ASHRAE TECHNOLOGY AWARDS APPLICATION FORM (Page 1)
APPLICATION MUST BE COMPLETE TO BE CONSIDERED FOR JUDGING
(Required for Society-Level Competition)

(For ASHRAE Staff Use Only)

I. Identification (0 Points)

Name of building or project: Rosa Parks Apartments

II. Category (Check one and indicate New or Existing, if applicable)

○ Commercial Buildings	○ New or	○ Existing
Institutional Buildings:		
○ Educational Facilities	○ New or	○ Existing
○ Other Institutional	○ New or	○ Existing
○ Health Care Facilities	○ New or	○ Existing
○ Industrial Facilities or Processes	○ New or	○ Existing
○ Public Assembly	○ New or	○ Existing
◉ Residential (Single and Multi-Family)	◉ New or	○ Existing

III. Project Description (0 Points)

1. Type of building or process: 94 Affordable multi-unit rental units among 8 buildings
2. Size – gross floor area of building (ft. sq. or m. sq.): 131,601 ft. sq.
3. Function of major areas (such as offices, retail, food services, laboratories, guest/patient rooms, laundry, operating rooms, warehouse/storage, computer rooms, parking, manufacturing, process, etc., or industrial process description:

   85% residences, 15% laundry, meeting, storage

4. Project study period: 09/2011 (Begin date (mm/yyyy)) to 10/2013 (End date (mm/yyyy))

APPLICATION MUST BE COMPLETE TO BE CONSIDERED FOR JUDGING
(Required for Society-Level Competition)

1. **Name of Building or Project:** Rosa Parks Apartments

2. **Entrant (ASHRAE member with significant role in project):**
   a. Name: Katrakis (Last) John (First) Theodore (Middle)
      Membership Number: 2024117
      Chapter: Illinois Chapter
      Region: Midwest
   b. Entrant's Design Firm/Company: J. T. Katrakis & Associates, Inc
   c. Address (including country): 418 North Avenue
      Barrington (City) IL (State) 60010 (Zip) USA (Country)
   d. Telephone: (O) 847-382-1877 e. Email: john@jtkatrakisassociates.com
   f. Entrant's Role in Project: MEP Engineer of Record, LEED Consultant and Fundamental Commissioning Authority
   g. List the names of Design Team Members (A maximum of three may be listed below)
      1. Peter Landon, Landon Bone Baker Architects
      2. John Katrakis, J. T. Katrakis & Associates, Inc.
      3. David Lehman, Lehman Design Consultants, Inc.

3. **Certification of entrant (0 Points) (If multiple entrants, all must be listed on this form)**

   I certify the information submitted is correct, and that this entry satisfies the requirements of the ASHRAE Technology Award competition.

   Typed Name: John T. Katrakis, ~~PE, LEED~~ AP, QCxP Title: President

   Signature: [signature] Date: October 6, 2013

4. **Building Owner's release (0 Points)**

   I certify that I am the owner or the authorized representative of this project, and hereby grant permission to ASHRAE to use all the enclosed data and information in the judging and subsequent publicity of this project.

   Typed Name: Michael Burton Title: Asset Management Director

   Signature: [signature] Date: 10/7/2013

   (Signatures must be on form submitted to ASHRAE)

   Company: Bickerdike Redevelopment Corporation
   Address: 2550 W. North Avenue
   Chicago (City) IL (State) 60647 (Zip) USA (Country)
   Telephone: (O) 773-278-5669 x0015 Email: mburton@Bickerdike.org

APPLICATION MUST BE COMPLETE TO BE CONSIDERED FOR JUDGING
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5. **Engineer of record:** Required unless a written explanation is provided why the engineer of record will not grant his/her consent.

I consent to the presentation of this project for consideration in the ASHRAE Technology Awards Program.

Typed Name: John T. Katrakis   Title: President

Signature: [signature]   Date: 10/06/13

(Signatures must be on form submitted to ASHRAE)

Company: J. T. Katrakis & Associates, Inc.

Address: 418 North Avenue

Barrington (City)   IL (State)   60010 (Zip)   USA (Country)

Telephone: (O) 847-382-1877   Email: john@jtkatrakisassociates.com

The topics below should be addressed on separate pages and formatted according to the requirements listed in the overview.

1. **Energy Efficiency (15 Points)**
2. **Indoor Air Quality (15 Points)**
3. **Innovation (15 Points)**
4. **Maintenance & Operation (15 Points)**
5. **Cost Effectiveness (15 Points)**
6. **Environmental Impact (15 Points)**
7. **Quality of Presentation (5 Points) (No response required)**

Return Completed Application to your Chapter Technology Transfer Committee Regional Vice-Chair.

For additional information, contact:

Rosy Douglas
Chapter Programs Manager
678/539-1128
rdouglas@ashrae.org

ILLINOIS CHAPTER
ASHRAE TECHNOLOGY AWARD APPLICATION 2013
ROSA PARKS APARTMENTS
October 7, 2013

INTRODUCTION

Project Description. The new Rosa Parks Apartments is a multifamily rental development constructed in Chicago's 27th ward, concentrated in a four block area, bordered by Huron Street on the north, Franklin Boulevard on the south, Drake Avenue on the west, and Sawyer Street on the east. All 94 of the rental units are affordable to households earning 50% or below area median income. The units are distributed among:

One 27-unit, four story elevator building at 541 N Homan Ave (aka Homan)
One 16-unit, four story elevator building-adjacent to (east of) Homan on Ohio St (aka Ohio)
One 15-unit three story walk-up building
One 12-unit three story walk-up building
Four 6-unit three story walk-up buildings

The developer is Bickerdike Redevelopment Corp (BRC). The builder is Humboldt Construction Company. Bickerdike Apartments is the property Manager. The Architect is Landon Bone Baker Architects (LBBA) and the MEP/LEED Consultant is J. T. Katrakis & Associates, Inc. (JKA). The project timeline was: Design 2006-08, Construction 2008-2009, Start of Occupancy 2009, Performance Monitoring-On-going.

Along with providing affordable housing the objectives of this project were to:

a. Provide a healthy and comfortable indoor environment for the occupants
b. Augment the living conditions in the neighborhood
c. Minimize the utility costs necessary to operate the building
d. Minimize tenant-paid utility costs, protect tenants from volatile energy price changes and help guarantee the long term affordability of this housing;
e. Be easily and affordably maintained and operated by the management staff;
f. Assess the applicability of new building technologies to affordable housing (such as pre-cast concrete building envelope/structural systems, energy recovery, ground-source heat pumps for heating and cooling, solar water heating.)

The 94 units range from 1 to 4-bedroom units with a total livable floor area of 98,873 sq. ft. for an average of 1052 sq. ft. of floor area per unit. The total floor area of the development is 131,601 sq. ft. The four apartment templates are repeatedly used in different combinations through all eight buildings to minimize costs yet exhibit variety among the buildings.

Design Conditions & Requirements. All eight buildings had to comply at the very minimum with the requirements for LEED Certification under NC Version 2.2 and the Green Communities Grant program criteria. This required compliance with at least ASHRAE 90.1-2004 building energy standard. The buildings also had to comply with the more stringent Illinois Super-insulation programs standards in order to be eligible for grants. These requirements made it possibly for Rosa Parks apartments to easily comply with the newly promulgated Chicago Energy Code. Table 1 shows the indoor air comfort and quality criteria. Table 2 shows the occupancy rates and schedules.

Table 1. Temperature and Relative Humidity Criteria

Space type	**Temp (S/W°Fdb)**	**% RH or °F wb Sum/Wint**	**Outside Air Rate**
Indoor			
Apartments	76 / 72	45 / 25	20 cfm/p[1]
Hallways/Corridors	80 / 68	45 / 25	0.3 cfm/sf
Exercise Room	76 / 72	40 / 25	20 cfm/p
Community Room	76/72	40/25	15 cfm/p
Locker/Storage Areas	80 / 65	45 / 40	0.2 cfm/sf
Outdoor	88/-6	77 wb/N.A.	N.A.

1. The apartments all have operable window vent areas that are at least 4% of the floor area and thus meet the requirements for natural ventilation.

Table 2. Design Occupancy Parameters

Occupied periods	24/7, 7 days per week
Number of Occupants	3.6 occupants per unit, or 338 occupants

System Descriptions. All eight buildings share many design features; they are all of pre-manufactured concrete panel construction with metal stud and drywall interior wall surfaces. The largest building (27-unit on Homan Ave, aka Building #7) showcases innovative energy and environmental technologies such as ventilation air energy recovery to temper the corridor make-up air and the apartment outdoor air, heat pumps with a compact standing well geo-exchange field under the permeable-paved parking lot, solar thermal water heating. These features, along with the LEED-required commissioning process, enabled it to achieve LEED-NC version 2.2 Gold certification. Table 3 compares the key energy efficiency and indoor air quality features of Homan and the other 7 buildings. All eight buildings have mechanically supplied outdoor air to the apartments. At Homan, the energy recovery tempered outdoor air supply made it possible to eliminate the automatic outdoor air shut-off dampers when the apartment heating is off.

Table 3. Distribution of Energy Efficiency Features

System Features	Homan	7 Other Sites
Super-Insulated Building Envelope	X	X
High-thermal mass wall construction	X	X
Low-infiltration construction	X	X
Mechanically Provided Outdoor Air Apartments Make-up Air to Corridors	 X X	 X N.A.
Energy Recovery Ventilation	X	N.A.
High efficiency (90%) gas furnaces	N.A.	X
High Efficiency (SEER=14) efficiency split AC units	N.A.	X
Water to Air Heat Pumps	X	N.A.
High-performance standing well geo-exchange wells	X	N.A.
High Efficiency Interior & Exterior Lighting	X	X
Low-flow water fixtures	X	X
High-efficiency domestic water heaters	X	X
Solar Domestic Water Heating	X	N.A.
Energy Efficient Apartment Appliances	X	X

1. ENERGY EFFICIENCY

Load Calculations. The cooling and heating loads were determined using ASHRAE engineering procedures. At the Homan Ave building the 40/34 tons (cooling/heating) geo-exchange field was sized to not require any back-up heating. For peace-of-mind the initial design put out for bid called for the domestic hot water heaters to also be available as back-up heat the geo-exchange loop. This was later replaced with a separate gas-fired boiler for simplicity and to totally separate the ethylene-glycol/water ground-loop fluid from the potable water. The back-up gas-fired system has not had to be used at all.

Energy Use Simulation. Energy use projections for the Homan Ave building with the GXHP system are summarized in Table 4. The original energy use projections were based on data from similar buildings.

The LEED energy model was created using VisualDOE simulation software. The projected energy usage is higher than both the original energy use projections and the measured energy usage. Yet for the LEED certification the design model indicated over 30% savings relative to the base case energy model. This apparent contradiction is due to the particular requirements by both the LEED process and the ASHRAE 90.1 standard for creating both the base case and design energy models. This focus of this process is to minimize the opportunities to "game" the energy modeling process—and to compare the relative of energy performance of various design options—not necessarily to accurately predict the absolute energy use of the building.

The utility bill analysis was based on resident and common area utility bills for the 12 month period ending in August 2011. As previously described, monthly utility data was retrieved from over 60% of the apartments at the Homan and Ohio buildings. Complete details and data are available in the Measurement and Verification report done by Katrakis and Rasmussen.[1]

1. Katrakis, J.T., Rasmussen, M.F. Rosa Parks Apartments Energy Performance Measurement & Verification Report. March 31, 2012.

Table 4. Comparison of Energy Use and Cost Projections at Homan Ave.

END USE	ORIGINAL HVAC & DHW ENERGY USE PROJECTIONS					LEED ENERGY MODEL		UTILITY BILL ANALYSIS RESULTS[2,3]				
	Electricity[1]		Gas[1]		Total[2,3]	Electric	Gas	Electricity		Gas		Total
(---)	(kWh/yr)	($/yr)	(Th/yr)	($/yr)	($/yr)	(kWh/yr)	(Th/yr)	(kWh/yr)	($/yr)	(Th/yr)	($/yr)	($/yr)
Apartments												
Space Heating	34,090	3,409	0	0	5,114	65,381	0	45,347	6,849	0	0	6,849
Space Cooling	9,720	972	0	0	1,458	16,956	0	10,200	1,541	0	0	1,541
Ventilation Fans	32,400	3,240	0	0	4,860	34,557	0	21,385	3,230	0	0	3,230
Total Apt's	**76,210**	**7,621**	**0**	**0**	**11,432**	**116,894**	**0**	**76,932**	**11,619**	**0**	**0**	**11,619**
Common Areas												
Space Heating[4]	0	0	0	0	0	38,311	0	26,572	3,056	0	0	3,056
Space Cooling[4]	0	0	0	0	0	8,668	0	5,214	600	0	0	600
Ventilation Fans[4]	0	0	0	0	0	40,223	0	24,891	2,862	0	0	2,862
Pumps & Misc.	13,190	1,319	0	0	1,517	80,619	0	16,979	1,953	0	0	1,953
Dom. Hot Water	0	0	6,480	6,480	7,258	0	2,779	0	0	3,267	3,659	3,659
Solar DHW	0	0	-880	-880	-986	0	-880	0	0	-880	-986	-986
Total Com. Areas	**13,190**	**1,319**	**5,600**	**5,600**	**7,789**	**167,821**	**1,899**	**73,656**	**8,470**	**2,387**	**2,673**	**11,144**
Direct Comparison[4]	**89,400**	**8,940**	**5,600**	**5,600**	**19,220**	**197,513**	**1,899**	**93,911**	**13,572**	**2,387**	**2,673**	**16,245**
Grand Total	**89,400**	**8,940**	**5,600**	**5,600**	**19,220**	**284,715**	**1,899**	**150,588**	**20,090**	**2,387**	**2,673**	**22,763**

Notes:

1. 2007 prices for Apartments and Common areas: Electricity @ $0.10/kWh & Gas & 1.00/therm
2. 2011 prices for Apartments: electricity @ $0.15/kWh & Gas @$1.91/therm
3. 2011 prices for Common areas: electricity @$0.115/kWh & Gas @ $1.12/therm at Homan and Gas @$0.91/therm at Ohio
4. Common area Space Heating, Space Cooling and Ventilation Fans and the contribution of solar domestic water heating were not included in the original projections.
5. The utility bill analysis yielded a gas cost for DHW of $2,673. The projected avoided cost due to the solar DHW heating system is $986 (We are not using the measured avoided cost because it is unrealistically high at $2,480). Therefore, the estimated gas cost for DHW without any assistance from solar DHW would have been $ 2,773 - $ 986 = $ 3,659.

Measured Energy Consumption. Figure 1[2] shows the Energy Utilization Indices for the Homan Avenue and Ohio buildings. We were able to analyze one full year of apartment utility data from two-thirds of the apartments at both buildings by getting utility bill releases from the residents. We also analyzed the utility bills paid by the Owner for the common areas of each building. Utility data was analyzed from apartments that were occupied for the 12-month period of analysis ending in August 2011.[3] The average occupancy rates during this period were 2.1 people/unit for Homan and 3.3 people/unit at Ohio. The measurement and verification study done at the Homan and Ohio buildings enabled us to estimate the energy use for the key end uses. For example, baseload energy use includes apartment loads such as lighting, computers/audio-visual systems, as well as common area lighting. We assume that the Ohio building energy use and distribution are representative of the other six buildings with individual gas-fired furnaces and dx cooling for each apartment. Note that space heating and cooling accounts for over 50% of the energy use at the Ohio building—typical for Chicago residences—but less than 33% of total energy use at Homan.

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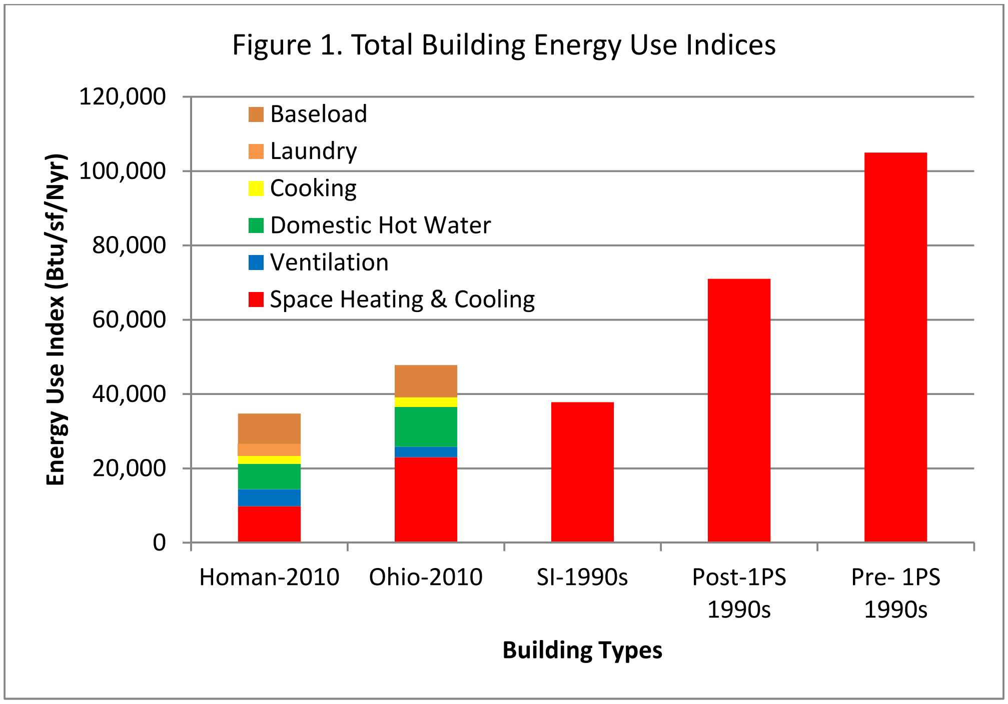
2. Presentation at Landon Bone Baker Architects. July 25, 2012.Katrakis, J.T. AirLab 2012--Rosa Parks Apartments Mechanical Systems & Energy Performance.
3. Katrakis, J.T., Rasmussen, M.F. ibid.

For purposes of comparison, Figure 1 also shows the space heating (only heating—does not include any cooling which in these building is typically done with window AC units) energy use for two other groups of energy efficient Chicago multifamily housing: SI-1990s refers to buildings that were gut-rehabbed according to the guidelines of the IDCEO Super-Insulation program during the 1990s; Post-1PS are space heating (only) indices for occupied retrofitted single-pipe steam buildings done by the Center for Neighborhood Technology (CNT) in the 1990s and Pre-1PS are their corresponding pre-retrofit space heating indices.



The energy using systems at Homan have reduced the total building energy use (for both residents and common areas) down to the level where it is conceivable to add more on-site renewable energy sources and approach the performance of net-zero energy buildings.

4. INDOOR AIR QUALITY

Outdoor Air. At all eight buildings each apartment has operable windows with sufficient operable area (operable window area is over 4% of the floor area) to define the apartments as being naturally ventilation according to ASHRAE Standard 62.1. Besides the operable windows, outdoor air is provided mechanically at all eight buildings by introducing outdoor air to the return side of each furnace or heat pump. At Ohio and the other six non-LEED buildings outdoor air is introduced untempered by individual ducts that go directly to the nearest outside wall for each apartment furnace. At the Homan building the outside air is distributed from two roof-top energy recovery ventilators (ERVs) that first temper the air with heat from the bathroom exhaust air during the winter, or with “coolth” from the bathroom exhaust air during the cooling season.

The central ERVs have their own filters for the incoming outdoor air and the air intakes are located about 40ft above street level and about 40ft away from the street. Therefore we expect this outdoor air to be of better quality than outside air available through open windows and air intakes located closer to the streets. This feature may be especially important considering that Homan is located at the intersection of two busy streets, with over 10,000 cars per day of traffic that generate over 6,000,000lbs of pollution per day.[4]

The two four story buildings, Homan and Ohio are almost tall enough where the Chicago building code requires a make-up air system to introduce 100% outside air to pressurize the corridors relative to the apartments. This is intended to contain odors to the apartments where they were generated. The Homan building, with its relatively large and long corridors on each floor and several central laundry facilities did receive a corridor makeup air system. The Ohio building with its much smaller corridor areas does not have a corridor makeup air system.

The design called for using MERV 8 filters at all the apartment heat pumps or furnaces. This level of filtration requires pleated filters and is at least double of the typical glass fiber mesh filters which are intended primarily to protect the HVAC equipment from damage and dirt. MERV 8 filters are not sufficiently efficient to capture the sub-micron particles generated by street traffic that are small enough to travel deep into the lung alveoli and are too small to be captured and removed by the natural action of the cilia lined bronchial passages of the human lung.

In order to qualify for LEED certification and desired Indoor Air Quality Credits, at least three apartments were randomly selected at the Homan building and received blower door pressurization testing to measure leakage rates, and to identify the locations where additional tightening was done. Both Homan and Ohio buildings allow smoking in the apartments. Table 5 shows that with all apartment windows closed the measured CO2 levels in Homan are lower than the maximum allowed by Chicago City Code and Illinois Department of Public Health—1000ppm.

Table 5. Indoor Air Quality at Homan

Outdoor Air Conditions: December 10, 2010; 43.7°F, 48.9% R.H., 370ppm CO_2

Parameter	Basement	Apt #102	#301	#302	#307
Room Air Temp	55	76	74.1	70.7	78.7
CO2 Space (ppm)	539	677	820	573	814 est
Approximate OA Rate (cfm/person)	20	16	13	18	13

Further work is needed to determine whether the added features at Homan result in better indoor air quality than at Ohio and the other six buildings with conventional ventilation systems and direct outdoor air supplied to each apartment furnace.

4. Airlab” a 3-year partnership of the LBBA (project architect) and Bickerdike (owner and manager of Rosa Parks Apartments) to facilitate a 6-week summer workshops to develop high school and youth resident green leaders at to study indoor air quality (IAQ) at Rosa Parks Apartments and educate other residents on its impacts on their daily lives. July 2011-2013.

5. INNOVATION

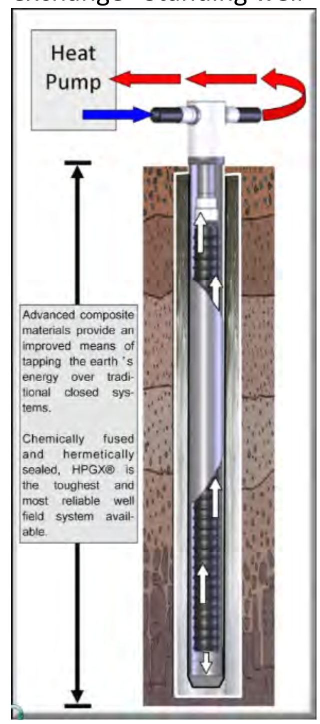
The Homan building includes the following **innovative MEP design features:**

1) Geo-exchange supplied distributed heat pumps for each apartment, and condition 98% of the common areas including the corridor make-up air, central laundry facilities and basement areas;

2) Geo-exchange well field under a permeably paved parking lot to address the constraints of doing geothermal in small urban lots. The permeable pavement helps to keep the well-field irrigated with rainwater which helps to maintain the ground-to-well thermal heat transfer;

3) The Project team selected and installed high-efficiency modified "standing-well" geo-exchange well technology because of minimal available ground area in this urban setting. As shown in Figure 2 This modified standing well features: concentrically arranged heat exchangers with an inner supply tube in each well with exterior rifling and high velocity flow in the annulus to induce turbulent flow between the geo-exchange fluid and the well wall; high thermally conductive graphite composite well tube; high performance grout. The test well that was used to measure the thermal conductivity of the ground resulted in a k-value of 2.35—much higher than the typical high end value of 1.4 for standard geo-exchange wells in the Chicago area. We suspect the extraordinarily high k-value at this site may also be due to an unusually high amount of underground water movement.

Figure 2. Modified Gero-exchange "Standing well"



4) central apartment exhaust system with roof-top energy recovery ventilators to temper the corridor make-up air supply and to provide tempered outside air directly to reach apartment. The central exhaust runs continuously for a constant low level of ventilation. And each bathroom has its own timer-controlled fan to provide an extra level of exhaust while the bathroom is in use.

5) solar domestic water heating system includes 10 roof-mounted panels. The original bid documents design had this system interconnected via a heat exchanger with the geo-exchange system to allow excess solar thermal energy to automatically transfer into the geo-exchange field as a seasonal solar thermal storage system. This would also enable the gas-fired domestic water heaters to serve as supplemental/back-up in case the geo-exchange field could not provide the necessary heat. In order to simplify the system and eliminate any possibility of contamination of the potable domestic hot water by the anti-freeze based geo-exchange fluid.

As mentioned previously, all the buildings have outdoor air supplied directly to each apartment. The 90% efficient gas furnaces at Ohio and other non-LEED buildings use sealed-combustion—outdoor air is ducted directly from the outside avoid negatively pressurizing the apartments relative to the outside.

Innovative architectural features. In order to achieve economy of scale and affordability, the buildings vary from 6 to 27 units, and are all a variation on a theme of the same modular facade. Only 2 types of windows are used throughout the development and scattered 1 and 2-story colored bays project from the front and rear of the buildings adding definition to their facades. All of the buildings are built of 8-inch thick precast concrete walls with engineered wood trusses at floors and roofs. The insulation embedded in the pre-cast concrete panels plus additional wall and roof insulation and high performance windows allow all the buildings to meet the Illinois DCEO super-insulation standards.

6. MAINTENANCE & OPERATION

Detailed O&M manuals were developed by Bickerdike staff and are kept on-site, along with logs for periodically documenting building system conditions. Orientation sessions are provided for residents that include instructions for using the key systems in the apartments and common areas. The Bickerdike facility management team is conscientious about developing and applying standard operating procedures and making the necessary adjustments to optimize these systems. O&M Issues include:

a. **Selection and use of the apartment thermostats.** The original thermostats at Homan were replaced—as they were too complicated for the residents. Residents were instructed to: set heating and cooling setpoints sufficiently apart to avoid rapid switching between heating and cooling; program automatic setback and setup of setpoints; use fan "auto" settings to reduce fan energy;
b. **indoor air quality.** It is not clear whether the extra IAQ enhancing features includes at Homan are providing any benefits. As discussed previously, the Airlab activity is facilitating documenting and IAQ at both the Homan and Ohio buildings;
c. **servicing the central geo-exchange loop pumps.** In late Summer 2013 a power surge made the two central geo-exchange loop pumps inoperable; they and their corresponding variable speed drives (VSDs) will be serviced and repaired.

7. COST-EFFECTIVENESS

All installed cost documentation was prepared by the mechanical contractor who installed both the GXHP system at Homan and the conventional systems at the other seven buildings. This was the first commercial GHXP system for this contractor. Table 6 summarizes the installed HVAC system costs at each of the buildings with 90% gas heating and SEER 13 split Air Conditioning (AC). The average per unit cost over the total of 67 living units is $10,304.

Table 6. HVAC Costs at Rosa Parks Apts with 90% Gas Heating and Split AC

Site #	Address	HVAC Cost $	# Units	$/unit
1	3221 W. Huron St	60,872	6	10,145
2	649 N. Sawyer Ave	68,851	6	11,475
3	601 N. Drake Ave	59,903	6	9,984
4	526 N. St. Louis Ave	121,082	12	10,090
5	521 N. St. Louis Ave	61,642	6	10,274
6	532 N. Trumbull Ave	144,747	15	9,650
8	3341 W. Ohio St	173,290	16	10,831
	Total/Average	690,387	67	10,304 (avg)

Table 7. Summarizes the first costs of the buildings and breaks out the HVAC components.

Table 7. Total Building and HVAC system Installed Costs

	HARD COSTS		
	Homan	Other 7	Total
Floor Area (sf)	34,602	96,999	131,601
# Living Units	27	67	94
Total Bld'g Cost ($)	5,576,463	11,999,250	17,575,713
$/unit	206,536	179,093	186,976
$/sf	161	124	134
HVAC w/o ERV Cost ($)	627,058	690,368	1,317,426
$/unit	23,224	10,304	14,015
$/sf	18.12	7.12	10.01
% Total	11%	6%	7%
All HVAC Costs ($)	678,458	690,368	1,368,826
$/unit	25,128	10,304	14,562
$/sf	19.61	7.12	10.40
% Total	12%	6%	8%

Geo-Exchange Heat Pump System. Table 8 summarizes the incremental costs of the geo-exchange heat pump system at the Homan building. The incremental per unit cost for the geo-exchange heat pump system at Homan is $12,921 or a total of $348,850 as itemized in Table 8. The corresponding measured annual energy savings for heating and cooling costs is $6,932 for a simple payback of 50 years or a return on investment of 2%. The $66,150 geo-exchange heat pump grant from the Chicago Dept. of Energy improves the payback to 41 years.

Table 8. GXHP System Incremental Economics

Geo-Exchange Heat Pump (GXHP) System Incremental Cost Components ($)	
Distribution Piping, Valves/Pumps	207,767
Heat Pumps & Tstats	88,583
90% Boiler for Back-up	10,000
GeoExchange Borings	152,950
GeoExchange Excavation	4,800
Sub-total Extras	464,100
Deduct for Furnaces & AC	70,250
Deduct for Gas Piping	45,000
Sub-total Deducts	115,250
NET TOTAL INCREMENT	348,850
Per Unit Incremental cost	12,921

GXHP System Economics[1,2]	
% Annual Energy Savings	68%
% Annual Energy Cost Reduction	34%
Annual Avoided Energy Costs	$ 6,932
Incremental Costs of GXHP System[3]	$ 348,850
Return on Investment (%)	2%
Simple Payback	50 years

Notes
1. Relative to 90% EFF Gas Furnaces & 13 SEER AC and the same super-insulated building envelope AC used at the other seven Rosa Parks Apartments buildings
2. Utility rates (2010-2011).
3. Does not include any of the grants/incentives provided for the geo-exchange heat pump system.

90% Efficient Gas Furnaces. The very high efficiency (90%) furnaces installed at the other 7 buildings yield at least 12% gas savings compared to the 80% efficiency requirement for ASHRAE Standard 90.1-2010. Changing a building like Homan from 80% to 90% efficient furnaces would save $2,014 per year (at 2010-11) gas prices, for an additional $15,000 in first cost and have a payback of 7.5 years or about a 14% Return on Investment (ROI). Changing Homan from 80% furnaces/SEER 13 AC to the present GXHP system would save $ 8,945 per year at a cost of $ 363,850 for a payback of 40 years and 2.5% ROI.

8. ENVIRONMENTAL IMPACT

Since all eight buildings were designed to comply with both the LEED Version 2.2 New Construction standards and the Green Communities environmental criteria—they all have a smaller environmental "footprint" than the standard new affordable multifamily housing.

Improved IAQ in urban settings. The buildings include HVAC features and indoor finishes to improve the indoor quality in for residence in urban environments where outside air may not be "fresh" air.

Reduced Emissions. The HVAC systems contribute to the smaller burden on the environment due to their reduced energy use. Focusing on the HVAC systems Table 9 shows the reduction in annual equivalent carbon dioxide emissions (metric tons of CO_2 equivalent per year) for various HVAC-related measures. The calculations are done for Homan by itself and also for all eight buildings.

Refrigerant. The heat pumps use R-410a refrigerant which has negligible greenhouse gas emissions.

Anti-freeze. Various anti-freeze products were considered for this project. Ethylene glycol was finally selected. It biodegrades when combined with CO2 and H2O. Non-persistent organic acids are formed.

Table 9. HVAC Efficiency Measures Impact on Greenhouse Gas Emissions

Measure	Homan (MTCO2e/yr)	All 8 Buildings (MTCO2e/yr)
Convert from 80% to 90% Eff Furnaces	5.4	17.1
Convert 90% Eff Furnaces to GXHP	2.1	8
Convert 80% Eff Furnaces to GXHP	7.5	25.1

CONCLUSIONS

1. Geo-exchange heat pump heating and cooling technologies combined with very efficient building envelopes significantly reduce building energy use--to the point where adding on-site renewable energy production enables approaching zero net energy use.

2. Although the geo-exchange heating and cooling system at Homan resulted in significant energy savings, its incremental investment has a long payback. This is due to its high first cost, low energy prices in Chicago and because high energy efficiency can be cost-effectively achieved through the well-insulated building envelope and 90% efficient gas heating.

3. Determining accurate energy savings and their impact on greenhouse gas emissions requires using the best available data on actual building energy usage—both for the representative base case and for the new building being analyzed. This data is essential to serve as a reality check and to calibrate the building energy model.

4. Further work is necessary to:
   a. Review the accuracy of the first cost calculations for both the GXHP and Gas Furnace options. The large cost difference between the two options warrants such a review.
   b. Work on reduce the first cost of future geo-exchange heat pump systems. Focus on reducing the cost of the interior distribution piping systems and geo-exchange well field;
   c. determine the cost-effectiveness and effect on indoor air quality of central energy recovery ventilators and the corridor make-up air system at Homan.