# TUFTS LIBRARY
**Weymouth, MA**

**Energy Efficiency Report**
**Based on Bid Set**

**Final Report**
December 6, 2018

PREPARED FOR

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## EXECUTIVE SUMMARY

Andelman and Lelek Engineering, Inc. performed computer building energy consumption simulations to evaluate the energy efficiency performance of Tufts Library in Weymouth, MA. The main objective of the study was to create eQUEST models of the *as currently designed* building and a *baseline* building and to quantify the difference in annual energy consumption between the two buildings. The base case building elements (building shell construction, mechanical systems performance, lighting system performance, etc) are assumed to meet the requirements of ASHRAE Standard 90.1-2010. This task was undertaken to evaluate the library building design in the context of earning points under LEED v4; the project is targeting LEED Silver Certification.

This is a final report conducted based on the bid documents dated November 1, 2018.

The current *proposed* building achieves **29.1%** energy cost savings (**44.2%** site energy savings) over a comparable *baseline* building that meets the requirements of ASHRAE Standard 90.1-2010. The source energy use intensity (EUI) for the *proposed* building is 91 kBtu/sf. Table 1 on the following page summarizes the results of this study. For information on the facility and the analysis methodology, please refer to the subsequent sections of this report.

In addition the following report sections are provided:

- *Energy Efficiency Measures Incorporated into Building Design* – this section provides a brief description of energy conservation measures that appear to be already incorporated into the building design.

## Table 1 – Summary of Energy Consumption Comparison

| End Use | Regulated Load ? (Y/N) | Energy Type | Units of Annual Energy & Peak Demand | | Baseline Building Results | As Designed | Percent Savings |
|---|---|---|---|---|---|---|---|
| Area Lights | Y | Electricity | Energy Use | kWh | 172,907 | 104,843 | 39.4% |
| | | | Demand | kW | 55.3 | 36.7 | 33.6% |
| Misc Equip | N | Electricity | Energy Use | kWh | 151,652 | 151,652 | 0.0% |
| | | | Demand | kW | 47.4 | 47 | 0.0% |
| Space Heating | Y | Electricity | Energy Use | kWh | 0 | 1,399 | 0.0% |
| | | | Demand | kW | 0.0 | 14 | 0.0% |
| Space Cooling | Y | Electricity | Energy Use | kWh | 106,782 | 69,034 | 35.4% |
| | | | Demand | kW | 147.0 | 65.3 | 55.6% |
| Heat Rejection | Y | Electricity | Energy Use | kWh | 0 | 493 | 0.0% |
| | | | Demand | kW | 0.0 | 7 | 0.0% |
| Pumps & Aux. | Y | Electricity | Energy Use | kWh | 4,052 | 32,144 | -693.3% |
| | | | Demand | kW | 3.3 | 7.0 | -112.4% |
| Vent Fans | Y | Electricity | Energy Use | kWh | 82,063 | 61,704 | 24.8% |
| | | | Demand | kW | 27.8 | 19.2 | 30.9% |
| Domestic Hot Water | Y | Natural Gas | Energy Use | Therms | 430 | 375 | 12.8% |
| | | | Demand | Therms/hr | 0.1 | 0.1 | 0.0% |
| Exterior Usage | Y | Electricity | Energy Use | kWh | 33,176 | 9,604 | 71.1% |
| | | | Demand | kW | 7.6 | 2.2 | 71.1% |
| Space Heating 2 | Y | Natural Gas | Energy Use | Therms | 8,568 | 420 | 95.1% |
| | | | Demand | Therms/hr | 12.0 | 3.3 | 72.4% |
| Total Energy Use (kBtu/year) | | | | | 2,779,086 | 1,550,056 | 44.2% |
| Annual Process Energy (kBtu/year) | | | | | 518 | 518 | 0.0% |

**Energy Cost and Consumption by Energy Type - Performance Rating Method Compliance**

| Energy Type | | | Baseline Design | As Designed | Percent Savings |
|---|---|---|---|---|---|
| Electricity | Usage | kWh | 550,631 | 430,873 | 21.7 % |
| Electricity | Cost | $ | 100,685 | 78,162 | 22.4 % |
| Natural-Gas | Usage | Therms | 8,998 | 795 | 91.2 % |
| Natural-Gas | Cost | $ | 11,213 | 1,181 | 89.5 % |
| Total Site Energy Use (kBtu/year) | | | 2,779,086 | 1,550,056 | **44.2%** |
| Total Energy Cost ($) | | | $ 111,898 | $ 79,343 | **29.1%** |

## FACILITY DESCRIPTION

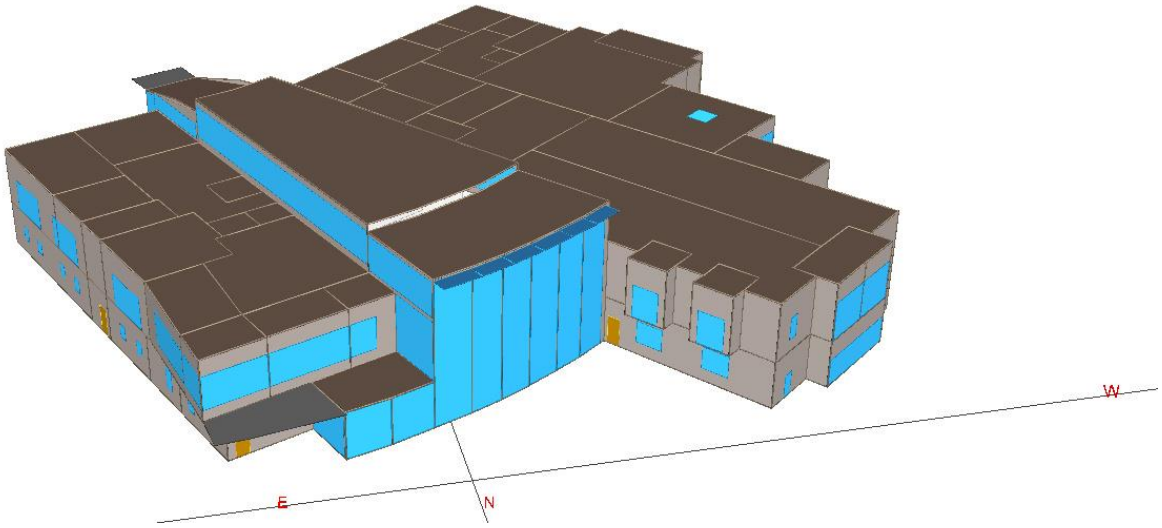


**Figure 1: eQuest model of Tufts Library**

### General

Tufts Library is located 46 Broad Street in Weymouth, MA. The building occupancy pattern assumed in this analysis is based on information provided by the town of Weymouth and is generally consistent with public library operation. The building is open between 9:00 am and 9:00 pm Monday through Thursday, 9:00 am to 5:00 pm Friday and Saturday. The building is closed on Sunday, and also on Saturday between Memorial Day and Labor Day. Offices are occupied Monday to Friday between 8:00 am and 6:00 pm weekdays only. The building is closed on major holidays. The building is used year round, with increased occupancy during the summer. There are 27 staff members and peak visitor occupancy is 900 people.

Electric and gas service are provided by National Grid.

### Architectural

The new building has a total area of approximately 50,345 sf and is two stories high. The building includes study rooms, meeting rooms, a digital media room/lab, offices, history archive, children's and teen rooms, and utility and support spaces.

The table below provides a brief description of the spaces located on each floor.

| | |
|---|---|
| 1st floor | Children's room, meeting and conference rooms, study room, multipurpose room, story room and mechanical spaces |
| 2nd floor | Book collections/stacks, study rooms, offices, history archive rooms, meeting and conference rooms, teen room, AV and periodicals |

The building envelope components of the project are briefly described below.

Wall Constructions:

The predominant wall types are shown below:

EX1 and EX2 have 4" masonry veneer on the outside, 2" air space, 3" polyisocyanurate (R-15.2 ci), ½" gypsum sheathing, R-13 batt insulation, 8" (EX1) or 3 5/8" (EX2) metal studs, 5/8" gypsum wall board. Overall U-0.042.

EX5 and EX6 have phenolic panels, 2" air space, 3" stone wool (R-13 ci), R-19 batt insulation, 8" metal studs, 5/8" gypsum wall board. Overall U-0.045.

Roof Constructions:

RF1- TPO roofing on metal deck: TPO membrane roofing, ½" gypsum cover board, minimum 6" polyisocyanurate (average 7"), 5/8" gypsum sheathing, metal deck. Overall U-0.026.

RA2- TPO roofing on concrete deck: TPO membrane roofing, ½" gypsum cover board, minimum 6" polyisocyanurate (average 7", R-39), 5/8" gypsum sheathing, concrete deck, metal deck. Overall U-0.026.

RA3- TPO roofing assembly at vaulted roof: TPO membrane roofing, ½" gypsum cover board, 8" polyisocyanurate (R-45), 5/8" gypsum sheathing, metal deck. Overall U-0.022.

Windows:

The project includes fixed aluminum framed windows and entrances and glazed steel and aluminum curtain walls. All of the windows are proposed triple glazed with argon fill. SHGC is 0.3 for south, east and west exposures and 0.4 for north exposure. Overall, windows will constitute approximately 40% of the total wall area. In the analysis presented in this report all fenestration (window types) on this project have the following thermal performance based on the information from the Bid Set.

| Window Type | Frame Type | Overall U-value | SHGC |
|---|---|---|---|
| Fixed and Operable Windows | Aluminum framed | U-0.3 | SHGC-0.3 (south/east/west) SHGC-0.4 (north) |
| Steel and Aluminum Glazed Curtain walls | Aluminum framed | U-0.28 | |
| Storefront | Aluminum framed | U-0.45 | |

**Mechanical Systems**

Air-Side HVAC

The building will be served by the HVAC systems described below.

<table>
<tr><th>Systems</th><th>Area Served</th><th>Features</th></tr>
<tr><td>ERUs-1 & 2</td><td>All regularly occupied spaces</td><td>ERUs 1 and 2 are water source heat pumps that provide ventilation air to spaces served by VRF fan coil units. The ventilation air is provided to the VRF indoor units via VAV boxes, which modulate in response to $CO_2$ sensors.
<table>
<tr><th rowspan="2">Unit ID</th><th>Supply/ Exhaust Airflow</th><th>Supply Fan</th><th>Exhaust Fan</th><th>Cooling Capacity</th><th>Heating Capacity</th><th>Cooling Efficiency</th><th>Heating Efficiency</th><th colspan="2">Energy Recovery Effectiveness</th></tr>
<tr><th>cfm</th><th>hp</th><th>hp</th><th>MBh</th><th>MBh</th><th>EER</th><th>COP</th><th>Winter</th><th>Summer</th></tr>
<tr><td>ERU-1</td><td>7,000</td><td>7.2</td><td>7.2</td><td>256</td><td>294</td><td>15</td><td>4.5</td><td>0.7</td><td>0.63</td></tr>
<tr><td>ERU-2</td><td>3,500</td><td>7</td><td>4.5</td><td>187</td><td>177</td><td>15.5</td><td>4.5</td><td>0.61</td><td>0.61</td></tr>
</table></td></tr>
<tr><td>VRF</td><td>CHP and DHP</td><td>These are water-cooled VRF fan coil units. Ducted units (DHP) serve large interior spaces. Non-ducted (CHP—cassette type) serve perimeter spaces. The VRF system utilizes refrigerant heat recovery through use of branch circuit controllers as well as heat recovery between condensing units on the condenser water loop.</td></tr>
<tr><td>AC-1 to 4</td><td>Server/IDF rooms</td><td>Dedicated air-cooled DX split systems. Two units have a cooling capacity of 36 MBh with 16.2 SEER and two units have a cooling capacity of 12 MBH with 15.2 SEER.</td></tr>
<tr><td>Unit heaters</td><td>Stairwells and mechanical spaces</td><td>These are unit heaters and cabinet unit heaters with hot water coils.</td></tr>
</table>

Water-side HVAC

The indoor VRF units are served by four water-cooled condensing units. The VRF refrigerant temperature is maintained by the condenser water loop, which is maintained between 63F and 85F; heat addition is provided from three gas-fired high efficiency condensing boilers and heat rejected is provided from a cooling tower. The boilers each have input capacity of 750 MBh and 93.5% efficiency. The 117 ton closed circuit cooling tower has three cells with variable speed fans.

Two gas-fired high efficiency condensing boilers serves the unit heaters and radiant floor heating in the two main entry vestibules and cafe. Both boilers have an input capacity of 220 MBh and 93.5% efficiency. The design HWST is 120F with a 10 degree temperature differential.

The heat pump condenser water loop will be served by three pumps (one is spare), P-1, P-2 and P-3, each sized at 235 gpm and 5 hp and controlled with VFDs. There are two pumps (one is spare) serving the radiant heating loop; each pump is sized at 30 gpm and ¾ hp .

**Lighting Systems and Equipment Loads**

The interior lighting system for the proposed building will consist of 100% LED fixtures. The targeted lighting power density (LPD) for the proposed building is 0.79 W/sf, with area of 50,345 sf. This equates to about 34% reduction from the ASHRAE 90.1-2010 maximum of 1.19 W/sf (building area method). The design is expected to include occupancy sensors in nearly all spaces, Daylighting controls are provided for most perimeter spaces.

Miscellaneous equipment loads are assumed to be as follows:

- 1.5 W/sf for offices
- 1.0 W/sf for stacks, meeting rooms, children's and teen room, study rooms
- 0.2 W/sf for all other spaces such as lobby, corridors, stairs, etc.
- Equipment load in equipment and server rooms is based on 30% of design cooling capacity (3.16 kW for 36 MBh units/1.05 kW for 12 MBh units)

Equipment loads comprise all non-HVAC equipment plugged into convenience outlets, including computers, printers, monitors, etc.

**Domestic Hot Water System**

The domestic hot water (DHW) loads are expected to include primarily lavatory sinks. There is one condensing water heater with thermal efficiency of 95%, input capacity of 76 MBh each, and storage tanks with capacity of 50 gallons. The energy consumption associated with domestic hot water heating was estimated based on average daily use of 0.6 gallons of hot water per occupant and an assumed average occupancy of 400.

**Energy Management Systems**

A complete building management system (BMS) will be provided for all mechanical systems and other facility systems as included in the project documents. Direct digital controls (DDC) will be provided for all ERUs, VRF units, cooling tower, boilers, pumps and terminal units. The DDC will be tied into the BMS and many system outputs will be available to view as live data or trends.

**Renewable Energy**

There are currently no plans to include renewable energy systems.

**Energy Use Intensity**

The goal source Energy Use Intensity (EUI) for this project targeted at the initial energy goals meeting on May 25, 2018 was 100 kBtu/sf/year. This was based on an assumption of 8 kWh/sf/yr of electricity and 0.15 therms/sf/yr based on previous similar projects. The baseline and proposed EUI (site and source energy) are shown in the table below.

| | Site EUI (kBtu/sf/yr) | Source EUI (kBtu/sf/yr) |
|---|---|---|
| Energy goals meeting target | | 100 |
| Proposed model | 31.4 | 91 |
| Baseline model | 56.8 | 132.9 |

## ANALYSIS METHODOLOGY AND BASELINE DESIGN DESCRIPTION

The comparison of the *baseline* and the *proposed* building was performed according to the LEEDv4 energy savings calculation protocol and followed the analysis methodology described in the informative Appendix G to ASHRAE Standard 90.1-2010. Software used in the analysis is eQUEST version 3.65 build 7164 (DOE 2.3). Boston, MA TMY3 weather data was used. The *proposed* and the *baseline* building eQUEST models were compiled using information obtained from bid documents dated November 1, 2018 and anticipated use schedules for the facility provided by the building owner.

eQUEST does not have the capability to model water-cooled VRF systems directly. The systems were modeled as water-cooled heat pumps. This allows the refrigerant energy recovery between VRF systems to be captured as well as energy recovery between condensing units on the same condenser water loop. In eQUEST, the heat pumps are zonal systems; therefore, the cooling and heating efficiencies of the associated central compressors was assigned to each zonal heat pump.

Electric utility costs and cost savings were calculated using National Grid G2 rate while natural gas costs and cost savings were calculated using National Grid's G-41b rate.

A list of all items that differ in the two building models is provided in Table 2 at the end of this section. The list also provides values used in those varying components in the *proposed* and *baseline* building models. Any components not mentioned in the table are identical in both models.

## Summary of Major Differences between Proposed and Baseline Building

| ASHRAE 90.1 Section 5: Building Envelope | | |
|---|---|---|
| **Model Input Parameter / Energy Efficiency Measure** | **Proposed Case** | **Baseline Case** |
| Building Shape | Per design documents | Same as proposed case |
| Building Square Footage | 50,345<br>(49,300 per model) | Same as proposed case |
| Building Orientation | plan north rotated 22.5° west of True North | Same as proposed case |
| Wall Insulation | Walls:<br>Masonry Veneer (Metal Framed): R-13 + R-15.2ci (assembly U value-0.041)<br>Phenolic Siding (Metal Framed): R-19 + R-11ci (assembly U-value: 0.45) | ASHRAE 90.1-2010<br>R-13+R-7.5 ci. (Metal Framed) |
| | Mass: R-15.2 ci. | N/A |
| Roof Insulation | Membrane roof assembly – EPDM membrane roofing with average 7" rigid insulation (R-39). Assembly U-value: 0.026) | ASHRAE 90.1-2010<br>R-20 (Insulation Entirely above Deck) |
| Slab on grade (unheated) | R-10 under entire slab<br>F-0.36 | ASHRAE 90.1-2010<br>F-0.73 (No insulation required) |
| Slab on grade (heated) | R-15 for 36 in below (F-0.79) | R-15 for 24 in below (F-0.86) |
| Window distribution | Approximately 40% window to wall ratio | Same as proposed case |
| Windows Thermal Properties | Windows fixed: U-0.30<br>Windows, operable: U-0.30<br>Curtainwalls (Steel & Aluminum): U-0.28<br>Storefronts: U-0.45<br>SHGC: 0.3 South/East/West<br>SHGC: 0.4 North | ASHRAE 90.1-2010<br>Metal Framing: U-0.55<br>Curtainwalls/Storefront (Metal framed): U-0.45<br>SHGC-0.4 |

| ASHRAE 90.1 Section 6: HVAC (Air-side) | | |
|---|---|---|
| **Model Input Parameter / Energy Efficiency Measure** | **Proposed Case** | **Baseline Case** |
| HVAC System Types | Per available design documents | Per ASHRAE 90.1-2010 Table G3.1.1A "Baseline HVAC System Types" and Table G3.1.1B "Baseline System Descriptions" |
| | **Most library spaces:** water cooled VRF with refrigerant energy recovery.<br><br>Ductless indoor VRF fan coil units for perimeter spaces and ducted VRF FCUs for large interior spaces<br><br>Ventilation air is provided by two energy recovery units (water source heat pumps) | Appendix G Methodology: Baseline System 5- Packaged VAV with reheat. The design air flow is allowed to be self-sized; same outside air flow as in the proposed case. The equipment capacities are oversized by 15% for cooling and 25% for heating according to App. G3.1.2.2 ASHRAE 90.1-2010. |
| | radiant floor heating in several perimeter spaces/vestibules | N/A |
| | Unit heaters: hot water | Same as proposed case |
| | **IDF/Data Room(s):** DX split systems | Baseline System 3 - Packaged rooftop air-conditioner |
| Equipment Capacities | Water-cooled condensing units: (1) 288 MBh cooling caxpacity; (3) 240 Mbh cooling capacity<br>VRF units: indoor unit cooling capacity between 8 and 96 MBh and heating capacity between 9 and 108 MBh; | Baseline equipment is self sized<br>RTU-1 (1st floor): 23,592 cfm, 1,129 Mbh cooling, 1,547 Mbh heating<br>RTU-2 (2nd Floor): 37,377 cfm, 1757 Mbh cooling, 2507 Mbh heating |
| Equipment Efficiencies (COP, EER, etc) | Modelled as water source heat pumps<br>Condensing unit efficiency of 10.8 EER (240 MBh cooling capacity ) and 11.7 EER (288 MBh cooling capacity)<br>ERU-1: assumed EER of 15<br>ERU-2 15.5 EER<br>Data room split systems have EER of 10.8 (AC-1&2) and 12 (AC-3&4) | Based on minimum requirements of Table 6.8.1<br>RTU-1 & RTU-2: 9.5 EER<br>AC units: 12 EER |
| HVAC Air-side Economizer Cycle | N/A | OA Drybulb for System 5 |
| Economizer High-Limit Shutoff | N/A | 70F OA Dry bulb |
| Fan System Operation | ERU supply and exhaust fans run continuously during occupied periods | Same as proposed |
| Fan Capacity Control for VAV units | VAV control of ERU<br>FCUs 3 speed (modeled as variable volume with minimum flow of 70%) | Variable volume fans for RTUs; minimum flow of 0.3 or ventilation requirement, whichever is greater |
| Fan Power (kW) **(supply, return, and exhaust fans)** | Calculated based on the scheduled hp and airflows<br>VRF indoor units: 0.00027 kW/cfm<br>ERU-1: 0.000834 kW/cfm supply, 0.000834 kW/cfm exhaust<br>ERU-2: 0.00139 kW/cfm supply, 0.000906 kW/cfm exhaust | 0.000677 kW/cfm for RTU-1 Sys 5 (supply and return)<br>0.000665 kW/cfm for RTU-2 Sys 5 (supply and return) |
| Exhaust Air Energy Recovery | ERU 1: 0.7 (winter)/0.63 (summer) total effectiveness<br>ERU 2: 0.61 total effectiveness | No for RTUs 1 & 2 (<30% OA) |
| Demand Controlled Ventilation | All spaces | Several meeting rooms, café, lobby |
| Ventilation (minimum design outside air) | ERU-1 airflow is 7,000 cfm/ERU-2 3500<br>VAV boxes will control the ventilation air to the spaces and modulate based on CO2 levels | All areas are provided with the same amount of OA as in the proposed case (constant volume) |
| Supply Air Temperature Reset Parameters | None | 5F for units modeled as system 5: between 55F and 60F |

| ASHRAE 90.1 Section 6: HVAC (Water-side) | | |
|---|---|---|
| **Model Input Parameter / Energy Efficiency Measure** | **Proposed Case** | **Baseline Case** |
| Boiler plant | Five high efficiency gas fired condensing boilers<br>B-1, B-2, B-3 750 Mbh input with 93.5% efficiency serving VRF condenser loop<br>B-4, B-5 with 220 MBh input and efficiency of 93.5% serving radiant floor heating loop | Two equally sized atmospheric gas-fired boilers 80% thermal efficiency per ASHRAE Table 6.8.1F<br>B-1 & 2 (self sized at 739 Mbh each) |
| HW Supply Temp Reset | HW supply temp 80F(condenser water loop)<br>HW supply setpoint 120ºF temperature and return temperature of 110ºF (Radiant loop) | HW supply (water leaving boiler) reset between 180ºF@20ºF and 150ºF@50ºF OA temp, as per G3.1.3.4 |
| Hot Water Pumps | VRF Condenser water loop: (2) pumps (1 spare), 350 gpm, 5 hp each<br>Radiant HW Loop: (2) pumps (1 spare) 30 gpm, 3/4 hp each | HW pumps<br>self sized at 74 gpm<br>19 W/gpm |
| Boiler Pumps | BP-1, 2, 3 (condenser water loop): each 45 gpm, 3/4 hp<br>BP-4,5 (radiant floor loop): each 23 gpm | N/A |
| Pump Control | Variable speed | Constant volume |
| HHW Loop Configuration | Primary/secondary assumed minimum flow of 25% | Primary Only |
| Cooling Tower | 3-cell cooling tower sized at 117 tons (4) 5 hp fans, variable speed control | N/A |

| | | |
|---|---|---|
| **ASHRAE 90.1 Section 9: Lighting** | | |
| Interior lighting system wattage density | 0.62 W/sf | 1.18 W/sf (building type: Library) |
| Occupancy Sensors | most spaces | per ASHRAE 90.1-2010<br>Offices (<250 sf)<br>Conference/Multipurpose Rooms<br>Restrooms<br>storage rooms |
| Daylight Controls | Assumed to be in most perimeter rooms regardless of area | per ASHRAE 90.1-2010 (perimeter spaces with area > 250 sf |
| Exterior lighting system wattage density | 2.2 kW | 7.6 kW |
| **ASHRAE 90.1 Section 7: Service Water Heating** | | |
| Domestic Hot Water Heater | Gas-fired condensing hot water heater<br>76 Mbh, 94% efficiency, 120F supply temperature<br>50 gallon storage | 80% efficiency gas-fired |
| **Miscellaneous** | Fans PF-1 to 4 are destratification fans, each with 19,292 cfm and 53.7 W<br>EF-1 serves the mechanical room; 1000 cfm and 0.25 hp | same as proposed case |
| Equipment Loads | 1.5 W/sf for offices<br>1.0 W/sf for stacks, meeting rooms, children's and teen room, study rooms, cafe<br>0.2 W/sf for all other spaces such as lobby, corridors, stairs, etc.<br>IDF/Data rooms: 3.16 kW for 36 MBh units/1.05 kW for 12 MBh units | same as proposed case |
| Electric Rate Schedules | National Grid G-2 | same as proposed case |
| Gas Rate Schedules | National Grid G41b natural gas rate | same as proposed case |

## ENERGY EFFICIENCY MEASURES INCORPORATED INTO BUILDING DESIGN

Based on the Bid Set and on conversations with the design team, it appears that a number of energy efficiency measures and technologies are already incorporated into the building design and are accounted for in the *proposed* building model presented in this report. A brief description of each measure is provided below.

1. Building envelope enhancements:
    a. Roof insulation (R-39/R-45) that exceeds code minimum requirements (R-20).
    b. Exterior walls with assembly insulation value (R-13 + R-15.2 ci and R-19 + R-13 ci) exceeding code minimum requirements (R-13 + R-7.5 ci).
    c. Glazing with thermal properties (overall U-0.30, SHGC-0.40) that exceed code minimum requirements (U-0.45 for curtain wall/storefront, U-0.55 for metal-framed windows, SGHC-0.40).
2. High efficiency gas-fired condensing boilers.
3. High efficiency water-cooled VRF systems instead of baseline packaged VAV rooftops.
4. Enhanced controls, including demand controlled ventilation (DCV) for VAV boxes providing ventilation air to most spaces where DCV is not required by code.
5. Exhaust air energy recovery with 61%-70% heat recovery effectiveness for ERUs 1 and 2; no energy recovery is required in the baseline because the baseline RTUs have less than 30% OA.
6. High-efficiency lighting system with 33% lower lighting power density less than the code maximum allowance.
7. High efficiency condensing domestic water heater.