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Final Report

Application Evaluation of the Market Square Project, Cleveland, Ohio

Technical Support Services for
Ohio Air Quality Development Authority (OAQDA)
Task 1

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EXECUTIVE SUMMARY

This report for Technical Support Services: Task 1. Application Evaluation of the Market Square Project, Cleveland, Ohio, summarizes the technical analysis performed on the materials provided that estimate the emissions reduction for the energy efficient design of the Market Square Project in Cleveland, Ohio. This technical analysis evaluates the technical merits of the project proposal to conserve air as a natural resource by preventing air pollution from electric power production from fossil fuel combustion in Ohio and from on-site combustion of natural gas. The analysis is based on project application materials received from Dunham Engineering consisting of an overall project description and input/out files from the EQUEST 3.65 whole-building simulation used to calculate the electricity and natural gas use.

To perform the analysis for Task 1 the following sub-tasks were completed:

- Task 1.1: Receive and review project application materials, including construction drawings, calculations, and other documents.
- Task 1.2: Analysis of the energy code compliance with ASHRAE Standard 90.1-2010.
- Task 1.3: Analysis of the simulated electricity and natural gas savings from the Office and Apartment buildings at Market Square, including calculation of key whole-building energy use metrics for the project.
- Task 1.4: Calculation of the 40 to 60 kW PV installation.
- Task 1.5: Analysis of air pollution savings from electricity and natural gas savings from the energy efficient design of the Office and Apartment buildings at the Market Square Project in Cleveland, Ohio.
- Task 1.6: Identification of limitations and risks that may occur during construction and operation of the project that may adversely impact the expected benefits to the State in energy savings and emissions reductions.

In summary, this analysis has verified the total annual energy savings of:

- Total electricity savings of 2,353,255 kWh (includes grid losses = 4.9%),
- Total natural gas savings of 4,085 MMBtu (includes pipeline losses = 5%),
- Total cost savings of $332,893,
- Total electricity savings of $300,606,
- Total natural gas savings of $32,287.

As well as total annual emissions reduction of:

- Total NOx reductions of 2,127 lbs (electric + natural gas),
- Total SO2 reductions of 2,826 lbs (electric + natural gas),
- Total CO2 reductions of 3,399,140 lbs (electric + natural gas).

These savings represent the calculated annual energy savings and resultant annual emissions reduction for the intended operation of the proposed project to serve as an Air Quality Facility as defined in Chapter 3706 of the Ohio revised code.

This analysis has identified the following Energy Conservation Design Measures (ECDMs) as contributing significantly to reducing the overall annual energy use:

- The use of energy efficient windows,
- The use of an Energy Recovery Ventilator (ERV) for exhaust air,
- Improved boiler and chiller efficiencies,
- Improved interior, exterior lighting,
- Shading of the Office building,
- Improved insulation levels (walls, ceiling and floors),
- Improved ventilation system (parking),
- The use of thermal mass (i.e., concrete, steel & timber).

	Annual Consumption of Office, Retail, Apts, Parking & Lighting		
	Electric Consumption (kWh, site+grid)	Natural Gas Consumption (MMBtu,site+p.loss)	Total Energy Consumption (MMBtu)
Energy Code Complaint Baseline	5,987,068	9,233	29,666
Proposed	3,633,814	5,149	17,551
Savings	2,353,255	4,085	12,115
% Savings	39%	44%	41%
	Annual Emissions of Office, Retail, Apts, Parking & Lighting		
	Nitrous Oxide (NOx) Emissions (lbs)	Sulfur Dioxide (SO2) Emissions (lbs)	CO2 Emissions (lbs)
Energy Code Complaint Baseline	5,408	7,188	8,513,832
Proposed	3,281	4,364	5,114,692
Savings	2,127	2,826	3,399,140
% Savings	39%	39%	40%

Total Energy Savings and Emissions Reductions from the proposed Market Square Project

The calculated savings do not include the electricity production from on-site renewable energy systems based on the project application materials submitted to date.

The calculated savings do not include energy savings associated with the embodied energy use representative of the materials used in the project (i.e., timber). Where the “Embodied energy use is sum of all the energy required to produce any goods or services, considered as if that energy was incorporated or ‘embodied’ in the product itself” (Source” www.wikipedia.org, 2019).

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TASK 1.1. Receive and review project application materials, including construction drawings, calculations, and other documents.

The project application materials received for the Market Square Project consist of the following items:

- Market Square – OAQDA Application for Financing of Air Quality Control Facility – April 23, 2019, 126 pages (See Appendix A).
- Dunham Engineering - Schematic Design (SD) Energy Modeling of Market Square, 4 page (See Appendix B).
- Dunham Engineering – MS Schematic Energy Modeling (EM) files, June 11, 2019, zip file containing 12 files (See Appendix C).
- Dunham Engineering – 20190723 MarketSquare Ext Parking Lighting and Fans
- Dunham Engineering – MS Retail Energy Models files, June 24, 2019

These materials were received and inspected and information was extracted for use in the analysis of the energy savings and emissions reductions for the Market Square project.

TASK 1.2. Analysis of the energy code compliance with ASHRAE Standard 90.1-2010.

An analysis of the compliance with ASHRAE Standard 90.1-2010 (Figure 1.1) was performed on the information provided by Dunham Engineering (Appendix B, C) for the Office building, Apartment building and Retail as shown in Table 1.1 (Office), Table 1.2 (Apartment) building and Table 1.3 (Retail) buildings. In each of these tables the item being considered is listed on the leftmost column (i.e., Climate Zone, Floor Area, etc.) with the values provided by the Dunham Letter (Appendix B) for the base case and proposed buildings and the minimum value required by ASHRAE Standard 90.1-2010. Meeting the minimum code compliance in the base case building is required when considering the energy savings and emissions reduction "above code".

Table 1.1 (Office) shows that the base-case Office building meets or exceeds the code compliance required for ASHRAE Standard 90.1-2010.

Table 1.2 (Apartment) shows that the base-case Apartment building meets or exceeds the code compliance required for ASHRAE Standard 90.1-2010.

Table 1.3 (Retail) shows that the base-case Retail building meets or exceeds the code compliance required for ASHRAE Standard 90.1-2010.

The review of the building characteristics for the base-case Office building in the Dunham Engineering document showed the building complied with ASHRAE 90.1-2010 (Table 1.1).

The review of the building characteristics for the base-case Apartment building in the Dunham Engineering document identified two claimed building characteristics that *are not allowed* in ASHRAE Standard 90.1-2010 (Table 1.2), even though the claims appear to be reasonable assumptions.

- The first characteristic is the "reduction due to energy efficient appliances" in the plug loads. Therefore, this characteristic was not included in the verification simulation of the Proposed Apartment building.
- The second characteristic is the "load reduction due to low flow fixtures and energy efficient appliances" in the DHW analysis. In a similar fashion as the plug loads, this characteristic was also not included in the verification simulation of the Proposed Apartment building.

As a result, since neither the plug load reductions nor the reduced DHW loads were used in the verification simulations of the Apartment building, and since the verification simulations were able to achieve 90%+ of the proposed reductions, it can be concluded that the impact of each of these measures has a small effect on the overall simulation results of the Apartment building, and therefore, the Apartment building meets the code requirement of ASHRAE Standard 90.1-2010.

Table 1.1. Analysis of ASHRAE Standard 90.1 Code Compliance (Office)

OFFICE			
	Dunham letter Basecase	ASHRAE 90.1-2010 Minimum Code	Dunham letter Proposed
Climate Zone	Zone 5A	Zone 5A	Zone 5A
Floor Area (ft2)	204,300	-	204,300
Floor Area/Floor (ft2)	22,700	-	22,700
# of floors	9	-	9
Floor to floor ht. (ft)	14	-	14
Roof Insulation	R-20Ci	R-20Ci, U=0.048	R-25Ci, U=0.04
Wall Description	Steel framed		Steel framed
Wall Insulation	R-13+R-7.5Ci	R-13+R-7.5Ci, U=0.064	R-13+R-10Ci
WtW Ratio	40%	40%	65%
Window Descr.	Fixed	-	Fixed
Window Assembly Uvalue	0.45	0.45 (max assembly)	U=0.36
Window SHGC	0.4	0.4 (all)	SHGC=0.23
Exterior shading	None	None	from Terraces
Lighting Int. LPD	0.9	0.9	0.35
Lighting/Daylighting	Proposed=Code	Proposed=Code	Proposed=Code
Lighting/OccSens	Proposed=Code	Proposed=Code	Proposed=Code
Plug Loads	Proposed=Code	Proposed=Code	Proposed=Code
HVAC System	VAV/w-HW-Reheat	System 2: VAV, chilled water, hot-water boiler	Fan-powered term units
Air Handling Units	VAV w/ heating, cooling coils	VAV w/ heating, cooling coils	VAV DOAS w/ Heat Recovery
Economizer	Airside		Waterside
Heating System	Boiler, 80% eff.	80% eff, Table 6.8.1 Gas fired boilers, min.eff	Boiler, 92% eff.
Cooling System	Air cooled chillers	EER > 9.562, Table 6.8.1 water chilling packages	High eff.chillers
DHW	-	80% eff, Table 7.8 Perf. Requirements for Water Heating Equipment	-

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Table 1.2. Analysis of ASHRAE Standard 90.1 Code Compliance (Apartment)

APARTMENT				
	Dunham letter	ASHRAE 90.1-2010	Dunham letter	Notes:
	Basecase	Minimum Code	Proposed	
Climate Zone	Zone 5A	Zone 5A	Zone 5A	TMY2 Cleveland, OH
Floor Area (ft2)	243,600	-	243,600	
Floor Area/Floor (ft2)	40,600	-	40,600	
# of floors	6	-	6	
Floor to floor ht. (ft)	11.5	-	11.5	
Roof Insulation	R-20Ci	R-20Ci, U=0.048	R-25Ci	
Wall Description	Steel Framed		Steel Framed	
Wall Insulation	R-13+R-7.5Ci	R-13+R-7.5Ci, U=0.064	R-13+R-10Ci	
WtW Ratio	40%	40%	60%	
Window Descr.	Operable	-	Operable	
Window Assembly Uvalue	0.55	0.55	0.4	
Window SHGC	0.4	0.4	0.23	
Exterior shading	None	None	None	
Lighting Int. LPD	0.5	0.6, multifamily, Table 9.5.1	0.5	
Lighting/Daylighting	None	None	None	
Lighting/OccSens	None	None	None	
Plug Loads	-	-	"Reduction due to energy efficient appliances"	Not included in analysis. Not allowed for credit in 90.1-2010.
HVAC System	Packaged Terminal Heat Pump, varying sizes	Min 11.9 EER, as of 6/1/2011, Table 6.8.1A,	Air Cooled VRF, DOAS w/heat recovery, varying sizes	Sized in accordance with ASHRAE 90.1-2010, Section 6.4.2.1.
DHW	-	80% eff, Table 7.8 Perf. Requirements for Water Heating Equipment	Load Reduction due to low flow fixtures and energy efficient appliances	Not included in analysis. Not allowed for credit in 90.1-2010.

Table 1.3. Analysis of ASHRAE Standard 90.1 Code Compliance (Retail)

RETAIL

Proj.	**Market Square Ohio**			
#	0419171/0419253			
Code	90.1-2010 as path through 2012 IECC			
CZ	5A			
	Usage		**Retail**	
	Area	sf	55,000	
	# of Floors	Qty	2	
	Floor To Floor Height	ft	varies	
	Parameter	Units	**Baseline**	**Proposed Design**
	File name root			
Envelope				
	Office Tower Floor		1st: 12" Conc, 3" Insul, 3" Topping	1st: 12" Conc, 3" Insul, 3" Topping
	Residential Tower Floors		1st: 12" Conc, 3" Insul, 3" Topping 2nd:" 9" Concrete	1st: 12" Conc, 3" Insul, 3" Topping 2nd:" 9" Concrete
	Roof Description		Insulation Entirely Above Deck	Insulation Entirely Above Deck
	Roof Insulation	hr-sf-F/Btu	R-20ci	R-30ci
	Wall Description		Steel framed	Steel framed
	Wall Insulation	hr-sf-F/Btu	R-13 + R-7.5ci	'Walls' are insulated spandrel sections of the window wall system with batt in cavity.
	Window to Wall Ratio	%	40%	80%
	Window Description		Fixed	Fixed
	Window COG U	Btu/hr-sf-F	N/A	0.24
	Window Assembly U	Btu/hr-sf-F	0.45	0.36
	Window SHGC	Unitless	0.4	0.24
	Window VLT	%	N/A	41%
	Exterior Shading		None	From Terraces
	Terrace Floors		Thermally Separated	Thermally Separated
	Skylights		None	None
	Usage		**Retail**	
Lighting				
	Interior LPD	W/sf	1.68	1.22
	Daylighting		Proposed = Code	
	Vac / Occ Sensor		Proposed = Code	
Plug Loads			Proposed = Code	
HVAC				
	Space distribution		Air Source Heat Pump	Air Source Heat Pump
	Cooling Efficiency		13 SEER	19 SEER
	Heating Efficiency		7.7 HPSF	8.2 HPSF
	Economizer		None while units less than 54 kBtu/hr	None
	Heat Recovery		None Required	Sensible Flat Plate
	Central Heating Plant		N/A	N/A
	Central Cooling Plant		N/A	N/A
DHW			Electric Point of Use	Electric Point of Use

TASK 1.3. Analysis of the simulated electricity and natural gas savings from the Office/Retail, Apartment and buildings at Market Square, including calculation of key whole-building energy use metrics for the project.

In this task an analysis of the simulated electricity and natural gas savings from the Office and Apartment buildings at the proposed Market Square project was undertaken to determine if the proposed energy savings for the Office and Apartment buildings could be confirmed.

To accomplish this task the following sub-tasks were taken:

- Confirm that the EQUEST simulation files provided by Dunham Engineering match the energy savings provided in the document "The Energy Modeling of Market Square re: OAQDA Application" for the base case and proposed buildings.

- Isolate and re-simulate the individual savings results by subtracting individual savings measures from the total proposed simulation input files for the Office and Apartment buildings.

- Assemble the individual measures into a summary simulation input file that confirms that the total simulated measures are within ±10% of the base-case simulations

- Extract the key whole-building energy use metrics for each simulation.

- Evaluate the end-use changes in energy use for the Proposed vs Base Line simulations of the Office and Apartment buildings.

Results of these sub-tasks can be seen in Table 1.4 - Analysis of simulated electricity and natural gas savings from the Proposed Office and Apartment buildings at Market Square.

TASK 1.3.1. Confirm that the EQUEST simulation files provided by Dunham Engineering match the energy savings provided in the document "The Energy Modeling of Market Square re: OAQDA Application" for the base case and proposed buildings.

In this task of the analysis the groups of input/output files received from Dunham Engineering were loaded into the EQUEST program and individually re-simulated with the Cleveland, OH TMY2 weather file as shown Table 1.4 in the first eight rows of the table labeled "OFF BASE – Dunham" – through "APT PROP – Rerun Files".

In Sub-task 1.3.1 the EQUEST simulation .INP input files for the base-case simulations (i.e., OFF BASE, APART BASE and RETAIL BASE) and proposed simulations (i.e., OFF BASE, OFF PROP RETAIL BASE) of the Office, Apartment and Retail building were re-simulated using EQUEST Version 3.65 to confirm that the results of the simulations from the input files received by Dunham Engineering matched with the EQUEST simulation .SIM output files.

The results of the analysis showed that the six .INP input files generated six .SIM output files that exactly matched the .SIM files received from Dunham Engineering (See Table 1.3 or the extracted portion of Table 1.3 above). This sub-task was a necessary step to accomplish before any editing of the input files was undertaken.

TASK: 1.3.2. Isolate and re-simulate the individual savings results by subtracting individual savings measures from the total proposed simulation input files for the Office/Retail and Apartment buildings.

In this sub-task individual Energy Conservation Design Measures (ECDMs) were determined, from those that were listed in the Dunham Engineering report *"The Energy Modeling of Market Square re: OAQDA Application",* or by inspection of the EQUEST .INP input file. These individual ECDMs were then entered into the EQUEST .INP input file and the simulation re-run to determine the impact of the individual measure.

The results can be seen in Table 1.4 in the groups of runs labeled "APT PROP + …" and "OFF PROP + …"

The individual measures evaluated for the Proposed Apartment building included:

- APT PROP + window U 0.4 to 0.55, SC 0.26 to 0.46. This measure involved changing the Uvalue of the windows from 0.4 (proposed) to 0.55 (base case) and changing the Shading Coefficient (SC) from 0.26 (proposed) to 0.46 (base case). The impact of changing these simulation inputs raised the total annual site energy use from 6,762 MMBtu per year to 7,032 MMBtu per year.
- APT PROP + exhaust recovery. This measure removed the exhaust heat recovery from the simulation. The impact of removing the heat recovery raised the total annual site energy use from 6,762 MMBtu per year to 8,787 MMBtu per year.
- APT PROP + EIR Heat 0.217 to 0.37 Cool 0.233 same. This measure reduced the efficiency of the heating equipment from an Energy Input Ratio of 0.217 to 0.37 (which was used in the base-case), with the cooling equipment EIR remaining the same. The impact of this measure raised the total annual site energy use from 6,762 MMBtu per year to 7,328 MMBtu per year.

The individual measures evaluated for the Office portion of the proposed Office/Retail building included:

- OFF PROP + Chiller EIR 0.126 to 0.370. This measure represents changing the chiller efficiency in the simulation from an EIR of 0.126 to an EIR of 0.370. The impact of this measure raised the total annual site energy use from 6,804.5 MMBtu per year to 7,542.5 MMBtu per year.
- OFF PROP + Boiler HIR 1.064 to 1.25.This measure represents changing the boiler HIR efficiency from 1.064 to and HIR of 1.25. The impact of this measure raised the total annual site energy use from 6,804.5 MMBtu per year to 7,385.2 MMBtu per year.
- OFF PROP + lighting 0.34 to 0.9 w/ft2. This measure represents changing the lighting energy use from an efficient 0.34 Watts/ft2 to a less efficient 0.90 Watts/ft2. The impact of this measure raised the total annual site energy use from 6,804.5 MMBtu per year to 7,671.0 MMBtu per year.
- OFF PROP + window U 0.36 to 0.45 + SHGC 0.23 to 0.40. This measure represents changing the window Uvalue from 0.36 to 0.45 and changing the SHGC from 0.23 to 0.40. The impact of this measure raised the total annual site energy use from 6,804.5 MMBtu per year to 7,619.0 MMBtu per year.
- OFF PROP + exhaust heat recovery. This measure represents disabling the exhaust heat recovery in the simulation. The impact of this measure raised the total annual site energy use from 6,804.5 MMBtu per year to 7,472 MMBtu per year.
- OFF PROP + shade. This measure represents the removal of the external shading in the simulation of the proposed building. The impact of this measure raised the total annual site energy use from 6,804.5 MMBtu per year to 6,815.8 MMBtu per year.

The individual measures evaluated for the proposed Retail portion of the Office building included:

- RETAIL PROP + H EIR 0.2612 to 0.2741 C EIR 0.1589 to 0.2507. This measure represents changing the boiler efficiency and chiller efficiency. The impact of this measure raised the total annual site energy use from 2,156.0 MMBtu per year to 2,272.8 MMBtu per year.
- RETAIL PROP + lighting 1.22 to 1.68.This measure represents changing the lighting energy use from an efficient 1.22 Watts/ft2 to a less efficient 1.68 Watts/ft2. The impact of this measure raised the total annual site energy use from 2,156.0 MMBtu per year to 2,410.0 MMBtu per year.
- RETAIL PROP + window U-0.347 to 0.52 SC 0.28 to 0.46. This measure represents changing the window Uvalue from 0.52 to 0.347 and changing the SHGC from 0.46 to 0.28. The impact of this measure raised the total annual site energy use from 2,156.0 MMBtu per year to 2,277.0 MMBtu per year.
- RETAIL PROP + ERV. This measure represents disabling the exhaust heat recovery in the simulation. The impact of this measure raised the total annual site energy use from 2,156.0 MMBtu per year to 2,651.7 MMBtu per year.

TASK 1.3.3. Assemble the individual measures into a summary simulation input file that confirms that the total simulated measures are within +10% of the base-case simulations.

The combined measures evaluated for the Proposed Apartment building included:

- APT PROP + Win + exh + H EIR *FINAL*. This measure represents the combined change to the windows + the change to the exhaust recovery + the change to the heating system efficiency. It was the final simulation used to verify the proposed Apartment building. The impact of these combined measures raised the total annual site energy use from 6,762 MMBtu per year to 10,569 MMBtu per year, which is within 90% of the energy efficient design measures claimed in the Dunham Engineering document.

The combined measures evaluated for the Office portion of the proposed Office/Retail building included:

- OFF PROP + chill+boil+light+win+ERV+shade *FINAL*. This measure represents the combined change to the chiller + boiler + lighting + windows + exhaust + shading. It was the final simulation used to verify the proposed Office building. The impact of these combined measures raised the total annual site energy use from 6,804.5 MMBtu per year to 10,962 MMBtu per year, which is within 90% of the energy efficient design measures claimed in the Dunham Engineering document.

The combined measures evaluated for the Retail portion of the propose Office/Retail building included:

- RETAIL PROP +chill +boil +light +win +ERV *FINAL*. This measure represents the combined change to the chiller + boiler + lighting + windows + ERV. It was the final simulation used to verify the proposed Retail building. The impact of these combined measures raised the total annual site energy use from 2,156.0 MMBtu per year to 3,065.6 MMBtu per year, which is within 90% of the energy efficient design measures claimed in the Dunham Engineering document.

Table 1.4: Analysis of simulated electricity and natural gas savings from the Proposed Office/Retail and Apartment buildings at Market Square.

	BEPS (category - MMBtu/yr)															
	1	2	3	4	5	6	7	8	9	10	11	12		EUI (Site)	EUI (Source)	Percent
Whole-building Energy Simulation Run:	LIGHTS	TASK	MISC	S.HEAT	S.COOL	REJ.HEAT	PUMPS	VENT	REF	HT.PUMP	DHW	EXT	TOTAL	Use (BEPS)	Use (BEPS)	%
		LIGHTS	EQUIP	HEAT	COOL	REJECT	& AUX	FANS	DISP	SUPPLE	USAGE	USAGE	(MMBtu/yr)	Btu/ft2-yr	Btu/ft2-yr	
RETAIL BASE - Dunham	1098.0	0.0	163.4	941.2	384.8	0.0	9.7	112.2	0.0	355.9	21.2	0.0	3086.2	56,300	169,000	
RETAIL PROP - Dunham	793.3	0.0	163.4	559.6	170.2	0.0	9.5	149.9	0.0	285.8	21.2	0.0	2156.0	39,400	118,100	
RETAIL BASE - Rerun files	1098.0	0.0	163.4	941.2	384.8	0.0	9.7	112.2	0.0	355.9	21.2	0.0	3086.2	56,300	169,000	
RETAIL PROP - Rerun files	793.3	0.0	163.4	559.6	170.2	0.0	9.5	149.9	0.0	285.8	21.2	0.0	2156.0	39,400	118,100	*30.1%*
OFF BASE - Dunham	1,739.0	0.0	1,306.0	7,014.0	1,097.0	0.0	77.8	558.6	0.0	0.0	374.4	2.2	12,169.0	50,700	90,600	
OFF PROP - Dunham	616.7	0.0	1,306.0	3,271.0	347.8	0.0	450.3	436.1	0.0	0.0	374.4	2.2	6,804.5	28,400	55,000	
OFF BASE - Rerun files	1,730.0	0.0	1,306.0	7,014.0	1,097.0	0.0	77.8	558.6	0.0	0.0	374.4	2.2	12,169.0	50,700	90,600	
OFF PROP - Rerun files	616.7	0.0	1,306.0	3,271.0	347.8	0.0	450.3	436.1	0.0	0.0	373.7	2.2	6,803.8	28,400	55,000	44.1%
APT BASE - Dunham	905.0	0.0	2,364.0	2,040.0	853.7	0.0	15.9	759.8	0.0	2,665.0	1,419.0	1.9	11,024.0	42,100	115,400	
APT PROP - Dunham	905.0	0.0	2,189.0	925.7	429.7	0.0	76.7	619.0	0.0	338.3	1,277.0	1.9	6,762.0	25,800	67,700	
APT BASE - Rerun files	905.0	0.0	2,364.0	2,040.0	853.7	0.0	15.9	759.8	0.0	2,665.0	1,419.0	1.9	11,024.0	42,100	115,400	
APT PROP - Rerun files	905.0	0.0	2,189.0	925.7	429.7	0.0	76.7	619.0	0.0	338.3	1,277.0	1.9	6,762.0	25,800	67,700	38.7%
RETAIL PROP + H EIR 0.261 to 0.274 C EIR 0.158 to 0.250	797.3	0.0	163.4	671.6	268.4	0.0	9.8	149.9	0.0	191.2	21.2	0.0	2272.8	41,500	124,400	
RETAIL PROP + lighting 1.22 to 1.68	1098.2	0.0	163.4	571.2	190.4	0.0	10.1	148.7	0.0	261.2	21.2	0.0	2410.0	44,000	132,000	
RETAIL PROP + window U-0.347 to 0.52 SC 0.28 to 0.46	797.3	0.0	163.4	621.8	229.0	0.0	9.5	181.2	0.0	254.4	21.2	0.0	2277.7	41,600	124,700	
RETAIL PROP + ERV	797.3	0.0	163.4	696.4	166.7	0.0	9.3	86.2	0.0	711.2	21.2	0.0	2651.7	48,400	145,200	
RETAIL PROP + EIR + lighting + window + ERV *FINAL*	1098.0	0.0	163.4	929.2	384.8	0.0	9.8	111.3	0.0	348.0	21.2	0.0	3065.6	56,000	167,900	
APT PROP + window U 0.4 to .55, SC .26 to .46	905.0	0.0	2,189.0	1,008.0	582.7	0.0	76.8	633.1	0.0	360.3	1,276.0	1.9	7,032.0	26,800	70,800	
APT PROP + exhaust heat recovery	905.0	0.0	2,189.0	1,635.0	440.1	0.0	18.0	441.0	0.0	1,881.0	1,277.0	1.9	8,787.4	33,500	90,800	
APT PROP + EIR Heat 0.217 to 0.37 Cool 0.233 same	905.0	0.0	2,189.0	1,312.0	429.0	0.0	75.3	622.9	0.0	516.5	1,277.0	1.9	7,328.6	28,000	74,100	
APT PROP + Win + exh + H EIR *FINAL*	905.0	0.0	2,189.0	2,157.0	593.0	0.0	16.7	459.6	0.0	2,970.0	1,276.0	1.9	10,569.0	40,300	111,200	
OFF PROP + Chiller EIR 0.126 to 0.370	616.7	0.0	1,306.0	3,271.0	1,003.0	15.1	519.3	436.1	0.0	0.0	373.7	2.2	7,542.5	31,400	64,000	
OFF PROP + Boiler HIR 1.064 to 1.25	616.7	0.0	1,306.0	3,840.0	347.8	0.0	450.3	436.1	0.0	0.0	373.7	2.2	7,385.2	30,800	57,300	
OFF PROP + lighting 0.34 to 0.9 w/ft2	1,586.0	0.0	1,306.0	3,073.0	389.2	13.9	453.9	473.0	0.0	0.0	373.5	2.2	7,671.0	32,000	67,300	
OFF PROP + window U 0.36 to 0.45 + SHGC 0.23 to 0.40	616.7	0.0	1,306.0	3,737.0	447.5	16.8	568.2	551.8	0.0	0.0	373.6	2.2	7,619.0	31,700	61,100	
OFF PROP + ERV	616.7	0.0	1,306.0	3,963.0	354.0	12.9	424.5	418.8	0.0	0.0	373.7	2.2	7,472.5	31,100	57,400	
OFF PROP + shade	616.7	0.0	1,306.0	3,271.0	347.8	12.4	450.3	436.1	0.0	0.0	373.7	2.2	6,815.8	28,400	55,000	
OFF PROP + chill+ boil+ light+ win+ ERV+ shade *FINAL*	1,580.0	0.0	1,306.0	4,987.0	1,465.0	23.3	640.8	584.3	0.0	0.0	373.4	2.2	10,962.0	45,700	92,500	

TASK 1.3.4. Extract the key whole-building energy use metrics for each simulation.

In this sub-task the key whole-building energy use metrics for each simulation were extracted from the EQUEST program using the BEPS output page (Table 1.5). In general, these whole-building energy use metrics have predictable relationship to the Total energy use, with the exception that the source EUIs have a higher value that accounts for the source energy consumed at the power plants to generate electricity.

For the Apartment building verification simulation the combined total energy use (10,569 MMBtu) had an Site EUI of 40,300 Btu/ft2-yr, which compares well with the Apartment base-case EUI of 42,100 Btu/ft2-yr reported in the Dunham Engineering report.

In the Office building verification simulation the combined total energy use (10,962 MMBtu) had a Site EUI of 45,700 Btu/ft2-yr, which compares well with the Office base-case EUI of 50,700 Btu/ft2-yr reported in the Dunham Engineering report. However, the EUI of the verification simulation (92,500 Btu/ft2-yr) was about 2% higher than the EUI of the base-case simulation reported by Dunham Engineering, which is most likely due to changes in the conditioned area associated with the removal of the building shading.

For the Retail building verification simulation the combined total energy use (3,056.6 MMBtu) had a Site EUI of 56,000 Btu/ft2-yr, which compares well with the Retail base-case EUI of 56,300 Btu/ft2-yr reported in the Dunham Engineering report.

The proposed Market Square project significantly reduced the EUIs for the Office, Apartment and Retail as shown below (Appendix E).

Comparison of EUIs	
	EUI (Site) (Btu/ft2-yr)
RETAIL EPA Port/Man (CBECS enc. mall)	65,700
RETAIL BASE - Dunham	56,300
RETAIL PROP - Dunham	39,400
Difference (Dunham Base-Prop/base)	*30%*
Difference (EPA-Prop/EPA)	*40%*
OFFICE EPA Port/Man (CBECS Off)	52,900
OFF BASE - Dunham	50,700
OFF PROP - Dunham	28,400
Difference (Dunham Base-Prop/base)	*44%*
Difference (EPA-Prop/EPA)	*46%*
APT EPA Port/Man (CBECS enc. mall)	59,600
APT BASE - Dunham	42,100
APT PROP - Dunham	25,800
Difference (Dunham Base-Prop/base)	*39%*
Difference (EPA-Prop/EPA)	*57%*
SOURCE: US EPA Portfolio Manager, August 2018	

Table 1.5: Key whole-building Energy Use Metrics for Each Simulation.

Whole-building Energy Simulation Run:	TOTAL (MMBtu/yr)	EUI (Site) Use (BEPS) Btu/ft2-yr	EUI (Source) Use (BEPS) Btu/ft2-yr
RETAIL BASE - Dunham	**3086.2**	**56,300**	**169,000**
RETAIL PROP - Dunham	**2156.0**	**39,400**	**118,100**
RETAIL BASE - Rerun files	3086.2	56,300	169,000
RETAIL PROP - Rerun files	2156.0	39,400	118,100
OFF BASE - Dunham	**12,169.0**	**50,700**	**90,600**
OFF PROP - Dunham	**6,804.5**	**28,400**	**55,000**
OFF BASE - Rerun files	12,169.0	50,700	90,600
OFF PROP - Rerun files	6,803.8	28,400	55,000
APT BASE - Dunham	**11,024.0**	**42,100**	**115,400**
APT PROP - Dunham	**6,762.0**	**25,800**	**67,700**
APT BASE - Rerun files	11,024.0	42,100	115,400
APT PROP - Rerun files	6,762.0	25,800	67,700
RETAIL PROP + H EIR 0.261 to 0.274 C EIR 0.158 to 0.250	2272.8	41,500	124,400
RETAIL PROP + lighting 1.22 to 1.68	2410.0	44,000	132,000
RETAIL PROP + window U-0.347 to 0.52 SC 0.28 to 0.46	2277.7	41,600	124,700
RETAIL PROP + ERV	2651.7	48,400	145,200
RETAIL PROP + EIR + lighting + window + ERV *FINAL*	**3065.6**	**56,000**	**167,900**
APT PROP + window U 0.4 to .55, SC .26 to .46	7,032.0	26,800	70,800
APT PROP + exhaust heat recovery	8,787.4	33,500	90,800
APT PROP + EIR Heat 0.217 to 0.37 Cool 0.233 same	7,328.6	28,000	74,100
APT PROP + Win + exh + H EIR *FINAL*	**10,569.0**	**40,300**	**111,200**
OFF PROP + Chiller EIR 0.126 to 0.370	7,542.5	31,400	64,000
OFF PROP + Boiler HIR 1.064 to 1.25	7,385.2	30,800	57,300
OFF PROP + lighting 0.34 to 0.9 w/ft2	7,671.0	32,000	67,300
OFF PROP + window U 0.36 to 0.45 + SHGC 0.23 to 0.40	7,619.0	31,700	61,100
OFF PROP + ERV	7,472.5	31,100	57,400
OFF PROP + shade	6,815.8	28,400	55,000
OFF PROP + chill+ boil+ light+ win+ ERV+ shade *FINAL*	**10,962.0**	**45,700**	**92,500**

TASK 1.3.5. Evaluate the end-use changes in energy use for the Proposed vs Base Line simulations of the Office/Retail and Apartment buildings.

In this sub-task an analysis of the changes to the end-use energy use categories was performed as an additional cross-check to determine how the stated energy efficient design measures were providing the anticipated savings (Table 1.6).

In Table 1.6 the proposed simulation of the Office and Apartment buildings is compared for each end use using the ratio (BASE-PROP)/BASE. The analysis shows the following end-use changes:

Office portion of Office/Retail Building

- 65% reduction in the lighting energy end use.
- 53% reduction in the heating energy end use.
- 68% reduction in the cooling energy end use.
- 479% increase in the pumping and auxillary energy end use.
- 22% decrease in the vent and fan energy end use.
- 44% overall site energy use reduction.

Retail portion of Office/Retail building

- 28% reduction in the lighting energy end use.
- 41% reduction in the heating energy end use.
- 56% reduction in the cooling energy end use.
- 2% reduction in the pumping and auxillary energy end use.
- 34% increase in the vent and fan energy end use.
- 30% overall site energy use reduction.

Apartment Building

- 0% reduction in the lighting energy end use.
- 7% reduction misc. equipment energy end use.
- 55% reduction in the heating energy end use.
- 50% reduction in the cooling energy end use.
- 382% increase in the pumping and auxillary energy end use.
- 19% decrease in the vent and fan energy end use.
- 87% decrease in heat pump supplemental energy end use.
- 10% decrease in DHW energy end use.
- 39% overall site energy use reduction.

Tracking the changes to end-use energy throughout the process was a helpful tool in determining which inputs to change in the proposed simulation files to recreate the base case simulations.

Table 1.6 Changes to End-use energy use for the Proposed vs Base Case Simulations.

Change in BEPS (category - MMBtu/yr)															
Whole-building Energy Simulation Run	LIGHTS	TASK LIGHTS	MISC EQUIP	S.HEAT HEAT	S.COOL COOL	REJ.HEAT REJECT	PUMPS & AUX	VENT FANS	REF DISP	HT.PUMP SUPPLE	DHW USAGE	EXT USAGE	TOTAL (MMBtu/yr)
OFF BASE - Dunham	*1,739.0*	*0.0*	*1,306.0*	*7,014.0*	*1,097.0*	*0.0*	*77.8*	*558.6*	*0.0*	*0.0*	*374.4*	*2.2*	*12,169.0*
OFF PROP - Dunham	*616.7*	*0.0*	*1,306.0*	*3,271.0*	*347.8*	*0.0*	*450.3*	*436.1*	*0.0*	*0.0*	*374.4*	*2.2*	*6,804.5*
Percent reduction (BASE-PROP)/BASE	65%	0%	0%	53%	68%	0%	-479%	22%	0%	0%	0%	0%	44%
APT BASE - Dunham	*905.0*	*0.0*	*2,364.0*	*2,040.0*	*853.7*	*0.0*	*15.9*	*759.8*	*0.0*	*2,665.0*	*1,419.0*	*1.9*	*11,024.0*
APT PROP - Dunham	*905.0*	*0.0*	*2,189.0*	*925.7*	*429.7*	*0.0*	*76.7*	*619.0*	*0.0*	*338.3*	*1,277.0*	*1.9*	*6,762.0*
Percent reduction (BASE-PROP)/BASE	0%	0%	7%	55%	50%	0%	-382%	19%	0%	87%	10%	0%	39%
RETAIL BASE - Dunham	*1098.0*	*0.0*	*163.4*	*941.2*	*384.8*	*0.0*	*9.7*	*112.2*	*0.0*	*355.9*	*21.2*	*0.0*	*3086.2*
RETAIL PROP - Dunham	*793.3*	*0.0*	*163.4*	*559.6*	*170.2*	*0.0*	*9.5*	*149.9*	*0.0*	*285.8*	*21.2*	*0.0*	*2156.0*
Percent reduction (BASE-PROP)/BASE	28%	0%	0%	41%	56%	0%	2%	-34%	0%	20%	0%	0%	30%

TASK 1.4. Calculation of the savings from measures applied to the parking structure and area lighting.

The individual measures evaluated for the proposed Parking structure of the project and area lighting included:

Improved parking level lighting. This measure includes the savings from increasing the lighting efficiency of the parking structure from 0.25 W/ft2 to 0.15 W/ft2, which saves 135,403 kWh per year ($13,540).

Improved parking exhaust fans. This measure includes more efficient control of the exhaust fans in the parking garage, which maintain safe CO levels while reducing fan energy use. The measure was estimated to save 149,796 kWh per year ($14,980). This measure complies with Section 6.4.3.4.5, exception b of ASHRAE Standard 90.1-2010 (shown below):

> **6.4.3.4.5 Enclosed Parking Garage Ventilation.** Enclosed parking garage *ventilation systems* shall automatically detect contaminant levels and stage fans or modulate fan airflow rates to 50% or less of *design capacity* provided acceptable contaminant levels are maintained.
>
> **Exceptions:**
>
> a. Garages less than 30,000 ft^2 with *ventilation systems* that do not utilize *mechanical cooling* or *mechanical heating*
> b. Garages that have a garage area to *ventilation system motor nameplate hp* ratio that exceeds 1500 ft^2/hp and do not utilize *mechanical cooling* or *mechanical heating*.
> c. Where not permitted by the *authority having jurisdiction*.

Improved exterior lighting. This measure reduces the lighting energy use for the exterior lighting on the project, which saves 8,322 kWh/yr ($832). This measure is based on the use of energy efficient fixtures for the following (Source: Dunham Engineering):

- (20) pole lights x 40W = 800W
- (5) decorative suspended fixtures x 100W = 500W
- (50) landscape lights x 10W = 500W
- (75) decorative sconces x 30W = 2250W
- (50) downlights x 15W = 750W
- (40) bollard lights x 20W = 800W
- Total = 5,600W

The detailed calculations for these measures are included in Table 1.7 (Dunham Engineering).

Table 1.7 Estimated savings for parking lighting, ventilation and area lighting (Dunham Engineering).

Dunham/Windsor																					Conversion Factors				
Market Square																					Source	Blended Rate		EPA Portfolio Manager	2016 eGRID RFCW Electricity from
0419171-000-00																					Source	From prior modeling			https://www.epa.gov/energy/power-profiler
																						Annual Electric Cost	Unit Conversion	Site to Source Conversion	Nitrous Dioxide (NO_2) Emissions	Nitrous Oxide (NO_x) Emissions	Sulfur Dioxide (SO_2) Emissions	Carbon Dioxide (CO_2)Emissions	Greenhouse Gas (GHG) Emissions in CO_2 equivalent
																					Value	$0.10	3.412141286	2.8	0.019	0.945	1.199	1243.439	1251.472
																					Units	$/kWh	kBtu/kWh	kBtu/kBtu	lbs/MWh	lbs/MWh	lbs/MWh	lbs/MWh	lbs/MWh
Exterior Lighting											Electric Power Draw (kW)	Daily Hours of Operation (hrs/day)	Annual Hours of Operation (hrs/yr)	Annual Electric Consumption (kWh)	Annual Electricity Cost ($)	Site Energy (millions of Btus)	Source Energy (millions of Btus)	Annual Nitrous Dioxide (NO_2) Emissions (lbs)	Annual Nitrous Oxide (NO_x) Emissions (lbs)	Annual Sulfur Dioxide (SO_2) Emissions (lbs)	Annual CO2 Emissions (lbs)	Annual GHG CO_{2eq} Emissions (lbs)
	Baseline										7.5	12	4,380	32,850	$3,285	112.1	313.8	0.6	31.0	39.4	40,847	41,111
	Proposed										5.6	12	4,380	24,528	$2,453	83.7	234.3	0.5	23.2	29.4	30,499	30,696
	Savings										1.9			8,322	$832	28.4	79.5	0.2	7.9	10.0	10,348	10,415
Parking Level Lighting											Parking Level (sf)	Lighting Power Density (W/sf)	Electric Power Draw (kW)	Full Load Equivalent Daily Hours of Operation (hrs/day)	Annual Hours of Operation (hrs/yr)	Annual Electric Consumption (kWh)	Annual Electricity Cost ($)	Site Energy (millions of Btus)	Source Energy (millions of Btus)	Annual Nitrous Dioxide (NO_2) Emissions (lbs)	Annual Nitrous Oxide (NO_x) Emissions (lbs)	Annual Sulfur Dioxide (SO_2) Emissions (lbs)	Annual CO2 Emissions (lbs)	Annual GHG CO_{2eq} Emissions (lbs)
	Baseline										237,800	0.25	59	15.6	5,694	338,508	$33,851	1155.0	3234.1	6.4	319.9	405.9	420,914	423,634
	Proposed										237,800	0.15	36	15.6	5,694	203,105	$20,310	693.0	1940.5	3.9	191.9	243.5	252,549	254,180
	Savings												23.78			135,403	$13,540	462.0	1293.6	2.6	128.0	162.3	168,366	169,453
Parking Garage Exhaust Fans											Parking Area (SF)	Exhaust Fan Airflow (CFM)	Exhaust Fan (BHP)	Exhaust Fan Motor (HP)	SF/Motor HP	Exhaust Fan Motor Efficiency (%)	Electric Power Draw (kW)	kW/CFM	Full Load Equivalent Daily Hours of Operation (hrs/day)	Annual Hours of Operation (hrs/yr)	Annual Electric Consumption (kWh)	Annual Electricity Cost ($)	Site Energy (millions of Btus)	Source Energy (millions of Btus)	Annual Nitrous Dioxide (NO_2) Emissions (lbs)	Annual Nitrous Oxide (NO_x) Emissions (lbs)	Annual Sulfur Dioxide (SO_2) Emissions (lbs)	Annual CO2 Emissions (lbs)	Annual GHG CO_{2eq} Emissions (lbs)
	Baseline 0.75 CFM/SF Fans										234,000	11,700	2	2	7,313	88.50%	1.5	0.0001	24	8,760	13,140	$1,314	44.8	125.5	0.2	12.4	15.8	16,339	16,444
	Baseline 0.05 CFM/SF Fans										234,000	175,500	27	30		88.50%	22.8	0.0001	24	8,760	199,728	$19,973	681.5	1908.2	3.8	188.7	239.5	248,350	249,954
	Proposed 0.75 CFM/SF Fans										234,000	11,700	2	2	7,313	88.50%	1.5	0.0001	24	8,760	13,140	$1,314	44.8	125.5	0.2	12.4	15.8	16,339	16,444
	Proposed 0.05 CFM/SF Fans										234,000	175,500	27	30		88.50%	22.8	0.0001	6	2,190	49,932	$4,993	170.4	477.1	0.9	47.2	59.9	62,087	62,488
	Savings																				149,796	$14,980	511.1	1431.2	2.8	141.6	179.6	186,262	187,465
Sheet Total Savings																					Annual Electric Consumption (kWh)	Annual Electricity Cost ($)	Site Energy (millions of Btus)	Source Energy (millions of Btus)	Annual Nitrous Dioxide (NO_2) Emissions (lbs)	Annual Nitrous Oxide (NO_x) Emissions (lbs)	Annual Sulfur Dioxide (SO_2) Emissions (lbs)	Annual CO2 Emissions (lbs)	Annual GHG CO_{2eq} Emissions (lbs)
	Baseline																				584,226	58,423	1,993	5,582	11	552	700	726,450	731,143
	Proposed																				290,705	29,070	992	2,777	6	275	349	361,474	363,809
	Savings																				293,521	$29,352	1001.5	2804.3	5.6	277.4	351.9	364,976	367,334

TASK 1.5. Calculation of the 40 to 60 kW PV installation.

In this sub-task the potential electric power generation from the proposed 40 to 60 kW PV installation was calculated using the PVWatt Calculator provided by the National Renewable Energy Laboratory – NREL in Golden, Colorado (https://pvwatts.nrel.gov/ NREL).

Figure 1.1 below shows a rendering of the Market Square project that shows the proposed location of the PV panels. In Appendix D, Figure D.1 and Figure D.2 provide screen shots of the PVWatt calculator.

The analysis shows that the calculated electricity production for the 40 kW system would be 51,759 kWh/yr and 77,639 kWh/yr for the 60 kW system with the highest electricity production in the summer months.

Calculation of energy reductions from the installation of photovoltaic panels was not included in this Task 1 report.

Figure 1.1: Image of the proposed Market Square project showing the possible photovoltaic (PV) panel installation.

TASK 1.6. Total project savings: Office, Retail, Apartment, Parking and Area Lighting and 40 to 60 kW PV installation

The total project savings for the Market Square project are shown in Table 1.8. This table is divided into the savings estimates for the:

- Office portion of the Office building,
- Apartment building,
- Retail portion that reside below the Office and Apartment buildings,
- Energy efficient lighting in the parking garage,
- Energy efficient ventilation in the parking garage, and
- General area lighting savings.

Total project savings (i.e., Office + Apartment + Retail + Parking-lighting + Parking-ventilation + Area-lighting) are listed at the bottom of the table.

For each category listed columns are provided for:

- the Basecase design energy use,
- the Proposed design energy use,
- the Energy Savings (i.e., basecase – proposed),
- grid factor (electric or natural gas),
- total site energy savings, and
- total cost savings (using $0.134/kWh and $0.83/therm, site conversion).

The emissions reduction for NOx, SO2 and CO2 are provided in the remaining three columns on the right side of the table for:

- NOX - Electric conversion: 0.9 lb/MWh, Natural Gas conversion: 2.2 lbs/scf*10^6
- SO2 - Electric conversion: 1.2 lb/MWh, Natural Gas conversion: 0.6 lb/scf*10^6
- CO2 – Electric conversion: 1,243.4 lb/MWh, Natural Gas conv: 120,000 lb/scf*10^6

The results show annual savings of:

- Total electricity savings of 2,353.3 MWh (includes grid losses = 4.9%),
- Total natural gas savings of 4,084.5 MMBtu (includes pipeline losses = 5%),
- Total electricity cost savings of $300,606,
- Total natural gas savings of $32,287.

As well as emissions reduction of:

- Total NOx reductions of 2,127 lbs (electric + natural gas),
- Total SO2 reductions of 2,826 lbs (electric + natural gas),
- Total CO2 reductions of 3,399,140 lbs (electric + natural gas).

These savings represent the calculated annual energy savings and resultant annual emissions reduction, which do not include savings associated with the embodied energy use. Savings also do not include electricity production from on-site renewable energy systems (i.e., photovoltaic).

These savings are based on the following:

Emissions: NOx: Ele: 0.9 lb/MWh, NG: 2.2 lb/scf*10^6; SO2: Ele: 1.2 lb/MWh, NG: 0.6 lb/scf*10^6;
CO2: Ele: 1,243.4 lb/MWh, NG: 120,000 lb/scf*10^6
Grid loss for electricity from EGRID, 2016, RFCW region = 1.049
Grid loss for natural gas from R.Webb, University Texas, April 2015 study = 1.05
1 therm = 100,000 Btu = 96,525, 1 cf = 1,036 Btu
Savings from the use of timber included in EQUEST simulation (base case vs proposed, material prop)
Savings from the proposed PV shown in the Market Square rendering are not included.
1 kWh = 3,412.14 Btu
$0.134/kWh from BLS 1-23-2018 report
$0.83/therm from BSL 1-23-2018 report
N0x, SO2, CO2 values from 2016 EGRID, RFCW region

NOTE: Differences in the numbers above (from Table 1.8) and the Summary Table provided in the Executive Summary are due to rounding.

Table 1.8 Total Project Savings: Office, Retail, Apartment, Parking and Area lighting.

ESTIMATED ENERGY SAVINGS FOR MARKET SQUARE PROJECT						
	Simulated Market Sq. Basecase Usage (site)	Simulated Market Sq. Proposed Usage (site)	Simulated Market Sq. Savings (site)	Grid loss factor (grid)	Energy Savings (site+grid)	Energy Cost Savings (site)
						Ele. ($/kWh)=
						N.G.($/therm)=
OFFICE						
Electricity (MWh)	1,404.6	934.3	470.3	1.049	493.3	$ 63,019
Electricity (MMBtu)	4,793.7	3,188.6	1,605.1	1.049	1,683.7	
N.Gas (Therm)	73,752.0	36,272.0	37,480.0	1.050	39,354.0	$ 31,108
N.Gas (MMBtu)	7,375.2	3,627.2	3,748.0	1.050	3,935.4	
N.Gas (million CF)	7.1	3.5	3.6	1.050	3.8	
APARTMENT						
Electricity (MWh)	2,814.3	1,607.2	1,207.1	1.049	1,266.3	$ 161,754
Electricity (MMBtu)	9,605.2	5,485.3	4,119.9	1.049	4,321.8	
N.Gas (Therm)	14,186.0	12,766.0	1,420.0	1.050	1,491.0	$ 1,179
N.Gas (MMBtu)	1,418.6	1,276.6	142.0	1.050	149.1	
N.Gas (million CF)	1.4	1.2	0.1	1.050	0.1	
RETAIL						
Electricity (MWh)	904.3	631.9	272.4	1.049	285.7	$ 36,502
Electricity (MMBtu)	3,086.2	2,156.9	929.3	1.049	974.8	
N.Gas (Therm)	-	0.0	(0.0)	1.050	(0.0)	$ (0)
N.Gas (MMBtu)	-	0.0	(0.0)	1.050	(0.0)	
N.Gas (million CF)	-	0.0	(0.0)	1.050	(0.0)	
PARKING, lighting						
Electricity (MWh)	338.5	203.1	135.4	1.049	142.0	$ 18,144
Electricity (MMBtu)	1,155.0	693.0	462.0	1.049	484.6	
PARKING, ventilation						
Electricity (MWh)	212.9	63.1	149.8	1.049	157.1	$ 20,073
Electricity (MMBtu)	726.3	215.2	511.1	1.049	536.2	
AREA lighting						
Electricity (MWh)	32.9	24.5	8.3	1.049	8.7	$ 1,115
Electricity (MMBtu)	112.1	83.7	28.4	1.049	29.8	
TOTAL						
Electricity (MWh)	5,707.4	3,464.1	2,243.3	1.049	2,353.3	$ 300,606
Electricity (MMBtu)	19,478.6	11,822.7	7,655.8	1.049	8,031.0	
N.Gas (Therm)	87,938.0	49,038.0	38,900.0	1.050	40,845.0	$ 32,287.0
N.Gas (MMBtu)	8,793.8	4,903.8	3,890.0	1.050	4,084.5	
N.Gas (million CF)	8.5	4.7	3.8	1.050	3.9	
TOTAL (MMBtu)						
TOTAL Electricity (MMBtu)	19,478.6	11,822.7	7,655.8			
TOTAL Electricity (MMBtu+grid)	20,433.0	12,402.0	8,031.0	1.049	8,031.0	
TOTAL Nat. Gas (MMBtu)	8,793.8	4,903.8	3,890.0			
TOTAL Nat. Gas (MMBtu+loss)	9,233.5	5,149.0	4,084.5	1.050	4,084.5	
TOTAL - Ele + NG (MMBtu)	28,272.4	16,726.5	11,545.8			
TOTAL - Ele + NG (MMBtu+grid+loss)	29,666.5	17,551.0	12,115.5		12,115.5	
TOTAL - Ele + NG ($)						$ 332,893
NOTE:	Emissions: NOx: Ele: 0.9 lb/MWh, NG: 2.2 lb/scf*10^6; SO2: Ele: 1.2 lb/MWh, NG: 0.6 lb/scf*10^6;					
	CO2: Ele: 1,243.4 lb/MWh, NG: 120,000 lb/scf*10^6					
	Grid loss for electricity from EGRID, 2016, RFCW region = 1.049					
	Grid loss for natural gas from R.Webb, University Texas, April 2015 study = 1.05					
	1 therm = 100,000 Btu = 96,525, 1 cf = 1,036 Btu					
	Savings from the use of timber included in EQUEST simulation (base case vs proposed, material prop)					
	Savings from the proposed PV shown in the Market Square rendering are not included.					
	1 kWh = 3,412.14 Btu					
	$0.134/kWh from BLS 1-23-2018 report					
	$0.83/therm from BSL 1-23-2018 report					
	N0x, SO2, CO2 values from 2016 EGRID, RFCW region					

Table 1.8 Total Project Savings: Office, Retail, Apartment, Parking and Area lighting (cont).

ESTIMATED EMISSIONS REDUCTION FOR MARKET SQUARE PROJECT									
				Emissions Reduction: NOx		Emissions Reduction: SO2		Emissions Reduction: CO2	
	Electric	*$*	*0.134*	*0.9*		*1.2*		*1,243*	
	N.G.	*$*	*0.830*	*2.2*		*0.6*		*120,000*	
OFFICE									
Electricity (MWh)		Electricity (lbs)		444	lbs	592	lbs	613,413	lbs
Electricity (MMBtu)									
N.Gas (Therm)									
N.Gas (MMBtu)									
N.Gas (million CF)		N.Gas (lbs)		8.4	lbs	2.3	lbs	455,838	lbs
APARTMENT									
Electricity (MWh)		Electricity (lbs)		1140	lbs	1520	lbs	1,574,477	lbs
Electricity (MMBtu)									
N.Gas (Therm)									
N.Gas (MMBtu)									
N.Gas (million CF)		N.Gas (lbs)		0.3	lbs	0.1	lbs	17,270	lbs
RETAIL									
Electricity (MWh)		Electricity (lbs)		257	lbs	343	lbs	355,299	lbs
Electricity (MMBtu)									
N.Gas (Therm)									
N.Gas (MMBtu)									
N.Gas (million CF)		N.Gas (lbs)		0.0	lbs	0.0	lbs	(0)	lbs
PARKING, lighting									
Electricity (MWh)		Electricity (lbs)		128	lbs	170	lbs	176,606	lbs
Electricity (MMBtu)									
PARKING, ventilation									
Electricity (MWh)		Electricity (lbs)		141	lbs	189	lbs	195,383	lbs
Electricity (MMBtu)									
AREA lighting									
Electricity (MWh)		Electricity (lbs)		8	lbs	10	lbs	10,855	lbs
Electricity (MMBtu)									
TOTAL									
Electricity (MWh)		Electricity (MWh)		2,118	lbs	2,824	lbs	2,926,032	lbs
Electricity (MMBtu)									
N.Gas (Therm)									
N.Gas (MMBtu)									
N.Gas (million CF)		N.Gas (lbs)		9	lbs	2	lbs	473,108	lbs
TOTAL (MMBtu)									
	TOTAL	Elec + N.G.		2,127	lbs	2,826	lbs	3,399,140	lbs

Table 1.8 Total Project Savings: Office, Retail, Apartment, Parking and Area lighting (cont).

ESTIMATED EMISSIONS FOR MARKET SQUARE PROJECT (BASELINE)								
			Emissions Reduction: NOx		Emissions Reduction: SO2		Emissions Reduction: CO2	
	Electric	*$ 0.134*	*0.9*		*1.2*		*1,243*	
	N.G.	*$ 0.830*	*2.2*		*0.6*		*120,000*	
OFFICE								
Electricity (MWh)		Electricity (lbs)	1,326	lbs	1,768	lbs	1,832,006	lbs
Electricity (MMBtu)								
N.Gas (Therm)								
N.Gas (MMBtu)								
N.Gas (million CF)		N.Gas (lbs)	16	lbs	2	lbs	896,984	lbs
APARTMENT								
Electricity (MWh)		Electricity (lbs)	2,657	lbs	3,543	lbs	3,670,790	lbs
Electricity (MMBtu)								
N.Gas (Therm)								
N.Gas (MMBtu)								
N.Gas (million CF)		N.Gas (lbs)	3	lbs	1	lbs	172,532	lbs
RETAIL								
Electricity (MWh)		Electricity (lbs)	854	lbs	1,138	lbs	1,179,503	lbs
Electricity (MMBtu)								
N.Gas (Therm)								
N.Gas (MMBtu)								
N.Gas (million CF)		N.Gas (lbs)	-	lbs	-	lbs	-	lbs
PARKING, lighting								
Electricity (MWh)		Electricity (lbs)	320	lbs	426	lbs	441,521	lbs
Electricity (MMBtu)								
PARKING, ventilation								
Electricity (MWh)		Electricity (lbs)	201	lbs	268	lbs	277,649	lbs
Electricity (MMBtu)								
AREA lighting								
Electricity (MWh)		Electricity (lbs)	31	lbs	41	lbs	42,847	lbs
Electricity (MMBtu)								
TOTAL								
Electricity (MWh)	TOTAL	Electricity	5,388	lbs	7,184	lbs	7,444,316	lbs
Electricity (MMBtu)								
N.Gas (Therm)								
N.Gas (MMBtu)								
N.Gas (million CF)	TOTAL	N.Gas	20	lbs	3	lbs	1,069,516	lbs
TOTAL (MMBtu)								
	TOTAL	Elec + N.G.	5,408	lbs	7,188	lbs	8,513,832	lbs

Table 1.8 Total Project Savings: Office, Retail, Apartment, Parking and Area lighting (cont).

ESTIMATED EMISSIONS FOR MARKET SQUARE PROJECT (PROPOSED)								
			Emissions Reduction: NOx		Emissions Reduction: SO2		Emissions Reduction: CO2	
	Electric	*$ 0.134*	*0.9*		*1.2*		*1,243*	
	N.G.	*$ 0.830*	*2.2*		*0.6*		*120,000*	
OFFICE								
Electricity (MWh)		Electricity (lbs)	882	lbs	1,176	lbs	1,218,593	lbs
Electricity (MMBtu)								
N.Gas (Therm)								
N.Gas (MMBtu)								
N.Gas (million CF)		N.Gas (lbs)	8	lbs	2	lbs	441,146	lbs
APARTMENT								
Electricity (MWh)		Electricity (lbs)	1,517	lbs	2,023	lbs	2,096,312	lbs
Electricity (MMBtu)								
N.Gas (Therm)								
N.Gas (MMBtu)								
N.Gas (million CF)		N.Gas (lbs)	3	lbs	1	lbs	155,262	lbs
RETAIL								
Electricity (MWh)		Electricity (lbs)	597	lbs	795	lbs	824,204	lbs
Electricity (MMBtu)								
N.Gas (Therm)								
N.Gas (MMBtu)								
N.Gas (million CF)		N.Gas (lbs)	0	lbs	0	lbs	0	lbs
PARKING, lighting								
Electricity (MWh)		Electricity (lbs)	192	lbs	256	lbs	264,915	lbs
Electricity (MMBtu)								
PARKING, ventilation								
Electricity (MWh)		Electricity (lbs)	60	lbs	79	lbs	82,266	lbs
Electricity (MMBtu)								
AREA lighting								
Electricity (MWh)		*Electricity (lbs)*	23	*lbs*	31	*lbs*	31,993	*lbs*
Electricity (MMBtu)								
TOTAL								
Electricity (MWh)	TOTAL	Electricity	3,270	lbs	4,361	lbs	4,518,284	lbs
Electricity (MMBtu)								
N.Gas (Therm)								
N.Gas (MMBtu)								
N.Gas (million CF)	TOTAL	N.Gas	11	lbs	3	lbs	596,408	lbs
TOTAL (MMBtu)								
	TOTAL	Elec + N.G.	3,281	lbs	4,364	lbs	5,114,692	lbs

Figure 1.2: US EPA 2016 EGRID for Cleveland, Ohio

1. Subregion Output Emission Rates (eGRID2016)

eGRID subregion acronym	eGRID subregion name	Total output emission rates lb/MWh							Non-baseload output emission rates lb/MWh							Grid Gross Loss (%)
		CO_2	CH_4	N_2O	CO_2e	Annual NO_x	Ozone Season NO_x	SO_2	CO_2	CH_4	N_2O	CO_2e	Annual NO_x	Ozone Season NO_x	SO_2	
AKGD	ASCC Alaska Grid	1,072.3	0.077	0.011	1,077.3	6.5	6.5	0.5	1,367.8	0.110	0.016	1,375.0	6.8	6.7	0.7	5.25%
AKMS	ASCC Miscellaneous	503.1	0.023	0.004	504.9	7.0	6.5	0.6	1,533.8	0.068	0.012	1,538.9	21.8	20.8	2.0	5.25%
AZNM	WECC Southwest	1,043.6	0.079	0.012	1,049.0	1.0	0.9	0.3	1,384.8	0.097	0.014	1,391.2	1.3	1.1	0.4	4.23%
CAMX	WECC California	527.9	0.033	0.004	529.9	0.6	0.5	0.1	942.9	0.045	0.006	945.6	0.8	0.8	0.1	4.23%
ERCT	ERCOT All	1,009.2	0.076	0.011	1,014.1	0.5	0.6	1.0	1,402.8	0.108	0.015	1,409.8	0.8	0.7	1.6	4.89%
FRCC	FRCC All	1,011.7	0.075	0.010	1,016.4	0.5	0.5	0.4	1,188.5	0.078	0.011	1,193.3	0.6	0.6	0.4	4.49%
HIMS	HICC Miscellaneous	1,152.0	0.095	0.015	1,158.7	7.4	7.0	4.5	1,530.0	0.147	0.023	1,540.2	11.8	11.3	4.5	5.35%
HIOA	HICC Oahu	1,662.9	0.181	0.028	1,675.2	3.4	3.2	8.6	1,637.5	0.153	0.024	1,648.3	4.1	4.2	8.1	5.35%
MROE	MRO East	1,668.2	0.156	0.026	1,679.3	1.0	1.1	1.3	1,740.1	0.156	0.025	1,750.9	1.0	1.0	1.3	4.49%
MROW	MRO West	1,238.8	0.115	0.020	1,247.4	1.0	1.1	1.4	1,822.0	0.154	0.029	1,834.0	1.6	1.5	2.0	4.49%
NEWE	NPCC New England	558.2	0.090	0.012	563.7	0.4	0.4	0.1	975.1	0.086	0.011	980.5	0.5	0.4	0.2	4.49%
NWPP	WECC Northwest	651.2	0.061	0.009	655.4	0.6	0.7	0.4	1,524.9	0.124	0.020	1,533.8	1.4	1.4	0.8	4.23%
NYCW	NPCC NYC/Westchester	635.8	0.022	0.003	637.1	0.3	0.3	0.0	1,061.7	0.022	0.002	1,062.9	0.5	0.6	0.0	4.49%
NYLI	NPCC Long Island	1,178.3	0.126	0.016	1,186.0	0.9	0.8	0.2	1,338.8	0.036	0.004	1,340.9	0.9	0.9	0.3	4.49%
NYUP	NPCC Upstate NY	294.7	0.021	0.003	295.9	0.3	0.3	0.2	1,018.2	0.061	0.008	1,022.0	0.8	0.8	0.9	4.49%
RFCE	RFC East	758.2	0.050	0.009	762.1	0.6	0.6	0.6	1,434.4	0.079	0.017	1,441.4	1.2	1.1	1.2	4.49%
RFCM	RFC Michigan	1,272.0	0.067	0.018	1,278.9	0.9	0.9	1.7	1,806.1	0.101	0.025	1,816.1	1.3	1.2	2.8	4.49%
RFCW	RFC West	1,243.4	0.108	0.019	1,251.5	0.9	0.9	1.2	1,934.4	0.172	0.029	1,946.9	1.5	1.4	2.2	4.49%
RMPA	WECC Rockies	1,367.8	0.137	0.020	1,376.8	1.0	1.0	0.6	1,688.3	0.147	0.021	1,697.9	1.2	1.2	0.8	4.23%
SPNO	SPP North	1,412.4	0.149	0.022	1,422.2	0.8	0.9	0.5	1,990.8	0.202	0.029	2,004.1	1.4	1.5	1.1	4.49%
SPSO	SPP South	1,248.3	0.095	0.015	1,254.9	0.9	0.9	1.7	1,662.5	0.121	0.019	1,670.9	1.3	1.3	2.4	4.49%
SRMV	SERC Mississippi Valley	838.9	0.050	0.007	842.2	0.8	0.9	0.7	1,186.0	0.071	0.010	1,190.6	1.3	1.4	1.1	4.49%
SRMW	SERC Midwest	1,612.6	0.082	0.026	1,622.5	1.1	1.1	2.4	1,955.2	0.084	0.031	1,966.5	1.3	1.2	3.1	4.49%
SRSO	SERC South	1,089.4	0.087	0.013	1,095.1	0.5	0.5	0.4	1,453.5	0.115	0.017	1,461.1	0.8	0.7	0.6	4.49%
SRTV	SERC Tennessee Valley	1,185.4	0.093	0.017	1,192.6	0.7	0.7	1.0	1,757.4	0.135	0.025	1,767.9	1.1	1.1	1.6	4.49%
SRVC	SERC Virginia/Carolina	805.3	0.067	0.011	810.1	0.5	0.5	0.3	1,422.2	0.111	0.019	1,430.4	0.8	0.8	0.6	4.49%
U.S.		**998.4**	**0.080**	**0.013**	**1,004.2**	**0.7**	**0.7**	**0.8**	**1,501.0**	**0.111**	**0.018**	**1,508.9**	**1.1**	**1.0**	**1.3**	**4.48%**

Created: 2/15/2018

TABLE 1.4-2. EMISSION FACTORS FOR CRITERIA POLLUTANTS AND GREENHOUSE GASES FROM NATURAL GAS COMBUSTION[a]

Pollutant	Emission Factor ($lb/10^6$ scf)	Emission Factor Rating
CO_2[b]	120,000	A
Lead	0.0005	D
N_2O (Uncontrolled)	2.2	E
N_2O (Controlled-low-NO_X burner)	0.64	E
PM (Total)[c]	7.6	D
PM (Condensable)[c]	5.7	D
PM (Filterable)[c]	1.9	B
SO_2[d]	0.6	A
TOC	11	B
Methane	2.3	B
VOC	5.5	C

[a] Reference 11. Units are in pounds of pollutant per million standard cubic feet of natural gas fired. Data are for all natural gas combustion sources. To convert from $lb/10^6$ scf to $kg/10^6$ m^3, multiply by 16. To convert from $lb/10^6$ scf to 1b/MMBtu, divide by 1,020. The emission factors in this table may be converted to other natural gas heating values by multiplying the given emission factor by the ratio of the specified heating value to this average heating value. TOC = Total Organic Compounds. VOC = Volatile Organic Compounds.

[b] Based on approximately 100% conversion of fuel carbon to CO_2. $CO_2[lb/10^6 scf] = (3.67)(CON)(C)(D)$, where CON = fractional conversion of fuel carbon to CO_2, C = carbon content of fuel by weight (0.76), and D = density of fuel, $4.2x10^4$ $lb/10^6$ scf.

[c] All PM (total, condensible, and filterable) is assumed to be less than 1.0 micrometer in diameter. Therefore, the PM emission factors presented here may be used to estimate PM_{10}, $PM_{2.5}$ or PM_1 emissions. Total PM is the sum of the filterable PM and condensible PM. Condensible PM is the particulate matter collected using EPA Method 202 (or equivalent). Filterable PM is the particulate matter collected on, or prior to, the filter of an EPA Method 5 (or equivalent) sampling train.

[d] Based on 100% conversion of fuel sulfur to SO_2. Assumes sulfur content is natural gas of 2,000 grains/10^6 scf. The SO_2 emission factor in this table can be converted to other natural gas sulfur contents by multiplying the SO_2 emission factor by the ratio of the site-specific sulfur content (grains/10^6 scf) to 2,000 grains/10^6 scf.

Figure 1.3: US EPA 19987 AP-42 Emissions Factors for On-site Natural Gas Combustion.

TASK 1.8. Identification of limitations and risks that may occur during construction and operation of the project that may adversely impact the expected benefits to the State in energy savings and emissions reductions.

The risks and limitations that may occur during the construction and operation of the project that may adversely impact the project can be categorized into Design Risks, Construction Risks and Operation Risks. Each of these categories also include sub-categories of possible reasons why the expected air pollution benefits might not occur.

1. Changes to the as-built project design that differ from the Schematic Design simulations.
    a. Changes to the building envelope (i.e., window area, wall materials, roof materials, lighting types, etc.)
    b. Changes to the building HVAC system (i.e., chiller, boiler, air-handling units).
    c. Changes to other building systems (i.e., lighting, elevators, ventilation, pools, etc.)

2. Changes to the actual building compared to the as-built design.
    a. Changes to the actual building envelope.
    b. Changes to the actual building HVAC system.
    c. Changes to the actual other building systems.

3. Changes to the operation of the building that were not simulated by the schematic design analysis.
    a. Differences in the actual building schedules vs the simulated building schedules (i.e., occupancy, lighting, equipment, ventilation, etc.).
    b. Differences in the actual building equipment vs the as-built design (i.e., HVAC, lighting, elevators, pools, boilers, chillers, etc.).
    c. Allowances for unknown changes to the building that were not anticipated by the simulation (i.e., building vacancy, aging equipment, shading from new construction (not previously known).
    d. Application for and acceptance of new energy efficient features (i.e., retail space below the office and apartment complex).
4. Changes to the building operation due to degradation of energy efficient equipment.
    a. Changes to the actual building envelope (i.e., deterioration of glazing, insulation, etc.)
    b. Changes to the actual building HVAC system (i.e., wear and tear on HVAC equipment)
    c. Changes to the actual other building systems (i.e., wear and tear on non-HVAC equip.)
5. Changes to costing of Energy Conservation Design Measures (ECDMs) at varying stages of design and construction.
    a. Differences between costs of ECDMs at Schematic Design, and As-built Costs vs ECDMs that were simulated.
    b. Differences between estimated costs and actual project costs.
6. Changes to the electric utility grid in Ohio.
    a. Retirement of older electric power plants and replacement with cleaner-burning plants (i.e., change to the US EPA Egrid values).
7. Changes to the project design that are required to conform to State, Federal or Local regulations.
8. Changes to the project cost(s) that impact the performance of the project.

APPENDIX

A. Market Square – OAQDA Application for Financing of Air Quality Control Facility – 4/23/2019.

B. Dunham Engineering – Energy Modeling of Market Square re: OAQDA Application

C. Dunham Engineering – MS Schematic EM Files 6 11 2019

D. PVWatt Analysis of 40 to 60 kW system.

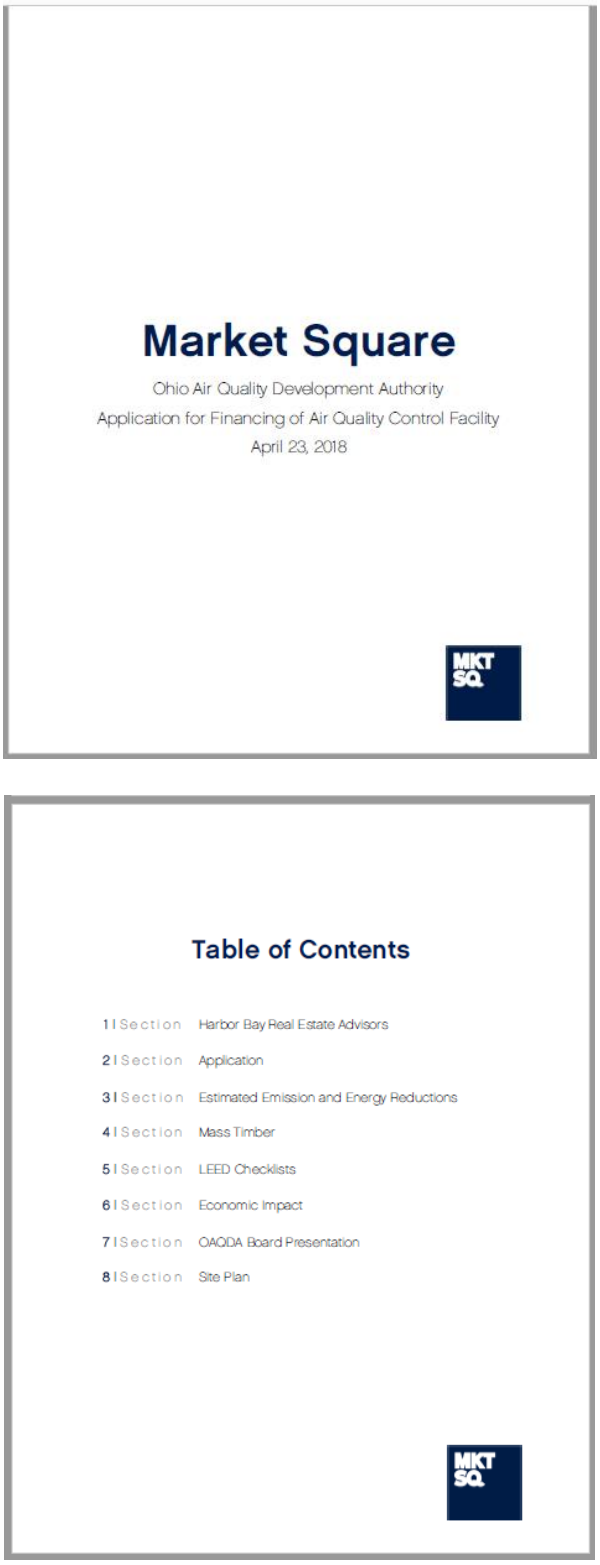
E. Reference EUIs for comparison

APPENDIX A.
Market Square – OAQDA Application for Financing of Air Quality Control Facility – 4/23/2019

The Market Square OAQDA Application for Financing of Air Quality Control Facility is a 126 page document that is presented in eight sections. Of interest to this report is Section three that presents the Estimated Emission and Energy Reductions. These values represent preliminary estimates of the energy reductions and emissions reductions that were updated in the 6/11/2019 Dunham Engineering SD Energy Modeling document and therefore were not used in this analysis.

Figure A1 shows the cover page of the report and the table of contents. Figure A2 shows the Market Square presentation that was presented to the OAQDA Board on March 19, 2019. The images in this section of the report were used to obtain an overall understanding of the project layout and design. Figure A3 and A4 show the initial energy savings estimates and emissions reductions that were presented to the OAQDA Board. These values were updated in the Dunham Engineering SD Energy Modeling document (Appendix B) and were therefore not used in this analysis.

Total savings in this report are significantly higher than those reported in the Preliminary Engineering estimate from Harbor Bay due to the use of grid factors, and the inclusion of parking (lighting + ventilation), area lighting and Retail space.



Market Square

Ohio Air Quality Development Authority

Application for Financing of Air Quality Control Facility

April 23, 2018

MKT SQ

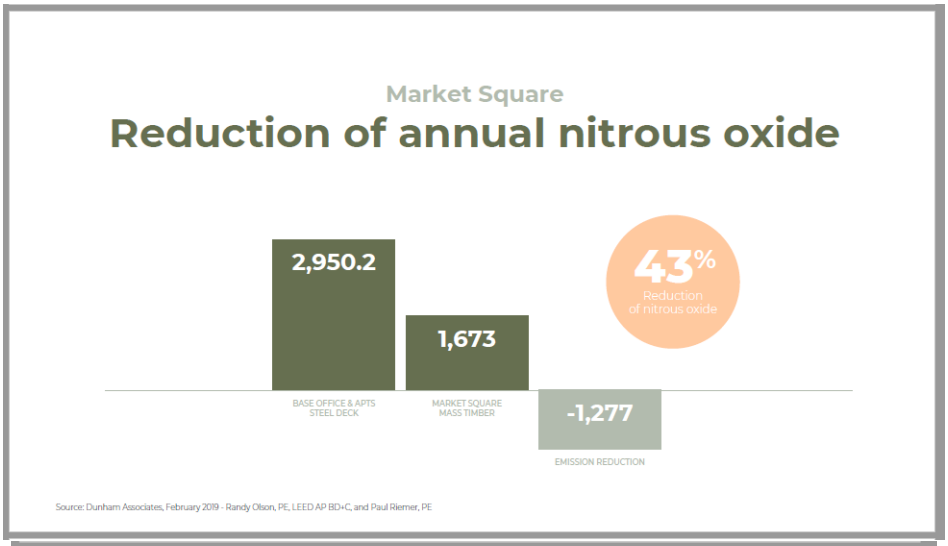
Table of Contents

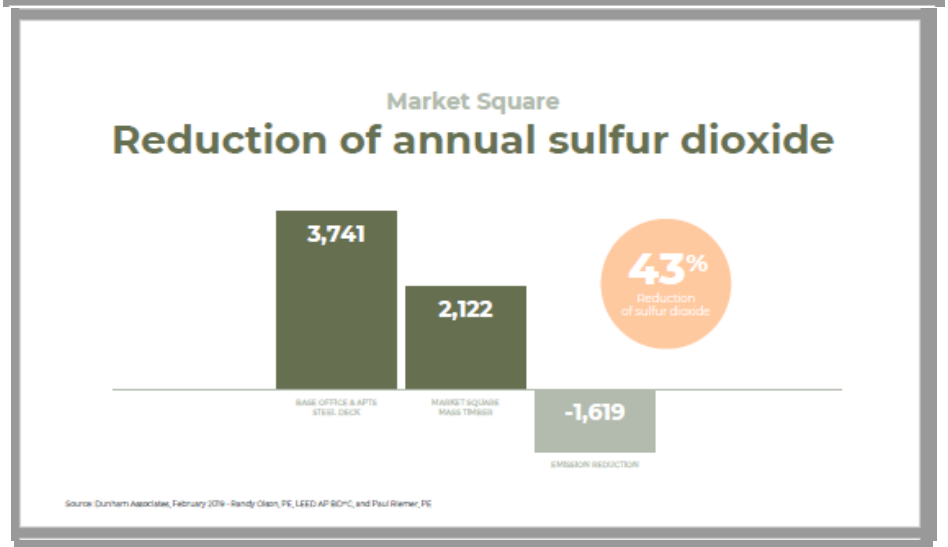
1 | Section Harbor Bay Real Estate Advisors
2 | Section Application
3 | Section Estimated Emission and Energy Reductions
4 | Section Mass Timber
5 | Section LEED Checklists
6 | Section Economic Impact
7 | Section OAQDA Board Presentation
8 | Section Site Plan

MKT SQ

Figure A1. Market Square cover page and table of contents.

Figure A2. Market Square rendering.





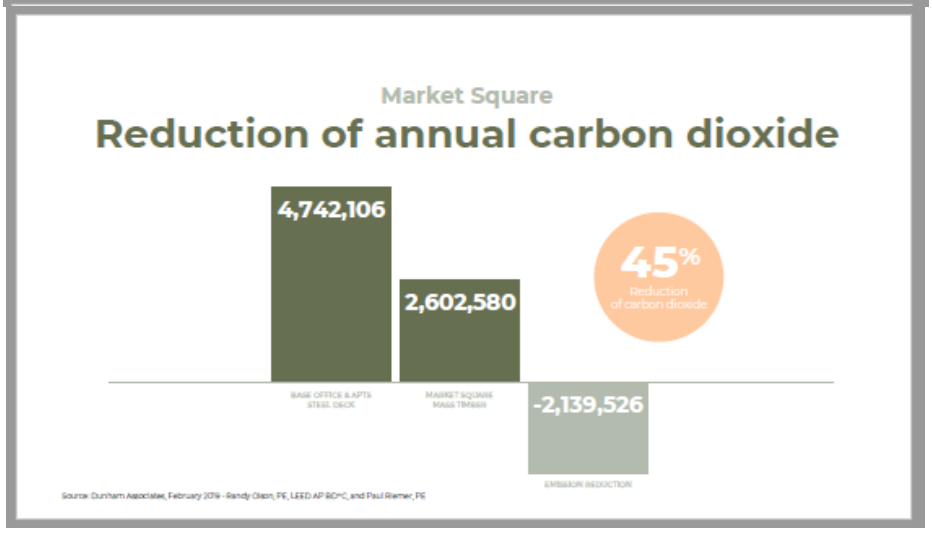


Figure A3. Emissions reduction reported in Market Square Application, 4/23/2019.

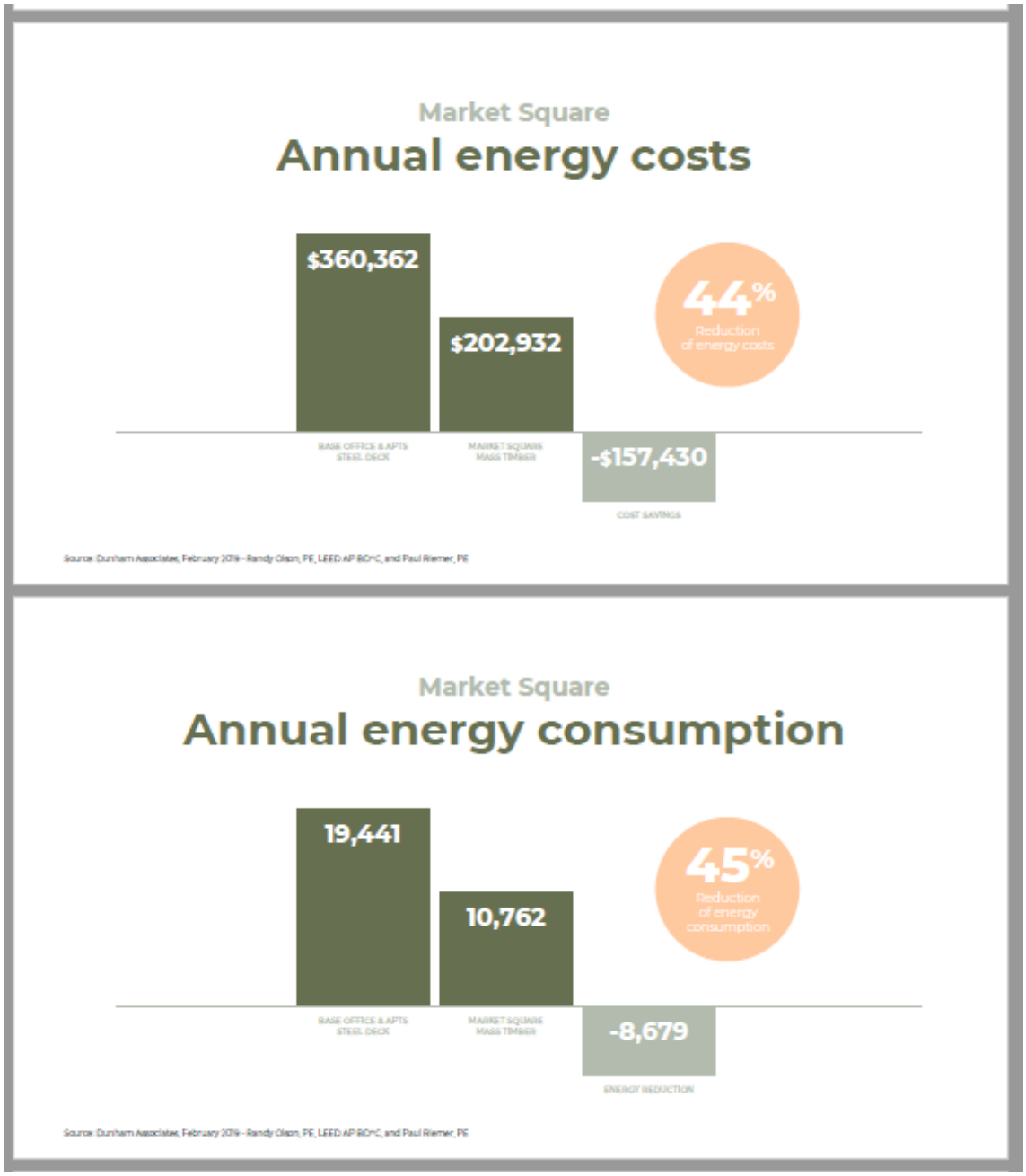


Figure A4. Annual Energy Costs and Annual Energy Consumption reported in Market Square Application, 4/23/2019.

APPENDIX B.
Dunham Engineering – Energy Modeling of Market Square re: OAQDA Application

The Energy Modeling of Market Square re: OAQDA Application document is a four page overview of the design and energy modeling Market Square project. This document includes an overview of the project and specific information about the energy modeling analysis performed by Dunham Engineering. Page one of the document cites ASHRAE Standard 90.1-2010 (climate zone 5A) as the commercial building energy code for the project and states that the EQUEST 3.65 (build 7175) was used in the whole-building energy analysis along with the Cleveland, Ohio TMY2 hourly weather file.

In addition, page one states:

- Schematic level and professional assumptions and simplifications were utilized.
- Retail space and sub-surface parking (not defined) were not included in the modeling.
- Building energy savings resulting from the use of Mass Timber were not included.

Key parameters regarding the modeling effort were included in a two page table and include:

- Results from the combined annual energy simulations of the base case and proposed Office building and Apartment building.
- Limited details about the PV installation (i.e., installed field size of 40 to 60 kW is being planned) including an estimate of 1 to 2% additional savings (i.e., no simulation).

Figures B1 – B4 contain the Dunham Engineering Schematic Design (SD) Modeling Report document that was used in this analysis.

DUNHAM

Energy Modeling of Market Square re OAQDA Application

Background
Harbor Bay Real Estate Advisors (Harbor Bay) is proposing to develop the Market Square mixed-use development in Cleveland, Ohio. Hartshorne Plunkard Architecture (HPA) is the architect of record for Market Square. Dunham was challenged to develop MEP system options by Harbor Bay to achieve profound operational efficiencies that would complement the embodied energy and carbon sequestration inherent within the use of Mass Timber. These options were analyzed through a schematic energy modeling process in order to maximize performance and reduce pollutants. Dunham was responsible for completing the necessary energy modeling and analysis included within the OAQDA application. The use of Mass Timber is a key structural and design feature of Market Square.

Although Dunham will continue to support Market Square, other entities are advancing the MEP design. These firms will serve as engineers of record.

Analysis to Date
Initially, Dunham was tasked with performing a schematic round of energy modeling to evaluate design options and project energy and greenhouse gas emissions savings compared to a minimally code compliant design. This modeling was updated on 6/11/2019 to reflect the most current architectural metrics, including additional residential areas that were not envisioned and not included within the initial models. This amounted to an increase of over 20% to the area included in the model. Since all of the area increase was in the residential portion of the building, and that portion is an all-electric system, electric consumption increased disproportionately. The applicable energy code is the 2012 IECC which allows 90.1-2010 as a compliance path. Cleveland, Ohio is located in climate zone 5A and the Cleveland OH TMY2 weather file was utilized. Dunham conducted their analysis using eQuest version 3.65 build 7175 with DOE2.2. Schematic level and professional assumptions and simplifications were utilized.

As is a common industry practice, the retail space and sub-surface parking were not incorporated within the energy modeling completed by Dunham. Regardless, these two components are being designed to achieve reductions in energy consumption with a focus on sustainable building practices. Additionally, the model does not include the anticipated building energy savings resulting from the use of Mass Timber as stated within the two Mass Timber-related studies that were included within Market Square's *Application for Financing of Air Quality Control Facility* that was submitted on April 23, 2019.

The following table shows the key parameters of that modeling effort.

50 South Sixth Street / Suite 1100 / Minneapolis, Minnesota 55402-1540 PHONE 612.465.7550 FAX 612.465.7551 WEB dunhameng.com

Figure B1. Dunham Engineering SD Energy Modeling Report (6/11/2019), page 1.

Key Parameters

			Office		Residential	
Usage						
Area	sf		204,300		243,600	
# of Floors	Qty		9		6	
Floor To Floor Height	ft		14		11.5	
Ave. Floor Plate Area	sf		22,700		40,600	
Parameter	Units		Baseline	Proposed Design	Baseline	Proposed Design
File name root			MS Off Base	MS Off Prop	MS Apt Base	MS Apt Prop
Envelope						
Interior Floor Description			Average 2.5" Concrete Topping on Corrugated Steel Decking	Average 2.5" Concrete Topping on 5" CLT	Average 2.5" Concrete Topping on Corrugated Steel Decking	Average 2.5" Concrete Topping on 5" CLT
Roof Description			Insulation Entirely Above Deck	Insulation Entirely Above Deck	Insulation Entirely Above Deck	Insulation Entirely Above Deck
Roof Insulation	hr-sf-F/Btu		R-20ci	R-25ci	R-20ci	R-25ci
Wall Description			Steel framed	Steel framed	Steel framed	Steel framed
Wall Insulation	hr-sf-F/Btu		R-13 + R-7.5ci	R-13 + R-10ci	R-13 + R-7.5ci	R-13 + R-10ci
Window to Wall Ratio	%		40%	65%	40%	60%
Window Description			Fixed	Fixed	Operable	Operable
Window COG U	Btu/hr-sf-F		N/A	0.25	N/A	0.25
Window Assembly U	Btu/hr-sf-F		0.45	0.36	0.55	0.4
Window SHGC	Unitless		0.4	0.23	0.4	0.23
Window VLT	%		N/A	42%	N/A	42%
Exterior Shading			None	From Terraces	None	No credit taken
Terrace Floors			Thermally Separated	Thermally Separated	Thermally Separated	Thermally Separated
Skylights			None	None	None	None

Figure B2. Dunham Engineering SD Energy Modeling Report (6/11/2019), page 2

Key Parameters

Usage		Office		Residential	
Lighting					
Interior LPD	W/sf	0.9	0.35	0.5	0.5
Daylighting		Proposed = Code		None	None
Vac / Occ Sensor		Proposed = Code		None	None
Plug Loads		Proposed = Code			Reduction due to energy efficient appliances.
HVAC					
Space distribution		Conventional VAV boxes with Hot Water Reheat	Fan powered terminal unit with heating and sensible cooling coils. AKA CoolSense	Packaged Terminal Heat Pump	Air Cooled VRF
Terminal Fan		N/A	Integral ECM Fan	Code Power	Improved Power
Central Air Unit		VAV AHU with cooling and heating coils	VAV DOAS with Heat Recovery and volume controlled by zone demand controlled ventilation.	None	DOAS w Heat Pump & Heat Recovery
Economizer		Airside	Waterside	None	None
Central Heating Plant		Conventional Natural Gas Boilers at 80% efficiency	Condensing Natural Gas Boilers at 92% efficiency	N/A	N/A
Central Cooling Plant		Air cooled chillers	Magnetic Bearing Centrifugal Water Cooled Chillers and Drycoolers	None	None
DHW					Load Reduction due to low flow fixtures and energy efficient appliances.

Figure B3. Dunham Engineering SD Energy Modeling Report (6/11/2019), page 3.

Results

	Annual Consumption of Office & Apartments		
	Electric Consumption (kWh)	Natural Gas Consumption (mmBtu)	Total Energy Consumption (mmBtu)
Energy Code Compliant Baseline	4,218,879	8,794	23,189
Proposed	2,541,469	4,904	13,575
Savings	1,677,410	3,890	9,613
% Savings	40%	44%	**41%**

	Annual Emissions of Office & Apartments				
	Nitrous Dioxide (NO2) Emissions (lbs)	Nitrous Oxide (NOx) Emissions (lbs)	Sulfur Dioxide (SO2) Emissions (lbs)	CO2 Emissions (lbs)	GHG CO2eq Emissions (lbs)
Energy Code Compliant Baseline	82.1	3,988.8	5,058.4	6,274,599	6,309,458
Proposed	49.4	2,402.8	3,047.2	3,733,798	3,754,754
Savings	32.7	1,586.0	2,011.2	2,540,801	2,554,704
% Savings	40%	40%	40%	40%	**40%**

Photovoltaic Installation

Harbor Bay is committed to incorporating photovoltaic panels into this project, with an installed field size of between 40 kW and 60 kW is being planned. This installation will further drop our source energy consumption and carbon impact even more. The extent of this contribution will be wetted out as design progresses, but it could reduce the factors that directly impact air quality by an additional 1% to 2%.

Figure B4. Dunham Engineering SD Energy Modeling Report (6/11/2019), page 4.

APPENDIX C.
Dunham Engineering – MS Schematic EM Files 6 11 2019

The MS Schematic Energy Modeling (EM) Files were received on June 11, 2019, from Dunham Engineering and include the following files:

Table C1. Simulation Files Received from Dunham Engineering.

File Name	File type	Description
MS Apt Base – Baseline Design	.SIM file	EQUEST output file of the baseline Apartment building
MS Apt Base	.INP file	EQUEST input file of the baseline Apartment building
MS Apt Base	.PD2 file	EQUEST log file of the baseline Apartment building
MS Apt Prop – Baseline Design	.SIM file	EQUEST output file of the proposed Apartment building
MS Apt Prop	.INP file	EQUEST input file of the proposed Apartment building
MS Apt Prop	.PD2 file	EQUEST log file of the proposed Apartment building
MS Off Base – Baseline Design	.SIM file	EQUEST output file of the baseline Office building
MS Off Base	.INP file	EQUEST input file of the baseline Office building
MS Off Base	.PD2 file	EQUEST log file of the baseline Office building
MS Off Prop – Baseline Design	.SIM file	EQUEST output file of the proposed Office building
MS Off Prop	.INP file	EQUEST input file of the proposed Office building
MS Off Prop	.PD2 file	EQUEST log file of the proposed Office building
MS RETAIL Base – Baseline Design	.SIM file	EQUEST output file of the baseline Retail building
MS RETAIL Base	.INP file	EQUEST input file of the baseline Retail building
MS RETAIL Base	.PD2 file	EQUEST log file of the baseline Retail building
MS RETAIL Prop – Baseline Design	.SIM file	EQUEST output file of the proposed Retail building
MS RETAIL Prop	.INP file	EQUEST input file of the proposed Retail building
MS RETAIL Prop	.PD2 file	EQUEST log file of the proposed Retail building

These files are the EQUEST (version 3.65) files that were used to simulate the annual energy use of the proposed Apartment and Office buildings at the Market Square Project.

The ".INP" files are the ASCII input files for the EQUEST program. These files can be viewed in a text editor (set to 80 character display). These input files contain the detailed information about the Office and Apartment buildings that is read by the EQUEST program for the simulation.

The ".SIM" files are the ASCII output files from the EQUEST program that can be viewed in a text editor (set to 132 character display). These output files contain the detailed results of the simulation of the Office and Apartment buildings.

The ".PD2" files are the log files that are produced by EQUEST that contain information about each simulation.

Figure C1 shows an example of the EQUEST simulation program's .SIM output file that was produced for each run of the simulation. This file consists of 1,604 pages of formatted ASCII TEXT output that describes the input values provided in the simulation .INP file, default values, results of the simulation and pages of hourly output values for pre-selected parameters.

In Figure C1 the Building Energy Performance Summary (BEPS) page is shown. This page was used to extract the on-site energy use values for the simulation (MBtu and Btu/Ft2). The Building Energy Performance Units (BEPU) page (not shown) was used to extract the output results in kWh (electricity) and therms (natural gas).

Figure C2 shows an example of the EQUEST input file that is used for each simulation. These ASCII TEXT input files are generated by the EQUEST simulation Graphical User Input (GUI) when the simulation was created by Dunham Engineering. The (4) input files (apx 68 pages for each simulation) for the base case and proposed simulations of the Office and Apartment buildings were carefully edited and resimulated to provide the results for this report. Separate folders were created for each case simulated to avoid over-writing the files upon execution.

Figure C4, C5 and C6 shows "views" of the simulation input files in the EQUEST program for the Office building (Figure C4), Apartment building (Figure C5) and Retail building (Figure C6). In these figures the Base case (upper) and Proposed (lower) images are shown. In Figure C4 it can be seen that the Office building consisted of 4 floors for the simulation. The square lower floor was used as a fictitious zone for calculating the impact of heating and cooling the incoming outside air during all seasons of the year. The volume of this zone was used by the simulation program for determine the calculation.

The input file contained one ground floor, one intermediate floor and one top floor to simplify the analysis (common practice). In order for the results to match the 9 floors of the Office building and the 6 floors of the Apartment building, the results from the intermediate floor were multiplied by the appropriate values.

Several features from these views were useful in the analysis. For example, in the lower view of Figure C4 the shading on the Proposed simulation model can be clearly seen when compared to the base case simulation (upper image). Also, the increased window area becomes evident when viewing these images side-by-side. In addition, the light grey lines in the images represent the thermal zoning of the simulation.

Figure C3 provides an example of the EQUEST .PD2 log file that is produced by EQUEST for each run of the simulation. This file contains useful information about each simulation.

Figure C6 provides a view of the EQUEST simulation input for the Retail space. This view appears different than the views for the Office and Apartment buildings because of the use of an equivalent thermal model that is a reasonable approximation of the thermal characteristics of the building.

MS Apt Prop DOE-2.2-50a 6/11/2019 12:55:31 BDL RUN 1

REPORT- BEPS Building Energy Performance WEATHER FILE- Cleveland OH TMY2

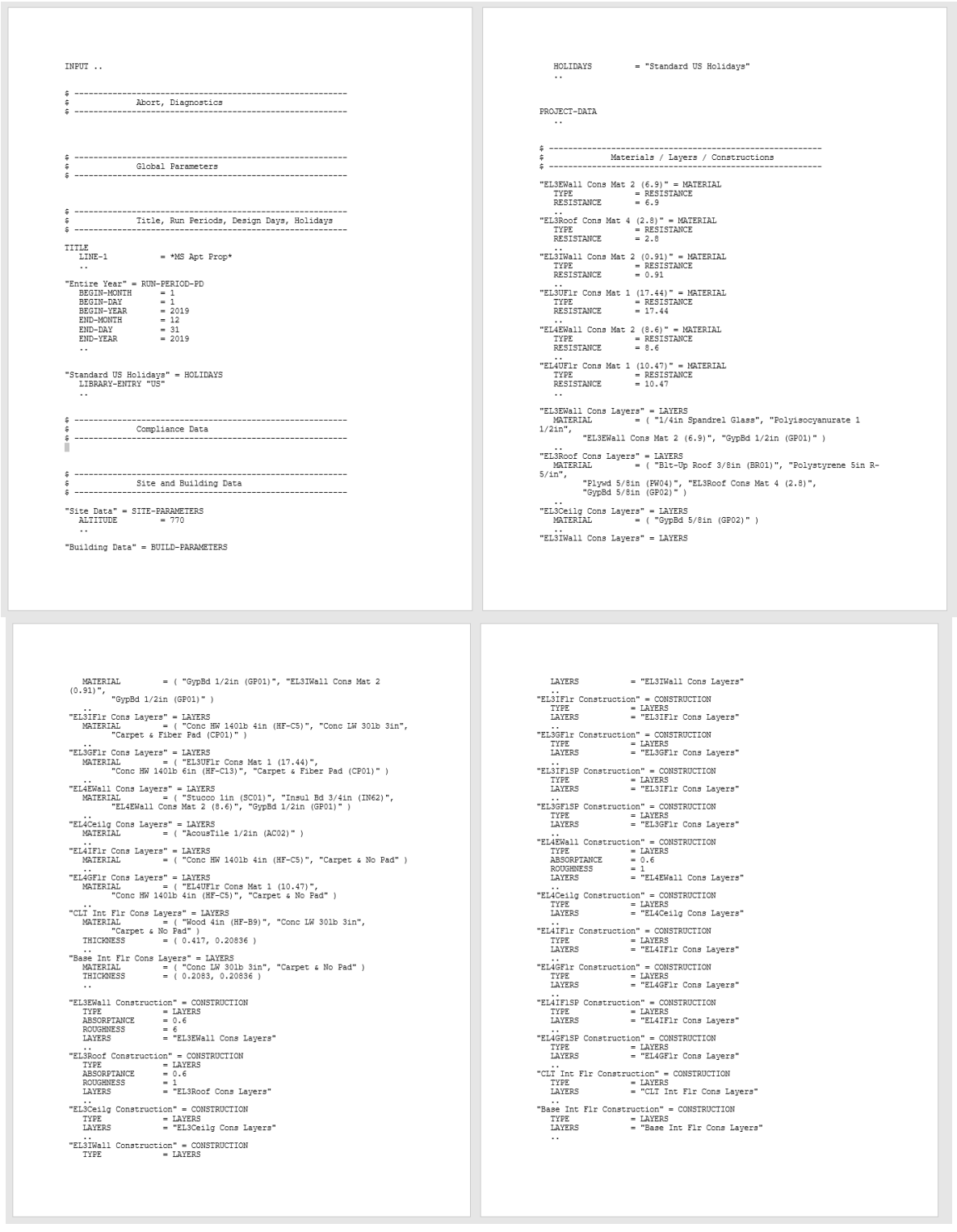
	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY													
MBTU	905.0	0.0	2189.0	925.7	429.7	0.0	76.7	619.0	0.0	338.3	0.0	1.9	5485.3
FM1 NATURAL-GAS													
MBTU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1277.0	0.0	1276.6
MBTU	905.0	0.0	2189.0	925.7	429.7	0.0	76.7	619.0	0.0	338.3	1277.0	1.9	6762.0

TOTAL SITE ENERGY 6761.96 MBTU 25.8 KBTU/SQFT-YR GROSS-AREA 25.8 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 17732.60 MBTU 67.7 KBTU/SQFT-YR GROSS-AREA 67.7 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 1.13
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 0
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 99

NOTE: ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.

Figure C1. Example EQUEST BEPS output file.



```
INPUT ..

$ ------------------------------------------------------------
$             Abort, Diagnostics
$ ------------------------------------------------------------



$ ------------------------------------------------------------
$             Global Parameters
$ ------------------------------------------------------------



$ ------------------------------------------------------------
$             Title, Run Periods, Design Days, Holidays
$ ------------------------------------------------------------

TITLE
   LINE-1           = *MS Apt Prop*
   ..

"Entire Year" = RUN-PERIOD-PD
   BEGIN-MONTH      = 1
   BEGIN-DAY        = 1
   BEGIN-YEAR       = 2019
   END-MONTH        = 12
   END-DAY          = 31
   END-YEAR         = 2019
   ..


"Standard US Holidays" = HOLIDAYS
   LIBRARY-ENTRY "US"
   ..


$ ------------------------------------------------------------
$             Compliance Data
$ ------------------------------------------------------------


$ ------------------------------------------------------------
$             Site and Building Data
$ ------------------------------------------------------------

"Site Data" = SITE-PARAMETERS
   ALTITUDE         = 770
   ..

"Building Data" = BUILD-PARAMETERS
```

```
   HOLIDAYS         = "Standard US Holidays"
   ..


PROJECT-DATA
   ..


$ ------------------------------------------------------------
$             Materials / Layers / Constructions
$ ------------------------------------------------------------

"EL3EWall Cons Mat 2 (6.9)" = MATERIAL
   TYPE             = RESISTANCE
   RESISTANCE       = 6.9
   ..
"EL3Roof Cons Mat 4 (2.8)" = MATERIAL
   TYPE             = RESISTANCE
   RESISTANCE       = 2.8
   ..
"EL3IWall Cons Mat 2 (0.91)" = MATERIAL
   TYPE             = RESISTANCE
   RESISTANCE       = 0.91
   ..
"EL3UFlr Cons Mat 1 (17.44)" = MATERIAL
   TYPE             = RESISTANCE
   RESISTANCE       = 17.44
   ..
"EL4EWall Cons Mat 2 (8.6)" = MATERIAL
   TYPE             = RESISTANCE
   RESISTANCE       = 8.6
   ..
"EL4UFlr Cons Mat 1 (10.47)" = MATERIAL
   TYPE             = RESISTANCE
   RESISTANCE       = 10.47
   ..

"EL3EWall Cons Layers" = LAYERS
   MATERIAL         = ( "1/4in Spandrel Glass", "Polyisocyanurate 1
1/2in",
          "EL3EWall Cons Mat 2 (6.9)", "GypBd 1/2in (GP01)" )
   ..
"EL3Roof Cons Layers" = LAYERS
   MATERIAL         = ( "Blt-Up Roof 3/8in (BR01)", "Polystyrene 5in R-
5/in",
          "Plywd 5/8in (PW04)", "EL3Roof Cons Mat 4 (2.8)",
          "GypBd 5/8in (GP02)" )
   ..
"EL3Ceilg Cons Layers" = LAYERS
   MATERIAL         = ( "GypBd 5/8in (GP02)" )
   ..
"EL3IWall Cons Layers" = LAYERS
```

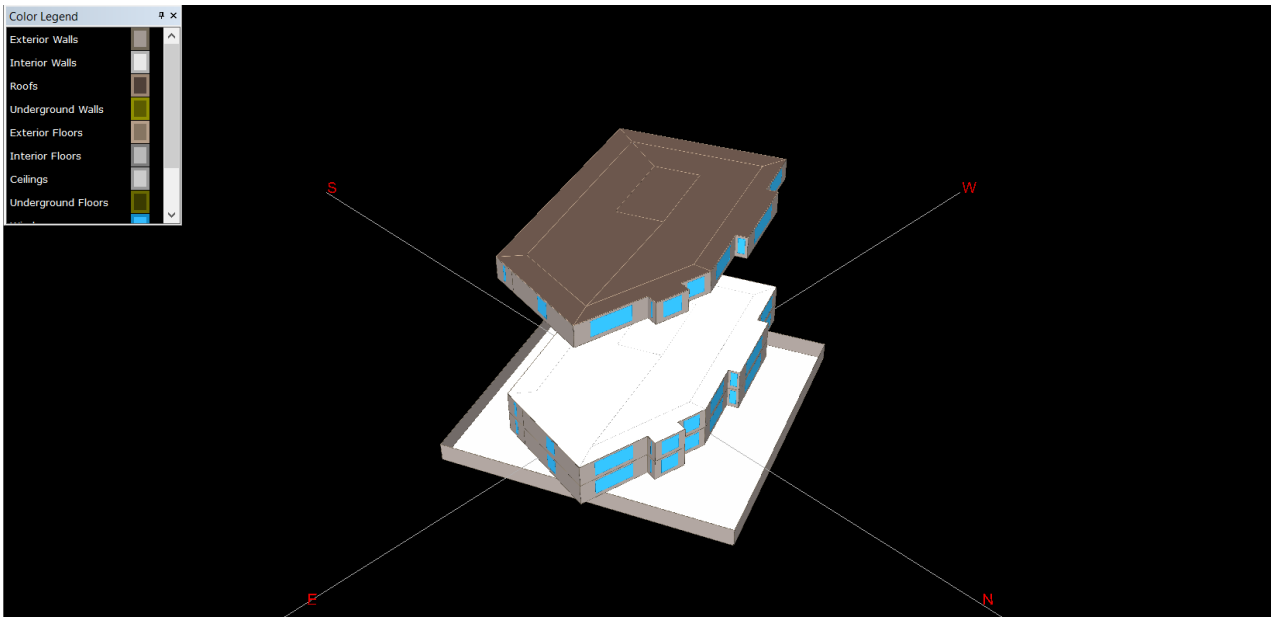
```
   MATERIAL         = ( "GypBd 1/2in (GP01)", "EL3IWall Cons Mat 2
(0.91)",
          "GypBd 1/2in (GP01)" )
   ..
"EL3IFlr Cons Layers" = LAYERS
   MATERIAL         = ( "Conc HW 140lb 4in (HF-C5)", "Conc LW 30lb 3in",
          "Carpet & Fiber Pad (CP01)" )
   ..
"EL3GFlr Cons Layers" = LAYERS
   MATERIAL         = ( "EL3UFlr Cons Mat 1 (17.44)",
          "Conc HW 140lb 6in (HF-C13)", "Carpet & Fiber Pad (CP01)" )
   ..
"EL4EWall Cons Layers" = LAYERS
   MATERIAL         = ( "Stucco 1in (SC01)", "Insul Bd 3/4in (IN62)",
          "EL4EWall Cons Mat 2 (8.6)", "GypBd 1/2in (GP01)" )
   ..
"EL4Ceilg Cons Layers" = LAYERS
   MATERIAL         = ( "AcousTile 1/2in (AC02)" )
   ..
"EL4IFlr Cons Layers" = LAYERS
   MATERIAL         = ( "Conc HW 140lb 4in (HF-C5)", "Carpet & No Pad" )
   ..
"EL4GFlr Cons Layers" = LAYERS
   MATERIAL         = ( "EL4UFlr Cons Mat 1 (10.47)",
          "Conc HW 140lb 4in (HF-C5)", "Carpet & No Pad" )
   ..
"CLT Int Flr Cons Layers" = LAYERS
   MATERIAL         = ( "Wood 4in (HF-B9)", "Conc LW 30lb 3in",
          "Carpet & No Pad" )
   THICKNESS        = ( 0.417, 0.20836 )
   ..
"Base Int Flr Cons Layers" = LAYERS
   MATERIAL         = ( "Conc LW 30lb 3in", "Carpet & No Pad" )
   THICKNESS        = ( 0.2083, 0.20836 )
   ..

"EL3EWall Construction" = CONSTRUCTION
   TYPE             = LAYERS
   ABSORPTANCE      = 0.6
   ROUGHNESS        = 6
   LAYERS           = "EL3EWall Cons Layers"
   ..
"EL3Roof Construction" = CONSTRUCTION
   TYPE             = LAYERS
   ABSORPTANCE      = 0.6
   ROUGHNESS        = 1
   LAYERS           = "EL3Roof Cons Layers"
   ..
"EL3Ceilg Construction" = CONSTRUCTION
   TYPE             = LAYERS
   LAYERS           = "EL3Ceilg Cons Layers"
   ..
"EL3IWall Construction" = CONSTRUCTION
   TYPE             = LAYERS
```

```
   LAYERS           = "EL3IWall Cons Layers"
   ..
"EL3IFlr Construction" = CONSTRUCTION
   TYPE             = LAYERS
   LAYERS           = "EL3IFlr Cons Layers"
   ..
"EL3GFlr Construction" = CONSTRUCTION
   TYPE             = LAYERS
   LAYERS           = "EL3GFlr Cons Layers"
   ..
"EL3IF1SP Construction" = CONSTRUCTION
   TYPE             = LAYERS
   LAYERS           = "EL3IFlr Cons Layers"
   ..
"EL3GF1SP Construction" = CONSTRUCTION
   TYPE             = LAYERS
   LAYERS           = "EL3GFlr Cons Layers"
   ..
"EL4EWall Construction" = CONSTRUCTION
   TYPE             = LAYERS
   ABSORPTANCE      = 0.6
   ROUGHNESS        = 1
   LAYERS           = "EL4EWall Cons Layers"
   ..
"EL4Ceilg Construction" = CONSTRUCTION
   TYPE             = LAYERS
   LAYERS           = "EL4Ceilg Cons Layers"
   ..
"EL4IFlr Construction" = CONSTRUCTION
   TYPE             = LAYERS
   LAYERS           = "EL4IFlr Cons Layers"
   ..
"EL4GFlr Construction" = CONSTRUCTION
   TYPE             = LAYERS
   LAYERS           = "EL4GFlr Cons Layers"
   ..
"EL4IF1SP Construction" = CONSTRUCTION
   TYPE             = LAYERS
   LAYERS           = "EL4IFlr Cons Layers"
   ..
"EL4GF1SP Construction" = CONSTRUCTION
   TYPE             = LAYERS
   LAYERS           = "EL4GFlr Cons Layers"
   ..
"CLT Int Flr Construction" = CONSTRUCTION
   TYPE             = LAYERS
   LAYERS           = "CLT Int Flr Cons Layers"
   ..
"Base Int Flr Construction" = CONSTRUCTION
   TYPE             = LAYERS
   LAYERS           = "Base Int Flr Cons Layers"
   ..
```

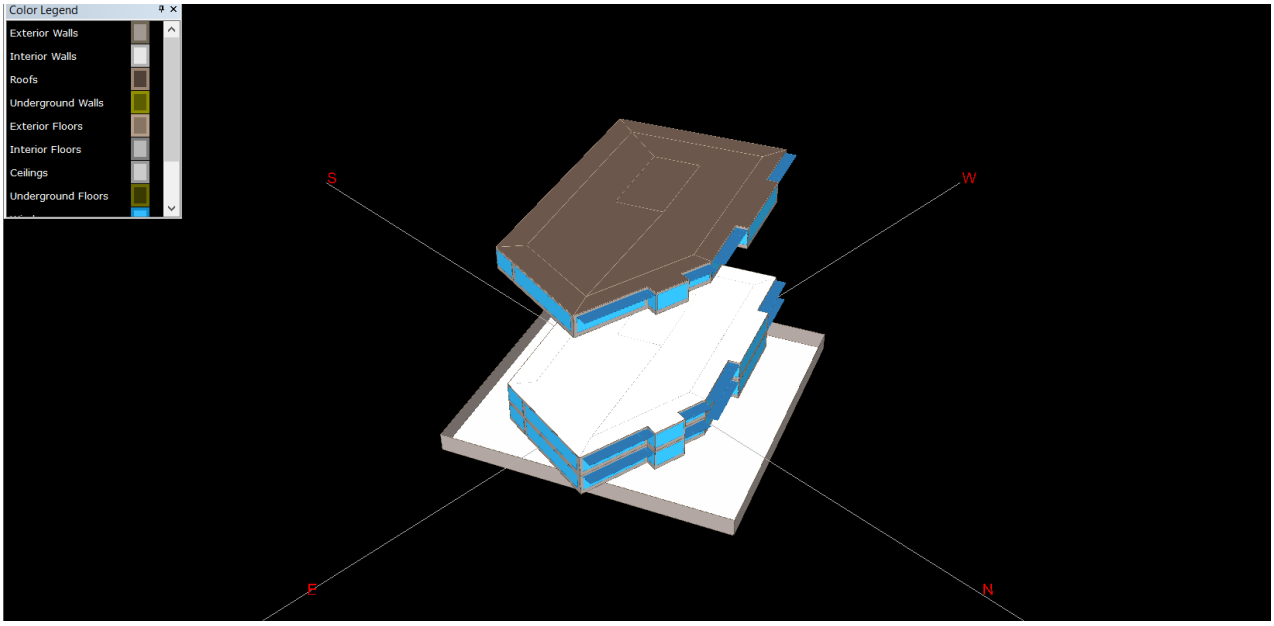
Figure C2. Example EQUEST input file.

```
Proj   "MS Apt Base"
   ProgramVersion = "eQUEST 3.65.7175"
   BDBaseVersion = 25
   ProductCode = "eQUEST"
   WeatherFile = "TMY2\CLEVELOH.bin"
   CreateDate = 1560275478
   ModDate = 1560275851
   RunDate = 1560275797
   LibraryFile = "eQ_Lib.dat"
   ActiveMode = 1
   InterfaceMode = 1
   AllowWizard = 0
   NotProjFile = "MS Apt Base"
   InputUnitsType = "English"
   OutputUnitsType = "English"
   PreviousName = "MSAB C PTHP Det 4Q - 2"
   ProjTreeType[1] = 0
   ProjTreeID[1] = 10000
   ProjTreeLabel[1] = "Project:  'MSAB C PTHP Det 4Q - 2'"
   ..

DiagData   "Detailed UI DiagData"
   ..

FacetColor   "By Wall Type"
   FacetType = "Walls"
   ColorOption = "By Wall Type"
   ..

FacetColor   "By Construction"
   FacetType = "Walls"
   ColorOption = "By Construction"
   ..

FacetColor   "Uniform"
   FacetType = "Windows"
   ColorOption = "Uniform"
   ..

FacetColor   "By Glass Type"
   FacetType = "Windows"
   ColorOption = "By Glass Type"
   ..

Light3D   "Light3D - Default"
   Type = "Default"
   ..

Light3D   "Light3D - User1"
   Type = "User Defined 1"
```

Figure C3. Example EQUEST .PD2 log file.

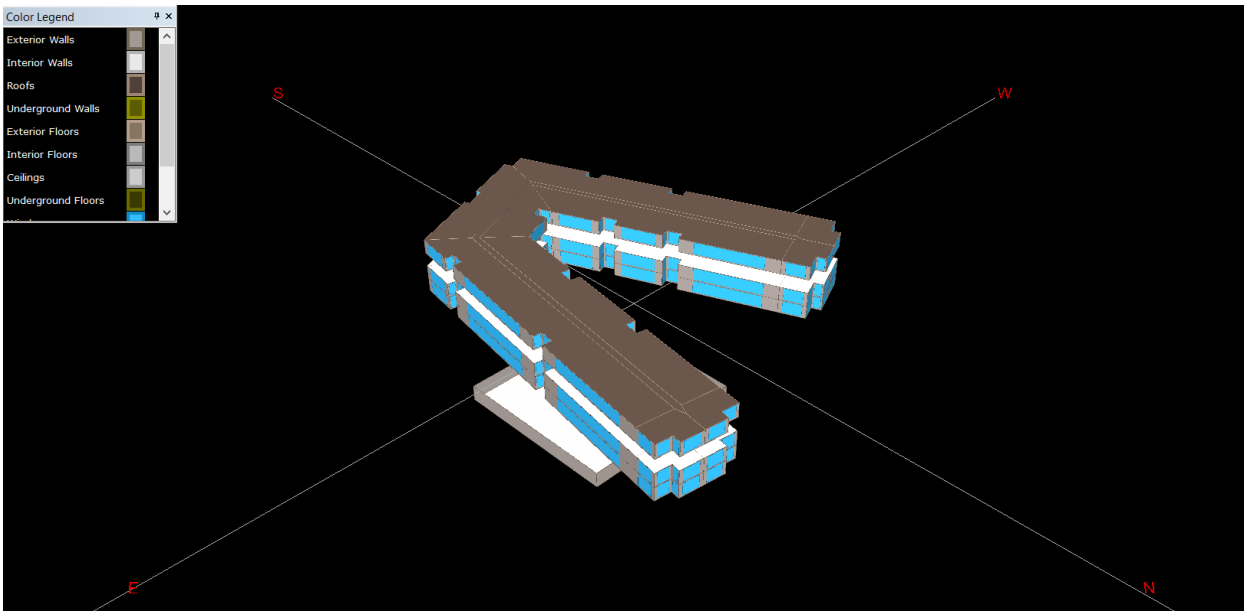


MS Office – Base case (EQUEST view)

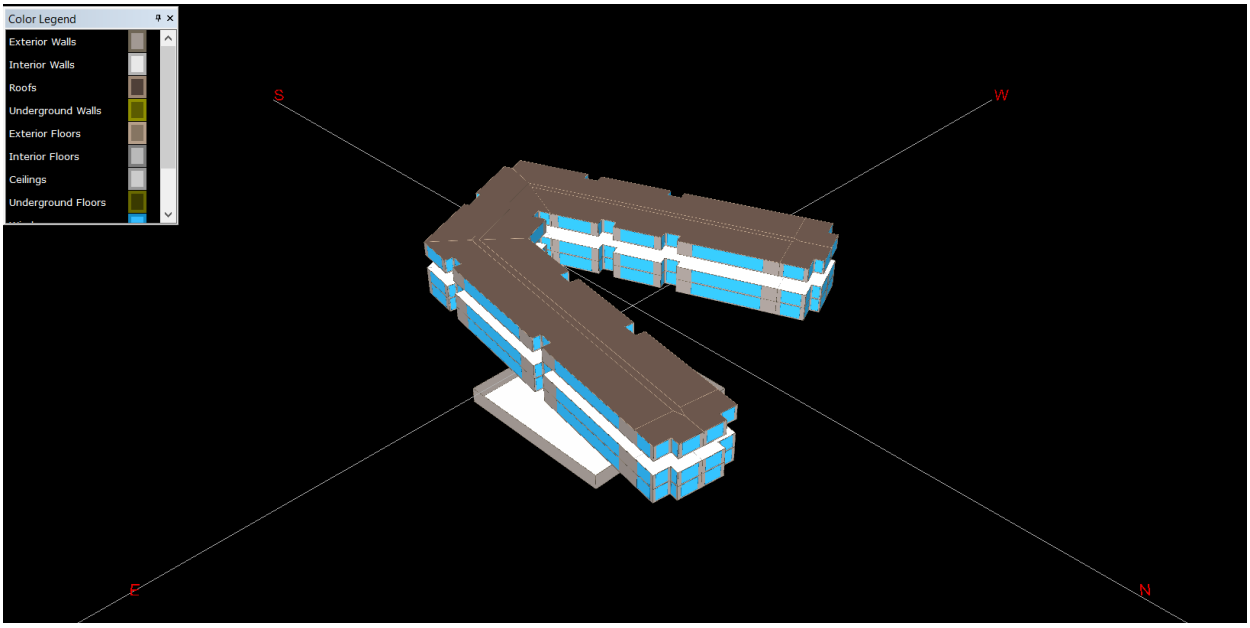


MS Office – Proposed (EQUEST view)

Figure C4: EQUEST views of the MS Office simulation.

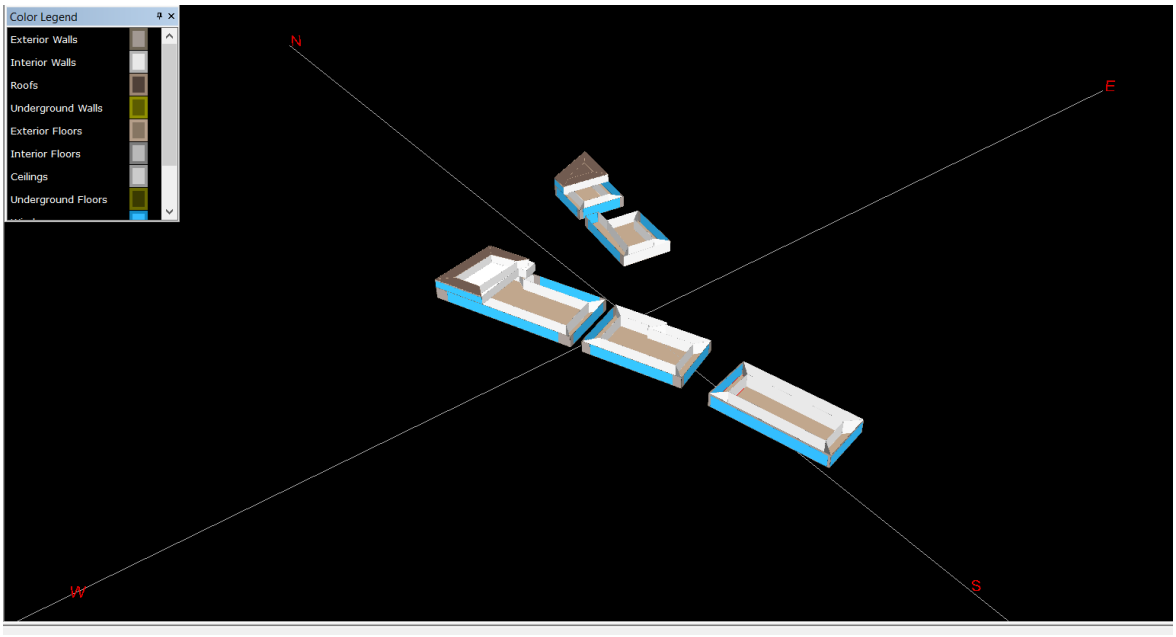


MS Apartment – Base case (EQUEST view)

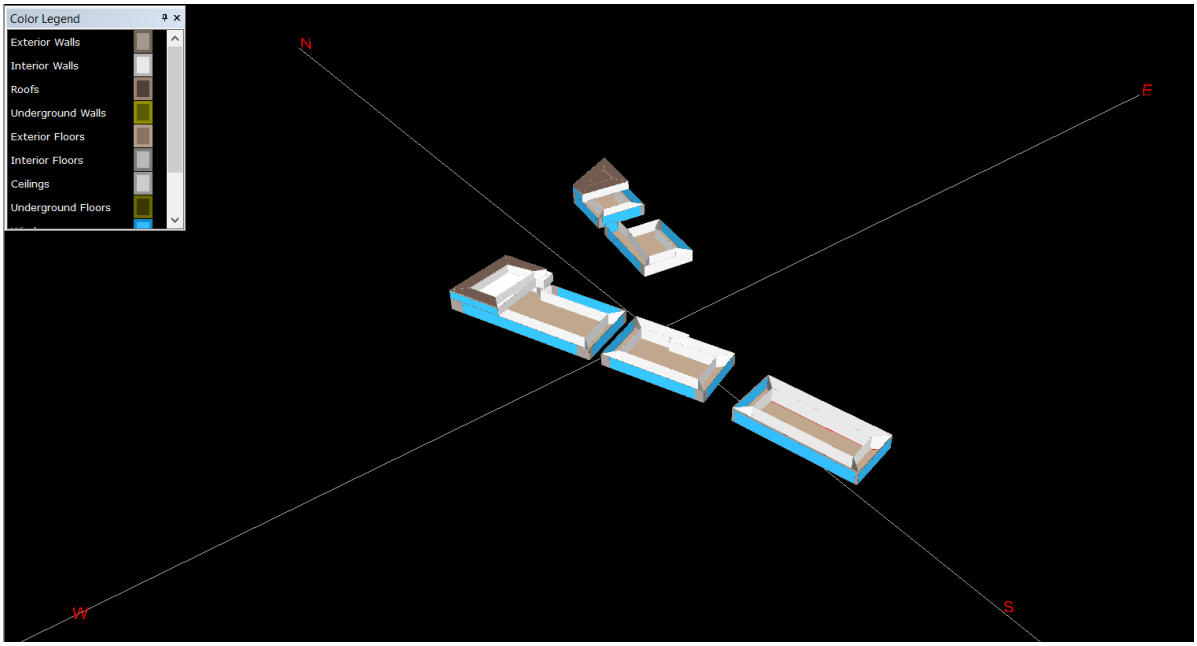


MS Apartment – Proposed (EQUEST view)

Figure C5. EQUEST views of the MS Apartment simulation.



MS Retail – Base case (EQUEST view)



MS Retail – Proposed (EQUEST view)

Figure C6. EQUEST views of the MS Retail simulation.

APPENDIX D.
PVWatts Analysis of 40 to 60 kW system.

The calculation of the 40 to 60 kW PV installation used the PVWatts Calculator provided by the National Renewable Energy Laboratory – NREL in Golden, Colorado (https://pvwatts.nrel.gov/ NREL). Figure D.1 and D.2 are screen shots of the PVWatts calculator. Figure D.1 shows the inputs used for the analysis of the 40 to 60 kW PV system in Cleveland, Ohio, and Figure D.2 shows the calculated electricity output for the 40 kW (upper) and 60 kW (lower) systems.

The Standard PV system chosen for the analysis uses 15% efficient crystalline silicon panels facing south that are tilted at 20 from the horizon. It has a 14% system loss, a 1.2 DC to AC size ratio, and a 96% inverter efficiency.

Figure D.2 shows the calculated electricity production for the 40 kW system would be 51,759 kWh/yr and 77,639 kWh/yr for the 60 kW system with the highest electricity production in the summer months.

Calculation of energy reductions from the installation of photovoltaic panels was not included in this Task 1 report.

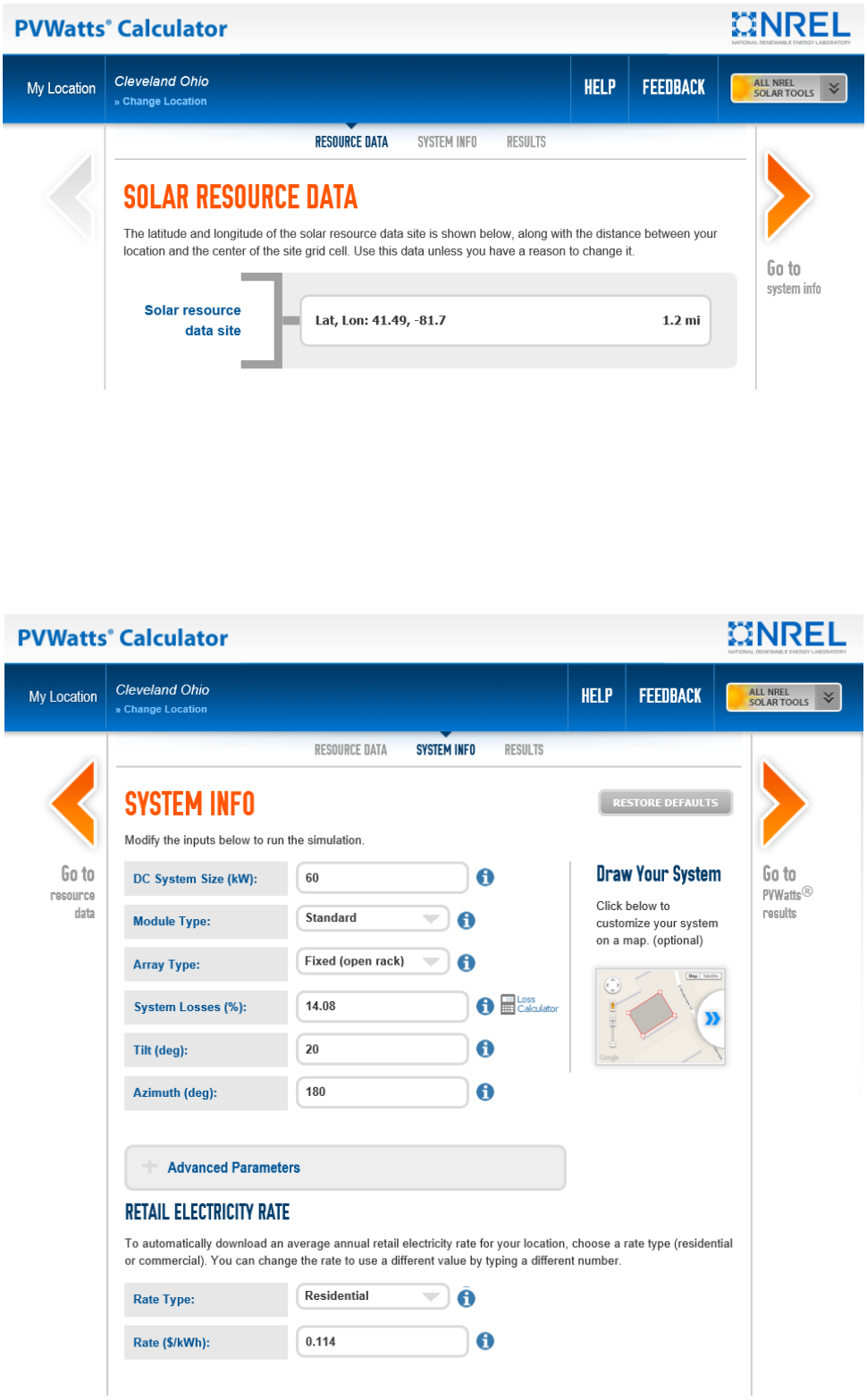


Figure D1. Input screens for NREL's PVWatts Calculator (https://pvwatts.nrel.gov/).

PVWatts® Calculator

NREL

My Location | Cleveland Ohio » Change Location | HELP | FEEDBACK | ALL NREL SOLAR TOOLS

RESOURCE DATA | SYSTEM INFO | RESULTS

Go to system info

RESULTS

Print Results

51,759 kWh/Year*

System output may range from 50,170 to 52,955 kWh per year near this location.
Click HERE for more information.

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)	Value ($)
January	2.30	2,489	283
February	3.15	3,041	346
March	4.34	4,509	513
April	5.21	5,054	575
May	5.93	5,771	657
June	6.48	5,873	668
July	6.82	6,296	716
August	6.07	5,643	642
September	5.20	4,708	536
October	3.79	3,799	432
November	2.67	2,612	297
December	1.82	1,965	224
Annual	4.48	51,760	$ 5,889

PVWatts® Calculator

NREL

My Location | Cleveland Ohio » Change Location | HELP | FEEDBACK | ALL NREL SOLAR TOOLS

RESOURCE DATA | SYSTEM INFO | RESULTS

Go to system info

RESULTS

Print Results

77,639 kWh/Year*

System output may range from 75,255 to 79,432 kWh per year near this location.
Click HERE for more information.

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)	Value ($)
January	2.30	3,733	425
February	3.15	4,561	519
March	4.34	6,763	770
April	5.21	7,582	863
May	5.93	8,657	985
June	6.48	8,809	1,003
July	6.82	9,443	1,075
August	6.07	8,465	963
September	5.20	7,062	804
October	3.79	5,698	648
November	2.67	3,918	446
December	1.82	2,947	335
Annual	4.48	77,638	$ 8,836

Figure D2. Output results from NREL's PVWatts Calculator (https://pvwatts.nrel.gov/).

APPENDIX E.
Reference EUIs for Comparison

Appendix E provides reference EUIs provided from the 2018 Energy Star Portfolio Manager for comparison purposes. This was provided to allow for a comparison of the EUIs from the base case and proposed Market Square development versus the EUIs from the US EPA Portfolio Manager as shown in the table below. The EUIs from the US EPA Portfolio Manager represent the median value energy use for buildings with similar functions as those proposed for the Market Square.

Comparison of EUIs	
	EUI (Site) (Btu/ft2-yr)
RETAIL EPA Port/Man (CBECS enc. mall)	65,700
RETAIL BASE - Dunham	56,300
RETAIL PROP - Dunham	39,400
Difference (Dunham Base-Prop/base)	*30%*
Difference (EPA-Prop/EPA)	*40%*
OFFICE EPA Port/Man (CBECS Off)	52,900
OFF BASE - Dunham	50,700
OFF PROP - Dunham	28,400
Difference (Dunham Base-Prop/base)	*44%*
Difference (EPA-Prop/EPA)	*46%*
APT EPA Port/Man (CBECS enc. mall)	59,600
APT BASE - Dunham	42,100
APT PROP - Dunham	25,800
Difference (Dunham Base-Prop/base)	*39%*
Difference (EPA-Prop/EPA)	*57%*
SOURCE: US EPA Portfolio Manager, August 2018	

Source: US EPA Portfolio manager, August 2018.

https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=5&cad=rja&uact=8&ved=2ahUKEwimk8q-zPPjAhWDna0KHTuHDbAQFjAEegQIAhAC&url=https%3A%2F%2Fportfoliomanager.energystar.gov%2Fpdf%2Freference%2FUS%2520National%2520Median%2520Table.pdf&usg=AOvVaw2_4goIe-UcFLf7o9h7t9n7

ENERGY STAR® PortfolioManager® Technical Reference

U.S. Energy Use Intensity by Property Type

OVERVIEW

This reference table is designed to help you to compare your property's energy use to the national median (or mid-point) energy use of similar properties.

Benchmarking your Property

When benchmarking in Portfolio Manager, we recommend that you focus on the primary function (or, main activity) in your building(s). Begin by selecting your primary function from the table below and then enter as few additional use types as possible. Benchmarking your building using a single use type will most closely approximate how your building would have been recorded in the reference data survey, and therefore yield the most accurate comparisons to median performance. In some cases, buildings may have multiple distinctly different uses. For example, an office and a hotel that share a common building. In these mixed-use settings, it is appropriate to enter multiple use types. Definitions of all property types are available at: www.energystar.gov/PMGlossary.

Using Median Site and Source Energy Use Intensity (EUI)

The ***national median source EUI*** is a recommended benchmark metric for all buildings. The median value is the middle of the national population – half of buildings use more energy, half use less. The median works better than the mean (arithmetic average) for comparing relative energy performance, because it more accurately reflects the mid-point of energy use for most property types.

The table presents the median in both ***site EUI*** and ***source EUI***. Site EUI is what you may be familiar with from your utility bills. Site EUI contains a mixture of what is called primary energy (i.e., a raw fuel like natural gas) and secondary energy (i.e., a converted product like electricity or district steam). Source energy provides the most equitable way to combine primary and secondary energy types into a single common unit, ensuring that no building receives either a credit or a penalty based on its energy source or utility. You can learn more about source energy and the way it is computed at www.energystar.gov/SourceEnergy. We strongly encourage you to use source EUI.

While almost all commercial building types have a national Median Source EUI, some (***presented in cyan***) will also have a 1-100 ENERGY STAR Score. The score evaluates a building relative to its peers, similar to the median energy use values, and also adjusts for climate and business activity. You can learn more about the score at: www.energystar.gov/ENERGYSTARScore.

Understanding Reference Data

The right-most column in the table indicates the reference data source we use to determine the median performance of buildings in your peer group. To compute the national median, we always rely on nationally representative data. For the majority of property types, the reference data is from the Commercial Building Energy Consumption Survey (CBECS). This is a national survey conducted by the U.S. Department of Energy's Energy Information Administration (for more information visit: http://www.eia.gov/consumption/commercial/). Three additional surveys are referenced for data centers, wastewater treatment plants, and multifamily housing. Additional information on these surveys can be found in the technical reference document for each property type.

ENERGY STAR® PortfolioManager®

Technical Reference

Broad Category	Primary Function	Further Breakdown (where needed)	Source EUI (kBtu/ft²)	Site EUI (kBtu/ft²)	Reference Data Source - Peer Group Comparison
Healthcare	Ambulatory Surgical Center		138.3	62.0	CBECS - Outpatient Healthcare
	Hospital	Hospital (General Medical & Surgical)*	426.9	234.3	Industry Survey
		Other/Specialty Hospital	433.9	206.7	CBECS - Inpatient Healthcare
	Medical Office*		121.7	51.2	CBECS - Medical Office
	Outpatient Rehabilitation/Physical Therapy		138.3	62.0	CBECS - Outpatient Healthcare
	Residential Care Facility		213.2	99.0	Industry Survey
	Senior Care Community*		213.2	99.0	Industry Survey
	Urgent Care/Clinic/Other Outpatient		145.8	64.5	CBECS - Clinic/Outpatient
Lodging/Residential	Barracks*		107.5	57.9	CBECS - Dormitory
	Hotel*		146.7	63.0	CBECS - Hotel & Motel/Inn
	Multifamily Housing*		118.1	59.6	Fannie Mae Industry Survey
	Prison/Incarceration		156.4	69.9	CBECS - Public Order and Safety
	Residence Hall/Dormitory*		107.5	57.9	CBECS - Dormitory
	Residential Care Facility		213.2	99.0	Industry Survey
	Senior Care Community*		213.2	99.0	Industry Survey
	Single Family Home		N/A	N/A	None Available
	Other - Lodging/Residential		143.6	63.6	CBECS - Lodging
Manufacturing/Industrial	Manufacturing/Industrial Plant		N/A	N/A	None Available
Mixed Use	Mixed Use Property		89.3	40.1	CBECS - Other
Office	Medical Office*		121.7	51.2	CBECS - Medical Office
	Office*		116.4	52.9	CBECS - Office & Bank/Financial
	Veterinary Office		145.8	64.5	CBECS - Clinic/Outpatient
Parking	Parking		N/A	N/A	None Available

ENERGY STAR® PortfolioManager®

Technical Reference

Broad Category	Primary Function	Further Breakdown (where needed)	Source EUI (kBtu/ft²)	Site EUI (kBtu/ft²)	Reference Data Source - Peer Group Comparison
Healthcare	Ambulatory Surgical Center		138.3	62.0	CBECS - Outpatient Healthcare
	Hospital	Hospital (General Medical & Surgical)*	426.9	234.3	Industry Survey
		Other/Specialty Hospital	433.9	206.7	CBECS - Inpatient Healthcare
	Medical Office*		121.7	51.2	CBECS - Medical Office
	Outpatient Rehabilitation/Physical Therapy		138.3	62.0	CBECS - Outpatient Healthcare
	Residential Care Facility		213.2	99.0	Industry Survey
	Senior Care Community*		213.2	99.0	Industry Survey
	Urgent Care/Clinic/Other Outpatient		145.8	64.5	CBECS - Clinic/Outpatient
Lodging/Residential	Barracks*		107.5	57.9	CBECS - Dormitory
	Hotel*		146.7	63.0	CBECS - Hotel & Motel/Inn
	Multifamily Housing*		118.1	59.6	Fannie Mae Industry Survey
	Prison/Incarceration		156.4	69.9	CBECS - Public Order and Safety
	Residence Hall/Dormitory*		107.5	57.9	CBECS - Dormitory
	Residential Care Facility		213.2	99.0	Industry Survey
	Senior Care Community*		213.2	99.0	Industry Survey
	Single Family Home		N/A	N/A	None Available
	Other - Lodging/Residential		143.6	63.6	CBECS - Lodging
Manufacturing/Industrial	Manufacturing/Industrial Plant		N/A	N/A	None Available
Mixed Use	Mixed Use Property		89.3	40.1	CBECS - Other
Office	Medical Office*		121.7	51.2	CBECS - Medical Office
	Office*		116.4	52.9	CBECS - Office & Bank/Financial
	Veterinary Office		145.8	64.5	CBECS - Clinic/Outpatient
Parking	Parking		N/A	N/A	None Available

ENERGY STAR® PortfolioManager®

Technical Reference

Broad Category	Primary Function	Further Breakdown (where needed)	Source EUI (kBtu/ft²)	Site EUI (kBtu/ft²)	Reference Data Source - Peer Group Comparison
Public Services	Courthouse*		211.4	101.2	CBECS - Courthouse
	Drinking Water Treatment & Distribution *(Average EUI presented in Energy per Flow in gallons per day)*		5.90	2.27	AWWA - Water Treatment Plant
	Fire Station		124.9	63.5	CBECS - Fire Station/Police Station
	Library		143.6	71.6	CBECS - Library
	Mailing Center/Post Office		96.9	47.9	CBECS - Service
	Police Station		124.9	63.5	CBECS - Fire Station/Police Station
	Prison/Incarceration		156.4	69.9	CBECS - Public Order and Safety
	Social/Meeting Hall		109.6	56.1	CBECS - Social/Meeting
	Transportation Terminal/Station		112.0	56.2	CBECS - Public Assembly
	Wastewater Treatment Plant* *(Average EUI presented in Energy per Flow in gallons per day)*		7.51	2.89	AWWA - Wastewater Plant
	Other - Public Services		89.3	40.1	CBECS - Other
Religious Worship	Worship Facility*		58.4	30.5	CBECS - Religious Worship
Retail	Automobile Dealership		124.1	55.0	CBECS - Retail other than Mall
	Convenience Store	Convenience Store with Gas Station	592.6	231.4	CBECS - Food Sales
		Convenience Store without Gas Station			
	Mall	Enclosed Mall	170.7	65.7	CBECS - Enclosed Mall
		Lifestyle Center	228.8	103.5	CBECS - Strip Shopping Mall
		Strip Mall			
		Other - Mall	225.3	101.6	CBECS - Enclosed Mall and Strip Shopping Mall
	Retail Store*		120.0	51.4	CBECS - Retail Store
	Supermarket/Grocery Store*		444.0	196.0	CBECS - Grocery Store/Food Market
	Wholesale Club/Supercenter*		120.0	51.4	CBECS - Retail Store

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