University of Massachusetts, Amherst

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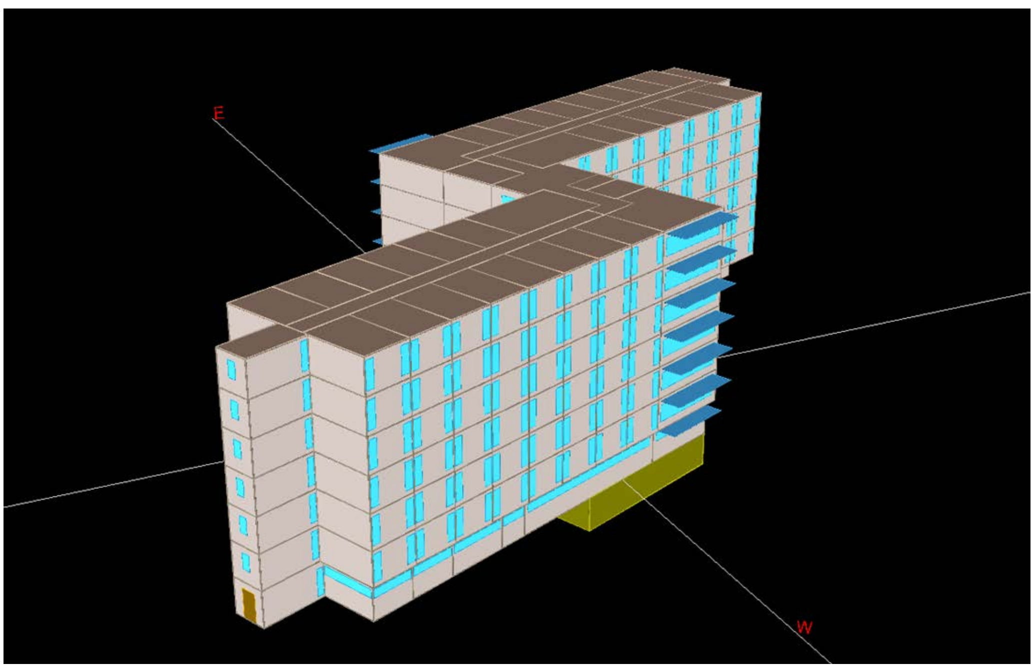
ENERGY DESIGN AND MODELING GUIDELINES



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1. General Information

1.1. Energy Modeling Benefits

The advancement and development of building modeling tools, and the availability of a large number of software packages with a broad range of functions has had a considerable impact on the building design professions. Today, project design teams have multiple professionals who share the responsibility of building simulation at different stages of design and construction to improve building performance and sustainability.

Building energy modeling is currently a widely accepted practice for architectural design and energy performance evaluation, even a requirement in most building operation rating standard systems. In addition to documentation for LEED (Leadership in Energy and Environmental Design) and code requirements, energy modeling has great potential to benefit the design process by informing design decisions and targeting energy conservation investments. The energy modeling guidelines presented here aim to clarify UMass Amherst ("UMA") expectations for energy models in order to reach consistency among campus projects and create a robust perspective on metered utility data from the early stages of design to the full life cycle of building operations.

1.2. Background

a. As per Executive Order No. 484, all new construction and major renovation projects (over 20,000 square feet) must meet the Mass. LEED Plus building standard[1]. This includes certification by the U.S. Green Building Council LEED program and 20% improved energy performance over the Massachusetts Energy Code.

b. UMA has chosen to adopt the LEED Plus green building standard established by the Commonwealth of Massachusetts Sustainable Design Roundtable, and therefore has mandated a minimum LEED Silver certification for all new construction and major renovation projects. Based on EO 484 "all new construction and major renovations, effective immediately, must meet the Mass. LEED Plus green building standard established by the Commonwealth of Massachusetts Sustainable Design Roundtable."

c. UMA is continuously working to reduce its building energy use by adopting more stringent standards for new construction and major renovation projects via the cumulative efforts of a diverse group of campus community actors. As a signatory of the American College & University Presidents' Climate commitment (ACUPCC), UMA has created institutional policies to direct the development and implementation of strategies to reduce its greenhouse gas ("GHG") emissions.

[1] Governor Deval Patrick Executive Order No. 484 – Leading By Example program
http://www.mass.gov/governor/legislationeexecorder/executiveorder/executive-order-no-484.html

1.3.UMA Intent

a. UMA requires energy modeling on all new construction and major renovation projects (over 29,000 SF) to serve the energy and emission reduction goals of the University's climate action plan, and its long-term carbon neutral growth commitment.

b. At the end of the construction document phase, the designer shall provide a copy of the latest updated energy modeling file to UMA (in its native format). This file will be used internally by UMA for ongoing maintenance and operations optimization.

c. Developing an energy model from the early stages of project research assures that energy targets set during the green building design process are being met, by providing a quantitative analysis to guide design decisions. The energy model is also required as a tool to confirm energy reduction goals and establish LEED certification eligibility. It serves as a general metric used to calculate energy utilization intensity ("EUI") per square foot, according to building use type. Space-use based EUI targets for new construction and major renovation projects are generally set on a project by project basis, but UMA's recommended EUI targets for general space types are as follows:

Dining hall	250 kbtu/sf
Residential	50 kbtu/sf
Recreation	45 kbtu/sf
Office and classroom	35 kbtu/sf
Laboratory	150 kbtu/sf

UMA expects design teams to make a concerted effort to meet these targets, or surpass them when budget allows. The energy consultant is also expected to maintain an updated energy model throughout the design process in order to enable energy performance assessment of design alternatives.

d. Energy modeling shall be developed in the early stages of design (pre-SD) with the primary objective of evaluating and optimizing energy use intensity. Results from the energy model will help define design strategies and Energy Conservation Measures as projects move forward.

e. The energy model will be used to support LEED certification, as well as to qualify each project for utility incentives and in-house continuous commissioning.

f. In addition to meeting the code and LEED documentation requirements, energy modeling is an opportunity to target energy efficiency investments and smart design decision making.

1.4. Modeling Software

a. UMA prefers energy models to be completed using eQUEST, primarily because it employs the no-cost DOE developed and continuously updated energy simulation application. Designers are expected to provide native eQUEST files and/or all inputs to the model, assumptions made by the modelers, and the primary simulation results for UMA review and subsequent use. Using other simulation software requires UMA approval.

1.5. Climate Data

UMA recommends that modelers use Chicopee Falls/Westover Air Force Base TMY weather data for projects on the Amherst Campus. Using other climate data requires approval by the UMA Campus Energy Engineer.

2. Energy Modeling Phases

The following explains energy modeling expectations for applicable projects at the University of Massachusetts, Amherst. These requirements must be included in the consultant scope of services and in contractual requirements of the design team prior to signing the contract.

UMA requires an energy modeling report for each design phase (study, schematic, design development, and construction document) that explains model inputs, assumptions, simplifications, energy efficiency measures, and predicted energy savings.

2.1. Plan

In the study phase, an energy modeling plan is required to be provided by the designers that explains the modeling approach through different stages of design. This plan must be consistent with UMA Energy Modeling Guidelines and shall be approved by the UMA Energy Engineer before commencement of the pre-SD stage.

The plan must describe the following for each stage of design:

1. Model input elements that are expected to be decided or are subject to assumption

2. Structure and system options that are expected to be evaluated
3. Energy modeling software to be used
4. Level of details introduced to the model
5. Anticipated level of detail, and presentation method for the results
6. Clear process for model adjustments subject to UMA review

2.2. Pre-Schematic/Conceptual Phase

A. Objectives

At this stage, evaluate the impacts of building orientation, general shape and size on heating and cooling loads. Compare and contrast concept variations in regards to energy use, using the same simplified HVAC system. This preliminary model will be used to estimate peak, monthly and annual utility consumption breakdown for heating and cooling loads, and can be used to estimate the project's actual energy demand.

Consider the benefits of stand-alone utility systems versus campus central or regional utility systems.

B. Modeling requirements

B.1. Scope of work

a. At this stage the design team should generate and model three acceptably different massing concepts that meet *UMA Construction Design Guidelines*, unless otherwise specified.
b. Estimate the energy use intensity using a preliminary white box model with the general building size and orientation, and a generic simplified HVAC system.

B.2. Model input assumptions

a. Follow UMA templates for loads, set-points, and occupancy schedules/density for the building type. These input assumptions must remain consistent throughout the modeling stages.
c. The model should consider three different seasons of activity: fall/spring, summer, and winter break.
b. Propose occupancy schedules, indoor thermostat set-points, and HVAC assumptions for UMA review, following recommendations in Appendix B-C.

B.3. Mechanical system description

a. An evaluation of alternative mechanical systems is not within the scope of work at this stage. However, consistency in choosing the default systems for different models created at this stage is critical. This enables a robust preliminary comparison of the models based on equal system assumptions (carry these assumptions to the schematic design model).
b. Equipment efficiencies shall be minimally compliant with ASHRAE 90.1 2010 or the relevant standard associated with the applicable building codes.

B.4. Results

a. Annual energy consumption by end use (KBtu/SF)
b. Annual energy consumption with central plant efficiencies (KBtu/SF)
    i) Natural gas (MMBtu & therms)
    ii) Electricity (MMBtu & KWh)
c. Peak energy demand by end use
    iii) Natural gas (MBTH and pph)
    iv) Electricity (MBH & KW)
d. Monthly end use data in spreadsheet and graphical format.

2.3.Schematic Design Phase

A. Objectives

Many critical aspects of design are decided at this stage. The SD energy model is aimed to assess the compliance of the design with EUI targets. Significant design elements of mechanical systems, envelope performance, control systems, comfort set-points, plug load assumptions, lighting and internal loads are decided in successive simulation runs as the project moves forward and more factors become known.

This model should approximate façade fenestration and shading elements, and should represent an accurate estimation of window and door placement. The model should contain an approximation of the proposed HVAC system.

The energy model developed at this stage is used as a design assist tool to resolve queries on energy tradeoffs for design decisions and update preliminary energy estimates and goals. The SD model should be used to evaluate potential ECMs that follow the reference standard in the front of this document/chapter and it is necessary at this stage to follow ASHRAE 90.1-2010 Appendix G modeling requirements, since the goal is a reliable savings analysis against a robust baseline model, as well as relative comparison of different ECM design variations.

B. Modeling requirements

B.1. Scope of work

a. Building Envelope: a comprehensive parametric study of the roofing, exterior wall and glazing thermal characteristics for optimized cost/benefit selection of the assembly profiles in LCCA terms.
b. Building systems: alternative HVAC system types shall be studied. Approval by UMA Energy Engineer is required to assure sufficient variety among the considered mechanical systems.
c. Lighting: taking full advantage of natural daylighting and reducing the overall energy usage and lighting power density, by implementing high efficiency lighting fixtures and adequate lighting control systems using daylight and occupancy sensors. LPD shall be modeled as target of at least 30% below ASHRAE Standard 90.1 – 2010.
d. The model created at this stage shall be a modified version of the Pre-SD model that aims to capture details of Energy Conservation Measures (ECM). Inclusion of interior details is required to the extent necessary for evaluation of energy conservation measure candidates.
e. Energy Conservation Measures Strategies: UMA requires all feasible measures to mitigate greenhouse gases have been taken into consideration by the end of schematic design stage. A diverse set of ECMs and renewable energy possibilities to meet the EUI target for the project shall be studied. UMA Energy Engineer needs to approve comprehensiveness and viability of the ECMs considered.
f. Alternate heating and cooling systems for on-site generation as an alternative to central utilities provided by the Central Heating Plan.
g. The results of the SD model should allow life cycle cost analysis (LCCA), simple payback and net present value calculations based on unitary energy costs and return on investment assumptions provided by UMA.

B.2. Model input assumptions

a. Provide easy interpretation of input assumptions for UMA review; the schematic design model assumptions and expected accuracy must be reviewed by UMA Campus Energy Engineer.
b. The baseline model needs to comply with mandatory provisions (sections 5.4, 6.4, 7.4, 8.4 and 10.4) in standard ASHRAE 90.1-2010 and to follow Appendix G modeling protocol.
c. Provide supplementary calculations that support assumptions

d. Resource requirements shall be in accordance with building type and program needs.
e. Assumptions for design occupancy, set-points, schedules and minimum load requirements shall be provided to UMA for approval.
f. Three different seasons of activity shall be considered by the model; fall/spring, summer, and winter break.
g. This model shall be used as a design aid tool and will be adjusted as the design process proceeds.

B.3 Mechanical system description

a. Accurate system assignment to thermal zones shall be reflected by the model at this stage for at least three different HVAC scenarios.
b. Seasonal thermostat occupied/unoccupied set-points shall be approved by UMA Energy Engineer.

B.4 Results

a. Annual energy consumption by end use (KBtu/SF)
    i) Steam (MMBtu & therms)
    ii) Electricity (MMBtu & KWh)
    iii) Chilled water (MMBtu & ton-hrs)
b. Peak energy demand by end use
    i) Steam (MBTH and pph)
    ii) Electricity (MBH & KW)
    iii) Chilled water (MBH & tons)
c. Monthly end use data in spreadsheet and graphical format.
d. Annual and monthly energy cost
e. Life Cycle Cost Analyses

    The energy model shall be used for evaluation of the alternative scenarios in life cycle cost analysis. Cost premium inputs for the alternatives shall be provided by the project cost consultant and unitary energy costs shall be provided by UMA when appropriate.
f. Parametric study

    For high performance equipment (such as boiler, heat recovery, and automated shading control options), provide a parametric study spreadsheet that represents a differential analysis of the cost premium and performance improvement resulting from the equipment.

C. Model Review

At the end of the schematic design phase the energy model results will be reviewed and compared against the project primary goals by UMA, the project team and the commissioning agent.

2.4.Design Development, LEED/Construction Document

A. Objectives

a. At this stage, system type selection and sizing decisions are finalized. The final SD model shall be updated with refined values for schedules, miscellaneous loads, space conditions, piping and ductwork sizing, system pressures and horsepower. Evaluation of control strategies takes place at this stage. Final refinement of cost estimates and minor changes evaluation of building components and system features such as envelope details, lighting design and shading elements shall be included in design development and construction document submissions.

b. The ASHRAE 90.1-2010 Appendix G modeling protocol is to be followed at this stage. The building performance compliance with the current energy code and EO 484 will be tracked using this model.

c. The DD model should be used to estimate the number of achievable LEED points and investigate the impacts of any remaining energy efficiency measures against the minimum code compliant baseline.

d. This model will be used as the base for total operational cost evaluation over the course of LCCA time period. Model assumptions and expected accuracy need to be reviewed by UMA.

e. This model will serve as the basic model for a detailed modeling procedure of utility rebate incentives.

B. Modeling requirements

B.1. Scope of work

a. Mechanical systems: Evaluation of alternatives for system controls and small refinements of system components shall be provided by the design team for UMA approval.
b. Lighting: Energy model shall be used for final decision making on shading techniques and lighting control strategies.

c. The DD model should reflect geometry, facades, floor plans, interior details, and other building parameters as described in the latest design. Location, envelope, internal gains, schedules, and electrical and HVAC systems should be fully reflected by the model at this stage.
d. At this stage the energy model needs to be completely detailed to be used for utility rebate analysis. These models/runs will differ from the Code Compliance/LEED models.

B.2 Model input assumptions

a. Provide easy interpretation of input assumptions for UMA review
b. Provide supplementary calculations that support assumptions
c. The baseline model must comply with mandatory provisions (sections 5.4, 6.4, 7.4, 8.4 and 10.4) in ASHRAE Standard 90.1-2010. In creating the baseline model, Appendix G modeling protocol shall be followed.
d. Final, detailed models are required to be created to the extent necessary to show compliance with the building code, potential LEED credits documentation, and utility incentives analysis. At this stage, same baseline model should be used for code/LEED/utility incentive analysis.
e. Resource requirements shall be in accordance with the building type and program needs.
f. Assumptions for design occupancy, set-points, schedules and minimum load requirements shall be provided to UMA for approval.
g. Three different seasons of activity shall be considered by the model; fall/spring, summer, and winter break.

B.3 Results

a. Annual energy consumption by end use (KBtu/SF)
   i) Steam (MMBtu & therms)
   ii) Natural gas (MMBtu & therms)
   iii) Electricity (MMBtu & KWh)
   iv) Chilled water (MMBtu & ton-hrs)
b. Annual energy consumption by end use with CHP efficiencies
   i) Natural gas (MMBtu & therms)
   ii) Electricity (MMBtu & KWh
c. Peak energy demand by end use
   i) Steam (MBTH and pph)
   ii) Natural Gas (MBTH & cfh)
   iii) Electricity (MBH & KW)
   iv) Chilled water (MBH & tons)

d. Energy use in KBtu/SF by end use for stand-alone and central plant efficiencies
e. Monthly end use data in spreadsheet and graphical format
f. Annual and monthly energy cost
g. Life Cycle Cost Analysis: the energy model shall be used for the evaluation of the alternative scenarios in life cycle cost analysis. Cost premium inputs for the alternatives shall be provided by the project cost consultant and unitary energy costs by UMA if applicable.
h. Parametric study: for high performance equipment (such as boiler, heat recovery, and automated shading control options) a parametric study spreadsheet that represents a differential analysis of the cost premium and performance improvement resulting from the equipment shall be provided.

B.4 Model Review

At the end of the Design Development phase energy model results will be reviewed and compared against the primary project goals set by UMA, the project team and the commissioning agent.

B.5 Submission

a. Making final modifications to DD and CD models for final submissions; Design Development model should be revised at this stage to two separate MA LEED Plus and MA Energy Code compliance analysis and documentation.
b. Both models should follow ASHRAE 90.1-2010 Appendix G modeling guidelines with Energy Use Intensity as the basis of code and Executive Order 484 compliance.
c. Energy benefits from the Cogeneration Heating Plant should be included in both models as per LEED protocol.
d. Complete documentation using the energy model requirements of LEED EA Prerequisite, Minimum Energy Performance, and EA Credit, Optimize Energy Performance.
e. The LEED model should follow ASHRAE 90.1-2010 Appendix G modeling guidelines with energy cost as the basis of LEED percentage of energy dollars savings.

2.5.Utility Incentive

A. Objectives

a. Utility incentive energy modeling is required to complete the analysis of ECMs in order to take advantage of incentives offered by electric and gas utilities.
b. Maximizing the incentives is a high priority for UMA.
c. An engineering services proposal that includes model inputs and assumptions should be provided to the utility to discuss rebate incentive options, the utility incentive model setup and rebate model process/schedule.
d. Gas incentives are only available to projects that are not connected to the campus steam distribution system.

B. Modeling Requirements

a. This model should follow NSTAR guidelines to investigate cumulative electricity and gas savings resulting from each ECM.
b. The baseline utility incentive model systems should be the same as design system types, but minimally compliant with ASHRAE 90.1-2010.
c. Energy savings from each consecutive ECM should be estimated separately by successive introduction of the ECMs to the model in a budget/payback time based order.
d. Savings from the central cogeneration plant should not be included in final savings calculations. Utility savings should be isolated to those resulting from the project itself, in terms of MMBTU and KWh for steam, electricity and chilled water (General Information on CHP can be found in Appendix A).

2.6.Measurement and Verification

UMA will compare energy model results against the actual metered utility data after two years of occupancy as required by the UMA Measurement and Verification Plan, and will share the results with the M&V Agent who provides post-design services based on the following:

a. No further review will be required if actual energy use data is within 15% of the energy model's prediction.

b. In the case that the model results are within 15-25% of actual data:

I. The consultant will provide a written report that explains the discrepancies.
II. The consultant will either update the energy model to match actual performance rates, or share the model with UMA for their refinement.

c. The consultant will conduct a walkthrough of the building, participate in reconciliation sessions, and provide a written document explaining the results, if results vary by more than 25%.

Appendix A – CHP General Info

The Central Heating Plant (CHP) is a 16 MW combined cycle cogeneration facility. Electricity and steam are produced using a 10MW gas combustion turbine (CT) paired with a heat recovery steam generator (HRSG), a 2 MW backpressure steam turbine (STG-1), a 4 MW backpressure steam turbine (STG-2), and three package boilers (Boiler 200, Boiler 300, Boiler 400). The plant meets all night and weekend loads during the non-cooling season and generates approximately 70% of the annual campus electrical demand. The fuel supply is primarily natural gas with Ultra Low Sulfur Diesel fuel oil (ULSD) as a backup. In late 2012, a liquefied natural gas (LNG) offloading facility was built to augment winter fuel supply and displace oil use.

Table 1. Annual efficiency of the CHP based on data for 2012 calendar year

Total Fuel			BTU
	Natural Gas		1,600,000,000,000
	Oil (ULSD)		22,000,000,000
	LNG		23,700,000,000
	Total		**1,645,000,000,000**
Total Steam		pounds	BTU
	HRSG	5.08E+08	591,310,000,000
	Boiler 200	1.46E+08	169,460,000,000
	Boiler 300	1.99E+08	207,140,000,000
	Boiler 400	1.26E+08	131,480,000,000
	Total	**1.01E+09**	**1,099,390,000,000**
Total Electricity Produced		kWh	BTU
	STG-1	9381421	32,011,000,000
	STG-2	16448341	56,124,000,000
	CT	69522765	237,221,000,000
	Total	**95352527**	**325,356,000,000**
Plant Efficiency			**0.77**

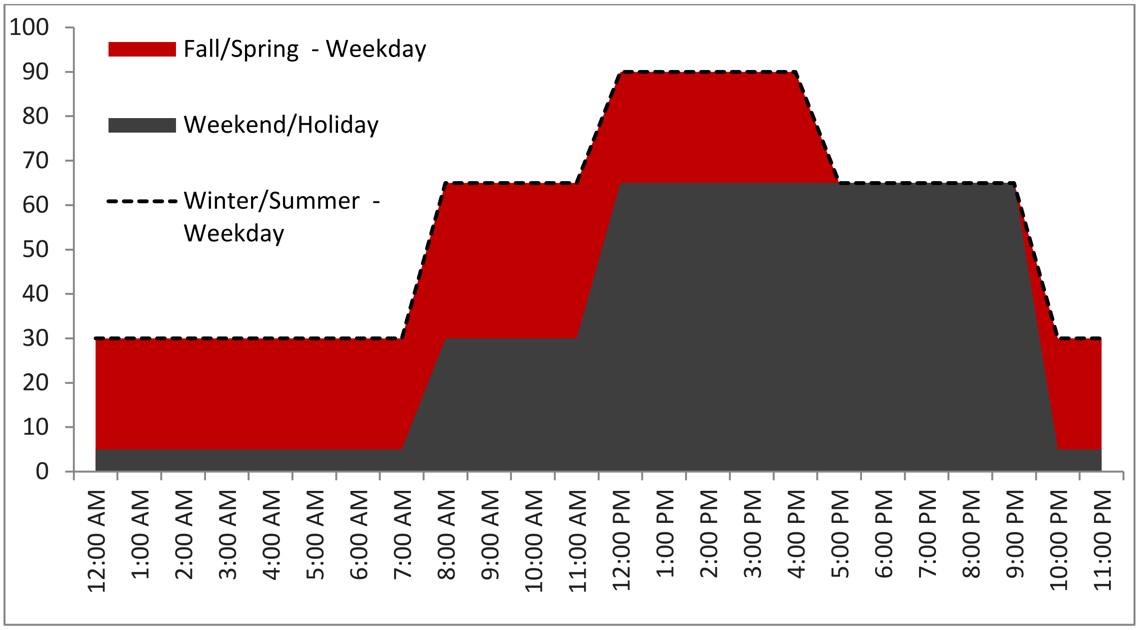
Steam distribution losses on campus were assessed during the Energy Master Plan process and have been calculated to be 15% on a mass basis.

Appendix B – Seasonal Thermostat Set-points

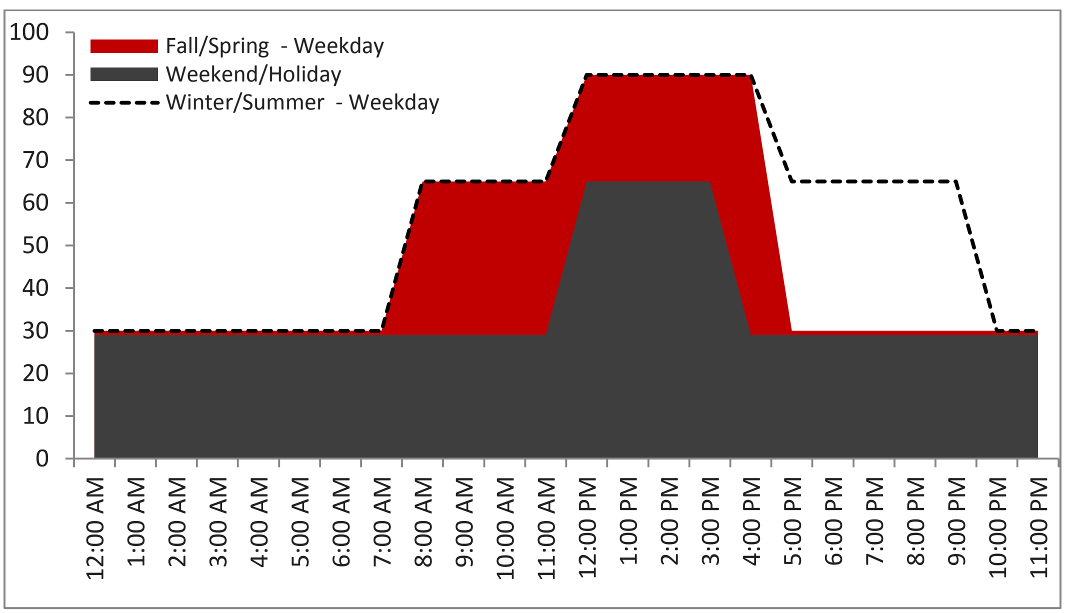
	Season	Occupied		Unoccupied	
		Cool	Heat	Cool	Heat
Office/Classroom	Fall/Spring	74	70	84	60
	Winter/Summer	74	70	84	60
	Weekend/Holidays	74	70	84	60
Laboratory	Fall/Spring	74	72	84	60
	Winter/Summer	74	72	84	60
	Weekend/Holidays	74	72	84	60
Residential	Fall/Spring	74	72	84	60
	Winter/Summer	74	72	84	60
	Weekend/Holidays	74	72	84	60
Recreation	Fall/Spring	74	72	84	60
	Winter/Summer	74	72	84	60
	Weekend/Holidays	74	72	84	60
Dining	Fall/Spring	74	70	84	60
	Winter/Summer	74	70	84	60
	Weekend/Holidays	74	70	84	60

Appendix C – Occupancy Schedule Templates

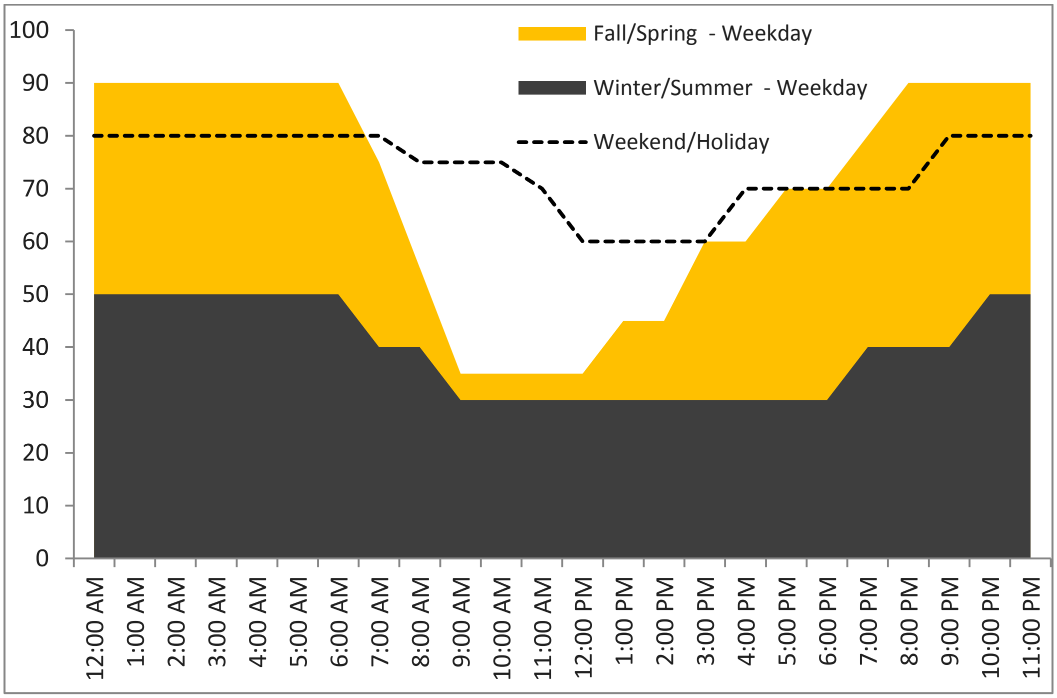
a. Laboratory



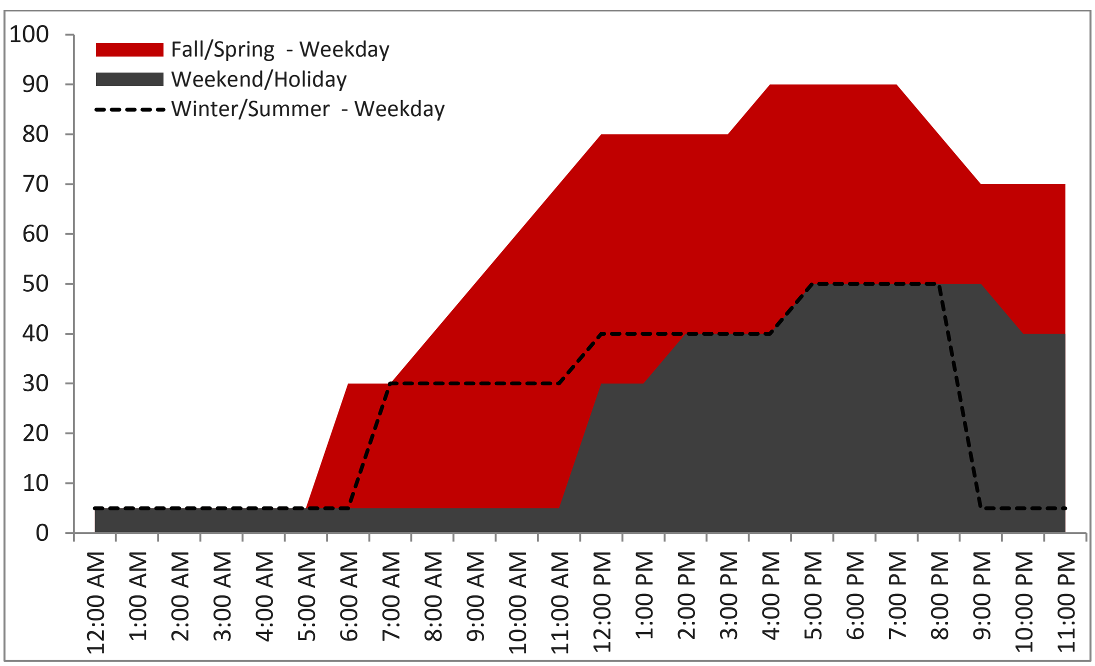
b. Office/Classroom



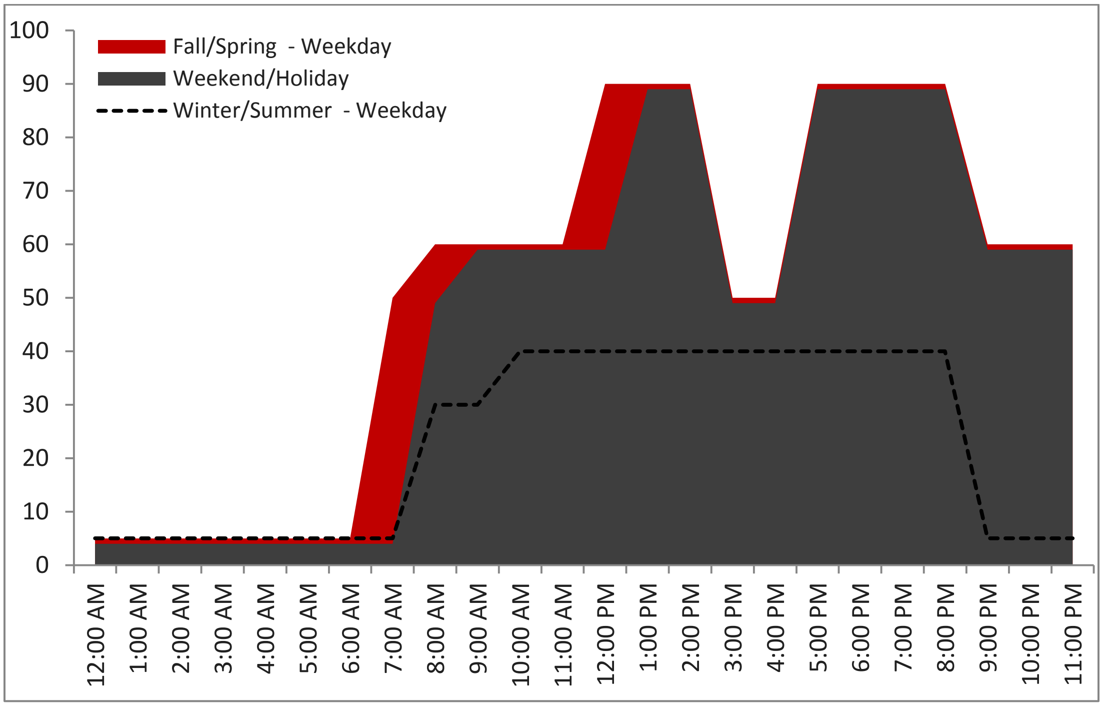
c. Residential



d. Recreation



e. Dining



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Fall/Spring - Weekday
Weekend/Holiday
Winter/Summer - Weekday
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