75 Ames Street:

Cambridge, Massachusetts

BROAD INSTITUTE

ELKUS | MANFREDI ARCHITECTS

BR+A

Nate Mooney | Mechanical Option
Advisor: William P. Bahnfleth, PH.D., PE
The Pennsylvania State University
Architectural Engineering
Spring 2013

BUILDING OVERVIEW

[COST] $188,000,000 Building Cost
[CONSTRUCTION] January 2012 → Early 2014

BROAD INSTITUTE

ELKUS | MANFREDI ARCHITECTS

BR+A

[SIZE] 250,000 SF

[LEVELS] 15 STORYS
GROUND FLOOR – RETAIL
L-11 – MIXED OFFICES & LABS
L-12 – VIVARIUM
3 MECHANICAL LEVELS M1,M2 & M3

[OCCUPANCY] Mixed Assembly
Restaurant | A-2
Large Conference & Meeting Rooms | A-3
Small Conference & Offices | B
Retail Tenant | M
Laboratory | H-2, H-3, H-4 High Hazard

[LOCATION] 75 Ames Street, Cambridge Massachusetts

BUILDING OVERVIEW

[COST] $188,000,000 Building Cost
[CONSTRUCTION] January 2012 → Early 2014

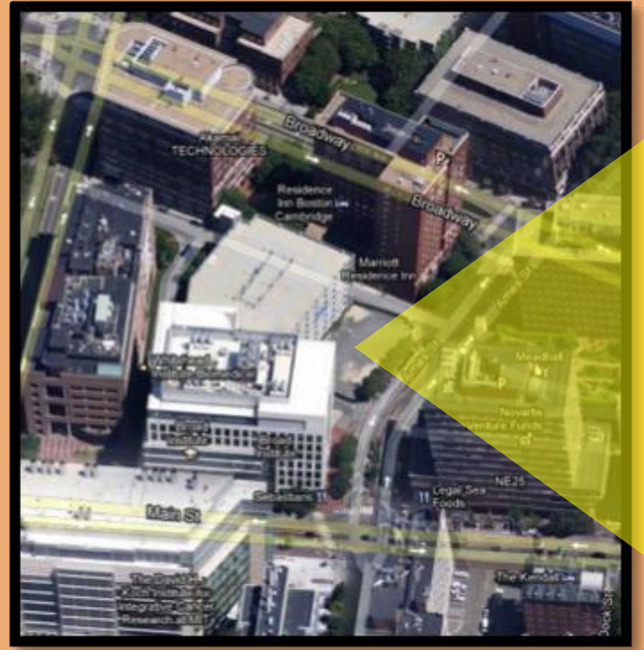
BROAD INSTITUTE

ELKUS | MANFREDI ARCHITECTS

BR+A

[SIZE]	250,000 SF
[LEVELS]	15 STORYS GROUND FLOOR – RETAIL L-11 – MIXED OFFICES & LABS L-12 – VIVARIUM 3 MECHANICAL LEVELS M1,M2 & M3
[OCCUPANCY]	Mixed Assembly Restaurant | A-2 Large Conference & Meeting Rooms | A-3 Small Conference & Offices | B Retail Tenant | M Laboratory | H-2, H-3, H-4 High Hazard

[LOCATION] 75 Ames Street, Cambridge Massachusetts



BUILDING OVERVIEW

[COST] $188,000,000 Building Cost
[CONSTRUCTION] January 2012 → Early 2014

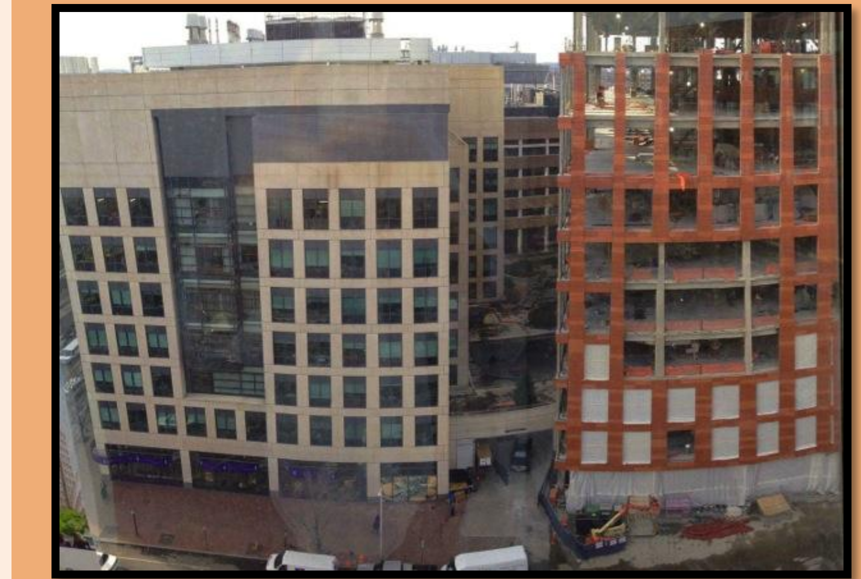
BROAD INSTITUTE

ELKUS | MANFREDI ARCHITECTS

BR+A

[SIZE]	250,000 SF
[LEVELS]	15 STORYS GROUND FLOOR – RETAIL L-11 – MIXED OFFICES & LABS L-12 – VIVARIUM 3 MECHANICAL LEVELS M1,M2 & M3
[OCCUPANCY]	Mixed Assembly Restaurant | A-2 Large Conference & Meeting Rooms | A-3 Small Conference & Offices | B Retail Tenant | M Laboratory | H-2, H-3, H-4 High Hazard

[LOCATION] 75 Ames Street, Cambridge Massachusetts



BUILDING OVERVIEW

[COST] $188,000,000 Building Cost
[CONSTRUCTION] January 2012 → Early 2014

BROAD INSTITUTE

ELKUS | MANFREDI ARCHITECTS

BR+A

[SIZE] 250,000 SF

[LEVELS] 15 STORYS
GROUND FLOOR – RETAIL
L-11 – MIXED OFFICES & LABS
L-12 – VIVARIUM
3 MECHANICAL LEVELS M1,M2 & M3

[OCCUPANCY] Mixed Assembly
Restaurant | A-2
Large Conference & Meeting Rooms | A-3
Small Conference & Offices | B
Retail Tenant | M
Laboratory | H-2, H-3, H-4 High Hazard

[LOCATION] 75 Ames Street, Cambridge Massachusetts

Frank Gehry – Ray & Maria Center at MIT

Existing Mechanical System

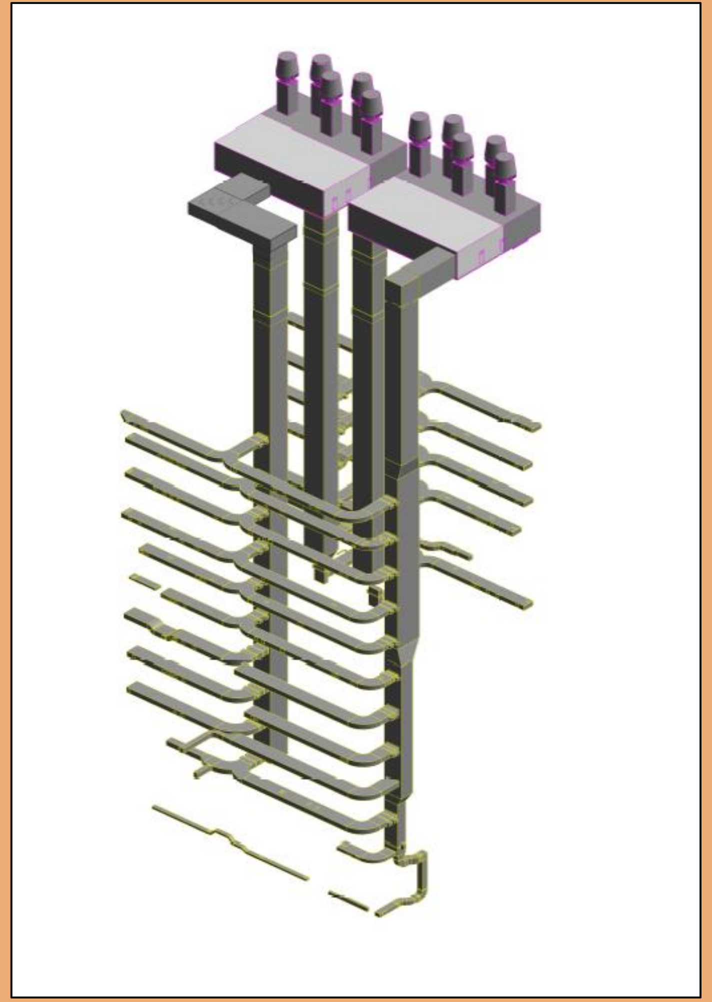
BROAD INSTITUTE

ELKUS | MANFREDI ARCHITECTS

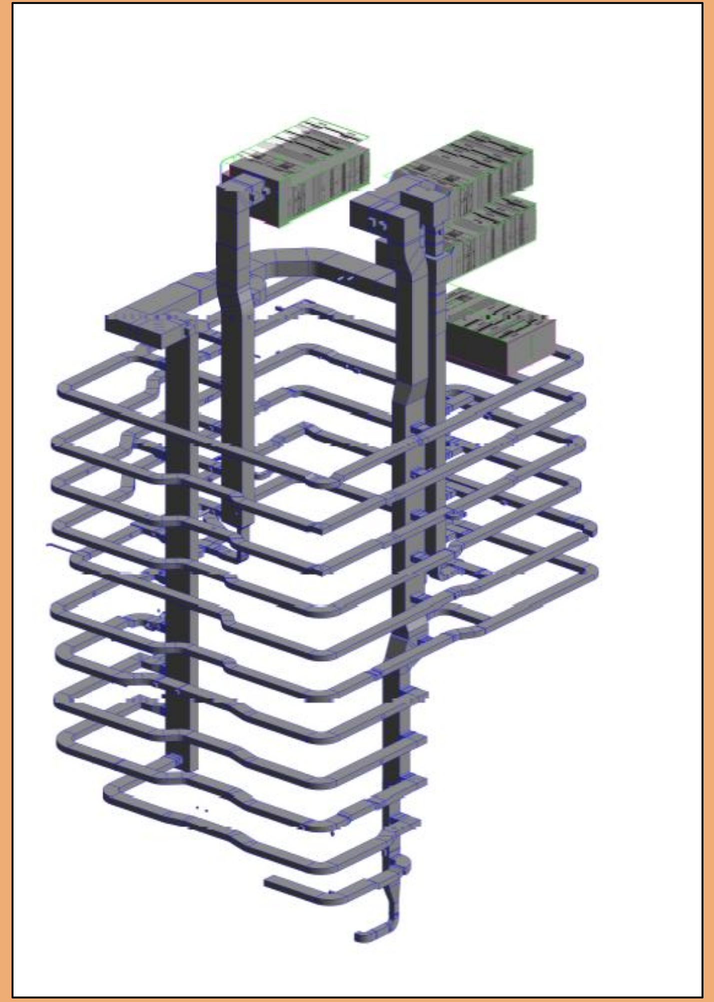
BR+A

[AIR SIDE]

- 100% Outside Air
  - 4 – Ganged 115,000 CFM AHU's
    - Basement → L-11
  - 1 – 60,000 CFM AHU
    - Vivarium L-12
  - 2 – 230,000 CFM EAHU
  - VAV Box with terminal reheat



Exhaust Air Handling Units



Air Handling Units

Existing Mechanical System

BROAD INSTITUTE

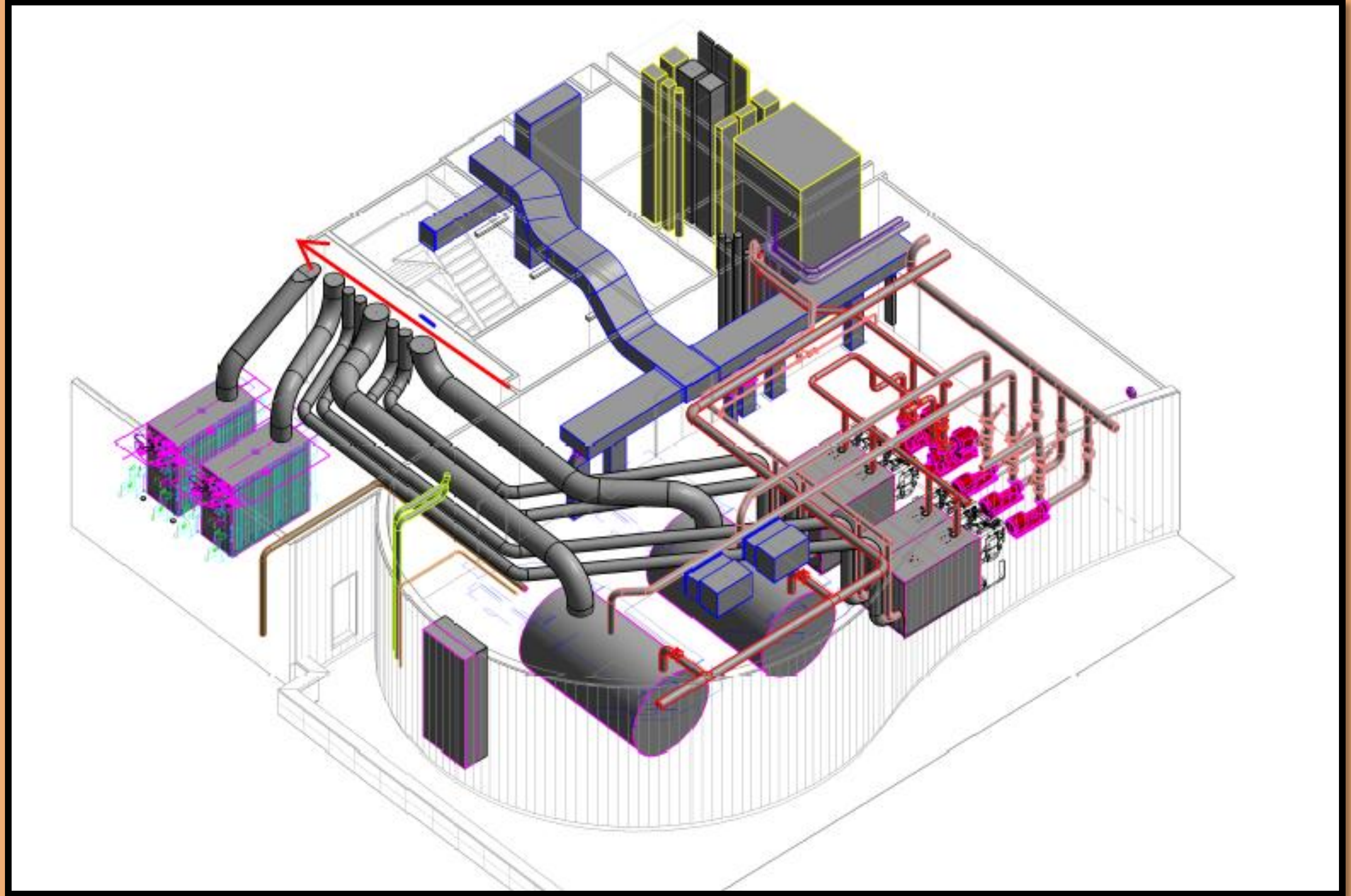
ELKUS | MANFREDI ARCHITECTS

BR+A

[WATER SIDE]

Heating Plant

- 2 - 500 BHP Preheat fire-tube Boilers
  - AHU 1,2,3,4,5 preheat
  - HVU's
- 4 – 120 BHP Reheat Condensing Boilers
  - Building terminal reheat
- 2 – 215 BHP MPS Boilers
  - 60 PSIG
  - Humidification
  - Process steam loads

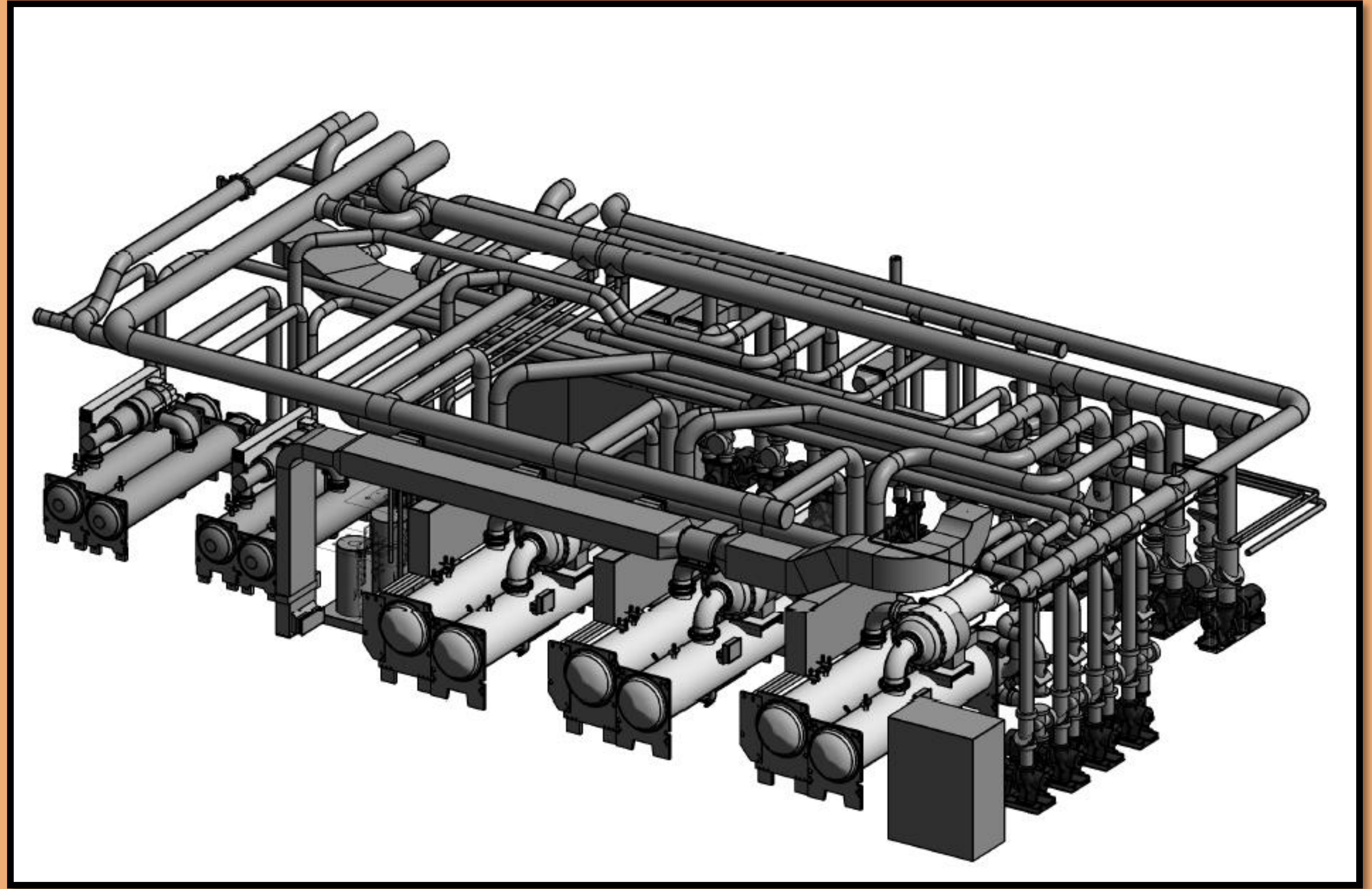


Existing Mechanical System

[WATER SIDE]

Chiller Plant

- 42 °F water
  - 3 – 1000 ton centrifugal chillers
    - 3 – 1000 ton cooling towers on VFD
    - AHU 1,2,3 & 4 cooling
  - 2 – 450 ton centrifugal chillers
    - 2 – 450 ton cooling towers on VFD
    - AHU 5
    - Process chilled water loads



Demand Controlled Ventilation with Aircuity's Optinet System

[GOAL]

Turn down ventilation air in order to save energy while maintaining appropriate room conditions.

Demand Controlled Ventilation with Aircuity's Optinet System

BROAD INSTITUTE

ELKUS | MANFREDI ARCHITECTS

BR+A

[HOW IT WORKS]

- Typical lab rooms are supplied with 6/12ACH
- Aircuity allows air change rates of 2/4ACH
  - 15-20 rooms every 15 minutes
    - Photoionization ~ Ammonia
    - Metal Oxide detector
    - Lasers
    - CO_2 Sensors
    - Dew point
- Dilution ventilation up to 15 ACH
  - Labs clean of contaminants 99% of time

Demand Controlled Ventilation with Aircuity's Optinet System

[RESULTS]

Using Trane TRACE 700 and the new ventilation rates of 2/4 ACH for a group of 32 select lab rooms

	Electricity (KWH)	Natural Gas (Therms)	Electricity Cost Per Year	Natural Gas Cost Per Year	Total Cost Per Year
Original System	9985524.00	107047.00	$ 2,007090.32	$ 170,954.06	$ 2,178,044.38
DCV	9,059,513.00	105,222.00	$ 1,820,962.11	$ 168,039.53	$ 1,989,001.65
Difference	926,011.00	1,825.00	$ 186,128.21	$ 2,914.53	$ 189,042.74
				% Change	-9%

		Original System VAV Reheat		Alternate DCV	
		Electric KWH	Gas Therms	Electric KWH	Gas Therms
Energy Usage	Jan	721,666	17,302	630,014	18,918
	Feb	654,882	16,453	571,874	18,323
	Mar	791,432	10,610	694,572	10,289
	Apr	746,783	6,680	659,139	4,954
	May	894,909	6,230	811,156	4,473
	June	978,922	4,318	923,273	3,839
	July	962,894	1,243	947,253	3,007
	Aug	1,040,655	3,556	987,417	3,922
	Sept	847,768	6,004	766,895	4,229
	Oct	895,855	7,054	800,672	4,943
	Nov	771,446	8,173	664,497	6,118
	Dec	678,311	19,423	602,751	22,206
	Total	9,985,524	107,047	9,059,513	105,222

Difference	
Electrical KWH	Gas Therms
-926,011	-1,825

75 Ames Street:

Nathaniel Mooney

The Broad Institute Expansion

Demand Controlled Ventilation with Aircuity's Optinet System

BROAD INSTITUTE

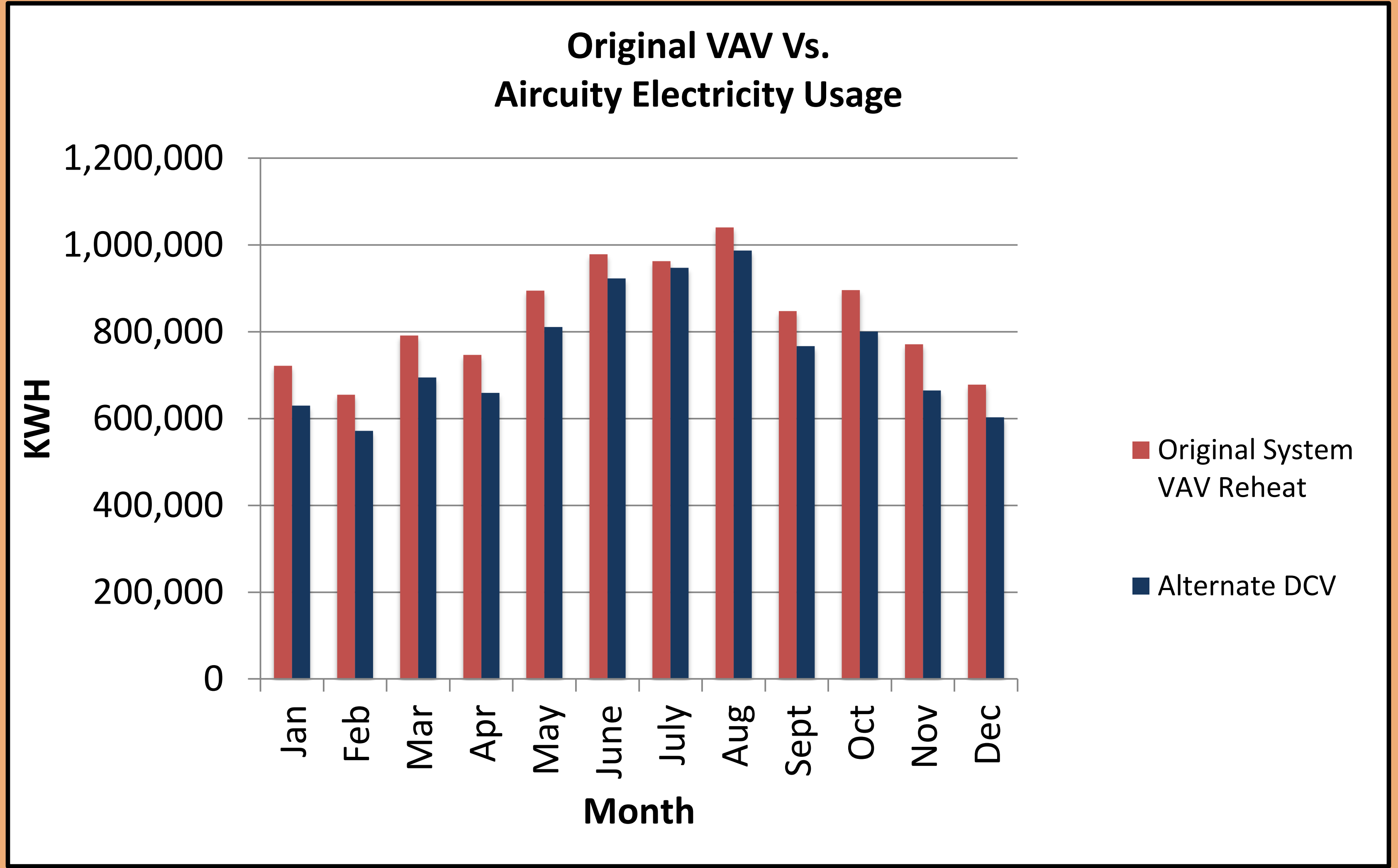
ELKUS | MANFREDI ARCHITECTS

BR+A

[RESULTS]

Using Trane TRACE 700 and the new ventilation rates of 2/4 ACH for a group of 32 select lab rooms

	Electricity (KWH)	Natural Gas (Therms)	Electricity Cost Per Year	Natural Gas Cost Per Year	Total Cost Per Year
Original System	9985524.00	107047.00	$ 2,007090.32	$ 170,954.06	$ 2,178,044.38
DCV	9,059,513.00	105,222.00	$ 1,820,962.11	$ 168,039.53	$ 1,989,001.65
Difference	926,011.00	1,825.00	$ 186,128.21	$ 2,914.53	$ 189,042.74
				% Change	-9%



75 Ames Street:

Nathaniel Mooney

Demand Controlled Ventilation with Aircuity's Optinet System

BROAD INSTITUTE

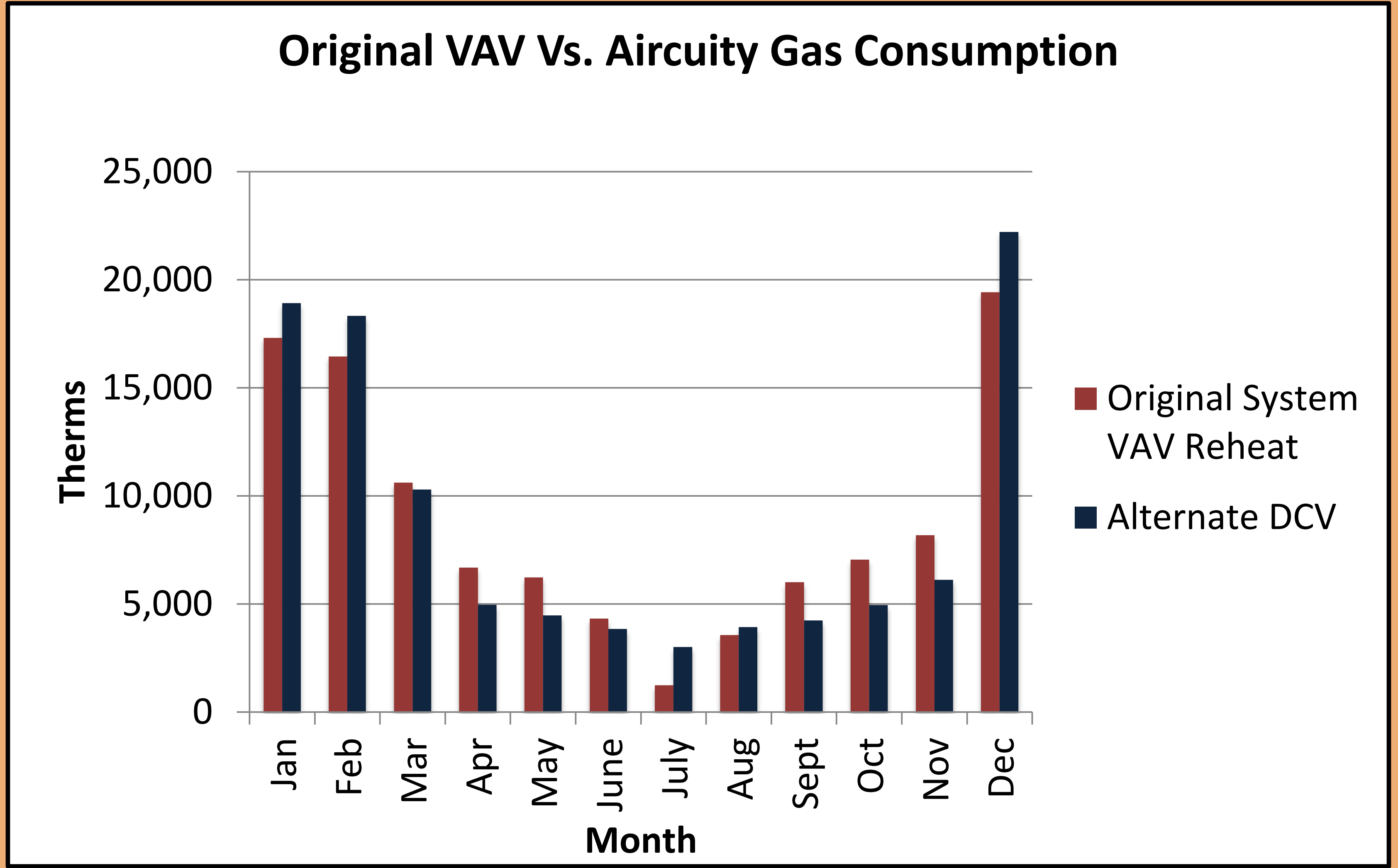
ELKUS | MANFREDI ARCHITECTS

BR+A

[RESULTS]

Using Trane TRACE 700 and the new ventilation rates of 2/4 ACH for a group of 32 select lab rooms

	Electricity (KWH)	Natural Gas (Therms)	Electricity Cost Per Year	Natural Gas Cost Per Year	Total Cost Per Year
Original System	9985524.00	107047.00	$ 2,007090.32	$ 170,954.06	$ 2,178,044.38
DCV	9,059,513.00	105,222.00	$ 1,820,962.11	$ 168,039.53	$ 1,989,001.65
Difference	926,011.00	1,825.00	$ 186,128.21	$ 2,914.53	$ 189,042.74
				% Change	-9%



Demand Controlled Ventilation with Aircuity's Optinet System

[COSTS & SAVINGS]

First Cost Estimate:

- Typically budgeted at $5,000 per space
- 32 spaces
- $160,000
- Optional:
  - $20,963 / Year Maintenance
  - 1st year waived

Payback

- Annual savings = 189,042.74
- 0.85 Year payback

2.5% Inflation					
10 Year Life Cycle Cost Analysis					
YEAR	Original System VAV Reheat	DCV - Aircuity Alternate	Savings	With Maintanance First Year Free	Savings
0	$-	$160,000.00	$(160,000.00)	$160,000.00	$(160,000.00)
1	$2,123,593.27	$2,095,276.61	$28,316.67	$2,095,276.61	$28,316.67
2	$4,141,006.88	$3,933,689.38	$207,317.50	$3,953,617.33	$187,389.55
3	$6,056,222.57	$5,678,871.97	$377,350.60	$5,717,731.48	$338,491.09
4	$7,873,089.34	$7,334,336.87	$538,752.46	$7,391,168.90	$481,920.44
5	$9,595,327.63	$8,903,479.24	$691,848.39	$8,977,360.87	$617,966.76
6	$11,226,533.33	$10,389,580.52	$836,952.80	$10,479,623.77	$746,909.56
7	$12,770,181.66	$11,795,812.07	$974,369.59	$11,901,162.66	$869,018.99
8	$14,229,630.99	$13,125,238.55	$1,104,392.44	$13,245,074.85	$984,556.14
9	$15,608,126.49	$14,380,821.32	$1,227,305.17	$14,514,353.20	$1,093,773.29
10	$16,908,803.70	$15,565,421.68	$1,343,382.02	$15,711,889.46	$1,196,914.24

Demand Controlled Ventilation with Aircuity's Optinet System

[EMISSIONS]

ENVIRONMENTAL IMPACT					
	Unit	Original System VAV Reheat	DCV - Aircuity Alternate	% Change	Difference
CO_2	lbm/yr	876,396,480	795,123,520	-9.27%	81,272,960
SO_2	gm/yr	2,742,078	2,487,791	-9.27%	254,287
NOX	gm/yr	742,165	673,340	-9.27%	68,825

Chilled Beams Alternate

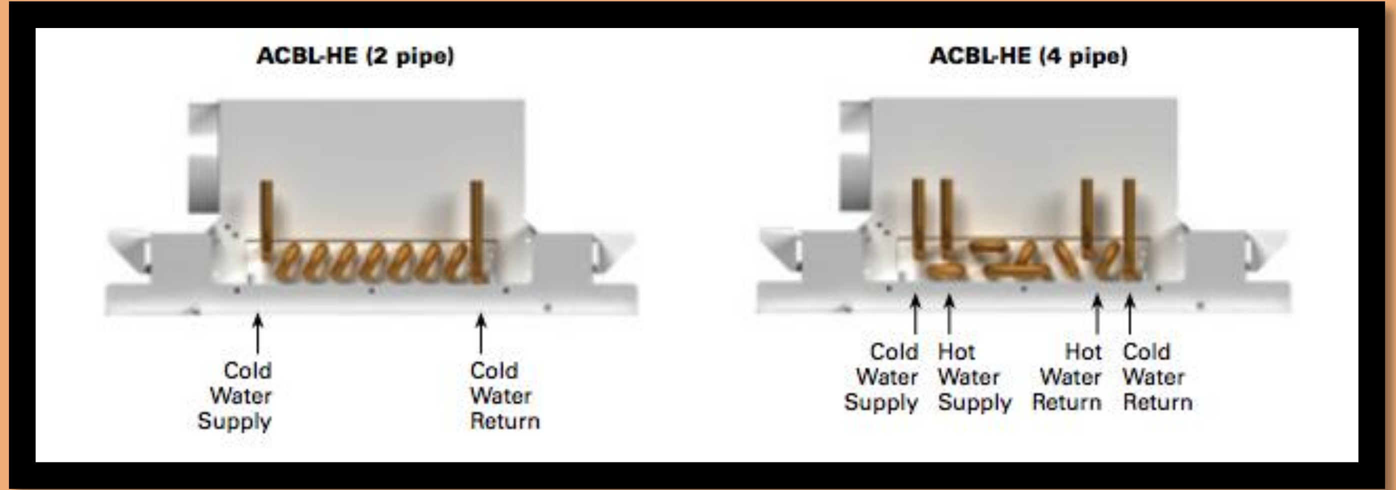
BROAD INSTITUTE

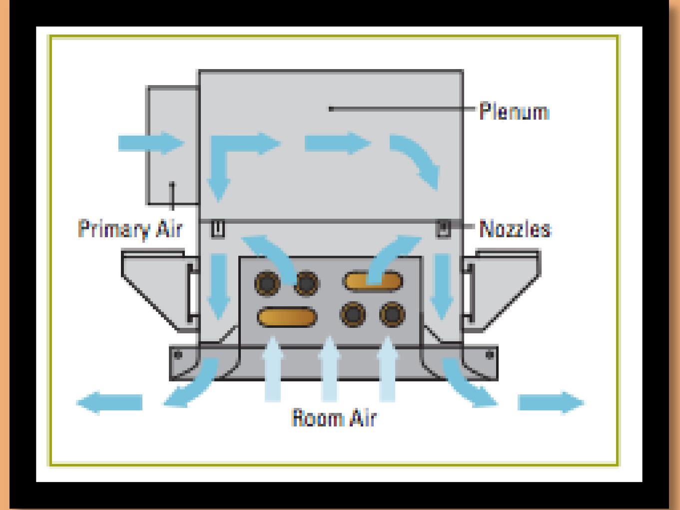
ELKUS | MANFREDI ARCHITECTS

BR+A

[GOAL]

To reduce energy consumption and carbon footprint compared to the original system by lowing supply air rates and need for reheat.





Chilled Beams Alternate

BROAD INSTITUTE

ELKUS | MANFREDI ARCHITECTS

BR+A

[OPERATION]

1) **Determine Sensible and Latent Loads for Space**
   - TRANE TRACE 700

2) **Air Flow Rate For Space**
   - V_{bz}= Rp * Pz + Ra * Az
   - **Office** 5 cfm / person & .06 cfm/ft^2
   - **Lab** 10 cfm / person & 18 cfm/ft^2

3) **Cooling Capacity of Air**
   - Humidity Ratio w_{supply}= 0.007997 lb_w/lb_{DA}
     w_{room} = 0.009233 lb_w/lb_{DA}
   - $Q_{latent} = 4840\ V_{bz}\ (w_{room} - w_{supply})$

4) **Required Supply Air To Remove Latent**
   - $Q_{latent} = 4840\ V_{bz\_new}\ (w_{room} - w_{supply})$
   - This gives a new sensible capacity of
     $Q_{sensible} = 1.08\ V_{bz\_new}\ (T_{room} - T_{supply})$

5) **Sensible Load for Chilled Beams**
   - Sensible load from Trace minus Q_{sens} above

6) **Size & Quantity**
   - From PRICE-HVAC catalogue

Chilled Beams Alternate

BROAD INSTITUTE

ELKUS | MANFREDI ARCHITECTS

BR+A

[RESULTS]

EXISTING			
AHU-1-2	VAV	77,274	26,333
AHU-3-4	VAV	223,882	121,876
REDESIGN			
AHU-1-2	VAV	77,274	26,333
	% CHANGE	0%	0%
AHU-3-4	ACTIVE CHILLED BEAMS	82,552	82,552
	% CHANGE	-63%	-32%

Unit	Fan Type	# Fans	Original	Redesign
AHU1	*plenum*	*4*	28750	30516
AHU2	*plenum*	*4*	28750	30516
AHU3	*plenum*	*4*	28750	30516
AHU4	*plenum*	*4*	28750	ELIMINATED
AHU5	*plenum*	*4*	15000	15000
EAHU1	*Cent.*	*5*	57,500	45,774
EAHU2	*Cent.*	*5*	57,500	45,774
EAHU3	*Cent.*	*3*	30000	30000

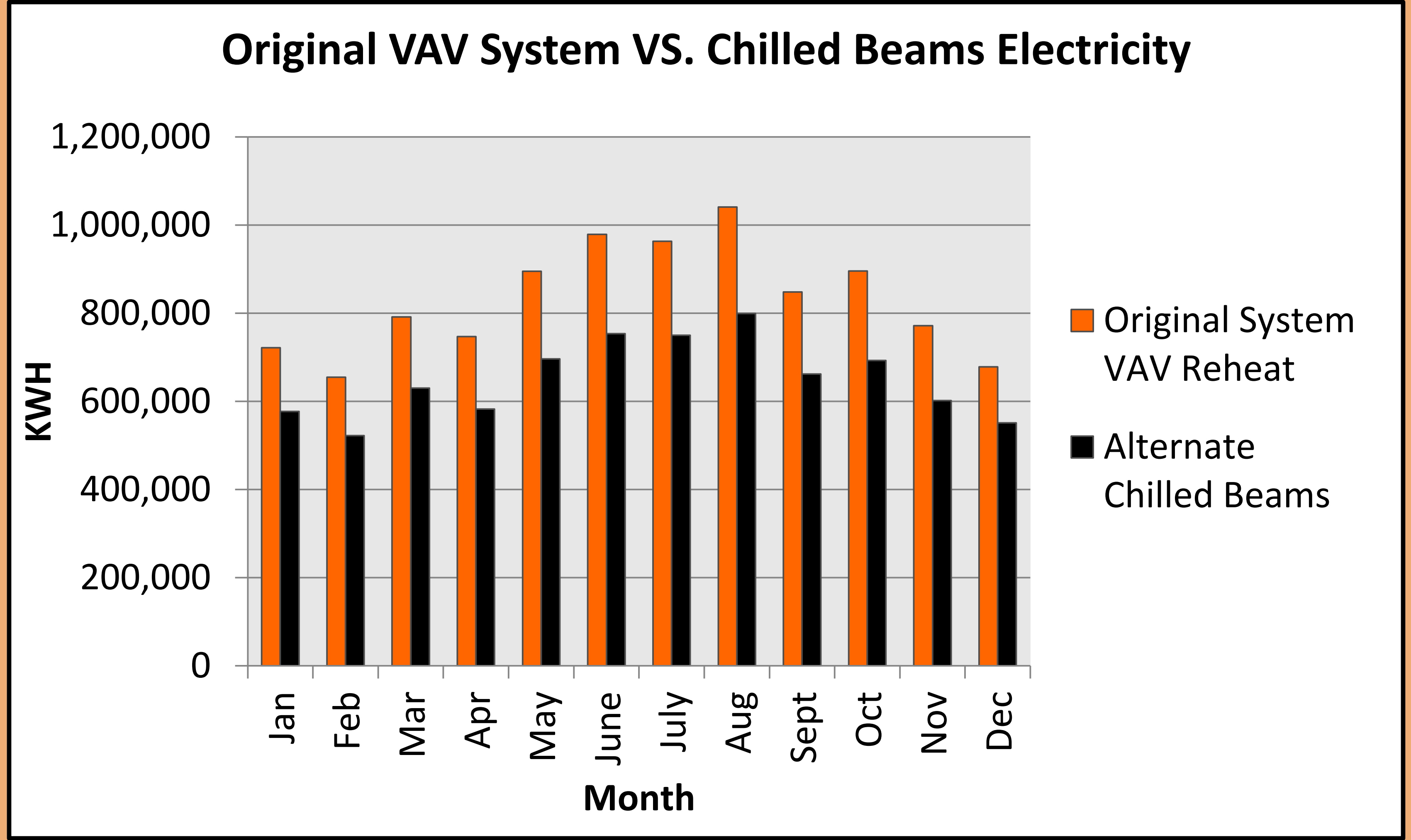
Unit	Type	Quantity	CFM	Min SP	HP	RPM
EXISTING						
AHU1	*plenum*	4	28750	7.5	75	1750
AHU2	*plenum*	4	28750	7.5	75	1750
AHU3	*plenum*	4	28750	7.5	75	1750
AHU4	*plenum*	4	28750	7.5	75	1750
AHU5	*plenum*	4	15000	7.5	50	1750
EAHU1	*Cent.*	5	57,500	5.3	100	770
EAHU2	*Cent.*	5	57,500	5.3	100	770
EAHU3	*Cent.*	3	30000	4.5	50	1132
REDESIGN						
AHU1	*plenum*	4	30516	7.5	89.76	1858
AHU2	*plenum*	4	30516	7.5	89.76	1858
AHU3	*plenum*	4	30516	7.5	89.76	1858
AHU5	*plenum*	4	15000	7.5	50	1750
EAHU1	*Cent.*	5	45,774	5.3	50.46	613
EAHU2	*Cent.*	5	45,774	5.3	50.46	613
EAHU3	*Cent.*	3	30000	4.5	50	1132

Chilled Beams Alternate

[RESULTS]

Utility	Unit	Cost
Electricity	$/KWH	0.201
Natural Gas	$/Therm	1.597

	Electricity (kWh)	Natural Gas (Therms)	Electricity Cost Per year	Natural Gas Cost per year	Total Cost Per Year
Original System	9,985,524.00	107,047.00	$2,007,090.32	$170,954.06	$2,178,044.38
Chilled Beams	7,817,379.00	46,671.00	$1,571,293.18	$74,533.59	$1,645,826.77
Difference	2,168,145.00	60,376.00	$435,797.15	$96,420.47	$532,217.62
				% change	-24%



75 Ames Street:

NATHANIEL MOONEY

THE BROAD INSTITUTE EXPANSION

Chilled Beams Alternate

BROAD INSTITUTE

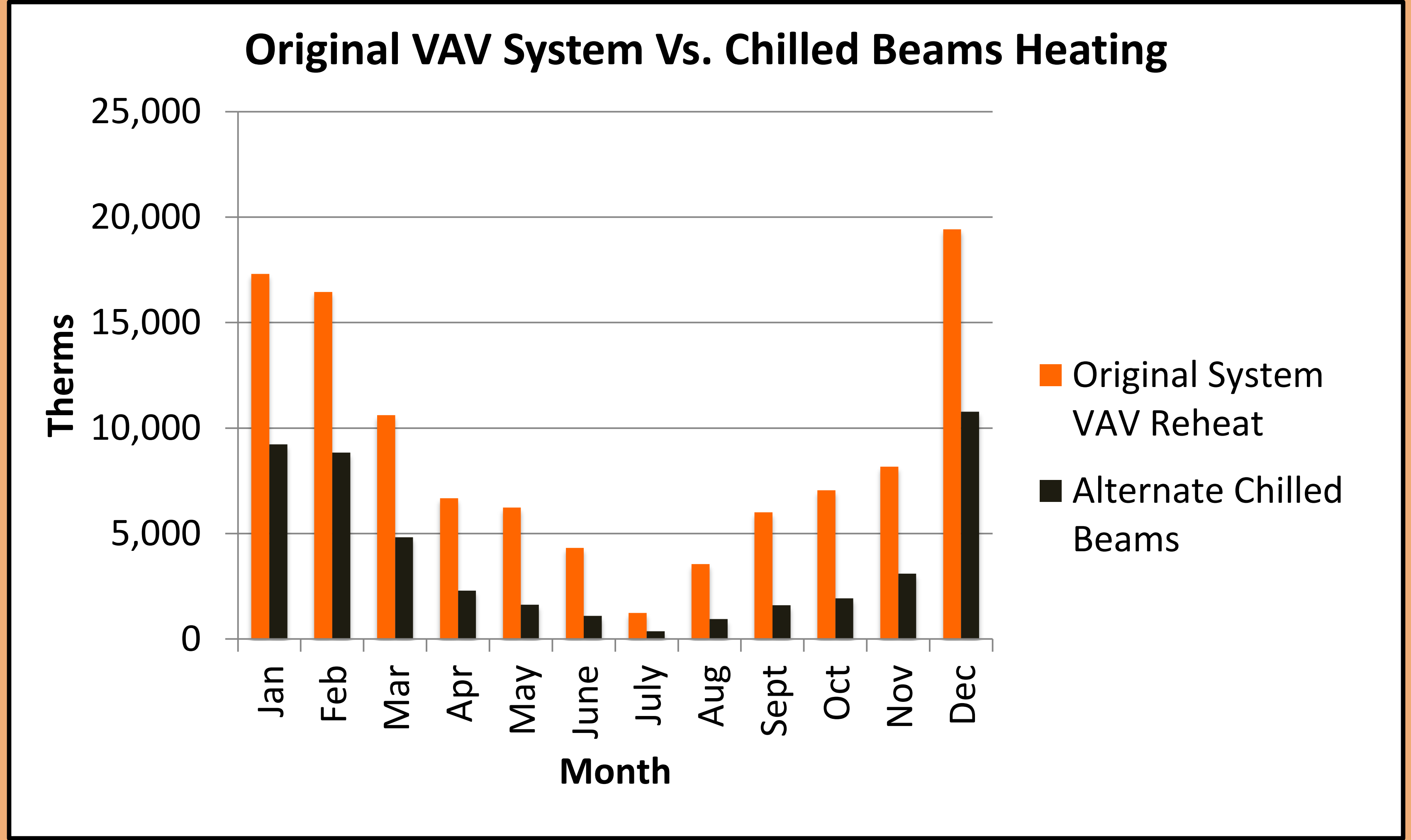
ELKUS | MANFREDI ARCHITECTS

BR+A

[RESULTS]

Utility	Unit	Cost
Electricity	$/KWH	0.201
Natural Gas	$/Therm	1.597

	Electricity (kWh)	Natural Gas (Therms)	Electricity Cost Per year	Natural Gas Cost per year	Total Cost Per Year
Original System	9,985,524.00	107,047.00	$2,007,090.32	$170,954.06	$2,178,044.38
Chilled Beams	7,817,379.00	46,671.00	$1,571,293.18	$74,533.59	$1,645,826.77
Difference	2,168,145.00	60,376.00	$435,797.15	$96,420.47	$532,217.62
				% change	-24%



Chilled Beams Alternate

[COST & SAVINGS]

- Chilled Beams $130/LF
- VAV box's priced on CFM
- Pipe priced at $50 LF
- CHWP From RS Means
- 1.4 years payback

Unit	Cost
Chilled Beams & Resized VAV Box's Total	$962,824.69
VAV BOX & Diffusers	($417,784.28)
Piping	$822,942.38
AHU Removal	($640,815.00)
CHW PUMP	$16,000.00
Total Cost	$743,167.79

W/ 2.5% inflation 10 Year Life Cycle Cost Analysis			
YEAR	Original System VAV Reheat	Chilled Beams Alternate	Savings
0	$-	$743,167.79	$(743,167.79)
1	$2,123,593.27	$2,329,269.69	$(205,676.42)
2	$4,141,006.89	$3,835,602.02	$305,404.87
3	$6,056,222.57	$5,265,161.94	$791,060.63
4	$7,873,089.33	$6,620,846.61	$1,252,242.73
5	$9,595,327.63	$7,905,456.32	$1,689,871.31
6	$11,226,533.33	$9,121,697.51	$2,104,835.81
7	$12,770,181.66	$10,272,185.74	$2,497,995.92
8	$14,229,630.99	$11,359,448.49	$2,870,182.49
9	$15,608,126.50	$12,385,927.99	$3,222,198.50
10	$16,908,803.70	$13,353,983.86	$3,554,819.84

Chilled Beams Alternate

[EMISSIONS]

ENVIRONMENTAL IMPACT					
	Unit	Original System VAV Reheat	Chilled Beams Alternate	% Change	Difference
CO2	lbm/yr	876,396,480	685,284,352	-21.81%	191,112,128
SO2	gm/yr	2,742,078	2,144,125	-21.81%	597,953
NOX	gm/yr	742,165	580,324	-21.81%	161,841

Chilled Beams + DC Alternate

BROAD INSTITUTE

ELKUS | MANFREDI ARCHITECTS

BR+A

[GOAL]

To reduce energy consumption and carbon footprint compared to the original system.

Chilled Beams + DC Alternate

[OPERATION]

Combine The Aircuity-Optinet system in labs with a chilled beam system using the design criteria from depth I & II already mentioned

INTRODUCTION
DEPTH I
DEPTH II
➤ DEPTH III
• GOAL
• OPERATION
➤ RESULTS
• COST & SAVINGS
• EMISSIONS
BREADTH I
CONCLUSION
ACKNOWLEDGEMENTS
QUESTIONS

Chilled Beams + DC Alternate

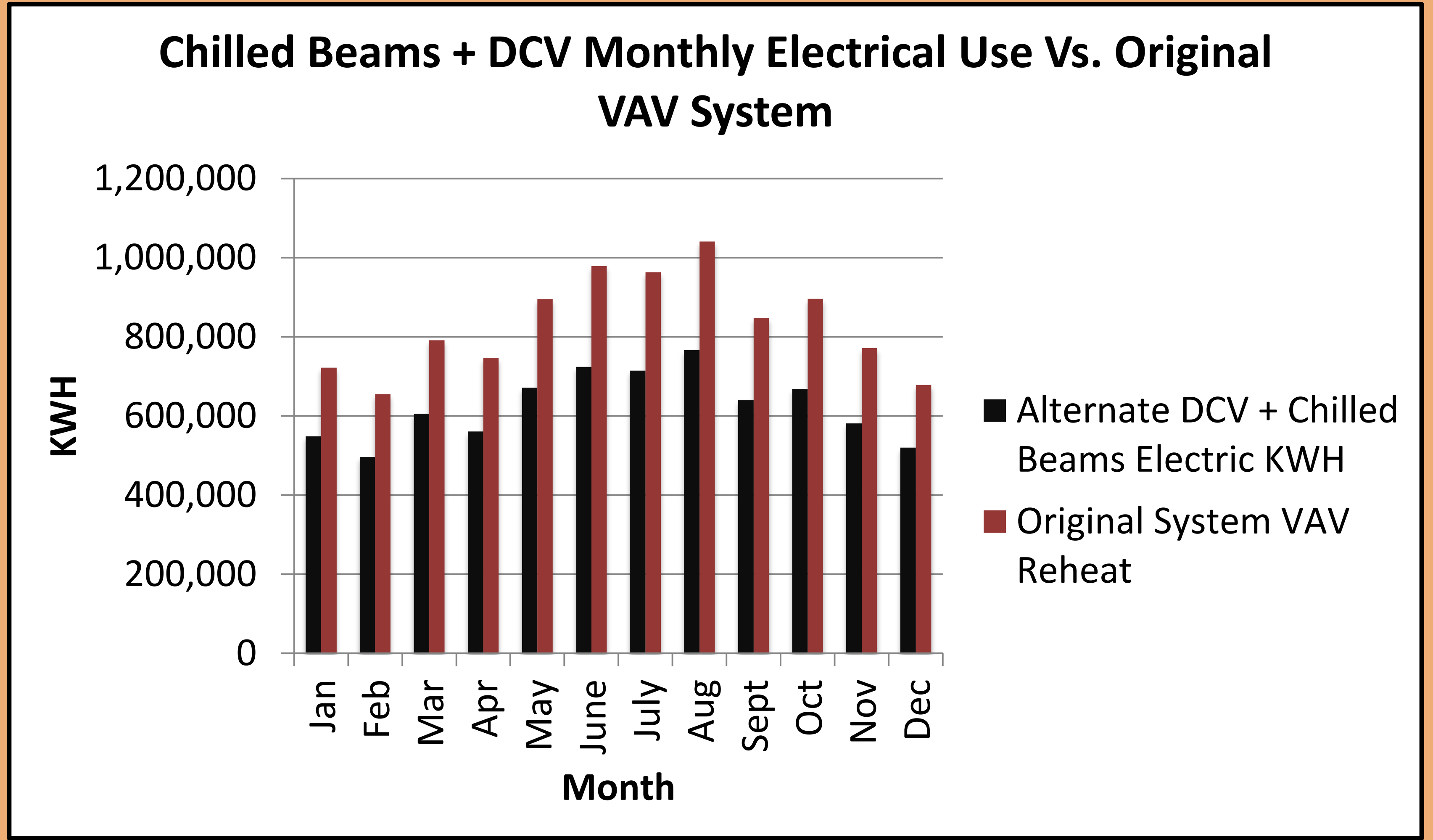
BROAD INSTITUTE

ELKUS | MANFREDI ARCHITECTS

BR+A

[RESULTS]

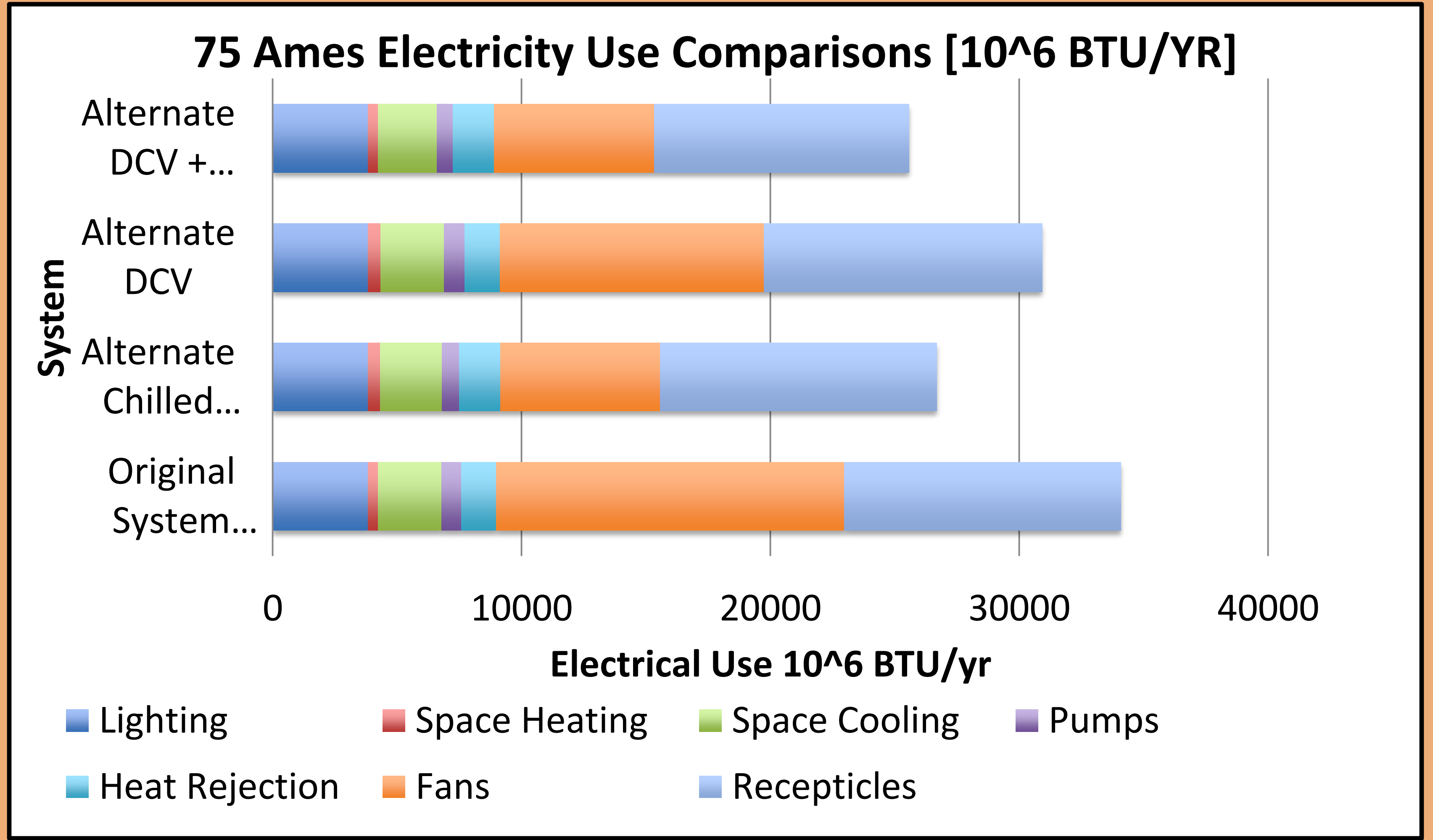
	Electricity (kWh)	Natural Gas (Therms)	Electricity Cost Per year	Natural Gas Cost per year	Total Cost Per Year
Original System	9,985,524.00	107,047.00	$2,007,090.32	$170,954.06	$2,178,044.38
Chilled Beams + DCV	7,493,006.00	42,136.00	$1,506,094.21	$67,291.19	$1,573,385.40
Difference	2,492,518.00	64,911.00	$500,996.12	$103,662.87	$604,658.99
				% change	-28%



Chilled Beams + DC Alternate

[RESULTS]

	Electricity (kWh)	Natural Gas (Therms)	Electricity Cost Per year	Natural Gas Cost per year	Total Cost Per Year
Original System	9,985,524.00	107,047.00	$2,007,090.32	$170,954.06	$2,178,044.38
Chilled Beams + DCV	7,493,006.00	42,136.00	$1,506,094.21	$67,291.19	$1,573,385.40
Difference	2,492,518.00	64,911.00	$500,996.12	$103,662.87	$604,658.99
				% change	-28%

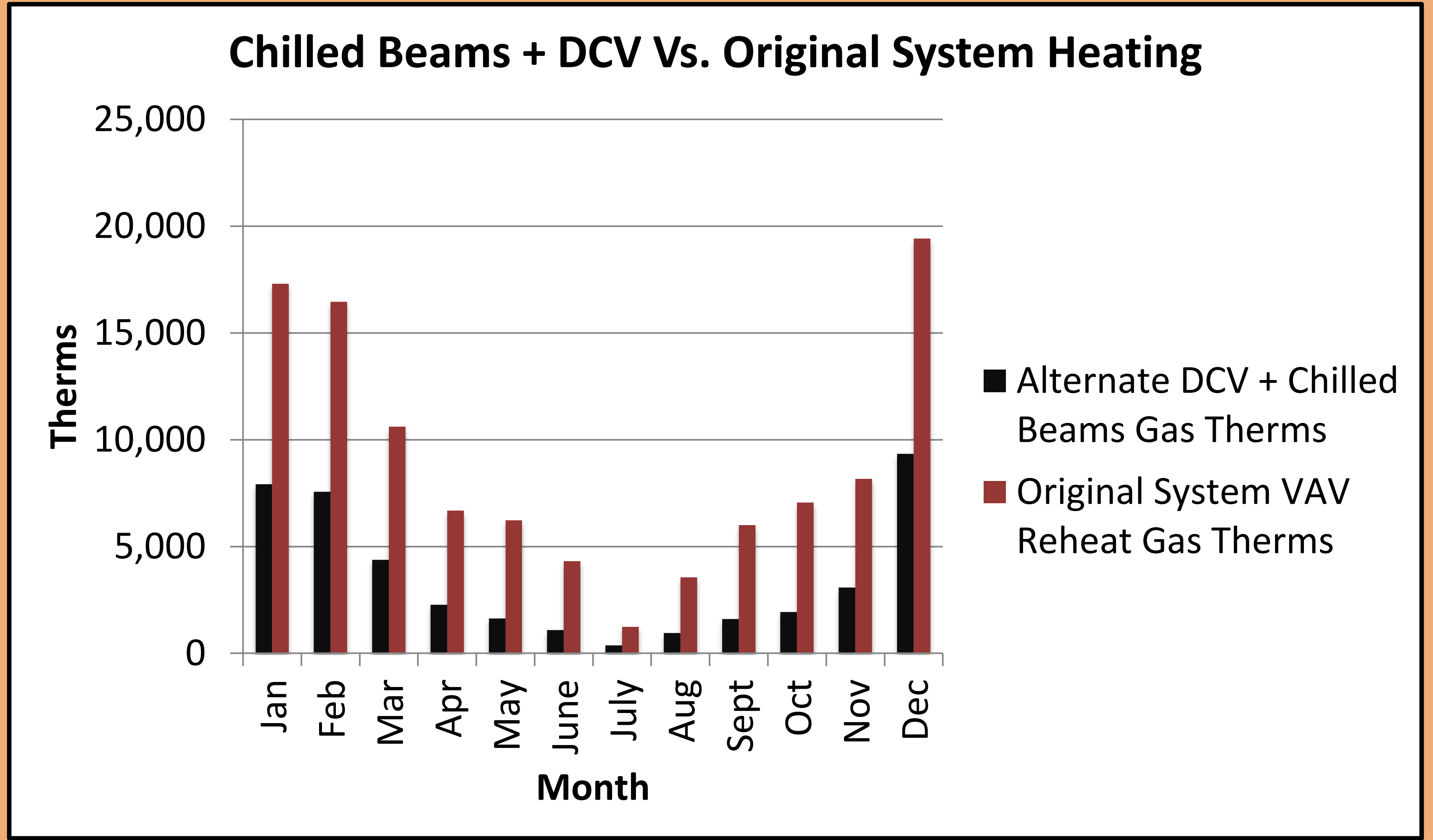


INTRODUCTION
DEPTH I
DEPTH II
➢ DEPTH III
• GOAL
• OPERATION
➢ RESULTS
• COST & SAVINGS
• EMISSIONS
BREADTH I
CONCLUSION
ACKNOWLEDGEMENTS
QUESTIONS

Chilled Beams + DC Alternate

[RESULTS]

	Electricity (kWh)	Natural Gas (Therms)	Electricity Cost Per year	Natural Gas Cost per year	Total Cost Per Year
Original System	9,985,524.00	107,047.00	$2,007,090.32	$170,954.06	$2,178,044.38
Chilled Beams + DCV	7,493,006.00	42,136.00	$1,506,094.21	$67,291.19	$1,573,385.40
Difference	2,492,518.00	64,911.00	$500,996.12	$103,662.87	$604,658.99
				% change	-28%



Chilled Beams + DC Alternate

[COST & SAVINGS]

First Cost

Chilled Beams + Aircuity = $903,167.79

Annual Savings

$604,658.99

Pay back

1.5 years

With 2.5% inflation 10 Year Life Cycle Cost Analysis					
YEAR	Original System VAV Reheat	DCV + Chilled Beams Alternate	Savings	With Maintenance First Year Free	Savings
0	*$-*	$903,167.79	$(903,167.79)	$903,167.79	$(903,167.79)
1	*$2,123,593.27*	$2,414,639.36	$(291,046.08)	$2,414,639.36	$(291,046.08)
2	*$4,141,006.88*	$3,849,972.87	$291,034.01	$3,869,900.82	$271,106.06
3	*$6,056,222.57*	$5,212,030.55	$844,192.01	$5,250,890.06	$805,332.51
4	*$7,873,089.34*	$6,503,579.12	$1,369,510.22	$6,560,411.15	$1,312,678.19
5	*$9,595,327.63*	$7,727,292.74	$1,868,034.89	$7,801,174.38	$1,794,153.25
6	*$11,226,533.33*	$8,885,755.94	$2,340,777.38	$8,975,799.19	$2,250,734.14
7	*$12,770,181.66*	$9,981,466.43	$2,788,715.23	$10,086,817.02	$2,683,364.64
8	*$14,229,630.99*	$11,016,837.79	$3,212,793.20	$11,136,674.09	$3,092,956.90
9	*$15,608,126.49*	$11,994,202.17	$3,613,924.33	$12,127,734.05	$3,480,392.45
10	*$16,908,803.70*	$12,915,812.80	$3,992,990.90	$13,062,280.58	$3,846,523.12

Chilled Beams + DC Alternate

[EMISSIONS]

ENVIRONMENTAL IMPACT					
Pollutant	Unit	Original System VAV Reheat	DCV & Chilled Beams Alternate	% Change	Difference
CO2	lbm/yr	876,396,480	657,636,416	-24.96%	218,760,064
SO2	gm/yr	2,742,078	2,057,619	-24.96%	684,459
NOX	gm/yr	742,165	556,911	-24.96%	185,254

Electrical Breadth

[GOAL]

To size the new electrical equipment (wires, conduit, breakers, starters) serving the new fans and chilled water pump for the chilled beam system

Electrical Breadth

BROAD INSTITUTE

ELKUS | MANFREDI ARCHITECTS

BR+A

[Method]

Fan HP found using fan affinity laws

FLC

- Table 430.250 Full load Current Three-Phase Alternating Current from NEC 2011

Find KVA

- *FLA=KVA / (Voltage√(3)) → KVA = (Voltage)(√(3))(FLA)*

Wire Size

- 1.25 for continuous loads
- Table 310.15(B)(16) from NEC 2-11
- THWN Type wire Copper
- Rated 75C

Circuit Breaker

- 2.5 multiplier
- Table 430.52 NEC 2011
- Next lowest breaker chosen

Ground Wire

- Based on breaker size
- Table 250.122 NEC 2011

Conduit

- Table C.1 NEC 2011
- EMT

INTRODUCTION
DEPTH I
DEPTH II
DEPTH III
➢ BREADTH I
• GOAL
➢ METHOD
• RESULT
CONCLUSION
ACKNOWLEDGEMENTS
QUESTIONS

Electrical Breadth

[Method]

Starter

NEMA Size	NEMA Continuous Amp Rating (Amp)	Maximum Horsepower (hp) Full Voltage Starting 200V	230V	460V 575V	Part Winding Starting 200V	230V	460V 575V	Wye Delta Starting 200V	230V	460V 575V
00	9	1 1/2	1 1/2	2						
0	18	3	3	5						
1	27	7.5	7.5	10	10	10	15	10	10	15
2	45	10	15	25	20	25	40	20	25	40
3	90	25	30	50	40	50	75	40	50	75
4	135	40	50	100	75	75	150	60	75	150
5	270	75	100	200	150	150	350	150	150	300
6	540	150	200	400		300	600	300	350	700
7	810		300	600		450	900	500	500	1,000

Disconnect

- **Standard Sizes** 30, 60, 100, and 200 amps
- Next higher disconnect is chosen based on the FLC.

Electrical Breadth

BROAD INSTITUTE

ELKUS | MANFREDI ARCHITECTS

BR+A

[RESULT]

Existing

UNIT	UNIT #	Volt	Phase	Fan HP	FLA	kVA	Wire	Wire amps	Conduit	Starter	Load Amp	CB Size	Gnd Size	Disc. A	Panel Board
AHU1	SF1	480	3	75	96	80	4 - #1	120	1-1/4"	NEMA SIZE 4	240	225	4	100	E4M31
	SF2	480	3	75	96	80	4 - #1	120	1-1/4"	NEMA SIZE 4	240	225	4	100	E4M32
	SF3	480	3	75	96	80	4 - #1	120	1-1/4"	NEMA SIZE 4	240	225	4	100	DP4M21
	SF4	480	3	75	96	80	4 - #1	120	1-1/4"	NEMA SIZE 4	240	225	4	100	DP4M21
AHU2	SF1	480	3	75	96	80	4 - #1	120	1-1/4"	NEMA SIZE 4	240	225	4	100	E4M32
	SF2	480	3	75	96	80	4 - #1	120	1-1/4"	NEMA SIZE 4	240	225	4	100	E4M32
	SF3	480	3	75	96	80	4 - #1	120	1-1/4"	NEMA SIZE 4	240	225	4	100	DP4M31
	SF4	480	3	75	96	80	4 - #1	120	1-1/4"	NEMA SIZE 4	240	225	4	100	DP4M31
AHU3	SF1	480	3	75	96	80	4 - #1	120	1-1/4"	NEMA SIZE 4	240	225	4	100	E4M32
	SF2	480	3	75	96	80	4 - #1	120	1-1/4"	NEMA SIZE 4	240	225	4	100	E4M31
	SF3	480	3	75	96	80	4 - #1	120	1-1/4"	NEMA SIZE 4	240	225	4	100	SWB-4M2
	SF4	480	3	75	96	80	4 - #1	120	1-1/4"	NEMA SIZE 4	240	225	4	100	SWB-4M2
AHU4	SF1	480	3	75	96	80	4 - #1	120	1-1/4"	NEMA SIZE 4	240	225	4	100	E4M32
	SF2	480	3	75	96	80	4 - #1	120	1-1/4"	NEMA SIZE 4	240	225	4	100	E4M32
	SF3	480	3	75	96	80	4 - #1	120	1-1/4"	NEMA SIZE 4	240	225	4	100	SWB-4M3
	SF4	480	3	75	96	80	4 - #1	120	1-1/4"	NEMA SIZE 4	240	225	4	100	SWB-4M3
AHU5	SF1	480	3	50	65	54	4 - #4	81.25	1"	NEMA SIZE 3	162.5	150	6	100	EDP4M31
	SF2	480	3	50	65	54	4 - #4	81.25	1"	NEMA SIZE 3	162.5	150	6	100	EDP4M31
	SF3	480	3	50	65	54	4 - #4	81.25	1"	NEMA SIZE 3	162.5	150	6	100	EDP4M31
	SF4	480	3	50	65	54	4 - #4	81.25	1"	NEMA SIZE 3	162.5	150	6	100	EDP4M31
EAHU1	EF1	480	3	100	124	103	4 - #2/0	155	2"	NEMA SIZE 4	310	300	3	200	E4M32
	EF2	480	3	100	124	103	4 - #2/0	155	2"	NEMA SIZE 4	310	300	3	200	E4M31
	EF3	480	3	100	124	103	4 - #2/0	155	2"	NEMA SIZE 4	310	300	3	200	SWB-4M3
	EF4	480	3	100	124	103	4 - #2/0	155	2"	NEMA SIZE 4	310	300	3	200	SWB-4M3
	EF5	480	3	100	124	103	4 - #2/0	155	2"	NEMA SIZE 4	310	300	3	200	SWB-4M3
EAHU2	EF1	480	3	100	124	103	4 - #2/0	155	2"	NEMA SIZE 4	310	300	3	200	E4M32
	EF2	480	3	100	124	103	4 - #2/0	155	2"	NEMA SIZE 4	310	300	3	200	E4M32
	EF3	480	3	100	124	103	4 - #2/0	155	2"	NEMA SIZE 4	310	300	3	200	SWB-4M2
	EF4	480	3	100	124	103	4 - #2/0	155	2"	NEMA SIZE 4	310	300	3	200	SWB-4M2
	EF5	480	3	100	124	103	4 - #2/0	155	2"	NEMA SIZE 4	310	300	3	200	SWB-4M2
EAHU3	EF1	480	3	50	65	54	4 - #4	81.25	1"	NEMA SIZE 3	162.5	150	6	100	E4M33
	EF2	480	3	50	65	54	4 - #4	81.25	1"	NEMA SIZE 3	162.5	150	6	100	E4M33
	EF3	480	3	50	65	54	4 - #4	81.25	1"	NEMA SIZE 3	162.5	150	6	100	E4M33

Redesign

UNIT	UNIT #	Volt	Phase	Fan HP	FLA	kVA	Wire	Wire amps	Conduit	Starter	Load Amp	CB Size	Gnd Size	Disc. A	Panel Board
AHU1	SF1	480	3	90	113	94	4 - #1/0	141.25	1-1/2"	NEMA SIZE 4	282.5	250	4	200	E4M31
	SF2	480	3	90	113	94	4 - #1/0	141.25	1-1/2"	NEMA SIZE 4	282.5	250	4	200	E4M32
	SF3	480	3	90	113	94	4 - #1/0	141.25	1-1/2"	NEMA SIZE 4	282.5	250	4	200	DP4M21
	SF4	480	3	90	113	94	4 - #1/0	141.25	1-1/2"	NEMA SIZE 4	282.5	250	4	200	DP4M21
AHU2	SF1	480	3	90	113	94	4 - #1/0	141.25	1-1/2"	NEMA SIZE 4	282.5	250	4	200	E4M32
	SF2	480	3	90	113	94	4 - #1/0	141.25	1-1/2"	NEMA SIZE 4	282.5	250	4	200	E4M32
	SF3	480	3	90	113	94	4 - #1/0	141.25	1-1/2"	NEMA SIZE 4	282.5	250	4	200	DP4M31
	SF4	480	3	90	113	94	4 - #1/0	141.25	1-1/2"	NEMA SIZE 4	282.5	250	4	200	DP4M31
AHU3	SF1	480	3	90	113	94	4 - #1/0	141.25	1-1/2"	NEMA SIZE 4	282.5	250	4	200	E4M32
	SF2	480	3	90	113	94	4 - #1/0	141.25	1-1/2"	NEMA SIZE 4	282.5	250	4	200	E4M31
	SF3	480	3	90	113	94	4 - #1/0	141.25	1-1/2"	NEMA SIZE 4	282.5	250	4	200	SWB-4M2
	SF4	480	3	90	113	94	4 - #1/0	141.25	1-1/2"	NEMA SIZE 4	282.5	250	4	200	SWB-4M2
AHU5	SF1	480	3	50	65	54	4 - #4	81.25	1"	NEMA SIZE 3	162.5	150	6	100	EDP4M31
	SF2	480	3	50	65	54	4 - #4	81.25	1"	NEMA SIZE 3	162.5	150	6	100	EDP4M31
	SF3	480	3	50	65	54	4 - #4	81.25	1"	NEMA SIZE 3	162.5	150	6	100	EDP4M31
	SF4	480	3	50	65	54	4 - #4	81.25	1"	NEMA SIZE 3	162.5	150	6	100	EDP4M31
EAHU1	EF1	480	3	50	65	54	4 - #4	81.25	1"	NEMA SIZE 3	162.5	150	6	100	E4M32
	EF2	480	3	50	65	54	4 - #4	81.25	1"	NEMA SIZE 3	162.5	150	6	100	E4M31
	EF3	480	3	50	65	54	4 - #4	81.25	1"	NEMA SIZE 3	162.5	150	6	100	SWB-4M3
	EF4	480	3	50	65	54	4 - #4	81.25	1"	NEMA SIZE 3	162.5	150	6	100	SWB-4M3
	EF5	480	3	50	65	54	4 - #4	81.25	1"	NEMA SIZE 3	162.5	150	6	100	SWB-4M3
EAHU2	EF1	480	3	50	65	54	4 - #4	81.25	1"	NEMA SIZE 3	162.5	150	6	100	E4M32
	EF2	480	3	50	65	54	4 - #4	81.25	1"	NEMA SIZE 3	162.5	150	6	100	E4M32
	EF3	480	3	50	65	54	4 - #4	81.25	1"	NEMA SIZE 3	162.5	150	6	100	SWB-4M2
	EF4	480	3	50	65	54	4 - #4	81.25	1"	NEMA SIZE 3	162.5	150	6	100	SWB-4M2
	EF5	480	3	50	65	54	4 - #4	81.25	1"	NEMA SIZE 3	162.5	150	6	100	SWB-4M2
EAHU3	EF1	480	3	50	65	54	4 - #4	81.25	1"	NEMA SIZE 3	162.5	150	6	100	E4M33
	EF2	480	3	50	65	54	4 - #4	81.25	1"	NEMA SIZE 3	162.5	150	6	100	E4M33
	EF3	480	3	50	65	54	4 - #4	81.25	1"	NEMA SIZE 3	162.5	150	6	100	E4M33
CHWP	CHILLED BEAMS	480	3	40	52	43	4 - #6	65	3/4"	NEMA SIZE 3	130	110	6	100	EDP4M21

Chilled Beams Alternate

[CONCLUSION]

- Chilled Beams coupled with Aircutiy demand controlled ventilation offers the best energy savings ($604,658.99) and environmental savings.
- Reduction of Air Handlers off sets most of the costs
- $20,963 maintenance important for keeping system working properly
- reasonable Payback 1.5 years

THANK YOU TO…

BR+A

The Broad Institute

EILKUS|MANFRDI Architects

Entire Project Design and Construction Team

Bryan Donovan

Tom Kolsun

Dr. William Bahnfleth

M. Kevin Parfitt, P.E.

Bob Holland

Corey Wilkinson

Friends and Family

AE Class 2013

75 Ames Street:

NATHANIEL MOONEY

THE BROAD INSTITUTE EXPANSION

And Thank You For Your Time…

BROAD INSTITUTE

ELKUS | MANFREDI ARCHITECTS

BR+A

Aircuity Rooms:

Chosen Based On:

- Size
- ACH
  - Labs 6/12
  - Tissue Culture 6/15

Areas to Aircuity		
Space	SpaceType	Area (SF)
2005 - RNAi LAB	Aircuity	1344.68994
2015 - RNAi LAB	Aircuity	1373.68994
3029 - TISSUE CULTURE ROOM	Aircuity- Tissue	314
3035 - NOVEL THERAPEUTICS/ CHEM BIO	Aircuity	3163
4045 - POST PCR LAB BL2	Aircuity	1366
5045 - RNAi BL2+ LAB	Aircuity	1509
5035 - RNAi BL2+ LAB	Aircuity	2077
6115 - GSAP LAB	Aircuity	3375
6128 - TISSUE CULTURE	Aircuity- Tissue	211
7045 - R&D	Aircuity	1510
7055 - ION DETECTION	Aircuity	1132
7065 - ILLUMINA	Aircuity	1831
7075 - SAMPLE PREP	Aircuity	3326
7085 - CLEAN SAMPLE 2	Aircuity	914
7095 - CLEAN SAMPLE 1	Aircuity	1373
8014 - TISSUE CULTURE ROOM	Aircuity- Tissue	252
8065 - POST PCR GAP LAB	Aircuity	4451

8075 - PRE PCR WHOLE GENOME	Aircuity	746
8095 - PRE PCR LOWPLEX	Aircuity	957
9070 - BL2 + TISSUE CULTURE ROOM	Aircuity- Tissue	421
9075 - LAB	Aircuity	6295
9086 - RADIO ISOTOPE RM	Aircuity	121
9076 - TISSUE CULTURE ROOM	Aircuity- Tissue	280
10079 - TISSUE CULTURE	Aircuity- Tissue	207
10090 - MICROSCOPY/ IMAGING	Animal Imaging	120
10082 - PROCEDURE ROOM	Aircuity	140
10076 - BACTERIAL ROOM	Aircuity	90
10068 - MICROSCOPY/ IMAGING	Animal Imaging	184
10075 - LAB	Aircuity	6705
9077 - TISSUE CULTURE ROOM	Aircuity- Tissue	484
10092 - BL2+ TISSUE CULTURE ROOM	Aircuity- Tissue	537
10078 - TISSUE CULTURE ROOM	Aircuity- Tissue	476
10078 - TISSUE CULTURE ROOM	Aircuity- Tissue	476

75 Ames Street:

Nathaniel Mooney

INTRODUCTION

DEPTH I

DEPTH II

DEPTH III

BREADTH I

CONCLUSION

ACKNOWLEDGEMENTS

➢ QUESTIONS

The Broad Institute Expansion

Questions…

Typical Building Loads

Room Set Points		Winter (°F)	Summer (°F)
	Temperature	*72*	*75*
	Humidity	*25% (±5)*	*50% (±5)*
Internal Loads		Lighting (Watts/SF)	Equipment (Watts/SF)
	Office	*1.2*	*2*
	Labs	*2*	*10*
	Tissue Culture:	*2*	*20*

Ventilation Rates		
	Labs	*6 to 12 ACH*
	Office	*20 CFM Per Person*

75 Ames Street:

Nathaniel Mooney

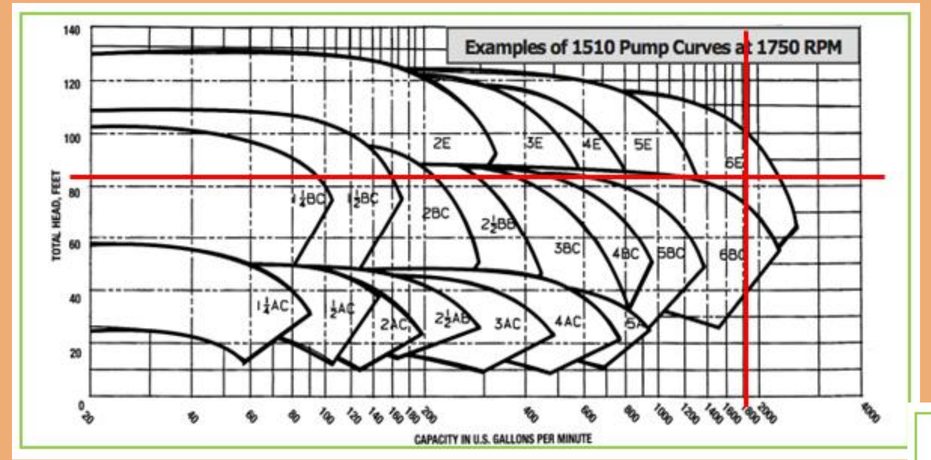
The Broad Institute Expansion

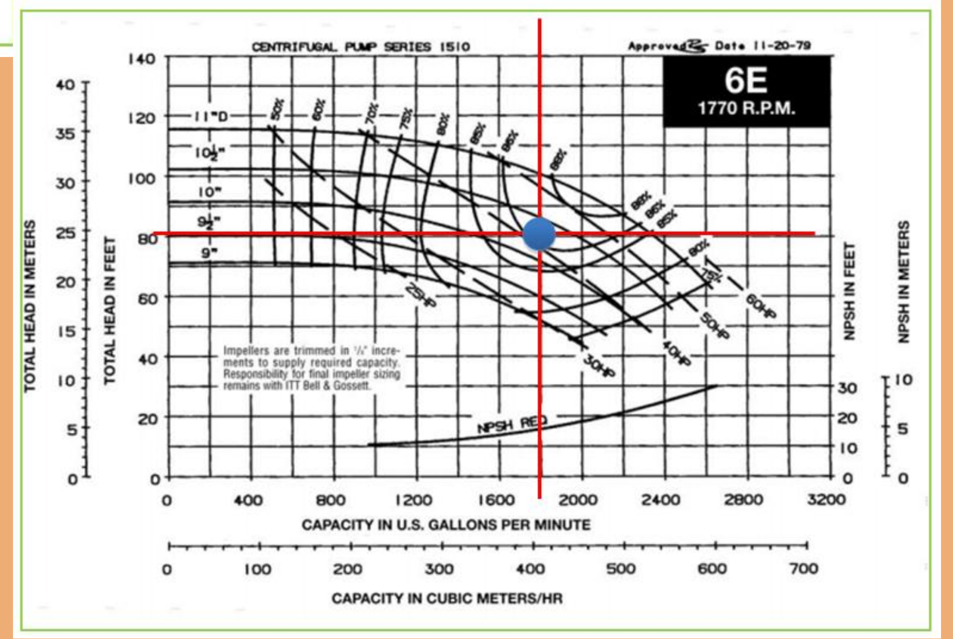
Pump Size

Q=500 x GPM x DT
DT=5
Q= 4582210 BTU/HR

GPM=1832.884

CHILLED BEAM AREA PER FLOOR					
Floor Number	AREA [FT^2]	PERCENT TOTAL	GPM PER FLOOR	Pipe Size [IN]	Head [FT H2O]
2	4807	4%	78	3	23.2844811
3	7013	6%	114	3	33.9700575
4	6611.1	6%	108	3	32.0233063
5	6624.06	6%	108	3	32.0860828
6	14575.124	13%	237	4	70.6
7	16807.1	15%	273	5	81.4114007
8	15341.99	14%	250	4	74.3145989
9	14467.989	13%	235	4	70.081052
10	14180	13%	231	4	68.6860709
11	12250	11%	199	4	59.3386329
TOTAL	112677.617	100%	1497		545.795683

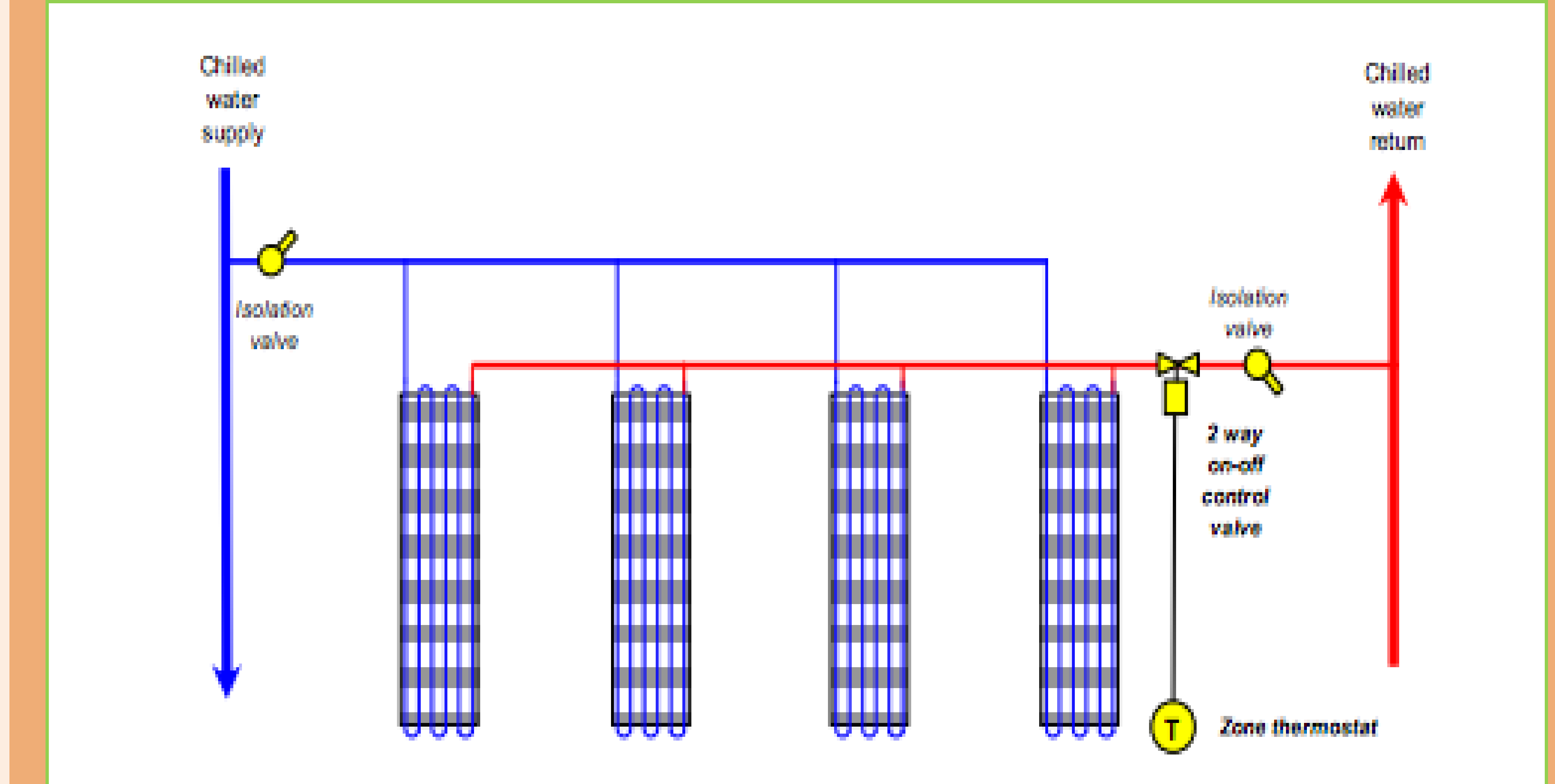




Chilled Beam Control

- On VAV
- Vary water flow rate through beam using zone level thermostats
  - 7-8 degree change can change cooling rates of beams by 60%
- Dew point sensors can be used in spaces where concern of condensation is high
  - Resets water temperature higher to prevent condensation

- Beam supply varied by 2 way on-off control valve controlled by zone thermostat.



Chilled beams within a single thermal zone