PN-ACR-067

"CAIRO CENTER" Office Building
Preliminary Energy Audit Report

EXECUTIVE SUMMARY

At the request of the United Bank of Egypt, NEXANT, LLC performed a preliminary energy audit of the Cairo Center office building in Garden City to examine the feasibility of upgrading or modifying the energy using equipment in the building to reduce operating energy costs. UBE has been evaluating various options to provide financing for energy efficiency projects implemented by Energy Service Companies (ESCO)s, and therefore, considered this real life project to be an opportunity to learn about the financial and operational feasibility of the ESCO approach.

Options to increase the efficiency of the building's energy systems were identified, and the potential savings and investment required were estimated. The assessments were made to assist UBE make a decision on improving the energy systems in the building. The findings from the preliminary audit including proposed suggestions for improvement and preliminary cost-benefit analysis are summarized below.

Opportunities for Savings

Lighting
The existing lamp fixtures in the building can be modified to improve lighting levels and reduce electricity consumption. Sensors can be installed to automatically switch lights. The two options combined provide an opportunity for annual savings of nearly LE 335,000, (65% of annual lighting costs), with a payback period of less than 2.5 years on the investment.

HVAC
The reduction in the lighting load will substantially reduce the heat load in the building allowing a change in the operating schedule for the chillers. The suggested change can reduce electricity costs by over LE 186,000 (over 40% of annual HVAC energy costs). Window glazing can be applied to further reduce building heat gain. Options to automate system operations are also suggested for improved performance and additional savings.

Billing
It was estimated that building management incurred about LE 215,000 of unnecessary costs for the year analyzed. A revised method has been suggested for estimating electricity costs attributable to various tenants. The suggested method would be more equitable to tenants and the building management, and provide tenants an incentive to save energy.

Conclusion

The preliminary energy audit indicates that the efficiency of energy use at the Cairo Center building can be improved considerably by implementing the options examined. Potential annual savings of over 520,000 LE can be realized by implementing some of the suggested options. This would require an up-front and one-time investment of about 730,000 LE, with a payback period of 1.4 years. Other cost savings are also possible through better building management practices. A detailed investment grade energy audit should be performed before proceeding to implementation of proposed options.

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INTRODUCTION

In support of its activities to develop market initiatives aimed at expanding the energy efficiency practice in Egypt, NEXANT, LLC performed a preliminary energy audit of the Cairo Center office building in Garden City. The 16-story commercial building is owned by the United Arab Realty Co., a real estate development entity owned by the United Bank of Egypt (UBE), one of the leading Egyptian banks in promoting energy and environmental management. As owners of the facility, UBE requested NEXANT to perform this preliminary evaluation to examine the feasibility of reducing energy use in the building using third party energy service companies to demonstrate the ESCO concept.

Cairo Center consists of 14 conventional floors, one ground floor, one mezzanine, and a basement housing most of the building's cooling and heating equipment. The total building floor area is approximately 19,300 m^2, most of which is presently occupied with the exception of 2 floors.

In performing this evaluation, several options to increase the efficiency of the energy systems installed in the building were identified ranging from low-cost operational options to equipment replacement options requiring capital investment. However, it is important to note that energy savings and investment requirements used in this report were only estimates given the preliminary nature of the report. The intent of this report is to assist UBE decide whether an energy improvement of the building should be considered. A detailed investment grade energy audit should be performed to more precisely estimate costs and savings before proceeding to implementation of options.

This report provides a summary of findings as a result of the preliminary audit including proposed suggestions for improvement. It also provides preliminary cost-benefit analysis for the options considered.

1. ELECTRICITY BILL ANALYSIS

The electricity bills from March 1999 through February 2000 were obtained from the building manager and analyzed. During the one-year period, the building used 6,329,471 kWh of electricity, which translates to a total energy cost of LE 1,261,160.

Table 1 shows the estimated electricity consumption in major building energy systems such as lighting, Heating Ventilation and Air Conditioning (HVAC), Air handling Units (AHU), and "Other" system. The breakdown of electricity use was estimated based on the building survey and data collected during the audit, and other assumptions[i]. The estimated cost of providing energy services during the one-year period is shown in **Table 2**[ii].

Table 1: Analysis of Building Electricity Use

Month	Total kWh	Lighting kWh	AHU kWh	HVAC kWh	Others kWh
Mar	525955	212625	66960	99994	146376
Apr	451500	212625	64800	181440	-7365
May	539975	212625	66960	187488	72902
Jun	510632	212625	64800	181440	51767
Jul	584659	212625	66960	287482	17592
Aug	598023	212625	66960	287482	30956
Sep	568909	212625	64800	278208	13276
Oct	646227	212625	66960	287482	79160
Nov	633818	212625	64800	181440	174953
Dec	404955	212625	66960	99994	25376
Jan	441477	212625	66960	99994	61898
Feb	423341	212625	62640	93542	54534
Total	**6,329,471**	**2,551,500**	**790,560**	**2,265,984**	**721,427**

See Endnote (i)

Table 2: Estimated Cost of Electricity Consumption by End-Use

End-Use	% of Total Building Consumption	Electricity Cost (LE)
Lighting	40%	508,392
HVAC	36%	451,502
AHU	13%	157,521
Others	11%	143,746

See Endnote (ii)

2. LIGHTING SYSTEM

Existing System

The existing system includes 450 fixtures per floor with 5 fluorescent lamps in each, representing a load of 140 Watts per fixture[iii]. According to the building management, each tenant organization has one light switch to control all lamps within their designated office space. Floors occupied by a single tenant have 2 light switches. Thus there are very few switches to control the large number of fixtures on each floor. The building personnel estimate that, on average, lights are on for about 12 hours per day and six days a week, with some spaces are lit for 18 hours or more.

The fixtures are old and the reflectors and diffusers are in poor condition, limiting the amount of light reaching the workstation - a light level of only 30 foot-candles was measured on a desktop directly under a lamp fixture.

Suggestions for Improvement

Light Fixtures Modification
The fixtures can be modified to improve lighting levels and reduce electricity consumption in a cost-effective manner. Light levels can be significantly improved by increasing the reflectivity of the fixtures and changing the diffusers. In fact, with the improved light levels, it may be possible to reduce the number of lamps per fixture from 5 to 4. It is also suggested that the 3 magnetic ballasts used in each existing fixture, which together dissipate about 50 Watts, be replaced with a single electronic ballast using only 8 Watts.

The above changes would reduce the load per fixture by 60 Watts. A preliminary inquiry has indicated that the required modifications to the light fixture would cost about LE 100 per fixture. The energy and cost savings, and the payback period for this measure are shown in Table 3[iv].

Table 3: Energy and Cost Savings as a result of Light Fixtures Retrofit

Reduction in Load (kW)	Annual Energy Savings (kWh)	Annual Cost Savings (LE)	Total Investment (LE)	Payback Period (years)
400	1,137,240	210,044	675,000	3.2

See Endnote (iv)

Use of Occupancy Sensors
The light switches are located inside the tenant offices, and it is expected that the last person to leave each office would turn off all lights. It is unlikely that tenants diligently do so, especially since tenants do not have individual energy meters and the costs are distributed across all tenants. Installing occupancy sensors is a simple option to ensure that lights are switched off automatically when the space is not occupied.

Sensors could be installed in several areas on each floor to detect the presence of people and switch on or switch off lights. Assuming that the use of sensors would bring down the average use of lamps from 12 to 8 hours per day, the energy and cost saving, and the payback period for this measure are shown in Table 4[v].

Table 4: Energy and Cost Savings in Lighting Systems by Retrofitting Fixtures

Annual Energy Savings (kWh)	Annual Cost Savings (LE)	Total Investment (LE)	Payback Period (months)
505,440	124,889	52,500	5

See Endnote (v)

Recommendations

The above two options, when combined, provide an opportunity to achieve over 65% savings in annual lighting costs with a simple payback period of less than 2.5 years. Moreover, the reduction in the lighting load typically reduces the heat load in the building leading to

additional savings in cooling energy costs. It is thus recommended that the above options be considered.

Changes should be scheduled over a period of time taking advantage of weekends and holidays to minimize business interruption. It is advisable that the building management performs this retrofit on a typical floor first with a pre and post monitoring of consumption to test problems likely to occur, and then extend the retrofit to the rest of the building.

3. THE HVAC SYSTEM

Existing System

The building's HVAC System was installed about 20 years ago and consists of two centrifugal chillers, each with a 300-ton capacity (one operating and one standby), with an additional reciprocating chiller of 160 tons. A new 300-ton screw compressor chiller is scheduled for installation in April-May 2000. There are three cooling water pumps of 40 HP each (two operating and one standby), and three chilled water pumps of 40 HP each (two operating and one standby). Four cooling towers are located on the building's roof, two large ones with one 40 HP fan each, and two smaller ones with one 15 HP fan each. Two 300 kW electric heaters are installed on the chilled water loop, but have never been used.

Each floor of the building is divided in two zones, each with its own constant volume AHU. The larger AHU on each floor has a 10 HP fan, and the smaller one has a 3 HP fan. A thermostat is installed in each zone to control the AHU's dampers and regulate the airflow through the chilled water coil. All thermostats have however, been disconnected a long time ago, and the dampers are controlled manually. Further, the AHU design does not provide any means to control the ratio of return air to fresh air. The chillers do not have a temperature set-point control and the chilled water temperature is maintained at 10^0C regardless of outside temperature. The return water temperature varies depending on ambient conditions.

According to the building engineering staff, the HVAC system runs 24 hours per day, every day of the year, to maintain comfort in the building. They also report that shutting the chillers results in undue heating of the building, even during winter. The number of chillers in operation at any time varies seasonally (See Endnote (i) for the chiller operation schedule).

In general, the system appears to be in a reasonably good condition, but it runs without any automatic controls.

Suggestions for Improvement

Impact of Lighting System Improvements on the HVAC System

The proposed modification to the lighting system is expected to reduce the connected lighting load by approximately 400 kW. Assuming a load factor of 75%, the reduction in the lighting load would be about 300 kW. Since all light energy is dissipated as heat, the reduction in lighting load would substantially reduce the heat load generated in the building, and consequently reduce the load and power consumption in the HVAC system. If the suggested option to install sensors to control lamp operation were adopted, the heat load would be further reduced, leading to greater reduction in cooling needs.

A 300 kW reduction in the lighting load would reduce the building heat load by over 1.0 million Btu/hr, or about 85 tons of cooling. Conservatively assuming the overall efficiency

of the HVAC system to be around 80-85%, the cooling demand would reduce by over 100 tons!

The chillers can thus be operated primarily during daytime and shut-off, or partially operated, in the night. In fact, it may be possible to shut-off the chillers all winter and have only the AHU's in operation to circulate fresh air. The change in operational practice would very significantly reduce energy consumption in the HVAC system. The potential energy and cost savings are shown in Table 5[vi].

Table 5: HVAC Energy and Cost Savings

Annual Energy Savings (kWh)	Annual Cost Savings (LE)	Total Investment (LE)	Payback Period
1,118,736	186,443	0.0	Immediate

See Endnote (vi)

The above savings in the HVAC system can be realized as a result of the modification in the lighting system and a consequent change in chiller operations practice. Since no direct investment in the HVAC system is required for this measure, the HVAC cost savings will reduce the payback period for the lighting system improvements from 2.2 years to 1.4 years.

Window Coating

Heat is transmitted through windows to the interior, creating a heat load. Applying a heat reflective coating to most southern and westerly facing windows can reduce the heat absorbed by the building. It is estimated that the use of the reflective coating can reduce the HVAC load by about 30 tons[vii]. Realizing that this was a preliminary audit, the availability and cost of such coating material was not determined, and thus the investment required for was not examined. Generally, the payback period for this measure is short.

Recommendations

The reduction in HVAC consumption due to reduced heat load from the lighting system alone translates to a 40% reduction in annual HVAC energy cost, and should thus be seriously considered. There are several other options that can significantly reduce energy consumption in the HVAC system. Some of the options that should be studied are:

- Addition of automatic controls to optimize the operation of chillers (especially a temperature set-point controller)
- Change the AHU from constant volume to variable volume
- Add control systems for optimal mixing of return air and fresh air
- Install 2-way control valves on the chilled water supply to the AHU's cooling coils, converting the constant-flow chilled water system to a variable-flow system.
- Add variable speed drives to all the electric motors (pumps and fans)

A detailed energy audit of the HVAC system is highly recommended to make an in-depth examination of the above options.

4. BUILDING OPERATIONS

Existing Billing Practice

The methodology used by the building management to allocate the monthly electric bill among different tenants was examined. The current practice is to divide the monthly bill by the total building floor area to determine the cost per square foot. Each tenant is then billed according to the floor area they occupy. The distribution of monthly charges to each tenant is shown in Figure 1. This allocation methodology introduces a few challenges with regard to equitable billing. For instance, there are 2 unoccupied floors since the USAID moved out of the building. With the current billing methodology, the total utility costs are allocated to the remaining tenants but based on the ratio of their occupied space to the total building. This allocates the percentage of the unoccupied space to the building management. Instead, the total energy costs should be allocated to the remaining tenants based on the ratio of their occupancy to the total occupied area.

We have estimated that this practice resulted in approximately LE 215,000 of unnecessary cost for the building management for the one-year period analyzed.

The current practice also provides a dis-incentive to tenants to reduce consumption, especially for those with additional power consuming equipment such as packaged air conditioners, electric heaters, and other office type equipment.

Suggestions for Improvement

Modification to Billing Electricity Costs to Building Tenants

Since unoccupied floors consume minimal energy, it is suggested that the cost per square meter be calculated based only on the occupied space. This would spread costs among existing tenants, and the building management would only pay for the space occupied by their offices.

Recommendations

Since it is impractical to install separate energy meters for each tenant, it is suggested that tenant offices be periodically inspected to estimate the demand for each tenant or group of tenants if possible. Energy bills can then be allocated among tenants based on floor area occupied and weighted by the expected demand.

5. CONCLUSIONS

The preliminary energy audit indicates that the efficiency of energy use at the Cairo Center Building can be improved considerably by implementing the options identified above. If the above recommendations are implemented, potential savings of over 520,000 LE can be realized annually requiring an up front one-time investment of approximately 730,000 LE. Other cost savings are also possible through better building management practices.

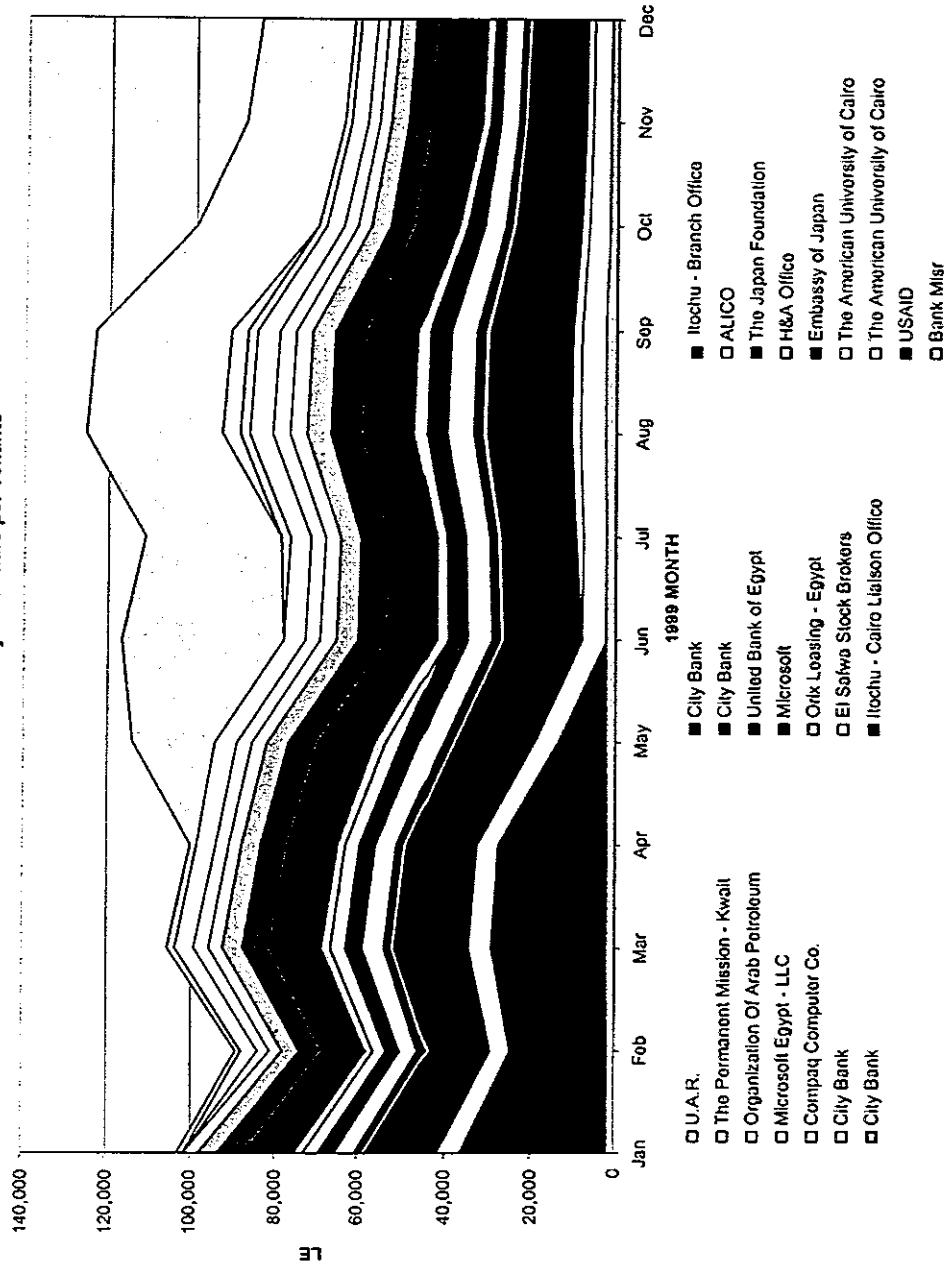
FIGURE 1: Electricity Bills share per Tenants
LE
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
1999 MONTH
U.A.R.
The Permanent Mission - Kwait
Organization Of Arab Petroleum
Microsoft Egypt - LLC
Compaq Computer Co.
City Bank
City Bank
City Bank
City Bank
United Bank of Egypt
Microsoft
Orix Leasing - Egypt
El Safwa Stock Brokers
Itochu - Cairo Liaison Office
Itochu - Branch Office
ALICO
The Japan Foundation
H&A Office
Embassy of Japan
The American University of Cairo
The American University of Cairo
USAID
Bank Misr

[i] Since some tenants changed during the year, it is assumed that, on average, 15 floors were occupied throughout the year. The breakdown of electricity consumption by end-use is based on the following assumptions.

End-Use	KW/Floor	Floors	Total kW	Load Factor	Hours/day	Days/month
Lighting	63	15	945	0.75	12	25
AHU	10	15	150	0.60	24	Actual days
HVAC				0.70	24	Actual days

Note that the purpose of this analysis is to estimate roughly the proportion on energy used in various end-uses and not to make an exact calculation. The emphasis is thus on the annual average percentage consumption in each major end-use rather than the actual kWh consumed in any given month.

The consumption in the HVAC system is based on the following chiller operation schedule, as reported by the building engineer. The operating kW is estimated to be 1.2 kW/ton (including chilled water and condenser pumps, and cooling tower fans and pumps).

December - March	160 tons
April - June	300 tons
July - October	460 tons
November	300 tons

[ii] The cost of electricity to commercial consumers is 0.1534 LE/kWh. Fixed monthly charges are LE 6,553 (was LE 6,271 up to June 1999). The bill includes total demand charges of LE 898 based on 7.3 LE/kW (was LE 859 up to June 1999). Stamp duties and miscellaneous charges vary depending on usage. The electricity cost for different end-uses is estimated based on an annual average cost of 0.1993 LE/kWh, which includes fixed costs, demand charges, and stamps duty.

[iii] Each lamp fixture has five 18-W fluorescent lamps and 3 ballasts - two 40W ballasts and one 20W ballast. Assuming that the three ballasts consume a total of 50 watts (dissipated as heat from the coils), the total wattage per fixture is (18W x 5) + 50W = 140W. This was confirmed by measurements taken at a several fixtures.

[iv] Reducing the number of lamps per fixture from 5 to 4 would reduce the load per fixture by 80 Watts, (18W x 4) + 8W = 80 W, representing savings of 60W per fixture (140W-80W). If all fixtures were modified, the total reduction in lighting load would be; (60W x 450 fixtures/floor x 15 floors)/1000 = 405 kW.

The corresponding annual energy savings would be; 405 kW x 0.75 load factor x 12 h/day x 6 day/week x 52 week/year = 1,137,240 kWh/year, and

The cost savings would be; (1,137,240 kWh/year x 0.1535 LE/kWh) + (0.060 kW x 450 fixtures x 15 floors x 7.30 LE/kW/month x 12 months) = 210,044 LE/year.

Given that the cost of modifying each fixture is LE 100, the payback period would be: (LE100 x 450 fixtures x 15 floors)/(210,044 LE/year) = 3.21 years

[v] The estimated annual energy savings from installing sensors would be; 0.080 kW x 0.75 load factor x 450 fixtures x 15 floors x (12-8) hr/day x 6 days/wk x 52 weeks/yr. = 505,440 kWh/year, and the cost saving would be;
(505,440 kWh/yr. x 0.1535 LE/kWh) + (0.080 kW x 450 fixtures x 15 floors x 7.3 LE/kW/month x 12 months) = 124,889 LE/year,

A sensor approximately costs 250 LE. Assuming that installation cost is approximately 100 LE per sensor, and that 10 sensors are needed per floor, the total cost of installing sensors would be; (250 + 100)LE x 10 sensors x 15 floors = 52,500 LE, and the payback period would be; 52,500 LE/124,889 LE/year = .42 years = 5 months

[vi] The HVAC system presently operates 24 hours per day as per the schedule shown in Endnote (i) above. The modification to the lighting system would lead to a reduction of over 100 tons in the cooling load, permitting a substantial change in the operating hours from the current operation schedule of the HVAC system. A possible new schedule for chiller operations could be:

January - March	0 tons	Fresh air re-circulation

April - June	160 tons	12 hr/day
July - October	300 tons	18 hr/day
November -December	160 tons	12 hr/day

With this reduced schedule, the energy consumption and potential savings in the chiller system would be;

Operation Period	Existing System (kWh)	Revised Schedule (kWh)	Energy Savings (kWh)
January - March	293,530	0	293,530
April - June	550,368	209,664	340,704
July - October	1,140,653	797,040	343,613
November -December	281,434	140,544	140,890
Total	1,265,984	1,147,248	1,118,736

Note: The operating kW is estimated to be 1.2 kW/ton (including chilled water and condenser pumps, and cooling tower fans and pumps), and the load factor for the revised schedule of operation is assumed to be 100% as opposed to 70% for the existing system. The existing system operates 24 hr/day as per the schedule in Endnote (i), while the revised system operates as shown above.

The corresponding electricity bill savings would be:

Energy Savings, LE	171,726
Demand Savings, LE	14,717
Total Savings, LE	186,443

Note: The energy savings are calculated based on the estimated savings and an energy charge of 0.1535 LE/kWh. The demand savings are calculated based on the actual tonnage of chillers in operation during specific months and the corresponding kW, and a demand charge of 7.3 LE/kW/month. Savings in stamp duties and taxes are ignored.

[vii] From the buildings plan drawings, it was estimated that the building has approximately a total of 20 windows per floor each measuring 7.5 m2. Thus the total window area for the building is about 2250 m^2 (or 24,219 sqft) considering 15 floors. The typical heat transfer coefficient of a window without glazing is 1.18 Btu/h/sqft/ °F. With glazing, the coefficient can be easily decreased to 0.8 Btu/h/sqft/°F. Assuming an average temperature differential of 7 °C between the ambient and indoors, the decrease in heat load would be: (1.18 – 0.8) Btu/h/sqft/°F x 24,219 sqft x 7 x 1.8 °F = 115,960 Btu/h

The typical solar heat gain in a climate like Cairo is estimated to be 75 Btu/sqft/hr. Assuming that only half of this window surface is exposed to the sun, the heat transfer surface is 12,110 sqft. The window shading coefficient (dimensionless) for a window without glazing is about 0.75. With glazing, this can be reduced to 0.55. The reduction in heat load would thus be: 75 Btu/sqft/hr x (0.75 – 0.55) x 12,110 sqft = 181,650 Btu/h.

The application of window glazing would thus decrease the building heat load by: (115,960 + 181,650) = 297,611 Btu/hr. This corresponds to a 30 ton decrease in HVAC load, assuming HVAC system efficiency of 80-85%.