Lyndon Baines Johnson Apartments
150 Erie Street, Cambridge, MA
Cambridge Housing Authority

Envelope: The Lyndon Baines Johnson Apartments is a 130,218 square foot (including conditioned basement), 12 story building designed for multifamily habitation. The 180 unit building is located on Erie St in Cambridge, MA. The building was constructed in the early 1970's and has one 5-story wing and one 12-story wing. Most units have balconies and all have floors and walls that extend from inside to outdoors without insulation. Starting with precast concrete construction with modest interior insulation and large areas of thermal bridging, the building is to be rehabbed with an air barrier and an exterior insulation and finish system including 2" exterior foam. The main roof of the building is composed of 6" pre-stressed concrete, and the roof was replaced in 1985 with a tapered layer of foam insulation with a specified R-25. As part of the renovations, a new attic roof will be added above the existing roof to house the mechanical equipment and ductwork. The attic space below the roof will be minimally conditioned, and the new roof will have R-30 insulation. Windows are currently double glazed aluminum frame (assumed U-value = .72, SHGC = .66) and will be replaced with low-e thermal break glazing with double Low E, Krypton, and thermal frames which yields a .36 U Factor and .27 SHGC. Completing the envelope, the floors above the garage areas will have 4" polystyrene insulation, and above grade foundation areas will be EIFS with extruded polystyrene, with 2" on exterior foundation walls. A band of tiled masonry at ground level will be insulated on the inside. Of great importance will be air sealing of the building, with air barrier at the envelope, air sealing between units and at floors, which is expected to reduce infiltration heat losses by 25%. Envelope improvements alone are expected to result in an approximate 25% decrease in energy use.

Equipment: The existing building is heated by electricity (baseboard for units, electric furnace for ventilation, etc.). Cooling, which exists in approximately 30% of the units, is achieved by window air conditioners with an approximate SEER (Seasonal Energy Efficiency Ratio) of 7. The new mechanical system will be water based for both heating and cooling, with vertical fan coils in the units and fan coils heating and cooling the ventilation air as well as heat recovery from the unit exhaust air. Heating water is supplied by a 94% efficient condensing boiler, and cooling is supplied by a super efficient SMARDT Chiller, which operates better at part load (most of the time) with .377 kW/ton IPLV (Integrated Part Load Value) and a full load rating of .577 kW/ton. For the first floor, except the kitchen which is heated and cooled by a hydronic fan coil, the system is completely different with a Mitsubishi City-Multi heat pump system providing both heating and cooling through multiple direct refrigerant exchange fan coils. This is a variable speed/refrigerant volume system with high energy efficiency (cooling SEER 12.7 Heating COP 3.7) in both heating and cooling modes. In addition, there are several other minor mechanical systems such as commercial kitchen exhaust, laundry make up air, kitchen appliances, ECM motors for fan coils, VSD pumping, etc., which add to the energy and cost savings.

Ventilation savings were achieved by using an energy recovery ventilator (ERV), which supplies the corridor make-up air. The apartments have exhaust only ventilation, and provide the exhaust side of the ERV, which recovers both sensible and latent heat from the outgoing stream of air. The sensible heat recovery has 72% average effectiveness for the two systems (normalized for airflow). The offices on the first floor are supplied with fresh air by a small heat recovery ventilator.

Envelope losses were dramatically reduced by a combination of envelope improvements, ventilation efficiency measures, and air sealing. Lighting improvements also save energy and reduce cooling loads. Envelope and glazing improvements, lighting power reductions (many already in place), high efficiency mechanical heating, and ventilation and cooling design combine to save over 423,825 kWh in electric energy or about 22%. Because of the switch to gas heat, there is an increase in fossil energy relative to current use, but the code base case requires specific equipment corresponding to the installed equipment. So for the code case, we will have minimum efficiency water cooled centrifugal air conditioning for the upper building and Packaged Terminal Heat Pump for the first floor rather than the actual electric heating systems.

Renewables: In addition to the Envelope, equipment and ventilation improvements described above, the building will have two types of renewable energy supply. A solar Matrix aspirated wall air heater will preheat incoming fresh air before it goes to the corridor make-up air system. This inexpensive air heater consists of perforated metal panels which heat air as it is drawn through the holes when the panel is heated by the sun. Due to the close contact between air and metal and the low operating temperature of the panels (they only need to heat air a few degrees to be effective), these panels operate at the highest possible thermal efficiency for solar collectors. In addition, there will be a rooftop photovoltaic array, calculated for a system of 80 peak watts. This is the approximate maximum size system that can fit on the roof of the twelve storey building. The lower roof will have too much shading for added panels. The electricity produced will be subtracted from the purchased electricity and will be eligible for the new Massachusetts feed-in tariff. Other incentives may reduce the initial cost of the system, so that the rate of return on this investment may be very high, and the pay back short.

Cogeneration: In the current phase of design, two 75 kW cogenerators are specified. These generators will use natural gas to generate electricity and capture much of the waste heat for heating domestic hot water first and space heat second. Approximately 54% of the fuel energy will be captured as heat, and 28% as electricity. Thus the cogenerator acts as a low efficiency boiler while producing substantial amounts of electricity as a primary product. The cogenerators provide a substantial fraction of the electric use of the building and reduce the electric use by 36% for the first generator (which can operate nearly full time heating domestic hot water), and an additional 22% for the second (which operates more in the winter for space heat). However, the production of electricity and heat results in an increase in gas use, since we are operating an low efficiency boiler instead of high efficiency, therefore, with cogeneration, gas use increases, though electric use decreases dramatically. Overall, the site energy usage increases slightly, while both the source energy and cost decrease dramatically. The overall cost savings for both cogenerators is a little over $50,000 per year.

Summary comparison: The final comparison of the design case building to the code base case includes the solar air and photovoltaic inputs as well as the cogeneration inputs. The building as designed is expected to use 22% less electrical energy than the code base case, with peak load savings of 29% in winter and 17% in summer. The reconstructed building is expected to perform 50% better than code requirements in gas consumption. The utility cost rates used for both the budget and as-designed cases were based on historical utility rates using the actual billing data for the latest annual electricity and natural gas costs.

Key Building Energy Efficiency Measures:

1. High Efficiency Lighting: Average lighting power density for the structure is .6 W/sf versus .7 W/sf allowed by the ASHRAE 90.1-2007 standard for apartments.

2. Additional Insulation: The attic buffer space with an R-30 roof and minimally conditioned attic will have an effective R-value of over 35, while an R-value of 30 is allowed by ASHRAE 90.1-2007 for insulation in a pitched roof in this climate. Similarly, the above grade walls will have a two inch layer of extruded polystyrene (R-11) as part of the EIFS system, and some of the walls currently have R-8 within the metal stud bays for a total wall R-value of 19. New walls at balconies will have integral R-19 as well as the exterior insulation and finish system. The R-value of the walls varies by area, but the average for opaque wall areas is roughly R-16.

3. Air sealing: the air sealing protocol will include the addition of a sealed air barrier, new windows, airsealing between units, and airsealing between floors. Special measures will be applied to elevator lobbies and shafts.

Overall the building is anticipated to reduce unwanted and expensive airflow by 25% or more.

4. High Efficiency Glazing: The building has a large area of glass – roughly 40% of the wall area, which is very high by current residential standards. The fenestration, both operable and fixed, as well as storefront on the first floor, is Double Low E, krypton filled and triple glazed provided by Keystone, with glazing U-Value of 0.36 versus 0.4 allowed by Mass Code. Solar Heat Gain Coefficient is 0.27 for these windows vs. Mass Code requirement of 0.70, and there is 51% visible transmittance.

5. The main part of the building, the corridor ventilation system and the units are heated by multiple fan coil systems, with setback thermostatic controls for each unit, supplied by a condensing boiler (Lochinvar, AFUE .94). The first floor is heated and cooled by the City-Multi variable refrigerant flow heat pump system.

6. The cooling system is powered by the SMARDT chiller, a magnetically lubricated variable speed compressor that has extremely high efficiency, particularly at part load. The integrated part load value (IPLV) for the system is .377 kW/ton IPLV and a full load rating of .577 kW/T. We anticipate fractional usage most of the time, and this system works best at part load.

7. Ventilation heating and cooling is also provided by two heat wheel type heat recovery ventilators (ERV), which supplies both corridor zones. The ERV is 72% effective at recovering heat from the outgoing air. The heat recovery ventilator also recovers latent heat at 70% effectiveness.

8. The hot water is heated by the same boilers at 94% efficiency through an indirectly heated tank. The overall DHW energy factor is 85%, calculated by the Energy Star method. Recirculation is temperature controlled.

9. Heating and cooling are provided to the units by high efficiency fan coils with electronically commutated motors (ECM), which cut the electricity needed for fans by more than half.

Description of Differences between ECB and DEC Case

The Code Base Case is Massachusetts Energy Code compliant with the base case established using Table 1304.2.8 BUILDING ENVELOPE REQUIREMENTS for Climate Zone 13a of the standard. The Code Base Case was modeled with a Minimum efficiency water based centrifugal system for cooling and with 80% eff. standard efficiency boiler (residential, fossil heat), and the Design case was the SMARDT system with 94% boiler.

Every building envelope element and equipment efficiency is substantially more energy efficient than the Code case as shown in the following chart. In addition, the design case includes reduced lighting as well as improved ventilation and high efficiency service hot water equipment. Fans and pumps are high efficiency. ECM drives are used on heat recovery ventilation equipment.

Comparison of Budget Design versus Design Energy Case

Building Element:	Building Design	ECB ASHRAE 90.1-2007
	(Design Energy Cost Case)	**Massachusetts Code Prescriptive Requirement**
		Performance Rating Method Case
BUILDING ENVELOPE	As currently designed	Values from 780 CMR-2007 Table 1304.2.5 (Climate Zone 13a)
Wall Construction	• EIFS façade w/R-11, 2" continuous exterior polystyrene, interior 1" foil faced foam t end walls and R-19 fiberglass in new wall areas. Avg. U-factor = 0.053 approx R-20	• Modeled with existing insulation average R-8
	• Foundation wall above grade 2" extruded polystyrene EIFS U=.09 No slab insulation	• Insulation not required for unheated slab on grade
Roof		
	• R-30 roof, minimum U-factor = 0.033	• Insulation frame roof existing R-25; U=.04 Required R-15
	• R-30 above garage	R-10 existing
Doors		
Opaque Doors	• Swinging Door, U-factor = 0.25	• Swinging Door, U-factor = 0.7
Sliding Glass Doors	• Tempered Safety glass, U-value = .36	• Tempered Safety glass, U-value = .7
Windows	• 40% window-to-wall ratio (including glass doors)	• 40% window-to-wall ratio (including glass doors) Modeled same area as proposed.
Metal Frame, Double-Pane	• low-E triple glass thermal frame U-factor = 0.36 • SHGC = 0.27 • τvis= .51	Double-Pane glass • Fixed U-factor = 0.40, • Curtain wall U-factor = 0.4 • SHGC = 0.7
Floor Slab	• R-11 EPS EIFS Perimeter	Slab-on-Grade: R-10 to 36" below top
Infiltration	• Existing – 25%	• N/A modeled same as existing 1.65 ACH (typical)

ELECTRICAL SYSTEMS		
Lighting Power Density	• Overall avg. 0.6 W/sf Including 10% credit for controls	• 0.7 W/sf
Equipment Power Density*	• 0.75 W/sf Same as base case	• 0.75 W/ft2 allowable
Outdoor Lighting	• 18 w controlled via photocell (on from dusk to dawn)	• 200 W controlled via photocell (on from dusk to dawn)
SCHEDULES	All Schedules same as base case	All Schedules same as base case
HVAC System		
HVAC System Type	• Fan coil heat with 94% efficiency boiler • High efficiency Chiller Full Load .577 kW/Ton, .377 IPLV • First floor Heat pump 12.7 SEER, 3.7 COP	• System Type 2 for first floor PTHP EER =9.105, COP = 2.81 • Chiller Full Load 4.9 COP 4.95 IPLV code minimum • Economizer not required per Table G3.1.2.6A
Fans	• High efficiency in HRV Fan Coils - Direct drive ECM motors, forward curved 3 spd fan 40w, .05HP • Fan coils 3 spd PSC 1/25 HP	• Forward Curved Centrifugal w/ inlet vanes; Static reset .25-.5 HP
Boiler Efficiency	94% AFUE	80% AFUE
Service Hot Water	• 300 gal tank Indirect fired by 94% boiler (85% effective efficiency, 85% EF per EnergyStar method) • Recirculation temperature/time controlled	• Storage gas water heater, 300 gallon, 50% EF w/Recirculation time control.
Ventilation System	• 30+ CFM per occupant. Heat recovery ventilator. Minimum 72% efficiency, demand controlled with CO2 sensors.	• Same ventilation rate as design case, Heat recovery efficiency 50%