:Variable Index Key Name
    Site Rain Status,          !- Output:Variable Name
    obFMU.fmu,                 !- FMU File Name
    obm_2ndFloor_MPcCntrlOffc214,  !- FMU Instance Name
    Outdoor_Rain_Indicator;  !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_SEndOffice201,  !- Output:Variable Index Key Name
    Zone Mean Air Temperature,  !- Output:Variable Name
    obFMU.fmu,                 !- FMU File Name
    obm_2ndFloor_SEndOffice201,  !- FMU Instance Name
    Zone_Temperature;          !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_SEndOffice201,  !- Output:Variable Index Key Name
    Zone Mean Air Temperature,  !- Output:Variable Name
    obFMU.fmu,                 !- FMU File Name
    obm_2ndFloor_SEndOffice201,  !- FMU Instance Name
    Zone_illum;                !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_SEndOffice201,  !- Output:Variable Index Key Name
    Zone Air CO2 Concentration,  !- Output:Variable Name
    obFMU.fmu,                 !- FMU File Name
    obm_2ndFloor_SEndOffice201,  !- FMU Instance Name
    Zone_co2;                  !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_SEndOffice201,       !- Output:Variable Index Key Name
    Zone Lights Electric Power,  !- Output:Variable Name
    obFMU.fmu,                 !- FMU File Name
    obm_2ndFloor_SEndOffice201,   !- FMU Instance Name
    Zone_Light_Power;          !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    Environment,  !- Output:Variable Index Key Name
    Site Outdoor Air Drybulb Temperature,  !- Output:Variable Name
    obFMU.fmu,                 !- FMU File Name
    obm_2ndFloor_SEndOffice201,  !- FMU Instance Name
    OutdoorAir_Drybulb_Temperature;  !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    Environment,               !- Output:Variable Index Key Name
    Site Rain Status,          !- Output:Variable Name
    obFMU.fmu,                 !- FMU File Name
    obm_2ndFloor_SEndOffice201,  !- FMU Instance Name
    Outdoor_Rain_Indicator;  !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_SWOffice206,    !- Output:Variable Index Key Name
    Zone Mean Air Temperature,  !- Output:Variable Name
    obFMU.fmu,                 !- FMU File Name
    obm_2ndFloor_SWOffice206,!- FMU Instance Name
    Zone_Temperature;          !- FMU Variable Name
```

```
ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_SWOffice206,    !- Output:Variable Index Key Name
    Zone Mean Air Temperature,  !- Output:Variable Name
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SWOffice206,!- FMU Instance Name
    Zone_illum;              !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_SWOffice206,    !- Output:Variable Index Key Name
    Zone Air CO2 Concentration,  !- Output:Variable Name
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SWOffice206,!- FMU Instance Name
    Zone_co2;                !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_SWOffice206,    !- Output:Variable Index Key Name
    Zone Lights Electric Power,  !- Output:Variable Name
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SWOffice206,!- FMU Instance Name
    Zone_Light_Power;        !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    Environment,    !- Output:Variable Index Key Name
    Site Outdoor Air Drybulb Temperature,  !- Output:Variable Name
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SWOffice206,!- FMU Instance Name
    OutdoorAir_Drybulb_Temperature;  !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    Environment,             !- Output:Variable Index Key Name
    Site Rain Status,        !- Output:Variable Name
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SWOffice206,!- FMU Instance Name
    Outdoor_Rain_Indicator;  !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_NWOffice222,    !- Output:Variable Index Key Name
    Zone Mean Air Temperature,  !- Output:Variable Name
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_NWOffice222,!- FMU Instance Name
    Zone_Temperature;        !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_NWOffice222,    !- Output:Variable Index Key Name
    Zone Mean Air Temperature,  !- Output:Variable Name
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_NWOffice222,!- FMU Instance Name
    Zone_illum;              !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_NWOffice222,    !- Output:Variable Index Key Name
    Zone Air CO2 Concentration,  !- Output:Variable Name
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_NWOffice222,!- FMU Instance Name
    Zone_co2;                !- FMU Variable Name
```

```
ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_NWOffice222,    !- Output:Variable Index Key Name
    Zone Lights Electric Power,  !- Output:Variable Name
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_NWOffice222,!- FMU Instance Name
    Zone_Light_Power;        !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    Environment,    !- Output:Variable Index Key Name
    Site Outdoor Air Drybulb Temperature,  !- Output:Variable Name
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_NWOffice222,!- FMU Instance Name
    OutdoorAir_Drybulb_Temperature;  !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    Environment,             !- Output:Variable Index Key Name
    Site Rain Status,        !- Output:Variable Name
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_NWOffice222,!- FMU Instance Name
    Outdoor_Rain_Indicator;  !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_SStairwellsShallway,  !- Output:Variable Index Key Name
    Zone Mean Air Temperature,  !- Output:Variable Name
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SStairwellsShallway,  !- FMU Instance Name
    Zone_Temperature;        !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_SStairwellsShallway,  !- Output:Variable Index Key Name
    Zone Mean Air Temperature,  !- Output:Variable Name
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SStairwellsShallway,  !- FMU Instance Name
    Zone_illum;              !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_SStairwellsShallway,  !- Output:Variable Index Key Name
    Zone Air CO2 Concentration,  !- Output:Variable Name
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SStairwellsShallway,  !- FMU Instance Name
    Zone_co2;                !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_SStairwellsShallway,       !- Output:Variable Index Key Name
    Zone Lights Electric Power,  !- Output:Variable Name
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SStairwellsShallway,   !- FMU Instance Name
    Zone_Light_Power;        !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    Environment,  !- Output:Variable Index Key Name
    Site Outdoor Air Drybulb Temperature,  !- Output:Variable Name
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SStairwellsShallway,  !- FMU Instance Name
    OutdoorAir_Drybulb_Temperature;  !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
```

```
    Environment,              !- Output:Variable Index Key Name
    Site Rain Status,         !- Output:Variable Name
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_SStairwellsShallway,  !- FMU Instance Name
    Outdoor_Rain_Indicator;  !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_SEOffice205,  !- Output:Variable Index Key Name
    Zone Mean Air Temperature,  !- Output:Variable Name
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_SEOffice205,  !- FMU Instance Name
    Zone_Temperature;         !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_SEOffice205,  !- Output:Variable Index Key Name
    Zone Mean Air Temperature,  !- Output:Variable Name
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_SEOffice205,  !- FMU Instance Name
    Zone_illum;               !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_SEOffice205,  !- Output:Variable Index Key Name
    Zone Air CO2 Concentration,  !- Output:Variable Name
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_SEOffice205,  !- FMU Instance Name
    Zone_co2;                 !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_SEOffice205,       !- Output:Variable Index Key Name
    Zone Lights Electric Power,  !- Output:Variable Name
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_SEOffice205,   !- FMU Instance Name
    Zone_Light_Power;         !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    Environment,  !- Output:Variable Index Key Name
    Site Outdoor Air Drybulb Temperature,  !- Output:Variable Name
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_SEOffice205,  !- FMU Instance Name
    OutdoorAir_Drybulb_Temperature;  !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    Environment,              !- Output:Variable Index Key Name
    Site Rain Status,         !- Output:Variable Name
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_SEOffice205,  !- FMU Instance Name
    Outdoor_Rain_Indicator;  !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_NEOffice223,  !- Output:Variable Index Key Name
    Zone Mean Air Temperature,  !- Output:Variable Name
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NEOffice223,  !- FMU Instance Name
    Zone_Temperature;         !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_NEOffice223,  !- Output:Variable Index Key Name
```

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    Zone Mean Air Temperature,  !- Output:Variable Name
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NEOffice223,  !- FMU Instance Name
    Zone_illum;               !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_NEOffice223,  !- Output:Variable Index Key Name
    Zone Air CO2 Concentration,  !- Output:Variable Name
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NEOffice223,  !- FMU Instance Name
    Zone_co2;                 !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    2ndFloor_NEOffice223,       !- Output:Variable Index Key Name
    Zone Lights Electric Power,  !- Output:Variable Name
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NEOffice223,   !- FMU Instance Name
    Zone_Light_Power;         !- FMU Variable Name

ExternalInterface:FunctionalMockupUnitImport:From:Variable,
    Environment,  !- Output:Variable Index Key Name
    Site Outdoor Air Drybulb Temperature,  !- Output:Variable Name
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NEOffice223,  !- FMU Instance Name
    OutdoorAir_Drybulb_Temperature;  !- FMU Variable Name

!-   ===========  ALL OBJECTS IN CLASS:
EXTERNALINTERFACE:FUNCTIONALMOCKUPUNITIMPORT:TO:SCHEDULE ===========
ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_HVAC_SCH_2ndFloor_NTeleConfRoom,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NTeleConfRoom,  !- FMU Instance Name
    Zone_HVAC_SCH,            !- FMU Variable Name
    0;                        !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_light_SCH_2ndFloor_NTeleConfRoom,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NTeleConfRoom,  !- FMU Instance Name
    Zone_light_SCH,           !- FMU Variable Name
    0;                        !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_infil_SCH_2ndFloor_NTeleConfRoom,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NTeleConfRoom,  !- FMU Instance Name
    Zone_infil_SCH,           !- FMU Variable Name
    0;                        !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_PlugLoad_SCH_2ndFloor_NTeleConfRoom,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NTeleConfRoom,  !- FMU Instance Name
```

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    Zone_PlugLoad_SCH,        !- FMU Variable Name
    0.3;                      !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_Thermostat_SCH_2ndFloor_NTeleConfRoom,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NTeleConfRoom,  !- FMU Instance Name
    Zone_Thermostat_SCH,      !- FMU Variable Name
    21.11;                    !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_ShadeAndBlind_SCH_2ndFloor_NTeleConfRoom,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NTeleConfRoom,  !- FMU Instance Name
    Zone_ShadeAndBlind_SCH,   !- FMU Variable Name
    0.0;                      !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_occ_SCH_2ndFloor_NTeleConfRoom,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NTeleConfRoom,  !- FMU Instance Name
    Zone_occ_SCH,             !- FMU Variable Name
    0;                        !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_HVAC_SCH_2ndFloor_NMechRoom,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NMechRoom,   !- FMU Instance Name
    Zone_HVAC_SCH,            !- FMU Variable Name
    0;                        !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_HVAC_SCH_2ndFloor_NICONLab,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NICONLab,  !- FMU Instance Name
    Zone_HVAC_SCH,            !- FMU Variable Name
    0;                        !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_light_SCH_2ndFloor_NICONLab,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NICONLab,  !- FMU Instance Name
    Zone_light_SCH,           !- FMU Variable Name
    0;                        !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_infil_SCH_2ndFloor_NICONLab,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NICONLab,  !- FMU Instance Name
    Zone_infil_SCH,           !- FMU Variable Name
```

```
    0;                        !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_PlugLoad_SCH_2ndFloor_NICONLab,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NICONLab,  !- FMU Instance Name
    Zone_PlugLoad_SCH,        !- FMU Variable Name
    0.3;                      !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_Thermostat_SCH_2ndFloor_NICONLab,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NICONLab,  !- FMU Instance Name
    Zone_Thermostat_SCH,      !- FMU Variable Name
    21.11;                    !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_ShadeAndBlind_SCH_2ndFloor_NICONLab,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NICONLab,  !- FMU Instance Name
    Zone_ShadeAndBlind_SCH,  !- FMU Variable Name
    0.0;                      !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_occ_SCH_2ndFloor_NICONLab,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NICONLab,  !- FMU Instance Name
    Zone_occ_SCH,             !- FMU Variable Name
    0;                        !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_light_SCH_2ndFloor_NMechRoom,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NMechRoom,  !- FMU Instance Name
    Zone_light_SCH,           !- FMU Variable Name
    0;                        !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_infil_SCH_2ndFloor_NMechRoom,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NMechRoom,  !- FMU Instance Name
    Zone_infil_SCH,           !- FMU Variable Name
    0;                        !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_PlugLoad_SCH_2ndFloor_NMechRoom,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NMechRoom,  !- FMU Instance Name
    Zone_PlugLoad_SCH,        !- FMU Variable Name
    0.3;                      !- Initial Value
```

```
ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_Thermostat_SCH_2ndFloor_NMechRoom,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NMechRoom,   !- FMU Instance Name
    Zone_Thermostat_SCH,      !- FMU Variable Name
    21.11;                    !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_ShadeAndBlind_SCH_2ndFloor_NMechRoom,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NMechRoom,   !- FMU Instance Name
    Zone_ShadeAndBlind_SCH,   !- FMU Variable Name
    0.0;                      !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_occ_SCH_2ndFloor_NMechRoom,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NMechRoom,   !- FMU Instance Name
    Zone_occ_SCH,             !- FMU Variable Name
    0;                        !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_HVAC_SCH_2ndFloor_MPcCntrlOffc214,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_MPcCntrlOffc214,  !- FMU Instance Name
    Zone_HVAC_SCH,            !- FMU Variable Name
    0;                        !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_light_SCH_2ndFloor_MPcCntrlOffc214,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_MPcCntrlOffc214,  !- FMU Instance Name
    Zone_light_SCH,           !- FMU Variable Name
    0;                        !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_infil_SCH_2ndFloor_MPcCntrlOffc214,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_MPcCntrlOffc214,  !- FMU Instance Name
    Zone_infil_SCH,           !- FMU Variable Name
    0;                        !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_PlugLoad_SCH_2ndFloor_MPcCntrlOffc214,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_MPcCntrlOffc214,  !- FMU Instance Name
    Zone_PlugLoad_SCH,        !- FMU Variable Name
    0.3;                      !- Initial Value
```

```
ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_Thermostat_SCH_2ndFloor_MPcCntrlOffc214,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_MPcCntrlOffc214,  !- FMU Instance Name
    Zone_Thermostat_SCH,     !- FMU Variable Name
    21.11;                   !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_ShadeAndBlind_SCH_2ndFloor_MPcCntrlOffc214,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_MPcCntrlOffc214,  !- FMU Instance Name
    Zone_ShadeAndBlind_SCH,  !- FMU Variable Name
    0.0;                     !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_occ_SCH_2ndFloor_MPcCntrlOffc214,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_MPcCntrlOffc214,  !- FMU Instance Name
    Zone_occ_SCH,            !- FMU Variable Name
    0;                       !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_HVAC_SCH_2ndFloor_SEndOffice201,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SEndOffice201,  !- FMU Instance Name
    Zone_HVAC_SCH,           !- FMU Variable Name
    0;                       !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_light_SCH_2ndFloor_SEndOffice201,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SEndOffice201,  !- FMU Instance Name
    Zone_light_SCH,          !- FMU Variable Name
    0;                       !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_infil_SCH_2ndFloor_SEndOffice201,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SEndOffice201,  !- FMU Instance Name
    Zone_infil_SCH,          !- FMU Variable Name
    0;                       !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_PlugLoad_SCH_2ndFloor_SEndOffice201,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SEndOffice201,  !- FMU Instance Name
    Zone_PlugLoad_SCH,       !- FMU Variable Name
    0.3;                     !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
```

```
    Zone_Thermostat_SCH_2ndFloor_SEndOffice201,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SEndOffice201,  !- FMU Instance Name
    Zone_Thermostat_SCH,     !- FMU Variable Name
    21.11;                   !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_ShadeAndBlind_SCH_2ndFloor_SEndOffice201,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SEndOffice201,  !- FMU Instance Name
    Zone_ShadeAndBlind_SCH,  !- FMU Variable Name
    0.0;                     !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_occ_SCH_2ndFloor_SEndOffice201,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SEndOffice201,  !- FMU Instance Name
    Zone_occ_SCH,            !- FMU Variable Name
    0;                       !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_HVAC_SCH_2ndFloor_SWOffice206,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SWOffice206,!- FMU Instance Name
    Zone_HVAC_SCH,           !- FMU Variable Name
    0;                       !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_light_SCH_2ndFloor_SWOffice206,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SWOffice206,!- FMU Instance Name
    Zone_light_SCH,          !- FMU Variable Name
    0;                       !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_infil_SCH_2ndFloor_SWOffice206,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SWOffice206,!- FMU Instance Name
    Zone_infil_SCH,          !- FMU Variable Name
    0;                       !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_PlugLoad_SCH_2ndFloor_SWOffice206,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SWOffice206,!- FMU Instance Name
    Zone_PlugLoad_SCH,       !- FMU Variable Name
    0.3;                     !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_Thermostat_SCH_2ndFloor_SWOffice206,  !- Name
```

```
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SWOffice206,!- FMU Instance Name
    Zone_Thermostat_SCH,     !- FMU Variable Name
    21.11;                   !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_ShadeAndBlind_SCH_2ndFloor_SWOffice206,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SWOffice206,!- FMU Instance Name
    Zone_ShadeAndBlind_SCH,  !- FMU Variable Name
    0.0;                     !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_occ_SCH_2ndFloor_SWOffice206,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SWOffice206,!- FMU Instance Name
    Zone_occ_SCH,            !- FMU Variable Name
    0;                       !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_HVAC_SCH_2ndFloor_NWOffice222,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_NWOffice222,!- FMU Instance Name
    Zone_HVAC_SCH,           !- FMU Variable Name
    0;                       !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_light_SCH_2ndFloor_NWOffice222,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_NWOffice222,!- FMU Instance Name
    Zone_light_SCH,          !- FMU Variable Name
    0;                       !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_infil_SCH_2ndFloor_NWOffice222,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_NWOffice222,!- FMU Instance Name
    Zone_infil_SCH,          !- FMU Variable Name
    0;                       !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_PlugLoad_SCH_2ndFloor_NWOffice222,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_NWOffice222,!- FMU Instance Name
    Zone_PlugLoad_SCH,       !- FMU Variable Name
    0;                       !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_Thermostat_SCH_2ndFloor_NWOffice222,  !- Name
    Any Number,              !- Schedule Type Limits Names
```

```
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NWOffice222,!- FMU Instance Name
    Zone_Thermostat_SCH,      !- FMU Variable Name
    21.11;                    !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_ShadeAndBlind_SCH_2ndFloor_NWOffice222,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NWOffice222,!- FMU Instance Name
    Zone_ShadeAndBlind_SCH,   !- FMU Variable Name
    0.0;                      !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_occ_SCH_2ndFloor_NWOffice222,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_NWOffice222,!- FMU Instance Name
    Zone_occ_SCH,             !- FMU Variable Name
    0;                        !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_HVAC_SCH_2ndFloor_SStairwellsShallway,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_SStairwellsShallway,  !- FMU Instance Name
    Zone_HVAC_SCH,            !- FMU Variable Name
    0;                        !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_light_SCH_2ndFloor_SStairwellsShallway,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_SStairwellsShallway,  !- FMU Instance Name
    Zone_light_SCH,           !- FMU Variable Name
    0;                        !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_infil_SCH_2ndFloor_SStairwellsShallway,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_SStairwellsShallway,  !- FMU Instance Name
    Zone_infil_SCH,           !- FMU Variable Name
    0;                        !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_PlugLoad_SCH_2ndFloor_SStairwellsShallway,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
    obm_2ndFloor_SStairwellsShallway,  !- FMU Instance Name
    Zone_PlugLoad_SCH,        !- FMU Variable Name
    0.3;                      !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_Thermostat_SCH_2ndFloor_SStairwellsShallway,  !- Name
    Any Number,               !- Schedule Type Limits Names
    obFMU.fmu,                !- FMU File Name
```

```
    obm_2ndFloor_SStairwellsShallway,  !- FMU Instance Name
    Zone_Thermostat_SCH,     !- FMU Variable Name
    21.11;                   !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_ShadeAndBlind_SCH_2ndFloor_SStairwellsShallway,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SStairwellsShallway,  !- FMU Instance Name
    Zone_ShadeAndBlind_SCH,  !- FMU Variable Name
    0.0;                     !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_occ_SCH_2ndFloor_SStairwellsShallway,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SStairwellsShallway,  !- FMU Instance Name
    Zone_occ_SCH,            !- FMU Variable Name
    0;                       !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_HVAC_SCH_2ndFloor_SEOffice205,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SEOffice205,  !- FMU Instance Name
    Zone_HVAC_SCH,           !- FMU Variable Name
    0;                       !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_light_SCH_2ndFloor_SEOffice205,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SEOffice205,  !- FMU Instance Name
    Zone_light_SCH,          !- FMU Variable Name
    0;                       !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_infil_SCH_2ndFloor_SEOffice205,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SEOffice205,  !- FMU Instance Name
    Zone_infil_SCH,          !- FMU Variable Name
    0;                       !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_PlugLoad_SCH_2ndFloor_SEOffice205,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SEOffice205,  !- FMU Instance Name
    Zone_PlugLoad_SCH,       !- FMU Variable Name
    0.3;                     !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_Thermostat_SCH_2ndFloor_SEOffice205,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SEOffice205,  !- FMU Instance Name
```

```
    Zone_Thermostat_SCH,     !- FMU Variable Name
    21.11;                   !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_ShadeAndBlind_SCH_2ndFloor_SEOffice205,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SEOffice205,  !- FMU Instance Name
    Zone_ShadeAndBlind_SCH,  !- FMU Variable Name
    0.0;                     !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_occ_SCH_2ndFloor_SEOffice205,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_SEOffice205,  !- FMU Instance Name
    Zone_occ_SCH,            !- FMU Variable Name
    0;                       !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_HVAC_SCH_2ndFloor_NEOffice223,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_NEOffice223,  !- FMU Instance Name
    Zone_HVAC_SCH,           !- FMU Variable Name
    0;                       !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_light_SCH_2ndFloor_NEOffice223,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_NEOffice223,  !- FMU Instance Name
    Zone_light_SCH,          !- FMU Variable Name
    0;                       !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_infil_SCH_2ndFloor_NEOffice223,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_NEOffice223,  !- FMU Instance Name
    Zone_infil_SCH,          !- FMU Variable Name
    0;                       !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_PlugLoad_SCH_2ndFloor_NEOffice223,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_NEOffice223,  !- FMU Instance Name
    Zone_PlugLoad_SCH,       !- FMU Variable Name
    0.3;                     !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_Thermostat_SCH_2ndFloor_NEOffice223,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_NEOffice223,  !- FMU Instance Name
    Zone_Thermostat_SCH,     !- FMU Variable Name
```

```
    21.11;                   !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_ShadeAndBlind_SCH_2ndFloor_NEOffice223,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_NEOffice223,  !- FMU Instance Name
    Zone_ShadeAndBlind_SCH,  !- FMU Variable Name
    0.0;                     !- Initial Value

ExternalInterface:FunctionalMockupUnitImport:To:Schedule,
    Zone_occ_SCH_2ndFloor_NEOffice223,  !- Name
    Any Number,              !- Schedule Type Limits Names
    obFMU.fmu,               !- FMU File Name
    obm_2ndFloor_NEOffice223,  !- FMU Instance Name
    Zone_occ_SCH,            !- FMU Variable Name
    0;                       !- Initial Value
```

Agent Based Modeling : NetLogo Code

```
extensions [
  profiler ;; to make the model faster
  array
  table
]
;;__includes [ "_building.nls" "_occupants.nls" "_lighting.nls"
"_organization.nls"]

breed [ managers manager ]
breed [ tenantreps tenantrep ]
breed [ occupants occupant ]
breed [ zones zone ]
breed [ equipments equipment ]

to getBuildingInfo
  file-open "bldg101_ke.idf"
  file-close
  file-open "bldg101_ke.idf"
  let $idf []
  while [ not file-at-end? ] [

  ]
  show $idf
end


globals [
  outContent

  syndataset
  cohort0 cohort1 cohort2 cohort3 cohort4 cohort5 cohort6 cohort7 cohort8
cohort9 cohort10
  cohort11 cohort12 cohort13 cohort14 cohort15 cohort16 cohort17 cohort18
cohort19 cohort20
```

```
  cohort21 cohort22 cohort23 cohort24 cohort25 cohort26 cohort27 cohort28
cohort29 cohort30
  cohort31 cohort32 cohort33 cohort34 cohort35

  sunrisesetList skycoverList daylightList

  skyCondition

  returnvalue headerListTmp contentListTmp

  bldgElectricity
  bldgEquipmentElectricity
  bldgInteriorLightsElectricity
  bldgHVACElectricity
  bldgGas

  totalFloors

  ;;; TIME ;;;
  totalHours
  daycount startDay startMonth startYear
  currentDay currentMonth currentYear
  currentWeekday weekdaystr endingHour
  listWeekday daysNumInMonth datetime


  ;;; BDI LOOKUP TABLE ;;;
  ;bdiPerception
  bdiActionValsTbl
  bdiPerceptionActionTbl
  clothingTbl

  comfortPMV
  comfortTemperature
  comfortLux

  luxFraction
]

zones-own [
  zoneID
  zoneFloorID
  zoneName
  zoneFacade
  zoneEquipmentList
  zoneOccupantList
  zoneTenantRep

  zoneLightElectricity
  zoneEquipmentElectricity
  zoneUpdateKWH

  meanAirT
  meanRadiantT
  airRelativeHumidity
  zoneDaylightLux
  zoneKWH
```

```
  zoneLightDim
  zoneTaskLightNum
  zonePortableHeaterNum

  zoneLightingDiscomfort          ;; number of lightingdiscomfort
  zoneThermalDiscomfort
  zoneEffort              ;; number of efforts

  zoneControl?

  zoneConsensusValuesTbl
]

equipments-own [
  equipmentID
  equipmentZoneIDList
  equipmentOccupantIDList
  equipmentKWH
]

managers-own [
  mnDoNothingCt
  mnThermostatCt
  mnReportReceivedCt
  mnDoNothingCurrHour
  mnThermostatCurrHour
  mnReportReceivedCurrHour
]

tenantreps-own [
  trZoneID
  trOccupantList

  trDoNothingCt
  trThermostatCt
  trOverheadLightCt
  trReportSentCt
  trReportReceivedCt

  trDoNothingCurrHour
  trThermostatCurrHour
  trOverheadLightCurrHour
  trReportSentCurrHour
  trReportReceivedCurrHour

  trConsensusValuesTbl
]

occupants-own [
  inZone?
  occZoneID
  occTenantRep

  isTenantRep?
```

```
hasEnergyMon?
portableHeaterON?
taskLightON?
windowsBlindOpen?
portableFanON?
windowsOPEN?

age
sex
occControl
occVentType
cohort_dataset

workStartHour
workEndHour
workDays

valOfEI
valOfEffort
valOfComfort
valOfCost

clothing
pmvValue
ppdValue
temperatureDiff
luxDiff


currentPerception
actionPlan
currentAction

occLightingDiscomfort
occThermalDiscomfort

occDoNothingCt
occTaskLightCt
occWindowsBlindCt
occClothesCt
occPortHeaterCt
occPortFanCt
occWindowsCt
occReportSentCt


Pthermal_Donothing
Pthermal_WindowsBlind
Pthermal_Clothes
Pthermal_PortHeater
Pthermal_ReportSent
Pthermal_Thermostat
Pthermal_PortFan
Pthermal_Windows

occThermalDiscomfortCurrHour
occLightingDiscomfortCurrHour
```

```
  occDoNothingCurrHour
  occTaskLightCurrHour
  occWindowsBlindCurrHour
  occClothesCurrHour
  occPortHeaterCurrHour
  occPortFanCurrHour
  occWindowsCurrHour
  occReportSentCurrHour

]



to GetDateTime
  ;; GET DATE TIME
  let $datetime (GetItemListStr "Date/Time" contentListTmp)
  tokenize $datetime "  "

  let $datestr (item 0 returnvalue)
  let $timestr (item 1 returnvalue)
  tokenize $datestr "/"
  set currentYear 2015
  set currentMonth read-from-string(item 0 returnvalue)
  set currentDay read-from-string(item 1 returnvalue)
  tokenize $timestr ":"
  set endingHour read-from-string(item 0 returnvalue)

  SetWeekDay currentDay currentMonth currentYear
;print (word weekdayStr " " currentDay "/" currentMonth "/" currentYear " "
endingHour ":00:00")
end

to GetBuildingData
  set totalFloors 0
  let $zoneid 0

  let $ptr 0
  while [ $ptr < length headerListTmp ] [
    let $fieldhdr (item $ptr headerListTmp)

    if (member? ":Zone Mean Air Temperature [C](Hourly)" $fieldhdr) [
      tokenize $fieldhdr ":"
      let $floorname (item 0 returnvalue)


      create-zones 1 [
        set zoneName (word $floorname ":" (item 1 returnvalue))
        if member? "0FLOORBASEMENT" $floorname [ set zoneFloorID 0 ]
        if member? "1STFLOOR" $floorname [ set zoneFloorID 1 ]
        if member? "2NDFLOOR" $floorname [ set zoneFloorID 2 ]
        if member? "3RDFLOOR" $floorname [ set zoneFloorID 3 ]
        if member? "ATTIC" $floorname [ set zoneFloorID 4 ]

        set zoneID $zoneid
        set zoneOccupantList []
        set zoneTenantRep nobody
```

```
        set zoneControl? false
        if (BldgControlLevel >= 50 and (member? "EOFFICE" zoneName) or
(member? "WOFFICE" zoneName)) [ set zoneControl? true ]
        if (BldgControlLevel >= 75 and member? "OFFICE" zoneName) [ set
zoneControl? true ]
        if (BldgControlLevel = 100) [ set zoneControl? true ]

      ]
      set $zoneid ($zoneid + 1)
    ]
    set $ptr ($ptr + 1)
  ]
end

to ResetZoneParams
  set zoneLightingDiscomfort 0
  set zoneThermalDiscomfort 0
  set zoneEffort 0

  set meanAirT (GetItemList (
      word zoneName ":Zone Mean Air Temperature [C](Hourly)") contentListTmp)
  set meanRadiantT (GetItemList (
      word zoneName ":Zone Mean Radiant Temperature [C](Hourly)")
contentListTmp)
  set airRelativeHumidity (GetItemList (
      word zoneName ":Zone Air Relative Humidity [%](Hourly)")
contentListTmp)
  set zoneLightElectricity (GetItemList (
      word zoneName ":Zone Lights Electric Energy [J](Hourly)")
contentListTmp)
  set zoneEquipmentElectricity (GetItemList (
      word zoneName ":Zone Electric Equipment Electric Energy [J](Hourly)")
contentListTmp)

  set zoneConsensusValuesTbl table:make
end

  ;;; BUILDING WIDE ;;;
to-report bldgNumOccupants
  report count occupants with [ inZone? = true ]
end
to-report bldgKWH
  report 0
end
to-report TotalBldgCost
  report ((bldgElectricity / 360000) * CentsKWH)
end
to-report TotalBldgThermalDiscomfort
  report sum [occThermalDiscomfortCurrHour] of occupants
end
to-report TotalBldgLightingDiscomfort
  report sum [occLightingDiscomfortCurrHour] of occupants
end

to-report TotalBldgEffort
  report TotalOccupantEffort + TotalTenantRepEffort
end
```

```
to-report TotalOccupantEffort
  report (sum [occTaskLightCurrHour] of occupants +
   sum [occWindowsBlindCurrHour] of occupants +
  sum [occClothesCurrHour] of occupants +
  sum [occPortHeaterCurrHour] of occupants +
  sum [occReportSentCurrHour] of occupants)
end

to-report CountOccupantsWithPMV [#scale]
  let numOccupants 0
  if #scale = 0 [ set numOccupants (count occupants with [pmvValue < 1]) +
(count occupants with [pmvValue > -1]) ]
  if #scale >= 1 [ set numOccupants (count occupants with [pmvValue >=
#scale]) - (count occupants with [pmvValue >= (#scale + 1)]) ]
  if #scale <= -1 [ set numOccupants (count occupants with [pmvValue <=
#scale]) - (count occupants with [pmvValue <= (#scale - 1)]) ]
  report numOccupants
end

to-report TotalTenantRepEffort
  report (sum [trThermostatCt] of tenantreps +
  sum [trOverheadLightCt] of tenantreps +
  sum [trReportSentCt] of tenantreps)
end

to-report TenantRepReportReceived
  report (sum [trReportReceivedCt] of tenantreps)
end

to-report TotalTenantRepReportSent
  report (sum [trReportSentCt] of tenantreps)
end

to-report TenantRepDoNothing
  report (sum [trDoNothingCt] of tenantreps)
end

to-report TotalManagerDoNothing
  report (sum [mnDoNothingCt] of managers)
end


;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;

to SetupLighting

  if (SimLighting) [
    LightingArrays
    SetupSkyCondition
    set luxFraction 0.18
  ]
end
```

```
to-report ConvertJToKWH [#joule]
  report precision (#joule / 3600000) 3
end

to-report ZoneTotalLux
  let $tasklightlux (zoneTaskLightNum * 228)
  report luxFraction * (zoneDaylightLux + ZoneLightLux + $tasklightlux)
end

to UpdateElectricity
  let $lightKWH ((zoneLightDim * zoneLightElectricity) + (zoneTaskLightNum *
100))
  let $equipmentKWH (zoneEquipmentElectricity + (zonePortableHeaterNum *
500))
end

to LightingArrays
  set daylightList (populateCSV "in_daylightlux.csv")
  set skycoverList (populateCSV "in_skycover.csv")
  set sunrisesetList (populateCSV "in_sunriseset.csv")
end

to-report Sunrise
  ;; get sunrise time
  let $dayid ((currentDay * 2) - 2)
  let currentSunrise ((read-from-string (getRowColCSV sunrisesetList
(currentMonth - 2) $dayid)) / 100)
  ifelse ((currentSunrise - floor currentSunrise) >= .3)
  [set currentSunrise (floor (currentSunrise + 1))]
  [set currentSunrise (floor currentSunrise)]

  report currentSunrise
end

to-report Sunset
  ;; get sunset time
  let $dayid ((currentDay * 2) - 1)
  let currentSunset ((read-from-string (getRowColCSV sunrisesetList
(currentMonth - 2) $dayid)) / 100)
  ifelse ((currentSunset - floor currentSunset) >= .3)
  [set currentSunset (floor (currentSunset + 1))]
  [set currentSunset (floor currentSunset)]

  report currentSunset
end

to-report percentCloudy
  report (round (read-from-string (
        getRowColCSV skycoverList 0 currentMonth )) + random 11 + random -11)
end

to SetupSkyCondition
  let tempvalue (random (93 + 112 + 160))
  if (tempvalue >= 0 AND tempvalue < 93) [set skyCondition ("Clear")]
  if (tempvalue >= 93 AND tempvalue < 205) [set skyCondition
("Partly_Cloudy")]
  if (tempvalue >= 205) [set skyCondition ("Overcast")]
```

```
end

to Daylighting
  ZoneFacadeTmpReference
  ifelse zoneFacade = "CENTER" [ set zoneDaylightLux 0 ]
  [
    let $shading "none"
    let $colstr ""
    if (skyCondition = "Clear" OR (skyCondition = "Partly_Cloudy" AND 100 >=
percentCloudy))
    [ if ($shading = "none") [ (set $colstr "CLEARSKY_NOSHADING")]
      ; if ($shading = "overhang") [ (set $colstr "CLEARSKY_OVERHANG")]
      ; if ($shading = "overhang&fins") [ (set $colstr
"CLEARSKY_OVERHANGFINS")]
      set $colstr (word $colstr "_" zoneFacade)
    ]
    if (skyCondition = "Overcast" OR (skyCondition = "Partly Cloudy" AND 100
< percentCloudy))
    [ if ($shading = "none") [ (set $colstr "OVERCAST_NOSHADING")]
      ; if ($shading = "overhang") [ (set $colstr "OVERCAST_OVERHANG")]
      ; if ($shading = "overhang&fins") [ (set $colstr
"OVERCAST_OVERHANGFINS")]
    ]

    let $hridx ((endingHour - 1) mod 24)
    ifelse (Sunrise = 4)
    [ set $colstr (word $colstr "_" Sunrise) ]
    [ set $colstr (word $colstr "_" Sunrise "-" Sunset) ]
;    let $colidx (position $colstr (item 0 daylightList))
;   type who type " | " type zoneName type " | " type zoneFloorID type " | "
type zoneFacade type " | " type $colstr type " | " print $colidx
    set zoneDaylightLux (read-from-string(getRowColCSV daylightList $hridx
$colstr))

  ]
end

to ZoneFacadeTmpReference
  if zoneName = "0FLOORBASEMENT:ELEVATORPUMPROOM" [ set zoneFacade "CENTER" ]
  if zoneName = "0FLOORBASEMENT:VITETTAOPENOFFICE" [ set zoneFacade "CENTER"
]
  if zoneName = "0FLOORBASEMENT:JANITORROOM" [ set zoneFacade "CENTER" ]
  if zoneName = "0FLOORBASEMENT:FRMRKTCHNLNCHAR" [ set zoneFacade "CENTER" ]
  if zoneName = "0FLOORBASEMENT:NHALLWAY" [ set zoneFacade "CENTER" ]
  if zoneName = "1STFLOOR:OPENOFFICEN119" [ set zoneFacade "NORTH" ]
  if zoneName = "1STFLOOR:MAINENTRANCE" [ set zoneFacade "EAST" ]
  if zoneName = "1STFLOOR:MECHANICALROOM%N108" [ set zoneFacade "CENTER" ]
  if zoneName = "1STFLOOR:MEN%SROOM110" [ set zoneFacade "NORTH" ]
  if zoneName = "1STFLOOR:CONFERENCEROOM114" [ set zoneFacade "NORTH" ]
  if zoneName = "1STFLOOR:CONFERENCEROOM115" [ set zoneFacade "NORTH" ]
  if zoneName = "1STFLOOR:PIDCOPENOFFICE101" [ set zoneFacade "SOUTH" ]
  if zoneName = "1STFLOOR:WOMEN%SROOM109" [ set zoneFacade "SOUTH" ]
  if zoneName = "1STFLOOR:CORRIDORLOBBY106111" [ set zoneFacade "WEST" ]
  if zoneName = "1STFLOOR:PIDCOPENOFFICE103" [ set zoneFacade "WEST" ]
  if zoneName = "1STFLOOR:OPENOFFICEN117" [ set zoneFacade "WEST" ]
  if zoneName = "1STFLOOR:MECHANICALROOM%S104" [ set zoneFacade "CENTER" ]
  if zoneName = "1STFLOOR:STAIRWELLS%N118" [ set zoneFacade "EAST" ]
```

```
  if zoneName = "1STFLOOR:CONFERENCEROOM112" [ set zoneFacade "SOUTH" ]
  if zoneName = "1STFLOOR:STAIRWELLS%S102" [ set zoneFacade "EAST" ]
  if zoneName = "2NDFLOOR:NTELECONFROOM" [ set zoneFacade "NORTH" ]
  if zoneName = "2NDFLOOR:NICONLAB" [ set zoneFacade "NORTH" ]
  if zoneName = "2NDFLOOR:NMECHROOM" [ set zoneFacade "CENTER" ]
  if zoneName = "2NDFLOOR:MPCCNTRLOFFC214" [ set zoneFacade "CENTER" ]
  if zoneName = "2NDFLOOR:SENDOFFICE201" [ set zoneFacade "SOUTH" ]
  if zoneName = "2NDFLOOR:SWOFFICE206" [ set zoneFacade "WEST" ]
  if zoneName = "2NDFLOOR:NWOFFICE222" [ set zoneFacade "WEST" ]
  if zoneName = "2NDFLOOR:SSTAIRWELLSSHALLWAY" [ set zoneFacade "CENTER" ]
  if zoneName = "2NDFLOOR:SEOFFICE205" [ set zoneFacade "EAST" ]
  if zoneName = "2NDFLOOR:NEOFFICE223" [ set zoneFacade "EAST" ]
  if zoneName = "2NDFLOOR:NSTAIRWELLSHALLWAY" [ set zoneFacade "CENTER" ]
  if zoneName = "2NDFLOOR:NHALLWAY" [ set zoneFacade "CENTER" ]
  if zoneName = "2NDFLOOR:SSERVERROOM" [ set zoneFacade "CENTER" ]
  if zoneName = "2NDFLOOR:MPCCNTRLOFFC212" [ set zoneFacade "CENTER" ]
  if zoneName = "2NDFLOOR:MPACECONTROLCONF213" [ set zoneFacade "CENTER" ]
  if zoneName = "3RDFLOOR:NENDOFFICE" [ set zoneFacade "NORTH" ]
  if zoneName = "3RDFLOOR:NMECHROOM" [ set zoneFacade "CENTER" ]
  if zoneName = "3RDFLOOR:MEASTENDOFFICE" [ set zoneFacade "EAST" ]
  if zoneName = "3RDFLOOR:SENDOFFICE" [ set zoneFacade "SOUTH" ]
  if zoneName = "3RDFLOOR:SWOFFICE306" [ set zoneFacade "WEST" ]
  if zoneName = "3RDFLOOR:NWOFFICE318" [ set zoneFacade "WEST" ]
  if zoneName = "3RDFLOOR:SSTAIRWELLSHALLWAY" [ set zoneFacade "CENTER" ]
  if zoneName = "3RDFLOOR:SEOFFICE305" [ set zoneFacade "EAST" ]
  if zoneName = "3RDFLOOR:NEOFFICE319" [ set zoneFacade "EAST" ]
  if zoneName = "3RDFLOOR:NSTAIRWELLSHALLWAY" [ set zoneFacade "CENTER" ]
  if zoneName = "3RDFLOOR:SSERVERROOM" [ set zoneFacade "CENTER" ]
  if zoneName = "ATTICN:ZONE1" [ set zoneFacade "NORTH" ]
  if zoneName = "ATTICS:ZONE1" [ set zoneFacade "SOUTH" ]
  if zoneName = "ATTICEASTEND:ZONE1" [ set zoneFacade "EAST" ]
  if zoneName = "ATTICHALLWAY:ZONE1" [ set zoneFacade "CENTER" ]
  if zoneName = "ATTICMAIN:ZONE3" [ set zoneFacade "CENTER" ]
  if zoneName = "ATTICMAIN:ZONE4" [ set zoneFacade "CENTER" ]
  if zoneName = "ATTICMAIN:ZONE5" [ set zoneFacade "CENTER" ]
end

to-report ZoneLightLux
  if zoneName = "0FLOORBASEMENT:ELEVATORPUMPROOM" [ report
(zoneLightElectricity / 417.485) ]
  if zoneName = "0FLOORBASEMENT:VITETTAOPENOFFICE" [ report
(zoneLightElectricity / 8998.637) ]
  if zoneName = "0FLOORBASEMENT:JANITORROOM" [ report (zoneLightElectricity /
265.765) ]
  if zoneName = "0FLOORBASEMENT:FRMRKTCHNLNCHAR" [ report
(zoneLightElectricity / 7880.176) ]
  if zoneName = "0FLOORBASEMENT:NHALLWAY" [ report (zoneLightElectricity /
1010.729) ]
  if zoneName = "1STFLOOR:OPENOFFICEN119" [ report (zoneLightElectricity /
4191.488) ]
  if zoneName = "1STFLOOR:MAINENTRANCE" [ report (zoneLightElectricity /
91.926) ]
  if zoneName = "1STFLOOR:MECHANICALROOM%N108" [ report (zoneLightElectricity
/ 401.535) ]
  if zoneName = "1STFLOOR:MEN%SROOM110" [ report (zoneLightElectricity /
1652.958) ]
```

```
  if zoneName = "1STFLOOR:CONFERENCEROOM114" [ report (zoneLightElectricity /
772.0934) ]
  if zoneName = "1STFLOOR:CONFERENCEROOM115" [ report (zoneLightElectricity /
415.7434) ]
  if zoneName = "1STFLOOR:PIDCOPENOFFICE101" [ report (zoneLightElectricity /
4515.426) ]
  if zoneName = "1STFLOOR:WOMEN%SROOM109" [ report (zoneLightElectricity /
1550.738) ]
  if zoneName = "1STFLOOR:CORRIDORLOBBY106111" [ report (zoneLightElectricity
/ 14175.39) ]
  if zoneName = "1STFLOOR:PIDCOPENOFFICE103" [ report (zoneLightElectricity /
4263.468) ]
  if zoneName = "1STFLOOR:OPENOFFICEN117" [ report (zoneLightElectricity /
4587.406) ]
  if zoneName = "1STFLOOR:MECHANICALROOM%S104" [ report (zoneLightElectricity
/ 451.1114) ]
  if zoneName = "1STFLOOR:STAIRWELLS%N118" [ report (zoneLightElectricity /
4288.985) ]
  if zoneName = "1STFLOOR:CONFERENCEROOM112" [ report (zoneLightElectricity /
1226.167) ]
  if zoneName = "1STFLOOR:STAIRWELLS%S102" [ report (zoneLightElectricity /
4289.625) ]
  if zoneName = "2NDFLOOR:NTELECONFROOM" [ report (zoneLightElectricity /
1216.66) ]
  if zoneName = "2NDFLOOR:NICONLAB" [ report (zoneLightElectricity /
2877.737) ]
  if zoneName = "2NDFLOOR:NMECHROOM" [ report (zoneLightElectricity /
455.2792) ]
  if zoneName = "2NDFLOOR:MPCCNTRLOFFC214" [ report (zoneLightElectricity /
1790.631) ]
  if zoneName = "2NDFLOOR:SENDOFFICE201" [ report (zoneLightElectricity /
4211.967) ]
  if zoneName = "2NDFLOOR:SWOFFICE206" [ report (zoneLightElectricity /
2806.321) ]
  if zoneName = "2NDFLOOR:NWOFFICE222" [ report (zoneLightElectricity /
3271.193) ]
  if zoneName = "2NDFLOOR:SSTAIRWELLSSHALLWAY" [ report (zoneLightElectricity
/ 352.81) ]
  if zoneName = "2NDFLOOR:SEOFFICE205" [ report (zoneLightElectricity /
4370.055) ]
  if zoneName = "2NDFLOOR:NEOFFICE223" [ report (zoneLightElectricity /
4370.055) ]
  if zoneName = "2NDFLOOR:NSTAIRWELLSHALLWAY" [ report (zoneLightElectricity
/ 352.811) ]
  if zoneName = "2NDFLOOR:NHALLWAY" [ report (zoneLightElectricity / 117.57)
]
  if zoneName = "2NDFLOOR:SSERVERROOM" [ report (zoneLightElectricity /
437.973) ]
  if zoneName = "2NDFLOOR:MPCCNTRLOFFC212" [ report (zoneLightElectricity /
747.6314) ]
  if zoneName = "2NDFLOOR:MPACECONTROLCONF213" [ report (zoneLightElectricity
/ 669.737) ]
  if zoneName = "3RDFLOOR:NENDOFFICE" [ report (zoneLightElectricity /
4211.97) ]
  if zoneName = "3RDFLOOR:NMECHROOM" [ report (zoneLightElectricity / 452.25)
]
```

```
  if zoneName = "3RDFLOOR:MEASTENDOFFICE" [ report (zoneLightElectricity /
3208) ]
  if zoneName = "3RDFLOOR:SENDOFFICE" [ report (zoneLightElectricity / 4212)
]
  if zoneName = "3RDFLOOR:SWOFFICE306" [ report (zoneLightElectricity /
2342.39) ]
  if zoneName = "3RDFLOOR:NWOFFICE318" [ report (zoneLightElectricity / 3735)
]
  if zoneName = "3RDFLOOR:SSTAIRWELLSHALLWAY" [ report (zoneLightElectricity
/ 353) ]
  if zoneName = "3RDFLOOR:SEOFFICE305" [ report (zoneLightElectricity / 4370)
]
  if zoneName = "3RDFLOOR:NEOFFICE319" [ report (zoneLightElectricity / 4370)
]
  if zoneName = "3RDFLOOR:NSTAIRWELLSHALLWAY" [ report (zoneLightElectricity
/ 352.8) ]
  if zoneName = "3RDFLOOR:SSERVERROOM" [ report (zoneLightElectricity / 437)
]
  if zoneName = "ATTICN:ZONE1" [ report (zoneLightElectricity / 4758.5) ]
  if zoneName = "ATTICS:ZONE1" [ report (zoneLightElectricity / 4758.5) ]
  if zoneName = "ATTICEASTEND:ZONE1" [ report (zoneLightElectricity / 464.3)
]
  if zoneName = "ATTICHALLWAY:ZONE1" [ report (zoneLightElectricity / 282.7)
]
  if zoneName = "ATTICMAIN:ZONE3" [ report (zoneLightElectricity / 6691.1) ]
  if zoneName = "ATTICMAIN:ZONE4" [ report (zoneLightElectricity / 4774.8) ]
  if zoneName = "ATTICMAIN:ZONE5" [ report (zoneLightElectricity / 6691.1) ]
end


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;;;;;;;;;;


to SimulateOccupantBehavior
; if zoneID = 2 [ type endingHour type " | " type zoneTenantRep type " | "
print zoneOccupantList ]
; if zoneID = 2 [ type endingHour type " | "  foreach zoneOccupantList [ type
[ occTenantRep] of ? type ":" type [occZoneID] of ? type ":" type [inZone?]
of ? type " | " ] print " " ]

  ;;; reset behavior parameters
  ask managers [ ResetManagerCurrHour ]
  ask occupants with [ occZoneID = [zoneID] of myself ] [
    if endingHour = 1 [ ResetOccupantParams ]
    ResetOccupantCurrHour ]

  ask tenantreps with [trZoneID = [zoneID] of myself ] [
   ResetTenantRepCurrHour ]

  ask occupants with [ occZoneID = [zoneID] of myself ] [
    OccupantInzone
    OccupantBehavior]
```

```
;ask occupants with [occZoneID = [zoneID] of myself] [type who type inZone?
type " | " type occZoneID type " | " ask myself [ type zoneID type " " type
zoneTenantRep type " " type zoneOccupantList ] type " | " print occTenantRep]
  ask tenantreps with [ trZoneID = [zoneID] of myself ] [ TenantRepBehavior ]
  ask managers [ ManagerBehavior ]
end

to OccupantBehavior
  if (SimThermal) [ ifelse (UseDataset) [ BDIThermal_dataset ] [ BDIThermal
]]
  if (SimLighting) [ BDILighting ]
end


to-report OccupantEffort
  report ( occTaskLightCt + occWindowsBlindCt + occClothesCt
         + occPortHeaterCt + occReportSentCt )
end



to SetupOccupants
  file-open occupant_fname

  let $rowfield ""
  set headerListTmp ""

  ;; read header
  if not file-at-end? [
    set $rowfield file-read-line
    tokenize $rowfield ","
    set headerListTmp returnvalue
  ]

  ;; the rest is the body
  while [ not file-at-end? ] [
    set $rowfield file-read-line

    create-occupants 1 [
      tokenize $rowfield ","
      set occZoneID (GetItemList "ZONE_ID" returnvalue)
      set age (GetItemList "AGE" returnvalue)
      set sex (GetItemListStr "SEX" returnvalue)
      set occControl (GetItemListStr "CONTROL" returnvalue)
      set occVentType (GetItemListStr "VENTTYPE" returnvalue)
      set workStartHour (GetItemList "WORKSTARTHR" returnvalue)
      set workEndHour (GetItemList "WORKENDHR" returnvalue)
      set workDays (GetItemListStr "WORKDAYS" returnvalue)
      set valOfEI (GetItemList "VALOFEI" returnvalue)
      set valOfEffort (GetItemList "VALOFEFFORT" returnvalue)
      set valOfComfort (GetItemList "VALOFCOMFORT" returnvalue)
      set valOfCost (GetItemList "VALOFCOST" returnvalue)
      set temperatureDiff (GetItemList "TEMPDIFF" returnvalue)
      set luxDiff (GetItemList "LIGHTDIFF" returnvalue)

      ResetOccupantParams
    ]
```

```
  ]
  print (word (count occupants) " occupants data is populated" )
  ;print ([ workDays ] of occupants with [occupantID = 24])   ;; for testing

  file-close
end

to ResetManagerParams
  set mnReportReceivedCt 0
  set mnDoNothingCt 0
  set mnThermostatCt 0
end

to ResetTenantRepParams
  set trZoneID 10000
  set trOccupantList []
  set trConsensusValuesTbl table:make

  set trDoNothingCt 0
  set trThermostatCt 0
  set trOverheadLightCt 0
  set trReportSentCt 0
  set trReportReceivedCt 0
end

to ResetOccupantParams
  set occDoNothingCt 0
  set occTaskLightCt 0
  set occWindowsBlindCt 0
  set occClothesCt 0
  set occPortHeaterCt 0
  set occReportSentCt 0

  set occLightingDiscomfort 0
  set occThermalDiscomfort 0
  set inZone? false
  set currentAction "do nothing"
  set currentPerception "normal"

  set pmvValue 0
  set portableHeaterON? false
  set portableFanON? false
  set windowsOPEN? false
  set taskLightON? false
  set windowsBlindOpen? false

  set occTenantRep nobody

  if ScenarioClo = "Business Suit" [ set clothing (table:get clothingTbl
"winter") ]
  if ScenarioClo = "Friday Casual" [ set clothing (table:get clothingTbl
"summer") ]
  if ScenarioClo = "Allow Change" [ set clothing (table:get clothingTbl
"summer") ]

end
```

```
to ResetManagerCurrHour
  set mnDoNothingCurrHour 0
  set mnThermostatCurrHour 0
  set mnReportReceivedCurrHour 0
end

to ResetTenantRepCurrHour
  set trDoNothingCurrHour 0
  set trThermostatCurrHour 0
  set trOverheadLightCurrHour 0
  set trReportSentCurrHour 0
  set trReportReceivedCurrHour 0
end

to ResetOccupantCurrHour
  set occDoNothingCurrHour 0
  set occTaskLightCurrHour 0
  set occWindowsBlindCurrHour 0
  set occClothesCurrHour 0
  set occPortHeaterCurrHour 0
  set occReportSentCurrHour 0
  set occThermalDiscomfortCurrHour 0
  set occLightingDiscomfortCurrHour 0
end

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to OccupantInzone
    let $currentHour (endingHour - 1)
    ifelse ((workdays = "M-Sun"
      AND ($currentHour * 100) >= workStartHour
        AND ($currentHour * 100) <= workEndHour)
       OR
       (workDays = "M-F"
         AND currentWeekDay >= 1
         AND currentWeekDay <= 5
         AND ($currentHour * 100) >= workStartHour
        AND ($currentHour * 100) <= workEndHour))
    [ if (not inZone?)
      [OccupantEnterZone]]
    [ if (inZone?) [ OccupantLeaveZone] ]
  ;SetOccupantValues
end
```

```
to OccupantEnterZoneOLD
  ask myself [
    set zoneOccupantList lput myself zoneOccupantList
  ]
  set inZone? true
  set color blue
  show-turtle
end

to OccupantLeaveZoneOLD
  set inZone? false
  set occTenantRep nobody

  ask myself [ set zoneOccupantList remove myself zoneOccupantList ]
  hide-turtle
end

to OccupantEnterZone
  ;;;;;;;;;;;;;;;; adding zone representative
  if occTenantRep = nobody [
    ifelse ([zoneTenantRep] of myself) = nobody [
      ask one-of tenantreps with [trZoneID = 10000] [
        ResetTenantRepParams
        set trZoneID ([occZoneID] of myself)
        set trOccupantList lput myself trOccupantList

        ask myself [ set occTenantRep myself ]
      ]
    ][
      set occTenantRep ([zoneTenantRep] of myself)
    ]

  ]
  ask myself [
    set zoneOccupantList lput myself zoneOccupantList
    if zoneTenantRep = nobody [ set zoneTenantRep ([occTenantRep] of myself)
]
  ]

  set inZone? true
  set color blue
  show-turtle
end

to OccupantLeaveZone
  ask myself [
    set zoneOccupantList remove myself zoneOccupantList
    if empty? zoneOccupantList [ set zoneTenantRep nobody ]
  ]
  ask occTenantRep [
    set trOccupantList remove myself trOccupantList
    if empty? trOccupantList [ ResetTenantRepParams ]
  ]

  set inZone? false
  set occTenantRep nobody
```

```
  hide-turtle
end


;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
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to increaseLightingDiscomfort
  set occLightingDiscomfortCurrHour 1
  set occLightingDiscomfort (occLightingDiscomfort +
occLightingDiscomfortCurrHour)
  ask myself [ set zoneLightingDiscomfort (zoneLightingDiscomfort +
[occLightingDiscomfortCurrHour] of myself) ]
end

to decreaseLightingDiscomfort
  set occLightingDiscomfortCurrHour 1
  set occLightingDiscomfort (occLightingDiscomfort -
occLightingDiscomfortCurrHour)
  ask myself [ set zoneLightingDiscomfort (zoneLightingDiscomfort -
[occLightingDiscomfortCurrHour] of myself) ]
end

to BDILighting
  if inZone?
  [ ;;;;;;;;;;;;;;;;;;;;;;;;;;;; BELIEF ;;;;;;;;;;;;;;;;;;;;;;;;;;;
    let $perceivedLux ([ZoneTotalLux] of myself + luxDiff)
    if not windowsBlindOpen? [ set $perceivedLux ($perceivedLux -
[zoneDaylightLux] of myself) ]

    ifelse ($perceivedLux >= first comfortLux AND $perceivedLux <= last
comfortLux)
    [ set currentPerception "normal" ]
    [ if ($perceivedLux > last comfortLux)
      [ set currentPerception "too bright"
        increaseLightingDiscomfort
      ]
    if ($perceivedLux < first comfortLux)
    [ set currentPerception "too dark"
      increaseLightingDiscomfort
    ]
    ]
    ;;;;;;;;;;;;;;;;;;;;;;;;;;;; DESIRE ;;;;;;;;;;;;;;;;;;;;;;;;;;;
    set actionPlan []
```

```
    ifelse (currentPerception = "normal")
    []
    [
      set actionPlan lput BDIOccupantAction actionPlan
    ]
    ;;;;;;;;;;;;;;;;;;;;;;;;;;;; INTENTION ;;;;;;;;;;;;;;;;;;;;;;;;;;;
    set currentAction ""
    if (empty? actionPlan = false)
    [ foreach actionPlan
      [ set currentAction ?
        if (currentAction = "do nothing") [ set occDoNothingCt
(occDoNothingCt + 1) ]
        if (currentAction = "task light") [ ActTaskLight ]
        if (currentAction = "windows blind") [ ifelse [zoneControl?] of
myself [ ActWindowsBlind ] [] ]
      ]
    ]
  ]
end

to increaseThermalDiscomfort
  set occThermalDiscomfortCurrHour (occThermalDiscomfortCurrHour + 1)
  set occThermalDiscomfort (occThermalDiscomfort +
occThermalDiscomfortCurrHour)
  ask myself [ set zoneThermalDiscomfort (zoneThermalDiscomfort +
[occThermalDiscomfortCurrHour] of myself) ]
end

to decreaseThermalDiscomfort
  set occThermalDiscomfortCurrHour (occThermalDiscomfortCurrHour - 1)
  set occThermalDiscomfort (occThermalDiscomfort -
occThermalDiscomfortCurrHour)
  ask myself [ set zoneThermalDiscomfort (zoneThermalDiscomfort -
[occThermalDiscomfortCurrHour] of myself) ]
end

to BDIThermal_dataset
  if inZone?
  [
    CalculatePMV
    ;;;;;;;;;;;;;;;;;;;;;;;;;;;;; BELIEF ;;;;;;;;;;;;;;;;;;;;;;;;;;;;

    ifelse (pmvValue >= first comfortPMV AND pmvValue <= last comfortPMV)
    [ set currentPerception "normal" ]
    [ if (pmvValue > last comfortPMV)
      [ set currentPerception "too hot"
        increaseThermalDiscomfort
      ]
    if (pmvValue < first comfortPMV)
    [ set currentPerception "too cold"
      increaseThermalDiscomfort
    ]
    ]
    ;;;;;;;;;;;;;;;;;;;;;;;;;;;;; DESIRE ;;;;;;;;;;;;;;;;;;;;;;;;;;;;
    set actionPlan []
    ifelse (currentPerception = "normal")
    []
```

```
    [ set actionPlan lput SyntheticProbabilityActions actionPlan
    ]
    ;;;;;;;;;;;;;;;;;;;;;;;;;;;; INTENTION ;;;;;;;;;;;;;;;;;;;;;;;;;;;
    set currentAction ""
    if (not empty? actionPlan)
    [ foreach actionPlan
      [ set currentAction ?
        if (currentAction = "do nothing") [ set occDoNothingCt
(occDoNothingCt + 1) ]
        if (currentAction = "change clothes") [ if ScenarioClo = "Allow
Change" [ActChangeClothes ]]
        if (currentAction = "portable heater") [ ActPortableHeater ]
        if (currentAction = "portable fan") [ ActPortableFan ]
        if (currentAction = "windows") [ ActWindows ]
      ]
    ]

  ]
end

to BDIThermal
  if inZone?
  [
    CalculatePMV
    ;;;;;;;;;;;;;;;;;;;;;;;;;;;;; BELIEF ;;;;;;;;;;;;;;;;;;;;;;;;;;;;

    ifelse (pmvValue >= first comfortPMV AND pmvValue <= last comfortPMV)
    [ set currentPerception "normal" ]
    [ if (pmvValue > last comfortPMV)
      [ set currentPerception "too hot"
        increaseThermalDiscomfort
      ]
    if (pmvValue < first comfortPMV)
    [ set currentPerception "too cold"
      increaseThermalDiscomfort
    ]
    ]
    ;;;;;;;;;;;;;;;;;;;;;;;;;;;;; DESIRE ;;;;;;;;;;;;;;;;;;;;;;;;;;;;
    set actionPlan []
    ifelse (currentPerception = "normal")
    []
    [
      set actionPlan lput BDIOccupantAction actionPlan
    ]

    ;;;;;;;;;;;;;;;;;;;;;;;;;;;; INTENTION ;;;;;;;;;;;;;;;;;;;;;;;;;;;
    set currentAction ""
    if (not empty? actionPlan)
    [ foreach actionPlan
      [ set currentAction ?
        if (currentAction = "do nothing") [ set occDoNothingCt
(occDoNothingCt + 1) ]
        if (currentAction = "change clothes") [ if ScenarioClo = "Allow
Change" [ActChangeClothes ]]
        if (currentAction = "portable heater") [ ActPortableHeater ]
        if (currentAction = "portable fan") [ ActPortableFan ]
        if (currentAction = "windows") [ ActWindows ]
```

```
      ]
    ]
  ]
end

to ActTaskLight
  if ((currentPerception = "too bright" AND taskLightON?)
    OR (currentPerception = "too dark" AND (NOT taskLightON?)))
  [ if (currentPerception = "too bright" AND taskLightON?)
    [ set taskLightON? false ]
    if (currentPerception = "too dark" AND (NOT taskLightON?))
    [ set taskLightON? true ]

    set occTaskLightCurrHour 1
    set occTaskLightCt (occTaskLightCt + occTaskLightCurrHour)

    decreaseLightingDiscomfort
  ]
end



to ActWindowsBlind
  ifelse windowsBlindOpen?
  [ set windowsBlindOpen? false ]
  [ set windowsBlindOpen? true ]

  set occWindowsBlindCurrHour 1
  set occWindowsBlindCt (occWindowsBlindCt + occWindowsBlindCurrHour)

  decreaseLightingDiscomfort
end



to ActChangeClothes
  let $CLOTemp 0
  if currentPerception = "too hot"
  [ set clothing (table:get clothingTbl "summer") ]
  if currentPerception = "too cold"
  [ set clothing (table:get clothingTbl "winter") ]

  set occClothesCurrHour 1
  set occClothesCt (occClothesCt + occClothesCurrHour)

  decreaseThermalDiscomfort
end

to ActPortableHeater
  if ((currentPerception = "too hot" AND portableHeaterON?)
    OR (currentPerception = "too cold" AND (NOT portableHeaterON?)))
  [ if (currentPerception = "too hot" AND portableHeaterON?)
    [ set portableHeaterON? false ]
    if (currentPerception = "too cold" AND (NOT portableHeaterON?))
    [ set portableHeaterON? true ]

    set occPortHeaterCurrHour 1
```

```
    set occPortHeaterCt (occPortHeaterCt + occPortHeaterCurrHour)

    decreaseThermalDiscomfort
  ]
end

to ActPortableFan
  if ((currentPerception = "too hot" AND (NOT portableFanON?))
    OR (currentPerception = "too cold" AND portableFAnON?))
  [ if (currentPerception = "too hot" AND (NOT portableFanON?))
    [ set portableFanON? true ]
    if (currentPerception = "too cold" AND portableFanON?)
    [ set portableFanON? false ]

    set occPortFanCurrHour 1
    set occPortFanCt (occPortFanCt + occPortFanCurrHour)

    decreaseThermalDiscomfort
  ]
end

to ActWindows
  if ((currentPerception = "too hot" AND (NOT windowsOPEN?))
    OR (currentPerception = "too cold" AND windowsOPEN?))
  [ if (currentPerception = "too hot" AND (NOT windowsOPEN?))
    [ set windowsOPEN? true ]
    if (currentPerception = "too cold" AND windowsOPEN?)
    [ set windowsOPEN? false ]

    set occWindowsCurrHour 1
    set occWindowsCt (occWindowsCt + occWindowsCurrHour)

    decreaseThermalDiscomfort
  ]
end


to-report BDIOccupantAction
  let $compareValueList []
  let $compareValueActionTbl table:make
  ;;;;;;;;;;;; MATCH THE PERCEPTION ACTION ;;;;;;;;;;;;;;;;
  let $actionList (table:get bdiPerceptionActionTbl currentPerception)
  foreach $actionList
  [ let $action ?

    let $valList (CalculateUtility $action)

    ifelse (NeedConsensus? $action)
    [ ;;;;;;;;;; ADD ACTIONS FOR CONSENSUS: REPORT TO TENANT REPRESENTATIVE
;;;;;;;;;;;

      ask occTenantRep
      [ let $oldValList [ 0 0 0 0 ]
        let $newValList []
        ;;; if the table are not empty, take the values for computation
        if (table:has-key? trConsensusValuesTbl $action)
        [ set $oldValList (table:get trConsensusValuesTbl $action) ]
```

```
        ;; compute the new values
        (foreach $oldValList $valList [ set $newValList lput (?1 + ?2)
$newValList ])
        ;;; put back with the new values
        table:put trConsensusValuesTbl $action $newValList
      ]
    ]
    [ ;;;;;; ELSE, INDIVIDUAL ACTIONS ;;;;;;
      let $totalValues (sum $valList)
      set $compareValueList lput $totalValues $compareValueList
      table:put $compareValueActionTbl $totalValues $action
    ]
  ]

  ;;;;;;;;;;;;;;; GET THE INDIVIDUAL ACTION ;;;;;;;;;;;;;;;;;
  if (not empty? $compareValueList)
  [ set $compareValueList sort $compareValueList
    report (table:get $compareValueActionTbl (first $compareValueList))
  ]

end

to-report CalculateUtility [ #action ]
  let utilList []
  let $valList (table:get bdiActionValsTbl #action)

  set utilList lput (valOfEI * (item 0 $valList)) utilList
  set utilList lput (valOfEffort * (item 1 $valList)) utilList
  set utilList lput (valOfComfort * (item 2 $valList)) utilList
  set utilList lput (valOfCost * (item 3 $valList)) utilList
  report utilList
end

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;

to OccupantReportTenantRepCt
  ;;; ask occupant
  set occReportSentCurrHour 1

  set occReportSentCt (occReportSentCt + occReportSentCurrHour)
  ask occTenantRep [
    set trReportReceivedCurrHour 1
    set trReportReceivedCt (trReportReceivedCt + trReportReceivedCurrHour) ]
end

to TenantRepReportManagerCt
  ;; ask tenantRep
  set trReportSentCurrHour 1
  set trReportSentCt (trReportSentCt + trReportSentCurrHour)
  ask managers [
    set mnReportReceivedCurrHour 1
    set mnReportReceivedCt (mnReportReceivedCt + mnReportReceivedCurrHour) ]
end
```

```
to-report NeedConsensus? [ #action ]

  ifelse (#action = "thermostat" OR #action = "overhead light")
  [ report true ] [ report false ]
end

to TenantRepBehavior
  let $winningActionRun? false
  if (table:length trConsensusValuesTbl > 0)
  [
    set trReportReceivedCt (trReportReceivedCt + 1)
    ifelse (((random-normal CommunicationLevel 10) / 100) < 0.5)
    [ set trDoNothingCt (trDoNothingCt + 1) ]
    [ if TenantRepAction = "thermostat"
      [ ;;; report to building manager
        TenantRepReportManagerCt
        ask myself [ set zoneConsensusValuesTbl
            (table:from-list (table:to-list [ trConsensusValuesTbl ] of
myself ))
        ]
      ]
      if TenantRepAction = "overhead light"
      [ ifelse [zoneControl?] of myself [ ActOverheadLight ] [] ]
    ]
  ]
end

to-report TenantRepAction

  set returnvalue ""
  let $myConsValsList table:keys trConsensusValuesTbl
  let $winningval 0
  let $winningid 0
  let $id 0
  while [ $id < (length $myConsValsList) ]
  [
    let $actid (item $id $myConsValsList)
    let $totalval sum (table:get trConsensusValuesTbl $actid)

    if (($winningval = 0) OR ($winningval > $totalval))
    [ set $winningval $totalval
      set $winningid $actid ]

    set $id ($id + 1)
  ]
  report $winningid
end

to ManagerBehavior
  let $winningActionRun? false
  if (table:length [zoneConsensusValuesTbl] of myself > 0)
  [ ifelse (((random-normal CommunicationLevel 20) / 100) < 0.5)
    [ set mnDoNothingCt (mnDoNothingCt + 1) ]
    [ if ManagerAction = "thermostat"
      [ ifelse [zoneControl?] of myself [ ActThermostat] [] ]
    ]
  ]
```

```
end

to-report ManagerAction
  set returnvalue ""
  let $myConsValsList table:keys [zoneConsensusValuesTbl] of myself
  let $winningval 0
  let $winningid 0
  let $id 0
  while [ $id < (length $myConsValsList) ]
  [ let $actid (item $id $myConsValsList)
    let $values (table:get [zoneConsensusValuesTbl] of myself $actid)
    let $concernedval (item 3 $values)  ;; Manager is COST oriented

    if (($winningval = 0) OR ($winningval > $concernedval))
    [ set $winningval $concernedval
      set $winningid $actid ]
    set $id ($id + 1)
  ]
  report $winningid
end

to ActThermostat
  let $temperaturesp 0
  ask myself [

      ;; convert list of agents to agentset
      let $occupantset occupants with [member? self ([zoneOccupantList] of
myself) ]
      set $occupantset $occupantset with [ occReportSentCurrHour = 1 ]
   if any? $occupantset [
      let $avgT (mean [temperatureDiff] of $occupantset)
      ;; take the average of temperature difference perceived by occupants
who report discomfort
      let $meanTempDiff (5 / 9 * $avgT - 32)

      ifelse (currentMonth > 4 AND currentMonth < 9)
      [ set $temperaturesp ((last comfortTemperature) + $meanTempDiff) ]
      [ set $temperaturesp ((first comfortTemperature) + $meanTempDiff) ]
    ]
  ]
  set mnThermostatCt (mnThermostatCt + 1)
end

to ActOverheadLight
  set trOverheadLightCt (trOverheadLightCt + 1)
end


;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;



to setup
```

```
  ct
  clear-all-plots
  setLookUpTables
  SetupOccupants
  SetupLighting
  set outContent [0]
  set SimLighting false

end

to write-outputfile
  if file-exists? output_fname [ file-delete output_fname ]
  file-open output_fname

  while [not empty? outContent]
  [
    file-print (item 0 outContent)
    set outContent remove-item 0 outContent
  ]
  file-close
end

to write-output [#inputstr]
  set outContent lput #inputstr outContent
end


to go
  file-open eplus_fname
file-close
  file-open eplus_fname
  ;; read header
  if not file-at-end? [
    tokenize file-read-line ","
    set headerListTmp returnvalue

    GetBuildingData
    print (word count zones " zones data is populated")
  ]

  create-managers 1 [ ResetManagerParams ]
  create-tenantreps (count zones) [ ResetTenantRepParams ]

  write-output (word "current
month,endingHour,output_fname,eplus_fname,occupant_fname,CommunicationLevel,B
ldgControlLevel,"
      "TotalBldgCost,PMV(+3),PMV(+2),PMV(+1),PMV(0),PMV(-1),PMV(-2),PMV(-
3),TotalBldgThermalDiscomfort,TotalBldgLightingDiscomfort,"
      "TotalOccupantEffort,TotalTenantRepEffort,"
      "TenantRepReportReceived,(TenantRepReportReceived -
TenantRepDoNothing),"
      "TotalTenantRepReportSent,(TotalTenantRepReportSent -
TotalManagerDoNothing),"
      "occTaskLightCurrHour [Sum],occWindowsBlindCurrHour
[Sum],occClothesCurrHour [Sum],"
      "occPortHeaterCurrHour [Sum],occReportSentCurrHour [Sum],mnThermostatCt
[Sum],trOverheadLightCt [Sum]")
```

```
  ;; read data
  while [ not file-at-end? ] [
    tokenize file-read-line ","
    set contentListTmp returnvalue
    GetDateTime

    set bldgElectricity (GetItemList "Electricity:Facility [J](Hourly)"
contentListTmp)
    set bldgEquipmentElectricity (GetItemList "InteriorEquipment:Electricity
[J](Hourly)" contentListTmp)
    set bldgInteriorLightsElectricity (GetItemList
"InteriorLights:Electricity [J](Hourly)" contentListTmp)
    set bldgHVACElectricity (GetItemList "Electricity:HVAC [J](Hourly)"
contentListTmp)
    set bldgGas (GetItemList "Gas:Plant [J](Hourly)" contentListTmp)
;    type bldgElectricity type " " type bldgEquipmentElectricity type " "
type bldgHVACElectricity print bldgInteriorLightsElectricity

    ask managers [ ResetManagerParams ]

    ask zones [
      if endingHour = 1 [ ResetZoneParams ]

      if (SimLighting) [ Daylighting ]

      SimulateOccupantBehavior
    ]
    update-plots
    write-output (word currentMonth "," endingHour ","
      output_fname "," eplus_fname "," occupant_fname "," CommunicationLevel
"," BldgControlLevel "," round TotalBldgCost ","
      CountOccupantsWithPMV 3 "," CountOccupantsWithPMV 2 ","
CountOccupantsWithPMV 1 "," CountOccupantsWithPMV 0 "," CountOccupantsWithPMV
-1 "," CountOccupantsWithPMV -2 "," CountOccupantsWithPMV -3 ","
      TotalBldgThermalDiscomfort "," TotalBldgLightingDiscomfort ","
TotalOccupantEffort "," TotalTenantRepEffort ","
      TenantRepReportReceived "," (TenantRepReportReceived -
TenantRepDoNothing) ","
      TotalTenantRepReportSent "," (TotalTenantRepReportSent -
TotalManagerDoNothing) ","
      (sum [occTaskLightCurrHour] of occupants) ","
      (sum [occWindowsBlindCurrHour] of occupants) ","
      (sum [occClothesCurrHour] of occupants) ","
      (sum [occPortHeaterCurrHour] of occupants) ","
      (sum [occReportSentCurrHour] of occupants) ","
      (sum [mnThermostatCt] of managers) ","
      (sum [trOverheadLightCt] of tenantreps) ",")

;type endingHour type " " print count tenantreps with [trZoneID = 10000 ]
  ]

  file-close
  write-outputfile
end
```

```
to setLookUpTables
  ;; response --- environment, effort, discomfort, cost
  set bdiActionValsTbl Table:make
  table:put bdiActionValsTbl "do nothing" [ 3 1 3 3 ]
  table:put bdiActionValsTbl "thermostat" [ 3 1 1 3 ]
  table:put bdiActionValsTbl "overhead light" [ 3 1 1 3 ]
  table:put bdiActionValsTbl "windows blind" [ 1 3 3 1 ]
  table:put bdiActionValsTbl "portable heater" [ 2 1 2 1 ]
  table:put bdiActionValsTbl "portable fan" [ 2 1 2 1 ]
  table:put bdiActionValsTbl "windows" [ 2 1 2 1 ]
  table:put bdiActionValsTbl "task light" [ 2 1 2 1 ]
  table:put bdiActionValsTbl "change clothes" [ 1 3 3 1 ]

  set bdiPerceptionActionTbl Table:make
  ;;;;; original ;;;;;;;
  table:put bdiPerceptionActionTbl "too hot" [ "do nothing" "thermostat"
"portable heater" "change clothes" "portable fan" "windows" ]
  table:put bdiPerceptionActionTbl "too cold" [ "do nothing" "thermostat"
"portable heater" "change clothes" ]
  table:put bdiPerceptionActionTbl "too bright" [ "do nothing" "overhead
light" "task light" "windows blind" ]
  table:put bdiPerceptionActionTbl "too dark" [ "do nothing" "overhead light"
"task light" "windows blind" ]

  set clothingTbl Table:make
  table:put clothingTbl "summer" 0.6
  table:put clothingTbl "winter" 2

  set comfortPMV [-2 2]
  set comfortTemperature [20 23]    ;; in C
http://en.wikipedia.org/wiki/Zone_temperature
  set comfortLux [125 175]
  ;set comfort_cotwo [0 600]          ;;
http://www.engineeringtoolbox.com/co2-comfort-level-d_1024.html
end

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

to SetWeekday [#day #month #year]
  set listweekday [0]
  let $lasttwo (#year mod 100)
  let $frac floor ($lasttwo / 4)
  set listweekday lput $lasttwo listweekday
  set listweekday lput $frac listweekday
  set listweekday lput #day listweekday
  TableCenturies #year
  TableMonths #year #month
  set listweekday remove-item 0 listweekday

  set currentWeekday (
    item 0 listweekday + item 1 listweekday + item 2 listweekday +
    item 3 listweekday + item 4 listweekday)
  set currentWeekday ( currentWeekday mod 7)
  GetWeekdaystr
end
```

```
to GetWeekdaystr
  if (currentWeekday = 0) [ set weekdaystr "Sunday" ]
  if (currentWeekday = 1) [ set weekdaystr "Monday" ]
  if (currentWeekday = 2) [ set weekdaystr "Tuesday" ]
  if (currentWeekday = 3) [ set weekdaystr "Wednesday" ]
  if (currentWeekday = 4) [ set weekdaystr "Thursday" ]
  if (currentWeekday = 5) [ set weekdaystr "Friday" ]
  if (currentWeekday = 6) [ set weekdaystr "Saturday" ]
end

to TableCenturies [#year]
  let $yearval 0
  if (#year >= 1700 AND #year <= 1799) [ set $yearval 4 ]
  if (#year >= 1800 AND #year <= 1899) [ set $yearval 2 ]
  if (#year >= 1900 AND #year <= 1999) [ set $yearval 0 ]
  if (#year >= 2000 AND #year <= 2099) [ set $yearval 6 ]
  if (#year >= 2100 AND #year <= 2199) [ set $yearval 4 ]
  if (#year >= 2200 AND #year <= 2299) [ set $yearval 2 ]
  if (#year >= 2300 AND #year <= 2399) [ set $yearval 0 ]
  if (#year >= 2400 AND #year <= 2499) [ set $yearval 6 ]
  if (#year >= 2500 AND #year <= 2599) [ set $yearval 4 ]
  if (#year >= 2600 AND #year <= 2699) [ set $yearval 2 ]

  set listWeekday lput $yearval listWeekday
end

to TableMonths [#year #month]
  let $monthval 0
  let $isleap 0
  set $isleap (#year mod 4)
  if (#month = 1)
     [ ifelse ($isleap = 0) [ set $monthval 6 ] [ set $monthval 0 ]]
  if (#month = 2)
     [ ifelse ($isleap = 0) [ set $monthval 2 ] [ set $monthval 3 ]]
  if (#month = 3) [ set $monthval 3 ]
  if (#month = 4) [ set $monthval 6 ]
  if (#month = 5) [ set $monthval 1 ]
  if (#month = 6) [ set $monthval 4 ]
  if (#month = 7) [ set $monthval 6 ]
  if (#month = 8) [ set $monthval 2 ]
  if (#month = 9) [ set $monthval 5 ]
  if (#month = 10) [ set $monthval 0 ]
  if (#month = 11) [ set $monthval 3 ]
  if (#month = 12) [ set $monthval 5 ]

  set listWeekday lput $monthval listWeekday
end

to TableNumDays [#year #month]
  let $daysnumInMonth 0
  let $isleap 0
  set $isleap (#year mod 4)
  if (#month = 1) [ set $daysNumInMonth 31 ]
  if (#month = 2)
     [ ifelse ($isleap = 0)
       [ set $daysNumInMonth 29 ]
       [ set $daysNumInMonth 28 ]
```

```
    ]
  if (#month = 3) [ set $daysNumInMonth 31 ]
  if (#month = 4) [ set $daysNumInMonth 30 ]
  if (#month = 5) [ set $daysNumInMonth 31 ]
  if (#month = 6) [ set $daysNumInMonth 30 ]
  if (#month = 7) [ set $daysNumInMonth 31 ]
  if (#month = 8) [ set $daysNumInMonth 31 ]
  if (#month = 9) [ set $daysNumInMonth 30 ]
  if (#month = 10) [ set $daysNumInMonth 31 ]
  if (#month = 11) [ set $daysNumInMonth 30 ]
  if (#month = 12) [ set $daysNumInMonth 31 ]

  set daysNumInMonth $daysNumInMonth
end


to SyntheticDataset
  set syndataset populateCSV synthetic_dataset
  type "dataset size: " print length syndataset
  SyntheticSetupCohorts

;  ;;;;;;; for debugging ;;;;;;;;;;
;  let filename "in_daylightlux.csv"
;  let col "CLEARSKY_OVERHANG_EAST_5-18"
;  let row 7
;
;  let dataset (populateCSV filename)
;
;  let columnset (getColCSV dataset col) print columnset
;  let rowset (getRowCSV dataset row)  print rowset
;  let colrowset (getRowColCSV dataset row col) print colrowset
end

to-report headerid [#dataset #col]
  let #colhead ""
  ifelse (is-number? #col) [ set #colhead (word #col) ] [ set #colhead #col ]
  report ( position #colhead (item 0 #dataset) )
end

;;; occupant level
to-report SyntheticProbabilityActions

  if (sex = "MALE" AND (age < 30) AND occVentType = "HVAC" AND
currentPerception = "too cold") [ set cohort_dataset cohort0 ]
  if (sex = "MALE" AND (age < 30) AND occVentType = "HVAC" AND
currentPerception = "too hot") [ set cohort_dataset cohort1 ]
  if (sex = "MALE" AND (age < 30) AND occVentType = "NATURAL" AND
currentPerception = "too cold") [ set cohort_dataset cohort2 ]
  if (sex = "MALE" AND (age < 30) AND occVentType = "NATURAL" AND
currentPerception = "too hot") [ set cohort_dataset cohort3 ]
  if (sex = "MALE" AND (age < 30) AND occVentType = "MIXED" AND
currentPerception = "too cold") [ set cohort_dataset cohort4 ]
  if (sex = "MALE" AND (age < 30) AND occVentType = "MIXED" AND
currentPerception = "too hot") [ set cohort_dataset cohort5 ]
  if (sex = "MALE" AND (age > 29 OR age < 50) AND occVentType = "HVAC" AND
currentPerception = "too cold") [ set cohort_dataset cohort6 ]
```

```
  if (sex = "MALE" AND (age > 29 OR age < 50) AND occVentType = "HVAC" AND
currentPerception = "too hot") [ set cohort_dataset cohort7 ]
  if (sex = "MALE" AND (age > 29 OR age < 50) AND occVentType = "NATURAL" AND
currentPerception = "too cold") [ set cohort_dataset cohort8 ]
  if (sex = "MALE" AND (age > 29 OR age < 50) AND occVentType = "NATURAL" AND
currentPerception = "too hot") [ set cohort_dataset cohort9 ]
  if (sex = "MALE" AND (age > 29 OR age < 50) AND occVentType = "MIXED" AND
currentPerception = "too cold") [ set cohort_dataset cohort10 ]
  if (sex = "MALE" AND (age > 29 OR age < 50) AND occVentType = "MIXED" AND
currentPerception = "too hot") [ set cohort_dataset cohort11 ]
  if (sex = "MALE" AND (age > 49) AND occVentType = "HVAC" AND
currentPerception = "too cold") [ set cohort_dataset cohort12 ]
  if (sex = "MALE" AND (age > 49) AND occVentType = "HVAC" AND
currentPerception = "too hot") [ set cohort_dataset cohort13 ]
  if (sex = "MALE" AND (age > 49) AND occVentType = "NATURAL" AND
currentPerception = "too cold") [ set cohort_dataset cohort14 ]
  if (sex = "MALE" AND (age > 49) AND occVentType = "NATURAL" AND
currentPerception = "too hot") [ set cohort_dataset cohort15 ]
  if (sex = "MALE" AND (age > 49) AND occVentType = "MIXED" AND
currentPerception = "too cold") [ set cohort_dataset cohort16 ]
  if (sex = "MALE" AND (age > 49) AND occVentType = "MIXED" AND
currentPerception = "too hot") [ set cohort_dataset cohort17 ]
  if (sex = "FEMALE" AND (age < 30) AND occVentType = "HVAC" AND
currentPerception = "too cold") [ set cohort_dataset cohort18 ]
  if (sex = "FEMALE" AND (age < 30) AND occVentType = "HVAC" AND
currentPerception = "too hot") [ set cohort_dataset cohort19 ]
  if (sex = "FEMALE" AND (age < 30) AND occVentType = "NATURAL" AND
currentPerception = "too cold") [ set cohort_dataset cohort20 ]
  if (sex = "FEMALE" AND (age < 30) AND occVentType = "NATURAL" AND
currentPerception = "too hot") [ set cohort_dataset cohort21 ]
  if (sex = "FEMALE" AND (age < 30) AND occVentType = "MIXED" AND
currentPerception = "too cold") [ set cohort_dataset cohort22 ]
  if (sex = "FEMALE" AND (age < 30) AND occVentType = "MIXED" AND
currentPerception = "too hot") [ set cohort_dataset cohort23 ]
  if (sex = "FEMALE" AND (age > 29 OR age < 50) AND occVentType = "HVAC" AND
currentPerception = "too cold") [ set cohort_dataset cohort24 ]
  if (sex = "FEMALE" AND (age > 29 OR age < 50) AND occVentType = "HVAC" AND
currentPerception = "too hot") [ set cohort_dataset cohort25 ]
  if (sex = "FEMALE" AND (age > 29 OR age < 50) AND occVentType = "NATURAL"
AND currentPerception = "too cold") [ set cohort_dataset cohort26 ]
  if (sex = "FEMALE" AND (age > 29 OR age < 50) AND occVentType = "NATURAL"
AND currentPerception = "too hot") [ set cohort_dataset cohort27 ]
  if (sex = "FEMALE" AND (age > 29 OR age < 50) AND occVentType = "MIXED" AND
currentPerception = "too cold") [ set cohort_dataset cohort28 ]
  if (sex = "FEMALE" AND (age > 29 OR age < 50) AND occVentType = "MIXED" AND
currentPerception = "too hot") [ set cohort_dataset cohort29 ]
  if (sex = "FEMALE" AND (age > 49) AND occVentType = "HVAC" AND
currentPerception = "too cold") [ set cohort_dataset cohort30 ]
  if (sex = "FEMALE" AND (age > 49) AND occVentType = "HVAC" AND
currentPerception = "too hot") [ set cohort_dataset cohort31 ]
  if (sex = "FEMALE" AND (age > 49) AND occVentType = "NATURAL" AND
currentPerception = "too cold") [ set cohort_dataset cohort32 ]
  if (sex = "FEMALE" AND (age > 49) AND occVentType = "NATURAL" AND
currentPerception = "too hot") [ set cohort_dataset cohort33 ]
  if (sex = "FEMALE" AND (age > 49) AND occVentType = "MIXED" AND
currentPerception = "too cold") [ set cohort_dataset cohort34 ]
```

```
  if (sex = "FEMALE" AND (age > 49) AND occVentType = "MIXED" AND
currentPerception = "too hot") [ set cohort_dataset cohort35 ]


  let ctFOpWin 0
  let ctFtstat 0
  let ctFheater 0
  let ctFportfan 0
  let ctFnotify 0
  let ctFcloth 0
  let ctFblinds 0
  ifelse (length cohort_dataset < 2) ;;;;;;; empty cohorts
  [ set ctFOpWin 1
    set ctFtstat 1
    set ctFheater 1
    set ctFportfan 1
    set ctFnotify 1
    set ctFcloth 1
    set ctFblinds 1
  ]
  [ set cohort_dataset remove-item 0 cohort_dataset  ;;;;;;;;;;; remove the
leading 0
    foreach cohort_dataset [
      let rowcontent ?

      let FOpWinVal item (headerid syndataset "FOpWin") rowcontent
      let FtstatVal item (headerid syndataset "Ftstat") rowcontent
      let FheaterVal item (headerid syndataset "Fheater") rowcontent
      let FportfanVal item (headerid syndataset "Fportfan") rowcontent
      let FnotifyVal item (headerid syndataset "Fnotify") rowcontent
      let FclothVal item (headerid syndataset "Fcloth") rowcontent
      let FblindsVal item (headerid syndataset "Fblinds") rowcontent

      ifelse (occControl = "YES") [
        if (FOpWinVal = "ALWAYS" OR FOpWinVal = "OFTEN") [set ctFOpWin
(ctFOpWin + 1) ]
        if (FtstatVal = "ALWAYS" OR FtstatVal = "OFTEN") [set ctFtstat
(ctFtstat + 1) ]
        if (FheaterVal = "ALWAYS" OR FheaterVal = "OFTEN") [set ctFheater
(ctFheater + 1) ]
        if (FportfanVal = "ALWAYS" OR FportfanVal = "OFTEN") [set ctFportfan
(ctFportfan + 1) ]
        if (FnotifyVal = "ALWAYS" OR FnotifyVal = "OFTEN") [set ctFnotify
(ctFnotify + 1) ]
        if (FclothVal = "ALWAYS" OR FclothVal = "OFTEN") [set ctFcloth
(ctFcloth + 1) ]
        if (FblindsVal = "ALWAYS" OR FblindsVal = "OFTEN") [set ctFblinds
(ctFblinds + 1) ]
      ]
      [
        if (FOpWinVal = "NOT AVAILABLE") [set ctFOpWin (ctFOpWin + 1) ]
        if (FtstatVal = "NOT AVAILABLE") [set ctFtstat (ctFtstat + 1) ]
        if (FheaterVal = "NOT AVAILABLE") [set ctFheater (ctFheater + 1) ]
        if (FportfanVal = "NOT AVAILABLE") [set ctFportfan (ctFportfan + 1) ]
        if (FnotifyVal = "NOT AVAILABLE") [set ctFnotify (ctFnotify + 1) ]
        if (FclothVal = "NOT AVAILABLE") [set ctFcloth (ctFcloth + 1) ]
        if (FblindsVal = "NOT AVAILABLE") [set ctFblinds (ctFblinds + 1) ]
```

```
      ]
    ]
  ]

  let n (length cohort_dataset)
;type n type " " type ctFblinds type " " type ctFcloth type " " type
ctFheater type " " type ctFnotify type " " type ctFtstat type " " type
ctFportfan type " " print ctFOpWin

  set Pthermal_Donothing 0
  set Pthermal_WindowsBlind (precision (ctFblinds / n) 2)
  set Pthermal_Clothes (precision (ctFcloth / n) 2)
  set Pthermal_PortHeater (precision (ctFheater / n) 2)
  set Pthermal_ReportSent (precision (ctFnotify / n) 2)
  set Pthermal_Thermostat (precision (ctFtstat / n) 2)
  set Pthermal_PortFan (precision (ctFportfan / n) 2)
  set Pthermal_Windows (precision (ctFOpWin / n) 2)

;type Pthermal_Donothing type " " type Pthermal_WindowsBlind type " " type
Pthermal_Clothes type Pthermal_PortHeater type " "
;type Pthermal_ReportSent type " " type Pthermal_Thermostat type " " type
Pthermal_PortFan type " " print Pthermal_Windows


  let $compareValueList [0]
  set $compareValueList lput Pthermal_Donothing $compareValueList
  set $compareValueList lput Pthermal_Clothes $compareValueList
  set $compareValueList lput Pthermal_PortHeater $compareValueList
  set $compareValueList lput Pthermal_PortFan $compareValueList
  set $compareValueList lput Pthermal_Windows $compareValueList
  set $compareValueList remove-item 0 $compareValueList

  let $compareValueActionTbl table:make

  table:put $compareValueActionTbl Pthermal_Donothing "do nothing"
  table:put $compareValueActionTbl Pthermal_Clothes "change clothes"
  table:put $compareValueActionTbl Pthermal_PortHeater "portable heater"
  table:put $compareValueActionTbl Pthermal_PortFan "portable fan"
  table:put $compareValueActionTbl Pthermal_Windows "windows"

  set $compareValueList sort $compareValueList
  report (table:get $compareValueActionTbl (last $compareValueList))

end

to-report random-binomial [n p]
     report sum n-values n [ifelse-value (p > random-float 1) [1] [0]]
end


to SyntheticSetupCohorts

  set  cohort0 [0]
  set  cohort1 [0]
  set  cohort2 [0]
  set  cohort3 [0]
  set  cohort4 [0]
```

```
  set  cohort5 [0]
  set  cohort6 [0]
  set  cohort7 [0]
  set  cohort8 [0]
  set  cohort9 [0]
  set  cohort10 [0]
  set  cohort11 [0]
  set  cohort12 [0]
  set  cohort13 [0]
  set  cohort14 [0]
  set  cohort15 [0]
  set  cohort16 [0]
  set  cohort17 [0]
  set  cohort18 [0]
  set  cohort19 [0]
  set  cohort20 [0]
  set  cohort21 [0]
  set  cohort22 [0]
  set  cohort23 [0]
  set  cohort24 [0]
  set  cohort25 [0]
  set  cohort26 [0]
  set  cohort27 [0]
  set  cohort28 [0]
  set  cohort29 [0]
  set  cohort30 [0]
  set  cohort31 [0]
  set  cohort32 [0]
  set  cohort33 [0]
  set  cohort34 [0]
  set  cohort35 [0]

  foreach syndataset [
    let rowcontent ?

    let SexVal item (headerid syndataset "Sex") rowcontent
    let AgeVal item (headerid syndataset "Age") rowcontent
    let VentypeVal item (headerid syndataset "Ventype") rowcontent
    let TA_MVAl item (headerid syndataset "TA_M") rowcontent

    let FOpWinVal item (headerid syndataset "FOpWin") rowcontent
    let FtstatVal item (headerid syndataset "Ftstat") rowcontent
    let FblindsVal item (headerid syndataset "Fblinds") rowcontent
    let FheaterVal item (headerid syndataset "Fheater") rowcontent
    let FportfanVal item (headerid syndataset "Fportfan") rowcontent
    let FventVal item (headerid syndataset "Fvent") rowcontent

    if(SexVal != "." AND AgeVal != "." AND VentypeVal != "." AND TA_MVal !=
".") [
      if (SexVal = "MALE" AND (AgeVal = "0-19" OR AgeVal = "20-29") AND
VentypeVal = "HVAC" AND read-from-string(TA_MVal) < 22) [ set cohort0 lput
rowcontent cohort0 ]
      if (SexVal = "MALE" AND (AgeVal = "0-19" OR AgeVal = "20-29") AND
VentypeVal = "HVAC" AND read-from-string(TA_MVal) > 22) [ set cohort1 lput
rowcontent cohort1 ]
```

```
      if (SexVal = "MALE" AND (AgeVal = "0-19" OR AgeVal = "20-29") AND
VentypeVal = "NV" AND read-from-string(TA_MVal) < 22) [ set cohort2 lput
rowcontent cohort2 ]
      if (SexVal = "MALE" AND (AgeVal = "0-19" OR AgeVal = "20-29") AND
VentypeVal = "NV" AND read-from-string(TA_MVal) > 22) [ set cohort3 lput
rowcontent cohort3 ]
      if (SexVal = "MALE" AND (AgeVal = "0-19" OR AgeVal = "20-29") AND
(VentypeVal = "HVAC/mixed" OR VentypeVal = "mixed") AND read-from-
string(TA_MVal) < 22) [ set cohort4 lput rowcontent cohort4 ]
      if (SexVal = "MALE" AND (AgeVal = "0-19" OR AgeVal = "20-29") AND
(VentypeVal = "HVAC/mixed" OR VentypeVal = "mixed") AND read-from-
string(TA_MVal) > 22) [ set cohort5 lput rowcontent cohort5 ]
      if (SexVal = "MALE" AND (AgeVal = "30-39" OR AgeVal = "40-49") AND
VentypeVal = "HVAC" AND read-from-string(TA_MVal) < 22) [ set cohort6 lput
rowcontent cohort6 ]
      if (SexVal = "MALE" AND (AgeVal = "30-39" OR AgeVal = "40-49") AND
VentypeVal = "HVAC" AND read-from-string(TA_MVal) > 22) [ set cohort7 lput
rowcontent cohort7 ]
      if (SexVal = "MALE" AND (AgeVal = "30-39" OR AgeVal = "40-49") AND
VentypeVal = "NV" AND read-from-string(TA_MVal) < 22) [ set cohort8 lput
rowcontent cohort8 ]
      if (SexVal = "MALE" AND (AgeVal = "30-39" OR AgeVal = "40-49") AND
VentypeVal = "NV" AND read-from-string(TA_MVal) > 22) [ set cohort9 lput
rowcontent cohort9 ]
      if (SexVal = "MALE" AND (AgeVal = "30-39" OR AgeVal = "40-49") AND
(VentypeVal = "HVAC/mixed" OR VentypeVal = "mixed") AND read-from-
string(TA_MVal) < 22) [ set cohort10 lput rowcontent cohort10 ]
      if (SexVal = "MALE" AND (AgeVal = "30-39" OR AgeVal = "40-49") AND
(VentypeVal = "HVAC/mixed" OR VentypeVal = "mixed") AND read-from-
string(TA_MVal) > 22) [ set cohort11 lput rowcontent cohort11 ]
      if (SexVal = "MALE" AND (AgeVal = "50-59" OR AgeVal = "60-69" OR AgeVal
= "70-79") AND VentypeVal = "HVAC" AND read-from-string(TA_MVal) < 22) [ set
cohort12 lput rowcontent cohort12 ]
      if (SexVal = "MALE" AND (AgeVal = "50-59" OR AgeVal = "60-69" OR AgeVal
= "70-79") AND VentypeVal = "HVAC" AND read-from-string(TA_MVal) > 22) [ set
cohort13 lput rowcontent cohort13 ]
      if (SexVal = "MALE" AND (AgeVal = "50-59" OR AgeVal = "60-69" OR AgeVal
= "70-79") AND VentypeVal = "NV" AND read-from-string(TA_MVal) < 22) [ set
cohort14 lput rowcontent cohort14 ]
      if (SexVal = "MALE" AND (AgeVal = "50-59" OR AgeVal = "60-69" OR AgeVal
= "70-79") AND VentypeVal = "NV" AND read-from-string(TA_MVal) > 22) [ set
cohort15 lput rowcontent cohort15 ]
      if (SexVal = "MALE" AND (AgeVal = "50-59" OR AgeVal = "60-69" OR AgeVal
= "70-79") AND (VentypeVal = "HVAC/mixed" OR VentypeVal = "mixed") AND read-
from-string(TA_MVal) < 22) [ set cohort16 lput rowcontent cohort16 ]
      if (SexVal = "MALE" AND (AgeVal = "50-59" OR AgeVal = "60-69" OR AgeVal
= "70-79") AND (VentypeVal = "HVAC/mixed" OR VentypeVal = "mixed") AND read-
from-string(TA_MVal) > 22) [ set cohort17 lput rowcontent cohort17 ]
      if (SexVal = "FEMALE" AND (AgeVal = "0-19" OR AgeVal = "20-29") AND
VentypeVal = "HVAC" AND read-from-string(TA_MVal) < 22) [ set cohort18 lput
rowcontent cohort18 ]
      if (SexVal = "FEMALE" AND (AgeVal = "0-19" OR AgeVal = "20-29") AND
VentypeVal = "HVAC" AND read-from-string(TA_MVal) > 22) [ set cohort19 lput
rowcontent cohort19 ]
      if (SexVal = "FEMALE" AND (AgeVal = "0-19" OR AgeVal = "20-29") AND
VentypeVal = "NV" AND read-from-string(TA_MVal) < 22) [ set cohort20 lput
rowcontent cohort20 ]
```

```
      if (SexVal = "FEMALE" AND (AgeVal = "0-19" OR AgeVal = "20-29") AND
VentypeVal = "NV" AND read-from-string(TA_MVal) > 22) [ set cohort21 lput
rowcontent cohort21 ]
      if (SexVal = "FEMALE" AND (AgeVal = "0-19" OR AgeVal = "20-29") AND
(VentypeVal = "HVAC/mixed" OR VentypeVal = "mixed") AND read-from-
string(TA_MVal) < 22) [ set cohort22 lput rowcontent cohort22 ]
      if (SexVal = "FEMALE" AND (AgeVal = "0-19" OR AgeVal = "20-29") AND
(VentypeVal = "HVAC/mixed" OR VentypeVal = "mixed") AND read-from-
string(TA_MVal) > 22) [ set cohort23 lput rowcontent cohort23 ]
      if (SexVal = "FEMALE" AND (AgeVal = "30-39" OR AgeVal = "40-49") AND
VentypeVal = "HVAC" AND read-from-string(TA_MVal) < 22) [ set cohort24 lput
rowcontent cohort24 ]
      if (SexVal = "FEMALE" AND (AgeVal = "30-39" OR AgeVal = "40-49") AND
VentypeVal = "HVAC" AND read-from-string(TA_MVal) > 22) [ set cohort25 lput
rowcontent cohort25 ]
      if (SexVal = "FEMALE" AND (AgeVal = "30-39" OR AgeVal = "40-49") AND
VentypeVal = "NV" AND read-from-string(TA_MVal) < 22) [ set cohort26 lput
rowcontent cohort26 ]
      if (SexVal = "FEMALE" AND (AgeVal = "30-39" OR AgeVal = "40-49") AND
VentypeVal = "NV" AND read-from-string(TA_MVal) > 22) [ set cohort27 lput
rowcontent cohort27 ]
      if (SexVal = "FEMALE" AND (AgeVal = "30-39" OR AgeVal = "40-49") AND
(VentypeVal = "HVAC/mixed" OR VentypeVal = "mixed") AND read-from-
string(TA_MVal) < 22) [ set cohort28 lput rowcontent cohort28 ]
      if (SexVal = "FEMALE" AND (AgeVal = "30-39" OR AgeVal = "40-49") AND
(VentypeVal = "HVAC/mixed" OR VentypeVal = "mixed") AND read-from-
string(TA_MVal) > 22) [ set cohort29 lput rowcontent cohort29 ]
      if (SexVal = "FEMALE" AND (AgeVal = "50-59" OR AgeVal = "60-69" OR
AgeVal = "70-79") AND VentypeVal = "HVAC" AND read-from-string(TA_MVal) < 22)
[ set cohort30 lput rowcontent cohort30 ]
      if (SexVal = "FEMALE" AND (AgeVal = "50-59" OR AgeVal = "60-69" OR
AgeVal = "70-79") AND VentypeVal = "HVAC" AND read-from-string(TA_MVal) > 22)
[ set cohort31 lput rowcontent cohort31 ]
      if (SexVal = "FEMALE" AND (AgeVal = "50-59" OR AgeVal = "60-69" OR
AgeVal = "70-79") AND VentypeVal = "NV" AND read-from-string(TA_MVal) < 22) [
set cohort32 lput rowcontent cohort32 ]
      if (SexVal = "FEMALE" AND (AgeVal = "50-59" OR AgeVal = "60-69" OR
AgeVal = "70-79") AND VentypeVal = "NV" AND read-from-string(TA_MVal) > 22) [
set cohort33 lput rowcontent cohort33 ]
      if (SexVal = "FEMALE" AND (AgeVal = "50-59" OR AgeVal = "60-69" OR
AgeVal = "70-79") AND (VentypeVal = "HVAC/mixed" OR VentypeVal = "mixed") AND
read-from-string(TA_MVal) < 22) [ set cohort34 lput rowcontent cohort34 ]
      if (SexVal = "FEMALE" AND (AgeVal = "50-59" OR AgeVal = "60-69" OR
AgeVal = "70-79") AND (VentypeVal = "HVAC/mixed" OR VentypeVal = "mixed") AND
read-from-string(TA_MVal) > 22) [ set cohort35 lput rowcontent cohort35 ]

    ]
  ]
end



to-report populateCSV [#filename]
  file-open #filename
  file-close
  file-open #filename
```

```
  let content [0]
  while [ not file-at-end? ]
  [
    let xstr file-read-line
    tokenize xstr ","
    let contentrow returnvalue
    set content lput contentrow content
  ]
  set content remove-item 0 content
  report content

end

to-report getColCSV [ #dataset #col ]
  let columnset []
  let #colhead ""
  ifelse (is-number? #col) [ set #colhead (word #col) ] [ set #colhead #col ]
  let colid ( position #colhead (item 0 #dataset) )
  foreach #dataset
  [ set columnset lput (item colid ?) columnset ]
  set columnset remove-item 0 columnset
  report columnset
end

to-report getRowCSV [ #dataset #row ]
  let #rowhead ""
  ifelse (is-number? #row) [ set #rowhead (word #row) ] [ set #rowhead #row ]
  foreach #dataset [ if (item 0 ? = #rowhead) [ report ? ]]
end

to-report getRowColCSV [ #dataset #row #col ]
  let #rowhead ""
  let #colhead ""
  ifelse (is-number? #col) [ set #colhead (word #col) ] [ set #colhead #col ]
  ifelse (is-number? #row) [ set #rowhead (word #row) ] [ set #rowhead #row ]
  let columnset []
  let colid ( position #colhead (item 0 #dataset) )
;type #dataset print #rowname  type " " type #colname type " " type colid
type " " print #colname
  foreach #dataset
  [ if (item 0 ? = #rowhead) [ report item colid ? ] ]
end



;; ----------------------------------------------------------------------
;;                          tokenize
;; ----------------------------------------------------------------------
to tokenize [#inputstr #delim]

  set returnvalue [0]
  while [not empty? #inputstr]
  [
    let delimpos position #delim #inputstr
    let pos 0

    ifelse is-number? delimpos
```

```
    [
      ;;if have not reached the last column
      let strInput substring #inputstr pos delimpos

      set returnvalue lput (TrimString strInput) returnvalue

      while [delimpos >= 0]
      [
        set #inputstr remove-item 0 #inputstr
        set delimpos (delimpos - 1)
      ]
    ]
    [
      ;; last column is reached
      let strInput #inputstr
      set returnvalue lput (TrimString strInput) returnvalue
      set #inputstr ""
    ]
  ]
  set returnvalue remove-item 0 returnvalue
end

;;; to trim leading and trailing spaces
to-report TrimString [ #original ]

  while [ (first #original) = " " ]
  [ set #original (remove-item 0 #original) ]

  while [ (last #original) = " " ]
  [ set #original (remove-item ((length #original) - 1) #original) ]

  report #original
end


to-report GetItemList [#str #list]
  let $pos (position #str headerListTmp)
  if is-number? $pos [ report read-from-string (item $pos #list) ]
  report 0
end

to-report GetItemListStr [#str #list]
  let $pos (position #str headerListTmp)
  if is-number? $pos [ report (item $pos #list) ]
  report " "
end



;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;
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;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;
```

```
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;
;; http://www.lumasenseinc.com/EN/products/thermal-comfort/pmv-calculation/
;http://books.google.com/books?id=-
5DuyPjGwIQC&pg=PA186&lpg=PA186&dq=relationship+of+dissatisfaction+with+indoor
+air+quality&source=bl&ots=R2krlWumle&sig=IrH8FTp6LtBUZupNA56CvvxZXTE&hl=en&e
i=9TfiTsSFMKH00gGA8amFBg&sa=X&oi=book_result&ct=result&resnum=8&sqi=2&ved=0CG
cQ6AEwBw#v=onepage&q=relationship%20of%20dissatisfaction%20with%20indoor%20ai
r%20quality&f=true

;; ----------------------------------------------------------------------------
-----------
;;                       CalculatePMV
;; +3 hot
;; +2 warm
;; +1 slightly warm
;; 0  neutral
;; -1 slightly cool
;; -2 cool
;; -3 cold
;; ----------------------------------------------------------------------------
-----------


to CalculatePMV
  let MET 1                                       ;; metabolism
  let TA ([meanAirT] of myself)
  let $FTA (9 / 5 * TA + 32)                       ;; farenheit
  let $TP  (5 / 9 * ($FTA + temperatureDiff - 32))  ;; perceived temperature

  set TA $TP                                       ;; set the perceived
temperature as the new TA
  let TR  ([meanRadiantT] of myself)              ;; radiant temperature
  let RH  ([AirRelativeHumidity] of myself)       ;; relative humidity
  let VEL 0.15                                    ;; air velocity
  let CLO clothing
  let _def 0.000001
  if (CLO = _def OR MET = _def OR TA = _def OR TR = _def
    OR RH = _def OR VEL = _def)
  [ report 0.0000001 ]

  let FNPS (exp (16.6536 - 4030.183 / (TA + 235)))
  let PA (RH * 10 * FNPS)
  let ICL (0.155 * CLO)
  let M (MET * 58.15)
  let FCL 0
  ifelse ICL < 0.078
     [ set FCL (1 + 1.29 * ICL) ]
     [ set FCL (1.05 + 0.645 * ICL) ]

  let HCF (12.1 * (VEL ^ 0.5))
  let TAA (TA + 273)
  let TRA (TR + 273)

  let TCLA (TAA + (35.5 - TA) / (3.5 * (6.45 * ICL + 0.1)))
  let P1 (ICL * FCL)
  let P2 (P1 * 3.96)
```

```
let P3 (P1 * 100.0)
let P4 (P1 * TAA)
let P5 (308.7 - 0.028 * M + P2 * ((TRA / 100) ^ 4))
let XN (TCLA / 100)
let XF (TCLA / 50)
let HCN (1.0e-6)
let HC (1.0e-6)
;XF = XN

let N 0
let EPS 0.0015
while [ (abs (XN - XF)) > EPS] [
  set XF ((XF + XN) / 2)
  set HCF (12.1 * (VEL ^ 0.5))
  set HCN (2.38 * ((abs (100 * XF - TAA)) ^ 0.25))

  ifelse (HCF > HCN) [ set HC HCF ] [ set HC HCN ]

  set XN ((P5 + P4 * HC - P2 * (XF ^ 4)) / (100 + P3 * HC))
  set N (N + 1)
]

let TCL (100 * XN - 273)
;; Skinn diff loss

let HL1 (3.05 * 0.001 * (5733 - 6.99 * M - PA))

;; Sweat loss
let HL2 0.0
ifelse (M > 58.15)
  [ set HL2 (0.42 * (M - 58.15)) ]
  [ set HL2 0.0 ]

;;Latent respiration loss
let HL3 (1.7 * 0.00001 * M * (5867 - PA))

;;Dry respiration loss
let HL4 (0.0014 * M * (34 - TA))

;;Radiation loss
let HL5 (3.96 * FCL * ((XN ^ 4) - ((TRA / 100) ^ 4)))

;;Convection loss
let HL6 (FCL * HC * (TCL - TA))

;;Thermal sensation to skin tran coef
let TS (0.303 * (exp (-0.036 * M)) + 0.028)

let TPO 0
ifelse (VEL < 0.2)
  [ set TPO (0.5 * TA + 0.5 * TR) ]
  [ ifelse (VEL < 0.6)
      [ set TPO (0.6 * TA + 0.4 * TR) ]
      [ set TPO (0.7 * TA + 0.3 * TR) ]
  ]

set pmvValue (TS * (M - HL1 - HL2 - HL3 - HL4 - HL5 - HL6))
```

```
  set ppdValue (100 - 95 * ( exp (-0.03353 * (pmvValue ^ 4) - 0.2179 *
(pmvValue ^ 2))));
end
```

Appendix E Manuscript: Using Synthetic Population Data for Prospective Modeling of Occupant Behavior during Design

Submission to *Energy and Buildings* special issue on occupancy behavior

Using Synthetic Population Data for Prospective Modeling of Occupant Behavior during Design

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Abstract

This paper addresses the challenge of incorporating occupant behavior into building performance simulation models used during the design process—that is, before the actual occupants are known. It proposes the use of synthetic population data, an approach that is novel in building performance modeling although common in urban planning and public health. A simpler approach embodied in the ASHRAE *Fundamentals* volume is to report standard distributions of values for behavioral variables, assuming that parameters vary independently of one another when in fact many co-vary or are interdependent. An alternative approach calibrates models of occupant behavior against actual occupants in specific existing buildings, but this raises questions of transferability. Needed is a database of “generic” occupants that designers can use prospectively during the design process. This paper documents a process of combining disparate field studies of commercial buildings into a larger occupant behavior database and generating a statistically similar synthetic data set that can be shared without compromising confidentiality requirements associated with field studies. The synthetic data set successfully incorporates much of the covariance structure of the underlying field data and supports multivariate modeling. Its scope and structure necessarily serve the needs of the associated modeling framework. Cooperative and systematic sharing of data by field researchers is crucial for building large enough data sets to serve as a behaviorally-robust basis for building design.

Highlights:

- Design work precedes building occupancy but designers should still consider occupant behavior.
- The transferability of occupant behavior data depends on incorporation of key contextual factors.
- Creating a synthetic set of generic building occupants captures aspects of context, is feasible and helpful in design practice, and is available now for commercial buildings.

Keywords: occupant behavior, energy, simulation, synthetic data

Acknowledgements: The authors have benefitted from participating in the IEA-EBC Annex 66 expert working group on Definition and Simulation of Occupant Behavior in Buildings. Funding was provided by the Consortium for Building Energy Innovation (CBEI) sponsored by the U.S. Department of Energy under Award Number DE-EE0004261.

1.0 Introduction

Occupants can affect a building's performance and vice versa, and sophisticated building operators often monitor occupant concerns and dynamically respond to their behaviors and preferences [1-3]. Design choices influence the energy and comfort performance of buildings, as do occupants [4], hence there is value in understanding occupant influence early in the design process, before occupancy actually occurs.

Many building performance modelers ignore aspects of occupant behavior by assuming fixed comfort targets and ignoring "unregulated" energy loads. This is the standard practice even though researchers have shown that occupants influence building performance by their choice of setpoints, schedules, and adaptive behaviors, many of which are heterogeneous, often habitual, and sometimes maladaptive [5, 6]. Missing from practice are parsimonious and reliable representations of expected adaptive behaviors that respond to comfort conditions experienced in new buildings [7]. This paper presents one way to bring insights from occupant behavior research to the building design process.

A key challenge is the nature of available evidence about occupant behavior in buildings. It is possible to collect some objective evidence that measures occupancy patterns, indoor environmental conditions, observable adaptive responses of occupants to changing conditions, and physiological effects. Yet much relevant evidence is subjective and takes the form of occupant perceptions of comfort, control and satisfaction; expressed preferences; and mental models of how building systems work. Widely employed research strategies include controlled experiments, which test stimulus and response within a narrow domain, and field observations, which better account for contextual factors but may lack precision, power and reliability. A problem much of this research faces is that behavior and perception may depend on context, so is this knowledge transferable?

Data collected about occupant behavior inevitably comes from existing buildings and experimental setups, whereas designers must build new buildings whose occupants are not yet known. If behavior can be context-dependent, there is a need to study how transferable the knowledge gained from retrospective study of occupant behavior is to new building contexts. This paper identifies four broad transfer approaches discussed in greater detail next: (1) develop standard distributions for design guidance; (2) calibrate building performance models against existing occupied buildings, then apply the calibrated building performance model elsewhere; (3) calibrate separate occupant behavior and building performance models in co-simulation against an existing building, then apply the calibrated occupant behavior model elsewhere; and (4) develop a representative occupant behavior data set for use in co-simulations that link occupant behavior and building performance models.

1.1 Develop standard distributions

Large data sets incorporating thousands of occupants in hundreds of buildings underlie standard distributions of thermal comfort preferences summarized in the ASHRAE *Fundamentals* volume [8] and adopted in ASHRAE *Standard 55* [9] and the associated primary literature, e.g., [10]. Occupants' predicted mean votes (PMV) on the ASHRAE 7-point thermal comfort scale, which ranges from cold (-3) to hot (3), depend strongly on their metabolic rate and clothing type, plus ambient air temperature, mean radiant temperature, air velocity, and relative humidity. PMV, in turn, drives the predicted percentage of dissatisfied occupants (PPD). ASHRAE *Standard 55* [9] focuses its guidance on the central tendency in this distribution, recommending that designers seek to satisfy the 90% of occupants whose PMV lies between -0.5 and +0.5 on the thermal comfort scale. Designers may assume fixed indoor air temperature targets for use in subsequent analysis and equipment sizing calculations.

Complicating contextual factors may cause the standard thermal comfort distribution to shift between summer and winter, and between buildings with mechanical and natural ventilation [11]. Indeed, "because of the large interpersonal variability in thermal requirements, some occupants in any uniformly conditioned environment will be too warm at the same time as others are too cool" [8, pg. 9.25]. A comparison of the 1989 and 2013 versions of the ASHRAE *Fundamentals* thermal comfort chapter shows that the older guidance focused on the central tendency in the distribution of occupant perceptions and responses, but the more recent version focuses also on the distribution of perceptions and behaviors around that central tendency, which opens up new design possibilities such as for personal environmental control systems [8, 12]. On this basis, designers may assume a *distribution* of desired indoor air temperatures when performing analysis and selecting equipment.

The standard distribution approach is transferable in the sense that it is easy to use and has been adopted in many parts of the world. However, it fails to capture the dynamic effects of feedbacks including adaptive responses by occupants to changing building conditions. Simulation modeling is necessary to add the dynamics.

1.2 Calibrating models using occupied buildings

Most building performance models simulate a dynamic system using deterministic equations driven by time-varying physical and behavioral parameters [13]. In an extension of the standard distribution approach discussed previously, guidance manuals such as ANSI/ASHRAE/IES *Standard 90.1* Appendix G [14] specify typical occupancy schedules, diversity factors and other standardized behavioral assumptions to include in simulations of new buildings. However, modelers find that the resulting simulations may not match reality when calibrated against existing buildings [15]. This is unsurprising given the many degrees of freedom in these multi-equation models.

Standardized calibration approaches have therefore emerged, with most relying on manual, iterative adjustments of parameters for a few key variables [16]. A growing literature recommends setting goodness-of-fit criteria in advance, gathering detailed data over time and by zone, seeking independent measurement of weather-related and internal loads, tuning weather-dependent variables first, and expecting more experienced modelers to fare better than those with less experience [17-22]. A complementary literature recommends statistical strategies for managing this underdetermined optimization problem by using systematic searches or heuristic strategies to identify the most influential variables, using penalty functions to reduce overall error, and taking spot measurements to reduce key uncertainties [23, 24, 16]. A consistent finding is that statistical noise due to occupancy patterns and occupant behavior limits the accuracy of calibration efforts [25, 26]. Most of these factors limit the transferability of calibrated models from existing to future buildings. Instead, it seems that the experience of the modeler is the most transferable element.

1.3 Co-simulating occupant behavior & building performance

Social and behavioral scientists have a long tradition of modeling human behavior [27, 28], and computer scientists have developed a parallel tradition relying on a procedural rather than correlative framing of behaviors, e.g., [29-31]. Recently a new class of building energy performance simulation models focusing on occupant behavior has emerged that favors probabilistic, Markov process, and agent-based modeling approaches to represent interactions between building systems and occupants, e.g., [32-35]. Of particular interest are models that co-simulate occupant behavior and building performance by dynamically coupling behavioral models with standard design tools such as *EnergyPlus* using interface ontologies such as *obXML* [36, 37].

Calibration of a coupled occupant behavior and building performance modeling system is an elaborate and interactive process that involves collecting the usual detailed data on building geometry and energy consumption at both the component and building-wide levels, as well as detailed data on occupancy patterns, occupant sensations and perceptions, and their adaptive responses to conditions in the building [38]. As was the case with building performance models discussed previously, calibration efforts are typically manual, iterative and rely on heuristics and the modeler's expertise. The constraining factor is usually the limited amount of occupant behavior data that is available, even for a well-funded study of an existing building.

1.4 Representative occupant population

Most research in the occupant behavior domain involves small data sets. Some researchers pursue longitudinal studies of a small number of occupants, e.g., [36], others do cross-sectional studies of a larger number of occupants, e.g., [39]. The typical calibration approach combines top-down and bottom-up elements by codifying a theory of human behavior in equations and fitting the parameters of those equations. One approach, reflecting the current state of data, is to focus on the distribution of values for each modeling parameter separately, that is, assuming independent bivariate functional relationships. This allows the modeler to borrow parameters and standard distributions from others to apply in the model when local data are not available. The modeling framework then needs to incorporate logic showing how these functional relationships interact to yield multivariate covariance, as is shown in [36]. A second approach, which the current paper advances, is to focus even more ambitiously on a representative population of occupants in order to capture interactions and covariation within a defined set of contextual parameters. Such a data set would be particularly helpful for calibrating agent-based models of occupant behavior but it should also be useful in other modeling traditions.

It is easier to imagine a representative population of building occupants than to find one that is well documented. There are many potential variables of interest, such as age, gender, schedule (daily, weekly, seasonal), metabolism, clothing, multiple adaptive behaviors, and comfort perceptions, and many measured values are context-dependent [40]. Currently, there is much data on thermal comfort and less on lighting, adaptive responses, and social aspects of behavior. In the long run, “big” behavioral data from smart buildings with ubiquitous sensors and interactive features will emerge. In the meantime, it is necessary to aggregate many small data sets together to provide an adequate foundation for the desired representative population of building occupants.

This paper illustrates that process by aggregating three disparate data sets, exploring the properties of each separately and in aggregate, and anonymizing the data by creating a synthetic population with covariance characteristics that are similar to the underlying data set. Given occupants’ privacy concerns, an important benefit of creating a synthetic population is to preserve anonymity in data sets that could become widely used in practice [41]. Its focus is commercial buildings.

Procedures for developing synthetic populations have not yet been applied to building occupant modeling but they been widely used in other fields including demography, public health and urban planning. Basic procedures are available for adjusting a sampled frequency table when the marginal tables are known [42]. An early application in micro-simulation modeling of local transportation system demand uses iterative proportional fitting to draw records from a data set in proportion to the marginal frequencies in a multi-way table of variables of interest, that is, by adjusting the covariance characteristics of a synthetic population to selected U.S. Census variables [43]. A more recent application synthesizes local population characteristics for use in an agent-based model of infectious disease epidemics [44].

Three main synthesis procedures are used: deterministic reweighting, conditional probability (Monte Carlo simulation) and combinatorial optimization (simulated annealing), with the last preferred if data and computing resources allow [45]. Deterministic re-weighting is computationally quickest and requires less setup, but along with the more computation-intensive conditional probability approach it is sensitive to the specification of constraint order and limited in the number of constraints applied; whereas simulated annealing (very computation-intensive) is not [45]. Simple versions of the conditional probability approach, such as sampling with replacement, suffer when there is missing data, but for multiple imputation of missing data, fully conditional specification (FCS) and multivariate normal imputation (MVNI) methods perform adequately [46, 47]. An implementation in **R**, used in the current paper, relies on classification and regression trees (CART) to generate synthetic populations [48].

2.0 Data and Methods

2.1 Combining three data sets

This section introduces three data sets of occupant behavior in commercial buildings that individually have complementary strengths and weaknesses, and that may have different properties when combined. These data form the basis for generating a synthetic sample of building occupants. They include a recent "cross-sectional" data set, a recent "longitudinal" data set, and the older, larger-scale ASHRAE RP-884 data set. The longitudinal data set is described in detail elsewhere [36] and it consists of twice-daily surveys conducted in 2012 and 2013 of 24 occupants of a single office building in Philadelphia for two-week periods in four seasons of one year, accompanied by more frequent observations of indoor and outdoor temperatures and other environmental factors. The much older and larger ASHRAE RP-884 data set has also been well described previously [11] and it includes 20,215 occupant thermal sensation data points spread across 160 buildings worldwide in a mix of cross-sectional and longitudinal data recorded during 1982 to 1997.

The more recent cross-sectional data set draws on a variety of small-N studies of occupant behavior in office buildings conducted by the authors between 2009 and 2014. The studies investigate a variety of questions including the range and frequency of adaptive responses, underlying reasons for particular behaviors, and selected physiological, psychological, social, and organizational factors that might influence comfort perceptions and adaptive behaviors. These studies were not designed beforehand for data pooling but it has proved to be feasible based on comparable parameters and some common protocols. The studies that contribute to the cross-sectional pooled data set are from surveys, interviews, and observations of 16 commercial buildings located in or near Philadelphia, PA, in ASHRAE Climate Zone 4A (Mixed Humid), including a total of 954 occupants, most performing office work [38, 39]. The supplemental material provides details on covariance characteristics of the data [49].

The process of pooling multiple data sets (longitudinal, cross-sectional, and the larger-scale ASHRAE RP-884) is to: (a) locate the data and code books for each study; (b) identify studies that include, at minimum, objective measurements of outside air temperature, indoor air temperature, thermal sensation perceptions, and frequency of a set of adaptive behaviors such as adjusting a thermostat or using a local space heater; (c) develop an equivalence basis to convert the various data coding schemes to a common scheme, and carry out the data transformations; (d) pool the data; (e) perform imputation of missing values to the extent it is reasonable to do so; (f) investigate bivariate and multivariate relationships in the underlying data sets; (g) replicate these investigations using the combined data set; and (h) characterize how robust the evidence is for specific bivariate and multivariate relationships in the combined data set.

Although created for different purposes, the three data sets share several variables in common as summarized in Figure 1. Definitions of the variables are shown in Table 1. Descriptive statistics for a selection of the shared variables are summarized in Table 2.

[Figure 1 Overlapping data fields in cross-sectional, longitudinal and ASHRAE RP-884 data sets about here]

[Table 1 Definitions of variables in occupant behavior data sets about here]

[Table 2 Descriptive statistics for selected shared variables in cross-sectional, longitudinal and ASHRAE RP-884 data sets]

The three data sets document different occupants, buildings, locations, and dates, but they show some consistent patterns. Among the variables summarized in Figure 1 and Table 2 (on a partial basis), the three data sets have statistically identical means for availability of portable space heaters and several other variables not shown to save space including availability of portable fans and the frequency of operation of portable fans. The means differ significantly for occupant age, occupant sex, daily average outdoor air temperature, and other variables not shown including daily average outdoor relative humidity, indoor air temperature, satisfaction with thermal conditions, availability of operable windows, and the frequency of operation of windows, interior doors, thermostats, and portable space heaters.

The combined data set inherits characteristics of the three underlying data sets in proportion to the number of observations in each. Thus the ASHRAE RP-884 data dominate the combined data set, and the small, cross-sectional data set is least influential. Table 2 confirms that the descriptive statistics of the combined data set are most similar to the ASHRAE RP-884 data set, which has older occupants, more naturally ventilated buildings, and warmer outdoor temperatures than in the smaller, more recent data sets.

2.2 Creating the synthetic population

This research employs the statistical software **R** to develop synthetic versions of the original data sets, The **R** code and results for this are given in the Appendix. The rows in Table 2 that are labeled "Synthetic" show summary statistics by variable.

2.3 Comparing covariance structures

We illustrate key aspects of the covariance structure within each data set by showing how well common explanatory variables predict an occupant behavior of interest in a series of logistic regression models. Logistic regression is an appropriate choice because the dependent variable is binary—whether an occupant has acquired a portable space heater (1=Yes, 0=No). Acquisition of a portable space heater is an interesting occupant behavior because it is maladaptive—it can impose a large energy consumption burden on a building.

3.0 Results

The mean of each variable shown in Table 2 is statistically identical at the 95% confidence level in the Synthetic and Combined Observed data sets based on paired t-tests. Table 3 shows regression models for the underlying observed data sets, the combined observed data set, and the synthetic data set. These models predict whether occupants have acquired portable space heaters. Explanatory variables include average outdoor air temperature, average indoor air temperature, occupant age, and occupant sex. As expected, the model based on the combined data set is most similar to that based on the large ASHRAE RP-884 data set. The models based on the smaller longitudinal and cross-sectional data sets lack explanatory power. All models agree on the sign (and with the exception of the small cross-sectional data set, the significance) of outdoor air temperature and occupant age in predicting portable heater acquisition, with colder locations and younger occupants being more likely to have heaters. The combined observed data set also supports significant roles for indoor air temperature and sex, with buildings having colder indoor temperatures and female occupants being more likely to have heaters.

Table 4 shows how the same regression model formulations perform on three selected subsets of the observed and synthetic data sets: (1) a selection including only naturally ventilated buildings; (2) a selection that only includes male occupants; and (3) a selection that only includes occupants under age 40. Models using the synthetic data are very similar to those using the observed data, further building our confidence that the synthetic data set closely matches the covariance structure of the combined observed data set.

In our portable space heater acquisition example shown in Table 4, the model has more explanatory power in naturally ventilated buildings than in the overall data set which also includes mechanically cooled and mixed buildings that are presumably more centrally controllable. Outdoor air temperature also plays a greater explanatory role, and indoor air temperature and age play lesser roles in naturally ventilated buildings. When selecting by gender, the explanatory power of age increases. When selecting by age, the explanatory power of gender does not change much. Table 4 thus illustrates how a synthetic population can be tailored to expected occupant and context profiles during prospective modeling supporting a design process.

4.0 Discussion

The previous section demonstrates the process of combining several data sets and then generating synthetic data. The descriptive statistics and modeling illustrate how well the process works, as well as the limitations of the process.

The combined observed data set has a covariance structure that echoes many of the patterns found in the underlying sources. Those original observed data sets draw on different enough locations, buildings, and people so that full decomposability is not expected, that is, the three original and the combined data sets are unlikely to exhibit identical covariance structures. Table 3 illustrates this finding, showing models built from each of the four data sets to predict a key adaptive action taken by occupants to local thermal comfort conditions. They differ from one another.

The underlying data sets each have strengths and weaknesses. The longitudinal data set provides a strong basis for exploring multivariate relationships, albeit within a narrow band defined by a single building and location, for 24 occupants. The cross-sectional data set proves to be too thin to support much multivariate analysis on thermal comfort adaptations. It draws on a larger number of respondents and buildings than the longitudinal data set but is more valuable for enumerating the range of conditions and occupant responses than for precisely characterizing the most common occupant behaviors. The older, larger ASHRAE RP-884 data set much more robustly supports multivariate analysis, although it is not perfectly targeted to the occupant behavior topic.

The combined data confirm several expected relationships along the causal chain from environmental condition, to environmental perceptions, to adaptive actions to improve thermal conditions (and lighting conditions, not discussed here). The data possess face validity because they demonstrate relationships previously identified in the literature. Similarly, relationships between thermal sensations and adaptive actions manifest mostly as expected.

Multivariate analysis is feasible with the combined data set. For example, the data support expected relationships between outdoor air temperature, indoor air temperature, age, sex, and the acquisition of local space heaters by occupants, as summarized by the models in Table 3. It is unable to characterize expected organizational influences on individual access to space heaters [50]. The combined data set is adequate for seed development of a synthetic population of building occupants that can be used by practitioners but it will be even more useful if it incorporates more data from other research groups. The synthetic data set supports multivariate relationships among dependent and explanatory variables that are very similar to those observed in the underlying combined data set.

A well-calibrated synthetic data set represents a more highly transferable form of occupant behavior information than (1) standard distributions, (2) building performance models calibrated to occupied existing buildings, and (3) building performance models linked in co-simulations to occupant behavior models calibrated to existing occupied buildings. It incorporates contextual information by supporting multivariate modeling of explanatory and dependent variables. It is flexible because it can support a variety of modeling approaches.

5.0 Conclusions and Recommendations

This paper focuses on methodology development to help set the scope for future work in assembling combined occupant behavior data sets and generating synthetic populations. Our data sets and **R** code are available at [49]. The creation of highly polished, large-N synthetic populations suitable for immediate use by building modeling practitioners will have immense practical value.

However, assembling disparate data sets into a combined data set to provide an empirical basis for synthesis involves significant challenges. Although we demonstrate the feasibility of assembling a useful combined data set from existing field studies, building designers would benefit if researchers develop a common core protocol that individual research groups willingly implement with rigor, and if they focus on the subset of occupant behavior topics that are (1) most relevant to simulation modeling aspects of design practice and are (2) also under-documented. These include adaptive responses to thermal and lighting comfort conditions and how they vary systematically by context and the occupant's personal attributes.

Transforming a combined data set into a synthetic occupant population for use by design practitioners is additionally valuable because it eliminates the risk that specific building occupants could be identified and thereby avoids potential research ethics concerns. Alternatives procedures for synthesizing data sets need to be compared in applications to occupant behavior data to identify those that are superior.

Synthetic data sets necessarily tie their content to specific modeling approaches, hence it is important to be able to generate tailored synthetic data to meet the needs of each modeling tradition. The emerging practice of linking separate occupant behavior and building performance simulation models in a co-simulation framework will particularly benefit from such data. For example, it could serve as an input to an occupant behavior co-simulation module such as that described in [34] and it could interface with an industry-standard tool provided with a co-simulation interface such as one now under development in [37]. The general structure of the framework in [37] includes space records, occupant records, behavior records, and schedule records. Each occupant has a name, age, gender, lifestyle, job type, and list of behaviors. Behaviors include occupant movements that are scheduled within space, plus a variety of adaptive responses to environmental conditions. The synthetic data described in the current paper match some of the available data fields, including location, occupant characteristics, and schedule. The synthetic population by necessity will not include location or schedule data because it is meant to be usable for studying occupant behavior in hypothetical buildings during the design process. Therefore any associated modeling framework will need to assign occupants to locations and schedules.

Finally, it is important to remember that many aspects of design practice are best served by identifying central tendencies and standard distributions of occupant behavior variables. Synthetic populations of building occupants are a useful tool for some but not all aspects of building performance modeling practice.

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Appendix: **R** code for generating synthetic data

To generate synthetic data sets we use an add-on package to **R** introduced in [48], **synthpop**

via

```
R> library("synthpop")
```

Before synthesizing the original data set by calling the function **syn()**, we need to load the file containing the data set into a data frame. The data set also needs to be clarified and recoded before being ready for analysis. The missing data code in the data set is recoded to **R**'s missing data code "NA." To make the process reproducible, an additional parameter **seed** is used. The resulting object of class **synds** is here called **sdata**, where sobdata stands for "synthesized occupant behavior dataset". The parameter **m** indicating the number of synthesis instances is set to 5 in order to generate several versions of the synthetic data that are then averaged, and other arguments are left as defaults. The parameter **drop.not.used** is set to FALSE (otherwise the method and **predictor.**matrix will miss information on variables that are excluded from the model). By default, all variables except for the first one in the visit sequence (**visit.sequence**) are synthesized using the **ctree** implementation of CART models that can handle any type of data. The first variable is a random sample with replacement drawn from its observed values. The **R** code for this is given below.

```
R> odata = read.csv("odata.csv")
R> head(odata)
R> odata $Age <- as.factor(odata$Age)
R> odata$Sex <- as.factor(odata $Sex)
R> odata $Fheater <- as.factor(odata $Fheater)
R> odata $Fportfan <- as.factor(odata $Fportfan)
R> my.seed <- 17914709
R> sdata <-syn(odata, m = 1, drop.not.used = FALSE, seed =
my.seed)
```

```
R> modelFheater.sdata <- glm.synds(Fheater ~ Age + Sex + dayav_ta
+ dayav_rh + TA_M, family = "binomial", data = sdata)

R> modelFheater.sdata <- glm(Fheater ~ Age + Sex + dayav_ta +
dayav_rh + TA_M, family = "binomial", data = odata)

R> compare.synds(sdata, odata, vars="Fheater")

R> compare.fit.synds(modelFheater.sds, odata)
```

A **synthpop** function, **compare.synds()**, provides an easy way to compare the synthesized variables with the original ones. It takes arguments of a synthetic data object and a data frame with original data and compares relative frequency distributions of each variable in tabular and graphic form. It can also be used for a subset of variables specified by a **vars** argument. We estimate the original data model using generalized linear model implemented in **R glm()** function. A function **glm.synds()** of the **synthpop** package estimates models for each of the **m** synthesized data sets. Function **compare.fit.synds()**, used in the code, allows the comparison of the estimates based on the synthesized data sets and those based on the original data.

Table 1: Definitions of variables in occupant behavior data sets

Variable	Definition
Age	1=0-19, 2=20-29, 3=30-39, 4=40-49, 5=50-59, 6=60-69, 7=70-79
Sex	1=male, 2=female
dayav_ta	outdoor average air temperature on day of survey, C
TA_M	indoor air temperature at 0.6 m above floor, C
Hheater	respondent's access to portable space heater, 1=has access, 0=doesn't have access
Ventcat	1=Mixed, 2=HVAC, 3=Natural ventilation
	The following variables are not shown in subsequent tables & charts to save space:
dayav_rh	outdoor average relative humidity on day of survey, %
HOpWin	respondent's access to operable windows, 1=has access, 0=doesn't have access
HInDoors	respondent's access to interior doors, 1=has access, 0=doesn't have access
Htstat	respondent's access to thermostat, 1=has access, 0=doesn't have access
Hblinds	respondent's access to window blinds, 1=has access, 0=doesn't have access
Hportfan	respondent's access to portable fan, 1=has access, 0=doesn't have access
FOpWin	how often respondent adjusts windows, 1=na, 2=never, 3=rarely, 4=sometimes, 5=often, 6=always
FInDoors	how often respondent adjusts interior doors, 1=na, 2=never, 3=rarely, 4=sometimes, 5=often, 6=always
Ftstat	how often respondent adjusts thermostat, 1=na, 2=never, 3=rarely, 4=sometimes, 5=often, 6=always
Fblinds	how often respondent adjusts window blinds, 1=na, 2=never, 3=rarely, 4=sometimes, 5=often, 6=always
Fportfan	how often respondent adjusts portable fan, 1=na, 2=never, 3=rarely, 4=sometimes, 5=often, 6=always
Fheater	how often respondent adjusts portable space heater, 1=na, 2=never, 3=rarely, 4=sometimes, 5=often, 6=always
SATEMP	respondent’s satisfaction with workspace temperature, 1=low to 7=high
Source	1=Longitudinal data set, 2=Cross-sectional data set, 3=ASHRAE RP-884 data set

Table 2: Descriptive statistics of selected shared variables in cross-sectional, longitudinal, and ASHRAE RP-884 observed data sets and the synthetic data set

Variable	Source	Mean	Standard Deviation	Minimum	Maximum	N
Age	Longitudinal	4.13	1.30	2.00	6.00	2408
	Cross-sectional	3.93	1.32	1.00	7.00	748
	ASHRAE RP-884	2.50	1.31	1.00	7.00	18834
	Combined	2.72	1.42	1.00	7.00	21990
	Synthetic	2.73	1.42	1.00	7.00	22004
Sex	Longitudinal	1.64	0.48	1.00	2.00	2497
	Cross-sectional	1.43	0.50	1.00	2.00	791
	ASHRAE RP-884	1.50	0.50	1.00	2.00	24212
	Combined	1.51	0.50	1.00	2.00	27500
	Synthetic	1.51	0.50	1.00	2.00	27465
Dayav_ta	Longitudinal	14.85	10.47	-5.00	33.00	2497
	Cross-sectional	16.94	5.16	1.56	26.50	955
	ASHRAE RP-884	18.93	9.92	-24.90	35.00	24847
	Combined	18.50	9.92	-24.90	35.00	28299
	Synthetic	18.48	9.89	-24.90	35.00	28262
TA_M	Longitudinal	23.21	1.46	16.39	27.75	2480
	Cross-sectional	24.15	0.71	21.00	25.89	600
	ASHRAE RP-884	22.07	8.36	0.00	42.67	24734
	Combined	22.22	7.91	0.00	42.67	27814
	Synthetic	22.21	7.92	0.00	42.50	27804
Hheater	Longitudinal	0.22	0.42	0.00	1.00	2269
	Cross-sectional	0.26	0.44	0.00	1.00	307
	ASHRAE RP-884	0.24	0.43	0.00	1.00	11544
	Combined	0.24	0.43	0.00	1.00	14120
	Synthetic	0.24	0.43	0.00	1.00	13855
Ventcat	Longitudinal	1.00	0.00	1.00	1.00	2497
	Cross-sectional	1.97	0.35	1.00	3.00	955
	ASHRAE RP-884	2.45	0.54	1.00	3.00	25124
	Combined	2.30	0.66	1.00	3.00	28576
	Synthetic	2.30	0.66	1.00	3.00	28576

Table 3: Logistic Regression Models for Underlying Observed Data Sets and Synthetic Data Set

Data Set	Longitudinal Observed	Cross-sectional Observed	ASHRAE RP-884 Observed	Combined Observed	Synthetic
Dependent Variable	Hheater				
Explanatory Variables	Coefficient (Std Dev)				
dayav_ta	-0.017** (0.006)	-0.052 (0.047)	-0.026*** (0.003)	-0.012*** (0.003)	-0.015*** (0.003)
TA_M	0.201*** (0.047)	-0.056 (0.231)	-0.361*** (.011)	-0.338*** (0.009)	-0.321*** (0.009)
Age	-0.318*** (0.048)	-0.005 (0.136)	-0.111*** (0.026)	-0.130*** (0.020)	-0.080*** (0.021)
Sex	0 (omitted)	-0.863* (0.369)	0.518*** (0.062)	0.837*** (0.055)	0.710*** (0.055)
Constant	-3.740** (1.088)	2.960 (5.72)	7.156*** (0.258)	5.930*** (0.219)	5.670*** (0.210)
Number of obs	1,495	147	8,674	10,894	10,878
LR $chi^2(5)$	70	7	3,231	3,162	2,823
Prob > chi^2	0.000***	0.14	0.000***	0.000***	0.000***
Pseudo R^2	0.04	0.04	0.32	0.25	0.23

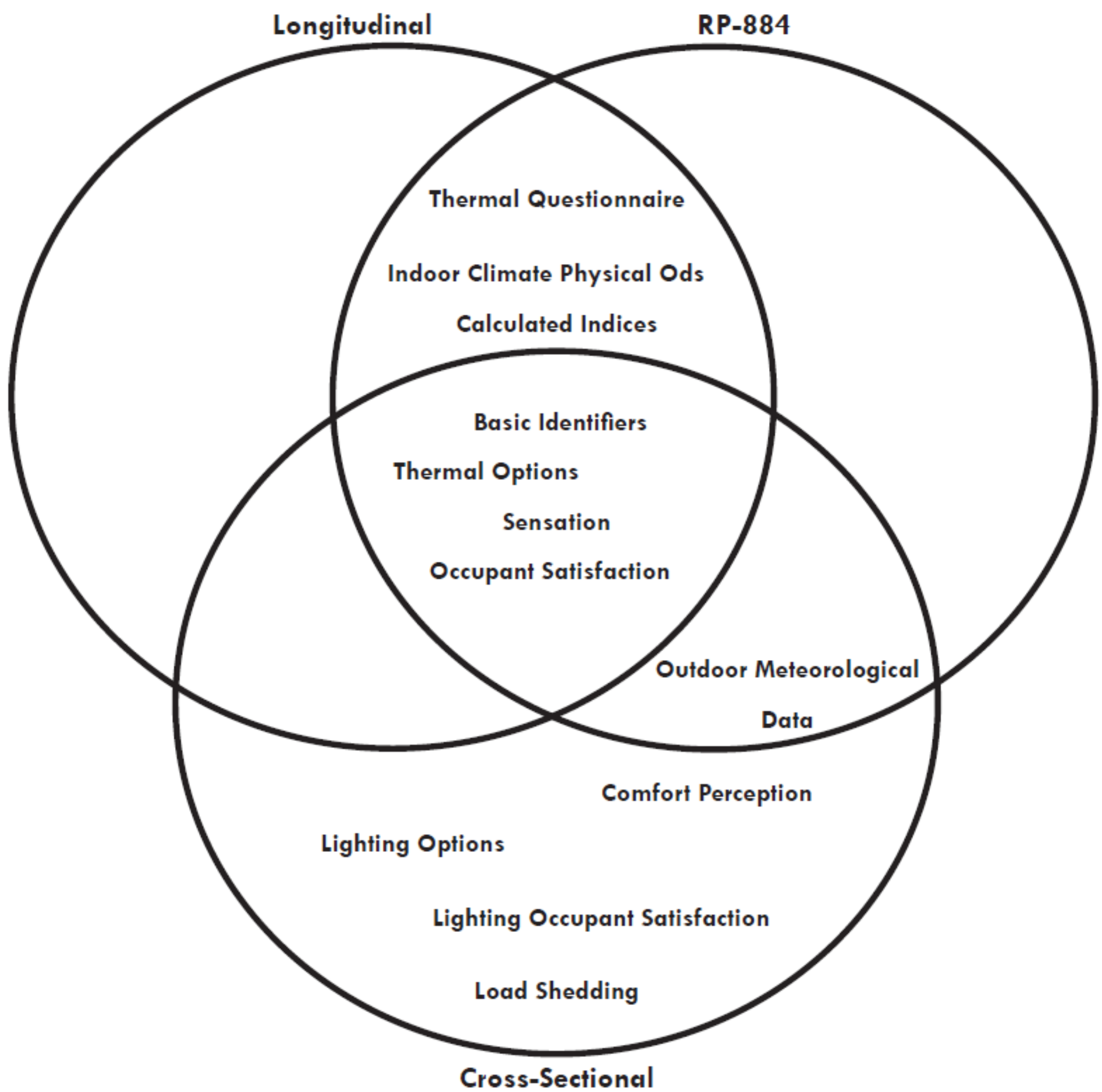
Note: Asterisks show which variables are significant at the 0.1 level (*), 0.01 level (**), and 0.001 level (***).

Table 4: Logistic Regression Models for Selected Subsets within Original and Synthetic Data Sets

Selection	Naturally ventilated buildings		Male occupants		Occupant age <40	
Data Set	Observed (Combined)	Synthetic	Observed (Combined)	Synthetic	Observed (Combined)	Synthetic
Dependent Variable	Hheater					
Explanatory Variables	Coefficient (Std Dev)					
dayav_ta	-0.204*** (0.012)	-0.184*** (0.011)	-0.015** (0.005)	-0.010*** (0.005)	-0.018*** (0.004)	-0.014** (0.004)
TA_M	-0.159*** (0.014)	-0.178*** (0.014)	-0.279*** (0.013)	-0.269*** (0.013)	-0.325*** (0.012)	-0.324*** (0.012)
Age	-0.357*** (0.039)	-0.222*** (0.037)	-0.387*** (0.039)	-0.369*** (0.039)	-0.260*** (0.054)	-0.231*** (0.054)
Sex	0.878*** (0.091)	0.629 (0.089)	0 (omitted)	0 (omitted)	0.666*** (0.071)	0.512*** (0.072)
Constant	6.600*** (0.281)	6.690*** (0.272)	6.220*** (0.305)	5.890*** (0.277)	6.250*** (0.279)	6.280*** (0.268)
Number of obs	5,086	4,949	4,785	4,710	6,334	6,297
LR chi2(5)	3,191	3,037	991	1,093	2,082	1,986
Prob > chi2	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
Pseudo R2	0.47	0.46	0.21	0.22	0.29	0.28

Note: Asterisks show which variables are significant at the 0.1 level (*), 0.01 level (**), and 0.001 level (***).

Figure 1: Overlapping data fields in cross-sectional, longitudinal and ASHRAE RP-884 data sets



Occupant Behavior in Commercial Buildings: Synthetic Population, Co-Simulation, with EnergyPlus and Agent Based Modeling

Acknowledgements & Disclaimer

This research was supported by the Consortium for Building Energy Innovation, sponsored by the U.S. Department of Energy under Award Number DE-EE0004261.

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Project Name

Occupant Behavior in Commercial Buildings: Synthetic Population,
Co-Simulation with EnergyPlus and Agent Based Modeling

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Disclaimer and Acknowledgement

This research was supported by the Consortium for Building Energy Innovation, sponsored by the U.S. Department of Energy under Award Number DE-EE0004261.

Description

These files accompany a technical manual titled: "Occupant Behavior in Commercial Buildings: Synthetic Population, Co-Simulation with EnergyPlus and Agent Based Modeling".

This project describes the steps involved in the Co-Simulation of Synthetic Population with EnergyPlus project. It includes writing co-simulation codes on obXML format by using a standardized occupant behavior modeling tool, obFMU and co-simulation with EnergyPlus using ExternalInterface. The building model was created by Ke Xu as part of his dissertation project (Xu, 2012)

The project presents the processes involved in the Agent Based Modeling (ABM) project. It first describes the characteristics of building occupant agents and their interactions with the building and each other. It also covers a step-by-step instruction of setting up and running an ABM model on NetLogo, an ABM modeling tool written in Java.

The also includes processes involved in the Agent Based Modeling (ABM) project. It first describes the characteristics of building occupant agents and their interactions with the building and each other. It also covers a step-by-step instruction of setting up and running an ABM model on NetLogo, an ABM modeling tool written in Java.

References

Xu, K. (2012). “Assessing the minimum instrumentation to well tune existing medium sized office building energy models.” Ph.D. dissertation in Architectural Engineering.

Pennsylvania State University. University Park, PA.

List of Files

- README.txt - a description file
- Building101_2ndfloor.idf - EnergyPlus building model file
- obCoSim.xml - An example file describing the simulation time step, and the space mapping between obXML and the IDF.
- obFMU.fmu - obFMU cosimulation file
- obXML.xml - An example of obXML file generated based on obXML schema.
- Occupant_model.nlogo - a NetLogo file of Agent Based Model
- Weather file and datasets can be found at the link below:
  http://en.openei.org/datasets/dataset/ob-commercial-building

obCoSim.xml file

-


```
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```

```
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will be saved to the log file. -->
            <!-- The file should located in the same folder of the obFMU.fmu -->

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e>
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            <!-- End at 24:00:00 -->
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obXML.xml file

```
-----------------------------------------------------------------------------------------------
-
```


```
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```
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            <BehaviorID>B_W2</BehaviorID>
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office</Description>
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      <PercentTimePresence>5</PercentTimePresence>
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<SpaceCategory>OtherOffice</SpaceCategory>

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<SpaceCategory>MeetingRoom</SpaceCategory>

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illuminance">
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                              <DayofWeek>Weekday</DayofWeek>
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                              <DayofWeek>Weekday</DayofWeek>
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illuminance">
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Function</Description>
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                  <Drivers>
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                              <DayofWeek>Weekday</DayofWeek>
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                        </Interaction>
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                  <DayofWeek>Weekday</DayofWeek>
                  <SeasonType>Winter</SeasonType>
            </Time>
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            <OtherConstraint>NoOccupantsInRoom</OtherConstraint>
      </Drivers>
      <Actions>
            <Interaction>
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      </Systems>
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      <Drivers>
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                  <DayofWeek>Weekday</DayofWeek>
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            </Environment>
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Function</Description>
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            <Drivers>
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                        <DayofWeek>Weekday</DayofWeek>
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    </Behavior>



    <Behavior ID="B_AC1">
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        <Drivers>
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        </Drivers>
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        </Actions>
        <Systems>
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                    <DayofWeek>Weekday</DayofWeek>
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                            <CoefficientC>8</CoefficientC>
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            </Systems>
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                    <DayofWeek>Weekday</DayofWeek>
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                </Time>
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```
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                </HVAC>
            </Systems>
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			</Drivers>
			<Needs>
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			<Actions>
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							<CoefficientC>8</CoefficientC>
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                    </Time>
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                </Drivers>
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16</Date></Holiday>
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            <Holiday Name="Veterans Day"><Date>2015-11-11</Date></Holiday>
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Building101_2ndfloor.idf

-


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occupants.</Description>
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                  <Address>Philadelphia Navy Yard</Address>
                  <Spaces ID="Spaces_0">
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                              <Description>Outdoor space</Description>
                              <Type>Outdoor</Type>
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&lt;/Space&gt;
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&lt;/Space&gt;
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      <BehaviorID>B_L3</BehaviorID>

      <BehaviorID>B_Therm1</BehaviorID>
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      <BehaviorID>B_Therm3</BehaviorID>


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      <BehaviorID>B_AC2</BehaviorID>
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      <BehaviorID>B_AC1</BehaviorID>
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      <BehaviorID>B_AC1</BehaviorID>
      <BehaviorID>B_AC2</BehaviorID>
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      <BehaviorID>B_Therm3</BehaviorID>


      <BehaviorID>B_AC5</BehaviorID>
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      <BehaviorID>B_Therm3</BehaviorID>


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      <BehaviorID>B_AC7</BehaviorID>

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      <BehaviorID>B_W1</BehaviorID>
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      <Gender>Female</Gender>
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      <BehaviorID>B_PHeat1</BehaviorID>
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      <BehaviorID>B_PHeat3</BehaviorID>

      <BehaviorID>B_Therm1</BehaviorID>
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      <BehaviorID>B_Therm3</BehaviorID>


      <BehaviorID>B_AC5</BehaviorID>
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      <BehaviorID>B_PHeat3</BehaviorID>

      <BehaviorID>B_Therm1</BehaviorID>
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      <BehaviorID>B_Therm3</BehaviorID>


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      <BehaviorID>B_PHeat1</BehaviorID>
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      <BehaviorID>B_PHeat3</BehaviorID>

      <BehaviorID>B_Therm1</BehaviorID>
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      <BehaviorID>B_PHeat3</BehaviorID>

      <BehaviorID>B_Therm1</BehaviorID>
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      <BehaviorID>B_Therm3</BehaviorID>


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      <BehaviorID>B_AC2</BehaviorID>
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      <BehaviorID>B_PHeat1</BehaviorID>
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      <BehaviorID>B_PHeat3</BehaviorID>

      <BehaviorID>B_Therm1</BehaviorID>
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      <BehaviorID>B_AC1</BehaviorID>
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      <BehaviorID>B_PHeat1</BehaviorID>
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      <BehaviorID>B_PHeat3</BehaviorID>

      <BehaviorID>B_Therm1</BehaviorID>
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      <BehaviorID>B_Therm3</BehaviorID>


      <BehaviorID>B_AC1</BehaviorID>
      <BehaviorID>B_AC2</BehaviorID>
      <BehaviorID>B_AC3</BehaviorID>
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      <BehaviorID>B_PHeat1</BehaviorID>
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      <BehaviorID>B_PHeat3</BehaviorID>

      <BehaviorID>B_Therm1</BehaviorID>
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      <BehaviorID>B_AC2</BehaviorID>
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      <BehaviorID>B_Therm3</BehaviorID>


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      <BehaviorID>B_AC2</BehaviorID>
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      <BehaviorID>B_Therm1</BehaviorID>
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      <BehaviorID>B_AC1</BehaviorID>
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      <BehaviorID>B_AC1</BehaviorID>
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        <BehaviorID>B_Therm1</BehaviorID>
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        <BehaviorID>B_AC1</BehaviorID>
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        <BehaviorID>B_Therm1</BehaviorID>
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        <BehaviorID>B_AC1</BehaviorID>
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                <BehaviorID>B_Therm1</BehaviorID>
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                <BehaviorID>B_Therm1</BehaviorID>
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                <BehaviorID>B_AC5</BehaviorID>
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office</Description>
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<SpaceCategory>OtherOffice</SpaceCategory>

<PercentTimePresence>45.0000</PercentTimePresence>
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            <Holiday Name="Columbus Day"><Date>2015-10-02</Date></Holiday>
            <Holiday Name="Veterans Day"><Date>2015-11-11</Date></Holiday>
            <Holiday Name="Thanksgiving Day"><Date>2015-11-26</Date></Holiday>
            <Holiday Name="Christmas Day"><Date>2015-12-25</Date></Holiday>
```

```
    </Holidays>
</OccupantBehavior>
```

Occupant_model.nlogo

-

```
extensions [
  profiler ;; to make the model faster
  array
  table
]
;;__includes [ "_building.nls" "_occupants.nls" "_lighting.nls" "_organization.nls"]

breed [ managers manager ]
breed [ tenantreps tenantrep ]
breed [ occupants occupant ]
breed [ zones zone ]
breed [ equipments equipment ]

globals [
  outContent
  sunrisesetArr skycoverArr daylightArr
  sunrisesetHdrList skycoverHdrList daylightHdrList

  skyCondition

  returnvalue headerListTmp contentListTmp

  bldgElectricity
  bldgEquipmentElectricity
  bldgInteriorLightsElectricity
  bldgHVACElectricity
  bldgGas

  totalFloors

  ;;; TIME ;;;
  totalHours
  daycount startDay startMonth startYear
  currentDay currentMonth currentYear
  currentWeekday weekdaystr endingHour
  listWeekday daysNumInMonth datetime


  ;;; BDI LOOKUP TABLE ;;;
  ;bdiPerception
  bdiActionValsTbl
  bdiPerceptionActionTbl
  clothingTbl

  comfortPMV
  comfortTemperature
  comfortLux

  luxFraction
]

zones-own [
  zoneID
  zoneFloorID
  zoneName
```

```
  zoneFacade
  zoneEquipmentList
  zoneOccupantList
  zoneTenantRep

  zoneLightElectricity
  zoneEquipmentElectricity
  zoneUpdateKWH

  meanAirT
  meanRadiantT
  airRelativeHumidity
  zoneDaylightLux
  zoneKWH


  zoneLightDim
  zoneTaskLightNum
  zonePortableHeaterNum

  zoneLightingDiscomfort          ;; number of lightingdiscomfort
  zoneThermalDiscomfort
  zoneEffort              ;; number of efforts

  zoneControl?

  zoneConsensusValuesTbl
]

equipments-own [
  equipmentID
  equipmentZoneIDList
  equipmentOccupantIDList
  equipmentKWH
]

managers-own [
  mnDoNothingCt
  mnThermostatCt
  mnReportReceivedCt
  mnDoNothingCurrHour
  mnThermostatCurrHour
  mnReportReceivedCurrHour
]

tenantreps-own [
  trZoneID
  trOccupantList

  trDoNothingCt
  trThermostatCt
  trOverheadLightCt
  trReportSentCt
  trReportReceivedCt

  trDoNothingCurrHour
  trThermostatCurrHour
  trOverheadLightCurrHour
  trReportSentCurrHour
  trReportReceivedCurrHour

  trConsensusValuesTbl
]
```

```
occupants-own [
  inZone?
  occZoneID
  occTenantRep

  isTenantRep?

  hasEnergyMon?
  portableHeaterON?
  taskLightON?
  windowsBlindOpen?

  workStartHour
  workEndHour
  workDays

  valOfEI
  valOfEffort
  valOfComfort
  valOfCost

  clothing
  pmvValue
  ppdValue
  temperatureDiff
  luxDiff


  currentPerception
  actionPlan
  currentAction

  occLightingDiscomfort
  occThermalDiscomfort

  occDoNothingCt
  occTaskLightCt
  occWindowsBlindCt
  occClothesCt
  occPortHeaterCt
  occReportSentCt

  occThermalDiscomfortCurrHour
  occLightingDiscomfortCurrHour
  occDoNothingCurrHour
  occTaskLightCurrHour
  occWindowsBlindCurrHour
  occClothesCurrHour
  occPortHeaterCurrHour
  occReportSentCurrHour

]



to GetDateTime
  ;; GET DATE TIME
  let $datetime (GetItemListStr "Date/Time" contentListTmp)
  tokenize $datetime "  "

  let $datestr (item 0 returnvalue)
  let $timestr (item 1 returnvalue)
```

```
  tokenize $datestr "/"
  set currentYear 2015
  set currentMonth read-from-string(item 0 returnvalue)
  set currentDay read-from-string(item 1 returnvalue)
  tokenize $timestr ":"
  set endingHour read-from-string(item 0 returnvalue)

  SetWeekDay currentDay currentMonth currentYear
;print (word weekdayStr " " currentDay "/" currentMonth "/" currentYear " " endingHour
":00:00")
end

to GetBuildingData
  set totalFloors 0
  let $zoneid 0

  let $ptr 0
  while [ $ptr < length headerListTmp ] [
    let $fieldhdr (item $ptr headerListTmp)

    if (member? ":Zone Mean Air Temperature [C](Hourly)" $fieldhdr) [
      tokenize $fieldhdr ":"
      let $floorname (item 0 returnvalue)


      create-zones 1 [
        set zoneName (word $floorname ":" (item 1 returnvalue))
        if member? "0FLOORBASEMENT" $floorname [ set zoneFloorID 0 ]
        if member? "1STFLOOR" $floorname [ set zoneFloorID 1 ]
        if member? "2NDFLOOR" $floorname [ set zoneFloorID 2 ]
        if member? "3RDFLOOR" $floorname [ set zoneFloorID 3 ]
        if member? "ATTIC" $floorname [ set zoneFloorID 4 ]

        set zoneID $zoneid
        set zoneOccupantList []
        set zoneTenantRep nobody

        set zoneControl? false
        if (BldgControlLevel >= 50 and (member? "EOFFICE" zoneName) or (member? "WOFFICE"
zoneName)) [ set zoneControl? true ]
        if (BldgControlLevel >= 75 and member? "OFFICE" zoneName) [ set zoneControl? true
]
        if (BldgControlLevel = 100) [ set zoneControl? true ]

      ]
      set $zoneid ($zoneid + 1)
    ]
    set $ptr ($ptr + 1)
  ]
end

to ResetZoneParams
  set zoneLightingDiscomfort 0
  set zoneThermalDiscomfort 0
  set zoneEffort 0

  set meanAirT (GetItemList (
      word zoneName ":Zone Mean Air Temperature [C](Hourly)") contentListTmp)
  set meanRadiantT (GetItemList (
      word zoneName ":Zone Mean Radiant Temperature [C](Hourly)") contentListTmp)
  set airRelativeHumidity (GetItemList (
      word zoneName ":Zone Air Relative Humidity [%](Hourly)") contentListTmp)
  set zoneLightElectricity (GetItemList (
```

```
      word zoneName ":Zone Lights Electric Energy [J](Hourly)") contentListTmp)
  set zoneEquipmentElectricity (GetItemList (
      word zoneName ":Zone Electric Equipment Electric Energy [J](Hourly)")
contentListTmp)

  set zoneConsensusValuesTbl table:make
end

  ;;; BUILDING WIDE ;;;
to-report bldgNumOccupants
  report count occupants with [ inZone? = true ]
end
to-report bldgKWH
  report 0
end
to-report TotalBldgCost
  report ((bldgElectricity / 360000) * CentsKWH)
end
to-report TotalBldgThermalDiscomfort
  report sum [occThermalDiscomfortCurrHour] of occupants
end
to-report TotalBldgLightingDiscomfort
  report sum [occLightingDiscomfortCurrHour] of occupants
end

to-report TotalBldgEffort
  report TotalOccupantEffort + TotalTenantRepEffort
end

to-report TotalOccupantEffort
  report (sum [occTaskLightCurrHour] of occupants +
   sum [occWindowsBlindCurrHour] of occupants +
  sum [occClothesCurrHour] of occupants +
  sum [occPortHeaterCurrHour] of occupants +
  sum [occReportSentCurrHour] of occupants)
end

to-report CountOccupantsWithPMV [#scale]
  let numOccupants 0
  if #scale = 0 [ set numOccupants (count occupants with [pmvValue < 1]) + (count
occupants with [pmvValue > -1]) ]
  if #scale >= 1 [ set numOccupants (count occupants with [pmvValue >= #scale]) - (count
occupants with [pmvValue >= (#scale + 1)]) ]
  if #scale <= -1 [ set numOccupants (count occupants with [pmvValue <= #scale]) - (count
occupants with [pmvValue <= (#scale - 1)]) ]
  report numOccupants
end

to-report TotalTenantRepEffort
  report (sum [trThermostatCt] of tenantreps +
  sum [trOverheadLightCt] of tenantreps +
  sum [trReportSentCt] of tenantreps)
end

to-report TenantRepReportReceived
  report (sum [trReportReceivedCt] of tenantreps)
end

to-report TotalTenantRepReportSent
  report (sum [trReportSentCt] of tenantreps)
end

to-report TenantRepDoNothing
```

```
  report (sum [trDoNothingCt] of tenantreps)
end

to-report TotalManagerDoNothing
  report (sum [mnDoNothingCt] of managers)
end


;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

to SetupLighting
  if (SimLighting) [
    LightingArrays
    SetupSkyCondition
    set luxFraction 0.18
  ]
end

to-report ConvertJToKWH [#joule]
  report precision (#joule / 3600000) 3
end

to-report ZoneTotalLux
  let $tasklightlux (zoneTaskLightNum * 228)
  report luxFraction * (zoneDaylightLux + ZoneLightLux + $tasklightlux)
end

to UpdateElectricity
  let $lightKWH ((zoneLightDim * zoneLightElectricity) + (zoneTaskLightNum * 100))
  let $equipmentKWH (zoneEquipmentElectricity + (zonePortableHeaterNum * 500))
end

to LightingArrays
  set sunrisesetArr array:from-list n-values 12 [array:from-list n-values 63[0]]
  set skycoverArr array:from-list n-values 1 [array:from-list n-values 13[0]]
  set daylightArr array:from-list n-values 24 [array:from-list n-values 122[0]]

  populate-2darr-0 "daylight.csv"
end

to-report Sunrise
  ;; get sunrise time
  let $dayid ((currentDay * 2) - 1)
  let currentSunrise ((read-from-string (
        Item2dArr sunrisesetArr (currentMonth - 1) $dayid)) / 100)
  ifelse ((currentSunrise - floor currentSunrise) >= .3)
  [set currentSunrise (floor (currentSunrise + 1))]
  [set currentSunrise (floor currentSunrise)]

  report currentSunrise
end

to-report Sunset
  ;; get sunset time
  let $dayid (currentDay * 2)
  let currentSunset ((read-from-string (
        Item2dArr sunrisesetArr (currentMonth - 1) $dayid)) / 100)
  ifelse ((currentSunset - floor currentSunset) >= .3)
  [set currentSunset (floor (currentSunset + 1))]
  [set currentSunset (floor currentSunset)]

  report currentSunset
```

```
end

to-report percentCloudy
  report (round (read-from-string (
        Item2dArr skycoverArr 0 currentMonth)) + random 11 + random -11)
end

to SetupSkyCondition
  let tempvalue (random (93 + 112 + 160))
  if (tempvalue >= 0 AND tempvalue < 93) [set skyCondition ("Clear")]
  if (tempvalue >= 93 AND tempvalue < 205) [set skyCondition ("Partly_Cloudy")]
  if (tempvalue >= 205) [set skyCondition ("Overcast")]
end

to Daylighting
  ZoneFacadeTmpReference
  ifelse zoneFacade = "CENTER" [ set zoneDaylightLux 0 ]
  [
    let $shading "none"
    let $colstr ""
    if (skyCondition = "Clear" OR (skyCondition = "Partly_Cloudy" AND 100 >=
percentCloudy))
    [ if ($shading = "none") [ (set $colstr "CLEARSKY_NOSHADING")]
      ; if ($shading = "overhang") [ (set $colstr "CLEARSKY_OVERHANG")]
      ; if ($shading = "overhang&fins") [ (set $colstr "CLEARSKY_OVERHANGFINS")]
      set $colstr (word $colstr "_" zoneFacade)
    ]
    if (skyCondition = "Overcast" OR (skyCondition = "Partly Cloudy" AND 100 <
percentCloudy))
    [ if ($shading = "none") [ (set $colstr "OVERCAST_NOSHADING")]
      ; if ($shading = "overhang") [ (set $colstr "OVERCAST_OVERHANG")]
      ; if ($shading = "overhang&fins") [ (set $colstr "OVERCAST_OVERHANGFINS")]
    ]

    let $hridx ((endingHour - 1) mod 24)
    ifelse (Sunrise = 4)
    [ set $colstr (word $colstr "_" Sunrise) ]
    [ set $colstr (word $colstr "_" Sunrise "-" Sunset) ]

    let $colidx (position $colstr daylightHdrList)
;   type who type " | " type zoneName type " | " type zoneFloorID type " | " type
zoneFacade type " | " type $colstr type " | " print $colidx
    set zoneDaylightLux (read-from-string(Item2dArr daylightArr $hridx $colidx))

  ]
end

to ZoneFacadeTmpReference
  if zoneName = "0FLOORBASEMENT:ELEVATORPUMPROOM" [ set zoneFacade "CENTER" ]
  if zoneName = "0FLOORBASEMENT:VITETTAOPENOFFICE" [ set zoneFacade "CENTER" ]
  if zoneName = "0FLOORBASEMENT:JANITORROOM" [ set zoneFacade "CENTER" ]
  if zoneName = "0FLOORBASEMENT:FRMRKTCHNLNCHAR" [ set zoneFacade "CENTER" ]
  if zoneName = "0FLOORBASEMENT:NHALLWAY" [ set zoneFacade "CENTER" ]
  if zoneName = "1STFLOOR:OPENOFFICEN119" [ set zoneFacade "NORTH" ]
  if zoneName = "1STFLOOR:MAINENTRANCE" [ set zoneFacade "EAST" ]
  if zoneName = "1STFLOOR:MECHANICALROOM%N108" [ set zoneFacade "CENTER" ]
  if zoneName = "1STFLOOR:MEN%SROOM110" [ set zoneFacade "NORTH" ]
  if zoneName = "1STFLOOR:CONFERENCEROOM114" [ set zoneFacade "NORTH" ]
  if zoneName = "1STFLOOR:CONFERENCEROOM115" [ set zoneFacade "NORTH" ]
  if zoneName = "1STFLOOR:PIDCOPENOFFICE101" [ set zoneFacade "SOUTH" ]
  if zoneName = "1STFLOOR:WOMEN%SROOM109" [ set zoneFacade "SOUTH" ]
  if zoneName = "1STFLOOR:CORRIDORLOBBY106111" [ set zoneFacade "WEST" ]
  if zoneName = "1STFLOOR:PIDCOPENOFFICE103" [ set zoneFacade "WEST" ]
```

```
  if zoneName = "1STFLOOR:OPENOFFICEN117" [ set zoneFacade "WEST" ]
  if zoneName = "1STFLOOR:MECHANICALROOM%S104" [ set zoneFacade "CENTER" ]
  if zoneName = "1STFLOOR:STAIRWELLS%N118" [ set zoneFacade "EAST" ]
  if zoneName = "1STFLOOR:CONFERENCEROOM112" [ set zoneFacade "SOUTH" ]
  if zoneName = "1STFLOOR:STAIRWELLS%S102" [ set zoneFacade "EAST" ]
  if zoneName = "2NDFLOOR:NTELECONFROOM" [ set zoneFacade "NORTH" ]
  if zoneName = "2NDFLOOR:NICONLAB" [ set zoneFacade "NORTH" ]
  if zoneName = "2NDFLOOR:NMECHROOM" [ set zoneFacade "CENTER" ]
  if zoneName = "2NDFLOOR:MPCCNTRLOFFC214" [ set zoneFacade "CENTER" ]
  if zoneName = "2NDFLOOR:SENDOFFICE201" [ set zoneFacade "SOUTH" ]
  if zoneName = "2NDFLOOR:SWOFFICE206" [ set zoneFacade "WEST" ]
  if zoneName = "2NDFLOOR:NWOFFICE222" [ set zoneFacade "WEST" ]
  if zoneName = "2NDFLOOR:SSTAIRWELLSSHALLWAY" [ set zoneFacade "CENTER" ]
  if zoneName = "2NDFLOOR:SEOFFICE205" [ set zoneFacade "EAST" ]
  if zoneName = "2NDFLOOR:NEOFFICE223" [ set zoneFacade "EAST" ]
  if zoneName = "2NDFLOOR:NSTAIRWELLSHALLWAY" [ set zoneFacade "CENTER" ]
  if zoneName = "2NDFLOOR:NHALLWAY" [ set zoneFacade "CENTER" ]
  if zoneName = "2NDFLOOR:SSERVERROOM" [ set zoneFacade "CENTER" ]
  if zoneName = "2NDFLOOR:MPCCNTRLOFFC212" [ set zoneFacade "CENTER" ]
  if zoneName = "2NDFLOOR:MPACECONTROLCONF213" [ set zoneFacade "CENTER" ]
  if zoneName = "3RDFLOOR:NENDOFFICE" [ set zoneFacade "NORTH" ]
  if zoneName = "3RDFLOOR:NMECHROOM" [ set zoneFacade "CENTER" ]
  if zoneName = "3RDFLOOR:MEASTENDOFFICE" [ set zoneFacade "EAST" ]
  if zoneName = "3RDFLOOR:SENDOFFICE" [ set zoneFacade "SOUTH" ]
  if zoneName = "3RDFLOOR:SWOFFICE306" [ set zoneFacade "WEST" ]
  if zoneName = "3RDFLOOR:NWOFFICE318" [ set zoneFacade "WEST" ]
  if zoneName = "3RDFLOOR:SSTAIRWELLSHALLWAY" [ set zoneFacade "CENTER" ]
  if zoneName = "3RDFLOOR:SEOFFICE305" [ set zoneFacade "EAST" ]
  if zoneName = "3RDFLOOR:NEOFFICE319" [ set zoneFacade "EAST" ]
  if zoneName = "3RDFLOOR:NSTAIRWELLSHALLWAY" [ set zoneFacade "CENTER" ]
  if zoneName = "3RDFLOOR:SSERVERROOM" [ set zoneFacade "CENTER" ]
  if zoneName = "ATTICN:ZONE1" [ set zoneFacade "NORTH" ]
  if zoneName = "ATTICS:ZONE1" [ set zoneFacade "SOUTH" ]
  if zoneName = "ATTICEASTEND:ZONE1" [ set zoneFacade "EAST" ]
  if zoneName = "ATTICHALLWAY:ZONE1" [ set zoneFacade "CENTER" ]
  if zoneName = "ATTICMAIN:ZONE3" [ set zoneFacade "CENTER" ]
  if zoneName = "ATTICMAIN:ZONE4" [ set zoneFacade "CENTER" ]
  if zoneName = "ATTICMAIN:ZONE5" [ set zoneFacade "CENTER" ]
end

to-report ZoneLightLux
  if zoneName = "0FLOORBASEMENT:ELEVATORPUMPROOM" [ report (zoneLightElectricity /
417.485) ]
  if zoneName = "0FLOORBASEMENT:VITETTAOPENOFFICE" [ report (zoneLightElectricity /
8998.637) ]
  if zoneName = "0FLOORBASEMENT:JANITORROOM" [ report (zoneLightElectricity / 265.765) ]
  if zoneName = "0FLOORBASEMENT:FRMRKTCHNLNCHAR" [ report (zoneLightElectricity /
7880.176) ]
  if zoneName = "0FLOORBASEMENT:NHALLWAY" [ report (zoneLightElectricity / 1010.729) ]
  if zoneName = "1STFLOOR:OPENOFFICEN119" [ report (zoneLightElectricity / 4191.488) ]
  if zoneName = "1STFLOOR:MAINENTRANCE" [ report (zoneLightElectricity / 91.926) ]
  if zoneName = "1STFLOOR:MECHANICALROOM%N108" [ report (zoneLightElectricity / 401.535)
]
  if zoneName = "1STFLOOR:MEN%SROOM110" [ report (zoneLightElectricity / 1652.958) ]
  if zoneName = "1STFLOOR:CONFERENCEROOM114" [ report (zoneLightElectricity / 772.0934) ]
  if zoneName = "1STFLOOR:CONFERENCEROOM115" [ report (zoneLightElectricity / 415.7434) ]
  if zoneName = "1STFLOOR:PIDCOPENOFFICE101" [ report (zoneLightElectricity / 4515.426) ]
  if zoneName = "1STFLOOR:WOMEN%SROOM109" [ report (zoneLightElectricity / 1550.738) ]
  if zoneName = "1STFLOOR:CORRIDORLOBBY106111" [ report (zoneLightElectricity / 14175.39)
]
  if zoneName = "1STFLOOR:PIDCOPENOFFICE103" [ report (zoneLightElectricity / 4263.468) ]
  if zoneName = "1STFLOOR:OPENOFFICEN117" [ report (zoneLightElectricity / 4587.406) ]
```

```
  if zoneName = "1STFLOOR:MECHANICALROOM%S104" [ report (zoneLightElectricity / 451.1114)
]
  if zoneName = "1STFLOOR:STAIRWELLS%N118" [ report (zoneLightElectricity / 4288.985) ]
  if zoneName = "1STFLOOR:CONFERENCEROOM112" [ report (zoneLightElectricity / 1226.167) ]
  if zoneName = "1STFLOOR:STAIRWELLS%S102" [ report (zoneLightElectricity / 4289.625) ]
  if zoneName = "2NDFLOOR:NTELECONFROOM" [ report (zoneLightElectricity / 1216.66) ]
  if zoneName = "2NDFLOOR:NICONLAB" [ report (zoneLightElectricity / 2877.737) ]
  if zoneName = "2NDFLOOR:NMECHROOM" [ report (zoneLightElectricity / 455.2792) ]
  if zoneName = "2NDFLOOR:MPCCNTRLOFFC214" [ report (zoneLightElectricity / 1790.631) ]
  if zoneName = "2NDFLOOR:SENDOFFICE201" [ report (zoneLightElectricity / 4211.967) ]
  if zoneName = "2NDFLOOR:SWOFFICE206" [ report (zoneLightElectricity / 2806.321) ]
  if zoneName = "2NDFLOOR:NWOFFICE222" [ report (zoneLightElectricity / 3271.193) ]
  if zoneName = "2NDFLOOR:SSTAIRWELLSSHALLWAY" [ report (zoneLightElectricity / 352.81) ]
  if zoneName = "2NDFLOOR:SEOFFICE205" [ report (zoneLightElectricity / 4370.055) ]
  if zoneName = "2NDFLOOR:NEOFFICE223" [ report (zoneLightElectricity / 4370.055) ]
  if zoneName = "2NDFLOOR:NSTAIRWELLSHALLWAY" [ report (zoneLightElectricity / 352.811) ]
  if zoneName = "2NDFLOOR:NHALLWAY" [ report (zoneLightElectricity / 117.57) ]
  if zoneName = "2NDFLOOR:SSERVERROOM" [ report (zoneLightElectricity / 437.973) ]
  if zoneName = "2NDFLOOR:MPCCNTRLOFFC212" [ report (zoneLightElectricity / 747.6314) ]
  if zoneName = "2NDFLOOR:MPACECONTROLCONF213" [ report (zoneLightElectricity / 669.737)
]
  if zoneName = "3RDFLOOR:NENDOFFICE" [ report (zoneLightElectricity / 4211.97) ]
  if zoneName = "3RDFLOOR:NMECHROOM" [ report (zoneLightElectricity / 452.25) ]
  if zoneName = "3RDFLOOR:MEASTENDOFFICE" [ report (zoneLightElectricity / 3208) ]
  if zoneName = "3RDFLOOR:SENDOFFICE" [ report (zoneLightElectricity / 4212) ]
  if zoneName = "3RDFLOOR:SWOFFICE306" [ report (zoneLightElectricity / 2342.39) ]
  if zoneName = "3RDFLOOR:NWOFFICE318" [ report (zoneLightElectricity / 3735) ]
  if zoneName = "3RDFLOOR:SSTAIRWELLSHALLWAY" [ report (zoneLightElectricity / 353) ]
  if zoneName = "3RDFLOOR:SEOFFICE305" [ report (zoneLightElectricity / 4370) ]
  if zoneName = "3RDFLOOR:NEOFFICE319" [ report (zoneLightElectricity / 4370) ]
  if zoneName = "3RDFLOOR:NSTAIRWELLSHALLWAY" [ report (zoneLightElectricity / 352.8) ]
  if zoneName = "3RDFLOOR:SSERVERROOM" [ report (zoneLightElectricity / 437) ]
  if zoneName = "ATTICN:ZONE1" [ report (zoneLightElectricity / 4758.5) ]
  if zoneName = "ATTICS:ZONE1" [ report (zoneLightElectricity / 4758.5) ]
  if zoneName = "ATTICEASTEND:ZONE1" [ report (zoneLightElectricity / 464.3) ]
  if zoneName = "ATTICHALLWAY:ZONE1" [ report (zoneLightElectricity / 282.7) ]
  if zoneName = "ATTICMAIN:ZONE3" [ report (zoneLightElectricity / 6691.1) ]
  if zoneName = "ATTICMAIN:ZONE4" [ report (zoneLightElectricity / 4774.8) ]
  if zoneName = "ATTICMAIN:ZONE5" [ report (zoneLightElectricity / 6691.1) ]
end


;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;


to SimulateOccupantBehavior
; if zoneID = 2 [ type endingHour type " | " type zoneTenantRep type " | " print
zoneOccupantList ]
; if zoneID = 2 [ type endingHour type " | "  foreach zoneOccupantList [ type [
occTenantRep] of ? type ":" type [occZoneID] of ? type ":" type [inZone?] of ? type " | "
] print " " ]

  ;;; reset behavior parameters
  ask managers [ ResetManagerCurrHour ]
  ask occupants with [ occZoneID = [zoneID] of myself ] [
    if endingHour = 1 [ ResetOccupantParams ]
    ResetOccupantCurrHour ]

  ask tenantreps with [trZoneID = [zoneID] of myself ] [
   ResetTenantRepCurrHour ]

  ask occupants with [ occZoneID = [zoneID] of myself ] [
```

```
    OccupantInzone
    OccupantBehavior]

;ask occupants with [occZoneID = [zoneID] of myself] [type who type inZone? type " | "
type occZoneID type " | " ask myself [ type zoneID type " " type zoneTenantRep type " "
type zoneOccupantList ] type " | " print occTenantRep]
  ask tenantreps with [ trZoneID = [zoneID] of myself ] [ TenantRepBehavior ]
  ask managers [ ManagerBehavior ]
end

to OccupantBehavior
  if (SimThermal) [ BDIThermal ]
  if (SimLighting) [ BDILighting ]
end


to-report OccupantEffort
  report ( occTaskLightCt + occWindowsBlindCt + occClothesCt
         + occPortHeaterCt + occReportSentCt )
end



to SetupOccupants
  file-open occupant_fname

  let $rowfield ""
  set headerListTmp ""

  ;; read header
  if not file-at-end? [
    set $rowfield file-read-line
    tokenize $rowfield ","
    set headerListTmp returnvalue
  ]

  ;; the rest is the body
  while [ not file-at-end? ] [
    set $rowfield file-read-line
    create-occupants 1 [
      tokenize $rowfield ","
      set occZoneID (GetItemList "ZONE_ID" returnvalue)
      set workStartHour (GetItemList "WORKSTARTHR" returnvalue)
      set workEndHour (GetItemList "WORKENDHR" returnvalue)
      set workDays (GetItemListStr "WORKDAYS" returnvalue)
      set valOfEI (GetItemList "VALOFEI" returnvalue)
      set valOfEffort (GetItemList "VALOFEFFORT" returnvalue)
      set valOfComfort (GetItemList "VALOFCOMFORT" returnvalue)
      set valOfCost (GetItemList "VALOFCOST" returnvalue)
      set temperatureDiff (GetItemList "TEMPDIFF" returnvalue)
      set luxDiff (GetItemList "LIGHTDIFF" returnvalue)
type occZoneID type " " type workStartHour type " " type workEndHour type " " print
workDays
      ResetOccupantParams
    ]

  ]
  print (word (count occupants) " occupants data is populated" )
  ;print ([ workDays ] of occupants with [occupantID = 24])   ;; for testing

  file-close
end
```

```
to ResetManagerParams
  set mnReportReceivedCt 0
  set mnDoNothingCt 0
  set mnThermostatCt 0
end

to ResetTenantRepParams
  set trZoneID 10000
  set trOccupantList []
  set trConsensusValuesTbl table:make

  set trDoNothingCt 0
  set trThermostatCt 0
  set trOverheadLightCt 0
  set trReportSentCt 0
  set trReportReceivedCt 0
end

to ResetOccupantParams
  set occDoNothingCt 0
  set occTaskLightCt 0
  set occWindowsBlindCt 0
  set occClothesCt 0
  set occPortHeaterCt 0
  set occReportSentCt 0

  set occLightingDiscomfort 0
  set occThermalDiscomfort 0
  set inZone? false
  set currentAction "do nothing"
  set currentPerception "normal"

  set pmvValue 0
  set portableHeaterON? false
  set taskLightON? false
  set windowsBlindOpen? false

  set occTenantRep nobody

  if ScenarioClo = "Business Suit" [ set clothing (table:get clothingTbl "winter") ]
  if ScenarioClo = "Friday Casual" [ set clothing (table:get clothingTbl "summer") ]
  if ScenarioClo = "Allow Change" [ set clothing (table:get clothingTbl "summer") ]

end

to ResetManagerCurrHour
  set mnDoNothingCurrHour 0
  set mnThermostatCurrHour 0
  set mnReportReceivedCurrHour 0
end

to ResetTenantRepCurrHour
  set trDoNothingCurrHour 0
  set trThermostatCurrHour 0
  set trOverheadLightCurrHour 0
  set trReportSentCurrHour 0
  set trReportReceivedCurrHour 0
end

to ResetOccupantCurrHour
  set occDoNothingCurrHour 0
  set occTaskLightCurrHour 0
  set occWindowsBlindCurrHour 0
```

```
  set occClothesCurrHour 0
  set occPortHeaterCurrHour 0
  set occReportSentCurrHour 0
  set occThermalDiscomfortCurrHour 0
  set occLightingDiscomfortCurrHour 0
end

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;; OCCUPANT ;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

to OccupantInzone
    let $currentHour (endingHour - 1)
    ifelse ((workdays = "M-Sun"
      AND ($currentHour * 100) >= workStartHour
        AND ($currentHour * 100) <= workEndHour)
       OR
       (workDays = "M-F"
         AND currentWeekDay >= 1
         AND currentWeekDay <= 5
         AND ($currentHour * 100) >= workStartHour
        AND ($currentHour * 100) <= workEndHour))
    [ if (not inZone?)
      [OccupantEnterZone]]
    [ if (inZone?) [ OccupantLeaveZone] ]
  ;SetOccupantValues
end

to OccupantEnterZoneOLD
  ask myself [
    set zoneOccupantList lput myself zoneOccupantList
  ]
  set inZone? true
  set color blue
  show-turtle
end

to OccupantLeaveZoneOLD
  set inZone? false
  set occTenantRep nobody

  ask myself [ set zoneOccupantList remove myself zoneOccupantList ]
  hide-turtle
end

to OccupantEnterZone
  ;;;;;;;;;;;;;;;; adding zone representative
  if occTenantRep = nobody [
    ifelse ([zoneTenantRep] of myself) = nobody [
      ask one-of tenantreps with [trZoneID = 10000] [
        ResetTenantRepParams
        set trZoneID ([occZoneID] of myself)
        set trOccupantList lput myself trOccupantList

        ask myself [ set occTenantRep myself ]
      ]
    ][
      set occTenantRep ([zoneTenantRep] of myself)
    ]
```

```
  ]
  ask myself [
    set zoneOccupantList lput myself zoneOccupantList
    if zoneTenantRep = nobody [ set zoneTenantRep ([occTenantRep] of myself) ]
  ]

  set inZone? true
  set color blue
  show-turtle
end

to OccupantLeaveZone
  ask myself [
    set zoneOccupantList remove myself zoneOccupantList
    if empty? zoneOccupantList [ set zoneTenantRep nobody ]
  ]
  ask occTenantRep [
    set trOccupantList remove myself trOccupantList
    if empty? trOccupantList [ ResetTenantRepParams ]
  ]

  set inZone? false
  set occTenantRep nobody

  hide-turtle
end


;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;; OCCUPANT BEHAVIOR ;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

to increaseLightingDiscomfort
  set occLightingDiscomfortCurrHour 1
  set occLightingDiscomfort (occLightingDiscomfort + occLightingDiscomfortCurrHour)
  ask myself [ set zoneLightingDiscomfort (zoneLightingDiscomfort +
[occLightingDiscomfortCurrHour] of myself) ]
end

to decreaseLightingDiscomfort
  set occLightingDiscomfortCurrHour 1
  set occLightingDiscomfort (occLightingDiscomfort - occLightingDiscomfortCurrHour)
  ask myself [ set zoneLightingDiscomfort (zoneLightingDiscomfort -
[occLightingDiscomfortCurrHour] of myself) ]
end

to BDILighting
  if inZone?
  [ ;;;;;;;;;;;;;;;;;;;;;;;;;;;; BELIEF ;;;;;;;;;;;;;;;;;;;;;;;;;;;;
    let $perceivedLux ([ZoneTotalLux] of myself + luxDiff)
    if not windowsBlindOpen? [ set $perceivedLux ($perceivedLux - [zoneDaylightLux] of
myself) ]

    ifelse ($perceivedLux >= first comfortLux AND $perceivedLux <= last comfortLux)
    [ set currentPerception "normal" ]
    [ if ($perceivedLux > last comfortLux)
      [ set currentPerception "too bright"
        increaseLightingDiscomfort
```

```
      ]
    if ($perceivedLux < first comfortLux)
    [ set currentPerception "too dark"
      increaseLightingDiscomfort
    ]
    ]
    ;;;;;;;;;;;;;;;;;;;;;;;;;;;; DESIRE ;;;;;;;;;;;;;;;;;;;;;;;;;;;;
    set actionPlan []
    ifelse (currentPerception = "normal")
    []
    [ BDIOccupantAction currentPerception
      set actionPlan lput returnvalue actionPlan
    ]
    ;;;;;;;;;;;;;;;;;;;;;;;;;; INTENTION ;;;;;;;;;;;;;;;;;;;;;;;;;;
    set currentAction ""
    if (empty? actionPlan = false)
    [ foreach actionPlan
      [ set currentAction ?
        if (currentAction = "do nothing") [ set occDoNothingCt (occDoNothingCt + 1) ]
        if (currentAction = "task light") [ ActTaskLight ]
        if (currentAction = "windows blind") [ ifelse [zoneControl?] of myself [
ActWindowsBlind ] [] ]
      ]
    ]
  ]
end

to increaseThermalDiscomfort
  set occThermalDiscomfortCurrHour (occThermalDiscomfortCurrHour + 1)
  set occThermalDiscomfort (occThermalDiscomfort + occThermalDiscomfortCurrHour)
  ask myself [ set zoneThermalDiscomfort (zoneThermalDiscomfort +
[occThermalDiscomfortCurrHour] of myself) ]
end

to decreaseThermalDiscomfort
  set occThermalDiscomfortCurrHour (occThermalDiscomfortCurrHour - 1)
  set occThermalDiscomfort (occThermalDiscomfort - occThermalDiscomfortCurrHour)
  ask myself [ set zoneThermalDiscomfort (zoneThermalDiscomfort -
[occThermalDiscomfortCurrHour] of myself) ]
end

to BDIThermal
  if inZone?
  [
    CalculatePMV
    ;;;;;;;;;;;;;;;;;;;;;;;;;;;; BELIEF ;;;;;;;;;;;;;;;;;;;;;;;;;;;;

    ifelse (pmvValue >= first comfortPMV AND pmvValue <= last comfortPMV)
    [ set currentPerception "normal" ]
    [ if (pmvValue > last comfortPMV)
      [ set currentPerception "too hot"
        increaseThermalDiscomfort
      ]
    if (pmvValue < first comfortPMV)
    [ set currentPerception "too cold"
      increaseThermalDiscomfort
    ]
    ]
    ;;;;;;;;;;;;;;;;;;;;;;;;;;;; DESIRE ;;;;;;;;;;;;;;;;;;;;;;;;;;;;
    set actionPlan []
    ifelse (currentPerception = "normal")
    []
    [ BDIOccupantAction currentPerception
```

```
      set actionPlan lput returnvalue actionPlan
    ]

    ;;;;;;;;;;;;;;;;;;;;;;;;;;;; INTENTION ;;;;;;;;;;;;;;;;;;;;;;;;;;;;
    set currentAction ""
    if (empty? actionPlan = false)
    [ foreach actionPlan
      [ set currentAction ?
        if (currentAction = "do nothing") [ set occDoNothingCt (occDoNothingCt + 1) ]
        if (currentAction = "change clothes") [ if ScenarioClo = "Allow Change"
[ActChangeClothes ]]
        if (currentAction = "portable heater") [ ActPortableHeater ]
      ]
    ]
  ]
end

to ActTaskLight
  if ((currentPerception = "too bright" AND taskLightON?)
    OR (currentPerception = "too dark" AND (NOT taskLightON?)))
  [ if (currentPerception = "too bright" AND taskLightON?)
    [ set taskLightON? false ]
    if (currentPerception = "too dark" AND (NOT taskLightON?))
    [ set taskLightON? true ]

    set occTaskLightCurrHour 1
    set occTaskLightCt (occTaskLightCt + occTaskLightCurrHour)

    decreaseLightingDiscomfort
  ]
end

to ActWindowsBlind
  ifelse windowsBlindOpen?
  [ set windowsBlindOpen? false ]
  [ set windowsBlindOpen? true ]

  set occWindowsBlindCurrHour 1
  set occWindowsBlindCt (occWindowsBlindCt + occWindowsBlindCurrHour)

  decreaseLightingDiscomfort
end



to ActChangeClothes
  let $CLOTemp 0
  if currentPerception = "too hot"
  [ set clothing (table:get clothingTbl "summer") ]
  if currentPerception = "too cold"
  [ set clothing (table:get clothingTbl "winter") ]

  set occClothesCurrHour 1
  set occClothesCt (occClothesCt + occClothesCurrHour)

  decreaseThermalDiscomfort
end

to ActPortableHeater
  if ((currentPerception = "too hot" AND portableHeaterON?)
    OR (currentPerception = "too cold" AND (NOT portableHeaterON?)))
  [ if (currentPerception = "too hot" AND portableHeaterON?)
    [ set portableHeaterON? false ]
```

```
    if (currentPerception = "too cold" AND (NOT portableHeaterON?))
    [ set portableHeaterON? true ]

    set occPortHeaterCurrHour 1
    set occPortHeaterCt (occPortHeaterCt + occPortHeaterCurrHour)

    decreaseThermalDiscomfort
  ]
end



to BDIOccupantAction [ #perception ]
  let $compareValueList []
  let $compareValueActionTbl table:make
  ;;;;;;;;;;;; MATCH THE PERCEPTION ACTION ;;;;;;;;;;;;;;;;
  let $actionList (table:get bdiPerceptionActionTbl #perception)
  foreach $actionList
  [ let $action ?
    CalculateUtility $action
    let $valList returnvalue

    NeedConsensus? $action

    ifelse (returnvalue)
    [ ;;;;;;;;;; ADD ACTIONS FOR CONSENSUS: REPORT TO TENANT REPRESENTATIVE ;;;;;;;;;;

      ask occTenantRep
      [ let $oldValList [ 0 0 0 0 ]
        let $newValList []
        ;;; if the table are not empty, take the values for computation
        if (table:has-key? trConsensusValuesTbl $action)
        [ set $oldValList (table:get trConsensusValuesTbl $action) ]
        ;; compute the new values
        (foreach $oldValList $valList [ set $newValList lput (?1 + ?2) $newValList ])
        ;;; put back with the new values
        table:put trConsensusValuesTbl $action $newValList
      ]
    ]
    [ ;;;;;; ELSE, INDIVIDUAL ACTIONS ;;;;;;
      let $totalValues (sum $valList)
      set $compareValueList lput $totalValues $compareValueList
      table:put $compareValueActionTbl $totalValues $action
    ]
  ]

  ;;;;;;;;;;;;;;;; GET THE INDIVIDUAL ACTION ;;;;;;;;;;;;;;;;;
  if (not empty? $compareValueList)
  [ set $compareValueList sort $compareValueList
    set returnvalue (table:get $compareValueActionTbl (first $compareValueList))
  ]

end

to CalculateUtility [ #action ]
  set returnvalue []
  let $valList (table:get bdiActionValsTbl #action)

  set returnvalue lput (valOfEI * (item 0 $valList)) returnvalue
  set returnvalue lput (valOfEffort * (item 1 $valList)) returnvalue
  set returnvalue lput (valOfComfort * (item 2 $valList)) returnvalue
  set returnvalue lput (valOfCost * (item 3 $valList)) returnvalue
end
```

```
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

to OccupantReportTenantRepCt
  ;;; ask occupant
  set occReportSentCurrHour 1

  set occReportSentCt (occReportSentCt + occReportSentCurrHour)
  ask occTenantRep [
    set trReportReceivedCurrHour 1
    set trReportReceivedCt (trReportReceivedCt + trReportReceivedCurrHour) ]
end

to TenantRepReportManagerCt
  ;; ask tenantRep
  set trReportSentCurrHour 1
  set trReportSentCt (trReportSentCt + trReportSentCurrHour)
  ask managers [
    set mnReportReceivedCurrHour 1
    set mnReportReceivedCt (mnReportReceivedCt + mnReportReceivedCurrHour) ]
end

to NeedConsensus? [ #action ]
  set returnvalue false
  if (#action = "thermostat" OR #action = "overhead light")
  [ set returnvalue true ]
end

to TenantRepBehavior
  let $winningActionRun? false
  if (table:length trConsensusValuesTbl > 0)
  [
    set trReportReceivedCt (trReportReceivedCt + 1)
    ifelse (((random-normal CommunicationLevel 10) / 100) < 0.5)
    [ set trDoNothingCt (trDoNothingCt + 1) ]
    [ if TenantRepAction = "thermostat"
      [ ;;; report to building manager
        TenantRepReportManagerCt
        ask myself [ set zoneConsensusValuesTbl
            (table:from-list (table:to-list [ trConsensusValuesTbl ] of myself ))
        ]
      ]
      if TenantRepAction = "overhead light"
      [ ifelse [zoneControl?] of myself [ ActOverheadLight ] [] ]
    ]
  ]
end

to-report TenantRepAction

  set returnvalue ""
  let $myConsValsList table:keys trConsensusValuesTbl
  let $winningval 0
  let $winningid 0
  let $id 0
  while [ $id < (length $myConsValsList) ]
  [
    let $actid (item $id $myConsValsList)
    let $totalval sum (table:get trConsensusValuesTbl $actid)

    if (($winningval = 0) OR ($winningval > $totalval))
    [ set $winningval $totalval
```

```
      set $winningid $actid ]

    set $id ($id + 1)
  ]
  report $winningid
end

to ManagerBehavior
  let $winningActionRun? false
  if (table:length [zoneConsensusValuesTbl] of myself > 0)
  [ ifelse (((random-normal CommunicationLevel 20) / 100) < 0.5)
    [ set mnDoNothingCt (mnDoNothingCt + 1) ]
    [ if ManagerAction = "thermostat"
      [ ifelse [zoneControl?] of myself [ ActThermostat] [] ]
    ]
  ]
end

to-report ManagerAction
  set returnvalue ""
  let $myConsValsList table:keys [zoneConsensusValuesTbl] of myself
  let $winningval 0
  let $winningid 0
  let $id 0
  while [ $id < (length $myConsValsList) ]
  [ let $actid (item $id $myConsValsList)
    let $values (table:get [zoneConsensusValuesTbl] of myself $actid)
    let $concernedval (item 3 $values)  ;; Manager is COST oriented

    if (($winningval = 0) OR ($winningval > $concernedval))
    [ set $winningval $concernedval
      set $winningid $actid ]
    set $id ($id + 1)
  ]
  report $winningid
end

to ActThermostat
  let $temperaturesp 0
  ask myself [

      ;; convert list of agents to agentset
      let $occupantset occupants with [member? self ([zoneOccupantList] of myself) ]
      set $occupantset $occupantset with [ occReportSentCurrHour = 1 ]
   if any? $occupantset [
      let $avgT (mean [temperatureDiff] of $occupantset)
      ;; take the average of temperature difference perceived by occupants who report
discomfort
      let $meanTempDiff (5 / 9 * $avgT - 32)

      ifelse (currentMonth > 4 AND currentMonth < 9)
      [ set $temperaturesp ((last comfortTemperature) + $meanTempDiff) ]
      [ set $temperaturesp ((first comfortTemperature) + $meanTempDiff) ]
    ]
  ]
  set mnThermostatCt (mnThermostatCt + 1)
end

to ActOverheadLight
  set trOverheadLightCt (trOverheadLightCt + 1)
end
```

```
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;



to setup
  ct
  clear-all-plots
  setLookUpTables
  SetupOccupants
  SetupLighting
  set outContent [0]

end

to write-outputfile
  if file-exists? output_fname [ file-delete output_fname ]
  file-open output_fname

  while [not empty? outContent]
  [
    file-print (item 0 outContent)
    set outContent remove-item 0 outContent
  ]
  file-close
end

to write-output [#inputstr]
  set outContent lput #inputstr outContent
end


to go
  file-open eplus_fname
file-close
  file-open eplus_fname
  ;; read header
  if not file-at-end? [
    tokenize file-read-line ","
    set headerListTmp returnvalue

    GetBuildingData
    print (word count zones " zones data is populated")
  ]

  create-managers 1 [ ResetManagerParams ]
  create-tenantreps (count zones) [ ResetTenantRepParams ]
```

```
  write-output (word "current
month,endingHour,output_fname,eplus_fname,occupant_fname,CommunicationLevel,BldgControlLe
vel,"
      "TotalBldgCost,PMV(+3),PMV(+2),PMV(+1),PMV(0),PMV(-1),PMV(-2),PMV(-
3),TotalBldgThermalDiscomfort,TotalBldgLightingDiscomfort,"
      "TotalOccupantEffort,TotalTenantRepEffort,"
      "TenantRepReportReceived,(TenantRepReportReceived - TenantRepDoNothing),"
      "TotalTenantRepReportSent,(TotalTenantRepReportSent - TotalManagerDoNothing),"
      "occTaskLightCurrHour [Sum],occWindowsBlindCurrHour [Sum],occClothesCurrHour
[Sum],"
      "occPortHeaterCurrHour [Sum],occReportSentCurrHour [Sum],mnThermostatCt
[Sum],trOverheadLightCt [Sum]")

  ;; read data
  while [ not file-at-end? ] [
    tokenize file-read-line ","
    set contentListTmp returnvalue
    GetDateTime

    set bldgElectricity (GetItemList "Electricity:Facility [J](Hourly)" contentListTmp)
    set bldgEquipmentElectricity (GetItemList "InteriorEquipment:Electricity [J](Hourly)"
contentListTmp)
    set bldgInteriorLightsElectricity (GetItemList "InteriorLights:Electricity
[J](Hourly)" contentListTmp)
    set bldgHVACElectricity (GetItemList "Electricity:HVAC [J](Hourly)" contentListTmp)
    set bldgGas (GetItemList "Gas:Plant [J](Hourly)" contentListTmp)

    ask managers [ ResetManagerParams ]

    ask zones [
      if endingHour = 1 [ ResetZoneParams ]

      if (SimLighting) [ Daylighting ]

      SimulateOccupantBehavior
    ]
    update-plots
    write-output (word currentMonth "," endingHour ","
      output_fname "," eplus_fname "," occupant_fname "," CommunicationLevel ",
      " BldgControlLevel "," round TotalBldgCost ","
      CountOccupantsWithPMV 3 "," CountOccupantsWithPMV 2 "," CountOccupantsWithPMV 1 ",
      " CountOccupantsWithPMV 0 "," CountOccupantsWithPMV -1 ",
      " CountOccupantsWithPMV -2 "," CountOccupantsWithPMV -3 ","
      TotalBldgThermalDiscomfort "," TotalBldgLightingDiscomfort ",
      " TotalOccupantEffort "," TotalTenantRepEffort ","
      TenantRepReportReceived "," (TenantRepReportReceived - TenantRepDoNothing) ","
      TotalTenantRepReportSent "," (TotalTenantRepReportSent - TotalManagerDoNothing) ","
      (sum [occTaskLightCurrHour] of occupants) ","
      (sum [occWindowsBlindCurrHour] of occupants) ","
      (sum [occClothesCurrHour] of occupants) ","
      (sum [occPortHeaterCurrHour] of occupants) ","
      (sum [occReportSentCurrHour] of occupants) ","
      (sum [mnThermostatCt] of managers) ","
      (sum [trOverheadLightCt] of tenantreps) ",")

;type endingHour type " " print count tenantreps with [trZoneID = 10000 ]
  ]

  file-close
  write-outputfile
end
```

```
to setLookUpTables
  ;; response --- environment, effort, discomfort, cost
  set bdiActionValsTbl Table:make
  table:put bdiActionValsTbl "do nothing" [ 3 1 3 3 ]
  table:put bdiActionValsTbl "thermostat" [ 3 1 1 3 ]
  table:put bdiActionValsTbl "overhead light" [ 3 1 1 3 ]
  table:put bdiActionValsTbl "windows blind" [ 1 3 3 1 ]
  table:put bdiActionValsTbl "portable heater" [ 2 1 2 1 ]
  table:put bdiActionValsTbl "task light" [ 2 1 2 1 ]
  table:put bdiActionValsTbl "change clothes" [ 1 3 3 1 ]

  set bdiPerceptionActionTbl Table:make
  ;;;;; original ;;;;;;;
  table:put bdiPerceptionActionTbl "too hot"
     [ "do nothing" "thermostat" "portable heater" "change clothes" ]
  table:put bdiPerceptionActionTbl "too cold"
     [ "do nothing" "thermostat" "portable heater" "change clothes" ]
  table:put bdiPerceptionActionTbl "too bright"
     [ "do nothing" "overhead light" "task light" "windows blind" ]
  table:put bdiPerceptionActionTbl "too dark"
     [ "do nothing" "overhead light" "task light" "windows blind" ]

  set clothingTbl Table:make
  table:put clothingTbl "summer" 0.6
  table:put clothingTbl "winter" 2

  set comfortPMV [-2 2]
  set comfortTemperature [20 23]    ;; in C http://en.wikipedia.org/wiki/Zone_temperature
  set comfortLux [125 175]
  ;set comfort_cotwo [0 600]          ;; http://www.engineeringtoolbox.com/co2-comfort-
level-d_1024.html
end

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

to SetWeekday [#day #month #year]
  set listweekday [0]
  let $lasttwo (#year mod 100)
  let $frac floor ($lasttwo / 4)
  set listweekday lput $lasttwo listweekday
  set listweekday lput $frac listweekday
  set listweekday lput #day listweekday
  TableCenturies #year
  TableMonths #year #month
  set listweekday remove-item 0 listweekday

  set currentWeekday (
    item 0 listweekday + item 1 listweekday + item 2 listweekday +
    item 3 listweekday + item 4 listweekday)
  set currentWeekday ( currentWeekday mod 7)
  GetWeekdaystr
end

to GetWeekdaystr
  if (currentWeekday = 0) [ set weekdaystr "Sunday" ]
  if (currentWeekday = 1) [ set weekdaystr "Monday" ]
  if (currentWeekday = 2) [ set weekdaystr "Tuesday" ]
  if (currentWeekday = 3) [ set weekdaystr "Wednesday" ]
  if (currentWeekday = 4) [ set weekdaystr "Thursday" ]
  if (currentWeekday = 5) [ set weekdaystr "Friday" ]
  if (currentWeekday = 6) [ set weekdaystr "Saturday" ]
end
```

```
to TableCenturies [#year]
  let $yearval 0
  if (#year >= 1700 AND #year <= 1799) [ set $yearval 4 ]
  if (#year >= 1800 AND #year <= 1899) [ set $yearval 2 ]
  if (#year >= 1900 AND #year <= 1999) [ set $yearval 0 ]
  if (#year >= 2000 AND #year <= 2099) [ set $yearval 6 ]
  if (#year >= 2100 AND #year <= 2199) [ set $yearval 4 ]
  if (#year >= 2200 AND #year <= 2299) [ set $yearval 2 ]
  if (#year >= 2300 AND #year <= 2399) [ set $yearval 0 ]
  if (#year >= 2400 AND #year <= 2499) [ set $yearval 6 ]
  if (#year >= 2500 AND #year <= 2599) [ set $yearval 4 ]
  if (#year >= 2600 AND #year <= 2699) [ set $yearval 2 ]

  set listWeekday lput $yearval listWeekday
end

to TableMonths [#year #month]
  let $monthval 0
  let $isleap 0
  set $isleap (#year mod 4)
  if (#month = 1)
     [ ifelse ($isleap = 0) [ set $monthval 6 ] [ set $monthval 0 ]]
  if (#month = 2)
     [ ifelse ($isleap = 0) [ set $monthval 2 ] [ set $monthval 3 ]]
  if (#month = 3) [ set $monthval 3 ]
  if (#month = 4) [ set $monthval 6 ]
  if (#month = 5) [ set $monthval 1 ]
  if (#month = 6) [ set $monthval 4 ]
  if (#month = 7) [ set $monthval 6 ]
  if (#month = 8) [ set $monthval 2 ]
  if (#month = 9) [ set $monthval 5 ]
  if (#month = 10) [ set $monthval 0 ]
  if (#month = 11) [ set $monthval 3 ]
  if (#month = 12) [ set $monthval 5 ]

  set listWeekday lput $monthval listWeekday
end

to TableNumDays [#year #month]
  let $daysnumInMonth 0
  let $isleap 0
  set $isleap (#year mod 4)
  if (#month = 1) [ set $daysNumInMonth 31 ]
  if (#month = 2)
     [ ifelse ($isleap = 0)
       [ set $daysNumInMonth 29 ]
       [ set $daysNumInMonth 28 ]
     ]
  if (#month = 3) [ set $daysNumInMonth 31 ]
  if (#month = 4) [ set $daysNumInMonth 30 ]
  if (#month = 5) [ set $daysNumInMonth 31 ]
  if (#month = 6) [ set $daysNumInMonth 30 ]
  if (#month = 7) [ set $daysNumInMonth 31 ]
  if (#month = 8) [ set $daysNumInMonth 31 ]
  if (#month = 9) [ set $daysNumInMonth 30 ]
  if (#month = 10) [ set $daysNumInMonth 31 ]
  if (#month = 11) [ set $daysNumInMonth 30 ]
  if (#month = 12) [ set $daysNumInMonth 31 ]

  set daysNumInMonth $daysNumInMonth
end
```

```
;; ---------------------------------------------------------------------
;;                          populate-2Darray
;;
;; descp  : populate 2D array (arr2d) from excel file
;; param  : #filename
;; return : arr2d, arr2d-rownum, arr2d-colnum
;; excel format:
;;    <arr name>
;;    <rownum>,<colnum>
;;    <header0>      ,<header1>,   ...   ,<headern>
;;    data<row0,col0>,data<row0,col1>,...,data<row0,coln>
;;    data<row1,col0>,        ...        ,data<row1,coln>
;;    data<rown,col0>,        ...        ,data<rown,coln>
;; ---------------------------------------------------------------------
to populate-2darr-0 [#filename]
  file-open #filename
  file-close
  file-open #filename
  populate-2darr-1
end

to populate-2darr-1
  if not file-at-end? [
    let $arrname file-read-line ;; arrname
    let xstr file-read-line     ;; rownum,colnum
    tokenize xstr ","
    let arr2d_rownum read-from-string item 0 returnvalue
    let arr2d_colnum read-from-string item 1 returnvalue

    let arr2d array:from-list n-values arr2d_rownum
      [array:from-list n-values arr2d_colnum[0]]


    set xstr file-read-line ;; header
    tokenize xstr ","
    let header returnvalue

    let $rowptr 0
    while [$rowptr < arr2d_rownum]
    [
      set xstr file-read-line
      tokenize xstr ","
      let $colptr 0

      while [$colptr < arr2d_colnum]
      [
        let $val item $colptr returnvalue
        Insert2dArrItem arr2d $rowptr $colptr $val
        set $colptr ($colptr + 1)
      ]
      set $rowptr ($rowptr + 1)
    ]

    if ($arrname = "SUNRISESET") [
      set sunrisesetHdrList header
      set sunrisesetArr arr2d ]
    if ($arrname = "SKYCOVER") [
      set skycoverHdrList header
      set skycoverArr arr2d ]
    if ($arrname = "DAYLIGHTLUX") [
      set daylightHdrList header
      set daylightArr arr2d ]
    populate-2darr-1
```

```
  ]
  file-close
end

;; ----------------------------------------------------------------------
;;                            copy-2darray
;; ----------------------------------------------------------------------
to copy-2darray [#arr_orig]
  let $rownum (array:length #arr_orig)
  let $colnum (array:length (array:item #arr_orig 0))

  set returnvalue array:from-list n-values $rownum
             [array:from-list n-values $colnum[0]]

  let $rowptr 0
  while [$rowptr < $rownum ]
  [

    let $colptr 0

    while [$colptr < $colnum]
    [
      let $inputdata (array:item (array:item #arr_orig $rowptr) $colptr)
      Insert2dArrItem returnvalue $rowptr $colptr $inputdata

      set $colptr ($colptr + 1)
    ]
    set $rowptr ($rowptr + 1)
  ]
end

;; ----------------------------------------------------------------------
;;                         insert-to-2Darray
;; ----------------------------------------------------------------------
to Insert2dArrItem [#arr #row #col #val]
  array:set (array:item #arr #row) #col #val
  ;;print #arr ;; for testing
end

to-report Item2dArr [#arr #row #col]
  report (array:item (array:item #arr #row) #col)
end

;; ----------------------------------------------------------------------
;;                          tokenize
;; ----------------------------------------------------------------------
to tokenize [#inputstr #delim]

  set returnvalue [0]
  while [not empty? #inputstr]
  [
    let delimpos position #delim #inputstr
    let pos 0

    ifelse is-number? delimpos
    [
      ;;if have not reached the last column
      let strInput substring #inputstr pos delimpos

      set returnvalue lput (TrimString strInput) returnvalue

      while [delimpos >= 0]
      [
```

```
        set #inputstr remove-item 0 #inputstr
        set delimpos (delimpos - 1)
      ]
    ]
    [
      ;; last column is reached
      let strInput #inputstr
      set returnvalue lput (TrimString strInput) returnvalue
      set #inputstr ""
    ]
  ]
  set returnvalue remove-item 0 returnvalue
end

;;; to trim leading and trailing spaces
to-report TrimString [ #original ]

  while [ (first #original) = " " ]
  [ set #original (remove-item 0 #original) ]

  while [ (last #original) = " " ]
  [ set #original (remove-item ((length #original) - 1) #original) ]

  report #original
end


to-report GetItemList [#str #list]
  let $pos (position #str headerListTmp)
  if is-number? $pos [ report read-from-string (item $pos #list) ]
  report 0
end

to-report GetItemListStr [#str #list]
  let $pos (position #str headerListTmp)
  if is-number? $pos [ report (item $pos #list) ]
  report " "
end




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;; http://www.lumasenseinc.com/EN/products/thermal-comfort/pmv-calculation/

;; -------------------------------------------------------------------------------------
;;                       CalculatePMV
;; +3 hot
;; +2 warm
;; +1 slightly warm
;; 0  neutral
;; -1 slightly cool
;; -2 cool
;; -3 cold
;; -------------------------------------------------------------------------------------


to CalculatePMV
  let MET 1                                       ;; metabolism
  let TA ([meanAirT] of myself)
```

```
  let $FTA (9 / 5 * TA + 32)                          ;; farenheit
  let $TP  (5 / 9 * ($FTA + temperatureDiff - 32))  ;; perceived temperature

  set TA $TP                                          ;; set the perceived temperature as
the new TA
  let TR  ([meanRadiantT] of myself)                ;; radiant temperature
  let RH  ([AirRelativeHumidity] of myself)         ;; relative humidity
  let VEL 0.15                                      ;; air velocity
  let CLO clothing
  let _def 0.000001
  if (CLO = _def OR MET = _def OR TA = _def OR TR = _def
    OR RH = _def OR VEL = _def)
  [ report 0.0000001 ]

  let FNPS (exp (16.6536 - 4030.183 / (TA + 235)))
  let PA (RH * 10 * FNPS)
  let ICL (0.155 * CLO)
  let M (MET * 58.15)
  let FCL 0
  ifelse ICL < 0.078
     [ set FCL (1 + 1.29 * ICL) ]
     [ set FCL (1.05 + 0.645 * ICL) ]

  let HCF (12.1 * (VEL ^ 0.5))
  let TAA (TA + 273)
  let TRA (TR + 273)

  let TCLA (TAA + (35.5 - TA) / (3.5 * (6.45 * ICL + 0.1)))
  let P1 (ICL * FCL)
  let P2 (P1 * 3.96)
  let P3 (P1 * 100.0)
  let P4 (P1 * TAA)
  let P5 (308.7 - 0.028 * M + P2 * ((TRA / 100) ^ 4))
  let XN (TCLA / 100)
  let XF (TCLA / 50)
  let HCN (1.0e-6)
  let HC (1.0e-6)
  ;XF = XN

  let N 0
  let EPS 0.0015
  while [ (abs (XN - XF)) > EPS] [
    set XF ((XF + XN) / 2)
    set HCF (12.1 * (VEL ^ 0.5))
    set HCN (2.38 * ((abs (100 * XF - TAA)) ^ 0.25))

    ifelse (HCF > HCN) [ set HC HCF ] [ set HC HCN ]

    set XN ((P5 + P4 * HC - P2 * (XF ^ 4)) / (100 + P3 * HC))
    set N (N + 1)
  ]

  let TCL (100 * XN - 273)
  ;; Skinn diff loss

  let HL1 (3.05 * 0.001 * (5733 - 6.99 * M - PA))

  ;; Sweat loss
  let HL2 0.0
  ifelse (M > 58.15)
    [ set HL2 (0.42 * (M - 58.15)) ]
    [ set HL2 0.0 ]
```

```
  ;;Latent respiration loss
  let HL3 (1.7 * 0.00001 * M * (5867 - PA))

  ;;Dry respiration loss
  let HL4 (0.0014 * M * (34 - TA))

  ;;Radiation loss
  let HL5 (3.96 * FCL * ((XN ^ 4) - ((TRA / 100) ^ 4)))

  ;;Convection loss
  let HL6 (FCL * HC * (TCL - TA))

  ;;Thermal sensation to skin tran coef
  let TS (0.303 * (exp (-0.036 * M)) + 0.028)

  let TPO 0
  ifelse (VEL < 0.2)
    [ set TPO (0.5 * TA + 0.5 * TR) ]
    [ ifelse (VEL < 0.6)
        [ set TPO (0.6 * TA + 0.4 * TR) ]
        [ set TPO (0.7 * TA + 0.3 * TR) ]
    ]

  set pmvValue (TS * (M - HL1 - HL2 - HL3 - HL4 - HL5 - HL6))
  set ppdValue (100 - 95 * ( exp (-0.03353 * (pmvValue ^ 4) - 0.2179 * (pmvValue ^ 2))));
end
```