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Final Report

Duval County Unified Courthouse Facility

Jacksonville, Florida

Zach Polovchik

Mechanical

Advisor: Dustin Eplee

Duval County Unified Courthouse Facility

Jacksonville, Florida

PROJECT TEAM

Owner: City of Jacksonville
General Contractor: Turner Construction Company
Architect: KBJ Architects, Inc.
Structural Engineer: McVeigh & Mangum Engineering, Inc.
MEP Engineer: TLC Engineerng for Architecture, Inc.
Civil Engineer: CSI: Civil Services Inc.
Landscape Architect: FLAGG Design Studio, LLC.

PROJECT INFO

Cost: $224 Million
Building Size: 798,000 s.f.
Levels: 7 levels; All above grade
Construction Dates: May 2009 - May 2012
Delivery: Design-Build

ARCHITECTURE

- Aesthetics follow Neoclassical style through use of a symmetrical layout, a pediment-themed entrance, and dominant column use
- Seven levels with various occupancy types
  - Level 1: Office space, detention area, parking
  - Level 2: 51 total courtrooms and additional assembly and office spaces
  - Level 3: Office and hearing spaces
- Facade is dominated by limestone architectural precast concrete elements such as panels and columns and vertical strips of glazing.

STRUCTURAL

- Auger cast piles 55' feet for typical foundation or 70' for lateral piles with C.I.P. reinforced concrete pile caps and grade beams
- C.I.P. reinforced concrete columns, beams, and joists support elevated C.I.P reinforced concrete slabs
- Shear walls from lateral piles to roof levels at stair-wells and elevator shafts
- Roof supported by either C.I.P. concrete joists or steel beams/columns

ELECTRICAL/ LIGHTING

- Electric service provided by JEA public utility company with 4 transformers (2500 kVA)
- Emergency generator on site (1875 kVA)
- Lighting is primarily fluorescent T8, T5, or CFL
- Additional exterior lighting is Metal Halide

MECHANICAL

- 25 Air Handling Units (3300-50000 CFM) that are mostly VAV systems with terminal VAV boxes
- 16 two/four pipe Fan Coil Units in various locations
- Hot water provided by two boilers of 13390 MBH output
- Chilled water supplied by JEA public utility company
- Fire Protection is served by combination standpipes with wet and dry pipe systems connected to building fire alarm system

Zachary Polovchik | Mechanical Option | http://www.engr.psu.edu/ae/thesis/portfolios/2011/zap5003

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Acknowledgements

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Executive Summary

The Duval County Unified Courthouse Facility is a current construction project located in Jacksonville, Florida. It is a 798,000 square foot city/county government building that houses 51 courtrooms, judicial offices, hearing spaces, and required detention areas. The facility is expected to be completed in May 2012

The current mechanical system is a large Variable Air Volume system with terminal reheat VAV boxes for thermal conditioning. Ventilation air is brought in by three large Make-Up Air units, two of which are equipped with sensible energy wheels to reduce necessary ventilation air conditioning. Hot water for heating is generated by onsite natural gas boilers and chilled water for cooling is purchased from the local utility. The existing system is expected to achieve LEED Certification based on LEED V2.2 by the United State Green Building Council.

Alternatives were chosen in this study to achieve cooling load and necessary associated energy reduction. Alternatives were compared based on initial cost, life cycle cost, energy use & cost, simple payback, environmental impact, and LEED applicability. The alternative design options that were selected for analysis were solar load reduction via internal shading devices, a conversion to a decoupled Dedicated Outdoor Air System for ventilation and a hydronic Active Chilled Beam system for thermal conditioning, and the implementation of an onsite chiller plant. Internal shading proved to reduce the solar loads greatly and save energy on cooling. The decoupled Dedicated Outdoor Air System and Active Chilled Beams also reduced load and energy use through the reductions in airflow as well as ventilation air conditioning and an increase in cooling method efficiency. The chiller plant analyzed was a variable primary flow chiller plant with centrifugal chillers capable of handling the reduced loads. The chiller plant demonstrated more efficient means of supplying chilled water to the loads and required less total energy consumption than the system purchasing chilled water.

Additional topics such as a photovoltaic panel array analysis and a floor-to-floor height reduction analysis were also conducted. The solar panel array was sized in order to allow for an adequate simple payback period, yet still generate enough electricity to have an impact on the facility. Electricity generated by this array can be used to offset additional electrical uses from the motorized internal shading or chiller plant. It also assists in making the facility “greener” and applies to LEED. As a result of the system conversion to Dedicated Outdoor Air Systems and Active Chilled Beams, the required plenum space is reduced. The floor-to-floor height reduction saves both cost and construction time in the superstructure and building envelope.

After the analyses were performed, alternatives were compared based on the aforementioned criteria. The recommended alternative that had the best ratings in all categories was the conversion to a Dedicated Outdoor Air System with Active Chilled Beams and internal shading with the resulting floor-to-floor height reduction. This alternative with an additional chiller plant is considered the second most suitable alternative for the facility. This chiller plant alternative may prove to be a more feasible option if the purchased chilled water prices escalate.

Facility Introduction

The Duval County Unified Courthouse Facility is a 798,000 square feet, 7 level government building. The facility houses 51 total courtrooms as well as judicial offices, hearing spaces, and conference areas. It also includes parking areas, a detention zone, and building support areas on the first floor.

Its façade is predominantly precast limestone aggregate concrete panels and vertical spanning aluminum curtain wall vision glazing. Three large aluminum curtain walls with spandrel glazing also exist under the roofs to allow natural lighting into the front lobby and central atrium. The roof system is primarily a flat composite concrete insulated roof. Two sloped roofs exist over the lobby and central core of the building which use an insulated standing seam metal roof deck system.

The Duval County Unified Courthouse Facility is a $224 Million gross cost Design-Build project headed by the Turner Construction Company. It is expected to be complete in May 2012.

Existing Systems

Mechanical Design Objectives

The Duval County Unified Courthouse Facility is a very large judicial building that requires a system to handle such large floor area and volume of people. The building holds office space for administration and judges, courtrooms and hearing rooms, and a holding area. This being said, the mechanical system does not have to be complex to handle unique loads like laboratories or gymnasiums. The system has loads typical to that of a large office building. The system is designed to meet or exceed the minimum requirements of ASHRAE Standard 62.1 for ventilation and indoor air quality requirements. The system is also designed to meet most of the requirements in ASHRAE Standard 90.1 for energy efficiency. The building will obtain LEED Certification, and the mechanical systems' designs have been designed to earn the necessary LEED credits.

The facility operates on a weekday basis with typical government office building hours. Therefore, the mechanical systems have been designed with setbacks and optimal start and stop controls for higher efficiency and operate at a minimum rate for ventilation during unoccupied hours. Due to the building's location and climate in Florida, the mechanical systems have a large focus on the loads created by the weather, specifically the large solar gains and humid air conditions. The mechanical system is primarily used for cooling and dehumidification. The facility's heating system is designed to handle the mild winter that the location experiences.

Mechanical Systems Summary

Airside Operations

The Duval County Unified Courthouse Facility is served with outdoor air by three Make-Up Air Units (MAU). These MAUs distribute the ventilation air to 25 other Air Handling Units (AHU) in the building based on the need for fresh outdoor air. Two of these three MAUs utilize heat recovery

from the exhaust air via enthalpy wheels. The 51 courtrooms are served by 14 AHUs while the other 11 AHUs serve the remainder of the building. Most units are located on the interior of the building in mechanical rooms or penthouses. The exceptions to this are two AHUs and two MAUs that are located on the second floor roof.

The AHUs use CO2 sensors in the return air to determine the necessary ventilation air to be delivered to that unit. The AHUs mix the return air and ventilation air, and send it out to its served zones in the building. The units utilize optimum start and techniques to get the space to its ideal comfort level for the start of occupancy. The AHUs will remain off during unoccupied periods and only cycle on to main an unoccupied setback temperature. The MAUs are to remain operating 24/7 to dilute space air of CO2 and maintain building pressurization. The variable air volume from the MAUs is controlled via a Variable Frequency Drive on its supply fan. The MAUs that utilize energy recovery use an exhaust fan that is also equipped with a VFD. The supply air temperature and humidity from the MAUs is controlled by the enthalpy wheel, a pre-heating coil, a cooling coil, and re-heat coil. Pre-heat coils are utilized when the ambient outdoor air temperature drops too low to prevent freezing on the chilled water coil.

All AHUs utilize VFD's on the supply fan for variable air volume supply. The temperature in these units is controlled by the modulation of the valve for the chilled water coil. Zone airflow and extra thermal control is done via terminal VAV boxes. A total of 872 VAV boxes that range in size from 200 to 6300 CFM are used. If extra heating is needed, it is done in either the terminal VAV boxes or inside the unit with its own re-heat coil. Only four of these units have their own re-heat coil. These are the units that serve their own courtrooms at the north end of the building. Humidity control is modulated with a sensor in the return air. If the humidity rises above 60%, the cooling coil will lower its set point to dehumidify.

Schematics of the airside systems can be found either in Technical Report 3 or Appendix A of this report. The following tables provide schedules of the mechanical airside equipment used in the Duval County Unified Courthouse Facility.

Airside Equipment Schedules

Airside equipment is summarized in Tables 1-4.

Make Up Air Unit Schedule

	Supply Fan		Exhaust Fan		Filter	Energy Wheel	Cooling Coil					Pre-Heat & Re-Heat Coils			
Name	OA Flow (cfm)	HP	EA Flow (cfm)	HP	Class	Eff.	Sens. MBH	Total MBH	EWT	LWT	Flow (gpm)	Total MBH	EWT	LWT	Flow (gpm)
MAU-2E-1	40,000	60	26,000	25	MERV 13	74%	1,866	3,688	46°F	62°F	461	868	180°F	150°F	58
MAU-2W-1	40,000	60	26,000	25	MERV 13	74%	1,866	3,688	46°F	62°F	461	868	180°F	150°F	58
MAU-7-1	40,000	50	N/A	N/A	MERV 13	N/A	1,866	3,688	46°F	62°F	461	868	180°F	150°F	58

Table 1

Energy Wheel Properties				
	EA Dry Bulb	EA Wet Bulb	LA Dry Bulb	LA Wet Bulb
Summer	95	78	85	71
Winter	29	29	48	43

Table 2

Air Handling Unit Schedule													
Name	Airflows		Supply Fan	Filter	Cooling Coil					Heating Coil			
	OA (cfm)	Total (cfm)	HP	Class	Sens. MBH	Total MBH	EWT	LWT	Flow (gpm)	Total MBH	EWT	LWT	Flow (gpm)
AHU-2E-1	3,400	11,000	15	MERV 13	275	377	46 °F	62 °F	47	N/A	N/A	N/A	N/A
AHU-3E-1	5,290	14,100	20	MERV 13	352	483	46 °F	62 °F	60	N/A	N/A	N/A	N/A
AHU-3E-2	945	3,300	7.5	MERV 13	82	113	46 °F	62 °F	14	107	180 °F	150 °F	7
AHU-4E-1	5,290	14,100	20	MERV 13	352	483	46 °F	62 °F	60	N/A	N/A	N/A	N/A
AHU-4E-2	1,300	4,300	7.5	MERV 13	107	147	46 °F	62 °F	18	140	180 °F	150 °F	9
AHU-5E-1	5,290	14,100	20	MERV 13	352	483	46 °F	62 °F	60	N/A	N/A	N/A	N/A
AHU-6E-1	5,290	14,100	20	MERV 13	352	483	46 °F	62 °F	60	N/A	N/A	N/A	N/A
AHU-2W-1	3,400	11,000	15	MERV 13	275	377	46 °F	62 °F	47	N/A	N/A	N/A	N/A
AHU-3W-1	5,290	14,100	20	MERV 13	352	483	46 °F	62 °F	60	N/A	N/A	N/A	N/A
AHU-3W-2	945	3,300	7.5	MERV 13	82	113	46 °F	62 °F	14	107	180 °F	150 °F	7
AHU-4W-1	5,290	14,100	20	MERV 13	352	483	46 °F	62 °F	60	N/A	N/A	N/A	N/A
AHU-4W-2	1,300	4,300	7.5	MERV 13	107	147	46 °F	62 °F	18	140	180 °F	150 °F	9
AHU-5W-1	5,290	14,100	20	MERV 13	352	483	46 °F	62 °F	60	N/A	N/A	N/A	N/A
AHU-6W-1	5,290	14,100	20	MERV 13	352	483	46 °F	62 °F	60	N/A	N/A	N/A	N/A
AHU-2E-2	6,075	24,300	30	MERV 13	606	832	46 °F	62 °F	104	N/A	N/A	N/A	N/A
AHU-2E-3	12,500	50,000	75	MERV 13	1248	1712	46 °F	62 °F	214	N/A	N/A	N/A	N/A
AHU-7E-1	10,000	46,000	75	MERV 13	1148	1575	46 °F	62 °F	197	N/A	N/A	N/A	N/A
AHU-7E-2	5,000	46,000	75	MERV 13	1148	1575	46 °F	62 °F	197	N/A	N/A	N/A	N/A
AHU-7E-3	5,000	46,000	75	MERV 13	1148	1575	46 °F	62 °F	197	N/A	N/A	N/A	N/A

AHU-1W-1	12,500	50,000	75	MERV 13	1248	1712	46 °F	62 °F	214	N/A	N/A	N/A	N/A
AHU-2W-2	4,700	18,800	25	MERV 13	469	644	46 °F	62 °F	80	N/A	N/A	N/A	N/A
AHU-2W-3	4,150	16,500	20	MERV 13	412	565	46 °F	62 °F	71	N/A	N/A	N/A	N/A
AHU-7W-1	10,000	46,000	75	MERV 13	1148	1575	46 °F	62 °F	197	N/A	N/A	N/A	N/A
AHU-7W-2	5,000	46,000	75	MERV 13	1148	1575	46 °F	62 °F	197	N/A	N/A	N/A	N/A
AHU-7W-3	5,000	46,000	75	MERV 13	1148	1575	46 °F	62 °F	197	N/A	N/A	N/A	N/A

Table 3

Auxiliary Fan Schedule

Name	Service	Air Flow (cfm)	Type	HP
EF-1E-1	Fume Exhaust	11,250	Inline	2
EF-1E-2	General Exhaust	3030	Inline	1
EF-1E-3	Custodial Exhaust	1310	Inline	1/3
EF-1E-4	Garage Exhaust	18770	Inline	5
EF-2E-1	General Exhaust	10050	Roof Downblast	5
EF-5E-1	Server Room Purge	3300	Inline	3/4
EF-7E-1	General Exhaust	5000	Inline	3
EF-7E-2	Pressure Relief	20000	Inline	3
SF-E-1	Boiler Room Supply	8000	Wall Prop	1 1/2
EF-1W-1	Garage Exhaust	18770	Inline	5
EF-1W-2	Custodial Exhaust	1900	Inline	1/2
EF-1W-3	General Exhaust	3200	Inline	1
EF-2W-1	General Exhaust	9085	Roof Downblast	3
EF-2W-2	Server Room Purge	2000	Roof Downblast	3/4
EF-7W-1	General Exhaust	5000	Inline	3

Table 4

Waterside Operations

The hot water boilers provide heating services for the Duval County Unified Courthouse Facility through the use of heating coils in the Make-Up Air Units, Air Handling Units, and Terminal VAV Boxes. The boilers maintain a constant output temperature of 180 °F. Each boiler has two burners and two stages of firing per burner. Primary hot water is circulated through the boilers by two constant-speed pumps. Hot water is delivered to the loads by two secondary pumps controlled by Variable Frequency Drives. Most heating coils are controlled with two-way valves. Depending on humidity control requirements, one boiler may be shut off during intermediate seasons. When the occupancy schedule or optimum start dictates the heating system be enabled, the lead boiler will start with both burners operating at the high firing rate. As the water temperature reaches the low limit set point of 160 °F, the burners drop in firing rates as needed. As temperature drops to a 10 °F differential from the set point, the burners step back up. When the OA temperature is less than 65 °F, or if de-humidification requires re-heat, the lead boiler and its pumps will start. The lag boiler and its pumps will start when the OA temperature is less than 45 °F or if the return supply temperature cannot be maintained. The boiler will cycle on and off during unoccupied periods with the AHUs to maintain the night low limit set point.

Cooling for the facility is provided by purchased chilled water delivered to the site from the J.E.A Public Utility Company. Chilled water is distributed throughout the building through two variable flow chilled water pumps using VFDs. The pumps operate on an optimum start schedule related to the AHU schedules. The two pumps are sequenced to alternate the start and stop of the pumps based on chilled water demand. The chilled water supplied by the utility is normally 42 °F. The chilled water differential temperature (T_{CHWR}-T_{CHWS}) should be no less than 15.5 °F. If the supply water temperature is less than 44 °F and the temperature rise is less than 15 °F, the bypass valve will be modulated to mix and raise the supply temperature to no more than 44 °F.

Domestic cold water is provided by the J.E.A. Public Utility Company. This water enters a Triplex Pumping System to distribute domestic cold water throughout the building. At any point-of-use where hot water is required, an Instantaneous Electric Water Heater (IEW) is utilized.

Schematics of the water systems can be found in either Technical Report 3 or Appendix A of this report. The following tables provide schedules of the hydronic equipment used in the Duval County Unified Courthouse Facility.

Waterside Equipment Schedules

Waterside equipment is summarized in Tables5 & 6.

Boiler Schedule

Name	Fuel Type	Size (BHP)	Input Capacity (MBH)	Output Capacity (MBH)	Turndown
B-1	Nat. Gas	400	16,330	13,390	10:01
B-2	Nat. Gas	400	16,330	13,390	10:01

Table 5

Pump Schedule					
Name	System	Flow (gpm)	Type	Efficiency	HP
CHWP-1	Ch. Water	2,200	HSC	80%	200
CHWP-1	Ch. Water	2,200	HSC	80%	200
PHWP-1	Boiler	35	HSC	83%	15
PHWP-2	Boiler	35	HSC	83%	15
SHWP-1	Hot Water	175	HSC	80%	100
SHWP-2	Hot Water	175	HSC	80%	100
P-2W-1	MAU Circ.	25	Inline	63%	1
P-2E-1	MAU Circ.	25	Inline	63%	1
P-7-1	MAU Circ.	25	Inline	63%	1

Table 6

Design Conditions

Outdoor design conditions for the site of the Duval County Unified Courthouse Facility were taken from the 2009 ASHRAE Handbook of Fundamentals. The values are used for Jacksonville NAS, FL, USA and are summarized in Table 7.

Outdoor Design Conditions		
Heating Conditions (99.6%)	Cooling Conditions (0.4%)	
OA Dry Bulb (°F)	OA Dry Bulb (°F)	OA Wet Bulb (°F)
32.2	95.5	77.2

Table 7

The indoor design conditions were taken from the design documents provided for the facility. The summer and winter conditions are summarized in Table 8 below.

Indoor Design Conditions	
Summer Design T (°F)	Winter Design T (°F)
75	70

Table 8

Energy Sources

The Duval County Unified Courthouse Facility energy is primarily served by the J.E.A. Public Utility Company. Possible utilities available in Jacksonville are electricity, natural gas, domestic water & sewage, and district chilled water. The J.E.A Public Utility Company provides electricity, domestic water & sewage, and district chilled water. Electric consumption and demand rates from J.E.A. are summarized in Table 9. The domestic and chilled water rates are summarized in Table 10. Natural gas is provided in the area by TECO-People's Gas. The natural gas rates are provided in Table 11.

J.E.A. Electric Rates	
January-December	Unit Cost
Electric Demand	$10.00/kW
Electric Consumption	$0.10/kWh

Table 9

J.E.A. Water Rates	
Utility	Unit Cost
Domestic Water	$1.43/kgal
Chilled Water	$1.32/therm

Table 10

TECO Natural Gas Rate	
Utility	Unit Cost
Natural Gas	$0.83/therm

Table 11

In order to compare the energy costs, the rates of energy use have been converted to a cost per MBTU base. These prices are shown in Table 12. This shows that the least expensive source of energy is Natural Gas, and the most expensive energy to the site is Electricity.

Utility Rates	
Utility	Unit Cost
Electricity	$0.0292/MBTU
Chilled Water	$0.0132MBTU
Natural Gas	$0.0083/MBTU

Table 12

Mechanical System Cost

No cost information specific to the mechanical systems has been made available from the contractor. However, a net cost of $27,578,000 for HVAC, plumbing and fire protection has been made available. This equates to 16% of the total building cost. System cost information has been completed using RS Means Cost Estimating supplements. This was required in order to do Life Cycle Cost analyses on the existing and proposed systems. The total initial cost of the VAV and chilled water systems have been estimated to **$2,608,539**. This cost includes all air handling units, VAV systems and boxes, and components of the chilled water system. It however omits the cost of the boiler and its accessories because the heating system is not being analyzed in this report. The 20 Year Life Cycle Cost of the existing system has been calculated to be **$20,575,135**. The calculations for the LCC analysis are available in Appendix C of this report.

Ventilation Requirements Evaluation

An analysis on the Duval County Unified Courthouse Facility using ASHRAE Standard 62.1 was performed to determine the minimum ventilation rates required for occupied spaces. The HVAC system designed for ventilation utilizes three Make-Up Air Units to supply outdoor air to the multiple Air Handling Units that distribute air throughout the building. A comparison of the calculated and design ventilation rates are summarized in Table 13. The calculated values are those generated in the energy model ventilation calculations using ASHRAE 62.1 minimum requirements from Technical Report 2.

Building Airflow Comparison

	Total Airflow	Ventilation Airflow	Total Airflow per Unit Area	Ventilation Airflow per Unit Area
	(CFM)	(CFM)	(CFM/ft²)	(CFM/ft²)
Model	576,843	137,099	0.79	0.19
Design	585,600	133,535	0.80	0.18
% Deviation	**1.5%**	**2.7%**		

Table 13

Energy Efficiency Requirements Evaluation

An analysis on the Duval County Unified Courthouse Facility using ASHRAE Standard 90.1 was performed in order to determine the facility's compliance with energy standards. The facility has an extensive amount of glazing that is not in compliance with energy standards. The building uses the Building Envelope Trade-Off Option in order to allow for excess fenestration while making other equipment more efficient than the standard dictates. Most equipment used in the facility is in compliance with the standard, however fans for some AHUs exceed HP limitations set by the standard.

System Loads

The design loads were estimated using a load and energy simulation analysis tool. The software used for this process was Trane TRACE 700. The program performed an hourly analysis for one year to determine the loads and energy consumption for the building. The program requires that each space be modeled for certain loads such as internal loads from occupants, equipment, and lighting; ventilation loads based on required outdoor ventilation air needed in the space; and building envelope loads from exterior walls, glazing, and roofs based on the materials' properties.

Internal loads are dominated by occupants in the building. Default values in the software were used to calculate the occupant densities. Lighting loads used were based on the lighting power density of 1.209 W/ft^2 that was calculated as part of the ASHRAE Standard 90.1 lighting power density compliance check. Miscellaneous loads were assumed zero except in office spaces and server rooms. The internal loads templates used in the model have been summarized in Table 14 below.

Trane TRACE Internal Load Summary

Space Type	People Density	Sensible Load	Latent Load	Computer Load	Lighting Power Density	Misc. Power Density
	(ft^2/person)	(BTU/hr)	(BTU/hr)		(W/ft^2)	(W/ft^2)
Holding Cell	11	250	250	-	1.209	-
Computer Lab	50	250	250	1/person	1.209	0.5
Conference Space	20	245	155	-	1.209	-
Corridor	0	-	-	-	1.209	-
Courtroom	14	245	155	2 total	1.209	-
Library	100	250	250	.5/person	1.209	0.2
Lobby	16.7	245	155	-	1.209	-
Locker Room/ RR	120	250	250	-	1.209	-
Main Lobby	100	250	250	-	1.209	-
Mech./Elect. Rooms	0	-	-	-	1.209	-
Office Space	143	250	200	1/person	1.209	0.5
Parking	0	-	-	-	1.209	-
Sallyport	200	275	275	-	1.209	-
Server Room	0	-	-	-	1.209	50
Shaft	0	-	-	-	0	-
Storage Space	200	275	275	-	1.209	-

Table 14

Airflow loads were calculated by the software based on required minimum outdoor ventilation airflow to the spaces based on their type and occupancy. The program uses ASHRAE Standard 62.1 ventilation requirements. The airflow templates used in the model have been summarized in Table 15 below.

Trane TRACE Airflow Load Summary

Space Type	Std. 62.1		Infiltration	VAV Minimum
	People OA (cfm/person)	Area OA (cfm/ft²)	(AC/hr)	(% Airflow)
Computer Lab	10	0.12	0.3	30
Conference Space	5	0.06	0.3	30
Corridor	0	0.06	0.3	30
Courtroom	5	0.06	0.3	30
Elect./Mech. Spaces	0	0.06	0.3	30
Main Lobby	5	0.06	0.3	30
Holding Cells	5	0.12	0.3	30
Library	5	0.12	0.3	30
Lobby	5	0.06	0.3	30
Office Space	5	0.06	0.3	30
Parking	-	1.5	0.3	30
Locker Room/ RR	50	-	0.3	30
Sallyport	7.5	0.06	0.3	30
Server Room	5	0.06	0.3	30
Shaft	-	-	0.3	30
Storage Space	0	0.12	0.3	30
Waiting Areas	5	0.06	0.3	30

Table 15

The software uses construction templates to specify the building envelope materials' properties. All spaces have the same external envelope materials, so these templates are very similar. Envelope material values were taken from the design documents and are those that were analyzed in the ASHRAE Standard 90.1 energy compliance study. This template also takes into account the space and plenum heights. The ceiling heights in the Duval County Unified Courthouse Facility vary depending on space type. For example, courtrooms have 13 foot high ceilings, while most offices have 10 foot high ceilings. The construction templates used in this model have been summarized in Table 16.

Trane Trace Envelope Load Summary							
Space Type	Space Height	Plenum Height	Slab U-Factor	Roof U-Factor	Wall U-Factor	Glazing U-Factor	Glazing Shading Coefficient
	(ft)	(ft)	(BTU/h*ft²*F)	(BTU/h*ft²*F)	(BTU/h*ft²*F)	(BTU/h*ft²*F)	
Corridor	12	6	0.73	0.048	0.168	0.62	0.29
Courtroom	13	4					
Main Lobby	18	0					
Default	10	8					
Shaft	18	0					

Table 16

Each space is assigned a template for the three aforementioned load types based on its occupancy, purpose, and space type. A list of the spaces modeled in the Trane TRACE software is available in Appendix B. The list includes space type, area, internal load template, airflow load template, and construction template. For simplicity, shaft spaces for ducts, raceway, and elevators have been removed from the list.

The energy model also requires schedules for occupancy, lighting & miscellaneous equipment, and HVAC functions. These schedules dictate how often the loads affect the building and at what time. They also function as controls for the HVAC equipment to handle these loads.

Two occupancy schedules have been created for the model of the Duval County Unified Courthouse Facility. The first is an office occupancy schedule for normal weekdays. This is shown in Table 17. The detention area will most likely have occupants all 24 hours of the day, so a separate schedule has been created for those spaces. This is summarized in Table 18.

Office Occupancy Schedule		
Hours		Occupancy
Start	End	(%)
12:00 AM	6:00 AM	0
6:00 AM	7:00 AM	10
7:00 AM	8:00 AM	30
8:00 AM	11:00 AM	100
11:00 AM	1:00 PM	75
1:00 PM	5:00 PM	100
5:00 PM	6:00 PM	10
6:00 PM	12:00 AM	0

Table 17

Detention Area Occupancy Schedule		
Hours		Occupancy
Start	End	(%)
12:00 AM	12:00 AM	100

Table 18

Three schedules were created for the lighting and receptacles. Two schedules for office spaces, one for the typical weekday and the other for the weekend, are modeled. These schedules are summarized in Tables 19 & 20. The third schedule is for the detention area's requirement for constant lighting. This lighting schedule is summarized in Table 21.

Office Lighting/Receptacle Schedule (Weekday)		
Hours		Lighting/Equip. On
Start	End	(%)
12:00 AM	6:00 AM	5
6:00 AM	7:00 AM	25
7:00 AM	8:00 AM	80
8:00 AM	10:00 AM	90
10:00 AM	12:00 PM	95
12:00 PM	2:00 PM	85
2:00 PM	4:00 PM	90
4:00 PM	5:00 PM	95
5:00 PM	6:00 PM	80
6:00 PM	7:00 PM	70
7:00 PM	8:00 PM	60
8:00 PM	9:00 PM	40
9:00 PM	10:00 PM	30
10:00 PM	12:00 AM	20

Table 19

Office Lighting/Receptacle Schedule (Weekend)		
Hours		Lighting/Equip On
Start	End	(%)
12:00 AM	12:00 PM	5

Table 20

Detention Area Lighting Schedule		
Hours		Lighting/Equip. On
Start	End	(%)
12:00 AM	6:00 AM	35
6:00 AM	9:00 AM	75
9:00 AM	8:00 PM	100
8:00 PM	10:00 PM	50
10:00 PM	12:00 AM	35

Table 21

Three schedules were created for the HVAC equipment. Two schedules for office spaces, one for the typical weekday and the other for the weekend, are modeled. These schedules are summarized in Tables 22 & 23. The third schedule is for the detention area's requirement for constant ventilation and conditioning. This HVAC schedule is summarized in Table 24.

Office HVAC Schedule (Weekday)		
Hours		HVAC Equipment Operation
Start	End	(%)
12:00 AM	6:00 AM	0
6:00 AM	12:00 AM	100

Table 22

Office HVAC Schedule (Weekend)		
Hours		HVAC Equipment Operation
Start	End	(%)
12:00 AM	12:00 AM	0

Table 23

Detention Area HVAC Schedule		
Hours		HVAC Equipment Operation
Start	End	(%)
12:00 AM	12:00 AM	100

Table 24

With the aforementioned inputs, the program was able to calculate loads for each space and system. Table 25 below summarizes the total cooling and heating loads on the entire building. No design information for the systems' or building's loads have been provided by the engineering team, so no comparison has been done.

Building Loads			
Cooling Load (Tons)	Area/Cooling Load (ft^2/Ton)	Heating Load (MBH)	Heating Load/Area ($BTUh/ft^2$)
2030	360.6	10729	14.66

Table 25

Annual Energy Consumption & Costs

Energy consumption was modeled using the same Trane TRACE software and energy modeling analysis. The Duval County Unified Courthouse uses three sources of energy: Electricity for lighting, receptacles, equipment, fans and pumps; Natural Gas for the hot water boiler; and Purchased Chilled Water for cooling purposes. The annual energy consumptions and demands are summarized in Table 26.

Energy Use Summary						
Electric		Natural Gas		Chilled Water		Total
Consumption (kWh)	Peak Demand (kW)	Consumption (MCF)	Peak Demand (MCF/hr)	Consumption (kGal)	Peak Demand (Gal/hr)	Consumption (MMBTU)
5,176,611	1,880	783	5.8	341	227.7	55,081

Table 26

The total building energy consumption for one year is expressed in a total MMBTU format by converting all energy consumption values to this unit. The Duval County Unified Courthouse Facility uses approximately **55,081 MMBTU**. This simplifies down to **69.03 kBTU/ft^2**. The percentages of each energy sources' contribution to the total is in Chart 1.

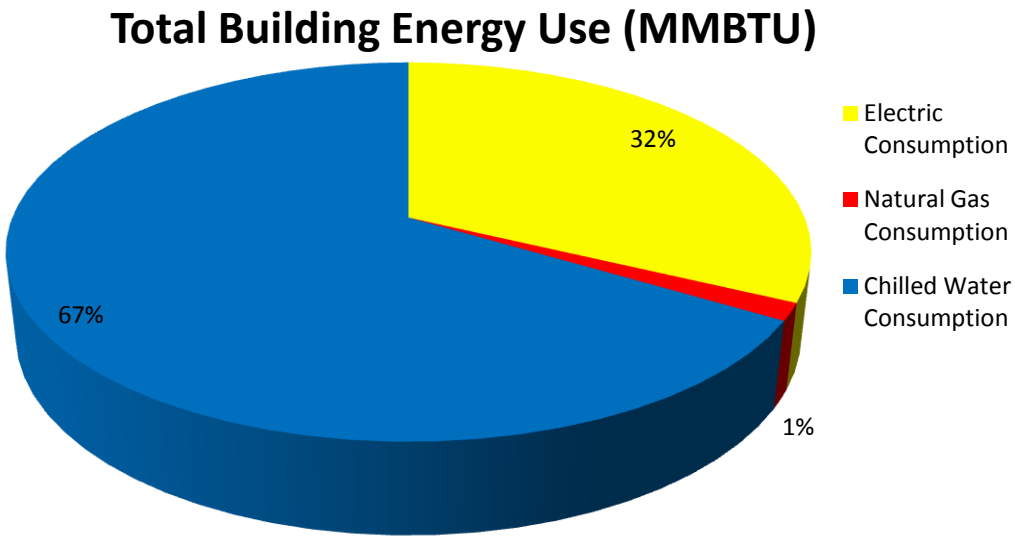


Chart 1

The monthly energy consumptions are shown in the charts below for each energy source. The profiles of monthly energy usage seem accurate based on what the energy is used for. The electric usage (Chart 2) has a relatively constant profile throughout the year because the electricity is only used for lighting, receptacles, fans, and pumps. It rises slightly in summer months, but this is only due to increased fan usage and chilled water pumping for cooling. The natural gas usage (Chart 3) follows the normal profile for heating with its peak in the winter months and no natural gas usage in the summer months. The purchased chilled water usage (Chart 4) also follows a normal profile for cooling as its peak is in the summer. Chilled water is still required in the winter months due to internal loads in the building.

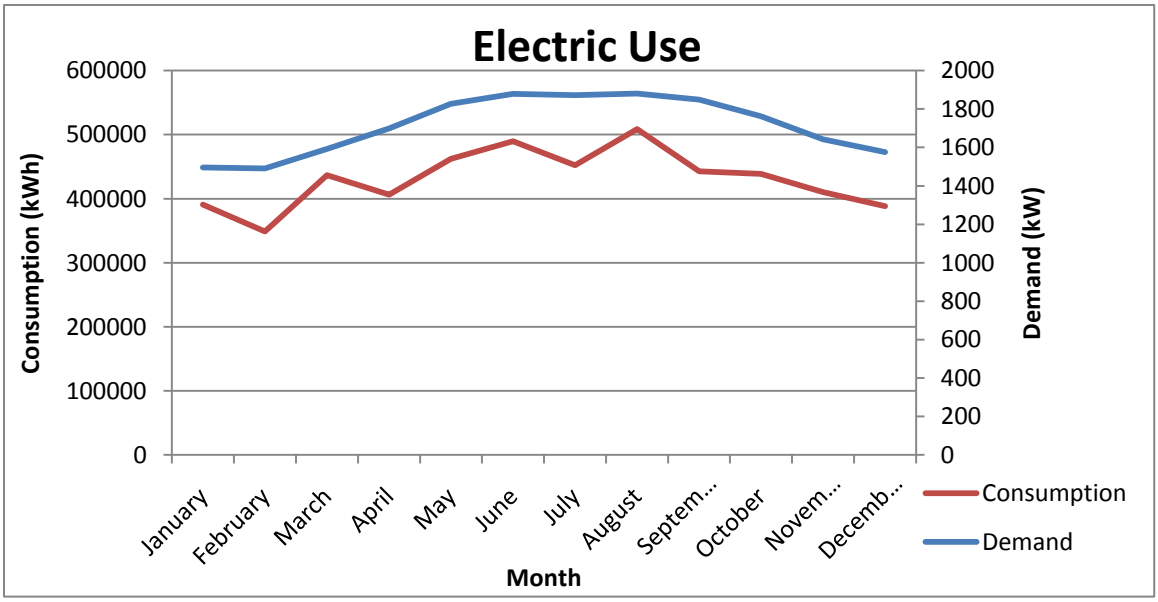


Chart 2

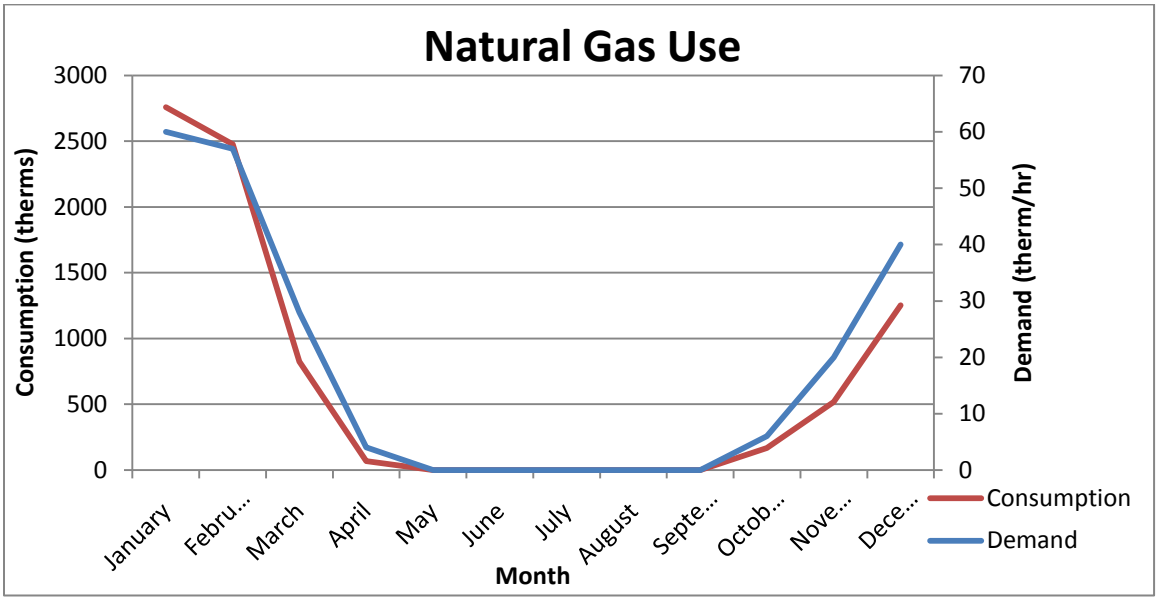


Chart 3

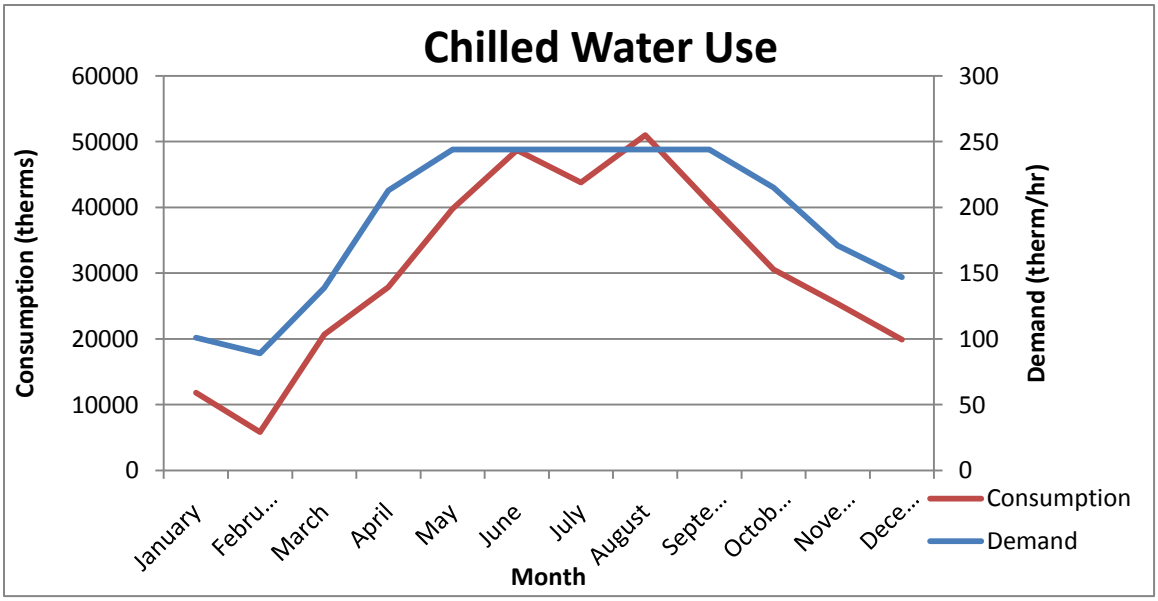


Chart 4

The Duval County Unified Courthouse Facility has no record of actual utility costs due to the fact that it is currently under construction. The utility rates used for the energy costs are those supplied by the engineering design team and summarized in the Energy Sources section of this report. Annual energy costs were analyzed using these rates and the energy consumption and demand values calculated in the energy model simulation. The annual utility costs are broken down by energy source in Table 27. The charges sum up to a total annual utility cost of **$1,213,321.98.** This equates to approximately **$1.52/ft²** annually. Chart 5 shows the percentages of each utility cost.

Energy Cost Summary					
Electric			Natural Gas	Chilled Water	Total
Consumption	Demand	Total	Consumption	Consumption	Consumption
$517,661.10	205,690.00	$723,351.10	$6,696.44	$483,274.44	$1,213,321.98

Table 27

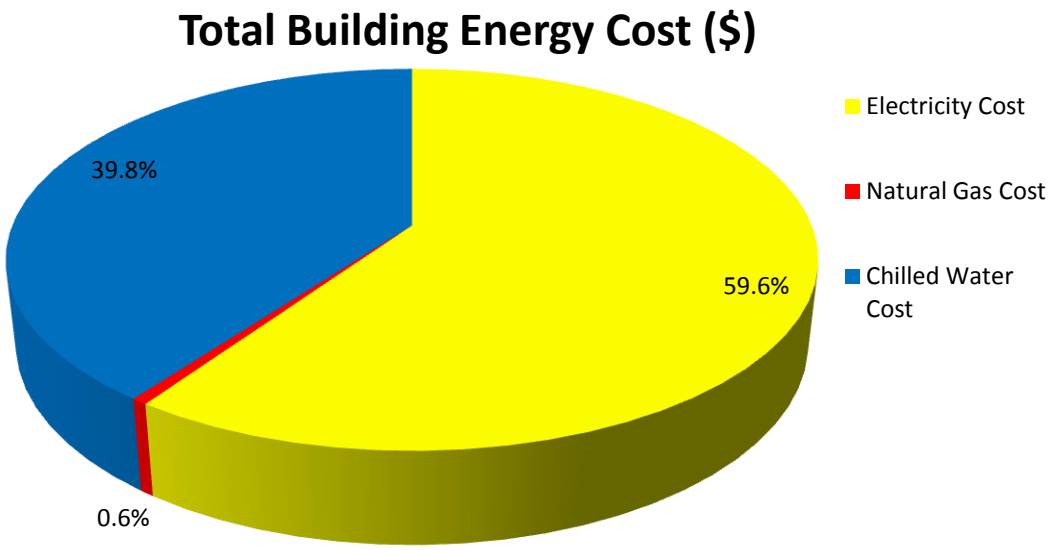


Chart 5

Emissions Data

The site of the Duval County Unified Courthouse Facility is in the FRCC region of the Eastern Interconnection of the United States Electrical Grid. The region is shown in Figure 1 below.

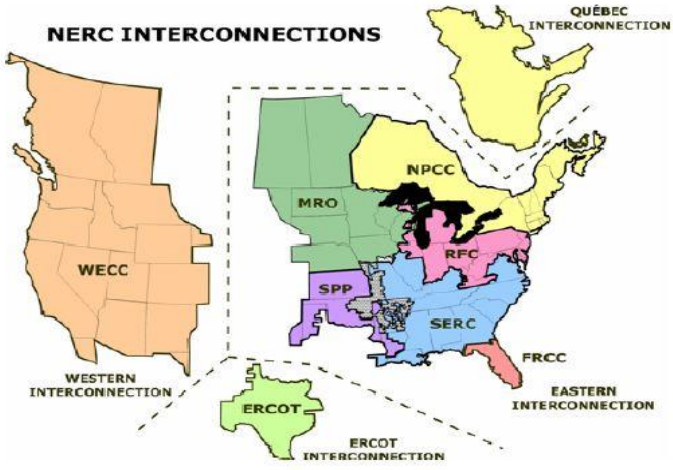


Figure 1

Through the use of the energy consumption information provided in the simulation model, annual emissions data can be generated using supplementary information from the National Renewable Energy Laboratory (NREL). Figure 2 below shows the emission factors for many different types of pollutants for each grid region.

Pollutant (lb)	National	Eastern	Western	ERCOT	Alaska	Hawaii
CO_{2e}	1.67E+00	1.74E+00	1.31E+00	1.84E+00	1.71E+00	1.91E+00
CO_2	1.57E+00	1.64E+00	1.22E+00	1.71E+00	1.55E+00	1.83E+00
CH_4	3.71E-03	3.59E-03	3.51E-03	5.30E-03	6.28E-03	2.96E-03
N_2O	3.73E-05	3.87E-05	2.97E-05	4.02E-05	3.05E-05	2.00E-05
NO_X	2.76E-03	3.00E-03	1.95E-03	2.20E-03	1.95E-03	4.32E-03
SO_X	8.36E-03	8.57E-03	6.82E-03	9.70E-03	1.12E-02	8.36E-03
CO	8.05E-04	8.54E-04	5.46E-04	9.07E-04	2.05E-03	7.43E-03
TNMOC	7.13E-05	7.26E-05	6.45E-05	7.44E-05	8.40E-05	1.15E-04
Lead	1.31E-07	1.39E-07	8.95E-08	1.42E-07	6.30E-08	1.32E-07
Mercury	3.05E-08	3.36E-08	1.86E-08	2.79E-08	3.80E-08	1.72E-07
PM10	9.16E-05	9.26E-05	6.99E-05	1.30E-04	1.09E-04	1.79E-04
Solid Waste	1.90E-01	2.05E-01	1.39E-01	1.66E-01	7.89E-02	7.44E-02

Figure 2

Based on the delivered electricity in kWh to the Duval County Unified Courthouse Facility calculated from the simulation and these emission factors, the total annual emissions for the building can be calculated for the specific grid region. This is summarized in Table 28.

Annual Emissions for Electrical Consumption				
Electric Use	1	kWh	5,176,611	kWh
Pollutant	Eastern Interconnection Emission Factor		Annual Pollution	
CO_{2e}	1.74E+00		9,007,303.14	lb
CO_2	1.64E+00		8,489,642.04	lb
CH_4	3.59E-03		18,584.03	lb
N_2O	3.87E-05		200.33	lb
NO_x	3.00E-03		15,529.83	lb
SO_x	8.57E-03		44,363.56	lb
CO	8.54E-04		4,420.83	lb
TNMOC	7.26E-05		375.82	lb
Lead	1.39E-07		0.72	lb
Mercury	3.36E-08		0.17	lb
PM10	9.26E-05		479.35	lb
Solid Waste	2.05E-01		1,061,205.26	lb

Table 28

NREL also provides emissions coefficients for onsite combustion in a commercial boiler. The boilers in the Duval County Unified Courthouse Facility consume approximate 783 MCF of natural gas annually. Figure 3 shows the emission factors associated with each pollutant for specific types of combustion. Table 29 is a summary of the pollutant emissions from the facility's boilers.

Pollutant (lb)	Commercial Boiler					
	Bituminous Coal *	Lignite Coal **	Natural Gas	Residual Fuel Oil	Distillate Fuel Oil	LPG
	1000 lb	1000 lb	1000 ft^3 ***	1000 gal	1000 gal	1000 gal
CO_{2e}	2.74E+03	2.30E+03	1.23E+02	2.56E+04	2.28E+04	1.35E+04
CO_2	2.63E+03	2.30E+03	1.22E+02	2.55E+04	2.28E+04	1.32E+04
CH_4	1.15E-01	2.00E-02	2.50E-03	2.31E-01	2.32E-01	2.17E-01
N_2O	3.68E-01	ND †	2.50E-03	1.18E-01	1.19E-01	9.77E-01
NO_X	5.75E+00	5.97E+00	1.11E-01	6.41E+00	2.15E+01	1.57E+01
SO_X	1.66E+00	1.29E+01	6.32E-04	4.00E+01	3.41E+01	0.00E+00
CO	2.89E+00	4.05E-03	9.33E-02	5.34E+00	5.41E+00	2.17E+00
VOC	ND †	ND †	6.13E-03	3.63E-01	2.17E-01	3.80E-01
Lead	1.79E-03	6.86E-02	5.00E-07	1.51E-06	ND †	ND †
Mercury	6.54E-04	6.54E-04	2.60E-07	1.13E-07	ND †	ND †
PM10	2.00E+00	ND †	8.40E-03	4.64E+00	1.88E+00	4.89E-01

* from the U.S. LCI data module: Bituminous Coal Combustion in an Industrial Boiler (NREL 2005)
** from the U.S. LCI data module: Lignite Coal Combustion in an Industrial Boiler (NREL 2005)
*** Gas volume at 60°F and 14.70 psia.
† no data available

Figure 3

Annual Emissions for Boiler				
Natural Gas Use	1	MCF	783	MCF
Pollutant	Natural Gas Emission Factor		Annual Pollution	
CO2e	1.23E+02		96,252.57	lb
CO2	1.22E+02		95,470.03	lb
CH4	2.50E-03		1.96	lb
N2O	2.50E-03		1.96	lb
Nox	1.11E-01		86.86	lb
Sox	6.32E-04		0.49	lb
CO	9.33E-02		73.01	lb
VOC	6.13E-03		4.80	lb
Lead	5.00E-07		0.00	lb
Mercury	2.60E-07		0.00	lb
PM10	8.40E-03		6.57	lb

Table 29

The facility does not put out emissions by making chilled water with an electric compressor, however, the facility still contributes to greenhouse gas emissions for the generation of the chilled water they purchase. The Energy Information Administration (EIA) provides some estimates on indirect greenhouse gas emission factors based on different types of purchased district energy. The district chilled water plant that is part of the J.E.A. Public Utility Company generates chilled water through the use of electric driven chillers. The information for this calculation was found in the Form EIA-1605 Appendices F&N. The equation for the emission factor of this type of purchased chilled water is below. Table 30 summarizes the calculation and emissions contribution for the district chilled water.

$EF_{Chilled\ Water}=0.921*EF_{Electric/Inventory}$ *(Equation 1)*

Where: $EF_{Chilled\ Water}$= Emissions factor in kg CO_{2e}/ton hour of chilled water purchased

$EF_{Electric/Inventory}$=Appropriate Regional Electricity Emissions Factor from Appendix F in MT CO_{2e}/MWh

Annual Emissions for Purchased Chilled Water						
Chilled Water Use	36,611,700	kBTU	3,050,975	Ton*hr		
Pollutant	Region Electric EF (Ton/MWh)		Chilled Water EF (kg/Ton*hr)		Annual Pollution (kg)	Annual Pollution (lb)
CO2e	0.678		0.624		1,905,144.73	4,191,318.40

Table 30

LEED Analysis

The Leadership in Energy and Environmental Design (LEED) was formed by the United States Green Building Council to help building owners and design teams utilize energy efficient and environmentally friendly construction practices. LEED has two categories that are directly influenced by the mechanical design team. These categories are Energy and Atmosphere (EA) and Indoor Environmental Quality (EQ). The Duval County Unified Courthouse Facility is currently on track to obtain LEED certification through the LEED for New Construction V2.2 with 32 points approved. However, some extra points are still under delegation and LEED Silver Certification under V2.2 is a possibility. For the purpose of the analysis on the Duval County Unified Courthouse Facility (DCUCF), only credits from the two aforementioned categories are being studied.

Energy & Atmosphere

EA Prerequisite 1: Fundamental Commissioning of the Building Energy Systems - Yes

Intent: Verify that the building's energy related systems are installed, calibrated and perform according to the owner's project requirements, basis of design, and construction documents.

DCUCF:A Commissioning Authority (CxA) has been designated to review and oversee the commissioning process. The owner has documented their Owner's Project Requirements (OPR)

and the design team has developed their Basis of Design (BOD). The CxA has reviewed both the OPR and BOD. Upon completion, a commissioning report shall be completed and delivered to the owner.

EA Prerequisite 2: Minimum Energy Performance – Yes

Intent: Establish the minimum level of energy efficiency for the building and systems.

DCUCF:The facility is in compliance with the required mandatory provisions of ASHRAE Standard 90.1 and meets the performance requirements outlined in Section 11 of the standard based on the prescriptive requirements for this credit.

EA Prerequisite 3: Fundamental Refrigerant Management– Yes

Intent: Reduce ozone depletion through reduction of CFC-based refrigerants.

DCUCF: No chiller system is on site, therefore no refrigerants are used.

EA Credit 1: Optimize Energy Performance – Yes

Intent: Achieve higher levels of energy efficiency for the building above the prerequisite for the building and its systems to further reduce environmental and economical impacts of excessive energy use.

DCUCF:The design team of the facility utilized a Whole Building Energy Simulation to keep track of this credit. The building was compared to the baseline building of ASHRAE Standard 90.1 with the Building Performance Rating Method of Appendix G in the standard. The building was analyzed using a software tool known as VisualDOE. The building achieved a 14% energy savings over the baseline building and received 2 points in this category.

EA Credit 2: On-Site Renewable Energy – No

Intent: Increase levels of on-site renewable energy to reduce environmental and economical impacts from fossil fuel energy use.

DCUCF:The design team did not incorporate any On-Site Renewable energy for the project.

EA Credit 3: Enhanced Commissioning – No

Intent: Begin commissioning process early and continue after design is complete for performance verification testing.

DCUCF:The scope of the project did not include enhanced commissioning, only Fundamental Commissioning Authority.

EA Credit 4: Enhanced Refrigerant Management –Yes

Intent: Reduce ozone depletion and support the Montreal Protocol.

DCUCF:The facility does not use refrigerants, therefore the point for this credit is applied.

EA Credit 5: Measurement and Verification – Maybe

Intent: Provide accountability for the energy use of the building over time.

DCUCF:The design team is currently developing a M&V Plan for post-construction. No further information has been provided on their strategy, but the credit is pending.

EA Credit 6: Green Power – No

Intent: Encourage use of renewable energy sources purchased from the electric grid.

DCUCF:The facility will not be purchasing any renewable energy through its grid.

Indoor Environmental Quality

EQ Prerequisite 1: Minimum IAQ Performance - Yes

Intent: Enhance indoor air quality by establishing a minimum IAQ performance and contribute to the comfort and well-being of occupants.

DCUCF:The facility meets the minimum requirements of Sections 4 through 7 of ASHRAE Standard 62.1 and all ventilation systems have been designed using the Ventilation Rate Procedure.

EQ Prerequisite 2: Environmental Tobacco Smoke Control – Yes

Intent: Minimize exposure of building occupants, indoor surfaces and ventilation air to Environmental Tobacco Smoke

DCUCF:Smoking is prohibited in the building. Therefore the facility automatically applies to this prerequisite.

EQ Credit 1: Outdoor Air Delivery Monitoring – Yes

Intent: Provide monitoring of the ventilation system to sustain occupant comfort and well-being.

DCUCF:Carbon Dioxide concentrations are monitored and outdoor air flow rates are measured to verify that the adequate amount is being supplied according to ASHRAE Standard 62.1.

EQ Credit 2: Increased Ventilation – No

Intent: Provide additional outdoor air ventilation to improve the indoor air quality.

DCUCF:The project team chose not to obtain this credit due to the large amount of air it must bring in due to its occupancy and size.

EQ Credit 3.1: Construction IAQ Management Plan; During Construction – Yes

Intent: Reduce IAQ problems resulting from construction processes to sustain the comfort and well-being of the construction workers and future occupants.

DCUCF:Turner Construction, the construction management team, is currently implementing a construction IAQ plan. All measures being implemented are being photographed and documented.

The construction plan includes the use of temporary filtration media and duct sealing and protection.

EQ Credit 3.2: Construction IAQ Management Plan; Before Occupancy – No

Intent: Reduce IAQ problems resulting from construction processes to sustain the comfort and well-being of the construction workers and future occupants.

DCUCF:The design team is not currently pursuing this credit.

EQ Credit 4.1: Low-Emitting Materials; Adhesives & Sealants – Yes

Intent: Reduce indoor air contaminants from materials that are harmful to the comfort or well-being of installers and occupants.

DCUCF: All sealants and adhesives used comply with the maximum VOC limits stated in this section.

EQ Credit 4.2: Low-Emitting Materials; Paints & Coatings – Yes

Intent: Reduce indoor air contaminants from materials that are harmful to the comfort or well-being of installers and occupants.

DCUCF:All paints and coatings used comply with the maximum VOC limits stated in this section.

EQ Credit 4.3: Low-Emitting Materials; Carpet Systems – Yes

Intent: Reduce indoor air contaminants from materials that are harmful to the comfort or well-being of installers and occupants.

DCUCF: All carpet systems installed comply with the maximum VOC limit stated in this section, as well as meet the required testing and product requirements of this section.

EQ Credit 4.4: Low-Emitting Materials; Composite Wood & Agrifiber Products – Yes

Intent: Reduce indoor air contaminants from materials that are harmful to the comfort or well-being of installers and occupants.

DCUCF:All composite wood and agrifiber products or laminating adhesives used in the facility contain no added urea-formaldehyde resins.

EQ Credit 5: Indoor Chemical & Pollutant Source Control – Yes

Intent: Minimize exposure of building occupants to hazardous particulates and chemical pollutants.

DCUCF:The entryways of the facility comply with the requirements of this section to capture dirt and particulates from entering the building from outdoors. The indoor parking garage exhaust rate is in compliance with this section to expel any harmful pollutants generated in the area. The filtration devices used in all air handlers comply with the Minimum Efficiency Reporting Value of MERV 13.

EQ Credit 6.1: Controllability of Systems; Lighting – Maybe

Intent: Provide high levels of lighting system control by individual occupants to promote the productivity, comfort, and well-being of occupants.

DCUCF:This credit is being pursued, however, no updates have been made on this credit and it has been deferred until further notice.

EQ Credit 6.2: Controllability of Systems; Thermal Comfort – No

Intent: Provide high levels of thermal comfort system control by individual occupants to promote the productivity, comfort, and well-being of occupants.

DCUCF:The design team is not pursuing this credit through individual controls for the building thermal comfort systems.

EQ Credit 7.1: Thermal Comfort; Design – Yes

Intent: Provide a comfortable thermal environment to support the productivity and well-being of occupants.

DCUCF:The HVAC system and building envelope of the facility have been designed to meet the requirements of ASHRAE Standard 55 for Thermal Comfort.

EQ Credit 7.2: Thermal Comfort; Verification – Maybe

Intent: Provide assessment of the building's thermal comfort over time.

DCUCF: The design team is pursuing this credit through the use of a thermal comfort survey. However, this credit has been deferred until further notice.

EQ Credit 8.1: Daylight & Views; Daylight 75% of Spaces – No

Intent: Provide a connection between indoor spaces and outdoors through the introduction of daylight and views.

DCUCF: The facility is not applicable for this credit due to its large size and large interior floor area that has no access to windows.

EQ Credit 8.2: Daylight & Views; Views for 90% of Spaces – No

Intent: Provide a connection between indoor spaces and outdoors through the introduction of daylight and views.

DCUCF: The facility is not applicable for this credit due to its large size and large interior floor area that has no access to windows.

System Evaluation

Due to the large size of the facility, the mechanical system needed to provide a large amount of air throughout the building for ventilation. It did this through selecting three large Make-Up Air Units to distribute air to smaller VAV Air Handling Units that mix and condition the air and send it to the spaces. The design team took advantage of the district chilled water and decided to purchase chilled water instead of operating a chiller plant and generating its own chilled water. The design team has mentioned that the cost of chilled water is expensive in Florida, however. According to utility analysis in the previous section, electricity costs more per unit of energy than chilled water. An option that was considered was to create a chiller plant for the single facility that could more efficiently create chilled water. This could only be feasible, however, by dramatically reducing the cooling loads on the building. The buildings large size, large building envelope area, and large area of fenestration increase the cooling load of the building considerably due to its climate. If these cooling loads can be reduced, the installation of a chiller plant could be practical. Another consideration that could be looked into is moving away from the all air system that is currently utilized. The building uses a total of 28 air handlers to move and condition a massive amount of air. This contributes to a very large amount of electricity being used on fans.

The facility does not lose much usable floor space due to dedicated mechanical spaces. However, the building has very large plenums, most likely due to the ductwork required for the system. The plenums range in size from five to nine feet high. If the plenum sizes can be reduced by using less ductwork in them, a dramatic construction cost could be mitigated.

The facility has attained LEED Certification and can possibly acquire LEED Silver Certification. Most of these credits, however, do not apply to the mechanical systems categories mentioned before. The facility only receives 3 out of the possible 17 points in Energy & Atmosphere. The mechanical systems leave room for energy efficiency improvement. On-site renewable such as solar are also a possibility that can be looked at due to the location's amount of solar gain.

Systems Redesign Proposal

Proposed Mechanical Redesigns

A main focus point of the entire proposal is to reduce the cooling loads on the building because they are excessively high due to the climate and large size of the building. Climatic loads are those from the high dry bulb and wet bulb temperatures of outdoor air that must be brought in for ventilation requirements as well as the conductive heat transfer through the building envelope materials and the solar heat gain through the expansive amount of glazing. The following topics are proposed to reduce the cooling load on the building or take care of the cooling load more efficiently. Through this, it may be feasible to implement a chiller plant for the building instead of purchasing chilled water from a district utility plant.

Building Envelope Thermal Load Reduction

The current system of the Duval County Unified Courthouse Facility is designed to overcome the large cooling loads associated with the thermal and envelope loads associated with the climate. The solar load on the building is quite large due to the expansive amount of glazing on the façade walls. It is proposed to reduce the loads on the building through the utilization of interior shading devices on the windows. There is currently no evidence of internal or external shading on the windows of the facility. Electronically controlled solar shading is to be proposed to track the sun as it follows its path throughout the day and causes peak solar loads on the building. This shading should greatly reduce the solar loads on the building, yet still allow adequate visible light into the building and views out of the building. General shading devices do not prove to be sufficient enough, however. Typical shades or blinds that are installed on the interior of the building may block most of the direct solar radiation entering the room through the glazing, but they are inefficient at redirecting this radiation back out the window. These shading devices instead absorb the solar radiation and as a result will give off heat over time. This heat will circulate around the blind and between it and the glazing. This heat eventually gets transferred into the plenum space or near ceiling space. While this heat will probably not be felt by any occupants in the room, the cooling system must still overcome this heat as it is in the plenum or near the ceiling where the cool air is supplied. This, in turn, will make the HVAC system work harder to cool the space. The solution to this is to use "MultiFilm" technology that is capable of reflecting the direct solar radiation back out the window. Most solar radiation is reflected out instead of being directly transferred into the space or absorbed by the material. These blinds, however, still maintain views out of the building and allow ambient visible light into the space. That means these devices provide the best of both facets by greatly decreasing solar radiation into the building, but still allowing natural views out and natural light in.

The shades will also need to be controlled. This entails the lowering of the shades based on some sort of optimum setting. The shades could be manually controlled in each room to allow occupants judgment on the sunlight, heat, and glare. However, an electrically driven motor to adjust the vertical length of the blinds would be more sufficient. There are only four main sides of the

building with glazing. This means that each side could potentially have its own photosensor to detect the solar radiation impacting on that general side instead of equipping each office or space with its own photosensor. An additional option would be to have the controls different per floor or for a set of floors. Each sensor would control the shades on a specific side of the building of a specific number of floors. By combining multiple spaces that face the same direction on one sensor, it will have less cost than having each space controlled individually.

Conversion to Hydronic Thermal Comfort System with DOAS Ventilation

The facility's HVAC system maintains comfort and indoor air quality levels through the use of an all-air system. This requires many large AHUs to mix ventilation and return air, a significant amount of fan power to move the excess air, excessive amounts of cooling and heating energy to condition the air, and complex systems of ductwork to transport the air around the building. A different approach to thermal comfort and ventilation is to decouple these aspects of the HVAC system into two different systems

One system maintains thermal comfort with a hydronic system. This hydronic system would continue to use chilled water for cooling and hot water for heating, but would not be used to condition air sent to the space. This system would instead send the water directly to a space to take care of thermal comfort. Water is a very effective means of transferring thermal energy due to its large heat capacity compared to air. Thermal conditioning would be controlled in the zones through use of varying the water flow to the equipment in the space. Equipment that can be used to condition the space could be fan coil units, active or passive chilled beams, or radiant cooling/heating systems.

The secondary system will take care of ventilation requirements through the use of Dedicated Outdoor Air Systems (DOAS). This system would supply only the required amount of outside air to the zone based on its area and occupancy rates. This means that significantly smaller volumes of air have to be moved to the various spaces. This air is initially conditioned and dehumidified upon entering the building in order to control latent loads of the building, but most space conditioning is done with the space hydronic equipment. Energy recovery in such a system is necessary. Enthalpy wheels that exchange heat between the exhaust air and incoming ventilation air will reduce the amount of energy needed to condition the incoming air.

The two systems can be tied together in the space via active chilled beams. These beams condition the space with cooling and/or heating coils in the beam and also bring in the ventilation air at this same location. This saves ceiling space and also increases the efficiency of the chilled beam itself. The conversion to these two systems can dramatically reduce the amount of air handling equipment, air conditioning equipment, and ductwork. This conversion not only reduces necessary fan energy but also energy required for thermal comfort of the space. The current system utilizes VAV techniques and cannot guarantee the exactly correct amount of outdoor air to each space. That means that most spaces end up receiving an excess amount of outdoor air, requiring extra cooling energy for this air. With DOAS, the ventilation air for each space can be accurately calculated and minimum volumes of air can be supplied.

Facility Chiller Plant Implementation

The Duval County Unified Courthouse currently purchases chilled water from the J.E.A. Public Utility district plant. The design engineer has mentioned that the price of J.E.A.'s chilled water is relatively expensive when compared to other locations. The facility will require a relatively large chiller plant to take care of its loads, however. With the aforementioned proposals, the building load and demand for chilled water should decrease. This implies that a smaller chiller plant can be used for the same building.

This study will analyze a vapor compression cycle plant design due to the large size and lack of CHP potential for absorption refrigeration. The feasibility of a chiller plant being applied to this facility depends on the reduction of chilled water capacity for the building. A chiller plant feasibility analysis is to be investigated for an educational purpose and to gain experience in the field of chiller plant design. Various pumping arrangements are available for vapor compression refrigeration cycles. Most chiller plants operate on a primary/secondary pumping system which uses a constant flow of chilled water through the chillers and a secondary pump near the loads to control the amount of chilled water going to the loads. This causes a large first cost in pumps and excessive pumping energy. A variable primary flow system uses a single pump in the plant to vary the flow of chilled water through the chillers and to the loads. This chiller plant analysis will include a variable primary flow pumping system in order to reduce chiller plant first cost and reduce electrical pumping energy required.

Additional Breadth Topics

Construction Management – Reduction in Building Height

The Duval County Unified Courthouse Facility currently has a floor-to-floor height of 18 feet. Some rooms, notably courtrooms, have a higher ceiling, but these are still only 13 feet tall. The large plenum spaces are a result of extensive ductwork, VAV terminals, and even entire AHUs placed in the plenum areas. The conversion to a hydronic system with DOAS requires much less spaces than the current all-air VAV system. The only space required is for water piping, dramatically smaller ductwork for ventilation, and smaller zone equipment such as chilled beams. With a smaller space requirement, plenum space can be decreased, therefore reducing the floor-to-floor height of the building. This reduction in building height will save in both materials and scheduling for the entire building. This includes the prefabricated concrete panels and glazing for the façade as well as cast-in-place concrete for the columns. Construction schedules for these components will be analyzed in order to calculate the reduction in construction time.

Electrical – Photovoltaic Panel Array

The Duval County Unified Courthouse Facility is located in a climate that has a large amount of solar radiation. The building also has a large area of flat roof available that would be ideal for a photovoltaic array. Photovoltaics (PV) are a method of generating electricity from solar radiation. The PV system converts the incident solar radiation on the panel into DC electricity. Solar panels can be mounted on this roof area in order to generate electricity. The growing demand for

renewable energy sources has created advances in this technology and more efficient panels are available, as well as better funding. PV panel arrays have the ability to track the sun as it follows its course through the sky in one or two axes. The system will also require the addition of some electrical components like inverters to convert the DC electricity to AC.

The electricity generated by this system may be used to power the proposed shading system. The shades will be motorized to control the vertical length. These motors can be powered by the electricity generated by the solar panels. If at any time the solar panels are not generating adequate energy due to lack of sunlight, the shading system can default up and will simply not be required due to this lack of sunlight.

The PV array and supplementary systems will have a high first cost, but incentives have been made available to decrease the first cost of the system. The system can simply not handle all electrical loads, but the main purpose is to generate some electricity to decrease electric utility costs of the building, especially with motorized blinds and a new chiller plant. The PV array will also make the facility "Greener" and increase the LEED score of the building with this use of renewable energy.

MAE Course Related Study

As part of the MAE thesis requirement, graduate level courses must be incorporated into the proposed alternative systems and design. AE 557, Centralized Cooling Production and Distribution Systems, focuses on the design of central chiller plants and the options available in the practice. The class discusses vapor compression and absorption refrigeration techniques, cooling tower analyses, and associated pumping arrangements. This course material will be used in the depth analysis of a central chiller plant design.

Integration of Studies

All proposed depth ideas for the Duval County Unified Courthouse Facility are integrated in the initiative to reduce loads and energy usage for the building. A reduction of the building envelope loads and necessary cooling capacity allow for smaller cooling plant requirements. The breadth topics proposed have two separate goals but both tie back to the main depth goal of energy and cost reductions. The first being the decrease in first cost of the overall building due to the conversion of mechanical systems to save plenum space. With this system change to hydronic and DOAS systems, the floor-to-floor height is decreased. This decreases required material and construction time, therefore reducing building first cost. The reduction in building height also continues to reduce the envelope thermal loads. The second breadth includes a higher first cost but decreases the need for purchasing electricity. If used to power the electrically driven shading system, the solar panel system will be a highly integrated part of the redesign of the building. This idea follows suit with reducing energy costs, especially if an electrically driven chiller is found suitable for the project. The electricity generated by the PV array can help to offset the increase in electricity required for a chiller plant.

Basis for Comparison

The options for redesign of the system will be compared to each other using specific guidelines to gage the benefits of each system. The following criteria will be used

Initial Cost

Facility owners often find initial cost of a system as a major factor in making decisions for alternative systems. The first cost, however, should play a minor role in decision-making when the facility is expected to operate over a long period of time.

Life Cycle Cost

Life Cycle Costs (LCC) are calculated based on initial system cost and the cost to operate the system. This includes maintenance, repairs, and most importantly utility costs. Life Cycle Costs are better at representing the overall cost of a system because it takes into account the longevity of the facility and its systems.

Energy Use & Cost

Energy use from each alternative will be compared from values calculated in the energy modeling process. The annual energy use based on each type of energy and total energy will be compared. Costs associated with the energy consumption will also be an important basis of comparison.

Simple Payback

Proposed upgrades over the existing system will include a simple payback period that dictates how long it takes the new system or upgrade to be paid for with the savings it generates. A smaller simple payback period means the system pays for itself faster. Each alternative's simple payback, with respect to the existing system, will be compared.

Environmental Impact

Environmental protection and quality is an important topic in the world today and reductions in emissions and building carbon footprints are growing more popular. Emission data for each alternative will be compared and rated.

LEED Applicability

The current facility is rated at LEED Certified and it is important to maintain that rating or increase it. The primary credit to be compared will be the reduction in energy use as this can add the most points to the LEED credit total. LEED ratings for each system alternatives will be compared and rated.

Internal Shading Analysis

Existing Solar Loads

The Duval County Unified Courthouse Facility has approximately 82,000 ft^2 of glazing as part of its façade for the occupied perimeter spaces. This equals roughly 43% of the façade which is not in compliance with ASHRAE Standard 90.1. This glazing imparts a large amount of solar radiation on the spaces. The existing glazing is in compliance with ASHRAE Standard 90.1 U-Values and Solar Heat Gain Coefficients (SHGC), but they still allow a large amount of solar radiation in. The existing total load on the systems is **2030 tons**. Solar load through glazing is **164 tons** and the load from glazing conduction is **110 tons.** These values sum to **274 tons** or **13.5%** of the total building load. These values can be dramatically reduced through the use of internal shading devices.

MultiFilm® Blinds

MultiFilm ® Blinds use multiple films of UV-absorbent polyester and a thin layer of reflective aluminum. These blinds allow solar radiation to be reflected back out the window before it turns into heat in the trapped space between the shade and the glazing. The composite blind still permits visible light through the surface. This allows for ambient light to enter the space for glare-free natural lighting as well as views out of the window. The film materials are shown in Figure 4 below. The image is courtesy of the MultiFilm® website. The blinds improve the SHGC and U-Value of the glazing systems, decreasing both solar gain and heat conduction through the window. For ease of modeling the blind system, the glazing systems' SHGC and U-Values have been modified instead of utilizing an internal shading model.

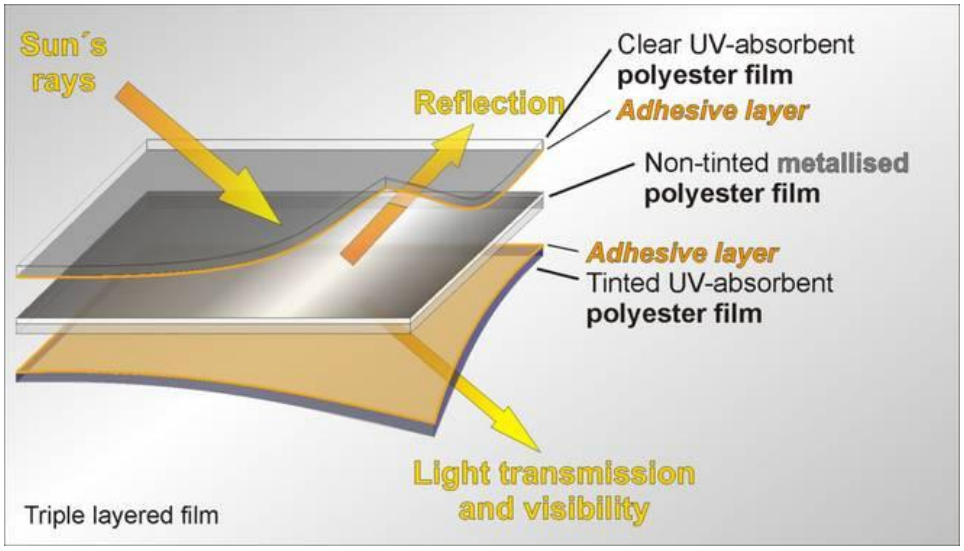


Figure 4

The MultiFilm® *Film-Façade Systems* product has been chosen for the Duval County Unified Courthouse Facility. The *Film-Façade System* is capable of covering the large glazing areas and

custom window sizes that the facility has. This type of system also allows for electrically motorized operation systems to adjust the vertical length of the blind. The motors used will be small and concealed. The maximum motor size would be 1/8 HP. This small motor size is advantageous due to both their relatively low price and their small size that can be concealed in the mounting hardware. Control of these shades and their motors will be done with photosensors on each main façade of the building. A total of 26 photosensors are to be used to measure sunlight hitting the building. Floors 1 and 2 will utilize 2 photosensors per façade direction for a total of 8 sensors controlling the two floors. Floors 3 and 4 will utilize 2 photosensors per North and South facades and 1 photosensor per East and West Facades. This is a total of 6 sensors controlling those two floors. The reason for fewer sensors is due to the East and West Facades having a smaller area on the third and fourth floors than on the lower floors. Floor 5 will have the same configuration of photosensors for another 6 sensors for this single floor. This floor is controlled by itself due to the sixth floor overhang along the south façade. Floor 6 and 7 will have the same configuration for another 6 photosensors. Figure 5 below shows a *Film-Façade System* used in a typical office building. The key points of this image are the available views out of the blind, the natural light entering the space, and the concealed mounting hardware.

Figure 5

Resulting Loads with Shading Devices

The energy model in Trane TRACE was modified to allow for better SHGC and U-Values of the glazing systems in the occupied perimeter areas. The new peak building load on the systems was reduced by 156.73 tons to a new peak load of **1873 tons**. The new glazing solar load is **49 tons** which is **70%** less than without the blinds. The new conduction load through the glazing is **70**

tons, a **31%** reduction. The new total load from the glazing is **119 tons** which is **56.5%** less than without the blinds. The new glazing load has been reduced to **6%** of the total building load.

Energy Use Reduction

The energy use of the Duval County Unified Courthouse Facility was calculated with the Trane TRACE energy model. The results are summarized in Table 31 below. Electricity consumption is slightly larger when compared to the existing system, however demand has dropped. Natural gas consumption has also decreased due to the improvement in the U-Value to reduce heating loads. The main reduction is in chilled water use. The reduction is equal to approximately **7%** less chilled water consumption. The total energy consumption of the building is also reduced by **2,529 MMBTU** which is a **4.6%** reduction in overall building energy use. The energy per square foot required for the facility is reduced to **65.8 kBTU/ft².** The percentages of each energy sources' contribution to the total is in Chart 6.

Energy Use Summary						
Electric		Natural Gas		Chilled Water		Total
Consumption (kWh)	Peak Demand (kW)	Consumption (MCF)	Peak Demand (MCF/hr)	Consumption (kGal)	Peak Demand (Gal/hr)	Consumption (MMBTU)
5,219,790	1,852	609	4.0	317	210	52,552

Table 31

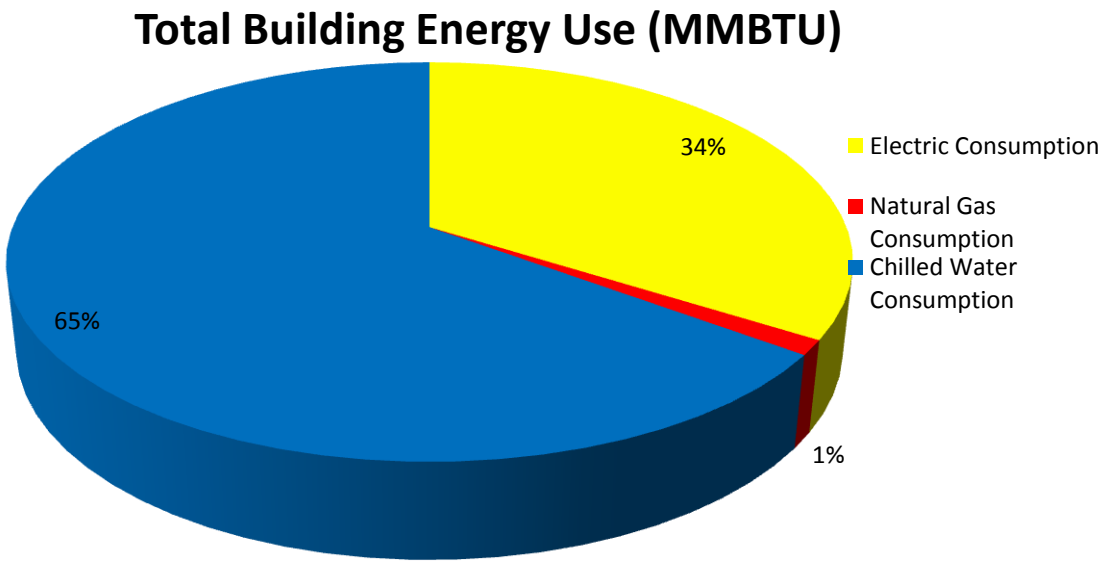


Chart 6

The new annual utility costs are broken down by energy source in Table 32. The charges sum to a total annual utility cost of **$1,180,381.33.** This is approximately **3%** less than the existing glazing system utility costs. This equates to approximately **$1.48/ft²** annually. Chart 7 shows the percentages of each utility cost.

Energy Cost Summary					
Electric			Natural Gas	Chilled Water	Total
Consumption	Demand	Total	Consumption	Consumption	Consumption
$521,979.00	$202,880.00	$724,859.00	$5,214.89	$450,307.44	$1,180,381.33

Table 32

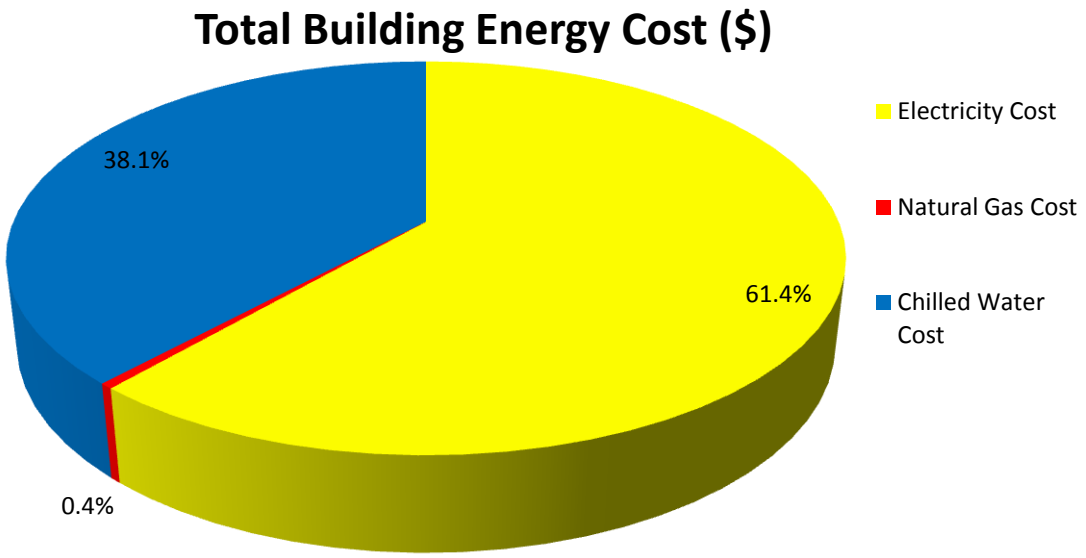


Chart 7

Emissions

The same emissions calculations were calculated based on the electrical grid, commercial boiler, and purchased chilled water values. The emissions associated with the reduced energy usage from the blinds systems are summarized in Tables 33, 34, & 35.

Annual Emissions for Purchased Chilled Water					
Chilled Water Use	34,114,200	kBTU	2,842,850	Ton*hr	
Pollutant	Region Electric EF (Ton/MWh)		Chilled Water EF (kg/Ton*hr)	Annual Pollution (kg)	Annual Pollution (lb)
CO2e	0.678		0.624	1,775,183.57	3,905,403.85

Table 33

Annual Emissions for Electrical Consumption				
Electric Use	1	kWh	5,219,790	kWh
Pollutant	Eastern Interconnection Emission Factor		Annual Pollution	
CO_{2e}	1.74E+00		9,082,434.60	lb
CO_2	1.64E+00		8,560,455.60	lb
CH_4	3.59E-03		18,739.05	lb
N_2O	3.87E-05		202.01	lb
NO_x	3.00E-03		15,659.37	lb
SO_x	8.57E-03		44,733.60	lb
CO	8.54E-04		4,457.70	lb
TNMOC	7.26E-05		378.96	lb
Lead	1.39E-07		0.73	lb
Mercury	3.36E-08		0.18	lb
PM10	9.26E-05		483.35	lb
Solid Waste	2.05E-01		1,070,056.95	lb

Table 34

Annual Emissions for Boiler				
Natural Gas Use	1	MCF	609	MCF
Pollutant	Natural Gas Emission Factor		Annual Pollution	
CO2e	1.23E+02		74,957.23	lb
CO2	1.22E+02		74,347.82	lb
CH4	2.50E-03		1.52	lb
N2O	2.50E-03		1.52	lb
Nox	1.11E-01		67.64	lb
Sox	6.32E-04		0.39	lb
CO	9.33E-02		56.86	lb
VOC	6.13E-03		3.74	lb
Lead	5.00E-07		0.00	lb
Mercury	2.60E-07		0.00	lb
PM10	8.40E-03		5.12	lb

Table 35

LEED Analysis

With the new MultiFilm® Blinds system, the building achieves roughly 18% energy savings over the baseline building. EA Credit 1, "Optimize Energy Performance", awards three points for 17.5%

energy savings over baseline. This increases the LEED Credits by one point to 33 points. This grants the Duval County Unified Courthouse Facility LEED Silver Certification.

Economics

The shading system's initial cost was calculated using estimates from RS Means Cost Estimating data. The cost of materials and installation is approximately **$1,154,400** for the MultiFilm® *Film-Façade System* on the Duval County Unified Courthouse Facility. Since this is a supplemental system to the existing mechanical systems, the Life Cycle Cost (LCC) analysis of this option requires the initial cost and maintenance costs of the existing mechanical system as well. The LCC calculations for all alternatives can be found in Appendix C of this report. Economics of this project are summarized in Table 36 below.

MultiFilm® Blinds Economics	
Initial Cost	$1,154,400
Total Savings	$32,940.65
Simple Payback	35 Years
20 Year LCC	$21,244,274

Table 36

DOAS & Active Chilled Beam Systems

Existing Airflows and Loads

The existing facility's VAV system requires large airflows in order to condition the spaces. With the MultiFilm® Blinds addition, the existing VAV Air system requires a total cooling airflow of **486,632 CFM** and supplies **137,099 CFM** of outdoor ventilation air. This equates to approximately 28% outside air for the facility. The system brings in excess air due to the controls of the VAV system not being able to correctly supply the minimum amount of outdoor air. This increases ventilation loads. The current total building cooling load is **1873 tons** with a cooling load from ventilation of **504** tons. The ventilation loads can be reduced through the use of a Dedicated Outdoor Air System (DOAS) to supply adequate fresh air to spaces. The spaces can also be cooled more efficiently through the use of Active Chilled Beams that hydronically cool the space directly.

Dedicated Outdoor Air System

Dedicated Outdoor Air Systems are very effective methods of increasing building efficiency by reducing ventilation loads and also assist in indoor air quality. DOAS are capable of supplying much less air than typical VAV systems. Through this reduction in supply air flow, ductwork and fans can be downsized as well. Additionally, the downsizing of ductwork results in lower floor-to-floor heights which saves additional construction costs. DOAS allows for the decoupling of thermal

comfort from ventilation air. This means the DOAS unit is only required to condition incoming ventilation air to the adequate temperatures and relative humidity for the space and not responsible for the complete load of the space. The DOAS units will handle 100% of latent loads on the space that result from people and outdoor air dehumidification. Through this conditioning for latent loads, the DOAS unit can usually handle 30% of the sensible loads with the assistance of a total enthalpy wheel.

According to Stanley Mumma, a DOAS specialist, VAV systems tend to have issues with properly ventilating every space with enough outdoor air. DOAS is capable of supplying every space with the proper ventilation air and increase the indoor air quality because the air supply is not varied. Additionally, VAV systems tend to use 20-70% more outdoor air than is required in the effort to assure proper ventilation and air distribution to all zones. VAV systems also use more terminal reheat at the zone level than is required by DOAS because VAV systems require more air.

DOAS was modeled in the Trane TRACE energy model for dehumidification and space latent load purposes. All DOAS units are equipped with a total enthalpy wheel that exchanges sensible and latent energy with the exhaust air. This wheel provides "free" outdoor air conditioning and lessens the load requirement on the coils in the unit. The wheel, however, requires energy to power it and has an increased pressure drop through it which requires slightly higher fan power. A total of twelve DOAS units were specified for the Duval County Unified Courthouse Facility. Seven units are specified to supply air to office, hearing, meeting, and jury spaces throughout the facility with one unit per floor. Five more units are used for the 51 courtrooms with one unit per floor of courtrooms. Spaces such as storage, office restrooms, and corridors that are not suited for DOAS and chilled beams were kept on VAV systems similar to the existing system. One VAV unit per floor supplies these spaces for a total of seven VAV systems. A schematic of a typical DOAS unit for the facility is illustrated in Figure 6.

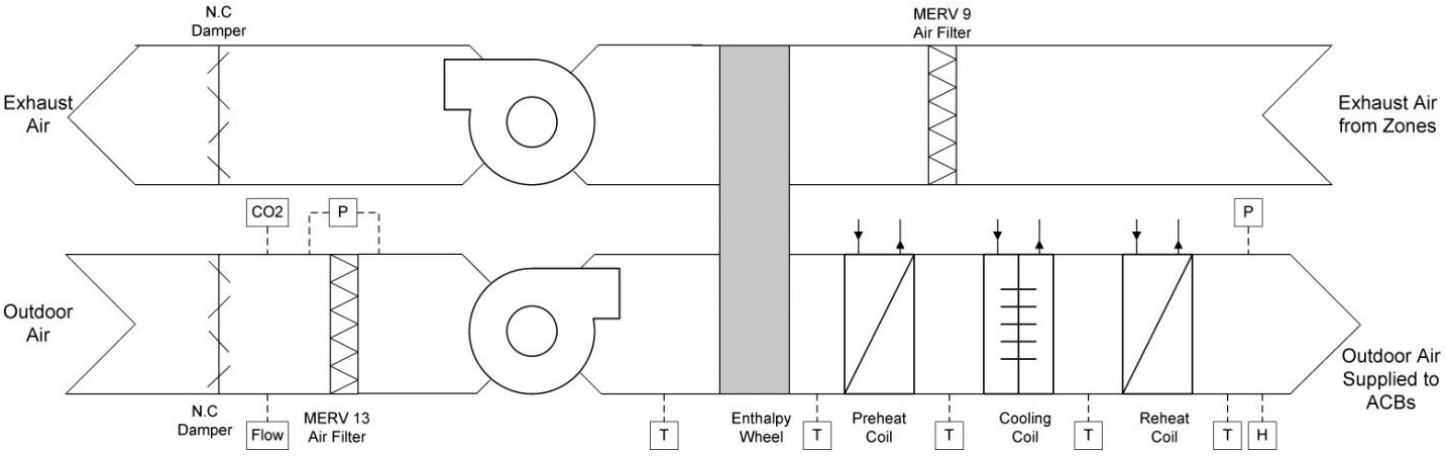


Figure 6

Active Chilled Beam System

Active Chilled Beams (ACB) are a relatively new technology that gets its basis from the induction unit. They are more efficient and sophisticated, but operate on the premise of the buoyancy of air. Through induction, fan energy can be reduced for air movement across the coils in the ACB. The ACB uses high pressure nozzles to supply the ventilation air that is required in the space. These nozzles create turbulence, induce room air into the ACB, and mix the airflows. The turbulent air mixing allows for warmer water temperatures in the cooling coil (55-60 °F) achieving the same cooling capacity as a conventional VAV unit (45-50 °F). Water has a much higher heat capacity than air, therefore, the energy requirements for the mechanical system are decreased. Passive Chilled Beams, a simpler version of the ACB, do not supply the ventilation air and therefore have a smaller cooling capacity. The ACB system was selected due to the higher capacity and the fact that ventilation air can be supplied at the same location in the space. Figure 7 illustrates how an Active Chilled Beam operates in cooling mode.

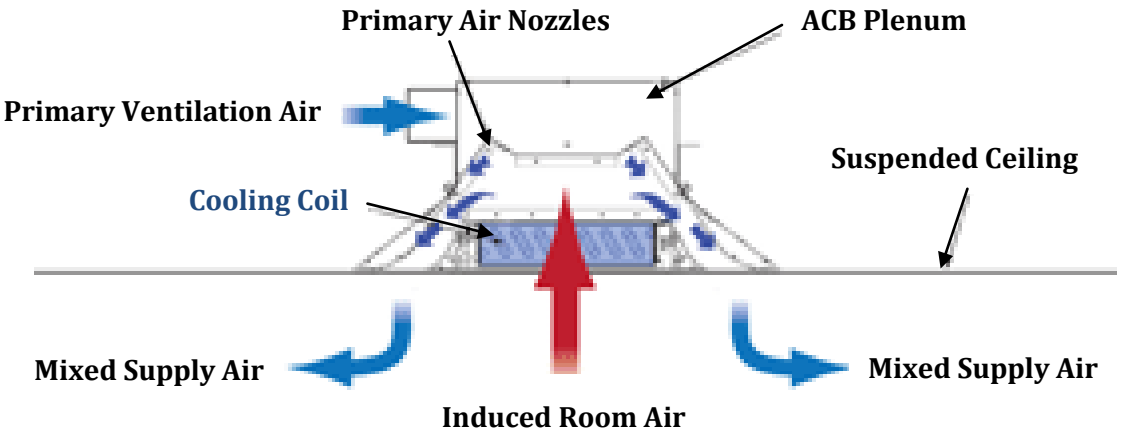


Figure 7

Active Chilled Beams, however, have some disadvantages. Four-pipe ACBs are available that are capable of both heating and cooling, but they are less efficient at heating. This, however, should not be a problem for the Duval County Unified Courthouse Facility due to its mild winters. The largest issue with ACBs, though, is that they can condense water. With the ACBs in the ceiling, this is a risky location for condensation as water may drop from them. A study was done with chilled beams, however, in which the beams were 14 °F below the space dew point temperature for 8.5 hours with no dripping condensation. Operation of the chilled beam below the space dew point is still not recommended, however. Lastly, since ACBs are relatively new, many contractors and commissioners have little or no experience with them. The technology is spreading, however, and more companies are manufacturing them and more ACB specialists are becoming available.

Active Chilled Beams require ceiling space in the area to be cooled in order to provide the cooling. If the space has inadequate ceiling space, ACBs will not work. In order to be certain that each zone

has enough ceiling space for the required chilled beam capacity; a simple calculation was done for each zone of each floor.

$A=Q_Z * 3500\ W/Ton * (1/C_{CB})$ (*Equation 2)*

Where A is the Required Ceiling Area for Active Chilled Beams

Q_Z is the space cooling load in tons

3500 W/Ton is the conversion factor between Watts and Tons

C_{CB} is the ACB cooling capacity per square foot of ACB in W/ft^2. The chilled beam selected has a cooling capacity of 101 W/ft^2

Table 37 summarizes the ACB required ceiling areas per floor. A more detailed version of the calculation based on zone requirements is in Appendix D. Most spaces require minimal amounts of ceiling space for the ACBs. As the table shows, all floors require between 4 and 10% of ceiling space for the ACBs.

Active Chilled Beam Ceiling Area Requirements				
Floor	Cooling Tons	Required S.F	Available S.F	% Ceiling Area ACB
1	98.5	3,413	87,549	4%
2	235.1	8,147	112,225	7%
3	123.9	4,294	41,833	10%
4	122.8	4,255	43,529	10%
5	127.7	4,425	46,548	10&
6	122.8	4,255	51,405	8%
7	117.7	4,079	59,321	7%

Table 37

Resulting Airflows & Loads with DOAS & ACB

The energy and load model in Trane TRACE was modified with different systems to accommodate the new DOAS and ACB systems. The aforementioned MultiFilm® Blinds that were proposed are also being accounted for in the model. The 25 VAV AHU systems were replaced with 12 DOAS/ACB and 7 VAV AHU systems. The new DOAS/ACB systems supply a total of **102,717 CFM** of outdoor ventilation air to their spaces. The remaining VAV systems supply a total of **106,269 CFM** with **24,809** CFM of outdoor ventilation air. The total air supplied by all systems is **208,986 CFM** with **127,526 CFM** of outdoor ventilation air. Supply air is reduced by **277,646 CFM** or **57%** and outdoor air is reduced by **9,573** or **7%**. This large reduction in airflow allows the duct sizes required for the new systems to be considerably reduced. The new peak building load on the

systems was reduced by 443 tons to a new peak load of **1431 tons.** The new ventilation load is **322 tons**, which is **36%** less than the original systems' ventilation load.

Energy Use Reduction

The energy use of the Duval County Unified Courthouse Facility with shading and new DOAS/ACB systems was calculated with the Trane TRACE energy model. The results are summarized in Table 38 below. Both electricity and chilled water consumption and demand have dropped. This is due to the spaces being cooled more efficiently with DOAS and ACBs. Electricity consumption has dropped by **18%** when compared to the existing systems with shading addition. Chilled water consumption has dropped by **35%** when compared to the existing systems with shading addition. Natural gas consumption has increased because ACBs are not as efficient at heating as they are at cooling. The increase, however, is minor due to the mild winters and low natural gas price. The total energy consumption of the building is also reduced by **14,525 MMBTU,** approximately **28%** less, with respect to the existing system with shading addition and **17,054 MMBTU**, approximately **31%** less, when compared to the existing system alone. The energy required per square foot for the facility is reduced to **47.6 kBTU/ft².** The percentage of each energy sources' contribution to the total is in Chart 8 below.

Energy Use Summary

Electric		Natural Gas		Chilled Water		Total
Consumption (kWh)	Peak Demand (kW)	Consumption (MCF)	Peak Demand (MCF/hr)	Consumption (kGal)	Peak Demand (Gal/hr)	Consumption (MMBTU)
4,262,701	1,283	1,219	4.0	206	159	38,027

Table 38

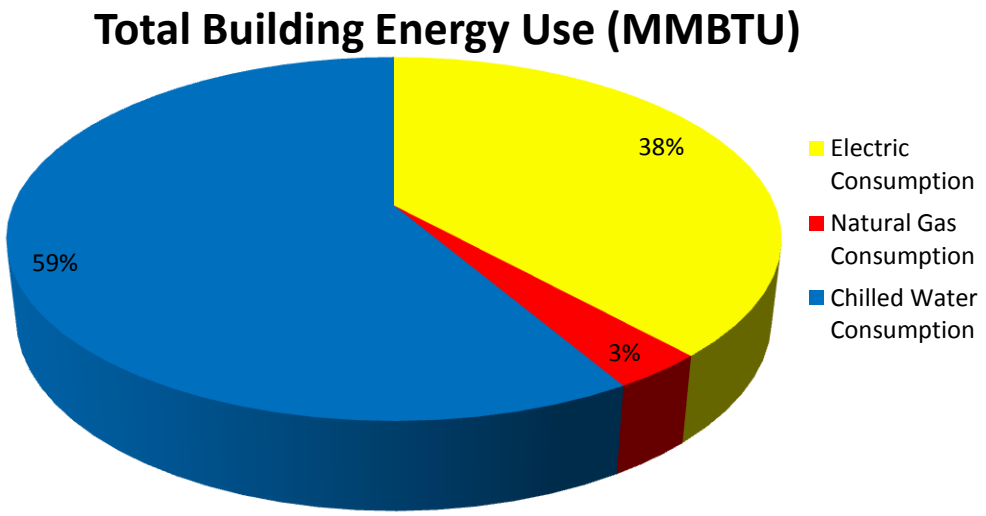


Chart 8

The new annual utility costs are broken down by energy source in Table 39. The charges sum to a total annual utility cost of **$870,899.70.** This cost is **30%** less than the cost associated with the existing system alone and **26%** less than that of the existing system with shading addition. This equates to approximately **$1.09/ft²** annually. Chart 9 shows the percentages of each utility cost.

Energy Cost Summary					
Electric			Natural Gas	Chilled Water	Total
Consumption	Demand	Total	Consumption	Consumption	Consumption
$426,270.10	$140,820.00	$567,080.10	$10,427.46	$293,382.14	$870,899.70

Table 39

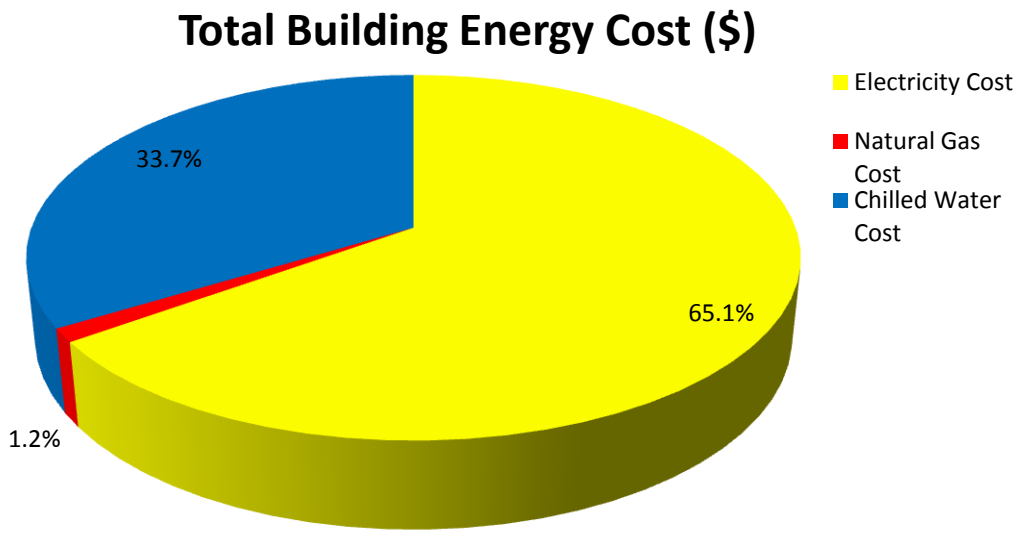


Chart 9

Emissions

The same emissions calculations were calculated based on the electrical grid, commercial boiler, and purchased chilled water values. The emissions associated with the reduced energy usage from the new DOAS/ACB Systems with shading additions are summarized in Tables 40, 41, & 42.

Annual Emissions for Purchased Chilled Water							
Chilled Water Use	22,225,920	kBTU	1,852,160	Ton*hr			
Pollutant	Region Electric EF (Ton/MWh)		Chilled Water EF (kg/Ton*hr)			Annual Pollution (kg)	Annual Pollution (lb)
CO2e	0.678		0.624			1,156,559.09	2,544,429.99

Table 40

Annual Emissions for Electrical Consumption				
Electric Use	1	kWh	4,262,701	kWh
Pollutant	Eastern Interconnection Emission Factor		Annual Pollution	
CO_{2e}	1.74E+00		7,417,099.74	lb
CO_2	1.64E+00		6,990,829.64	lb
CH_4	3.59E-03		15,303.10	lb
N_2O	3.87E-05		164.97	lb
NO_x	3.00E-03		12,788.10	lb
SO_x	8.57E-03		36,351.35	lb
CO	8.54E-04		3,640.35	lb
TNMOC	7.26E-05		309.47	lb
Lead	1.39E-07		0.59	lb
Mercury	3.36E-08		0.14	lb
PM10	9.26E-05		394.73	lb
Solid Waste	2.05E-01		873,853.71	lb

Table 41

Annual Emissions for Boiler				
Natural Gas Use	1	MCF	1,219	MCF
Pollutant	Natural Gas Emission Factor		Annual Pollution	
CO2e	1.23E+02		149,881.05	lb
CO2	1.22E+02		148,662.50	lb
CH4	2.50E-03		3.05	lb
N2O	2.50E-03		3.05	lb
Nox	1.11E-01		135.26	lb
Sox	6.32E-04		0.77	lb
CO	9.33E-02		113.69	lb
VOC	6.13E-03		7.47	lb
Lead	5.00E-07		0.00	lb
Mercury	2.60E-07		0.00	lb
PM10	8.40E-03		10.24	lb

Table 42

LEED Analysis

With the new DOAS/ACB systems replacing most of the VAV systems, the building achieves roughly 40% energy savings over the baseline building. EA Credit 1, "Optimize Energy Performance", awards nine points for 38.5% energy savings over baseline. This increases the original LEED

credits by 7 points to 39 points. This grants the Duval County Unified Courthouse Facility LEED Gold Certification.

Economics

The new Dedicated Outdoor Air Systems' and Active Chilled Beams Systems' initial costs were calculated using estimates from RS Means Cost Estimating Data. The cost of materials and installation for this new system is approximately **$3,849,077** for the DOAS units, ACBs, new VAV units, and auxiliary equipment for the Duval County Unified Courthouse Facility. The existing chilled water system for the facility will remain and its cost of $125,400 must also be added to this total. For the purpose of the LCC analysis, the new system initial cost will also include the existing chilled water system cost and the aforementioned Multifilm® Blinds installation. The LCC calculations for all alternatives can be found in Appendix C of this report. Economics of this new system are summarized in Table 43 below.

DOAS/ACB with Shading Addition Economics	
Initial Cost	$5,128,882.10
Total Savings	$342,422.28
Simple Payback	15 Years
20 Year LCC	$17,880,987

Table 43

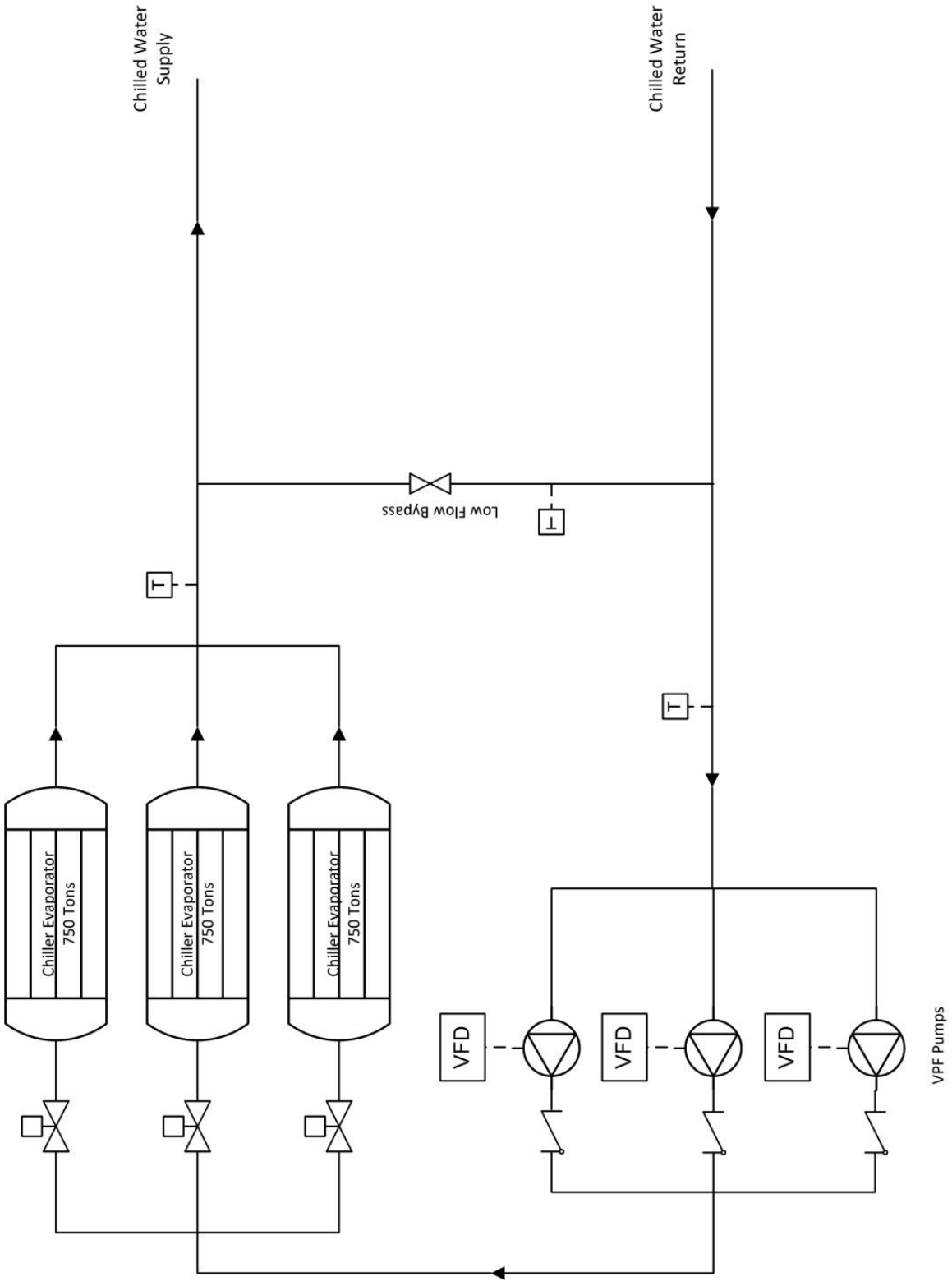
Chiller Plant Implementation

The Duval County Unified Courthouse Facility currently purchases chilled water from the J.E.A. Public Utility Company at $1.32/therm. As a recommendation from the mechanical design engineer and as an educational study, it is proposed to add a chiller plant to the facility to handle the cooling loads and discontinue purchasing of chilled water. With the aforementioned proposals that reduce the building load and necessary chilled water, the smaller chiller plant may be a feasible approach for the project.

Modeling Analysis

The model of the Duval County Unified Courthouse Facility with new internal shading and DOAS/ACB systems was used for this study in the Trane TRACE software. The current cooling load on the building is 1431 tons. The chiller plant design chosen was a Dedicated Variable Primary Flow Parallel Chiller Plant. It includes three two-stage centrifugal chillers piped in parallel with their own VFD controlled cooling tower. Each chiller has its own variable volume chilled water pump. Each chiller and cooling tower is sized to handle half the load. Therefore the chillers and cooling towers are sized at 750 tons each. Three chillers, towers, and pumps are being used for

"n+1" redundancy. With this redundancy, chiller and pump operation sequencing is possible and the equipment will last longer. The variable volume chilled water pumps are sized at 150 HP each and are equipped with VFDs. The primary pumps will match the load requirements. The plant is also equipped with a Low-Flow Bypass between the chiller supply and return lines. This bypass will open when the system loading is greater than what the chillers can supply. Variable primary flow has the benefits of a lower first than ordinary primary/secondary systems due to the elimination of secondary and tertiary pumps. Additionally, it has lower energy and operating costs than primary/secondary. The chillers are better utilized and there is less operation of the chiller auxiliary equipment. Also, variable primary flow is more capable of handling "Low ΔT Syndrome" where the chiller plant temperature change is less than design intended. This could serve to be very beneficial to the chilled beam system because the ACBs do not typically require a water temperature as low as that of an all-air system. The main disadvantage of the pumping arrangement is the complexity of the controls and control stability. The chiller plant schematics for evaporator side (Figure 8) and condenser side (Figure 9) are shown on the following pages.


Chilled Water Supply
Chilled Water Return
Low Flow Bypass
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Chiller Evaporator 750 Tons
Chiller Evaporator 750 Tons
Chiller Evaporator 750 Tons
VFD
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VPF Pumps

Figure 8

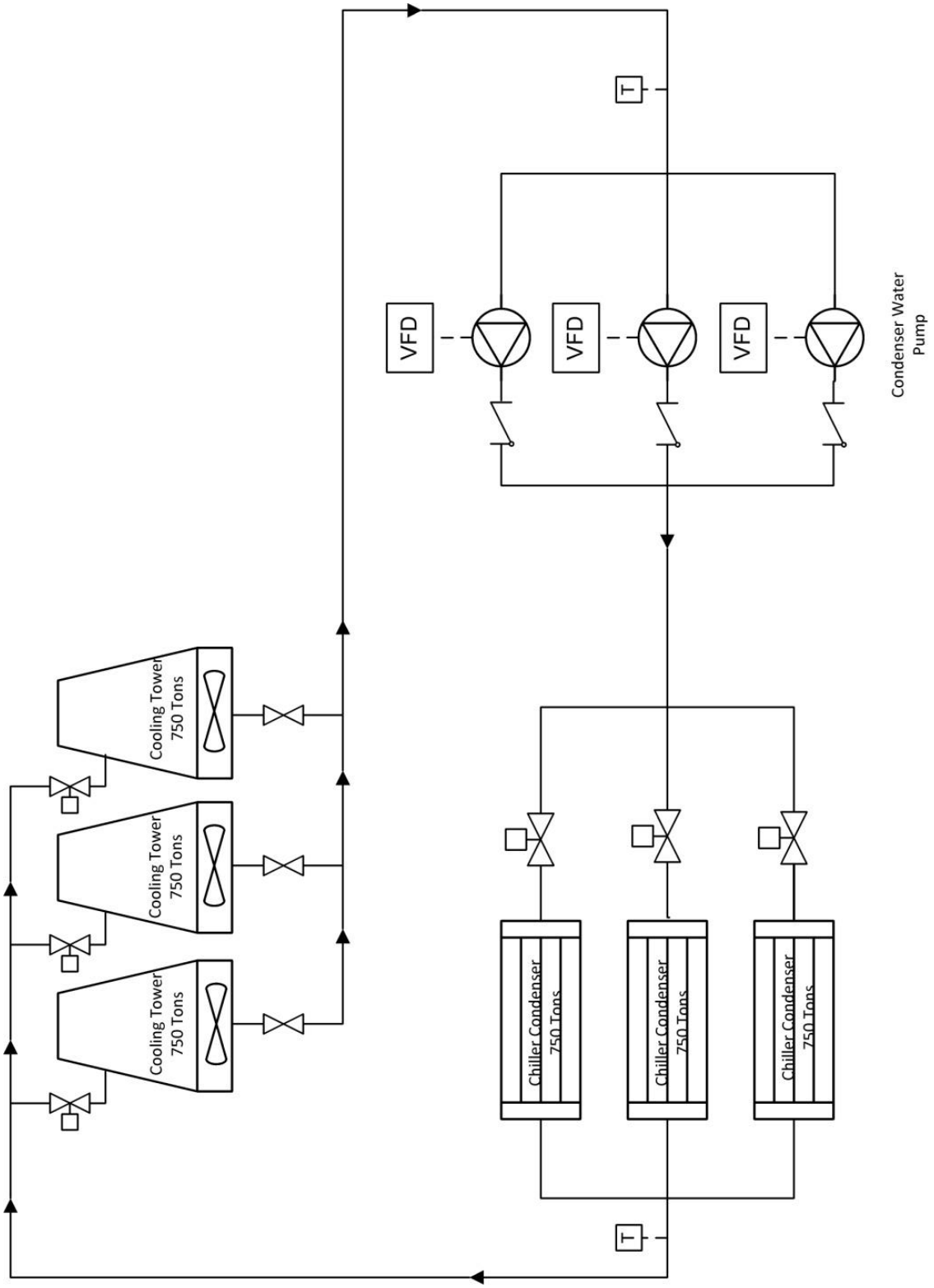
T
VFD
VFD
VFD
Condenser Water Pump
Cooling Tower 750 Tons
Cooling Tower 750 Tons
Cooling Tower 750 Tons
Chiller Condenser 750 Tons
Chiller Condenser 750 Tons
Chiller Condenser 750 Tons
T

Figure 9

Energy Use

The energy use of the Duval County Unified Courthouse Facility equipped with its shading devices, DOAS/ACB systems, and Variable Primary Flow Centrifugal Chiller Plant was calculated in the Trane TRACE energy model. The energy results are summarized in Table 44 below. With the implementation of the chiller plant, the electrical consumption and demand has increased considerably, but the factor of purchased chilled water has been eliminated completely. Electrical consumption has increased by approximately **43%**. The chiller plant did not affect the natural gas use. With the chiller plant, domestic water is required to be purchased to be used as condenser water. The annual consumption of condenser water is **8,226 kGal**. The total energy consumption has dropped by **15,904 MMBTU**, approximately **42%**, with respect to the new DOAS/ACB with shading addition energy use. The energy required per square foot for the facility is reduced to **28 kBTU/ft²**. Chart 10 shows the new percentages of the energy sources' contributions to the total energy consumption of the facility.

Energy Use Summary				
Electric		Natural Gas		Total
Consumption (kWh)	Peak Demand (kW)	Consumption (MCF)	Peak Demand (MCF/hr)	Consumption (MMBTU)
6,115,746	2,363	1,219	4.0	22,123

Table 44

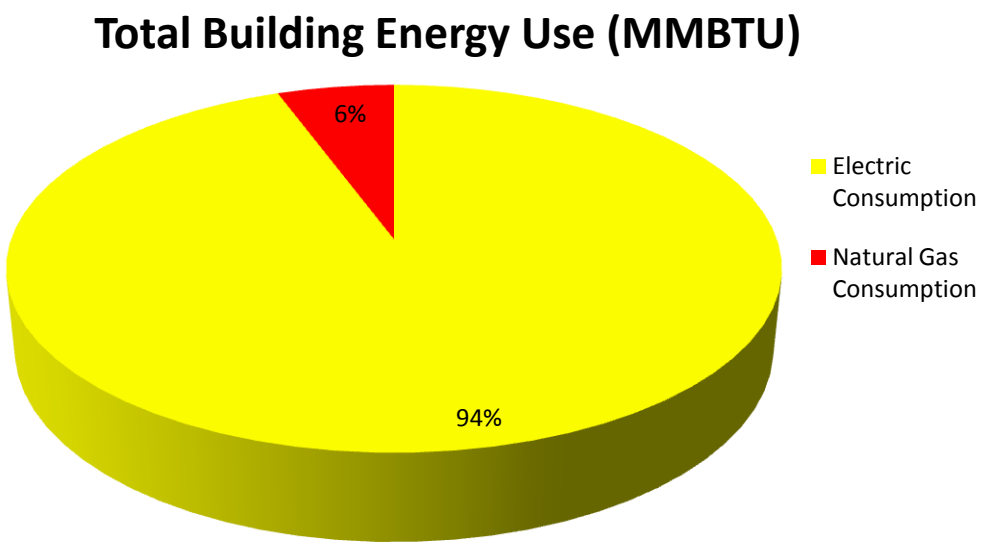

Chart 10

The monthly energy consumptions are also shown in the charts below for each energy source. The electric usage (Chart 11) now has a spike in the summer due to the chiller plant operation. The natural gas usage is no longer zero in the summer months due to the switch to the DOAS/ACB systems. These new systems require higher natural gas usage (Chart 12) due to dehumidification and the chilled beams lower heating efficiency. Also shown is the usage of domestic water for the condenser (Chart 13). It also has its peak in the summer months when the chiller plant is operating more.

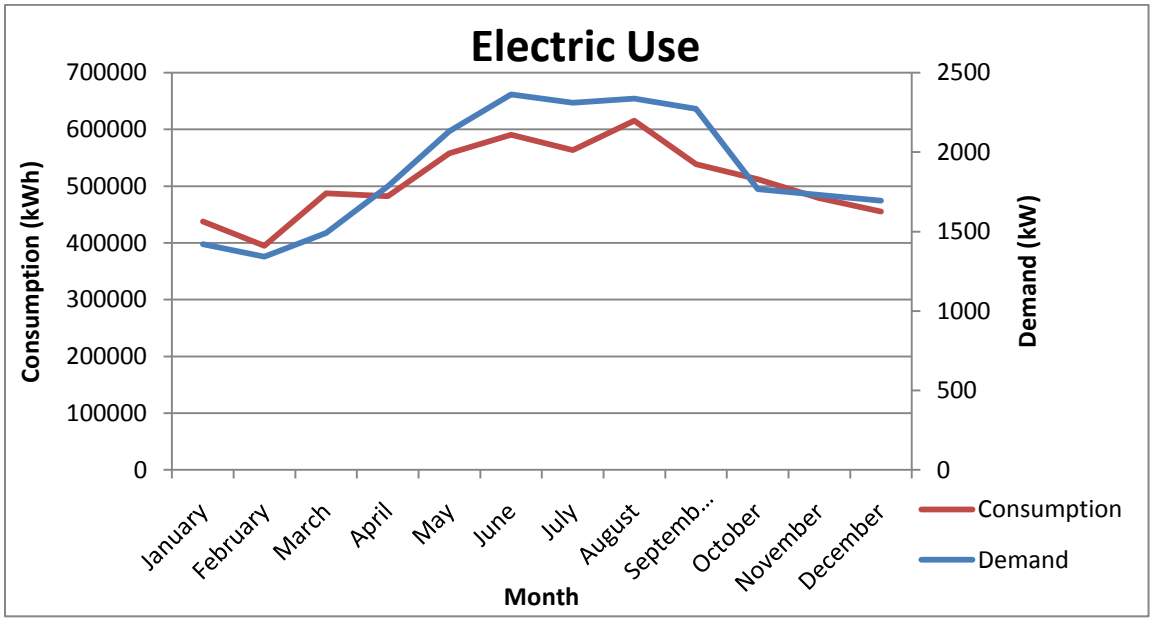

Chart 11

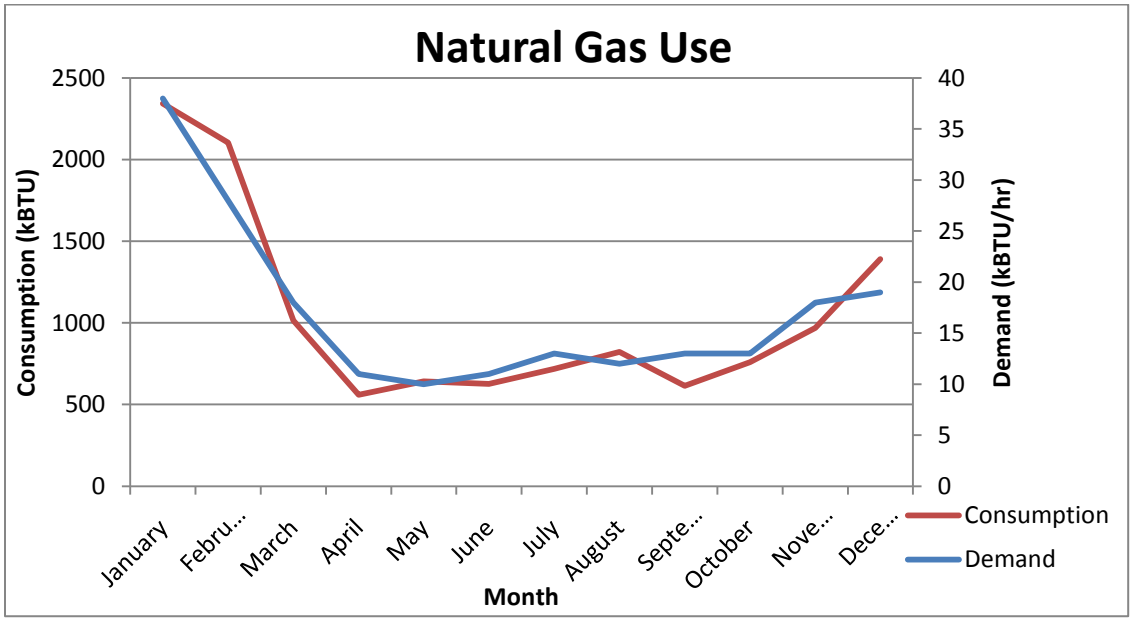

Chart 12

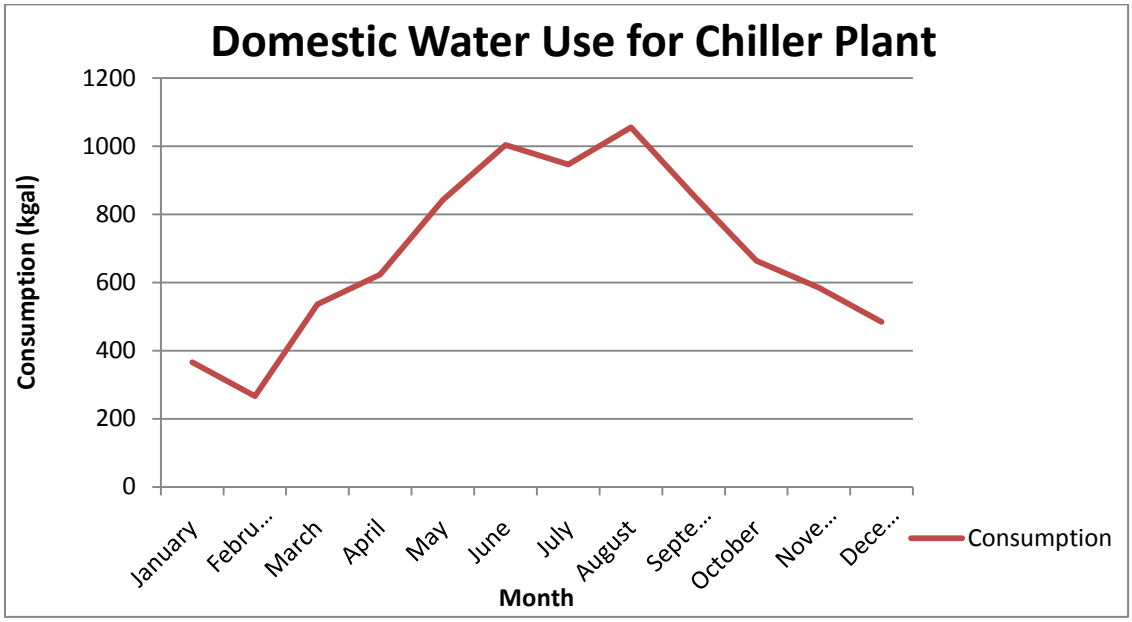

Chart 13

The new annual utility costs are broken down by energy source in Table 45. The charges sum to a total annual utility cost of **$859,320.34.** This cost is **30%** less than the cost associated with the existing system alone and **1.3%** less than that of the new DOAS/ACB system with shading addition on purchased chilled water. This equates to approximately **$1.07/ft²** annually. Chart 14 shows the percentages of each utility cost.

Energy Cost Summary					
Electric			Natural Gas	Condenser Water	Total
Consumption	Demand	Total	Consumption	Consumption	Consumption
$611,574.56	$226,460.00	$838,034.56	$10,427.46	$10,858.32	$859,320.34

Table 45

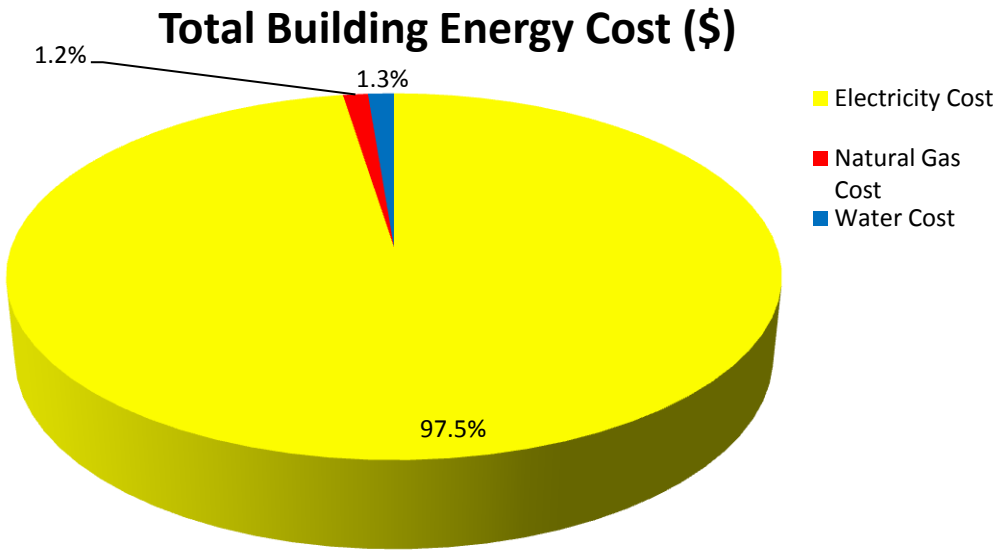

Chart 14

Emissions

The same emissions calculations were calculated based on the electrical grid calculations. The emissions associated with the electricity usage from the chiller plant implementation are summarized in Table 46. Emissions from the natural gas boiler are the same as the previous topic without the chiller plant. Therefore, these emissions calculations are not being shown again.

Annual Emissions for Electrical Consumption				
Electric Use	1	kWh	6,115,746	kWh
Pollutant	Eastern Interconnection Emission Factor		Annual Pollution	
CO_{2e}	1.74E+00		10,641,397.34	lb
CO_2	1.64E+00		10,029,822.78	lb
CH_4	3.59E-03		21,955.53	lb
N_2O	3.87E-05		236.68	lb
NO_x	3.00E-03		18,347.24	lb
SO_x	8.57E-03		52,411.94	lb
CO	8.54E-04		5,222.85	lb
TNMOC	7.26E-05		444.00	lb
Lead	1.39E-07		0.85	lb
Mercury	3.36E-08		0.21	lb
PM10	9.26E-05		566.32	lb
Solid Waste	2.05E-01		1,253,727.85	lb

Table 46

LEED Analysis

With the proposed new shading devices and new DOAS/ACB systems, the building achieves over 42% energy savings over the baseline building. This is the maximum that EA Credit 1 "Optimize Energy Performance" goes up to and awards 10 points for at least 42% energy savings. This increases the LEED credits of the facility with its aforementioned upgrades by one point to 40 points. The addition of the chiller plant, however, violates EA Credit 4 "Enhanced Refrigerant Management" by utilizing a refrigerant with its chiller plant. This reduces the LEED credits by one point. The Duval County Unified Courthouse Facility is still granted LEED Gold Certification with 39 points.

Economics

The new chiller plant's initial costs were calculated using estimates from RS Means Cost Estimating Data. The cost of materials and installation for this plant is approximately **$1,867,550** for chillers, cooling towers, controls, and pumps. For the purpose of the LCC analysis, the alternatives initial cost will also include the previous initial costs of the DOAS/CHB and shading systems. The LCC calculations for all alternatives can be found in Appendix C of this report. Economics of the new chiller plant are summarized in Table 47 below.

Chiller Plant Economics	
Initial Cost	$1,867,550
Purchased Ch.W Savings	$11,579.36
Additional Proposals Cost	$5,003,482
Additional Proposals Savings	$342,422.28
Simple Payback	19 Years
Lice Cycle Cost	$19,766,007

Table 47

Photovoltaic Array Analysis

The Duval County Unified Courthouse Facility is in a climate that is dominated by solar radiation. This being said, photovoltaic (PV) panels are being investigated to provide onsite power generation. This will decrease the necessary annual electric consumption of the building and decrease the facility's dependence on the utility grid. PV panels work by converting incident solar electro-magnetic radiation into direct current electricity via the photovoltaic effect. Since the electricity generated is Direct Current, an inverter is required as part of the system to convert the power into commonly used Alternating Current. With the large electric consumption of the facility, a system that generates excess power to sell back to grid is not feasible. A small system that generates electricity in order to reduce required electricity purchasing can prove beneficial.

The National Renewable Energy Laboratory (NREL) provides information on feasibility and benefits of renewable energy. Figure 10 is an annual PV solar radiation map of the United States created by NREL. According to this figure, Jacksonville, FL is capable of receiving 5.0-5.5 kWh/m^2 per day for PV panels facing south and at a tilt equal to the location's latitude. This averages to approximately 178 kWh/ft^2 in an average year.

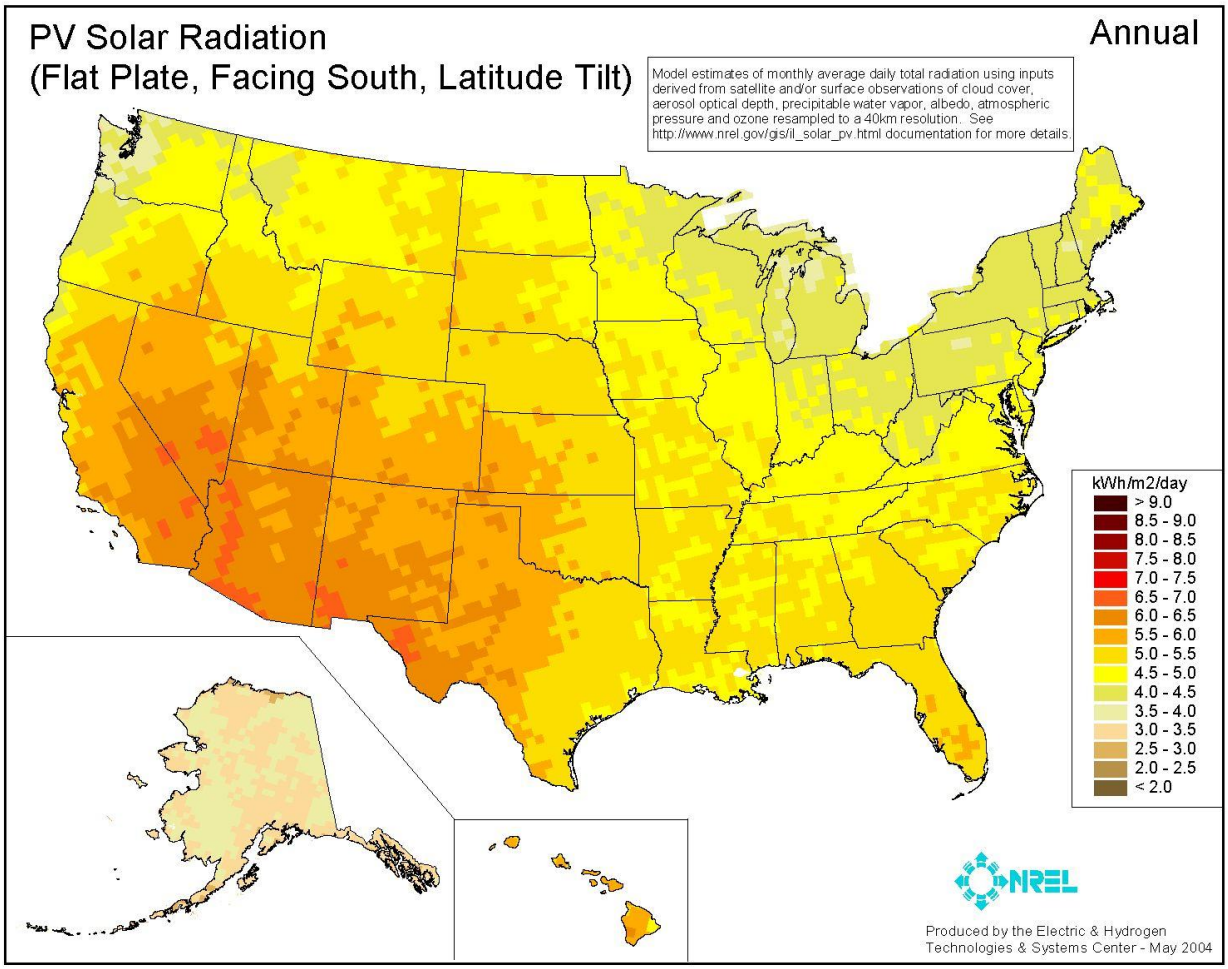

Figure 10

The specific PV model researched for the Duval County Unified Courthouse Facility was the BP 3280T by BP Solar. This pane; has advantages of longevity and resistance to degradation. It is also one of the highest maximum power output panels on the market. The roof area that is available for PV panels is approximately 54,000 ft^2. This is a very large footprint and would allow for a large PV array. If the roof was filled with panels, spaced far enough apart to eliminate panel shading by neighboring panels, 2,520 of these panels could be place on the roof. This equates to roughly a 700 kW array. This array is simply too large because of costs. Estimates from RS Means Cost Estimating Data and BP Solar approximate the price at about $6.50/W. This price includes the panel, installation, and associated costs with wiring and inverters. This brings the price for a BP 3280T panel to $1,800. Rebates and incentives are available, however, to drive down the initial cost of the

system. The **Florida Solar Energy System Incentives Program** offers a rebate of $4.00/Watt with a maximum rebate available of $100,000. The **U.S. Department of Treasury Renewable Energy Grants**, a federal grant program, offers grants up to 30% of the initial system cost. With the Florida state incentive, a large array will not get any more of a rebate than an array of 25 kW. With these two incentives, an array was sized based on the Simple Payback period. Typical PV panels last 25 years, so a system that pays itself off before this 25 year period is ideal. With this requirement, a 100 kW array was specified. This array consists of 358 panels distributed over the large roof of the Duval County Unified Courthouse Facility. With a smaller number of panels, the panels can be spaced farther apart to completely eliminate panel shading as well as decrease the dead load on the roof structure by distributing them better. The 100 kW array should generate an average of **146,350 kWh** annually. The total array cost without incentives is $644,400. However, incentives include $100,000 from the Florida state rebate and $193,320 from the federal grant for a total cost reduction of $293,320. This decreases the PV system's cost to **$351,080.** At a rate of $0.10/kWh, the array can save approximately **$14,640** in annual electricity costs. This equates to a Simple Payback of 24 years, meaning the array should be paid back with roughly one year to spare on the life of the PV panels. The electricity generated by the PV array shall be used to power the electrically motorized shading system that was proposed or help offset electricity costs of the proposed chiller plant.

Floor-to-Floor Height Reduction Analysis

The conversion from an all-air Variable Air Volume system to a Dedicated Outdoor Air System with Active Chilled Beams greatly reduced the airflow required. The supply air flow was reduced by 277,646 CFM, which was 57%. This reduction allows for significant decreases in ductwork and duct sizing that dominate the ceiling plenum. The existing VAV system also has 25 AHUs, most of which are also very large (up to 50,000 CFM). A few of these AHUs are actually located in plenum spaces between floors. The substantial number of terminal VAV boxes also utilizes a large amount of the plenum space. The reduction in ductwork, duct size, AHUs, and VAV boxes can free up a lot of space in the plenum. It is proposed that, with the system conversion to DOAS and ACBs, the floor-to-floor height of the Duval County Unified Courthouse Facility be reduced by four feet in the plenum space on each floor. This results in a total building height reduction of 28 feet. This height reduction saves both construction time and required materials for the building, notably the cast-in-place concrete structural columns and the façade materials. A cost and schedule reduction for both items has been analyzed.

Structural Concrete Columns

Using RS Means Cost Estimating Data, a total cost for materials and labor was calculated at $1,275 per cubic yard of cast-in-place concrete for columns. Table 48 provides data required for the analysis of the concrete columns. The calculations for column concrete volume reduction per floor are summarized in Table 49. Cost reduction is also available in this table.

Column Properties					
Column Size (ft)		Original Column Height (ft)	New Column Height (ft)	Column Height Reduction (ft)	Volume Reduction (CY)
Width	Length				
2	2	18	14	4	0.6

Table 48

Column Concrete Savings			
Floor	# Columns	Total Column Concrete Reduction (CY)	Total Column Construction Cost Reduction
1	242	145.2	$185,130.00
2	264	158.4	$201,960.00
3	126	75.6	$96,390
4	116	69.6	$88,740.00
5	116	69.6	$88,740.00
6	126	75.6	$96,390.00
7	120	72	$91,800.00
Total		**666**	**$849,150.00**

Table 49

Using the RS Means Cost Estimating Data, data on time consumption for placing the concrete columns was given as a daily output of 17.71 cubic yards of concrete per day. Using this labor output, the original height and reduced height column schedules were both estimated. Figure 11 shows the original schedule for 18 foot columns. Figure 12 is the new schedule with the reduced height columns. Figure 13 is the two schedules superimposed to get an idea of the amount of time saved. The total construction time on the concrete columns saved is **29.5 days.**

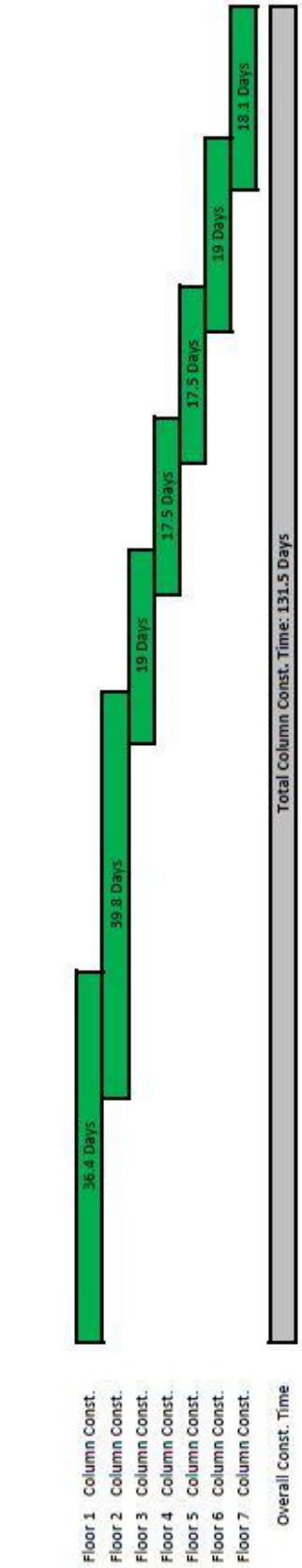

Figure 11

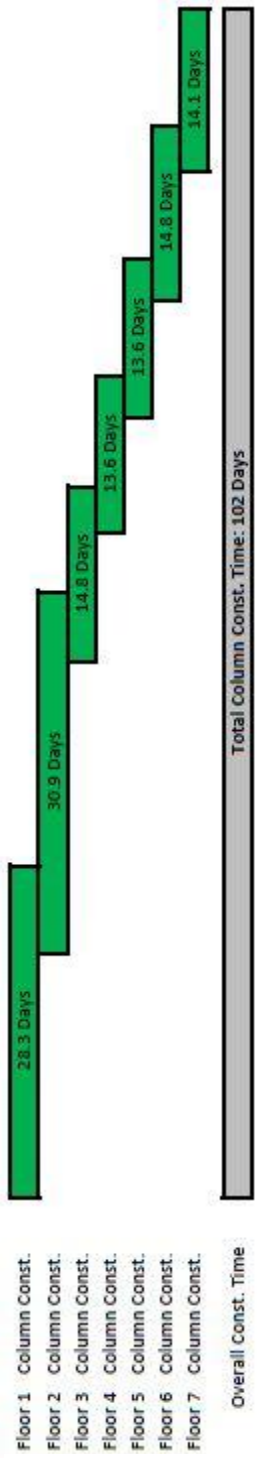

Figure 12

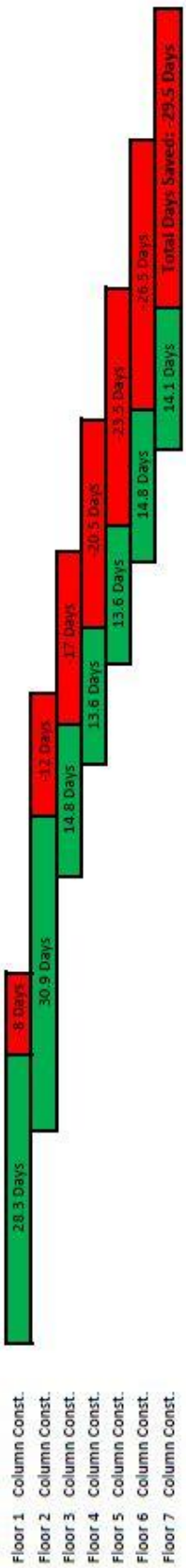

Figure 13

Façade Materials

The façade of the Duval County Unified Courthouse Facility is made up of architectural precast concrete panels and curtain wall glazing. Using RS Means Cost Estimating Data, a total cost for materials and labor was calculated at $43.61 per square foot of precast concrete panels and $90.50 per square foot of glazing. The percent façade that is glazing averages to be 43%. The calculations for façade reductions per floor and their associated cost reductions are in Tables 50 & 51.

Precast Concrete Panel Savings			
Floor	Perimeter (ft)	Concrete Façade Reduction (ft^2)	Concrete Façade Construction Cost Reduction
1	2223.5	5092.4	$222,078,69
2	2223.5	5092.4	$222,078.69
3	1937.8	4418.2	$192,677.00
4	1937.8	4418.2	$192,677.00
5	1937.8	4418.2	$192,677.00
6	1730.4	3945.3	$172,055.06
7	1730.4	3945.3	$172,055.06
	Total	**31329.9**	**$1,366,298.51**

Table 50

Façade Glazing Savings			
Floor	Perimeter (ft)	Concrete Façade Reduction (ft^2)	Concrete Façade Construction Cost Reduction
1	2223.5	3481.6	$347,666.61
2	2223.5	3481.6	$347,666.61
3	1937.8	3333.0	$301,637.95
4	1937.8	3333.0	$301,637.95
5	1937.8	3333.0	$301,637.95
6	1730.4	2976.3	$269,354.06
7	1730.4	2976.3	$269,354.06
	Total	**23,634.9**	**$2,138,955.19**

Table 51

Using the RS Means Cost Estimating Data, data on time consumption for erecting the precast concrete panels and glazing was given as a daily output of 512 square foot of concrete panels per day and 305 square foot of windows per day. Using this labor output, the original facade and reduced height facade schedules were both estimated. Figure 14 shows the original façade schedule for 18 foot floor heights. Figure 15 is the new façade schedule with the reduced floor heights. Figure 16 is the two schedules superimposed to get an idea of the amount of time saved. The total construction time on the façade system saved is **81 days.** Schedules are on the following page.

The total material and labor savings from this height reduction equates to **$4,354,403.70.** These savings dramatically decrease the initial cost of the DOAS/ACB system installation. If a chiller plant is implemented with the new system, these savings also carryover to reduce payback period. Tables 52 & 53 define the new economics of the DOAS/ACB system and chiller plant with this reduction in initial cost. New LCC analyses are also calculated in Appendix C.

DOAS/ACB with Shading Addition and Height Reduction Economics	
Original Cost	$5,128,882.10
Const. Cost Reduction	$4,354,403.70
New Initial Cost	$774,478.40
Total Savings	$342,422.28
Simple Payback	2.3 Years
20 Year LCC	$13,526,583

Table 52

Chiller Plant with Height Reduction Economics	
Initial Cost	$1,867,550
Purchased Ch.W Savings	$11,579.36
Additional Proposals Cost	$5,003,482
Additional Proposals Savings	$342,422.28
Const. Cost Reduction	$4,354,403.70
New Initial Cost	$2,516,628.30
Simple Payback	7.1 Years
Lice Cycle Cost	$15,411,603

Table 53

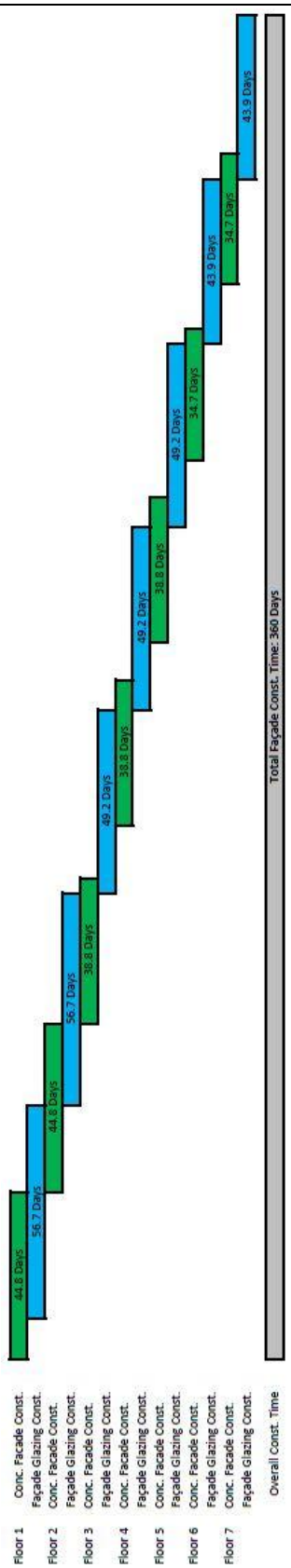

Figure 14

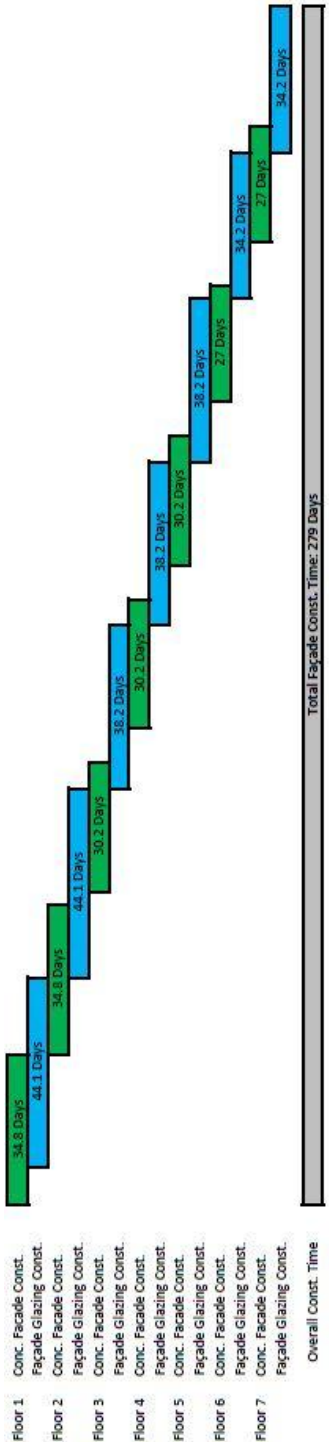

Figure 15

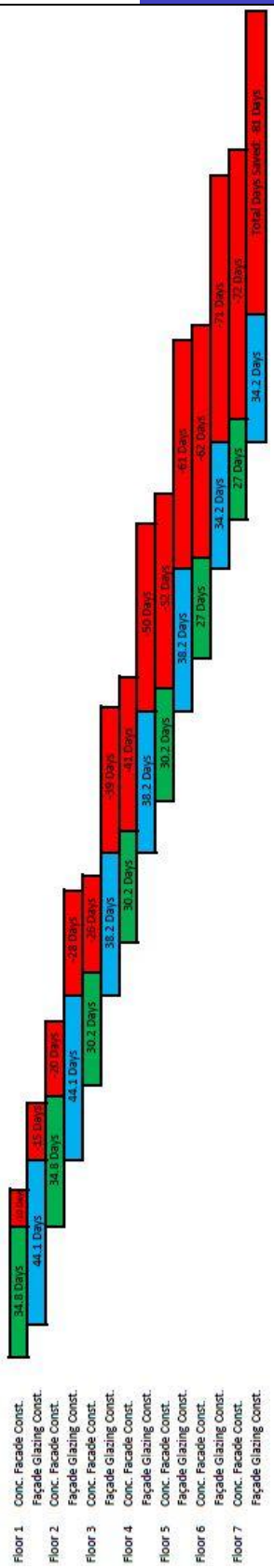

Figure 16

Alternative Comparisons & Conclusion

As previously mentioned, the proposed systems will be compared based on initial cost, life cycle cost, energy use & cost, simple payback, environmental impact, and LEED applicability.

Initial Cost

Each of alternative proposals' and the existing system's initial costs are compared and rated based on lowest initial cost in Table 54.

Initial Cost Comparison		
Alternative	Initial Cost	Rating
Existing VAV System	$2,608,539	3
Existing VAV System with Internal Shading	$3,762,944	4
DOAS/ACB with Internal Shading	$5,128,882	5
DOAS/ACB with Internal Shading and Height Reduction	$774,478	1
Chiller Plant with DOAS/ACB with Internal Shading	$6,871,032	6
Chiller Plant with DOAS/ACB with Internal Shading and Height Reduction	$2,516,628	2

Table 54

Life Cycle Cost

Each of the alternative proposals' and the existing system's life cycle costs are compared and rated based on lowed life cycle cost in Table 55. Life cycle cost analyses for all alternatives and the existing system can be found in Appendix C.

LCC Comparison		
Alternative	LCC	Rating
Existing VAV System	$20,575,135	5
Existing VAV System with Internal Shading	$21,244,274	6
DOAS/ACB with Internal Shading	$17,880,987	3
DOAS/ACB with Internal Shading and Height Reduction	$13,526,583	1
Chiller Plant with DOAS/ACB with Internal Shading	$19,766,007	4
Chiller Plant with DOAS/ACB with Internal Shading and Height Reduction	$15,411,603	2

Table 55

Energy Use & Cost

Each of the alternative proposals' and the existing system's energy usage are compared and rated based on least energy required in Table 56. The energy costs associated are compared and rated in Table 57.

Energy Use Comparison		
Alternative	Energy Use (MMBTU)	Rating
Existing VAV System	55,081	4
Existing VAV System with Internal Shading	52,552	3
DOAS/ACB with Internal Shading	38,027	2
DOAS/ACB with Internal Shading and Height Reduction	-	-
Chiller Plant with DOAS/ACB with Internal Shading	22,123	1
Chiller Plant with DOAS/ACB with Internal Shading and Height Reduction	-	-

Table 56

Energy Cost Comparison		
Alternative	Energy Cost	Rating
Existing VAV System	$,213,321.98	4
Existing VAV System with Internal Shading	$1,180,381.33	3
DOAS/ACB with Internal Shading	$870,899.70	2
DOAS/ACB with Internal Shading and Height Reduction	-	-
Chiller Plant with DOAS/ACB with Internal Shading	$859,320.34	1
Chiller Plant with DOAS/ACB with Internal Shading and Height Reduction	-	-

Table 57

Simple Payback

Each of the alternative proposals' simple payback with respect to savings over the existing system are compared and rated based on shortest payback period in Table 58.

Simple Payback Comparison		
Alternative	SPB	Rating
Existing VAV System	-	-
Existing VAV System with Internal Shading	35	5
DOAS/ACB with Internal Shading	15	3
DOAS/ACB with Internal Shading and Height Reduction	2.3	1
Chiller Plant with DOAS/ACB with Internal Shading	19	4
Chiller Plant with DOAS/ACB with Internal Shading and Height Reduction	7.1	2

Table 58

Environmental Impact

Each of the alternative proposals' and the existing system's emissions are compared and rated based on the least amount greenhouse gases total of equivalent Carbon Dioxide (CO_{2e}) in Table 59.

Emissions Comparison		
Alternative	Emissions (lb CO_{2e})	Rating
Existing VAV System	13,294,874.11	4
Existing VAV System with Internal Shading	13,062,795.68	3
DOAS/ACB with Internal Shading	10,111,410.78	1
DOAS/ACB with Internal Shading and Height Reduction	-	-
Chiller Plant with DOAS/ACB with Internal Shading	10,791,278.39	2
Chiller Plant with DOAS/ACB with Internal Shading and Height Reduction	-	-

Table 59

LEED Applicability

Each of the alternative proposals' and the existing system's LEED ratings are compared and rated based on the highest credits awarded in Table 60.

LEED Comparison		
Alternative	LEED Credits	Rating
Existing VAV System	32	4
Existing VAV System with Internal Shading	33	3
DOAS/ACB with Internal Shading	39	1
DOAS/ACB with Internal Shading and Height Reduction	-	-
Chiller Plant with DOAS/ACB with Internal Shading	39	1
Chiller Plant with DOAS/ACB with Internal Shading and Height Reduction	-	-

Table 60

System Selection Conclusion

In order to decide which alternative is most suitable for selection for the Duval County Unified Courthouse Facility, the ratings for each comparison are averaged together into a score in Table 61 below. The alternative with a score closest to 1 is the system that is most suitable based on the comparison criteria. Based on the scores, the alternative that is the most suitable for the Duval County Unified Courthouse Facility is the conversion from the existing Variable Air Volume system to the Dedicated Outdoor Air System with Active Chilled Beams and MultiFilm® Blinds addition with resulting floor-to-floor height reduction and without the chiller plant addition. The implementation of the facility chiller plant is still a feasible option, however, as it placed second in the scoring.

Rating Comparison		
Alternative	Average Score	**Rating**
Existing VAV System	4.000	**6**
Existing VAV System with Internal Shading	3.857	**5**
DOAS/ACB with Internal Shading	**2.428**	**3**
DOAS/ACB with Internal Shading and Height Reduction	**1.000**	**1**
Chiller Plant with DOAS/ACB with Internal Shading	2.714	**4**
Chiller Plant with DOAS/ACB with Internal Shading and Height Reduction	**2.000**	**2**

Table 61

The selected system actually does not require the facility owner to increase their budget for mechanical systems. However, it should be noted that these new alternatives may have increased costs with the designing and engineering of the system due to their complexities. The complexity of the system may also increase construction schedules for the mechanical installation.

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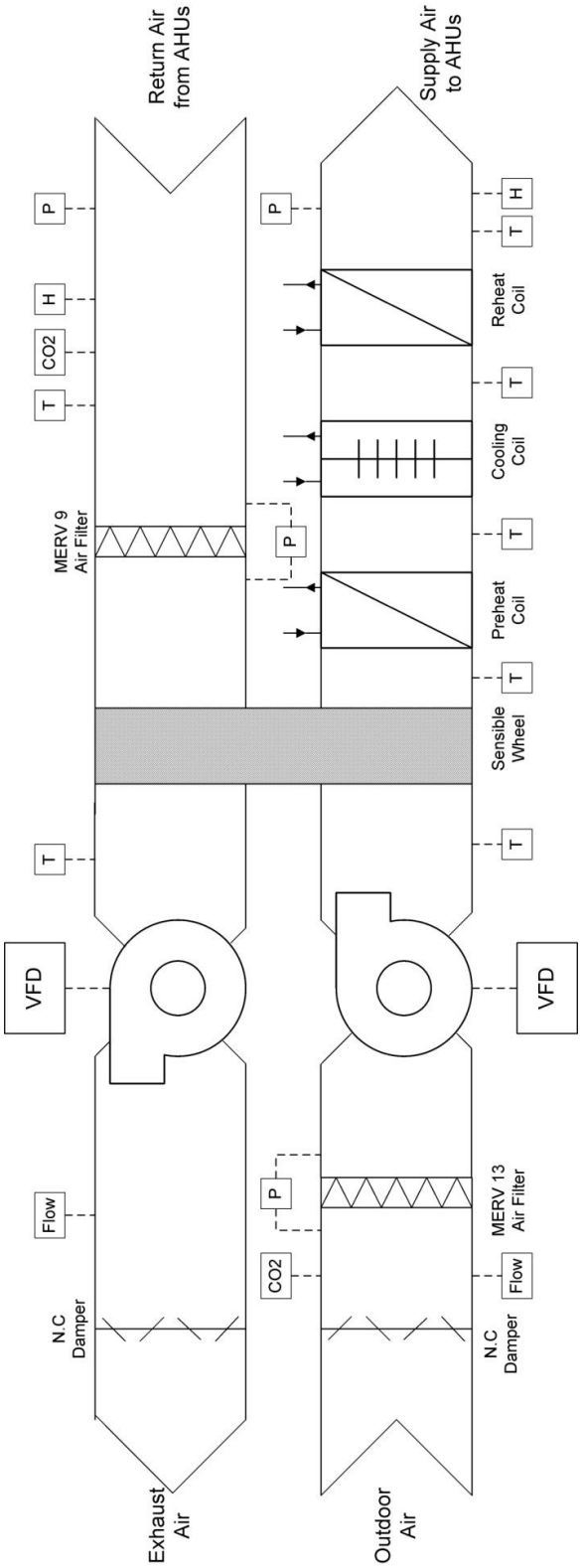
Trane TRACE 700 Software

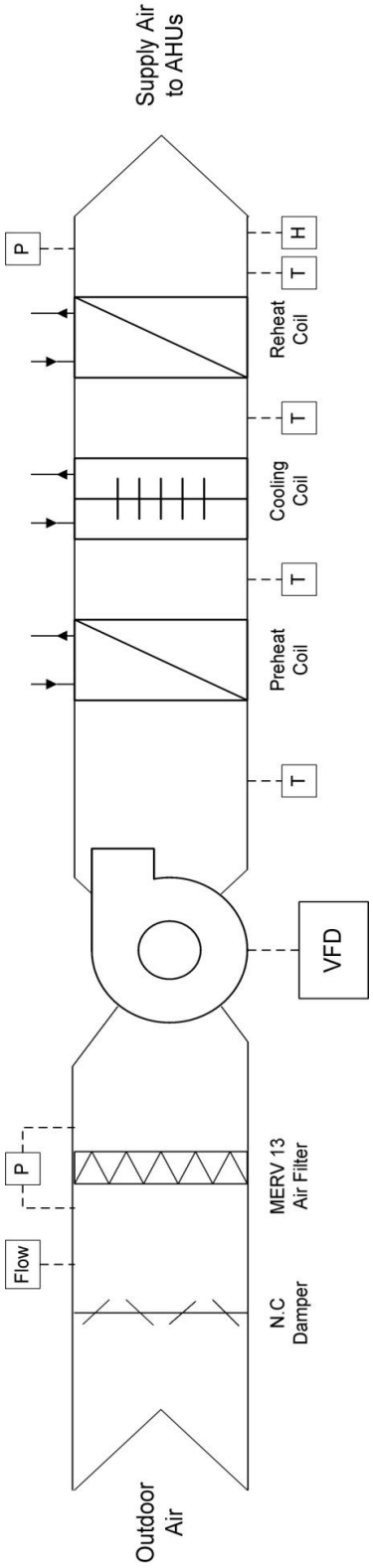
AE 557: Centralized Cooling Production and Distribution Systems Course Material

RS Means Cost Estimating Data 2011

Appendix A – Existing System Schematics



MAU with Energy Recovery



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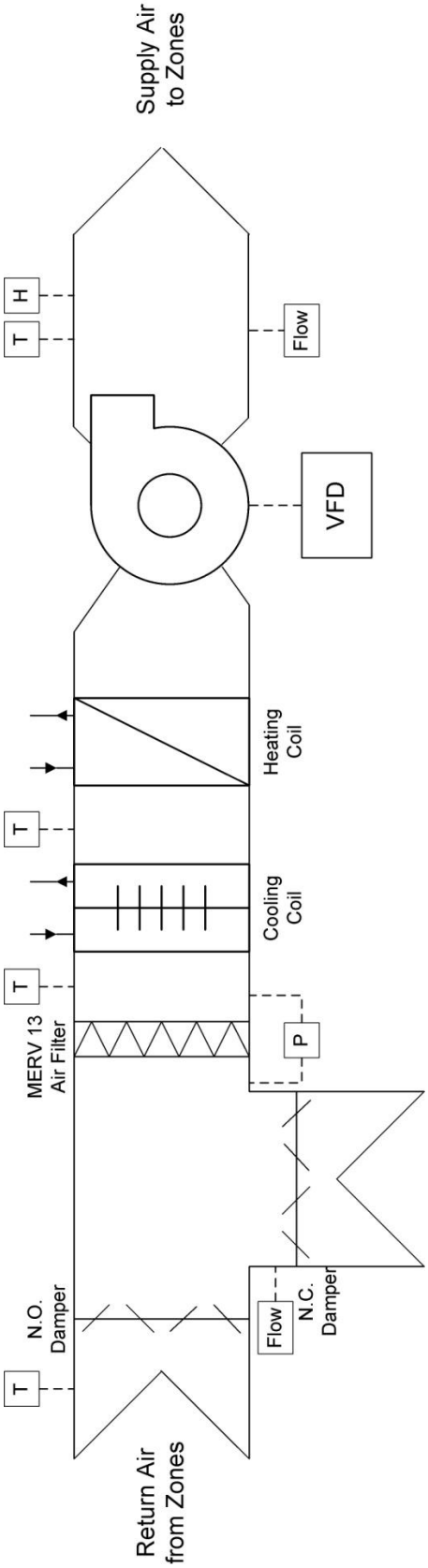
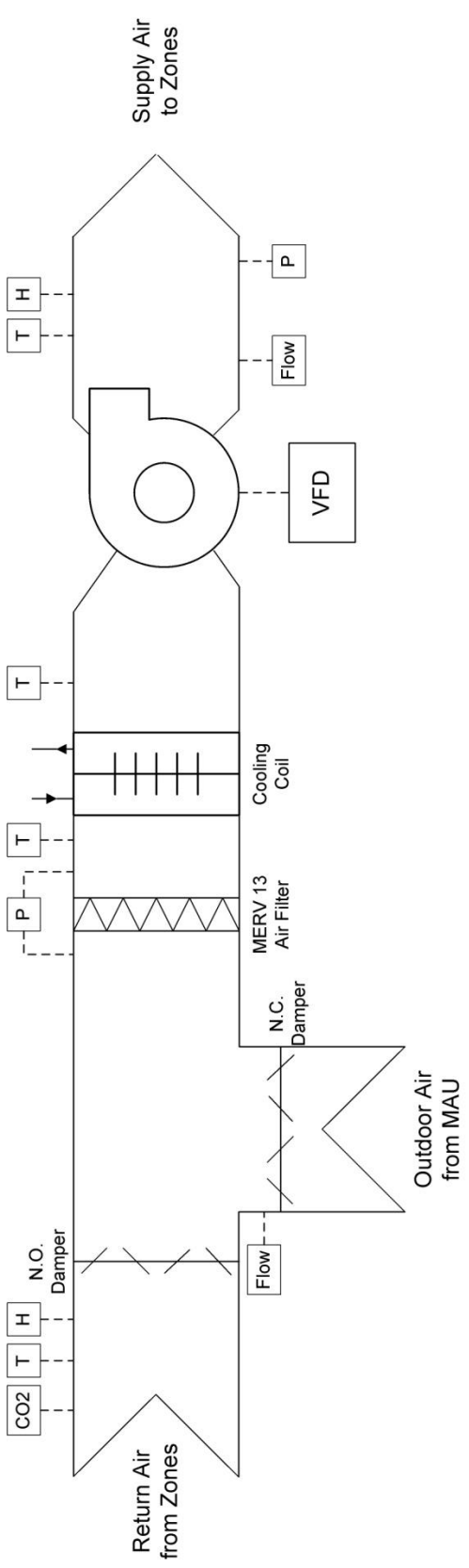
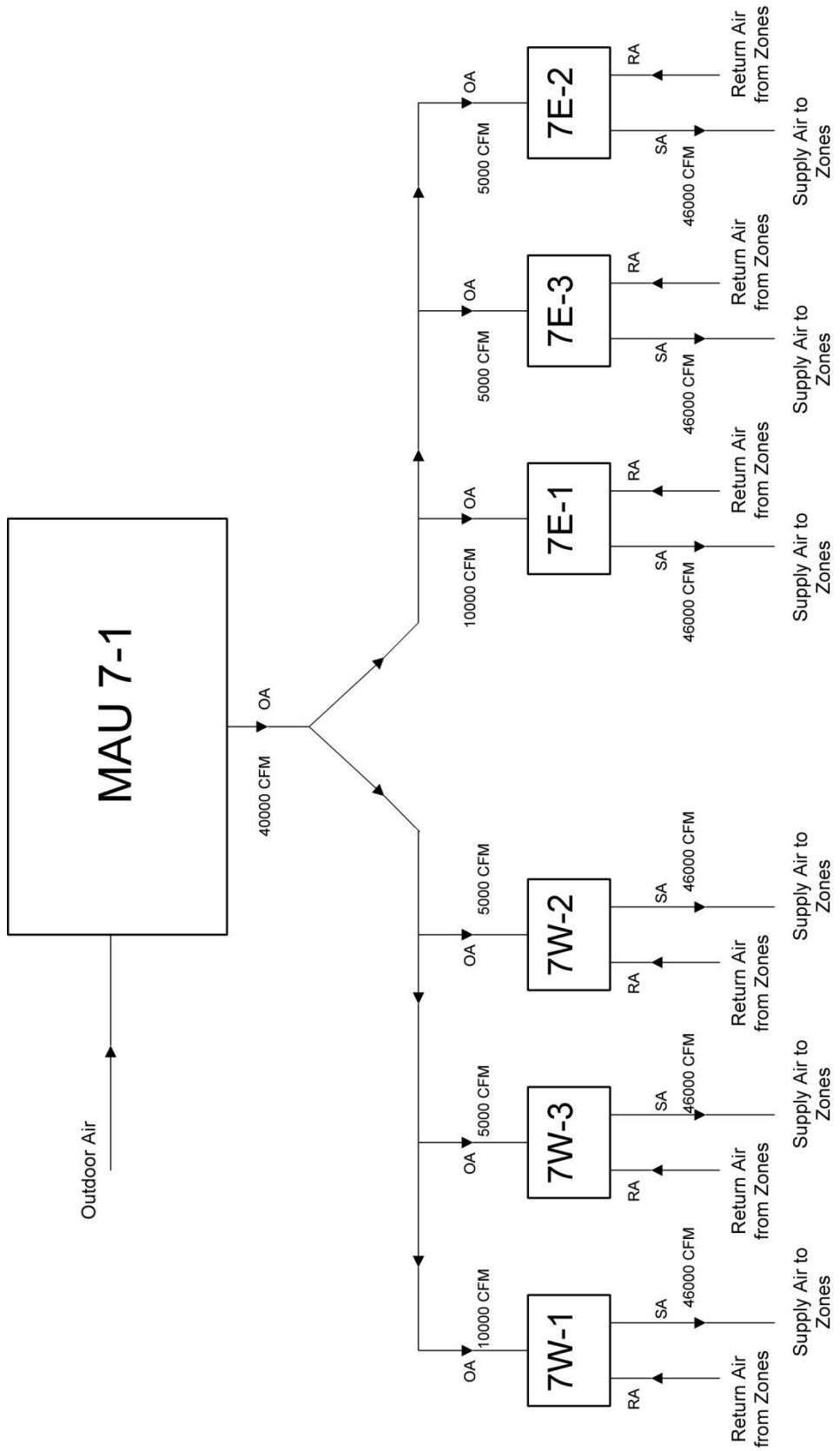


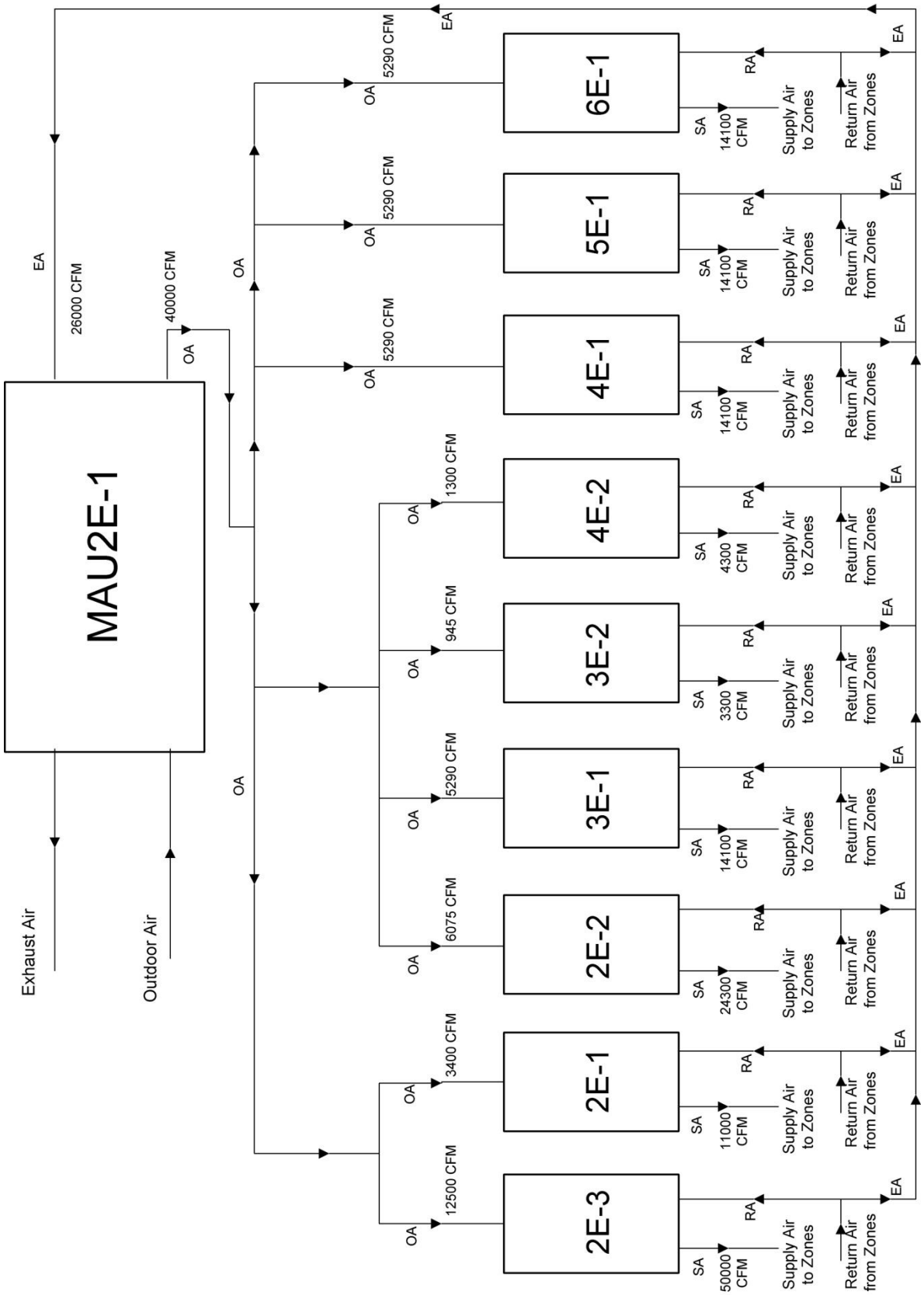
Courtroom AHU with Reheat Coil



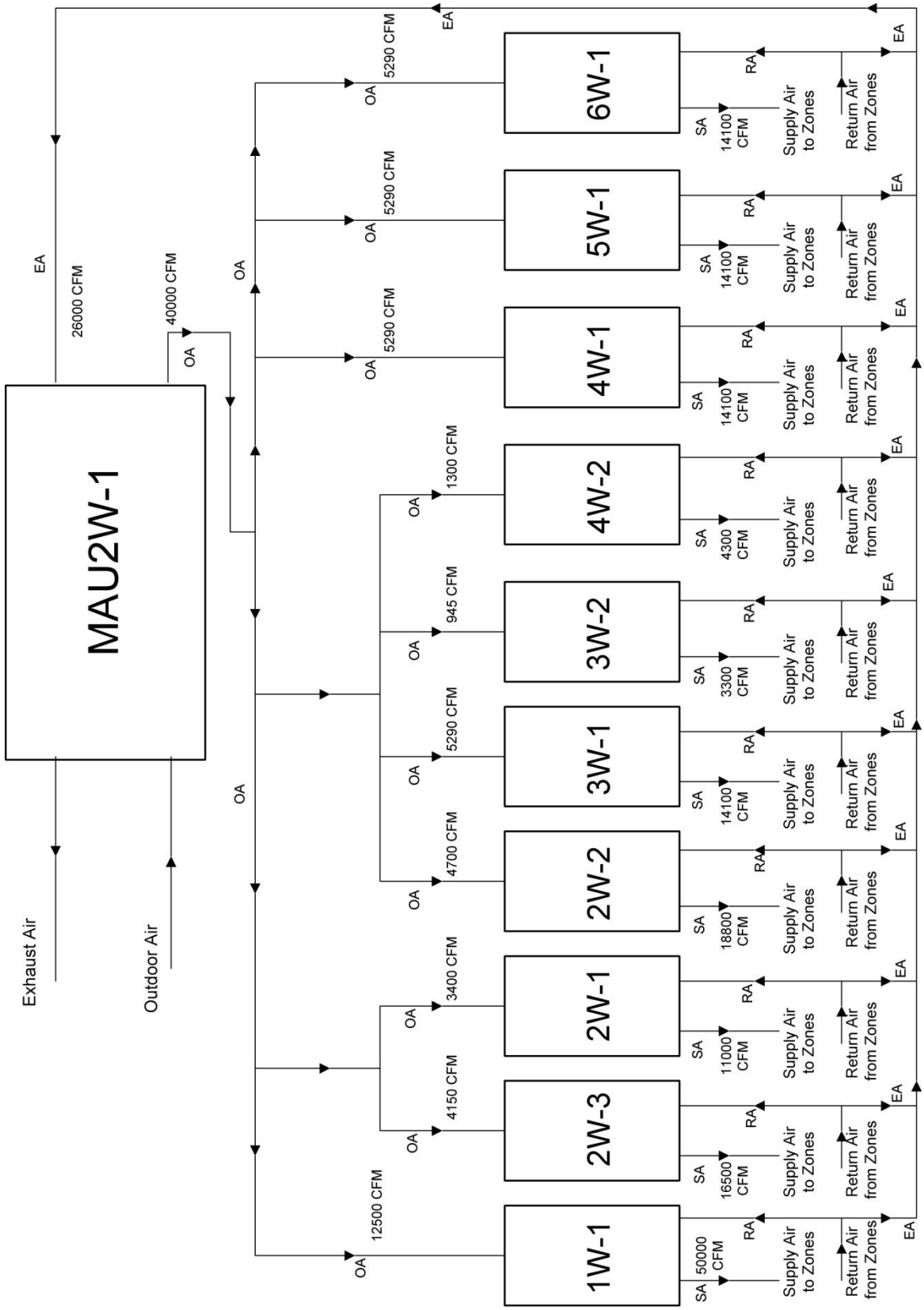
Typical AHU without Reheat Coil



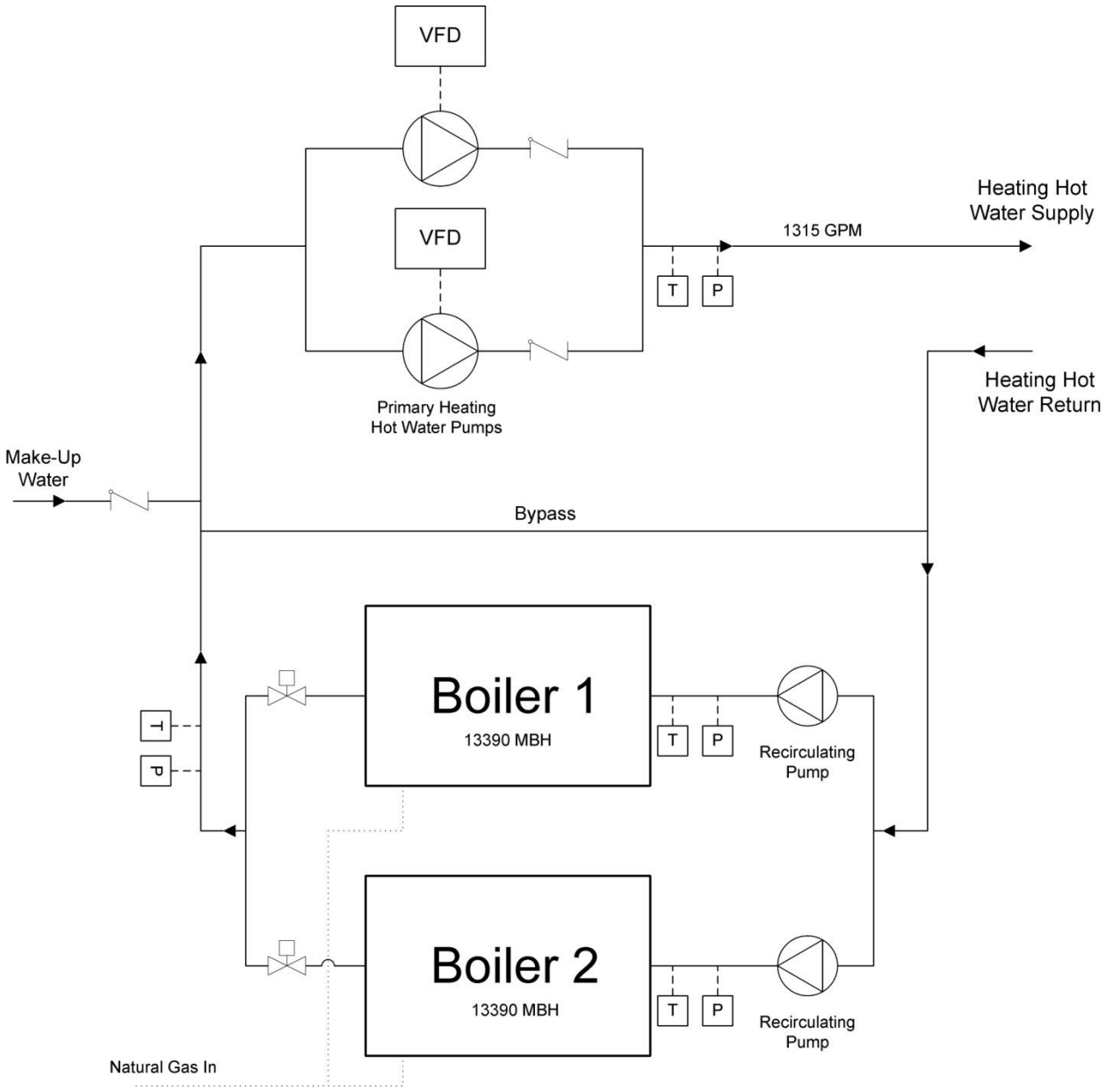
MAU 7-1 Air Distribution



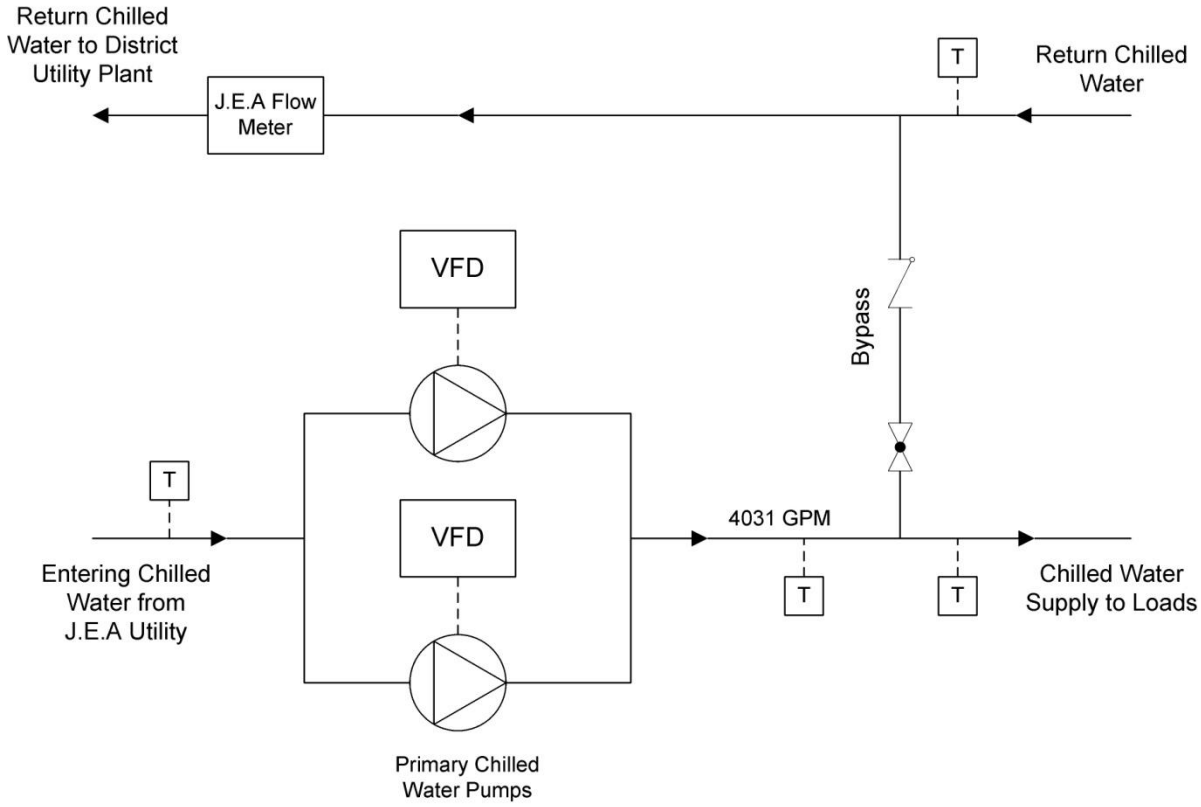
MAU 2E-1 Air Distribution



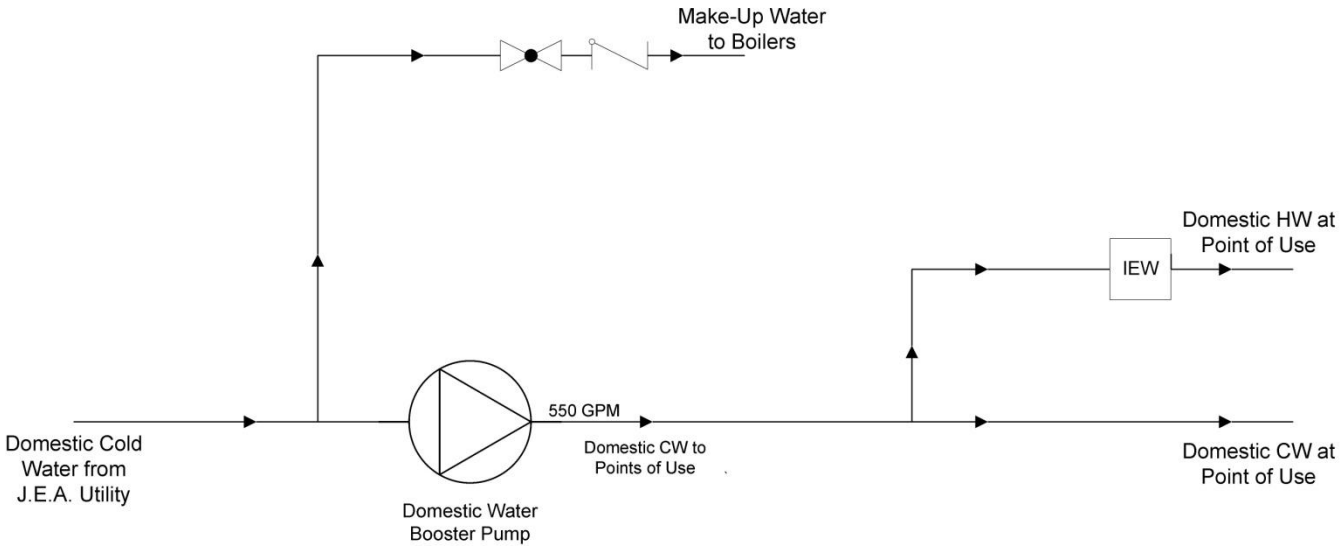
MAU 2W-1 Air Distribution



Heating Hot Water Schematic



Chilled Water Pumping Schematic



Domestic Water Schematic

Appendix B – Load & Energy Model Spaces

Trane TRACE Spaces and Associated Load Types					
Room #	Space	Area (ft^2)	Internal Load Type	Airflow Load Type	Construction Type
18	Mech.	675	Mech/Elect.	Mech/Elect.	Shaft
30	Lobby	2708	Lobby	Lobby	Default
31	Security/Lobby	7605	Main Lobby	Main Lobby	Main Lobby
32	Lobby	2541	Lobby	Lobby	Default
33	Lobby	9158	Main Lobby	Main Lobby	Main Lobby
37	General Office Space	7735	Office Space	Office Space	Default
48	General Office Space	16423	Office Space	Office Space	Default
83	General Office Space	7800	Office Space	Office Space	Default
87	Electrical Space	325	Mech/Elect.	Mech/Elect.	Shaft
90	Public Restrooms	707	Lockerroom/RR	Lockerroom/RR	Default
97	Parking	11657	Parking	Parking	Shaft
100	General Office Space	474	Office Space	Office Space	Default
103	Locker Room	807	Lockerroom/RR	Lockerroom/RR	Default
105	Storage Space	1101	Storage Space	Storage Space	Default
108	Mechanical Space	2620	Mech/Elect.	Mech/Elect.	Shaft
110	Electrical Space	142	Mech/Elect.	Mech/Elect.	Default
114	General Office Space	442	Office Space	Office Space	Default
117	Storage Space	2935	Storage Space	Storage Space	Default
123	Elect.	1137	Mech/Elect.	Mech/Elect.	Shaft
125	Sallyport	7309	Sallyport	Sallyport	Corridor
126	Holding Office Space	592	Office Space	Office Space	Default
131	Holding Office Space	190	Office Space	Office Space	Default
132	General Storage	106	Storage Space	Storage Space	Default
135	Holding Cells	650	Holding Cell	Holding Cell	Default
139	General Office Space	533	Office Space	Office Space	Default
146	Holding Cells	553	Holding Cell	Holding Cell	Default
159	Holding Office Space	107	Office Space	Office Space	Default
163	Holding Cells	428	Holding Cell	Holding Cell	Default
168	General Office Space	735	Office Space	Office Space	Default
185	Mech.	385	Mech/Elect.	Mech/Elect.	Shaft
186	Elect.	746	Mech/Elect.	Mech/Elect.	Shaft
190	General Office Space	1021	Office Space	Office Space	Default
197	Public Restrooms	601	Lockerroom/RR	Lockerroom/RR	Default
199	Electrical Space	209	Mech/Elect.	Mech/Elect.	Default
201	Shower Room	791	Lockerroom/RR	Lockerroom/RR	Default
208	General Office Space	7487	Office Space	Office Space	Default
218	Electrical Space	265	Mech/Elect.	Mech/Elect.	Default
222	Public Restrooms	703	Lockerroom/RR	Lockerroom/RR	Default
226	General Office Space	744	Office Space	Office Space	Default
231	Electrical Space	338	Mech/Elect.	Mech/Elect.	Default
235	Corridor	17441	Corridor	Corridor	Corridor
238	General Office Space	6069	Office Space	Office Space	Default
242	Parking	11677	Parking	Parking	Shaft
248	Storage Space	3704	Storage Space	Storage Space	Default

250	Electrical Space	256	Mech/Elect.	Mech/Elect.	Default
251	General Office Space	3229	Office Space	Office Space	Default
256	Storage Space	1797	Storage Space	Storage Space	Default
258	General Office Space	981	Office Space	Office Space	Default
263	Mechanical Space	256	Mech/Elect.	Mech/Elect.	Shaft
280	Storage Space	983	Storage Space	Storage Space	Default
2468	Holding Cells	552	Holding Cell	Holding Cell	Default
2517	General Office Space	15208	Office Space	Office Space	Default
287	General Office Space	2198	Office Space	Office Space	Default
308	Corridor	591	Corridor	Corridor	Corridor
312	General Office Space	4940	Office Space	Office Space	Default
319	Public Restrooms	688	Lockerroom/RR	Lockerroom/RR	Default
320	Storage Space	182	Storage Space	Storage Space	Default
321	Jury Lounge Lobby	1489	Lobby	Waiting Area	Default
329	Vending	2361	Corridor	Corridor	Corridor
330	General Office Space	4647	Office Space	Office Space	Default
340	Hearing Rooms	3186	Conference Space	Conference Space	Default
372	Electrical Space	332	Mech/Elect.	Mech/Elect.	Default
378	Womens Rr	317	Lockerroom/RR	Lockerroom/RR	Default
382	Office Space	817	Office Space	Office Space	Default
385	Meeting Rooms	605	Conference Space	Conference Space	Default
388	Restroom	196	Lockerroom/RR	Lockerroom/RR	Default
390	Storage Space	48	Storage Space	Storage Space	Default
392	Atrium	2390	Shaft	Shaft	Shaft
394	Public Restroom	507	Lockerroom/RR	Lockerroom/RR	Default
396	Mechanical Space	848	Mech/Elect.	Mech/Elect.	Shaft
397	Library	3648	Library	Library	Corridor
401	Electrical Space	186	Mech/Elect.	Mech/Elect.	Default
407	Storage	91	Storage Space	Storage Space	Default
414	Holding Cells	574	Holding Cell	Holding Cell	Default
418	Mechanical Space	176	Mech/Elect.	Mech/Elect.	Shaft
422	Storage Space	325	Storage Space	Storage Space	Default
424	Holding Cells	70	Holding Cell	Holding Cell	Default
431	Electrical Space	313	Mech/Elect.	Mech/Elect.	Default
436	Mens Rr	326	Lockerroom/RR	Lockerroom/RR	Default
438	Storage Space	670	Storage Space	Storage Space	Default
443	Courtroom	2090	Courtroom	Courtroom	Courtroom
456	Jury Space	412	Conference Space	Conference Space	Courtroom
460	Jury Space	411	Conference Space	Conference Space	Courtroom
464	Storage Space	191	Storage Space	Storage Space	Default
469	Courtroom	2099	Courtroom	Courtroom	Courtroom
474	Electrical Space	191	Mech/Elect.	Mech/Elect.	Default
479	Jury Space	408	Conference Space	Conference Space	Courtroom
480	Courtroom	2102	Courtroom	Courtroom	Courtroom
482	Jury Space	419	Conference Space	Conference Space	Courtroom
486	Courtroom	2111	Courtroom	Courtroom	Courtroom
491	Storage Space	94	Storage Space	Storage Space	Default
502	Storage Space	69	Storage Space	Storage Space	Default
515	Storage Space	91	Storage Space	Storage Space	Default
544	General Office Space	4812	Office Space	Office Space	Default
551	Conf. Rooms	1659	Conference Space	Conference space	Default

559	Conf. Rooms	1004	Conference Space	Conference space	Default
567	General Office Space	1697	Office Space	Office Space	Default
583	Storage Space	167	Storage Space	Storage Space	Default
600	Office Space	506	Office Space	Office Space	Default
604	General Office Space	6590	Office Space	Office Space	Default
614	Mechanical Space	225	Mech/Elect.	Mech/Elect.	Shaft
620	Server Room	1080	Server Room	Server Room	Default
627	General Office Space	3326	Office Space	Office Space	Default
632	Public Restrooms	501	Lockerroom/RR	Lockerroom/RR	Default
640	Courtroom	2167	Courtroom	Courtroom	Courtroom
642	Jury Space	411	Conference Space	Conference Space	Courtroom
646	Jury Space	417	Conference Space	Conference Space	Courtroom
651	Electrical Space	182	Mech/Elect.	Mech/Elect.	Default
654	Courtroom	2090	Courtroom	Courtroom	Courtroom
665	Storage Space	74	Storage Space	Storage Space	Default
689	Courtroom	2095	Courtroom	Courtroom	Courtroom
695	Storage Space	182	Storage Space	Storage Space	Default
699	Jury Space	415	Conference Space	Conference Space	Courtroom
702	Jury Space	413	Conference Space	Conference Space	Courtroom
708	Courtroom	2188	Courtroom	Courtroom	Courtroom
712	General Office Space	17935	Office Space	Office Space	Default
725	Holding Cells	443	Holding Cell	Holding Cell	Default
732	Holding Cells	75	Holding Cell	Holding Cell	Default
735	Corridor	1699	Corridor	Corridor	Corridor
740	Mechanical Space	184	Mech/Elect.	Mech/Elect.	Shaft
752	Waiting Room	662	Lobby	Waiting Area	Default
754	Mens RR	329	Lockerroom/RR	Lockerroom/RR	Default
758	Electrical Space	242	Mech/Elect.	Mech/Elect.	Default
762	General Office Space	6093	Office Space	Office Space	Default
768	Womens RR	331	Lockerroom/RR	Lockerroom/RR	Default
772	Electrical Space	279	Mech/Elect.	Mech/Elect.	Default
774	Corridor	5911	Corridor	Corridor	Corridor
2470	Holding Cells	565	Holding Cell	Holding Cell	Default
2472	Hearing Rooms	2699	Conference Space	Conference Space	Default
2479	Patio	1051	Corridor	Corridor	Corridor
2481	Cr Meeting Space	371	Conference Space	Conference space	Default
2482	Storage Space	89	Storage Space	Storage Space	Default
2483	Cr Meeting Space	431	Conference Space	Conference space	Default
2484	Cr Meeting Space	431	Conference Space	Conference space	Default
2485	Cr Meeting Space	397	Conference Space	Conference space	Default
2486	Storage Space	342	Storage Space	Storage Space	Default
2487	Storage Space	661	Storage Space	Storage Space	Default
2488	Cr Meeting Space	411	Conference Space	Conference space	Default
2489	Cr Meeting Space	429	Conference Space	Conference space	Default
2490	Cr Meeting Space	437	Conference Space	Conference space	Default
2491	Cr Meeting Space	383	Conference Space	Conference space	Default
2492	Hearing Room Lobby	2323	Lobby	Waiting Area	Default
2493	Corridor	218	Corridor	Corridor	Corridor
2494	Corridor	6702	Corridor	Corridor	Corridor
2495	Corridor	7938	Corridor	Corridor	Corridor
2496	Corridor	6123	Corridor	Corridor	Corridor

2518	Jury Lounge	6836	Conference Space	Conference Space	Courtroom
2519	General Office Space	6065	Office Space	Office Space	Default
779	General Office Space	319	Office Space	Office Space	Default
781	Corridor	9870	Corridor	Corridor	Corridor
787	Courtroom	2107	Courtroom	Courtroom	Courtroom
788	Jury Space	419	Conference Space	Conference Space	Courtroom
793	Jury Space	403	Conference Space	Conference Space	Courtroom
797	Storage Space	198	Storage Space	Storage Space	Default
801	Courtroom	2108	Courtroom	Courtroom	Courtroom
803	Storage	74	Storage Space	Storage Space	Default
805	Courtroom	2109	Courtroom	Courtroom	Courtroom
808	Electrical Space	201	Mech/Elect.	Mech/Elect.	Default
813	Jury Space	409	Conference Space	Conference Space	Courtroom
818	Jury Space	415	Conference Space	Conference Space	Courtroom
819	Courtroom	2104	Courtroom	Courtroom	Courtroom
824	Storage Space	92	Storage Space	Storage Space	Default
827	Courtroom	2544	Courtroom	Courtroom	Courtroom
831	General Office Space	322	Office Space	Office Space	Default
835	General Office Space	334	Office Space	Office Space	Default
838	Public Restroom	512	Lockerroom/RR	Lockerroom/RR	Default
840	Security Office	287	Office Space	Office Space	Default
843	Mechanical Space	359	Mech/Elect.	Mech/Elect.	Shaft
847	Jury Space	474	Conference Space	Conference Space	Courtroom
849	Corridor	794	Corridor	Corridor	Corridor
850	Storage Space	73	Storage Space	Storage Space	Default
856	Cr Meeting Space	391	Conference Space	Conference space	Default
860	Cr Meeting Space	401	Conference Space	Conference space	Default
867	Storage Space	69	Storage Space	Storage Space	Default
869	Cr Meeting Space	431	Conference Space	Conference space	Default
881	Storage Space	91	Storage Space	Storage Space	Default
891	Corridor	3090	Corridor	Corridor	Corridor
898	Holding Cells	436	Holding Cell	Holding Cell	Default
902	Holding Cells	79	Holding Cell	Holding Cell	Default
907	Storage Space	309	Storage Space	Storage Space	Default
908	Mechanical Space	196	Mech/Elect.	Mech/Elect.	Shaft
913	Holding Cells	561	Holding Cell	Holding Cell	Default
923	Cr Meeting Space	207	Conference Space	Conference space	Default
926	Holding Cell	300	Holding Cell	Holding Cell	Default
931	Cr Meeting Space	213	Conference Space	Conference space	Default
935	Courtroom	2513	Courtroom	Courtroom	Courtroom
936	Jury Space	528	Conference Space	Conference Space	Courtroom
937	Storage Space	104	Storage Space	Storage Space	Default
952	General Office Space	375	Office Space	Office Space	Default
955	Atrium	3162	Shaft	Shaft	Shaft
957	General Office Space	136	Office Space	Office Space	Default
958	Server Room	285	Server Room	Server Room	Default
964	Courtroom	2502	Courtroom	Courtroom	Courtroom
968	Electrical Space	246	Mech/Elect.	Mech/Elect.	Default
972	Jury Space	540	Conference Space	Conference Space	Courtroom
974	Storage Space	104	Storage Space	Storage Space	Default
976	Corridor	789	Corridor	Corridor	Corridor

977	Cr Meeting Space	226	Conference Space	Conference space	Default
980	Cr Meeting Space	217	Conference Space	Conference space	Default
985	Holding Cells	277	Holding Cell	Holding Cell	Default
991	Corridor	3074	Corridor	Corridor	Corridor
998	Holding Cells	565	Holding Cell	Holding Cell	Default
1004	Mech.	192	Mech/Elect.	Mech/Elect.	Shaft
1008	Storage Space	310	Storage Space	Storage Space	Default
1010	Holding Cell	77	Holding Cell	Holding Cell	Default
1024	Cr Meeting Space	366	Conference Space	Conference space	Default
1029	Storage Space	80	Storage Space	Storage Space	Default
1034	Cr Meeting Space	407	Conference Space	Conference space	Default
1040	Cr Meeting Space	406	Conference Space	Conference space	Default
1043	Storage Space	64	Storage Space	Storage Space	Default
1050	Cr Meeting Space	379	Conference Space	Conference space	Default
1057	Cr Meeting Space	381	Conference Space	Conference space	Default
1061	Storage Space	70	Storage Space	Storage Space	Default
1062	Jury Space	469	Conference Space	Conference Space	Courtroom
1066	Mech.	679	Mech/Elect.	Mech/Elect.	Shaft
1067	Public Restroom	524	Lockerroom/RR	Lockerroom/RR	Default
1069	Courtroom	2532	Courtroom	Courtroom	Courtroom
1074	Storage Space	92	Storage Space	Storage Space	Default
1077	Courtroom	2114	Courtroom	Courtroom	Courtroom
1081	Jury Space	417	Conference Space	Conference Space	Courtroom
1085	Jury Space	409	Conference Space	Conference Space	Courtroom
1090	Electrical Space	198	Mech/Elect.	Mech/Elect.	Default
1093	Courtroom	2116	Courtroom	Courtroom	Courtroom
1098	Courtroom	2104	Courtroom	Courtroom	Courtroom
1101	Storage Space	201	Storage Space	Storage Space	Default
1105	Jury Space	411	Conference Space	Conference Space	Courtroom
1110	Jury Space	442	Conference Space	Conference Space	Courtroom
1111	Courtroom	2090	Courtroom	Courtroom	Courtroom
1117	General Office Space	325	Office Space	Office Space	Default
1120	General Office Space	338	Office Space	Office Space	Default
1123	General Office Space	334	Office Space	Office Space	Default
2497	Cr Meeting Space	384	Conference Space	Conference space	Default
2498	Cr Meeting Space	430	Conference Space	Conference space	Default
2499	Corridor	4443	Corridor	Corridor	Corridor
2500	Corridor	4268	Corridor	Corridor	Corridor
2501	Storage Space	253	Storage Space	Storage Space	Default
2520	Holding Cells	453	Holding Cell	Holding Cell	Default
1129	General Office Space	319	Office Space	Office Space	Default
1131	Corridor	8206	Corridor	Corridor	Corridor
1137	Courtroom	2107	Courtroom	Courtroom	Courtroom
1139	Jury Space	403	Conference Space	Conference Space	Courtroom
1143	Storage Space	198	Storage Space	Storage Space	Default
1146	Courtroom	2108	Courtroom	Courtroom	Courtroom
1150	Courtroom	2109	Courtroom	Courtroom	Courtroom
1154	General Office Space	322	Office Space	Office Space	Default
1156	Jury Space	419	Conference Space	Conference Space	Courtroom
1161	Jury Space	409	Conference Space	Conference Space	Courtroom
1166	Electrical Space	201	Mech/Elect.	Mech/Elect.	Default

1168	Jury Space	415	Conference Space	Conference Space	Courtroom
1172	Courtroom	2104	Courtroom	Courtroom	Courtroom
1177	Atrium	4773	Shaft	Shaft	Shaft
1178	Courtroom	2544	Courtroom	Courtroom	Courtroom
1179	Storage Space	92	Storage Space	Storage Space	Default
1185	General Office Space	334	Office Space	Office Space	Default
1188	Public Restroom	512	Lockerroom/RR	Lockerroom/RR	Default
1190	General Office Space	287	Office Space	Office Space	Default
1192	Mechanical Space	359	Mech/Elect.	Mech/Elect.	Shaft
1197	Jury Space	474	Conference Space	Conference Space	Courtroom
1199	Storage Space	73	Storage Space	Storage Space	Default
1201	Corridor	933	Corridor	Corridor	Corridor
1209	Corridor	2260	Corridor	Corridor	Corridor
1210	Cr Meeting Space	398	Conference Space	Conference space	Default
1214	Cr Meeting Space	401	Conference Space	Conference space	Default
1220	Evidence	52	Storage Space	Storage Space	Default
1221	Storage Space	69	Storage Space	Storage Space	Default
1225	Cr Meeting Space	431	Conference Space	Conference space	Default
1232	Cr Meeting Space	430	Conference Space	Conference space	Default
1235	Storage Space	91	Storage Space	Storage Space	Default
1241	Cr Meeting Space	388	Conference Space	Conference space	Default
1248	Holding Cells	390	Holding Cell	Holding Cell	Default
1256	Holding Cell	79	Holding Cell	Holding Cell	Default
1258	Storage Space	309	Storage Space	Storage Space	Default
1262	Mech.	196	Mech/Elect.	Mech/Elect.	Shaft
1266	Holding Cell	561	Holding Cell	Holding Cell	Default
1274	Cr Meeting Space	203	Conference Space	Conference space	Default
1275	Closet	78	Storage Space	Storage Space	Default
1277	Jury Space	594	Conference Space	Conference Space	Courtroom
1279	Storage Space	83	Storage Space	Storage Space	Default
1283	Storage Space	267	Storage Space	Storage Space	Default
1288	Courtroom	3125	Courtroom	Courtroom	Courtroom
1290	Storage Space	71	Storage Space	Storage Space	Default
1295	Jury Space	556	Conference Space	Conference Space	Courtroom
1299	Cr Meeting Space	147	Conference Space	Conference space	Default
1301	Holding Cell	134	Holding Cell	Holding Cell	Default
1305	General Office Space	334	Office Space	Office Space	Default
1308	General Office Space	338	Office Space	Office Space	Default
1311	General Office Space	325	Office Space	Office Space	Default
1313	Public Restroom	524	Lockerroom/RR	Lockerroom/RR	Default
1318	Storage Space	92	Storage Space	Storage Space	Default
1319	Mechanical Space	679	Mech/Elect.	Mech/Elect.	Shaft
1320	Jury Space	469	Conference Space	Conference Space	Courtroom
1321	Storage Space	74	Storage Space	Storage Space	Default
1334	Electrical Space	191	Mech/Elect.	Mech/Elect.	Default
1350	General Office Space	1534	Office Space	Office Space	Default
1352	Grand Jury	1533	Conference Space	Conference space	Courtroom
1353	Jury Space	420	Conference Space	Conference Space	Courtroom
1358	Courtroom	2107	Courtroom	Courtroom	Courtroom
1359	Courtroom	2103	Courtroom	Courtroom	Courtroom
1360	Jury Space	409	Conference Space	Conference Space	Courtroom

1365	Jury Space	417	Conference Space	Conference Space	Courtroom
1366	Courtroom	2114	Courtroom	Courtroom	Courtroom
1367	Courtroom	2532	Courtroom	Courtroom	Courtroom
1377	Holding Cells	77	Holding Cell	Holding Cell	Default
1380	Corridor	2252	Corridor	Corridor	Corridor
1385	Holding Cell	49	Holding Cell	Holding Cell	Default
1386	Corridor	4322	Corridor	Corridor	Corridor
1388	Storage Space	80	Storage Space	Storage Space	Default
1392	Cr Meeting Space	407	Conference Space	Conference space	Default
1399	Cr Meeting Space	406	Conference Space	Conference space	Default
1402	Storage Space	64	Storage Space	Storage Space	Default
1409	Cr Meeting Space	379	Conference Space	Conference space	Default
1413	Cr Meeting Space	390	Conference Space	Conference space	Default
1419	Corridor	882	Corridor	Corridor	Corridor
1423	Cr Meeting Space	211	Conference Space	Conference space	Default
1428	Holding Cells	565	Holding Cell	Holding Cell	Default
1435	Mechanical Space	192	Mech/Elect.	Mech/Elect.	Shaft
1439	Storage Space	310	Storage Space	Storage Space	Default
1441	Closet	82	Storage Space	Storage Space	Default
1442	Holding Cells	142	Holding Cell	Holding Cell	Default
1446	Cr Meeting Space	140	Conference Space	Conference space	Default
1449	Storage Space	80	Storage Space	Storage Space	Default
1451	Jury Space	599	Conference Space	Conference Space	Courtroom
1455	Electrical Space	262	Mech/Elect.	Mech/Elect.	Default
1460	Courtroom	3141	Courtroom	Courtroom	Courtroom
1462	Storage Space	72	Storage Space	Storage Space	Default
1467	Jury Space	537	Conference Space	Conference Space	Courtroom
2502	Corridor	4449	Corridor	Corridor	Corridor
2521	Holding Cells	460	Holding Cell	Holding Cell	Default
1469	General Office Space	319	Office Space	Office Space	Default
1471	General Office Space	322	Office Space	Office Space	Default
1474	General Office Space	334	Office Space	Office Space	Default
1477	General Office Space	334	Office Space	Office Space	Default
1480	General Office Space	338	Office Space	Office Space	Default
1483	General Office Space	325	Office Space	Office Space	Default
1484	Atrium	4773	Shaft	Shaft	Shaft
1485	Corridor	6353	Corridor	Corridor	Corridor
1488	Courtroom	2107	Courtroom	Courtroom	Courtroom
1492	Jury Space	419	Conference Space	Conference Space	Courtroom
1497	Jury Space	403	Conference Space	Conference Space	Courtroom
1501	Storage Space	198	Storage Space	Storage Space	Default
1505	Courtroom	2108	Courtroom	Courtroom	Courtroom
1508	Courtroom	2109	Courtroom	Courtroom	Courtroom
1512	Electrical Space	201	Mech/Elect.	Mech/Elect.	Default
1517	Jury Space	409	Conference Space	Conference Space	Courtroom
1522	Jury Space	415	Conference Space	Conference Space	Courtroom
1523	Courtroom	2104	Courtroom	Courtroom	Courtroom
1528	Storage Space	92	Storage Space	Storage Space	Default
1531	Courtroom	2544	Courtroom	Courtroom	Courtroom
1535	Public Restrooms	512	Lockerroom/RR	Lockerroom/RR	Default
1537	General Office Space	287	Office Space	Office Space	Default

1540	Mechanical Space	359	Mech/Elect.	Mech/Elect.	Shaft
1544	Jury Space	474	Conference Space	Conference Space	Courtroom
1547	Storage Space	73	Storage Space	Storage Space	Default
1548	Corridor	1047	Corridor	Corridor	Corridor
1552	Cr Meeting Space	398	Conference Space	Conference space	Default
1555	Corridor	1733	Corridor	Corridor	Corridor
1559	Cr Meeting Space	401	Conference Space	Conference space	Default
1567	Storage Space	69	Storage Space	Storage Space	Default
1571	Cr Meeting Space	431	Conference Space	Conference space	Default
1578	Cr Meeting Space	430	Conference Space	Conference space	Default
1581	Storage Space	91	Storage Space	Storage Space	Default
1587	Cr Meeting Space	388	Conference Space	Conference space	Default
1596	Holding Cells	561	Holding Cell	Holding Cell	Default
1602	Mechanical Space	196	Mech/Elect.	Mech/Elect.	Shaft
1605	Storage Space	309	Storage Space	Storage Space	Default
1608	Holding Cell	79	Holding Cell	Holding Cell	Default
1614	Holding Cell	390	Holding Cell	Holding Cell	Default
1619	General Office Space	5009	Office Space	Office Space	Default
1624	Lockerrooms	442	Lockerroom/RR	Lockerroom/RR	Default
1631	Storage Space	258	Storage Space	Storage Space	Default
1643	Corridor	138	Corridor	Corridor	Corridor
1644	Computer Lab	1629	Computer Lab	Computer Lab	Default
1645	Corridor	191	Corridor	Corridor	Corridor
1647	General Office Space	2929	Office Space	Office Space	Default
1649	Server Room	647	Server Room	Server Room	Default
1651	Computer Lab	650	Computer Lab	Computer Lab	Default
1653	Storage Space	1444	Storage Space	Storage Space	Default
1656	Electrical Space	251	Mech/Elect.	Mech/Elect.	Default
1664	Corridor	680	Corridor	Corridor	Corridor
1667	Corridor	1678	Corridor	Corridor	Corridor
1672	Holding Cells	565	Holding Cell	Holding Cell	Default
1676	Mech.	192	Mech/Elect.	Mech/Elect.	Shaft
1683	Storage Space	310	Storage Space	Storage Space	Default
1685	Holding Cells	77	Holding Cell	Holding Cell	Default
1697	Cr Meeting Space	394	Conference Space	Conference space	Default
1704	Storage Space	90	Storage Space	Storage Space	Default
1708	Cr Meeting Space	438	Conference Space	Conference space	Default
1713	Cr Meeting Space	437	Conference Space	Conference space	Default
1718	Storage Space	72	Storage Space	Storage Space	Default
1724	Cr Meeting Space	408	Conference Space	Conference space	Default
1731	Cr Meeting Space	402	Conference Space	Conference space	Default
1736	Evidence	70	Storage Space	Storage Space	Default
1737	Jury Space	469	Conference Space	Conference Space	Courtroom
1741	Mech.	679	Mech/Elect.	Mech/Elect.	Shaft
1743	Public Restrooms	524	Lockerroom/RR	Lockerroom/RR	Default
1747	Courtoom	2532	Courtroom	Courtroom	Courtroom
1749	Jc	92	Storage Space	Storage Space	Default
1750	Courtroom	2114	Courtroom	Courtroom	Courtroom
1755	Jury Space	417	Conference Space	Conference Space	Courtroom
1760	Jury Space	409	Conference Space	Conference Space	Courtroom
1764	Electrical Sapce	198	Mech/Elect.	Mech/Elect.	Default

1768	Courtroom	2116	Courtroom	Courtroom	Courtroom
1773	Courtroom	2104	Courtroom	Courtroom	Courtroom
1776	Storage Space	201	Storage Space	Storage Space	Default
1779	Jury Space	411	Conference Space	Conference Space	Courtroom
1783	Jury Space	442	Conference Space	Conference Space	Courtroom
1786	Courtroom	2090	Courtroom	Courtroom	Courtroom
2504	Corridor	4449	Corridor	Corridor	Corridor
2505	Corridor	4268	Corridor	Corridor	Corridor
2523	Holding Cells	438	Holding Cell	Holding Cell	Default
1798	General Office Space	2123	Office Space	Office Space	Default
1800	General Office Space	322	Office Space	Office Space	Default
1802	General Office Space	1834	Office Space	Office Space	Default
1808	Courtroom	2090	Courtroom	Courtroom	Courtroom
1811	Jury Space	442	Conference Space	Conference Space	Courtroom
1820	Storage Space	201	Storage Space	Storage Space	Default
1824	Courtroom	2104	Courtroom	Courtroom	Courtroom
1830	Courtroom	2116	Courtroom	Courtroom	Courtroom
1831	Electrical Space	198	Mech/Elect.	Mech/Elect.	Default
1842	Courtroom	2114	Courtroom	Courtroom	Courtroom
1847	Jc	92	Storage Space	Storage Space	Default
1850	Courtroom	2532	Courtroom	Courtroom	Courtroom
1853	Public Restroom	524	Lockerroom/RR	Lockerroom/RR	Default
1855	Mech.	679	Mech/Elect.	Mech/Elect.	Shaft
1860	Jury Space	411	Conference Space	Conference Space	Courtroom
1876	Jury Space	409	Conference Space	Conference Space	Courtroom
1880	Jury Space	417	Conference Space	Conference Space	Courtroom
1884	Jury Space	469	Conference Space	Conference Space	Courtroom
1890	Corridor	1863	Corridor	Corridor	Corridor
1891	Corridor	1185	Corridor	Corridor	Corridor
1894	Corridor	6561	Corridor	Corridor	Corridor
1896	Corridor	1733	Corridor	Corridor	Corridor
1898	Corridor	2694	Corridor	Corridor	Corridor
1900	General Office Space	1842	Office Space	Office Space	Default
1919	Atrium	4773	Shaft	Shaft	Shaft
1920	Courtroom	2544	Courtroom	Courtroom	Courtroom
1921	Courtroom	2104	Courtroom	Courtroom	Courtroom
1922	Courtroom	2109	Courtroom	Courtroom	Courtroom
1923	Courtroom	2108	Courtroom	Courtroom	Courtroom
1924	Courtroom	2107	Courtroom	Courtroom	Courtroom
1928	Jury Space	474	Conference Space	Conference Space	Courtroom
1932	Jury Space	415	Conference Space	Conference Space	Courtroom
1936	Jury Space	409	Conference Space	Conference Space	Courtroom
1940	Jury Space	403	Conference Space	Conference Space	Courtroom
1944	Jury Space	419	Conference Space	Conference Space	Courtroom
1966	Electrical Space	198	Mech/Elect.	Mech/Elect.	Default
1969	General Office Space	2124	Office Space	Office Space	Default
1970	General Office Space	315	Office Space	Office Space	Default
1974	Storage Space	201	Storage Space	Storage Space	Default
1976	Storage Space	92	Storage Space	Storage Space	Default
1979	Public Restrooms	512	Lockerroom/RR	Lockerroom/RR	Default
1981	Security Office	287	Office Space	Office Space	Default

1982	Mechanical Space	359	Mech/Elect.	Mech/Elect.	Shaft
1990	Cr Meeting Space	401	Conference Space	Conference space	Default
1992	Cr Meeting Space	390	Conference Space	Conference space	Default
1997	Cr Meeting Space	366	Conference Space	Conference space	Default
2011	Cr Meeting Space	431	Conference Space	Conference space	Default
2013	Cr Meeting Space	430	Conference Space	Conference space	Default
2017	Cr Meeting Space	388	Conference Space	Conference space	Default
2021	Cr Meeting Space	398	Conference Space	Conference space	Default
2023	Cr Meeting Space	379	Conference Space	Conference space	Default
2024	Cr Meetingspace	406	Conference Space	Conference space	Default
2025	Cr Meeting Space	407	Conference Space	Conference space	Default
2037	Restroom	114	Lockerroom/RR	Lockerroom/RR	Default
2040	Restroom	123	Lockerroom/RR	Lockerroom/RR	Default
2055	Storage Space	80	Storage Space	Storage Space	Default
2057	Storage Space	64	Storage Space	Storage Space	Default
2060	Storage Space	70	Storage Space	Storage Space	Default
2062	Storage Space	73	Storage Space	Storage Space	Default
2063	Storage Space	69	Storage Space	Storage Space	Default
2065	Storage Space	91	Storage Space	Storage Space	Default
2068	Holding Cells	390	Holding Cell	Holding Cell	Default
2072	Holding Cells	79	Holding Cell	Holding Cell	Default
2076	Holding Cells	561	Holding Cell	Holding Cell	Default
2082	Holding Cell	557	Holding Cell	Holding Cell	Default
2087	Holding Cell	75	Holding Cell	Holding Cell	Default
2095	Storage Space	306	Storage Space	Storage Space	Default
2097	Mechanical Space	190	Mech/Elect.	Mech/Elect.	Shaft
2101	Mech.	196	Mech/Elect.	Mech/Elect.	Shaft
2104	Storage Space	309	Storage Space	Storage Space	Default
2121	Storage Space	365	Storage Space	Storage Space	Default
2124	General Office Space	643	Office Space	Office Space	Default
2129	General Office Space	1563	Office Space	Office Space	Default
2137	General Office Space	1841	Office Space	Office Space	Default
2144	General Office Space	299	Office Space	Office Space	Default
2147	General Office Space	2821	Office Space	Office Space	Default
2151	General Office Space	1503	Office Space	Office Space	Default
2158	Electrical Space	334	Mech/Elect.	Mech/Elect.	Default
2167	General Office Space	631	Office Space	Office Space	Default
2173	Conf. Room	811	Conference Space	Conference space	Default
2506	Corridor	4322	Corridor	Corridor	Corridor
2507	Corridor	4155	Corridor	Corridor	Corridor
2522	Holding Cells	438	Holding Cell	Holding Cell	Default
2175	Atrium	1605	Shaft	Shaft	Shaft
2176	Corridor	3828	Corridor	Corridor	Corridor
2180	Closet	188	Storage Space	Storage Space	Default
2181	Corridor	13874	Corridor	Corridor	Corridor
2182	Womens Rr	326	Lockerroom/RR	Lockerroom/RR	Default
2208	Restroom	56	Lockerroom/RR	Lockerroom/RR	Default
2209	Restroom	39	Lockerroom/RR	Lockerroom/RR	Default
2210	Restroom	178	Lockerroom/RR	Lockerroom/RR	Default
2212	Restroom	174	Lockerroom/RR	Lockerroom/RR	Default
2214	Restroom	135	Lockerroom/RR	Lockerroom/RR	Default

2216	Restroom	200	Lockerroom/RR	Lockerroom/RR	Default
2219	Restroom	88	Lockerroom/RR	Lockerroom/RR	Default
2220	Restroom	50	Lockerroom/RR	Lockerroom/RR	Default
2221	Restroom	53	Lockerroom/RR	Lockerroom/RR	Default
2222	Restroom	186	Lockerroom/RR	Lockerroom/RR	Default
2224	Restroom	191	Lockerroom/RR	Lockerroom/RR	Default
2226	Restroom	198	Lockerroom/RR	Lockerroom/RR	Default
2228	Restroom	188	Lockerroom/RR	Lockerroom/RR	Default
2230	Restroom	48	Lockerroom/RR	Lockerroom/RR	Default
2231	Restroom	50	Lockerroom/RR	Lockerroom/RR	Default
2232	Restroom	79	Lockerroom/RR	Lockerroom/RR	Default
2235	Restroom	225	Lockerroom/RR	Lockerroom/RR	Default
2236	Restroom	141	Lockerroom/RR	Lockerroom/RR	Default
2238	Restroom	173	Lockerroom/RR	Lockerroom/RR	Default
2240	Restroom	179	Lockerroom/RR	Lockerroom/RR	Default
2242	Restroom	37	Lockerroom/RR	Lockerroom/RR	Default
2243	Restroom	45	Lockerroom/RR	Lockerroom/RR	Default
2244	Restroom	193	Lockerroom/RR	Lockerroom/RR	Default
2246	Restroom	189	Lockerroom/RR	Lockerroom/RR	Default
2249	Restroom	120	Lockerroom/RR	Lockerroom/RR	Default
2250	Restroom	96	Lockerroom/RR	Lockerroom/RR	Default
2251	Restroom	53	Lockerroom/RR	Lockerroom/RR	Default
2252	Restroom	193	Lockerroom/RR	Lockerroom/RR	Default
2254	Restroom	96	Lockerroom/RR	Lockerroom/RR	Default
2255	Restroom	95	Lockerroom/RR	Lockerroom/RR	Default
2256	Restroom	190	Lockerroom/RR	Lockerroom/RR	Default
2258	Restroom	88	Lockerroom/RR	Lockerroom/RR	Default
2259	Restroom	92	Lockerroom/RR	Lockerroom/RR	Default
2261	Restroom	109	Lockerroom/RR	Lockerroom/RR	Default
2262	Restroom	64	Lockerroom/RR	Lockerroom/RR	Default
2263	Restroom	92	Lockerroom/RR	Lockerroom/RR	Default
2264	Restroom	200	Lockerroom/RR	Lockerroom/RR	Default
2266	Restroom	84	Lockerroom/RR	Lockerroom/RR	Default
2267	Restroom	193	Lockerroom/RR	Lockerroom/RR	Default
2269	Restroom	93	Lockerroom/RR	Lockerroom/RR	Default
2270	Restroom	100	Lockerroom/RR	Lockerroom/RR	Default
2271	Restroom	189	Lockerroom/RR	Lockerroom/RR	Default
2273	Restroom	93	Lockerroom/RR	Lockerroom/RR	Default
2276	Restroom	112	Lockerroom/RR	Lockerroom/RR	Default
2277	Restroom	196	Lockerroom/RR	Lockerroom/RR	Default
2279	Restroom	194	Lockerroom/RR	Lockerroom/RR	Default
2291	General Office Space	1439	Office Space	Office Space	Default
2295	General Office Space	1781	Office Space	Office Space	Default
2302	General Office Space	2440	Office Space	Office Space	Default
2306	General Office Space	1457	Office Space	Office Space	Default
2384	Hearing Rooms	3754	Conference Space	Conference Space	Default
2391	Hearing Rooms	5144	Conference Space	Conference Space	Default
2400	Hearing Rooms	4233	Conference Space	Conference Space	Default
2412	Hearing Rooms	5193	Conference Space	Conference Space	Default
2420	Hearing Rooms	3781	Conference Space	Conference Space	Default
2425	Conf. Room	1188	Conference Space	Conference space	Default

2435	Copy Room	207	Office Space	Office Space	Default
2436	Electrical Space	59	Mech/Elect.	Mech/Elect.	Default
2437	Storage Space	88	Storage Space	Storage Space	Default
2438	Mens Rr	340	Lockerroom/RR	Lockerroom/RR	Default
2441	Storage Space	75	Storage Space	Storage Space	Default
2443	Office Space	798	Office Space	Office Space	Default
2445	Electrical Space	229	Mech/Elect.	Mech/Elect.	Default
2448	Storage	152	Storage Space	Storage Space	Default
2451	Copy Room	108	Office Space	Office Space	Default
2453	Storage	151	Storage Space	Storage Space	Default
2457	Copy Room	205	Office Space	Office Space	Default
2458	Electrical Space	119	Mech/Elect.	Mech/Elect.	Default
2460	Storage Space	301	Storage Space	Storage Space	Default
2462	Storage Space	88	Storage Space	Storage Space	Default
2463	Electrical Space	75	Mech/Elect.	Mech/Elect.	Default
2464	Copy Room	195	Office Space	Office Space	Default
2477	Vestibule	936	Corridor	Corridor	Default
2524	General Office Space	13491	Office Space	Office Space	Default
2525	General Office Space	11512	Office Space	Office Space	Default

Appendix C – Life Cycle Cost Calculations

Base discount rate (real)	2.8	% (20-year OMB estimate)			**Existing System LCC**			
Date	Analysis Year	Capital	Overhauls	Other Maintenance	Nat Gas Esc.	Nat Gas Cost	Elect. Esc.	Electricity Cost	Ch. Water Cost
2011	1	$2,608,539	$0	$15,000	1.08	$7,232	0.94	$679,950	$483,274.44
2012	2		$0	$15,000	1.14	$7,634	0.95	$687,184	$483,274.44
2013	3		$0	$15,000	1.14	$7,634	0.96	$694,417	$483,274.44
2014	4		$0	$15,000	1.14	$7,634	0.96	$694,417	$483,274.44
2015	5		$0	$15,000	1.16	$7,768	0.95	$687,184	$483,274.44
2016	6		$0	$15,000	1.17	$7,835	0.96	$694,417	$483,274.44
2017	7		$0	$15,000	1.17	$7,835	0.98	$708,884	$483,274.44
2018	8		$0	$15,000	1.18	$7,902	0.98	$708,884	$483,274.44
2019	9		$0	$15,000	1.18	$7,902	0.98	$708,884	$483,274.44
2020	10		$0	$15,000	1.20	$8,036	0.98	$708,884	$483,274.44
2021	11		$223,550	$15,000	1.21	$8,103	0.99	$716,118	$483,274.44
2022	12		$0	$15,000	1.23	$8,237	0.99	$716,118	$483,274.44
2023	13		$0	$15,000	1.25	$8,371	0.99	$716,118	$483,274.44
2024	14		$0	$15,000	1.26	$8,438	1.00	$723,351	$483,274.44
2025	15		$0	$15,000	1.27	$8,504	1.01	$730,585	$483,274.44
2026	16		$0	$15,000	1.28	$8,571	1.01	$730,585	$483,274.44
2027	17		$0	$15,000	1.29	$8,638	1.02	$737,818	$483,274.44
2028	18		$0	$15,000	1.32	$8,839	1.03	$745,052	$483,274.44
2029	19		$0	$15,000	1.35	$9,040	1.04	$752,285	$483,274.44
2030	20		$0	$15,000	1.38	$9,241	1.06	$766,752	$483,274.44
Column NPV		$2,608,539	$169,607	$218,711		$118,830		$10,412,959	$7,046,489
Total NPV		**$20,575,135**							

Base discount rate (real)	2.8	% (20-year OMB estimate)	**MultiFilm® Blinds System LCC**

Date	Analysis Year	Capital	Overhauls	Other Maintenance	Nat Gas Esc.	Nat Gas Cost	Elect. Esc.	Electricity Cost	Ch. Water Cost
2011	1	$3,762,944	$0	$15,000	1.08	$5,632	0.94	$681,367	$450,307.44
2012	2		$0	$15,000	1.14	$5,945	0.95	$688,616	$450,307.44
2013	3		$0	$15,000	1.14	$5,945	0.96	$695,865	$450,307.44
2014	4		$0	$15,000	1.14	$5,945	0.96	$695,865	$450,307.44
2015	5		$0	$15,000	1.16	$6,049	0.95	$688,616	$450,307.44
2016	6		$0	$15,000	1.17	$6,101	0.96	$695,865	$450,307.44
2017	7		$0	$15,000	1.17	$6,101	0.98	$710,362	$450,307.44
2018	8		$0	$15,000	1.18	$6,154	0.98	$710,362	$450,307.44
2019	9		$0	$15,000	1.18	$6,154	0.98	$710,362	$450,307.44
2020	10		$0	$15,000	1.20	$6,258	0.98	$710,362	$450,307.44
2021	11		$223,550	$15,000	1.21	$6,310	0.99	$717,610	$450,307.44
2022	12		$0	$15,000	1.23	$6,414	0.99	$717,610	$450,307.44
2023	13		$0	$15,000	1.25	$6,519	0.99	$717,610	$450,307.44
2024	14		$0	$15,000	1.26	$6,571	1.00	$724,859	$450,307.44
2025	15		$0	$15,000	1.27	$6,623	1.01	$732,108	$450,307.44
2026	16		$0	$15,000	1.28	$6,675	1.01	$732,108	$450,307.44
2027	17		$0	$15,000	1.29	$6,727	1.02	$739,356	$450,307.44
2028	18		$0	$15,000	1.32	$6,884	1.03	$746,605	$450,307.44
2029	19		$0	$15,000	1.35	$7,040	1.04	$753,853	$450,307.44
2030	20		$0	$15,000	1.38	$7,197	1.06	$768,351	$450,307.44
Column NPV		$3,762,944	$169,607	$218,711		$92,539		$10,434,666	$6,565,806
Total NPV		**$21,244,274**							

Base discount rate (real)	2.8	% (20-year OMB estimate)			**DOAS/ACB with Shading LCC**			
Date	Analysis Year	Capital	Overhauls	Other Maintenance	Nat Gas Esc.	Nat Gas Cost	Elect. Esc.	Electricity Cost	Ch. Water Cost
2011	1	$5,128,882	$0	$7,000	1.08	$11,262	0.94	$533,065	$293,382.14
2012	2		$0	$7,000	1.14	$11,887	0.95	$538,736	$293,382.14
2013	3		$0	$7,000	1.14	$11,887	0.96	$544,406	$293,382.14
2014	4		$0	$7,000	1.14	$11,887	0.96	$544,406	$293,382.14
2015	5		$0	$7,000	1.16	$12,096	0.95	$538,736	$293,382.14
2016	6		$0	$7,000	1.17	$12,200	0.96	$544,406	$293,382.14
2017	7		$0	$7,000	1.17	$12,200	0.98	$555,748	$293,382.14
2018	8		$0	$7,000	1.18	$12,304	0.98	$555,748	$293,382.14
2019	9		$0	$7,000	1.18	$12,304	0.98	$555,748	$293,382.14
2020	10		$0	$7,000	1.20	$12,513	0.98	$555,748	$293,382.14
2021	11		$31,325	$7,000	1.21	$12,617	0.99	$561,419	$293,382.14
2022	12		$0	$7,000	1.23	$12,826	0.99	$561,419	$293,382.14
2023	13		$0	$7,000	1.25	$13,034	0.99	$561,419	$293,382.14
2024	14		$0	$7,000	1.26	$13,139	1.00	$567,090	$293,382.14
2025	15		$0	$7,000	1.27	$13,243	1.01	$572,761	$293,382.14
2026	16		$0	$7,000	1.28	$13,347	1.01	$572,761	$293,382.14
2027	17		$0	$7,000	1.29	$13,451	1.02	$578,432	$293,382.14
2028	18		$0	$7,000	1.32	$13,764	1.03	$584,103	$293,382.14
2029	19		$0	$7,000	1.35	$14,077	1.04	$589,774	$293,382.14
2030	20		$0	$7,000	1.38	$14,390	1.06	$601,116	$293,382.14
Column NPV		$5,128,882	$23,766	$102,065		$185,037		$8,163,513	$4,277,723
Total NPV		**$17,880,987**							

Base discount rate (real)	2.8	% (20-year OMB estimate)			**Chiller Plant with Proposed Systems LCC**			
Date	Analysis Year	Capital	Overhauls	Other Maintenance	Nat Gas Esc.	Nat Gas Cost	Elect. Esc.	Electricity Cost	Dom. Water Cost
2011	1	$6,871,032	$0	$31,000	1.08	$11,262	0.94	$787,752	$10,858.32
2012	2		$0	$31,000	1.14	$11,887	0.95	$796,133	$10,858.32
2013	3		$0	$31,000	1.14	$11,887	0.96	$804,513	$10,858.32
2014	4		$0	$31,000	1.14	$11,887	0.96	$804,513	$10,858.32
2015	5		$0	$31,000	1.16	$12,096	0.95	$796,133	$10,858.32
2016	6		$0	$31,000	1.17	$12,200	0.96	$804,513	$10,858.32
2017	7		$0	$31,000	1.17	$12,200	0.98	$821,274	$10,858.32
2018	8		$0	$31,000	1.18	$12,304	0.98	$821,274	$10,858.32
2019	9		$0	$31,000	1.18	$12,304	0.98	$821,274	$10,858.32
2020	10		$0	$31,000	1.20	$12,513	0.98	$821,274	$10,858.32
2021	11		$47,100	$31,000	1.21	$12,617	0.99	$829,654	$10,858.32
2022	12		$0	$31,000	1.23	$12,826	0.99	$829,654	$10,858.32
2023	13		$0	$31,000	1.25	$13,034	0.99	$829,654	$10,858.32
2024	14		$0	$31,000	1.26	$13,139	1.00	$838,035	$10,858.32
2025	15		$0	$31,000	1.27	$13,243	1.01	$846,415	$10,858.32
2026	16		$0	$31,000	1.28	$13,347	1.01	$846,415	$10,858.32
2027	17		$0	$31,000	1.29	$13,451	1.02	$854,795	$10,858.32
2028	18		$0	$31,000	1.32	$13,764	1.03	$863,176	$10,858.32
2029	19		$0	$31,000	1.35	$14,077	1.04	$871,556	$10,858.32
2030	20		$0	$31,000	1.38	$14,390	1.06	$888,317	$10,858.32
Column NPV		$6,871,032	$35,735	$452,002		$185,037		$12,063,879	$4,277,723
Total NPV		**$19,766,007**							

Base discount rate (real)	2.8	% (20-year OMB estimate)			**DOAS/ACB with Shading and Height Reduction LCC**			
Date	Analysis Year	Capital	Overhauls	Other Maintenance	Nat Gas Esc.	Nat Gas Cost	Elect. Esc.	Electricity Cost	Ch. Water Cost
2011	1	$774,478	$0	$7,000	1.08	$11,262	0.94	$533,065	$293,382.14
2012	2		$0	$7,000	1.14	$11,887	0.95	$538,736	$293,382.14
2013	3		$0	$7,000	1.14	$11,887	0.96	$544,406	$293,382.14
2014	4		$0	$7,000	1.14	$11,887	0.96	$544,406	$293,382.14
2015	5		$0	$7,000	1.16	$12,096	0.95	$538,736	$293,382.14
2016	6		$0	$7,000	1.17	$12,200	0.96	$544,406	$293,382.14
2017	7		$0	$7,000	1.17	$12,200	0.98	$555,748	$293,382.14
2018	8		$0	$7,000	1.18	$12,304	0.98	$555,748	$293,382.14
2019	9		$0	$7,000	1.18	$12,304	0.98	$555,748	$293,382.14
2020	10		$0	$7,000	1.20	$12,513	0.98	$555,748	$293,382.14
2021	11		$31,325	$7,000	1.21	$12,617	0.99	$561,419	$293,382.14
2022	12		$0	$7,000	1.23	$12,826	0.99	$561,419	$293,382.14
2023	13		$0	$7,000	1.25	$13,034	0.99	$561,419	$293,382.14
2024	14		$0	$7,000	1.26	$13,139	1.00	$567,090	$293,382.14
2025	15		$0	$7,000	1.27	$13,243	1.01	$572,761	$293,382.14
2026	16		$0	$7,000	1.28	$13,347	1.01	$572,761	$293,382.14
2027	17		$0	$7,000	1.29	$13,451	1.02	$578,432	$293,382.14
2028	18		$0	$7,000	1.32	$13,764	1.03	$584,103	$293,382.14
2029	19		$0	$7,000	1.35	$14,077	1.04	$589,774	$293,382.14
2030	20		$0	$7,000	1.38	$14,390	1.06	$601,116	$293,382.14
Column NPV		$774,478	$23,766	$102,065		$185,037		$8,163,513	$4,277,723
Total NPV		**$13,526,583**							

Base discount rate (real)	2.8	% (20-year OMB estimate)	**Chiller Plant with Proposed Systems and Height Reduction LCC**

Date	Analysis Year	Capital	Overhauls	Other Maintenance	Nat Gas Esc.	Nat Gas Cost	Elect. Esc.	Electricity Cost	Dom. Water Cost
2011	1	$2,516,628	$0	$31,000	1.08	$11,262	0.94	$787,752	$10,858.32
2012	2		$0	$31,000	1.14	$11,887	0.95	$796,133	$10,858.32
2013	3		$0	$31,000	1.14	$11,887	0.96	$804,513	$10,858.32
2014	4		$0	$31,000	1.14	$11,887	0.96	$804,513	$10,858.32
2015	5		$0	$31,000	1.16	$12,096	0.95	$796,133	$10,858.32
2016	6		$0	$31,000	1.17	$12,200	0.96	$804,513	$10,858.32
2017	7		$0	$31,000	1.17	$12,200	0.98	$821,274	$10,858.32
2018	8		$0	$31,000	1.18	$12,304	0.98	$821,274	$10,858.32
2019	9		$0	$31,000	1.18	$12,304	0.98	$821,274	$10,858.32
2020	10		$0	$31,000	1.20	$12,513	0.98	$821,274	$10,858.32
2021	11		$47,100	$31,000	1.21	$12,617	0.99	$829,654	$10,858.32
2022	12		$0	$31,000	1.23	$12,826	0.99	$829,654	$10,858.32
2023	13		$0	$31,000	1.25	$13,034	0.99	$829,654	$10,858.32
2024	14		$0	$31,000	1.26	$13,139	1.00	$838,035	$10,858.32
2025	15		$0	$31,000	1.27	$13,243	1.01	$846,415	$10,858.32
2026	16		$0	$31,000	1.28	$13,347	1.01	$846,415	$10,858.32
2027	17		$0	$31,000	1.29	$13,451	1.02	$854,795	$10,858.32
2028	18		$0	$31,000	1.32	$13,764	1.03	$863,176	$10,858.32
2029	19		$0	$31,000	1.35	$14,077	1.04	$871,556	$10,858.32
2030	20		$0	$31,000	1.38	$14,390	1.06	$888,317	$10,858.32
Column NPV		$2,516,628	$35,735	$452,002		$185,037		$12,063,879	$4,277,723
Total NPV		**$15,411,603**							

Appendix D – Active Chilled Beams Ceiling Area Requirements

Floor 1					Floor 2				
Zone	Tons	Req. S.F	Avail. S.F	% Ceil.	Zone	Tons	Req. S.F	Avail. S.F	% Ceil.
E-Core1	12.6	437	10,983	4%	E-Core2	17.9	620	7,466	8%
NE-Per1	7.7	267	5,934	4%	E-CR2	26.1	904	8,402	11%
N-Core1	5.5	191	3,779	5%	NE-Per2	14.6	506	7,476	7%
NW-Per1	10.7	371	9,711	4%	N-Core2	10.2	353	8,793	4%
SE-Per1	24.8	859	24,223	4%	NW-Per2	21.7	752	17,935	4%
SW-Per1	24.1	835	21,277	4%	SE-Core2	19.1	662	7,820	8%
W-Core1	13.1	454	11,642	4%	SE-Per2	23	797	14,032	6%
					SW-Per2	37.3	1,293	21,059	6%
					W-Core2	38.6	1,338	10,701	12%
					W-CR2	26.6	922	8,541	11%
Total	98.5	3,413	87,549	4%	Total	235.1	8,147	112,225	7%
Required ACBs		**427**			**Required ACBs**		**1,018**		

Floor 3					Floor 4				
Zone	Tons	Req. S.F	Avail. S.F	% Ceil.	Zone	Tons	Req. S.F	Avail. S.F	% Ceil.
E-3	12	416	4,920	8%	E-4	16	554	7,197	8%
E-CR3	34.5	1,196	10,956	11%	E-CR4	27.6	956	8,856	11%
N-3	10.1	350	2,726	13%	N-4	8	277	2,987	9%
N-CR3	15.6	541	5,015	11%	N-CR4	19.5	676	6,266	11%
SE-Per3	2.2	76	997	8%	SE-Per4	2.2	76	997	8%
SW-Per3	2.4	83	975	9%	SW-Per4	2.4	83	975	9%
W-3	12.5	433	5,271	8%	W-4	12.5	433	5,278	8%
W-CR3	34.6	1,119	10,973	11%	W-CR4	34.6	1,119	10,973	11%
Total	123.9	4,294	41,833	10%	Total	122.8	4,255	43,529	10%
Required ACBs		**537**			**Required ACBs**		**532**		

Floor 5				
Zone	Tons	Req. S.F	Avail. S.F	% Ceil.
E-5	12.9	447	5,061	9%
E-CR5	34.6	1,199	10,956	11%
NE-Per5	8.1	281	4,558	6%
N-Core5	14	485	2,741	18%
NW-Per5	5.9	204	5,009	4%
SE-Per5	2.2	76	997	8%
SW-Per5	2.4	83	975	9%
W-5	13	450	5,278	9%
W-CR5	34.6	1,199	10,973	11%
Total	127.7	4,425	46,548	10%
Required ACBs		**553**		

Floor 6				
Zone	Tons	Req. S.F	Avail. S.F	% Ceil.
E-6	12.2	423	4,925	9%
E-CR6	34.5	1,196	10,956	11%
N-Core6	6.4	222	6,600	3%
N-Per6	9	312	4,113	8%
SE-Per6	6.6	229	4,279	5%
SW-Per6	6.6	229	4,281	5%
W-6	12.9	447	5,278	8%
W-CR6	34.6	1,199	10,973	11%
Total	122.8	4,255	51,405	8%
Required ACBs		**532**		

Floor 7				
Zone	Tons	Req. S.F	Avail. S.F	% Ceil.
Core7	15.4	534	6,312	8%
E-7	24.2	839	9,181	9%
EN-Per7	19.6	679	13,491	5%
S-Per7	15.6	541	9,732	6%
W-7	24	832	9,093	9%
WN-Per7	18.9	655	11,512	6%
Total	117.7	4,079	59,321	7%
Required ACBs		**510**		