Task 2: 3 Case Studies

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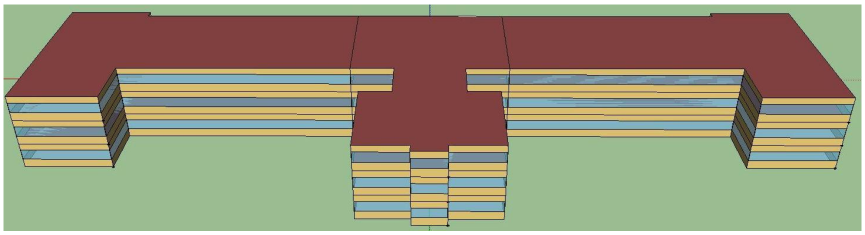
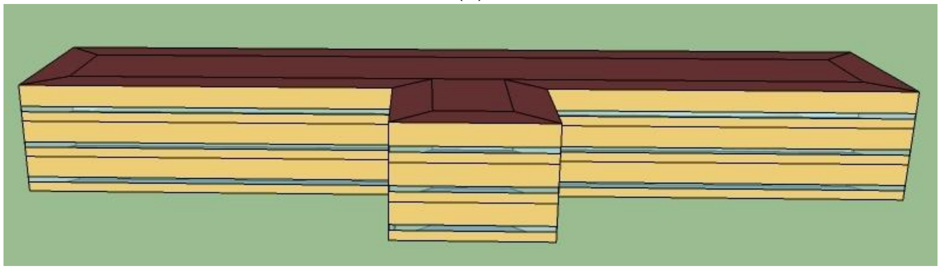
Case Study 1: Building 101, Philadelphia Navy Yard

In order to validate RMT models, Building 101 is used as one of the case studies. The RMT team used measured data from the installed sensors for Building 101 to determine operational inputs to the energy simulation models. Figure shows two different versions of a Building 101 model that were created directly by the RMT ruby scripts via OpenStudio API. Figure 1 (a) shows a detailed geometry model that takes more than 5 minutes to simulate Building 101 on recent personal computers. A more simplified model was created by using the T-shape method developed in the RMT (Figure 1 (b)). Simplification of building geometry decreases computational time. This simulation takes approximately 2.5 minutes to run on personal computers.



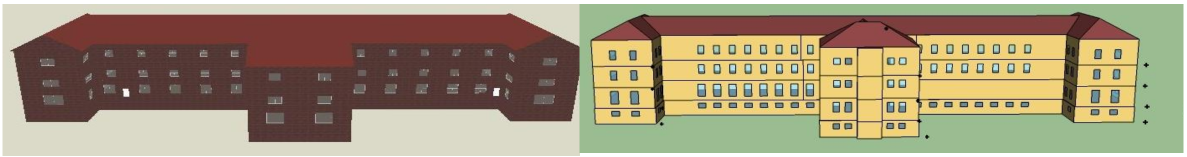
(a)



(b)

Figure 1 Energy simulation models created by the RMT for Building 101; (a) Energy model with detailed geometry and (b) Energy model with simplified geometry

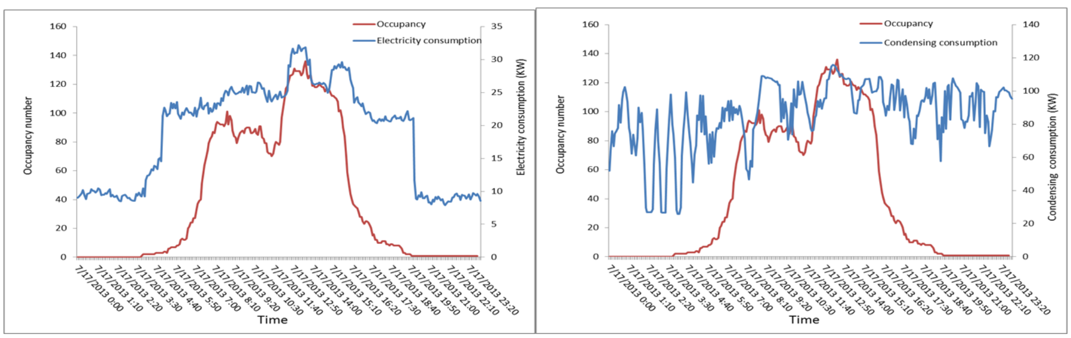
The RMT team created two detailed energy simulation models for Building 101 to demonstrate the required modeling efforts to achieve 15% accuracy for the selected case study. Figure 2 (a) shows the first detailed model created via DesignBuilder, and Figure 2 (b) illustrates the second detailed model developed via OpenStudio/SketchUP.



(a) (b)

Figure 2 Detailed energy simulation models created by (a) Design Builder and (b) OpenStudio/SketchUP

In order to determine the influence of occupant presence on the accuracy of energy simulations, this subtask is examining the correlation of building occupancy with the metered energy consumption data. Figure 1 shows an analysis of one-day data for Building 101. Primary consideration was given to understanding the drivers of energy consumption. The occupancy data showed a significant correlation with the overall amount of electricity used; the occupancy accounted for 78% of variation in electricity consumption for Building 101. Condensing energy use was used as a cooling energy. The result of the regression test shows that there is only a 16% correlation with occupancy. Further analyses are necessary to validate the results.



(a) (b)

Figure 1 Occupancy number versus hours for a day of measurement; (a) correlation between number of occupants and electricity consumption and (b) correlation between number of occupants and condensing unit electricity consumption

Case Study 2: One Montgomery Plaza

This subtask adopted ASHRAE Guideline in measuring the accuracy of RMT baseline energy simulations, due to the widespread use of this guideline in the energy modeling community. However, there is no well-defined approach to determine model complexity and time required for inputs. The RMT team used existing publications to propose a new approach that segregates the human factor from determination of the model complexity and time required for inputs. The RMT team proposes using two weighting factors to exclude the human factor from the analyses of the model complexity and time required for inputs. These two weighting factors are functions of (1) computational time required to perform the energy model for the selected variable and (2) time required to collect the inputs. In this report, the time required for collecting inputs on model variables is presented. This study uses the results of a survey conducted by Pacific Northwest National Laboratory (PNNL) to determine ease of data collection [1]. Three categories are used to describe a variable's input: (1) easy, (2) medium, and (3) difficult. Table provides the times required in each of these three categories to collect onsite data as defined by PNNL.

Table 1 Time required for the data collection of a single input variable/system for application in a building energy model as defined by PNNL [1]

	Easy	Medium	Difficult
Time Required	2 Minutes	5 to 10 Minutes	10 to 30 Minutes

The time required for inputs for both Building 101 and One Montgomery Plaza is less than 5 hours with the initial set of data already available to an experienced user, and the accuracies meet ASHRAE Guideline 14 requirements.

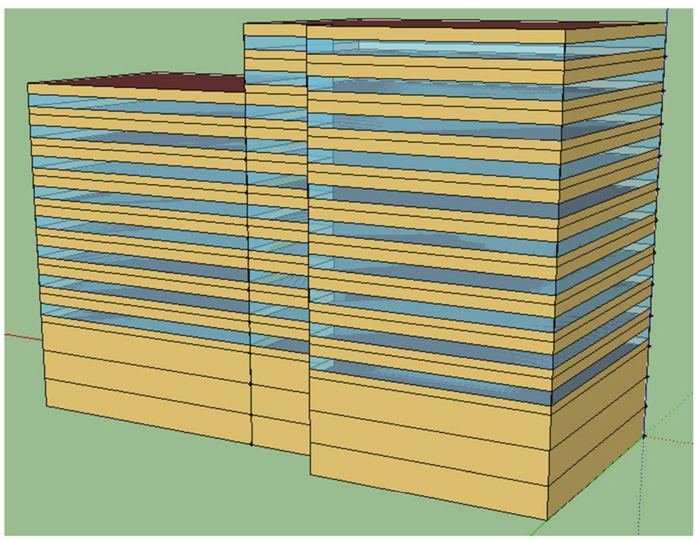


Figure shows the One Montgomery Plaza building modeled in the RMT and visualized in the OpenStudio API.

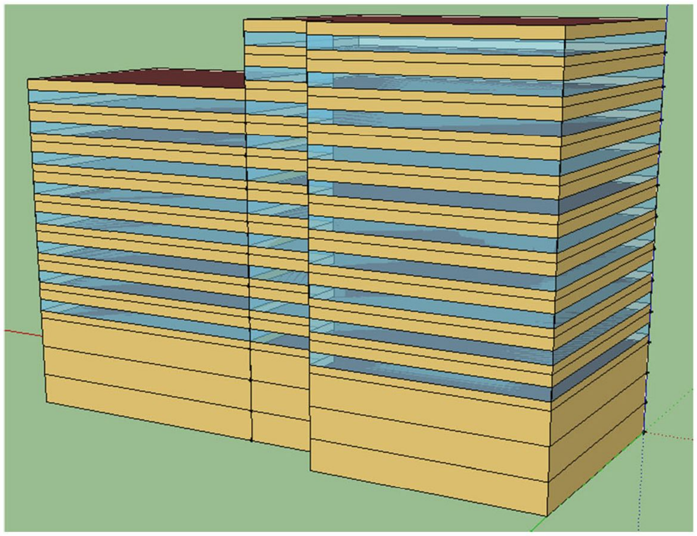


Figure 4 Representation of One Montgomery Plaza building modeled in RMT

First, the RMT team used information from the building drawings, including geometry, fenestration, and HVAC systems. Default values for load densities and associated schedules are used to model the building. In order to achieve more accurate results, sub-metered information were used to derive the internal loads and associated schedules as well as the temperature setpoints [2]. Actual Meteorological Year (AMY) data were then used to compare the building energy use with the utility bills. Figure 55 shows the comparison between the modeled and measured monthly gas consumptions. Based on ASHRAE Guideline 14, the Coefficient of Variation (CV) is 13.8%, and Normalized Mean Bias Error (NMBE) is 1.6%. They both meet the ASHRAE Guideline 14 requirements. It is important to note that temperature profiles show the building is overheated in May. Monthly measured indoor air temperature is used to develop detailed setpoint temperatures in the RMT; otherwise, it is not possible to explain overheating of the building space in some of these months. Figure 6 presents modeled and actual monthly electricity consumption. CVRSME and NMBE are 14.4% and 2.9% in 2013.

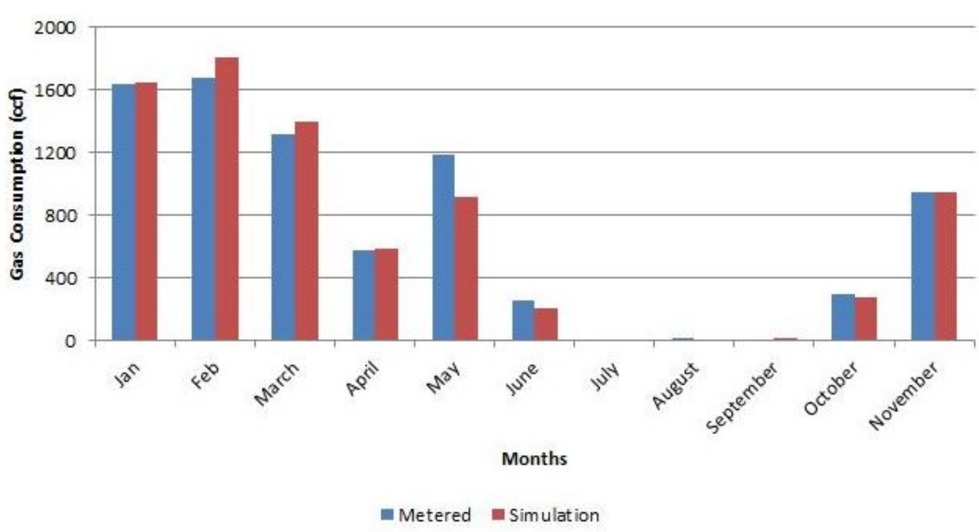


Figure 5 Utility bills and simulation monthly gas consumptions for One Montgomery Plaza in 2013

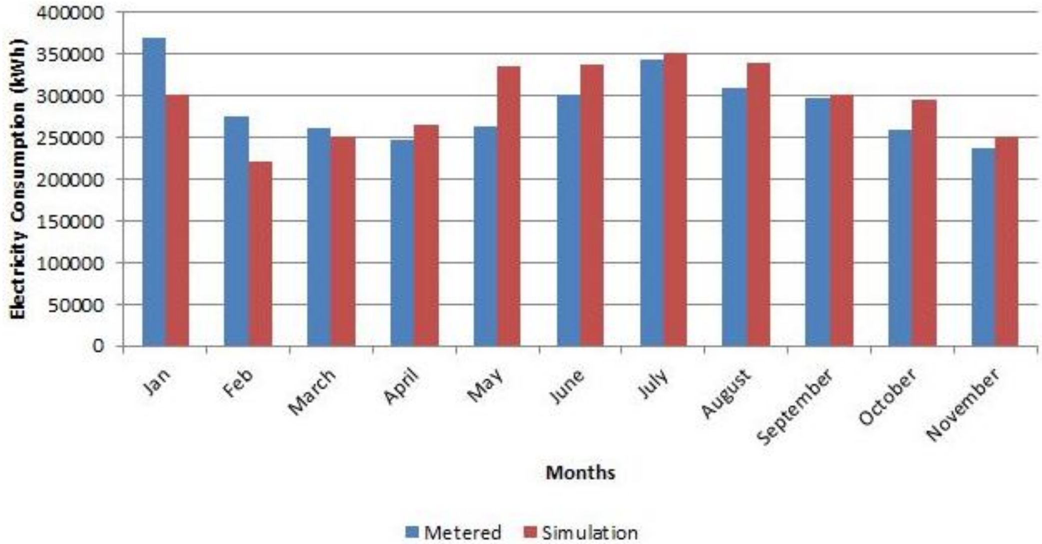


Figure 6 Utility bills and simulation monthly electricity consumptions for One Montgomery Plaza in 2013

In order to estimate the time required for inputs, this study uses Table 2.3.1 results to determine the time required for inputs. Table 1 summarizes the input time required for One Montgomery Plaza simulations by an experienced users. Individual inputs are categorized as easy, medium, and difficult in this time assessment, while the multipliers / weighting factors are gathered from the time records for an experienced user on the task. Overall, the total time required for input collection is less than 5 hours. It is important to note this time record assumes that the person who collects these data is an expert and already has access to building drawing, measured HVAC set points, and the sub metered building energy use.

Table 1 Time required for the data collection for One Montgomery Plaza adopted from the Asset Score Technical Report

Variable	Complexity	Time Required for inputs
Lighting and equipment schedules	Difficult	$2^{*}\times30/60=1$ hour
Geometry and Window-to-Wall Ratio	Easy	$2^{*}\times2/60=1/15$ hours
Cooling and heating setpoints	Difficult	$2^{*}\times30/60=1$ hour
HVAC (Boiler, Chiller, Pumps) specifications	Medium	$3^{*}\times10/60=1/2$ hour
Service Hot Water (SHW) specifications	Medium	$1^{*}\times10/60=1/6$ hour
Construction materials	Medium	$1^{*}\times10/60=1/6$ hour
Infiltration and outdoor air specifications	Difficult	$2^{*}\times30/60=1$ hour
AMY weather data	Difficult	$2^{*}\times30/60=1$ hour

* - these weighting factors are obtained from the time records for an experienced user on the task

Similarly, Building 101 was modeled with the RMT and the accuracy achieved for the model met the ASHRAE Guideline 14 requirements. The time required for inputs is similar to that for One Montgomery Plaza.

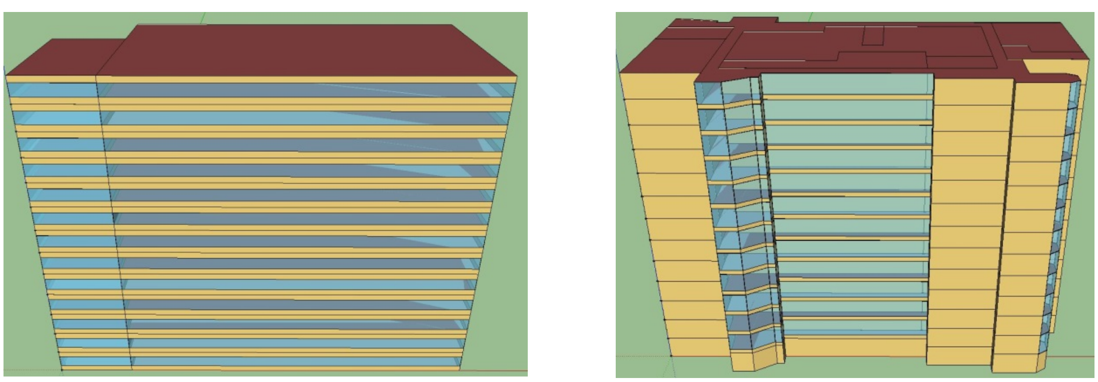
References.

[1] Commercial Building Energy Asset Score, Program Overview and Technical Protocols (Version 1.0). Accessible link:
http://www1.eere.energy.gov/buildings/commercial_initiative/pdfs/energy_asset_score_technical_protocol_phase1.pdf

[2] Data provided on the Sharepoint website for One Montgomery Plaza building

Case Study 3: Life Sciences Building

This subtask modeled the third case study, a life sciences building, located in Philadelphia. This building is a thirteen-story with 275,000 ft^2 (26,000 m^2) area, and it is part of a university hospital complex. The main function in the building is biomedical research laboratories occupying about 55% of the total floor area while the remaining areas are supporting offices, restrooms, equipment rooms, and circulation spaces. Figure 2.3.1 shows two models for this building to demonstrate RMT capabilities. This building has a complex geometry compared to Building 101 and One Montgomery Plaza buildings. Therefore, there is a need to make simplifications for the building geometry. Figure 2.3.1-a shows the simplified version of the building that is a combination of two rectangle shapes with a fixed window-to-wall ratio while Figure 2.3.1-b illustrates the detailed model. Using the detailed model for the RMT requires using additional features that are not possible with the existing web version of RMT.



(a) (b)

Figure 2.3.1 Screenshots of the energy model for the third case study: (a) simple model and (b) detailed model

During this final project quarter, we have also further examined the previous two case studies of office buildings, Building 101 and One Montgomery Plaza. We have found that re-ordering installation sequence of energy efficiency measures has little effect on net present value and long-term energy-savings, so long as load reduction measures precede equipment replacement, especially for de-centralized, cooling systems. The results suggest that simple-payback ranking of measures may miss substantial energy savings. Other findings are that ventilation and temperature setbacks have significant energy savings, and that cooling load reductions are preferred to heating load reductions in office buildings with setbacks, because heating equipment has less size-dependent replacement cost variation, internal gains are during occupied hours, peak heating load is offset by setbacks, and benefits from heat load reduction, primarily wall insulation, are offset by cooling load increase in shoulder seasons. This suggests that RMT should include load reduction potential for cooling systems, but not install-year variation of measures. RMT should use life-cycle cost instead of simple payback, and prioritize HVAC capacity, replacement dates, replacement cost, and peak load contributions as areas for accuracy refinement. Daylighting and operable window measures are priorities for development, as they offer substantial load reduction opportunities for cooling, and mitigate the counter-productive consequences of added insulation. Larger savings targets will require internal load reduction, major revisions of building enclosure for passive benefits of daylighting ventilation, and controlled solar gain, and changing the HVAC system type.