Dynamic Interactions and Competing Objectives in Multifamily Green Building Design

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ABSTRACT

The authors provided technical support for a mid-rise housing development in Boston Massachusetts. During the design process the development team chose to upgrade the initial building design criteria from Minimum Building Code to Energy Star and LEED® certified. As a subsidized housing development involving substantial public funds, the project faced many constraints. However, the project team also secured targeted funding from a number of sources to support advanced energy performance measures. The constraints of the project and conditions of targeted assistance ultimately impeded full integration of the design. As a result some measures appear to work at cross-purposes with other measures and objectives. This paper will shed light on the dilemmas that the designers faced as well as the performance paradoxes of a project that makes significant strides towards optimization but is fully grounded in present realities of the building industry.

INTRODUCTION

In November, 2001 US HUD awarded a HOPE VI grant to the Boston Housing Authority (BHA) to demolish 413 "severely distressed" apartments of public housing in East Boston Massachusetts and construct 286 new mid rise and low rise apartments on this site and 360 new mid rise and low rise apartments near this site. As part of the design development process BHA and Trinity East Boston Development (the competitively selected development team) investigated opportunities to construct "high performance" green housing for one of the mid-rise buildings with 119 apartments. Standard mid-rise construction practices used to prepare the winning bid included steel and poured in place concrete deck, steel stud and brick faced walls, distributed exhaust and central supply ventilation, gas-fired boilers, electric chillers, and two pipe vertical fan coil distribution systems. The development team, elected to upgrade these standards and design for this building to meet LEED®[1] certification, ENERGY STAR Homes criteria, and "healthy housing" guidelines advanced by BHA, tenants, the Boston Public Health Commission (BPHC), and a regional health advocacy group, the Boston Urban Asthma Coalition.

As part of a preliminary design charrette[2] in October, 2002 the development stakeholders set a high and, by most perspectives, achievable performance goal for the development with an impressive list of energy efficiency and green building features. As the design process continued, however, the integration of these features and design priorities into the baseline design and construction assumptions produced contradictions between various goals and objectives. Massachusetts State Sanitary Code, for example, imposed heating parameters that the energy models predicted would be difficult to meet by a single loop distribution system within a well-insulated and tight building enclosure. The design, construction, and development team wrestled with these financial, programmatic, and technology related contradictions remarkably well within the tight time and financial constraints. The solutions selected may have fallen short of the *ideal* conception of an integrated high performance green building. The challenges revealed through the development of Maverick Gardens, however, offer important lessons on the reality of green building today. Following is the author's analysis of the Maverick Gardens design team's response to the development stakeholder's design priorities for the project's key energy design and construction decisions.

[1] Leadership in Energy and Environmental Design, a voluntary green building standard developed by the United States Green Building Council.
[2] A copy of the design charrette report is available at:
http://www.mtpc.org/RenewableEnergy/green_buildings/projects/maverick_gardens_report.pdf

PROJECT DESCRIPTION:

One might reasonably expect that the budget constraints of a subsidized housing development and the risk aversion associated with public funding would have made such above-standard goals unrealistic. In this case the public funders enthusiastically encouraged the development team to investigate opportunities for higher-than-standard performance.

Building owner utility cost management priorities:

For the development team, long-term utility cost management is a major priority both in terms of long-term building affordability and in terms of the desired LEED® and ENERGY STAR certifications. In a departure from more common “split incentive” scenarios, the developer, Trinity East Boston Development, is both the construction contractor and building owner and manager. This being the case, the Developer was interested in both the up front capital cost and the long term operating cost and not merely the initial capital costs. In addition the development team partners saw “green building” as both the right thing to do and a potential competitive advantage in future construction projects.

FIGURE 1
Maverick Gardens Under Construction (Snell)

The project was able to leverage additional energy efficiency and green building investments through generous non-competitive and competitive grant solicitations from local utility system benefit charge program administrators. BHA solicited and secured energy efficiency funding and technical support through multiple funding sources[3]. Each funding source had its unique set of program design constraints and qualifying measures. MTC’s Green Building program support, for example, was partially contingent upon the LEED® certification and included funding for an initial design charrette, renewable energy, and high performance energy efficiency measures. Representatives of supporting programs became active participants in the design and development process.

Building components and features:

Table 1 outlines the major components of the building. The descriptions marked with an asterisk (*) represent specifications that were not part of the final design but implemented as a change order during construction.

[3] Funding sources included NSTAR Electric Company’s commercial and residential efficiency programs, KeySpan Energy’s commercial efficiency programs, the Massachusetts utilities’ collaborative Energy Star Homes residential efficiency programs, MA DOER’s Rebuild Massachusetts program, and US HUD’s Healthy Homes program. BHA solicited and secured renewable energy and green building funding support through a competive bid process from the Massachusetts Technology Collaborative’s (MTC) Green Building program.

TABLE 1
Summary of building energy components and features (Neuhauser)

Building Component or Feature	Specification or Description
Building Enclosure	
Roof assembly	U-factor: 0.026 Btu/h-ft2-°F, High albedo rolled roof membrane, 6" Polyisoncyanurate on metal deck
Wall system	U-factor: 0.0624 Btu/h-ft2-°F, brick veneer or metal panel, air space, 1" extruded polystyrene, denseglass sheathing, metal framing w/ R19 fiberglass batt insulation
Wall system air barrier	Roll (liquid) applied two-coat air barrier *
Windows	U factor: 0.32 Btu/h-ft2-°F, SHGC 0.33, double glazed, low-e, fiberglass frame, all orientations
Floor over semi-heated garage ceiling plenum	2-3" low-density urethane foam
Semi-heated garage ceiling plenum	R19 fiberglass, sidewalls and underside.
Central HVAC – Plant	
Primary heating and DHW plant	Internal Combustion natural gas combined heat and power generator, .49 MBtuh at 54% thermal EFF
Secondary heating and DHW plant	Direct-fired natural gas absorption chiller/boiler, 2.4 MBtuh boiler with full modulation at 85% EFF
Back-up heating and DHW plant	Sealed combustion, condensing 5:1 modulation turn down ratio, natural gas boiler 1.4 MBtuh at 85% - 98% EFF
Cooling Plant	Gas-fired absorption chiller/boiler, 170 ton, 1.2 COP Two-speed fan cooling tower, no water-side economizer
HVAC – Distribution	
Corridor Make-up air units (20-50% outdoor air)	Heat and cooling coils from primary loop, no economizer
Apartment-level terminal equipment with outdoor air intake (one per apartment)	Vertical fan-coil units, direct o.a. intake ~10% of rated flow, face-bypass damper, no intake damper, thermostat operates face-bypass damper
Apartment-level terminal equipment w/o fresh air intake	Vertical fan-coil unit, thermostat cycles fan
Apartment exhaust ventilation	Exhaust – continuous background exhaust in bathrooms with fixed dampers set to exhaust 50 cfm per apartment
DHW	
Storage tanks	2 – 575 gallon DHW tanks with internal heat exchangers
Lighting/Appliances	
Lighting-common areas	CFL, non-dimming, no occupancy sensors
Lighting-apartments	CFL for all hard-wired fixtures
Appliances	ENERGY STAR® where provided
On Site Generation	
Cogeneration plant – service to house meter	Internal combustion natural gas 75 kW, electrical generator efficiency 28%, Thermal efficiency 54%
Photovoltaic array – net meter to grid with disconnect	37kWdc, fixed panels, angled 42 degrees from horizontal

CENTRAL MECHANICAL SYSTEM SELECTION:

Standard practice for mid-rise multifamily construction in Boston is to install a central fossil fuel boiler and two-pipe vertical fan coil distribution system. Under Massachusetts State Sanitary Code, Management must be able to provide adequate heating in the apartments from September 15th through June 15th. [4] The Developer, with guidance from the design team, elected to accept this central mechanical system design

[4] Massachusetts Sate Sanitary Code requires that habitable rooms must be heated to a temperature of not less than 68 Fahrenheit (20 C) between 7:00 a.m. and 11:00 p.m. and 64 Fahrenheit (17 C) between 11:01 p.m. and 6:59 a.m., unless the occupant has agreed to supply the fuel under a written lease. [410.201]. In addition the temperature may not exceed 78 Fahrenheit (25 C) during the heating season.

and to provide central cooling rather than to accommodate the use of tenant-installed window air conditioners. Natural gas service is provided through a single gas meter for heating, DHW, cooling, and electricity generation. Electrical service is provided through a single house meter for common area electric loads and individual meters, one per apartment, for apartment lights, appliances, fan coil motors, and plug loads. The selection of mechanical systems is an aspect of the building design where targeted incentives played a significant role.

Installed equipment:

Installation incentives from the gas utility supported the development team's selection of a Broad Spectrum Model 7H4 integrated double absorption gas-fired chiller and boiler as both the primary heating and primary cooling source for the building. Advantages of this system included reduced summer electric demand, lower energy cost, simultaneous output of both chilled and domestic hot water, and rapid (45 minutes) transition between the heating and cooling. The integrated chiller/ boiler will provide management the option to switch the building's two pipe vertical fan coil distribution system on a daily basis instead of the standard management practice of only once per season for the duration of the heating or cooling season. The Broad Chiller/Boiler is also designed to contribute to DHW loads. A 60 kW Tecogen electric generator is also intended to contribute to building heating and DHW loads. A Fulton pulse combustion boiler, at 85%- 98% efficiency and 1,400 MBtu intput, is designed to provide back-up heating and DHW service. A single water loop serves the heating and cooling of the apartments, corridors and the preconditioning of make-up air supplied to the corridors. The system uses setback controls to modulate the temperature in the loop in response to outside temperature.

FIGURE 2
Broad Spectrum gas-fired chiller/ boiler (Snell)

Targeted funding from MTC and the gas utility supported the purchase of the 75 kW, 0.49 MBtuh combined heat and power plant. The economic rationale for the co-generation plant is based upon the combined effective efficiency of producing both electricity (at a 28% efficiency) and heat and domestic hot water (at a 54% efficiency) from natural gas input.

Absorption chiller and cogeneration interaction:

From a pure systems integration perspective the gas-fired absorption chiller and co-generation plant seems an odd pairing because an indirect fired absorption chiller would normally be able to run from the "waste heat" provided as a by-product of electrical generation in the co-generation plant. The pairing might seem odd again because an electric chiller would certainly present a greater demand for the power produced by the co-generation plant thus enabling it to operate more continuously where its benefits are maximized. In this installation it is likely that the co-generation plant will operate below capacity a significant portion of the time particularly during the summer.

Furthermore, since the single loop distribution system is limited to either heating *or* cooling the DHW storage tanks are the only sink for "waste heat" when the building is in cooling mode. As the chart in figure 3 indicates, the DOE2 energy modelling predicts that both the absorption chiller and co-generation plant will produce enough "waste heat" individually to meet the DHW load and a substantial portion of the heating load. This would suggest that either, the simultaneous heating and cooling ability of the chiller/boiler is not utilized or the co-generation plant cannot be run cost effectively. In other words, much of the "waste heat" is truly wasted.

TABLE 2
Monthly recoverable energy and DHW load (Neuhauser)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Absorption Chiller													
Recoverable Energy (MBtu)[1]	30	39	86	179	314	390	469	443	357	239	104	61	2,710
Co-Generation													
Recoverable Energy (MBtu)[1]	316	285	316	311	323	312	323	323	312	323	306	316	3,766
Recovered Energy Applied to Heating Load (MBtu)[1]	69	54	32	5							17	44	220
Total Recoverable Available to DHW Load (MBtu)	**278**	**270**	**370**	**484**	**637**	**702**	**791**	**766**	**669**	**562**	**394**	**333**	**6,256**
DHW Load2	126	118	128	124	118	104	102	94	92	100	105	118	1,327
Unused Recoverable Energy (MBtu)	**152**	**152**	**242**	**360**	**519**	**598**	**689**	**672**	**577**	**462**	**289**	**215**	**4,929**

1 Derived from DOE2.1e output report PS-E and PS-A
2 DHW load derived from DOE2.1e output report PS-E. Model did not directly simulate recovered energy serving DHW load.

Performance standards referenced in the LEED system focused the design team on concerns of thermal comfort and control of environmental tobacco smoke (ETS). Based on research performed on similar buildings and internal discussions the design team developed a three-part strategy to address these resident thermal comfort and tobacco smoke management. Strategy number one was to compartmentalize the three primary building use areas in the apartments, common areas, and the below grade garage. Strategy number two was to provide dedicated supply air to the apartments. Strategy number three was to identify and reduce high priority pollution sources.

Isolation and compartmentalization:

As a design priority, compartmentalization-related upgrades responded directly to both the thermal comfort and a LEED prerequisite relating to ETS control. Previous analysis and research in similar size mid-rise apartment buildings in Boston identified that uncontrolled air movement in standard construction buildings is a major concern. Uncontrolled air movement contributes to about 50% of the total heat load in standard construction mid-rise apartment buildings (MacDonald, 1995). Uncontrolled air movement compromises both the air quality and thermal comfort of standard construction mid-rise apartment buildings (Demokritou, 2002). Uncontrolled air movement can be managed more effectively with building apartment compartmentalization (Conservation Services Group, 2000).

In response to these “lessons learned” in existing Boston mid-rise apartment buildings the development team established higher standards of performance for the air, thermal, and moisture control for the building’s three primary use areas. For the apartments the priority was to isolate each apartment from other apartments and the common areas and to isolate and insulate the apartments from outside environment conditions. For the common area the priority was to isolate the hallways from the apartments and compartmentalize individual building floors from each other. For the garage the priority was to create a defensible air, thermal, and vermin barrier at the garage ceiling walls between the garage and the building. The ENERGY STAR Homes Program imposed a whole building air leakage limit of 4.0 sq. in. of equivalent 4 Pascal leakage area per 100 sq. ft. of building enclosure (ELA/100).

Dedicated apartment supply air:

In Boston, the de facto ventilation standard for mid-rise new construction apartment buildings comprises central corridor supply ventilation, air leakage from under apartment entry doors and through the building envelope, augmented by occasional use of bathroom exhaust fans. Massachusetts ENERGY STAR Homes Program, however, requires verifiable, controlled background ventilation in the apartments. Maverick Garden’s design team elected to meet the ENERGY STAR Homes Program standard and provide apartment exhaust ventilation through shared exhaust risers and direct supply air ventilation for each apartment without an air-to-air exchanger.

The source of make-up air for the exhaust ventilation system became a particularly vexing concern. From an energy management perspective the mechanical engineer had recommended to install a central air-to-air heat exchanger (or multiple exchangers) on the roof. The air-to-air heat exchanger(s) would draw exhaust air from the apartments and precondition supply air into the common corridors. This concept offered advantages in energy performance, however, it conflicted with the goal of compartmentalization. The mechanical engineer priced out the cost to install individual supply air branches to each apartment, however, the cost was prohibitive. As the developer summarized to the group "The cost to install supply air ductwork in the building is equal to the cost to build an apartment - take your pick". The design team investigated and was unable to identify a cost effective individual apartment air-to-air heat exchanger[5].

Indoor pollution source control:

As part of the design team's priority to provide good indoor air quality, the development team identified four high priority pollution sources to control - moisture, environmental tobacco smoke (ETS), pests, and dirt. Extensive flashing details and waterproof membranes on the roof and walls provide the primary protection from rain driven moisture sources. Fiberglass-framed windows and continuous exterior insulation reduced condensation potential. Continuous exhaust from the bathrooms is expected to reduce moisture loads. Electric stoves were installed in the kitchens instead of gas stoves; however, direct exhaust for cooking appliances was not installed.[6] The LEED system includes an ETS control prerequisite that, in the case of multifamily projects, can be satisfied by either prohibiting smoking in the building or meeting rigorous compartmentalization and ventilation performance standards. With tobacco smoking rates in public housing in the high range of about 20%-50% (Hynes, 2000) a smoke free building was unrealistic. The development team's intent is to meet the LEED prerequisite with the proposed extensive air sealing, continuous apartment exhaust, and slightly pressurized apartment corridors. Effective Pest management at Maverick will include integrated pest management best practices. Areas identified by a pest management consultant included durable, air tight/ vermin proof air sealing in the garbage collection room and around the base of the building. The primary strategy to address dirt brought into the building is to install walk off mats will be installed at each entrance to capture dirt brought in from outside.

BUILDING LOAD ANALYSIS:

As a necessary step to determine eligibility for LEED® energy performance credits, the project was modeled in a DOE2.1e simulation according to the procedures indicated in the ASHRAE90.1 standard and the LEED® standard. Throughout the early stages of the design process, several stakeholders and advisors to the processed debated the ability of the chosen HVAC system to provide adequate performance. The early simulation results illuminated these discussions by suggesting impacts of decisions relative to the thermal enclosure improvements and the type of distribution system.

Heating load reduced:

The DOE2.1e simulation calculated that the proposed shell upgrades for Maverick would reduce the predicted total heating load from a baseline condition of 617 MBtu/year (1.33 MBtuh peak) to 428 MBtu/year (1.10 MBtuh peak). Significant discussion occurred around the issue of equipment sizing with different perspectives coming from the energy modeling and mechanical engineering teams. From the Developer's perspective, however, the risk associated with installing potentially undersized mechanical equipment outweighed the capital cost savings from installing smaller equipment. The total heating capacity output of the installed mechanical equipment is about 4 MBtuh. Fortunately, the design team selected modulating equipment with higher part load efficiencies, which should mitigate the potential over-sizing penalty.

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[5] An additional consideration with individual air-to-air exchangers was the development team preference not to install another piece of mechanical equipment in the apartments that need to be maintained.
[6] Excess heat from cooking became an important contribution to cooling load management and thermal comfort problems along with moisture generated during cooking.

Cooling season extended:

In Massachusetts, State sanitary code and, consequently, standard management and design practice regards the period from September 15th to June 15th as the heating season. Table 3 represents simulation results for a typical apartment zone at Maverick Gardens under two scenarios. The simulation predicts appreciable cooling load hours to occur even during the height of the "heating season". Under the scenario in which both heating and cooling are available throughout the year, predicted zone temperatures remain within an acceptable range. However, when cooling is only available from June 16th to September 14th, the simulation predicts high maximum zone temperatures.

TABLE 3
Monthly load hours and minimum, maximum zone temperatures for typical zone (Neuhauser)

	Heating and Cooling Available All Year				Heating Available Sept 15 to June 15 Cooling Available June 16 to Sept 14	
Month	Cooling Load Hours	Heating Load Hours	Maximum Zone Temp. (F)	Minimum Zone Temp. (F)	Maximum Zone Temp. (F)	Minimum Zone Temp. (F)
Jan	61	367	74.1	70.1	79.0	70.1
Feb	98	248	74.0	70.1	78.6	70.1
Mar	235	208	74.2	70.1	86.9	70.1
Apr	407	45	75.3	70.2	92.9	70.1
May	631	4	76.0	70.2	94.3	70.1
Jun	706	-	76.8	72.9	97.2	70.1
Jul	744	-	77.3	73.8	77.2	73.8
Aug	743	-	76.3	73.7	76.2	73.7
Sep	667	2	76.2	72.2	89.0	70.1
Oct	496	31	74.6	70.2	85.4	70.2
Nov	257	138	74.1	70.2	81.5	70.1
Dec	147	254	74.1	70.1	83.6	70.1

The LEED Standard references "bounding comfort parameters" upon which optimized energy performance credits are preconditioned. Essentially, the project would not be eligible to claim any credits under this section of the LEED standard if the analysis used to establish energy efficient performance does not also predict that sensible temperature parameters will be maintained within the bounding comfort parameters. Table 4 compares the LEED bounding comfort temperature bin "hours allowed" to the predicted temperature bin hours under two different building operation scenarios for this apartment zone.

TABLE 4
Temperature bin analysis for typical zone (Neuhauser)

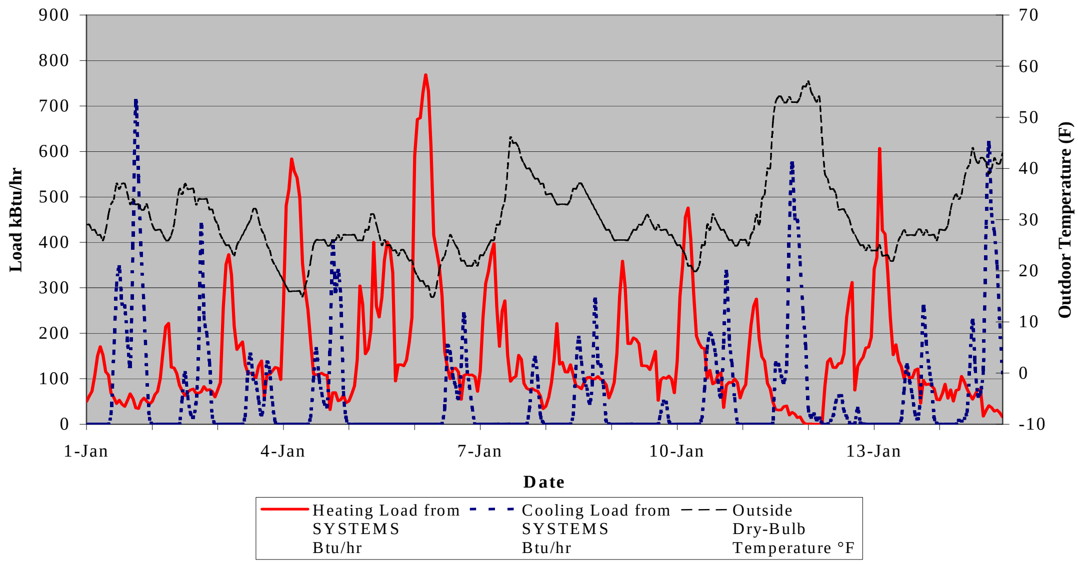
Temperature Range	Hours Allowed under LEED® Bounding Comfort Parameters	Simulation Results Hours within Each Temperature Range: Heating and Cooling Available All Year	Simulation Results Hours within Each Temperature Range: Seasonal Transition Heating and Cooling
>85°	<20	0	181
80-85°	<50	0	270
75-80°	<150	127	973
65-75°	no limit	8,633	7,336
60-65°	<50	0	0
55-60°	<20	0	0
<55°	Not allowed		

The third column shows the predicted total hours for each temperature bin with both heating and cooling available throughout the year. The fourth column shows the predicted total hours in each temperature bin for this zone where only heating is available September 15th-June 15th and only cooling is available June 16th to September 14th. The temperature bin analysis shows that the predicted performance for this building zone is outside the LEED bounding comfort parameters and that apartments will overheat during the winter beyond current Massachusetts State Sanitary Code requirements.

Daily heating and cooling hours become coincident:

The DOE2.1e modeling analysis shows that, for the building in aggregate, heating and cooling loads occur simultaneously. Figure 5 plots the predicted heating and cooling loads passed to the plant (boiler/chiller) by the systems (fan coils and make-up air units) together with the outdoor temperature during the first two weeks of January. On this plot, it is quite striking how spiky both the heating and cooling loads are and how there seems to be no clean separation between them. The profile of predicted building loads, together with the logic of load diversity between zones, convinced the design and development team that no amount of building operator interaction could maintain acceptable levels of comfort within all zones at all times.

FIGURE 3
Building loads and outdoor dry-bulb January 1-15 (Neuhauser)



One important conclusion that can be drawn from this thermal simulation analysis might also be drawn from simpler calculation methodologies. As the building incorporates more effective thermal insulation better air barriers, and better control of ventilation loads, the zones within the building become less sensitive to climate factors such as outside temperature that tend to act upon the building as a whole. Instead, more variable (and, in many cases, less predictable) load factors, such as cooking, solar gains, equipment and appliance use, take on greater significance.

Response to apartment temperature predictions:

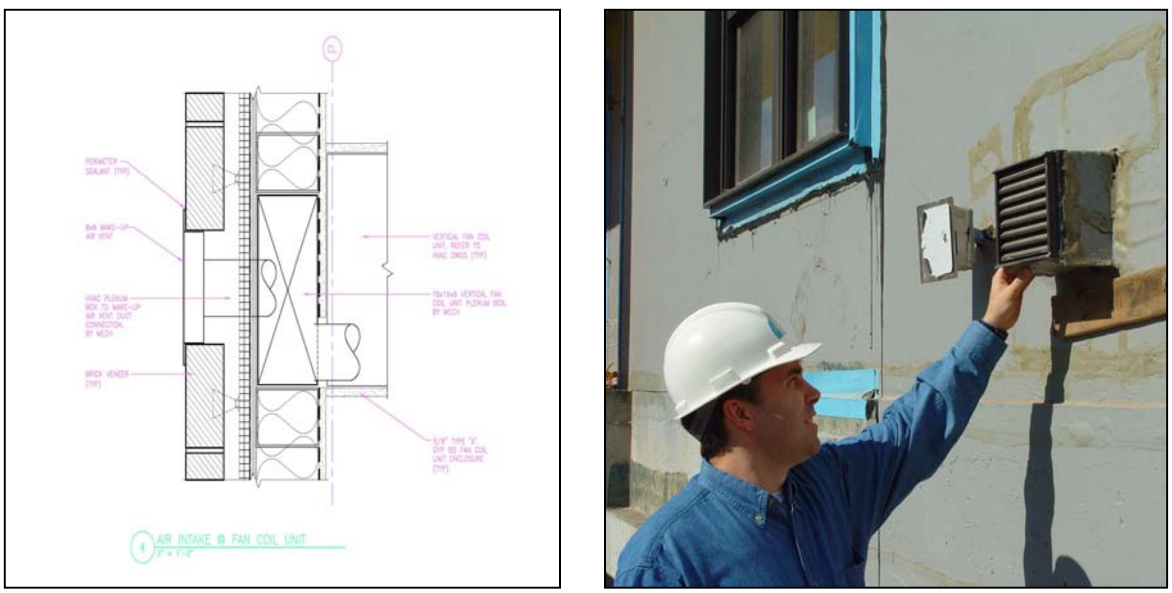
The energy modeling performance predictions presented daunting system selection challenges to the design team. The project had committed to install a single-loop, switchover system, yet the model predicted that this system would not deliver acceptable performance without significant modification. The design team reviewed resident interaction (open and close windows), face and bypass damper ventilation control, and extended operation of the cooling equipment to control potential apartment overheating. Concern with the operable window option focused on whether or not opening windows would work effectively to dissipate heat if individual apartment pressures are neutral or somewhat positive with respect to the exterior. The development team acknowledged that daily changeover of the system was extremely unlikely and that even such could not address load diversity. Concerns of cooling load management as well as for the ventilation supply path discussed earlier, both seemed to recommend the outdoor air, face and bypass damper strategy. With this option there remained questions of whether or not such a strategy could provide a measure of cooling to individual apartments in times when the building-wide system is in a heating mode. Despite these doubts and the late stage of the design process, the design team took on the task of revising the design to incorporate direct out door air intake at one fan coil unit in each apartment.

Apartment supply air detail:

Maverick Garden's direct apartment supply and bathroom exhaust ventilation system was designed to address both ventilation and some level of cooling during moderate outdoor temperature conditions. Consistent with other design decisions, the development team insisted on off-the-shelf components that did not require any non-standard skills for installation. The out door air intake option for the vertical fan coil unit satisfied this criterion.

As mentioned previously this ventilation design was very contentious. The architects were reluctant to "punch a hole" in the building enclosure. Doing so presented many challenges to both to building aesthetics and durability and complicated construction coordination between multiple building trades. The architects rose to the challenge and integrated the supply air intakes into the building envelope with minimal disruption to the building's unique exterior design, hand off between the trades, and preferred riser locations for the vertical fan coil assemblies. To facilitate building trade coordination of the supply air grille assembly the architects designed a metal "boot" for the building envelope trades to install during their work as show in Figure 4. This provided reasonable flexibility for the interior construction trades to install a connecting sleeve to the apartment fan coil air intake cut out. The cost to provide a direct air vent into each apartment in this manner was significant – on the order of about $1,000 (US) per apartment.

FIGURE 4
Fresh air intake details (ICON Architecture/ Snell)



From a building performance perspective there are a number of interesting questions regarding future performance of this apartment supply air installation. One consideration is whether or not the vertical fan-coil can induce adequate static pressure when the apartment is pressurized with respect to the exterior. In addition, if the fan is wired to run continuously, as originally delivered onsite, the fan motor would impose a significant energy cost burden on the low-income tenants. Because there is no operable damper on the outdoor air intake, the outdoor air intake represents a potential source of infiltration/exfiltration when the fan is not running. In the situation where EITHER the fan is not able to generate enough static pressure across the inlet to draw air in OR the fan does not run continuously, the outdoor air inlets are likely to be exfiltration points. In addition, the significant interior metal surface area of the supply air "boot" represents a likely energy penalty as well as a potential source for condensation during cold weather.

ELECTRIC GENERATION SYSTEM INTEGRATION:

With significant assistance from MTC's Green Building program (75% design and installation grant support) East Boston Development installed a 37 kW photovoltaic electric generation system on the building's roof. The combination of the 75 kW cogeneration and photovoltaic systems represents greater onsite peak electrical generation capacity than the building's projected common area average electric load when the elevators are not running (about 83 kW). Management would either need to turn off the cogeneration plant or become a net exporter of electricity back to the grid when this occurs.

Closely tied to this discussion about electric generation system integration is the issue of electric metering configuration in multifamily buildings. Ideally the PV and cogeneration systems would be able to supply electricity to the apartments when the common area electric load is satisfied. State law and a property management priority prevent this from happening. Under Massachusetts' new commercial energy code requirements multifamily buildings must install individual electric meters for each apartment. The rationale for this requirement is that the residents will reduce their electric consumption if made aware of how much they are using. Individual apartment meters are also an important priority from a property management perspective as a way to reduce future financial risk to the development. Both of these issues could be circumvented if management could sell excess electricity directly or through a third party to residents. In Massachusetts, however, the only legal electricity distributors are the state's investor-owned and municipal utility companies. As a hedge for better integration opportunities in the future the building infrastructure is set up to allow Management to address this issue at a later date.

FIGURE 5
Solar PV Installation (ICON Architecture)

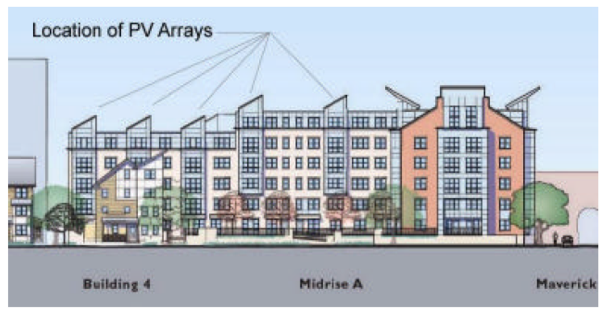


Figure 1: Proposed Solar Layout

SUMMARY AND DISCUSSION

Maverick Gardens, as a subsidized housing development project involving substantial public funds, faced many constraints for the development teams efforts to upgrade the design and construction process and meet high performance green building standards. With significant assistance from multiple energy-related funding sources the project team secured additional financial resources to investigate and invest in advanced energy performance measures. The constraints of the project and conditions of targeted assistance ultimately impeded full integration of the design. As a result some measures appear to work at cross-purposes with other measures and objectives. Despite these challenges the development team made significant strides towards optimization within the constraints of the present realities of the subsidized housing building industry.

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