The Sunshine Elementary School

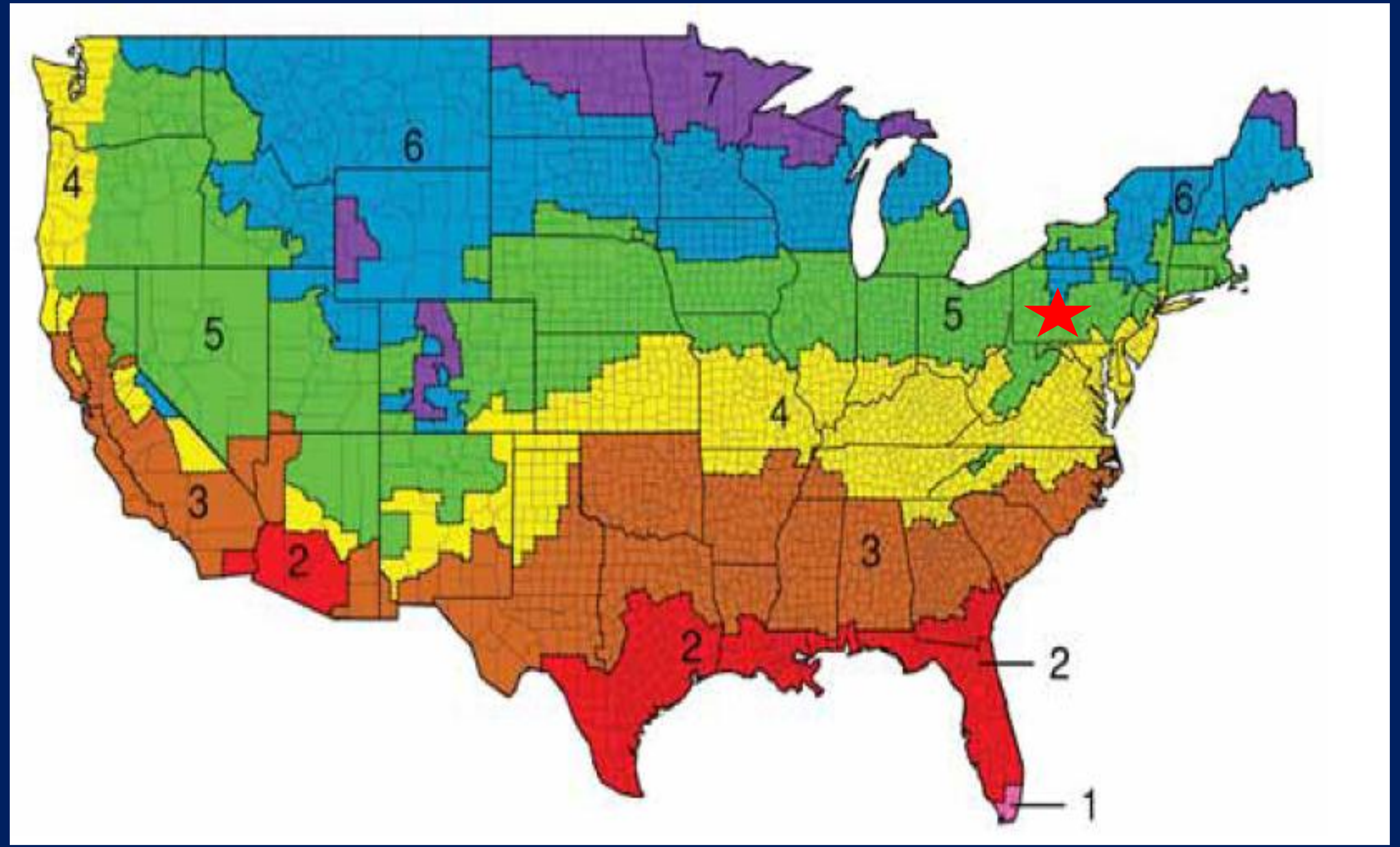
Redesign Proposal

Pennsylvania State University
AE Senior Thesis
Nicholas Scheib
Mechanical Option- IP

Presentation Outline

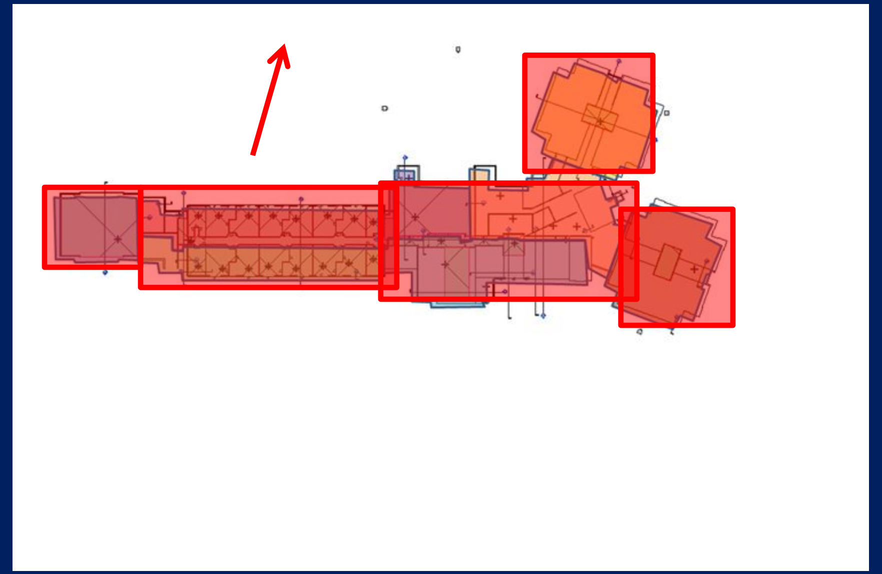
1. **Project Overview**
2. Existing Conditions
3. Depth
    1. Radiant Heating and Cooling
    2. Low Velocity Displacement Ventilation
4. Breadths
    1. Daylighting
    2. Acoustics
5. Overall Cost
    1. Initial Difference
    2. LCC
6. Pros versus Cons

The Sunshine Elementary School is located in Climate Zone 5. The design has met all ASHRAE requirements of this climate zone.



ASHRAE Climate Chart (Fundamentals, 2009)

General Information of Project



Size- 103,000 Square Feet

2 Levels

Overall Cost- $16,599,000

Brick Facade

Gable Roofs

Construction Dates- March 2010- June 2011

Silver LEED Accreditation Goal

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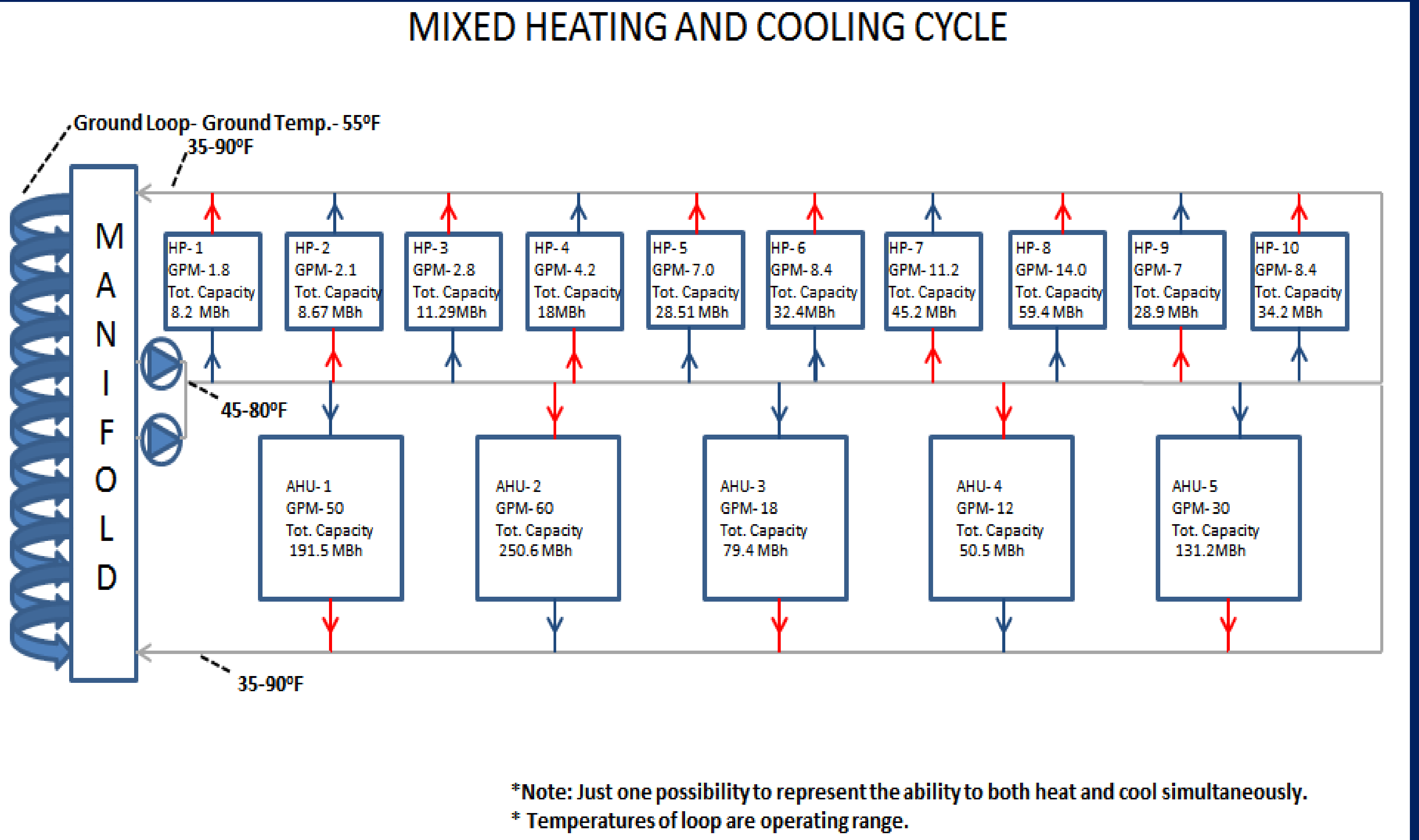
Original Design Components

- 144 Vertical Geothermal Wells- 12 x 12 grid
- Water-to-Air Heat Pumps- each room
- Energy Recovery Units
- CO_2 Sensors
- AHU's for gym and cafeteria
- eQuest© Energy Model- LEED approved
    - 42% more efficient then Baseline Model

Water-to-Air Heat Pumps Tied to Ground Loop



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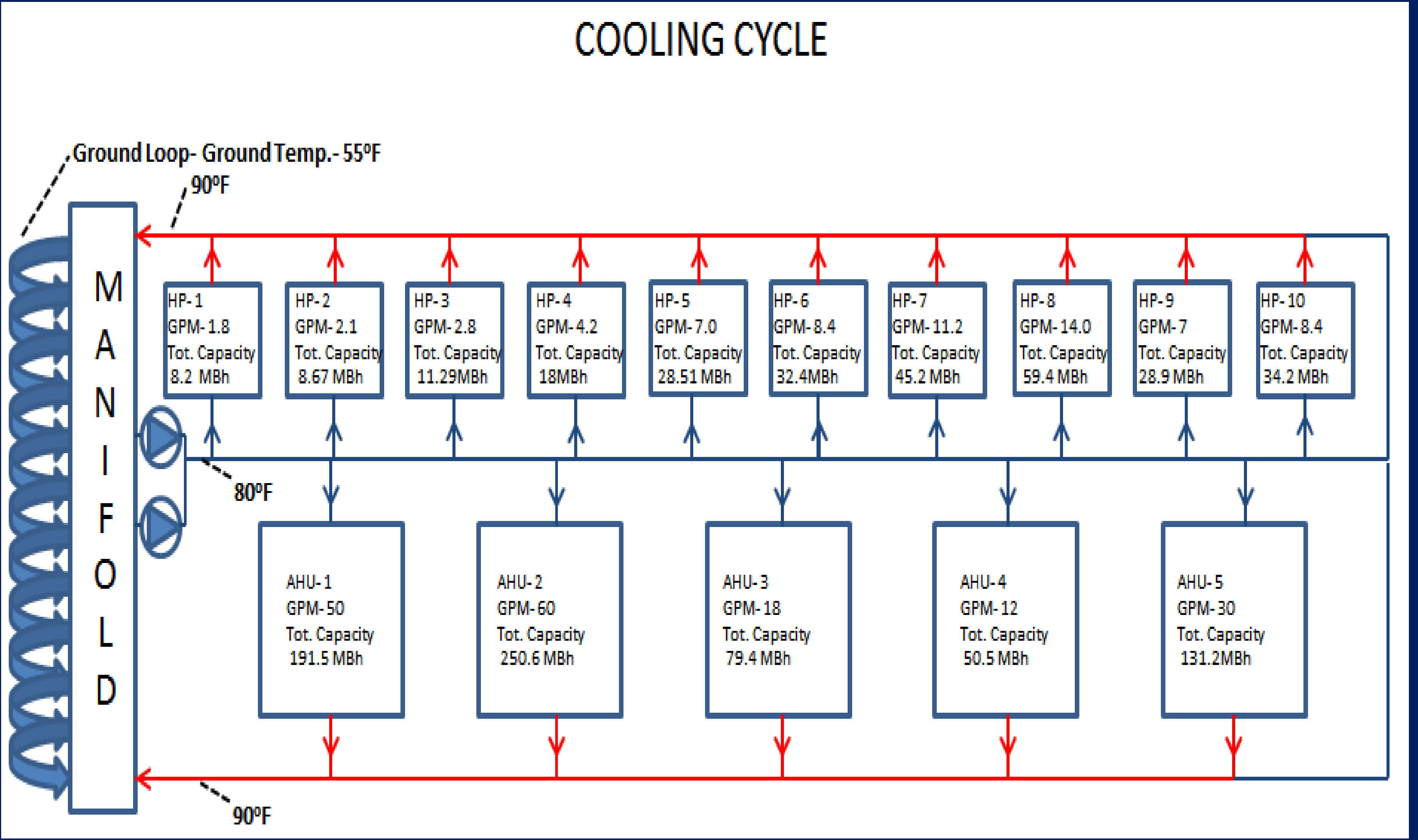

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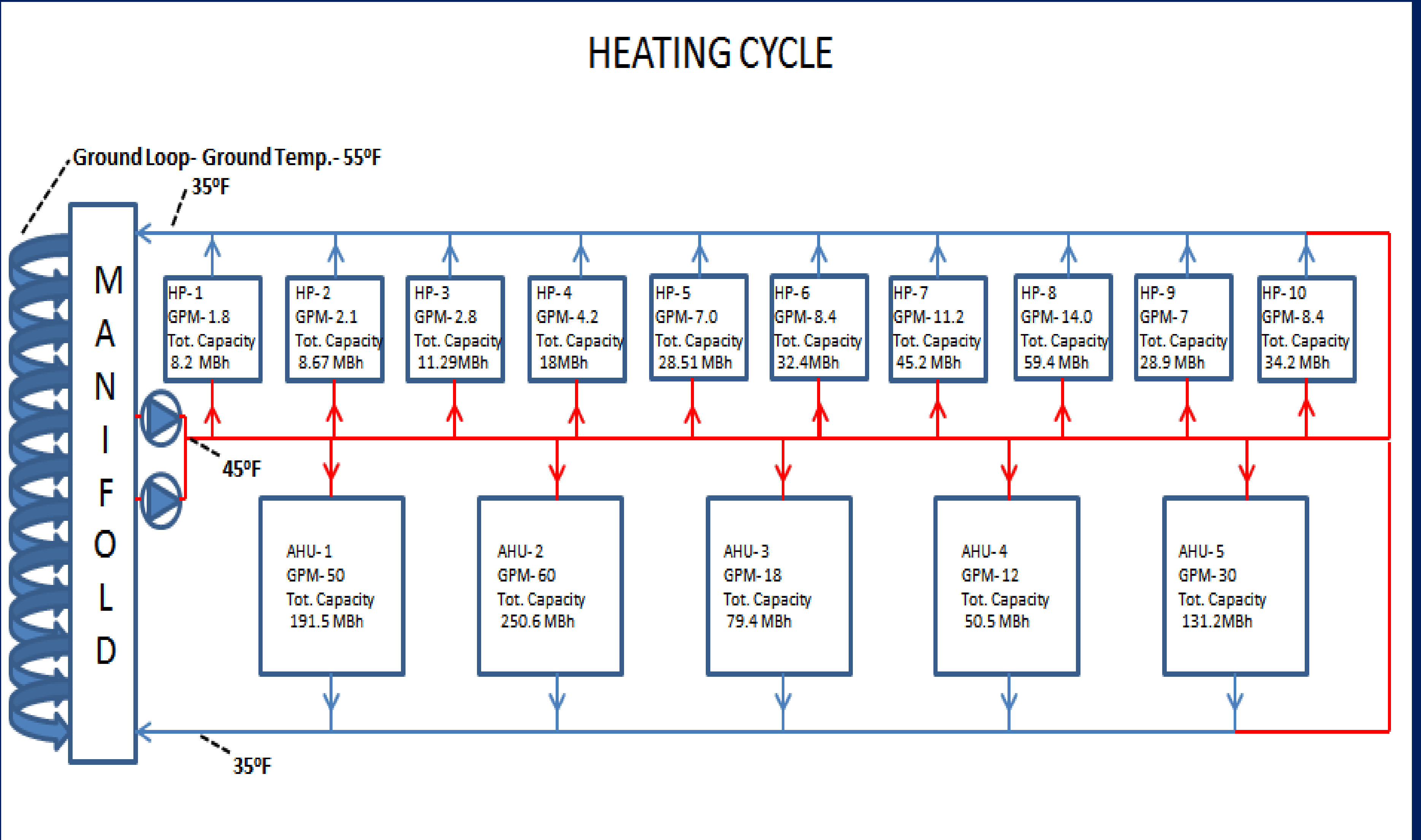

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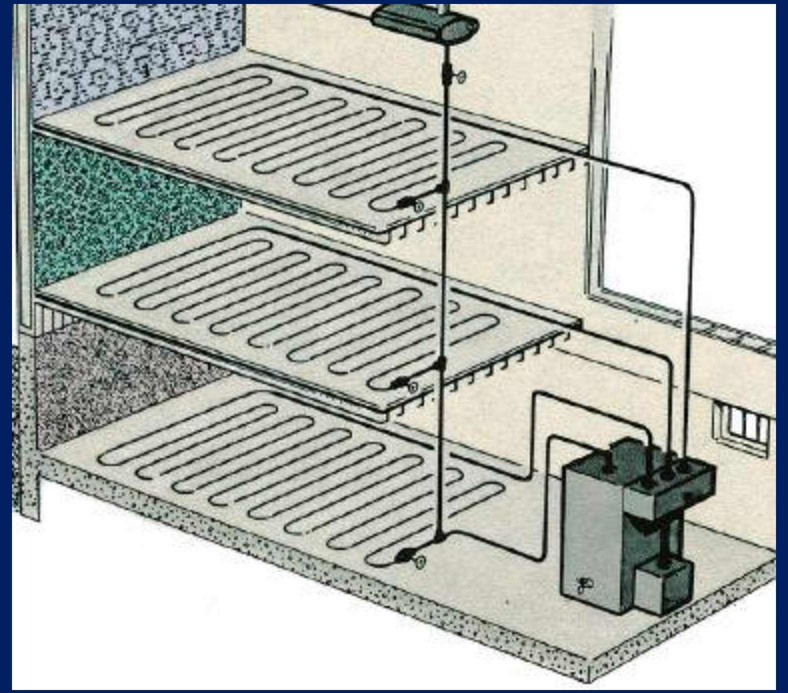
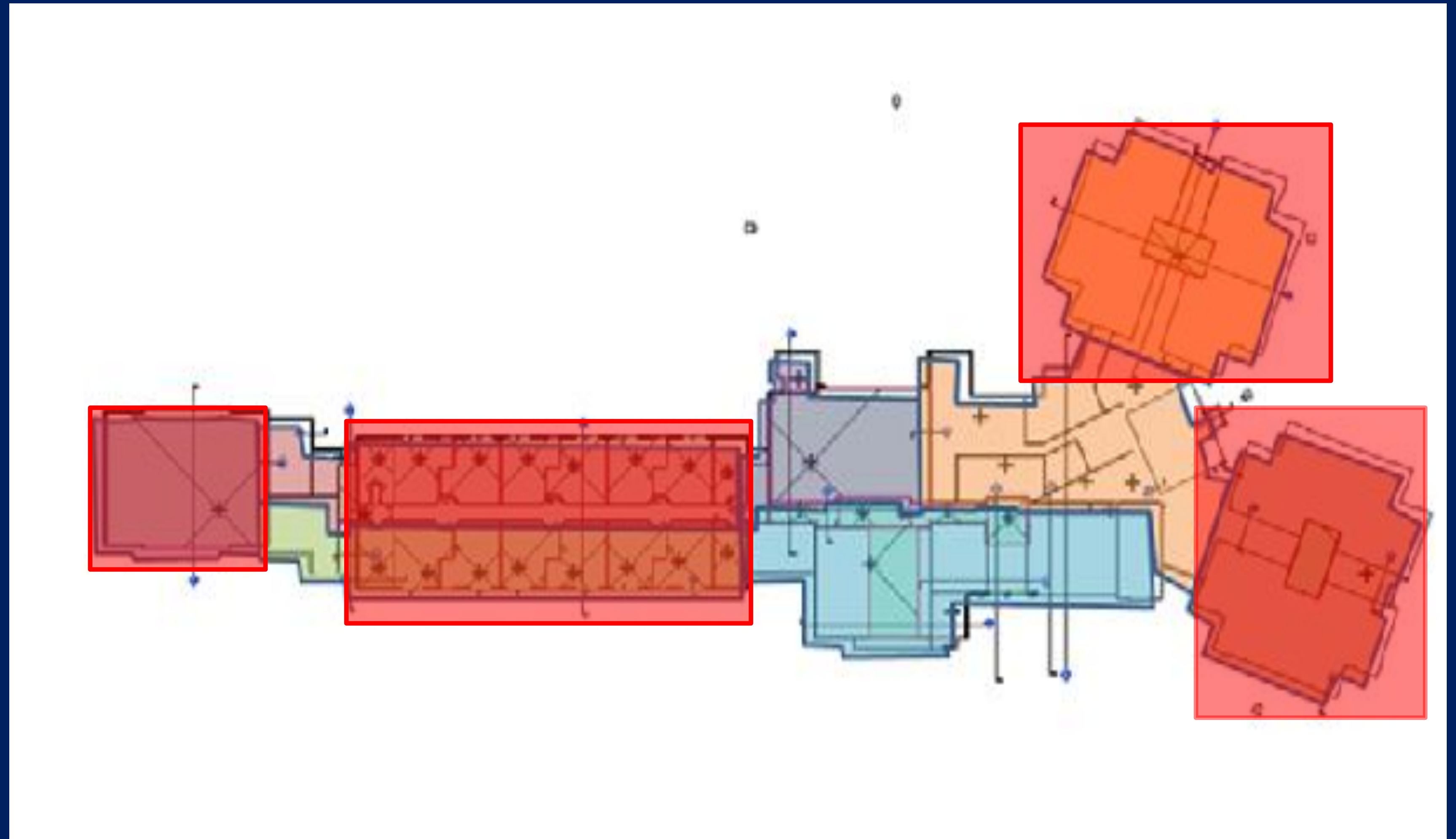
Radiant Heating and Cooling



Enough Capacity?

Radiant heating and cooling was designed in the gymnasium, 1st through 5th grade classrooms and kindergarten classrooms.



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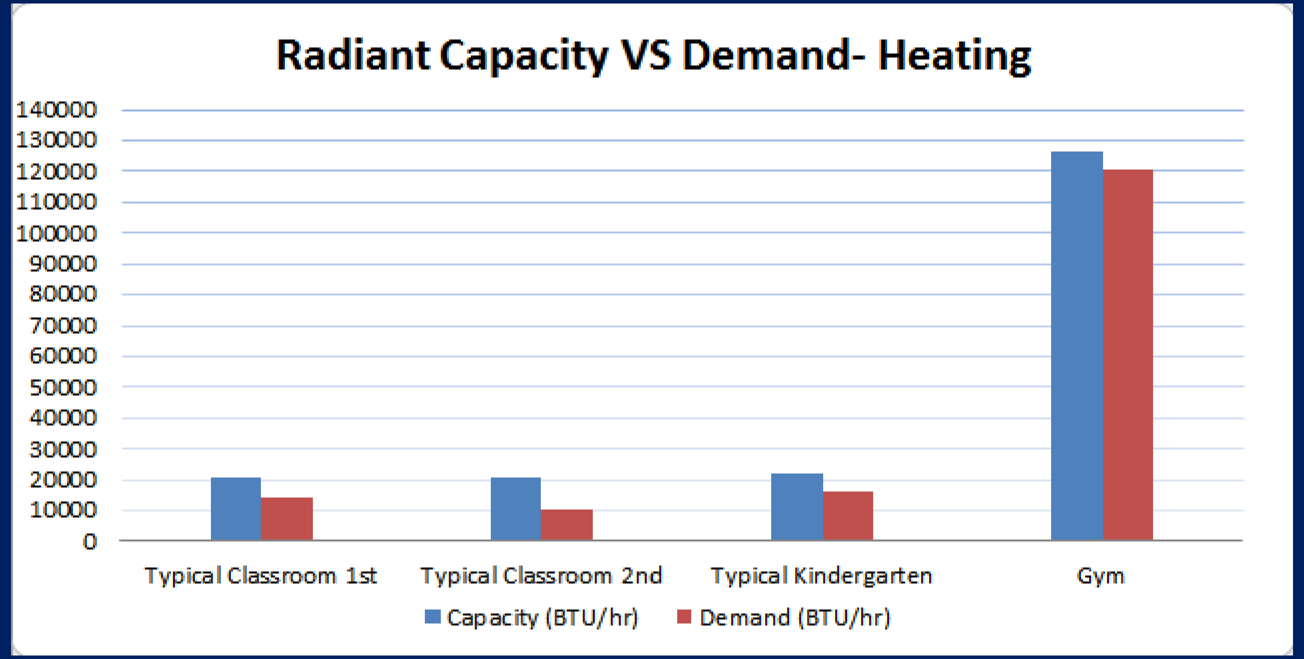
Using coefficients found by Bjarne W. Olesen the Radiant heating and Cooling capacities were found.

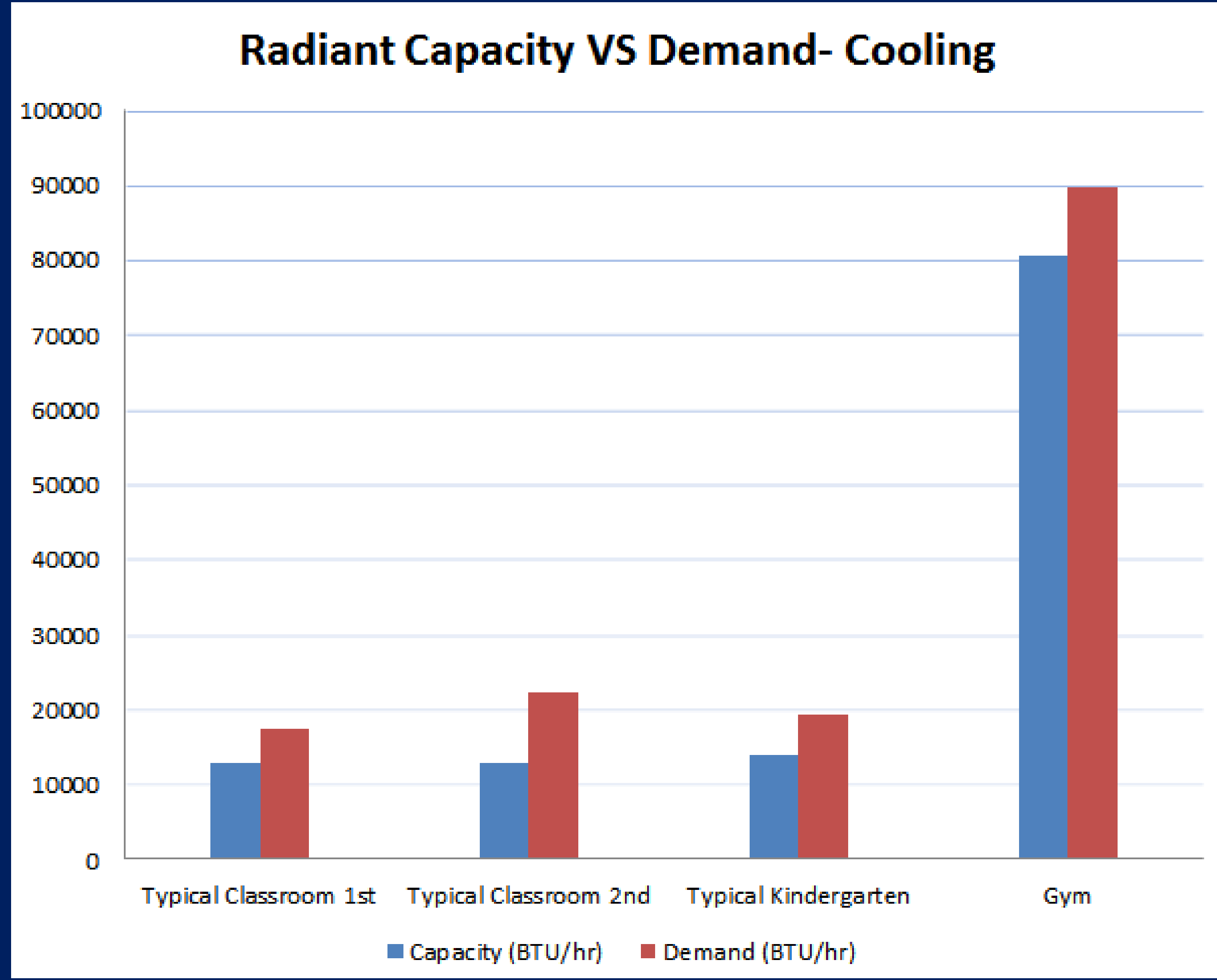
Total Heat Exchange Coefficients (BTU)/(hr*ft^2*F)		
	Heating	Cooling
Floor	1.94	1.24
Note: Floor areas with direct sun the overall heat transfer is up to 3x's Greater (Source: Bjarne W. Olesen)		

Table 28- Slab Heat Exchange Coefficients

Radiant Capacity = Coefficient* Floor Area * ΔT



The cooling Capacity of a radiant slab is less then that of heating.



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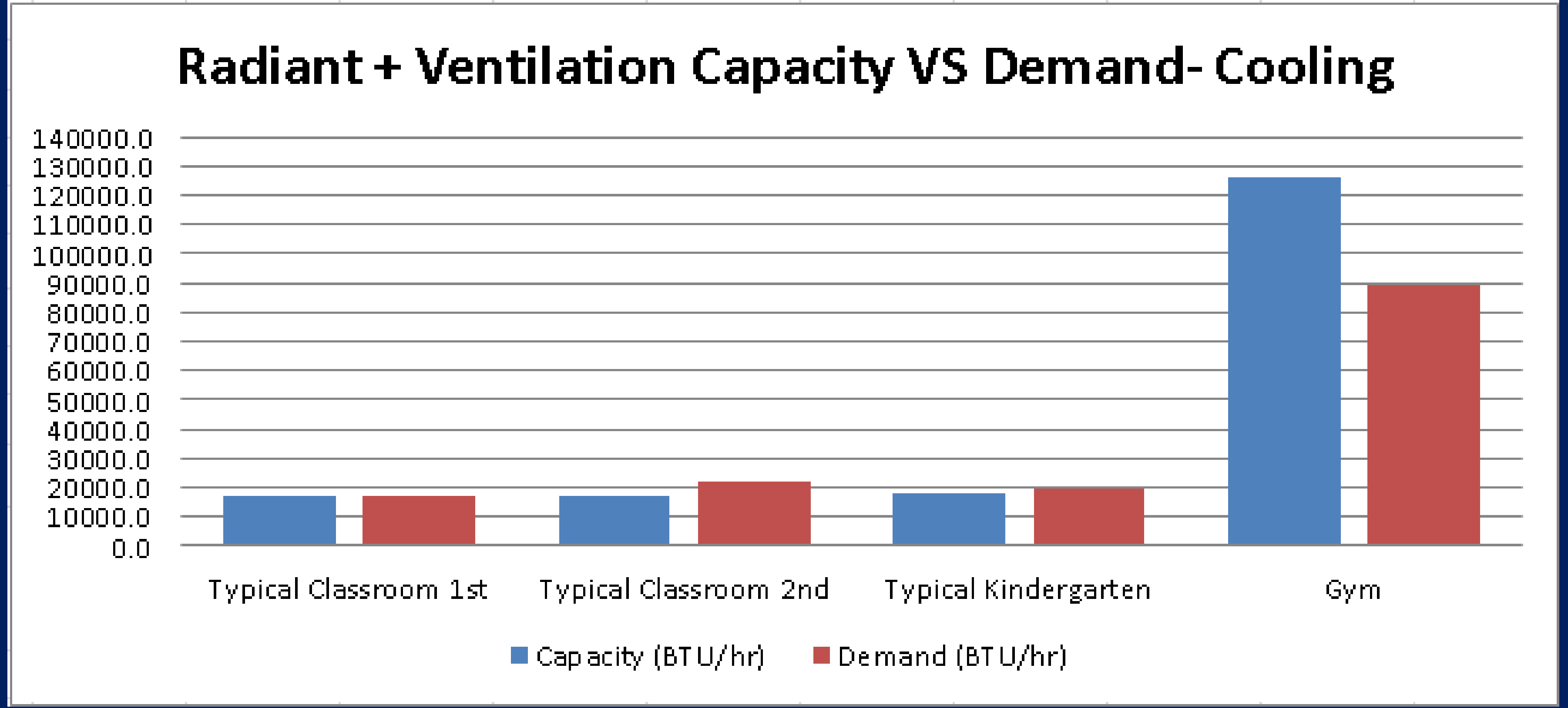
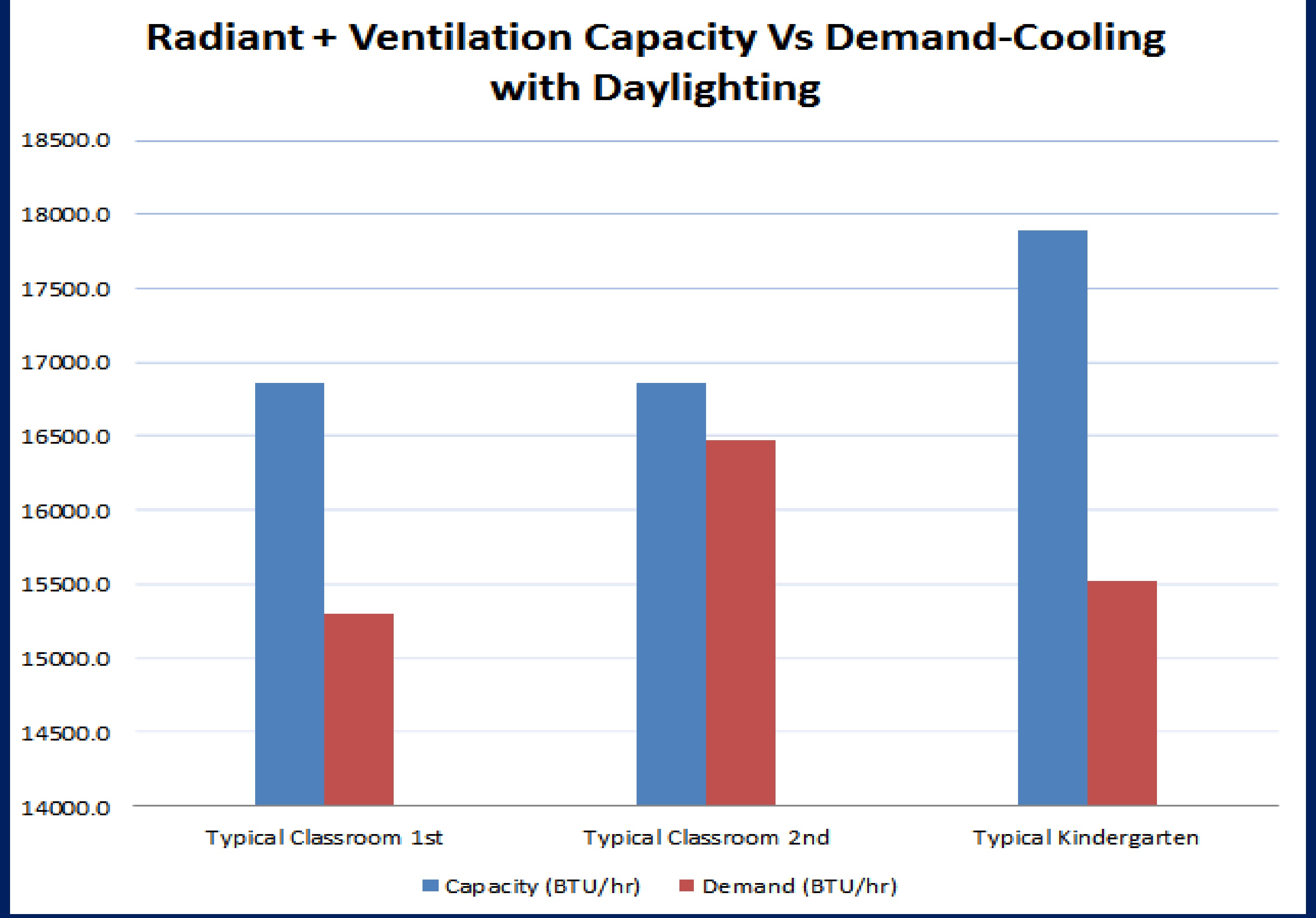
Conditioning Ventilation air will increase the system capacity but will prove to still not be enough.

Radiant Capacity + (1.08 x CFM x ΔT) = Total Capacity



By adding daylighting controls to the building the peak cooling demand is now met.



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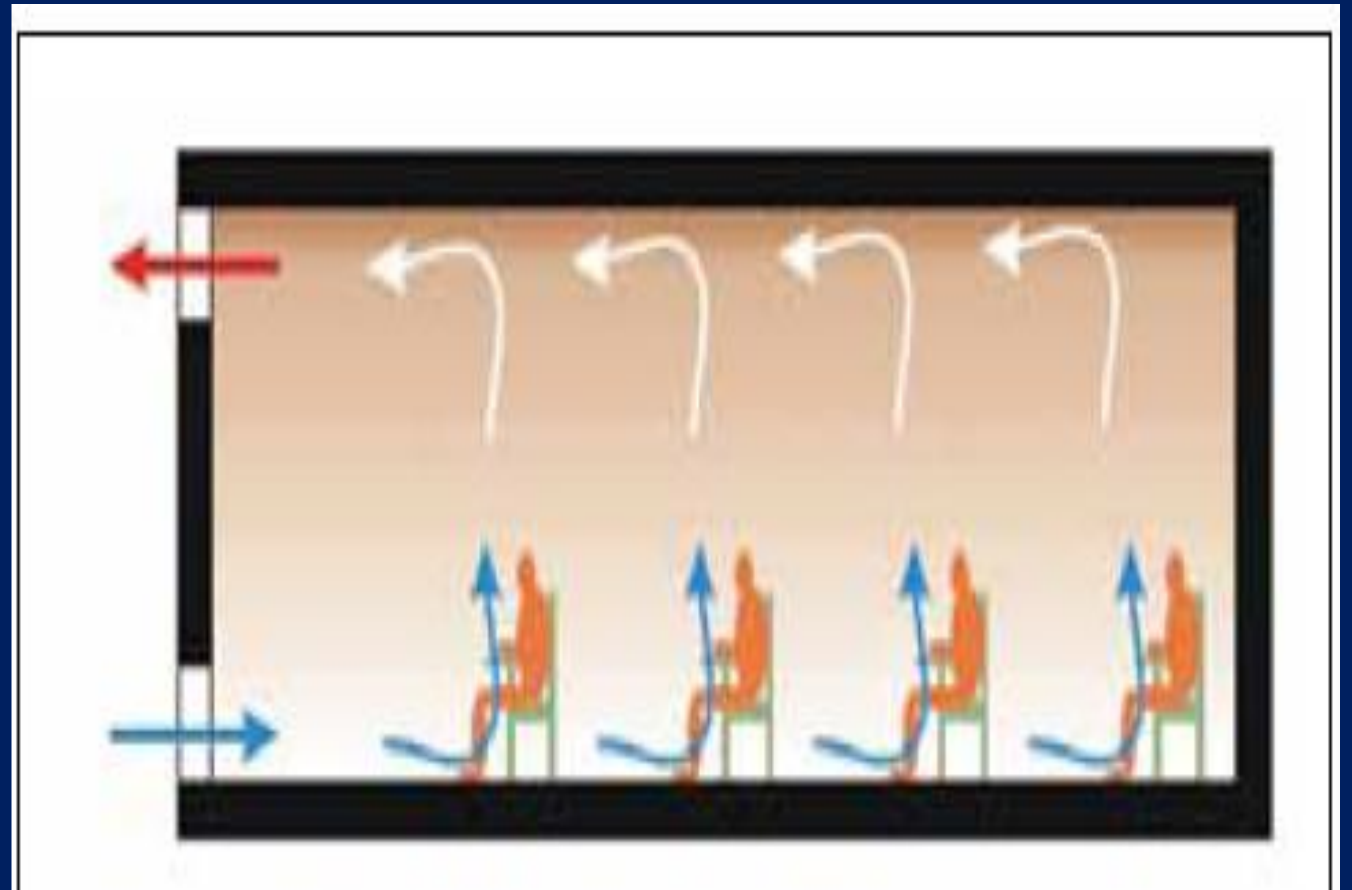
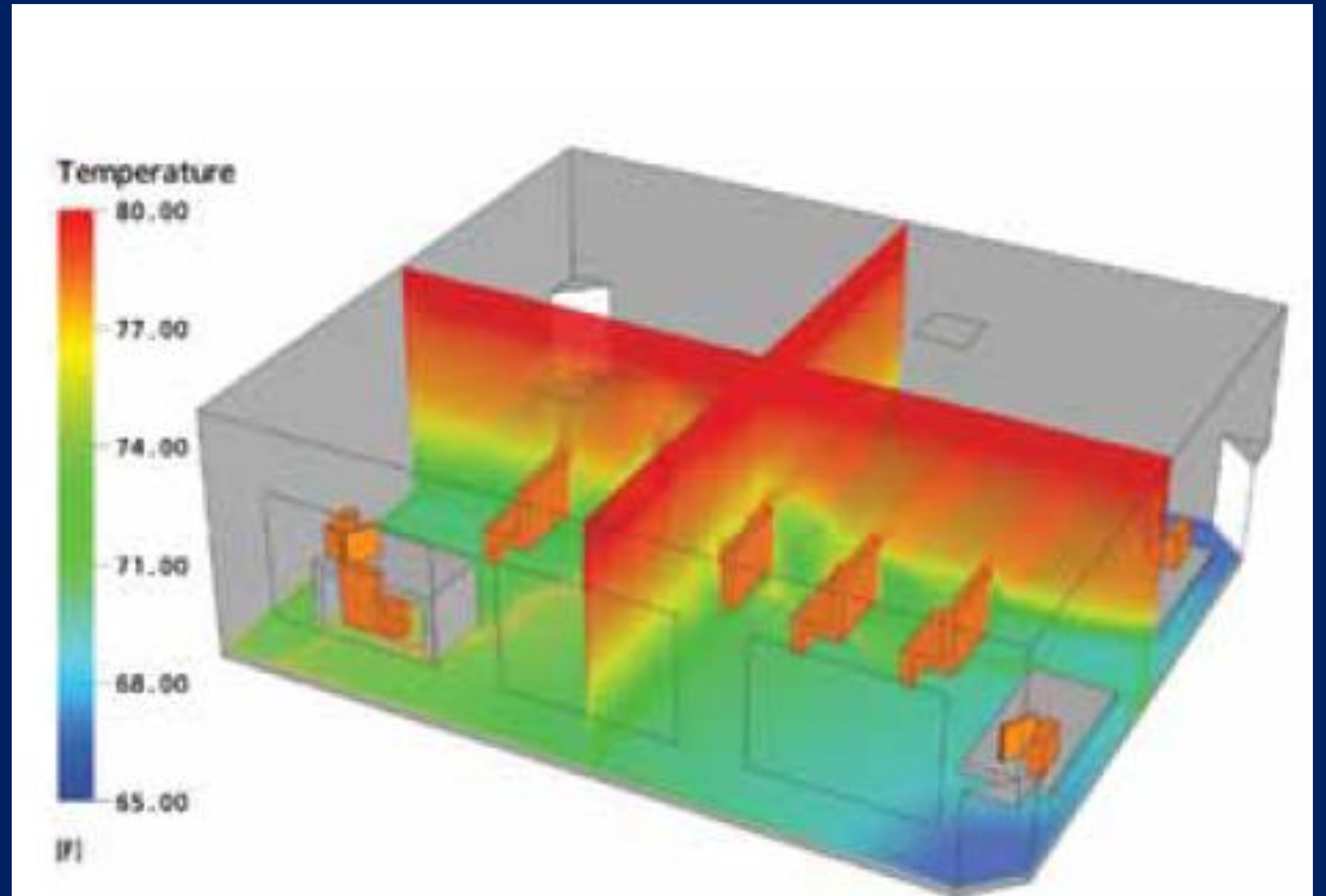
Low Velocity Displacement Ventilation couples well with radiant systems by increasing the stratification of the space.



(Price, 2007)

The combined effect of radiant systems and low velocity displacement ventilation treats the load where the demand is located.



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6. Pros versus Cons

The Air Change Effectiveness (Ez) is increased to 1.2 allowing of 30% increased outdoor air while reducing CFM by 13%.

ASHRAE 62.1 Ventilation Rate Calculations- Design		Classroom	Kindergarten
Ez		0.8	0.8
Az	sf	857	941
Pz	people	21	24
Raz	cfm/sf	0.12	0.12
Rpz	cfm/p	10	10
Vbz	cfm = RpzPz + RazAz =	312.8	352.9
Voz	cfm = Vbz/Ez =	391.1	441.2

Table 37- Original Design Ventilation Rate Calculations

Table 38- Proposed Redesigned Ventilation Rate Calculations

Increased Outdoor Air and contaminant controls greatly improves the indoor environment.

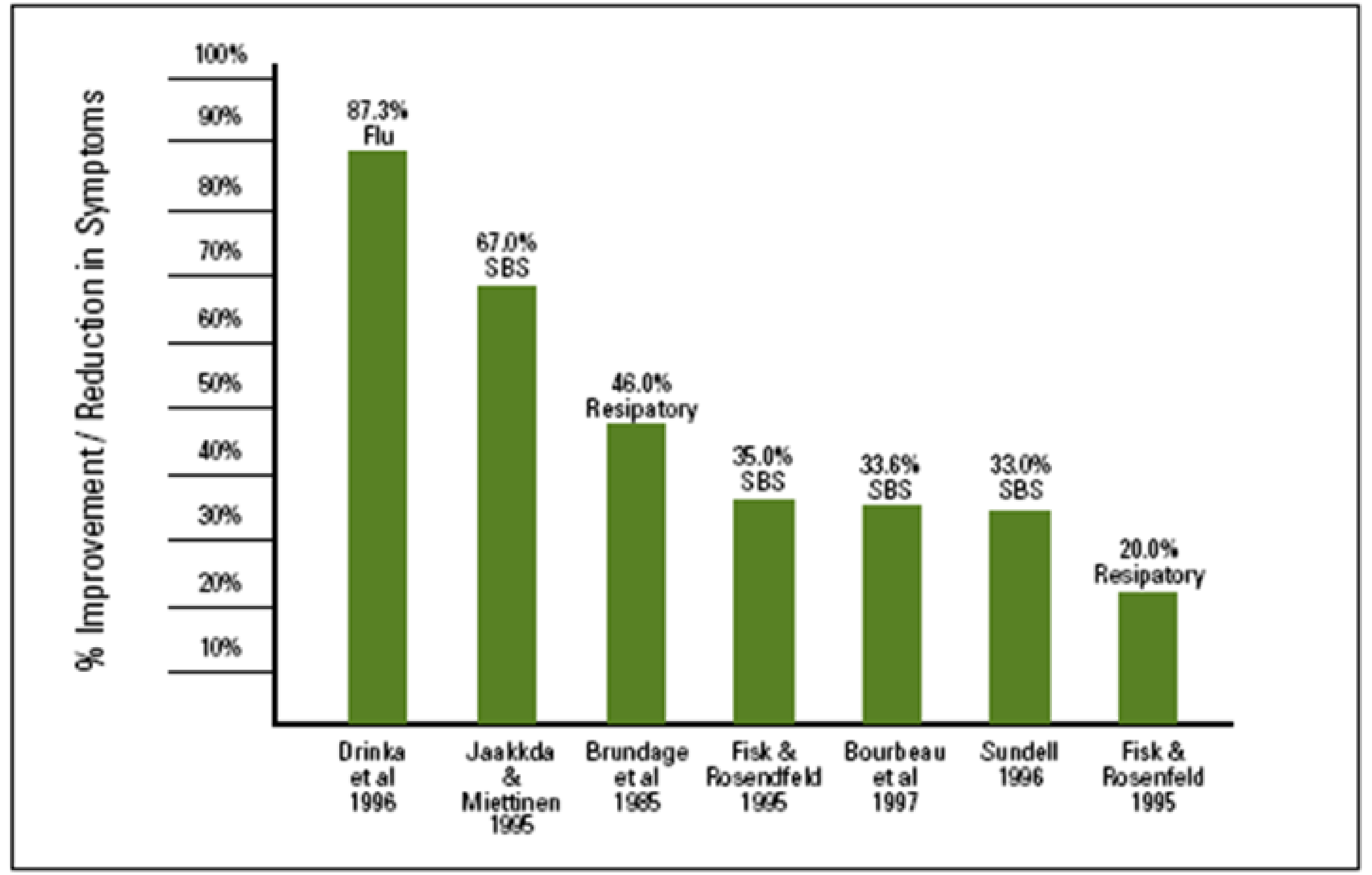

Figure 20- Increased Outdoor Air (Price, 2007)

(Price, 2007)

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Voz	cfm = Vbz/Ez =	**260.7**	**294.1**
	Additional 30%	**338.9**	**382.3**

Table 38- Proposed Redesigned Ventilation Rate Calculations

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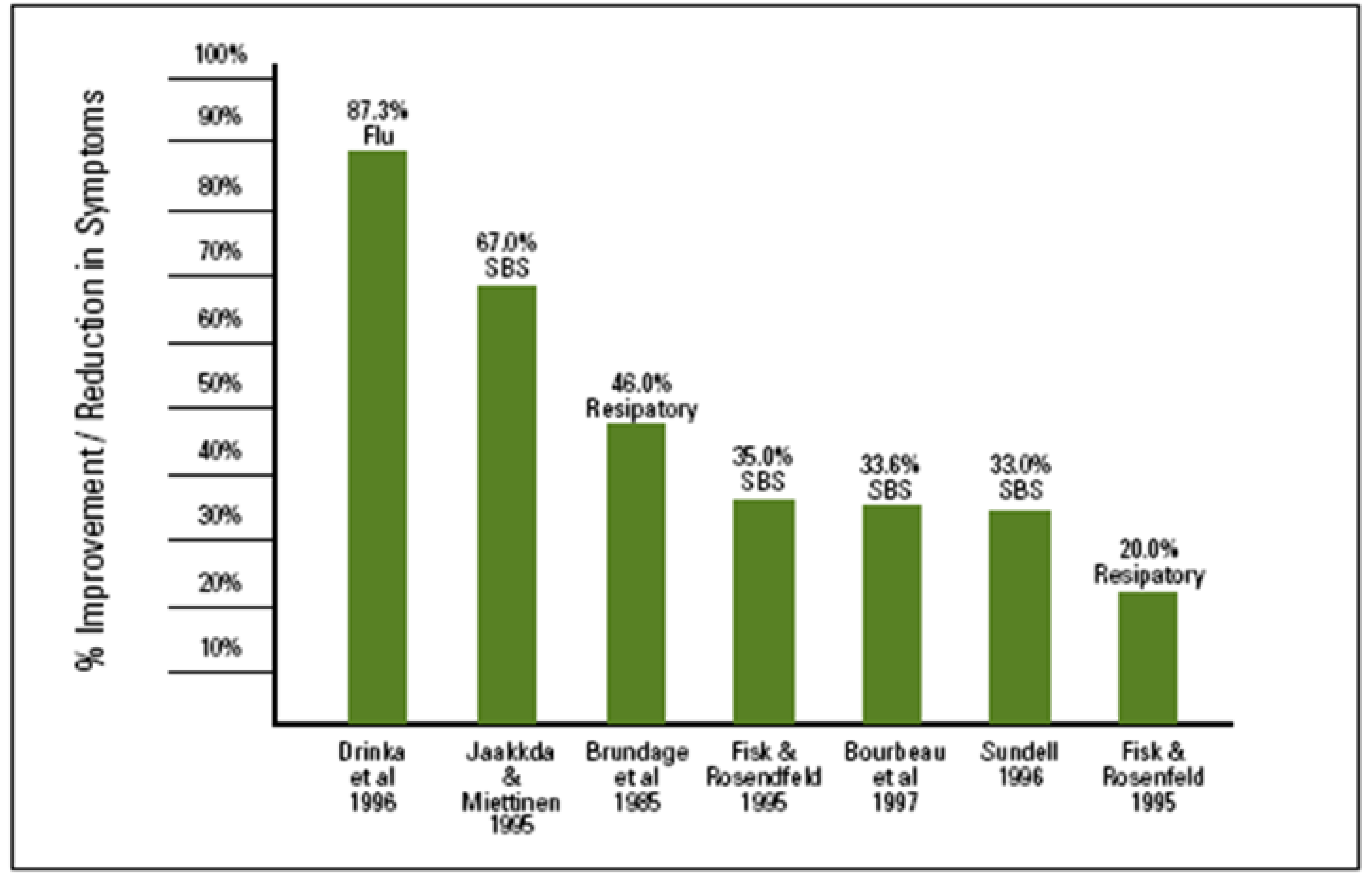

Figure 20- Increased Outdoor Air (Price, 2007)

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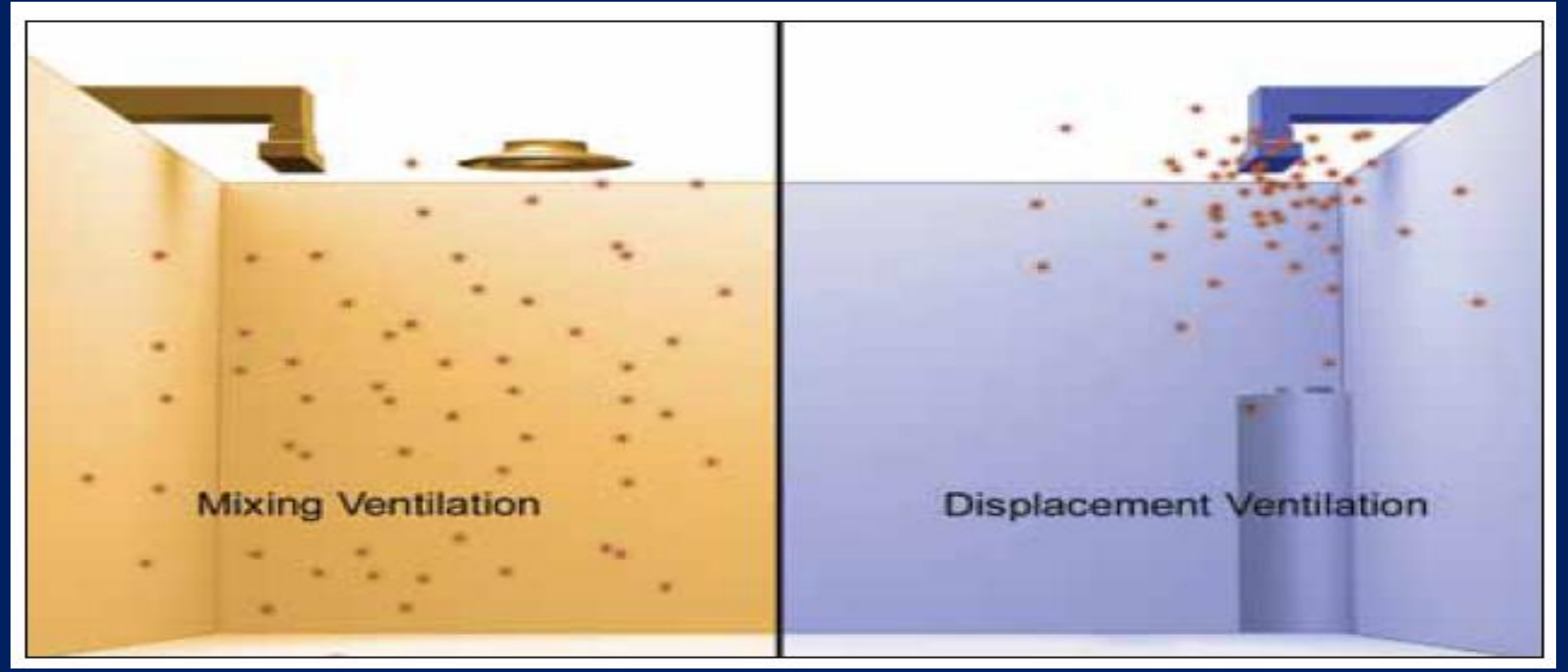

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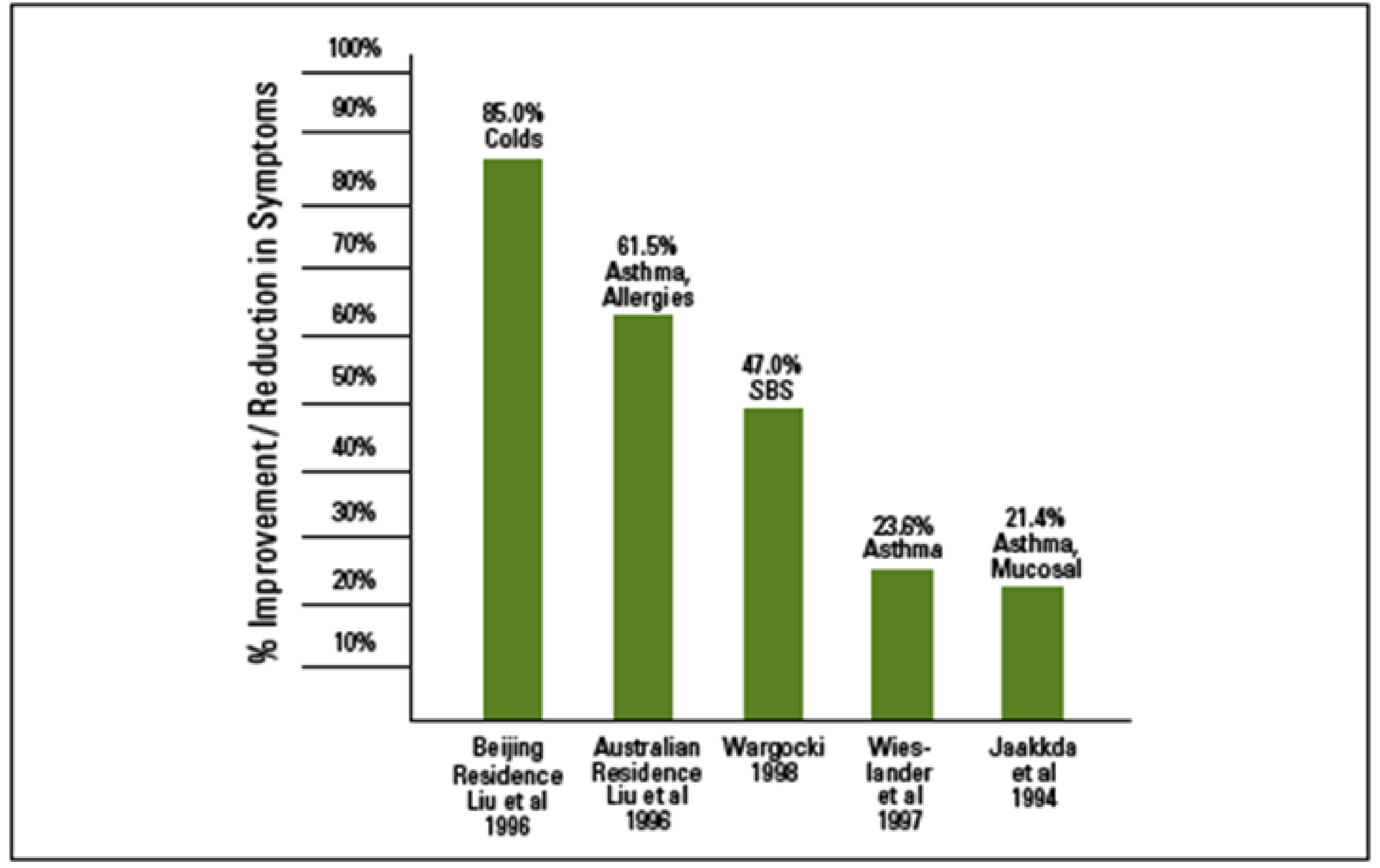

Figure 21- Pollutant Source Controls (Price, 2007)

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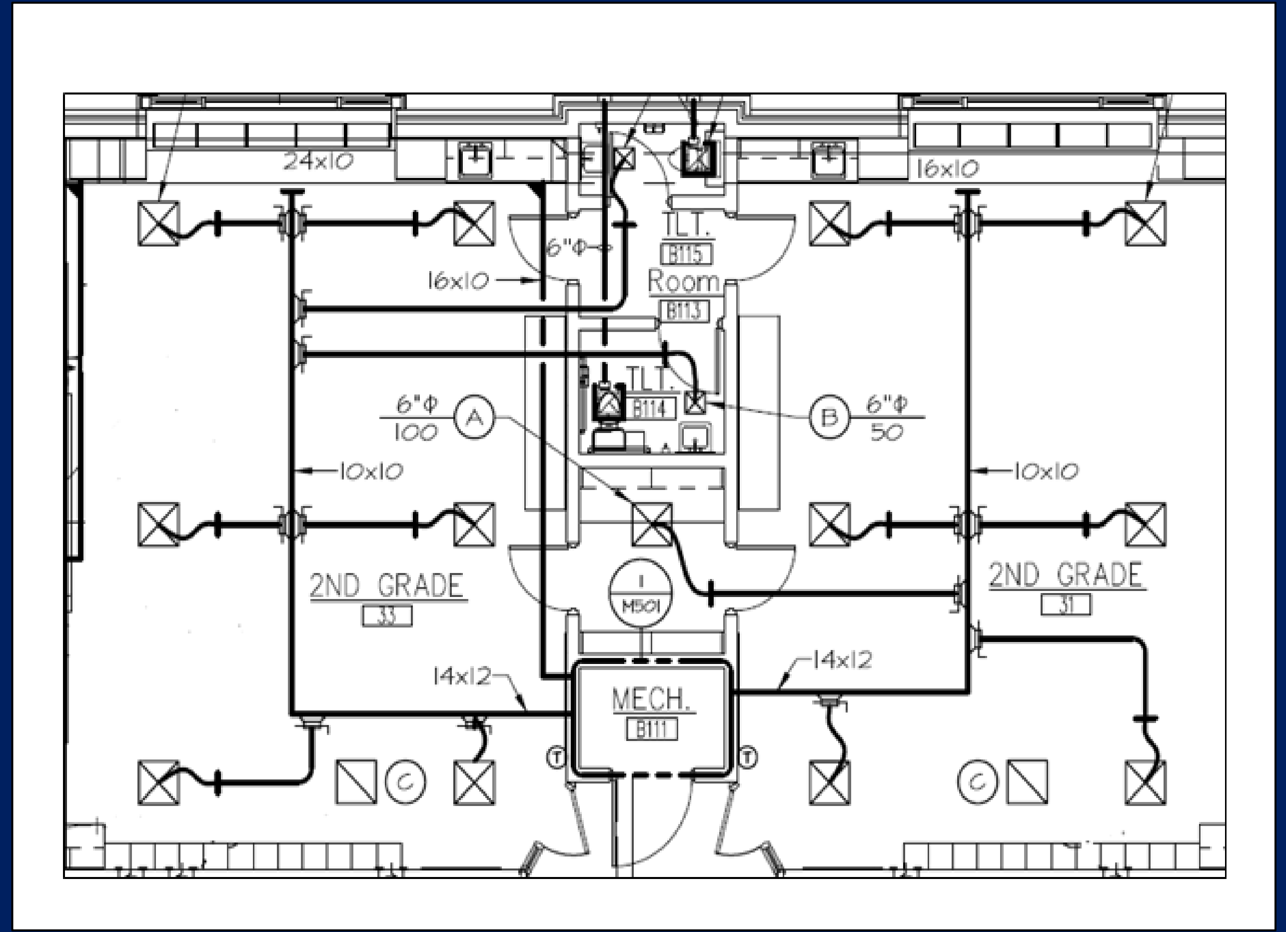
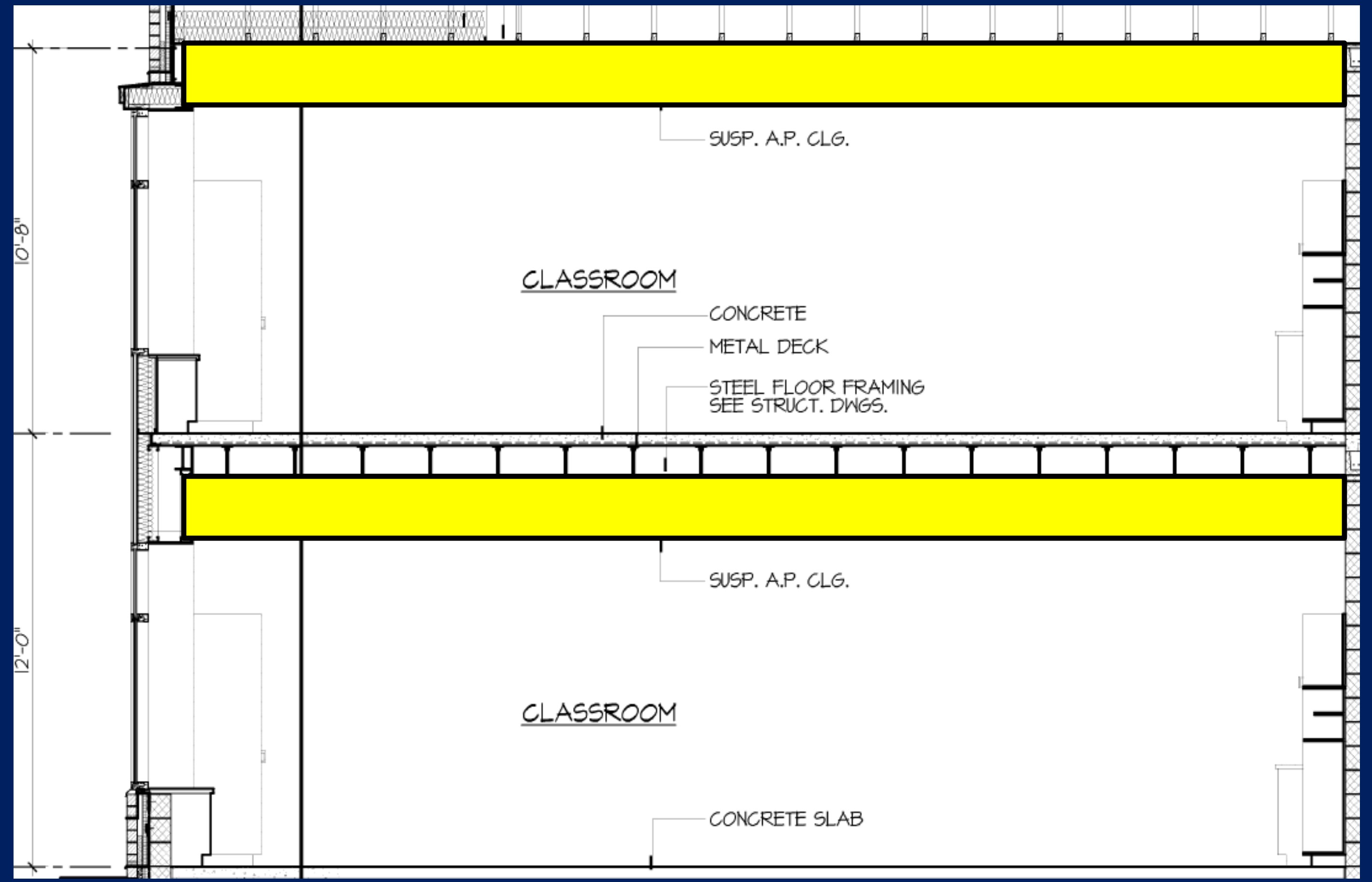
6. Pros versus Cons

Additional benefits are added by reducing needed ductwork to typical classrooms.

Original Ductwork



Without the need for ductwork above the suspended ceiling building height can be lowered by 32”.



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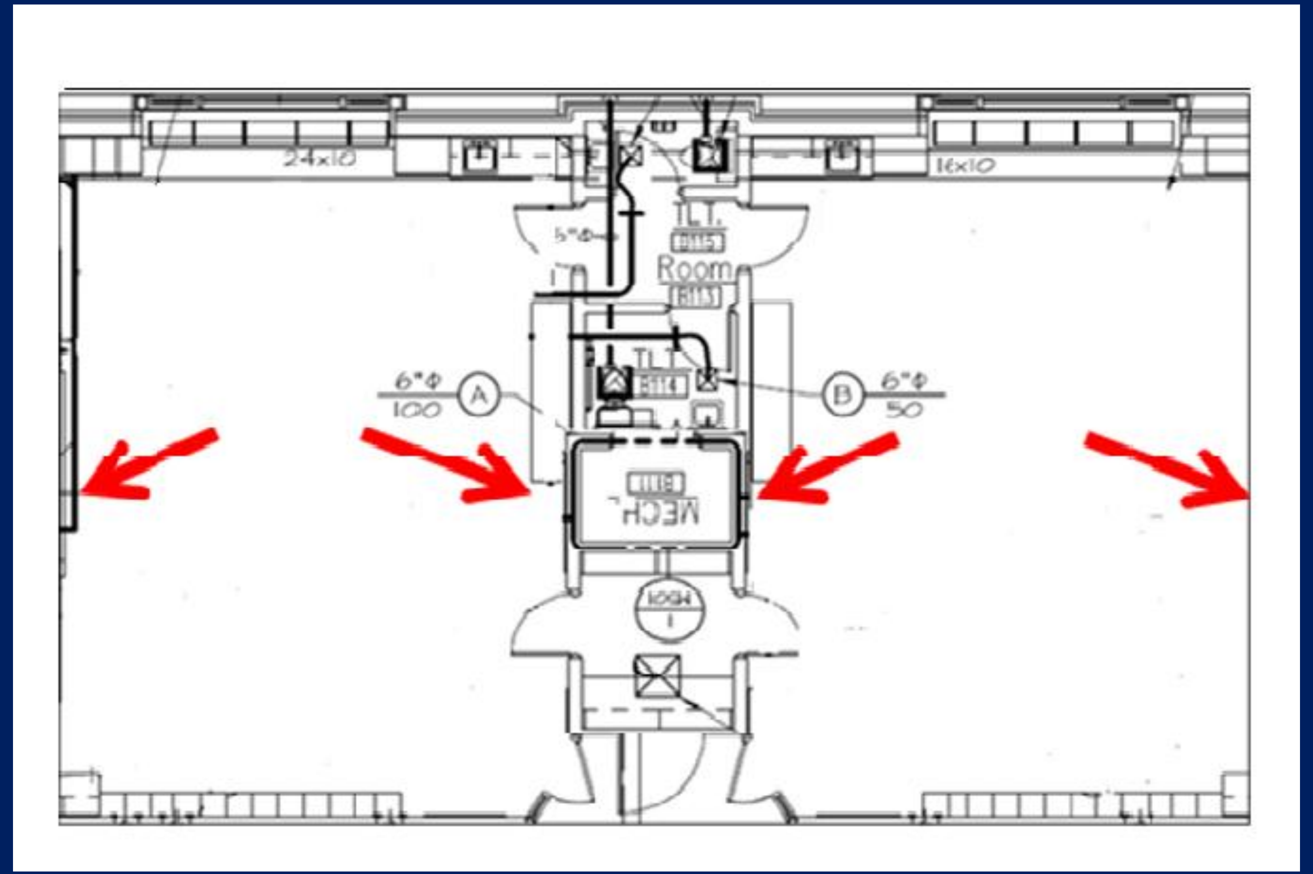
Redesign Ductwork



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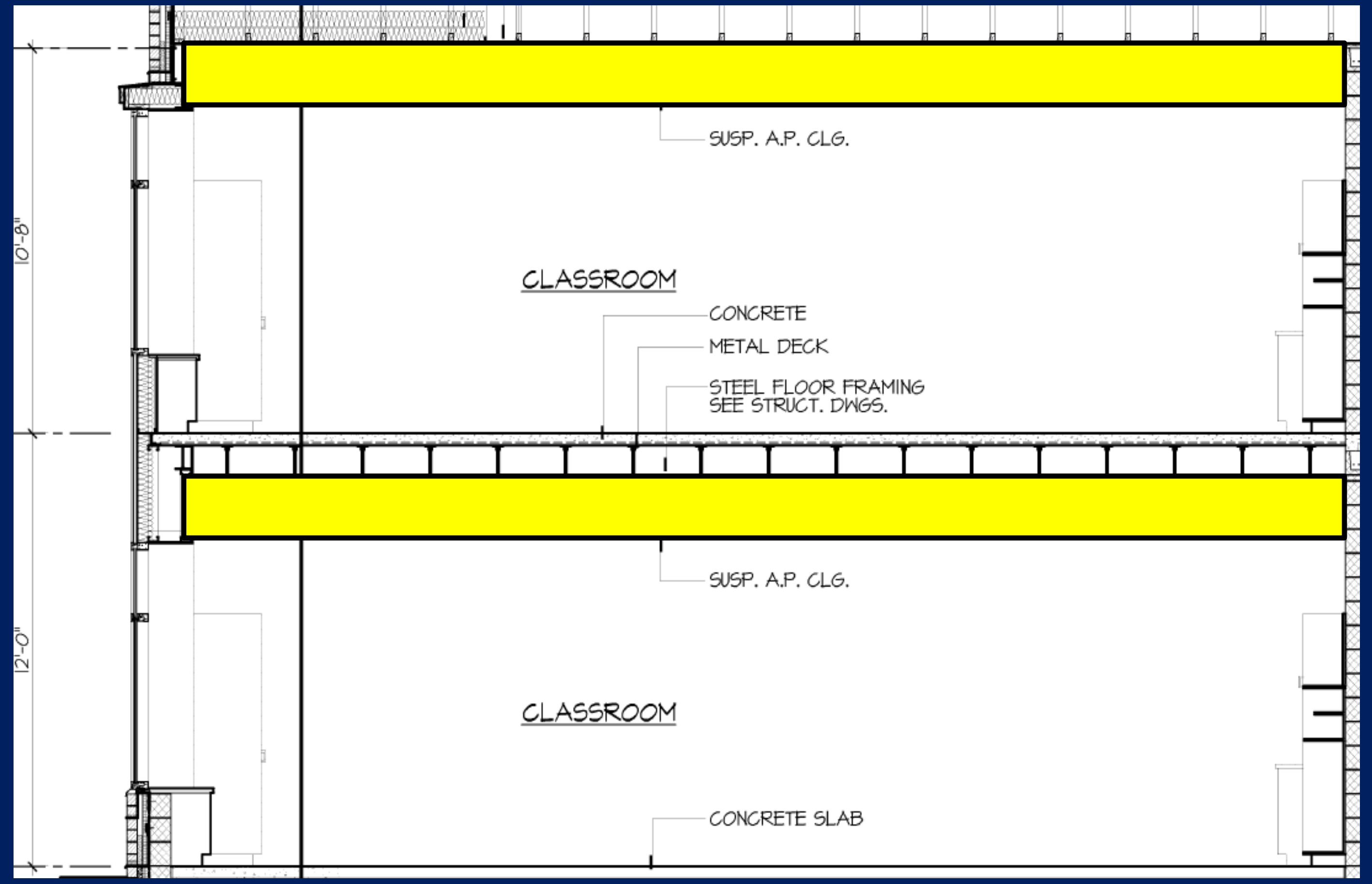

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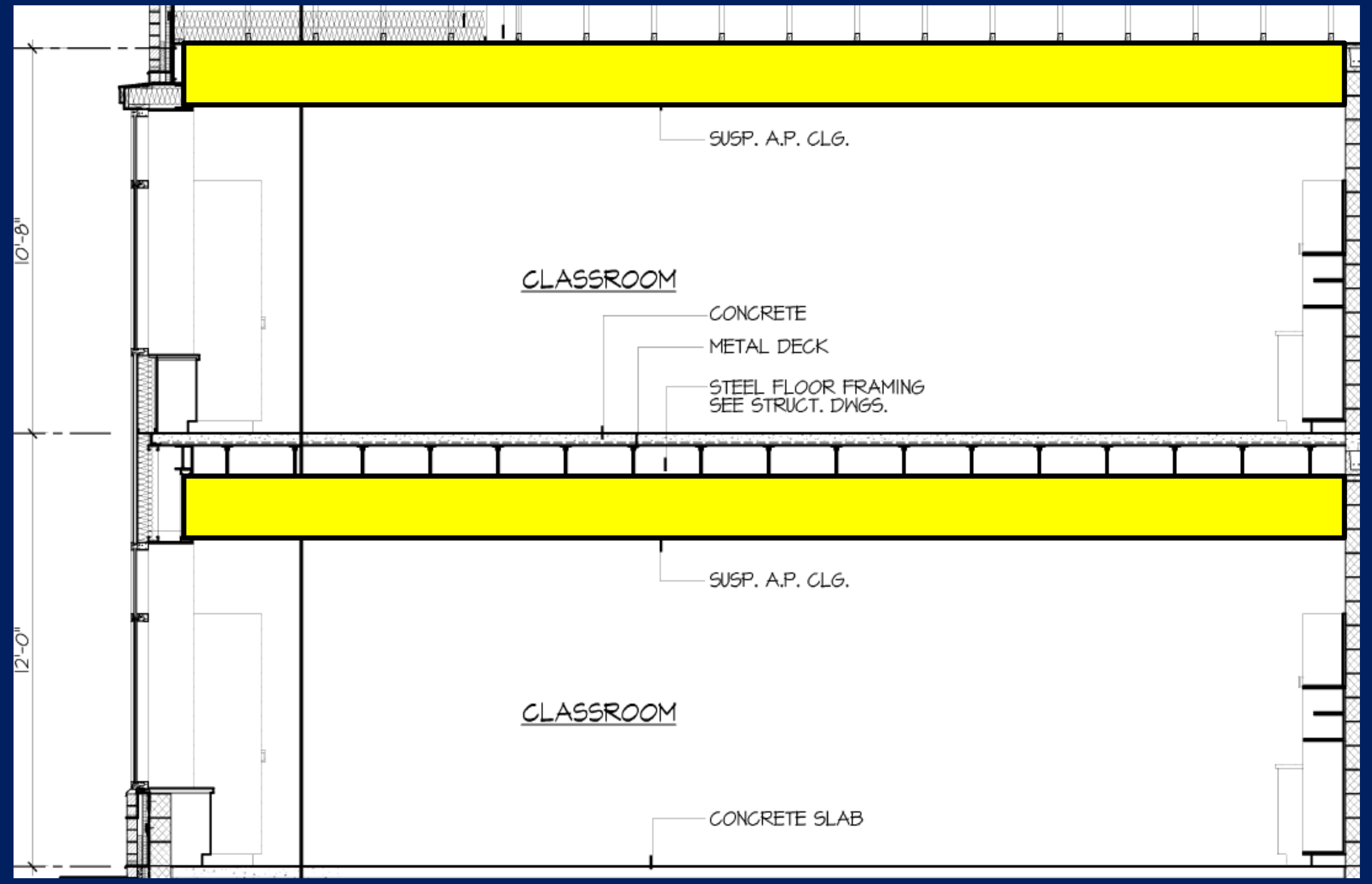
Rectangular Duct Take-off Original Design											
	Description	Unit	Crew	Daily Output	Labor Hours	Bare Materials	Bare Labor	Bare Total	Total O&P	Height % Increase	Total Cost
Typical Classroom	Over 5000 lb.	Lb.	Q10	285	0.084	0.57	3.56	4.13	6.13	0	57965.28
	12"x 8" Duct Fitting	Ea	1 Sheet	20	0.4	21.5	18.1	39.6	52	0	12480.00
	Flex Duct 8"	L.F.	Q9	180	0.089	2.66	3.62	6.28	8.53	0	8188.80
	Diffusers 24"x24"	Ea	1 Sheet	7	1.143	256	52	308	361	0	86640.00
Total Savings											165,274

Table 43- Typical Classroom Ductwork Takeoff

Without the need for ductwork above the suspended ceiling building height can be lowered by 32".



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Wall Assemblies Take-off					
Description	Unit	Material	Installation	Total	Total Savings
Brick Cavity Wall Insulated Backup- 12" CMU	S.F.	11	20.35	31.35	37,500
* Cost Extrapolated from R. S. Means Wall Assemblies					

Table 48- R. S. Means Wall Assembly Take-off

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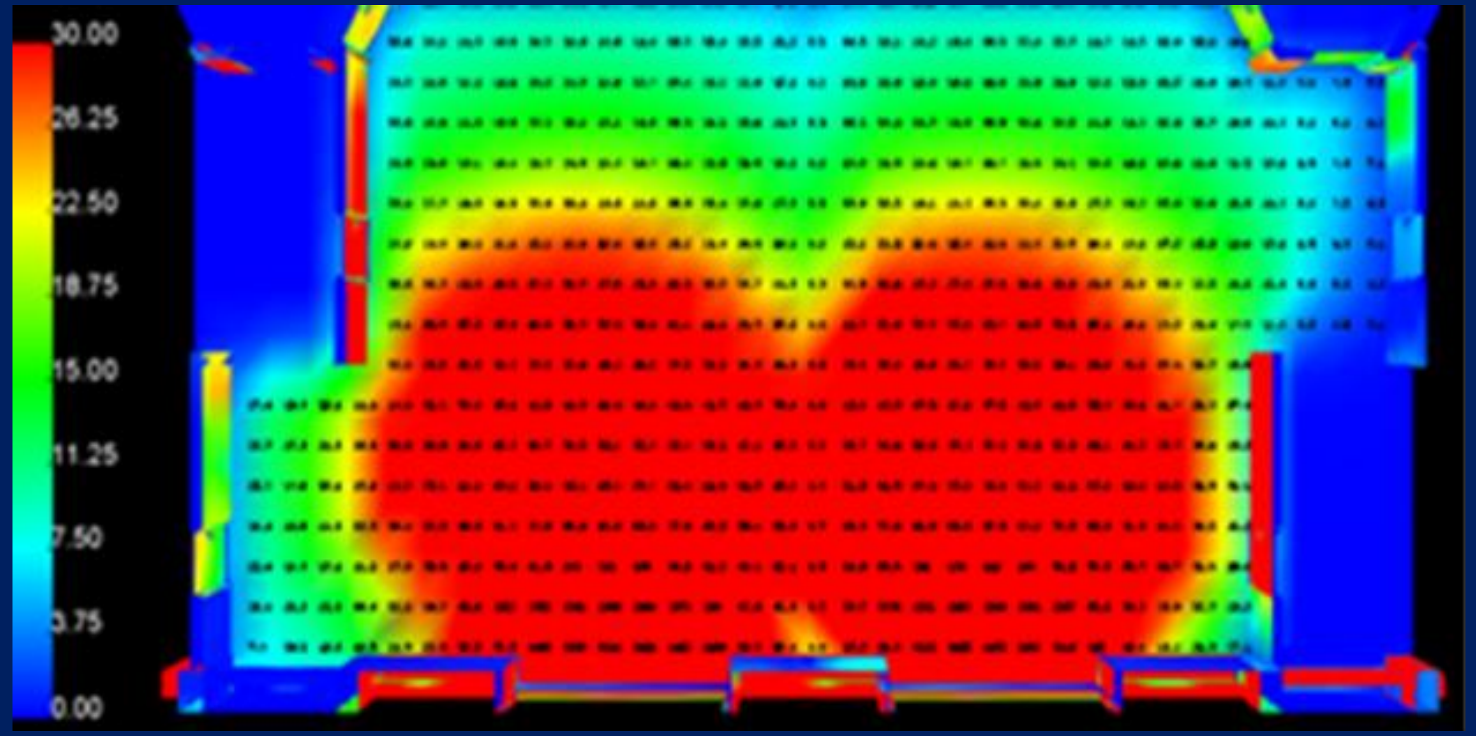
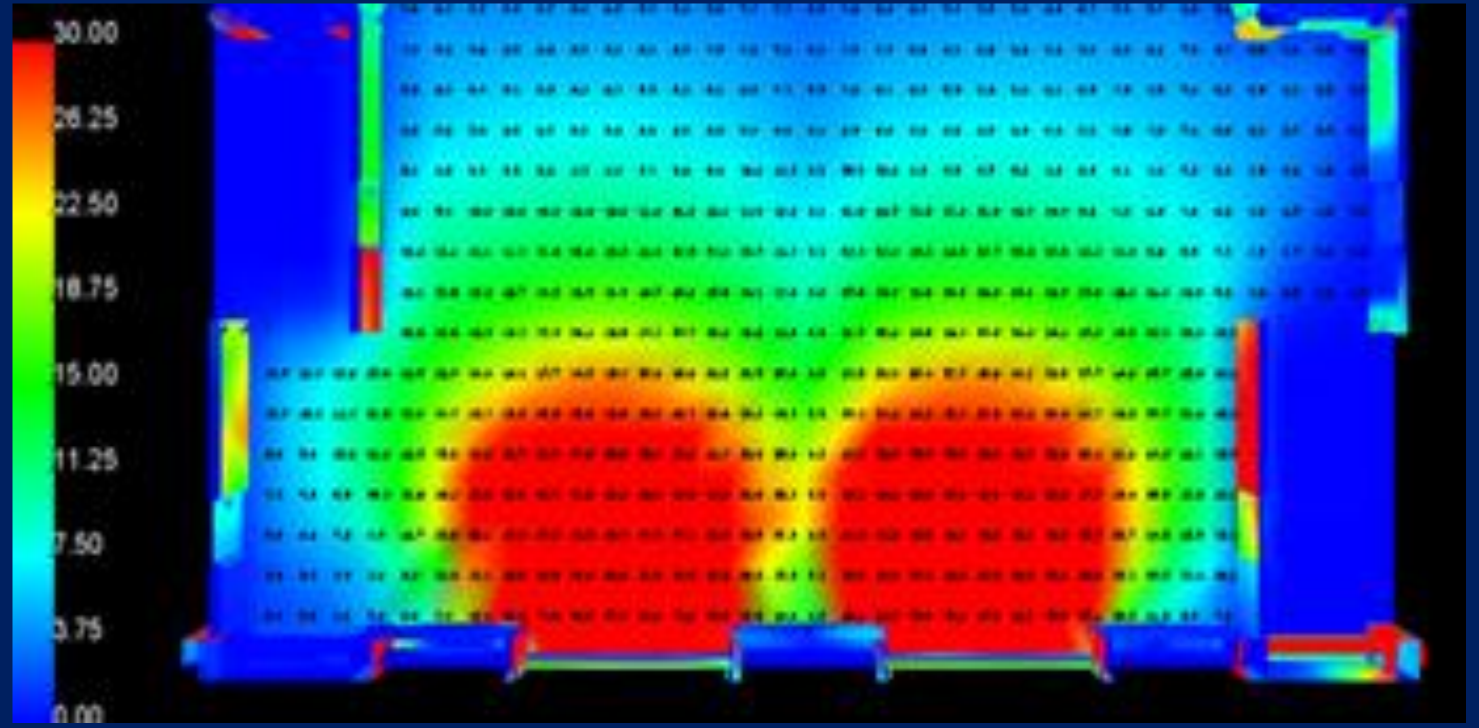
IESNA Lighting Design Guide the task of using a #2 pencil and softer leads is a performance of high contrast and large size.

Typical 1st Classroom South Sept. 21 at 12pm



The North facing classrooms receive less daylight then the South facing classrooms but still have dimming potential.

Typical 1st Classroom North Sept. 21 at 12pm



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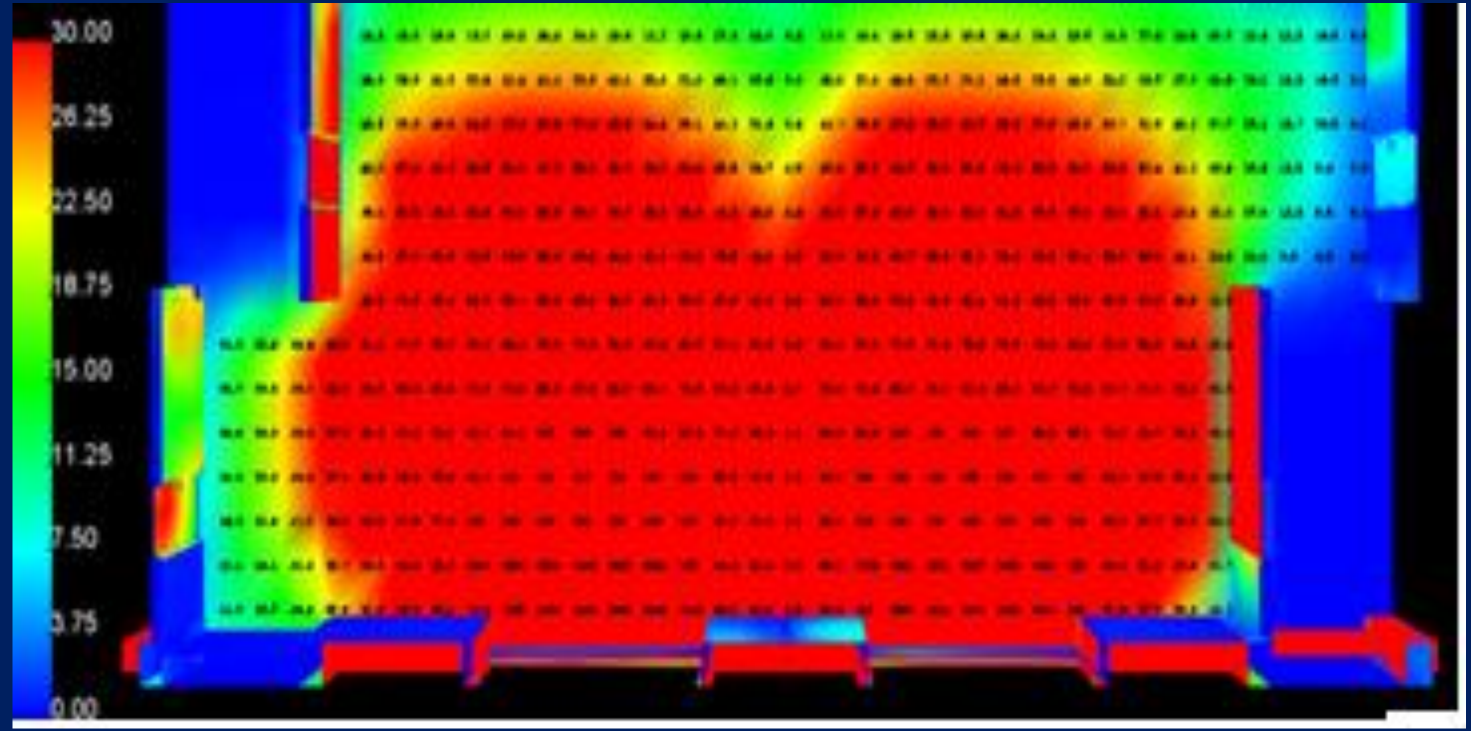
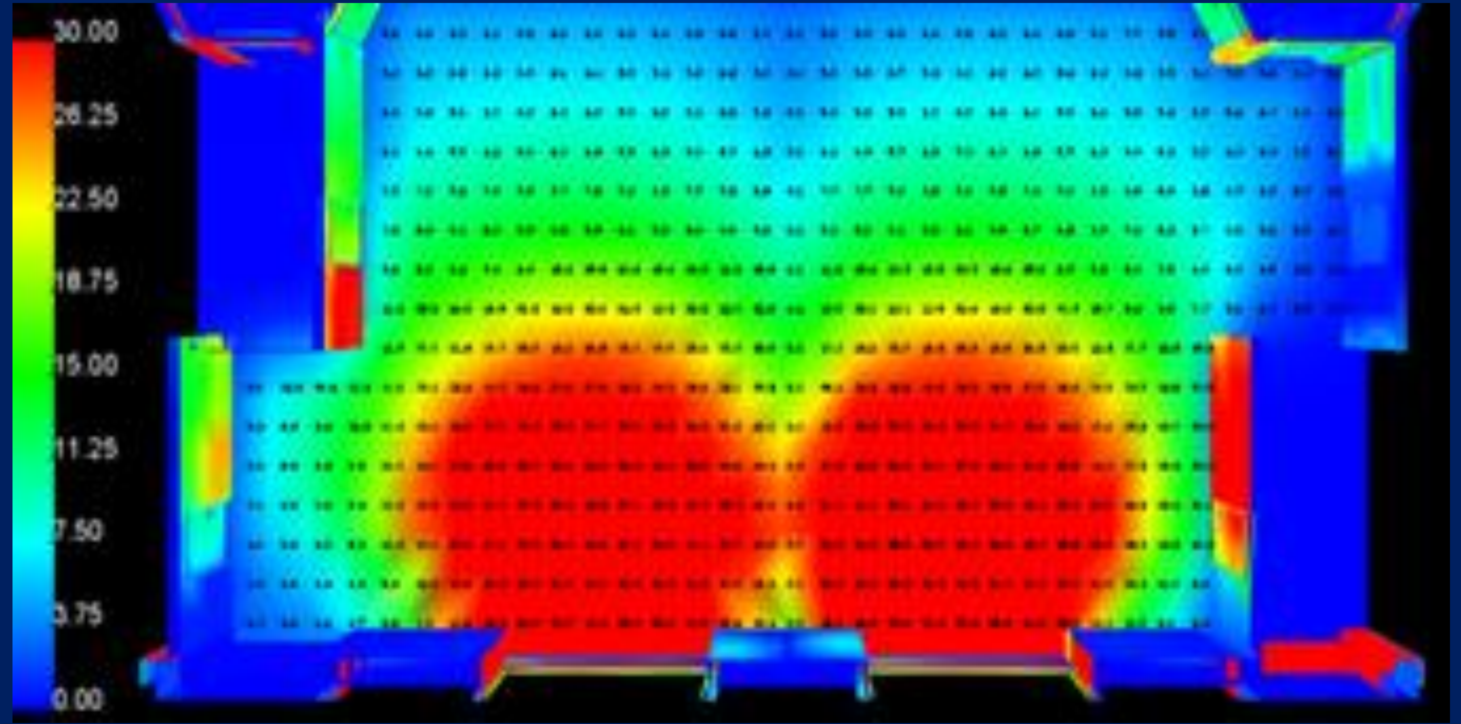
Typical 2nd Classroom South Sept. 21 at 12pm



The North facing classrooms receive less daylight then the South facing classrooms but still have dimming potential.

Typical 2ndClassroom North Sept. 21 at 12pm



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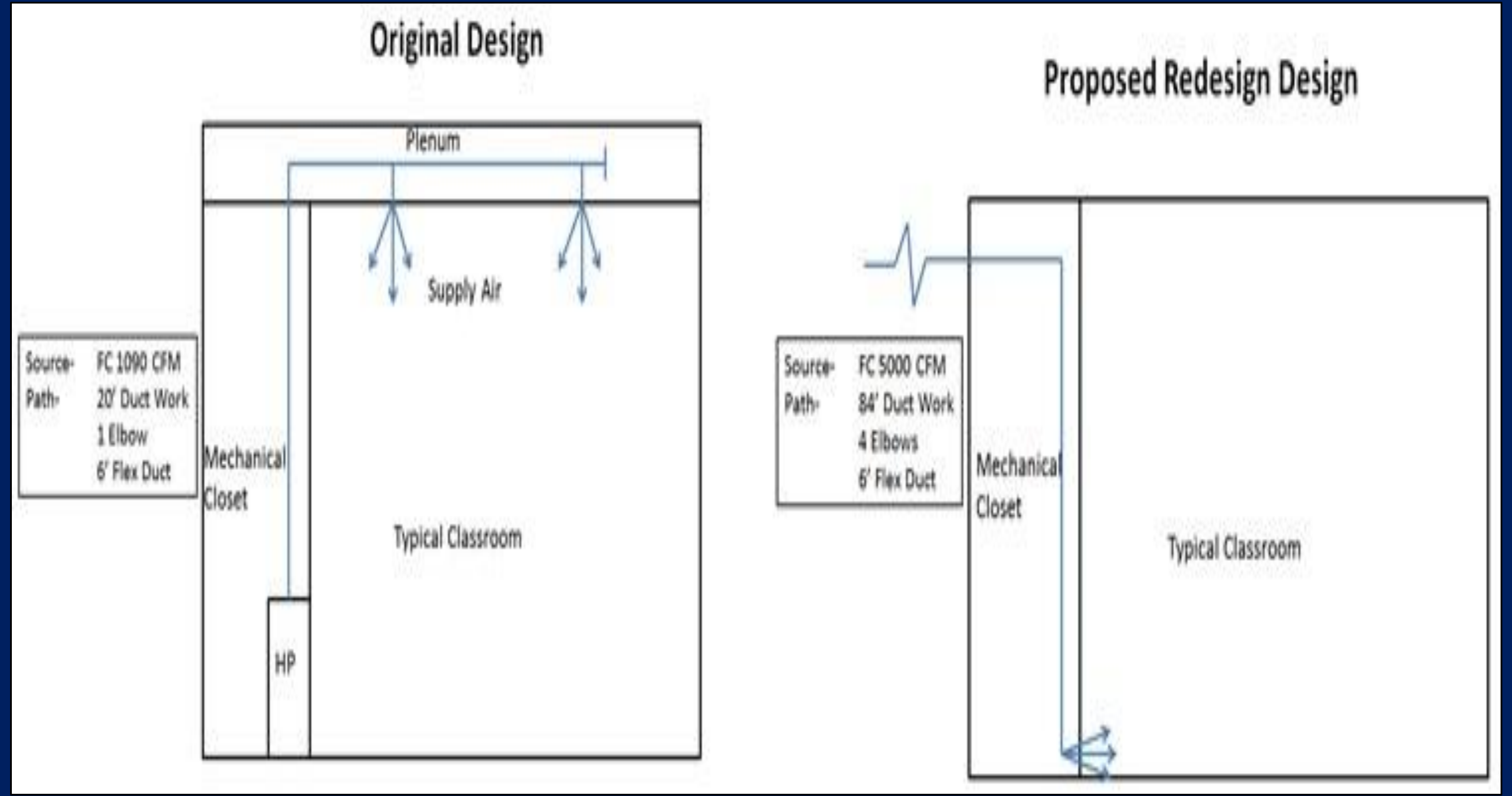
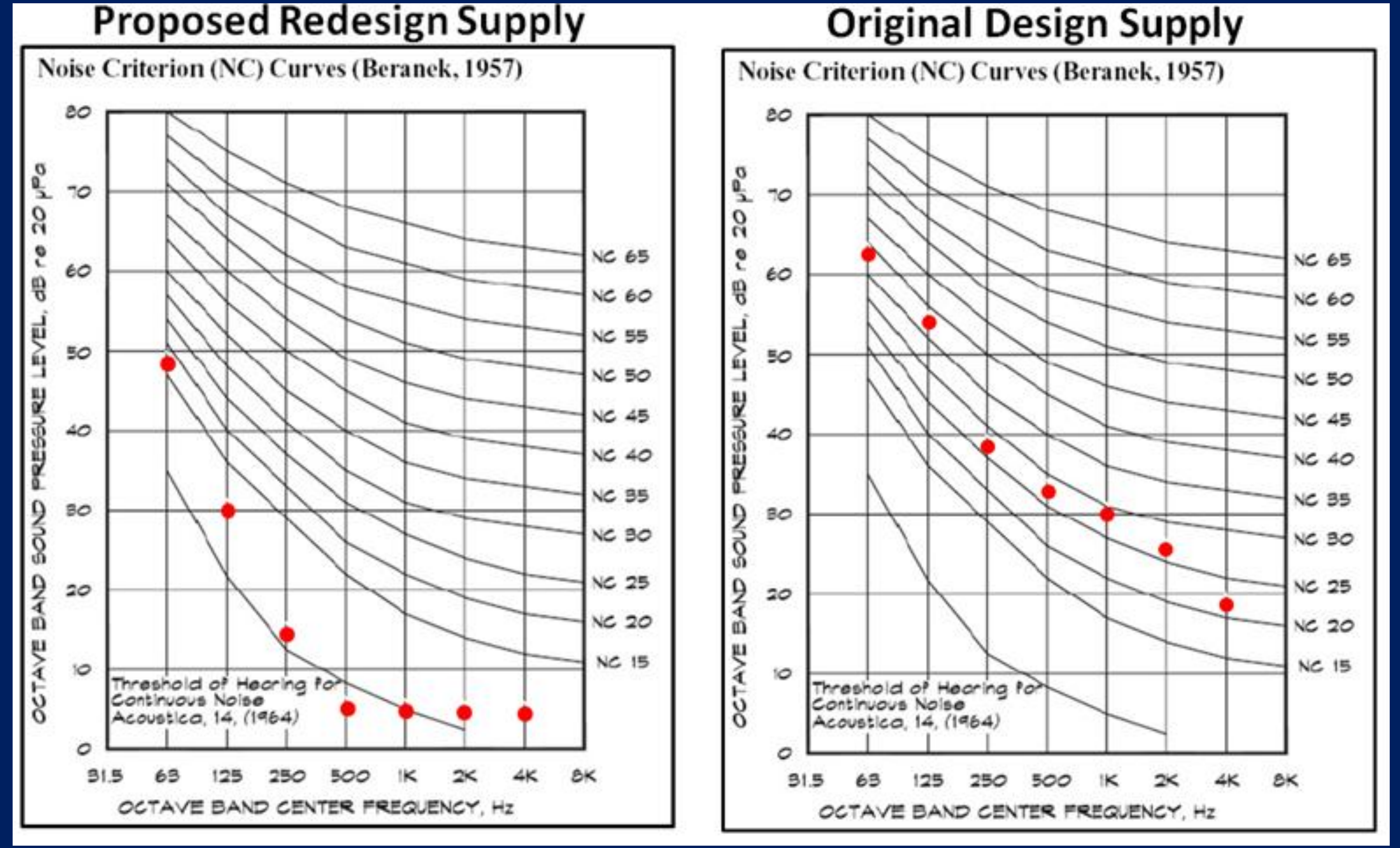
The redesign of the ventilation system changed the noise criteria rating of the air supply to the classrooms.



The noise criteria is reduced from a NC-39 to a NC-19 due to more attenuation within the duct work.



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Using RS Means a cost comparison was calculated for all changes made to original design.

Overall Cost Comparison Of Changes		
Item	Original	Redesign
Ductwork & Diffusers	$ 170,500	$ 30,000
Wall Assembly	$ 37,500	
Water-to-Water HP		$ 97,500
Water-to-Air HP	$ 106,000	$ 24,600
Gym AHU	$ 30,800	$ 8,200
Pex Tubing		$ 271,000
Daylighting Sensors		$ 8,760
Total Cost	$ 344,800	$ 440,060

Table 54- Overall Cost Comparison of Original to Redesign Changes

Overall the redesign was a 5% increase when compared to the initial cost.

Total MEP System Cost		
	Cost	Cost/ft²
Original	$ 1,979,200	$ 19.22
Redesign	$ 2,074,400	$ 20.14
% Difference	5%	5%

Table 55- Total MEP Cost Impact

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   2. Life-Cycle Cost Analysis
6. Pros versus Cons

Annual Energy Savings of the proposed redesign compared to the original design were calculated.

Trace® Pumping Energy Comparison			
	Proposed (kWh)	Original (kWh)	Difference (%)
CLG-HTG Plant 001-WSHP	181861	246999	26.4
CVCWP (MISC EQUIP)	10859	10656.8	-1.9
Plant Geothermal Pump	1352414	1352414	0.0
Pump Totals	**1545134**	**1610070**	**4.0**

Table 23: Trace Comparison of Pumping Energy

The savings in electric were then calculated using the electrical rates supplied by the designer.

eQuest® % Electrical Difference Overall Applied			
	Proposed (kWh)	Original (kWh)	Difference (%)
Overall Total	2262959	2409400	**6.1**

Table 26- eQuest® Overall Electrical Difference

Cost Impact of Energy Reduction			
	Proposed ($)	Original ($)	Annual Savings
Penelec Annual Bill	109416	116524	**7100**

Table 27- Electrical Reduction of Proposed System

Presentation Outline

1. Project Overview
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3. Depth
   1. Radiant Heating and Cooling
   2. Low Velocity Displacement Ventilation
4. Breadths
   1. Daylighting
   2. Acoustics
5. Overall Cost
   1. **Initial Difference**
   2. Life-Cycle Cost Analysis
6. Pros versus Cons

Annual Energy Savings of the proposed redesign compared to the original design were calculated.

Trace® Fan Energy Comparison			
	Proposed (kWh)	Original (kWh)	Difference (%)
Main Clg Fan	55623	135895	59.1
Main return fan	131477	273307	51.9
DOAS Fan	109193	109193	0.0
Fan Totals	**296293**	**518395**	**42.8**

Table 24: Trace Comparison of Fan Energy

The savings in electric were then calculated using the electrical rates supplied by the designer.

eQuest® % Electrical Difference Overall Applied			
	Proposed (kWh)	Original (kWh)	Difference (%)
Overall Total	2262959	2409400	**6.1**

Table 26- eQuest® Overall Electrical Difference

Cost Impact of Energy Reduction			
	Proposed ($)	Original ($)	Annual Savings
Penelec Annual Bill	109416	116524	**7100**

Table 27- Electrical Reduction of Proposed System

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6. Pros versus Cons

Annual Energy Savings of the proposed redesign compared to the original design were calculated.

Monthly Lighting Electrical Load													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Proposed	49.3	41.1	44.8	47	47.7	54.9	60.2	58.2	43.8	44.6	47.1	48.8	587.4
Original	53.3	45.5	50.4	53.4	54.7	63.6	69.6	66.7	50	50.4	51.5	53.3	662.6
% Saving	7.5	9.7	11.1	12.0	12.8	13.7	13.5	12.7	12.4	11.5	8.5	8.4	11.3%

Table 57- Lighting Load Comparison Table

The savings in electric were then calculated using the electrical rates supplied by the designer.

eQuest® % Electrical Difference Overall Applied			
	Proposed (kWh)	Original (kWh)	Difference (%)
Overall Total	2262959	2409400	6.1

Table 26- eQuest® Overall Electrical Difference

Cost Impact of Energy Reduction			
	Proposed ($)	Original ($)	Annual Savings
Penelec Annual Bill	109416	116524	7100

Table 27- Electrical Reduction of Proposed System

Presentation Outline

1. Project Overview
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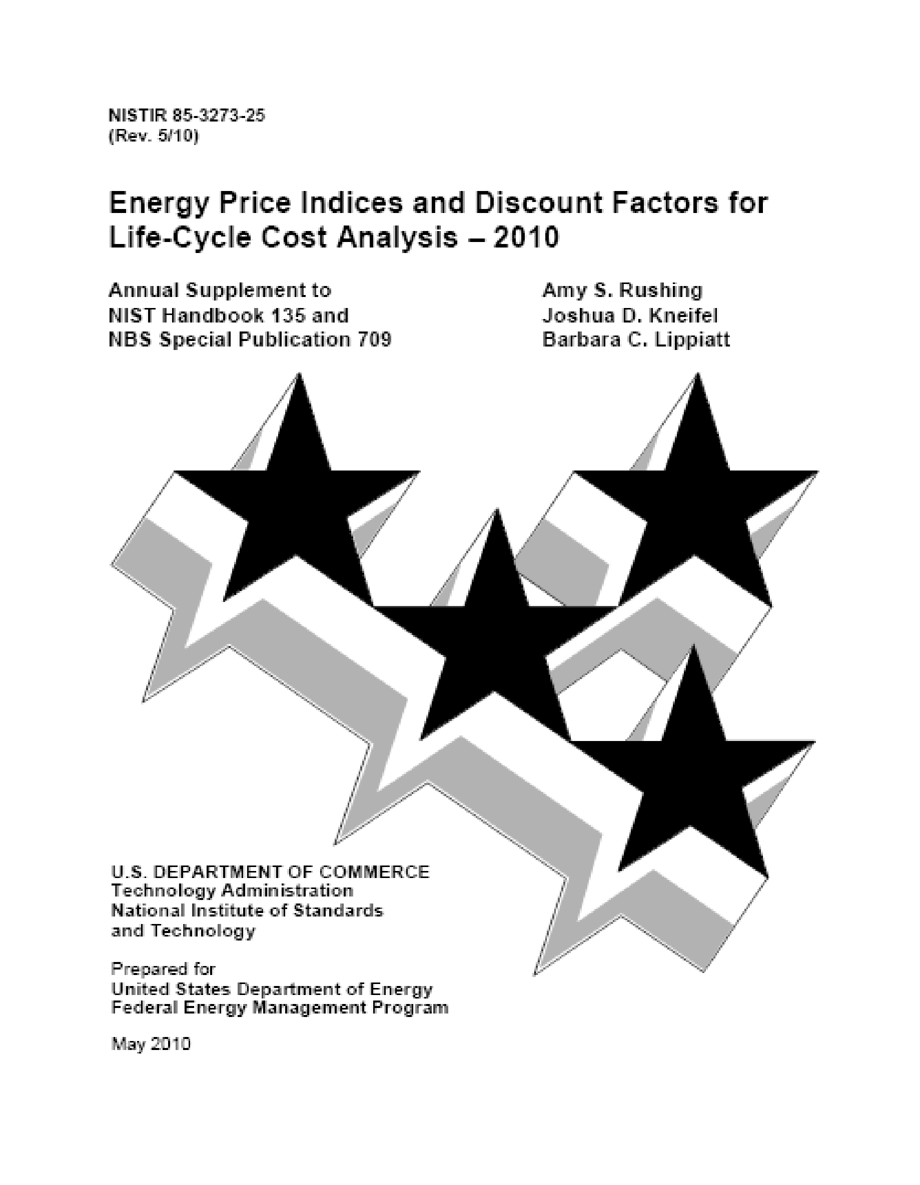
5. Overall Cost
    1. Initial Difference
    2. **Life-Cycle Cost Analysis**
6. Pros Versus Cons

A Life-Cycle Cost Analysis was performed for the annual energy savings versus initial cost.



NISTIR 85-3273-25
(Rev. 5/10)

Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis – 2010

Annual Supplement to
NIST Handbook 135 and
NBS Special Publication 709

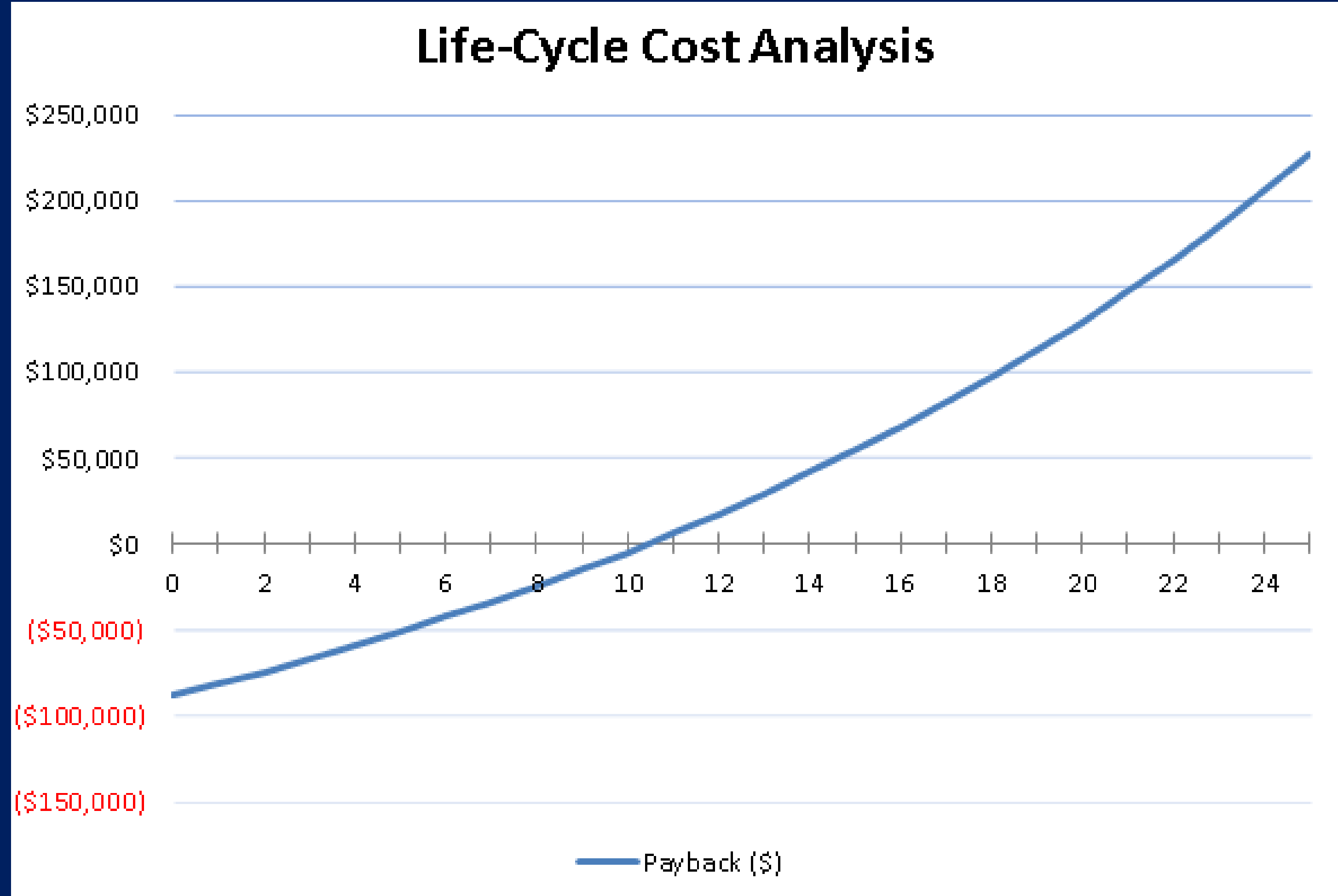
Amy S. Rushing
Joshua D. Kneifel
Barbara C. Lippiatt

U.S. DEPARTMENT OF COMMERCE
Technology Administration
National Institute of Standards
and Technology

Prepared for
United States Department of Energy
Federal Energy Management Program

May 2010

The Analysis showed a payback period of 10.5 years for the changes to the original design.



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    2. **Life-Cycle Cost Analysis**
6. Pros Versus Cons

A Life-Cycle Cost Analysis was performed for the annual energy savings versus initial cost.

Table S-1, continued. Projected fuel price indices with assumed general price inflation rates of 2 %, 3 %, 4 %, and 5 %, by end-use sector and fuel type.

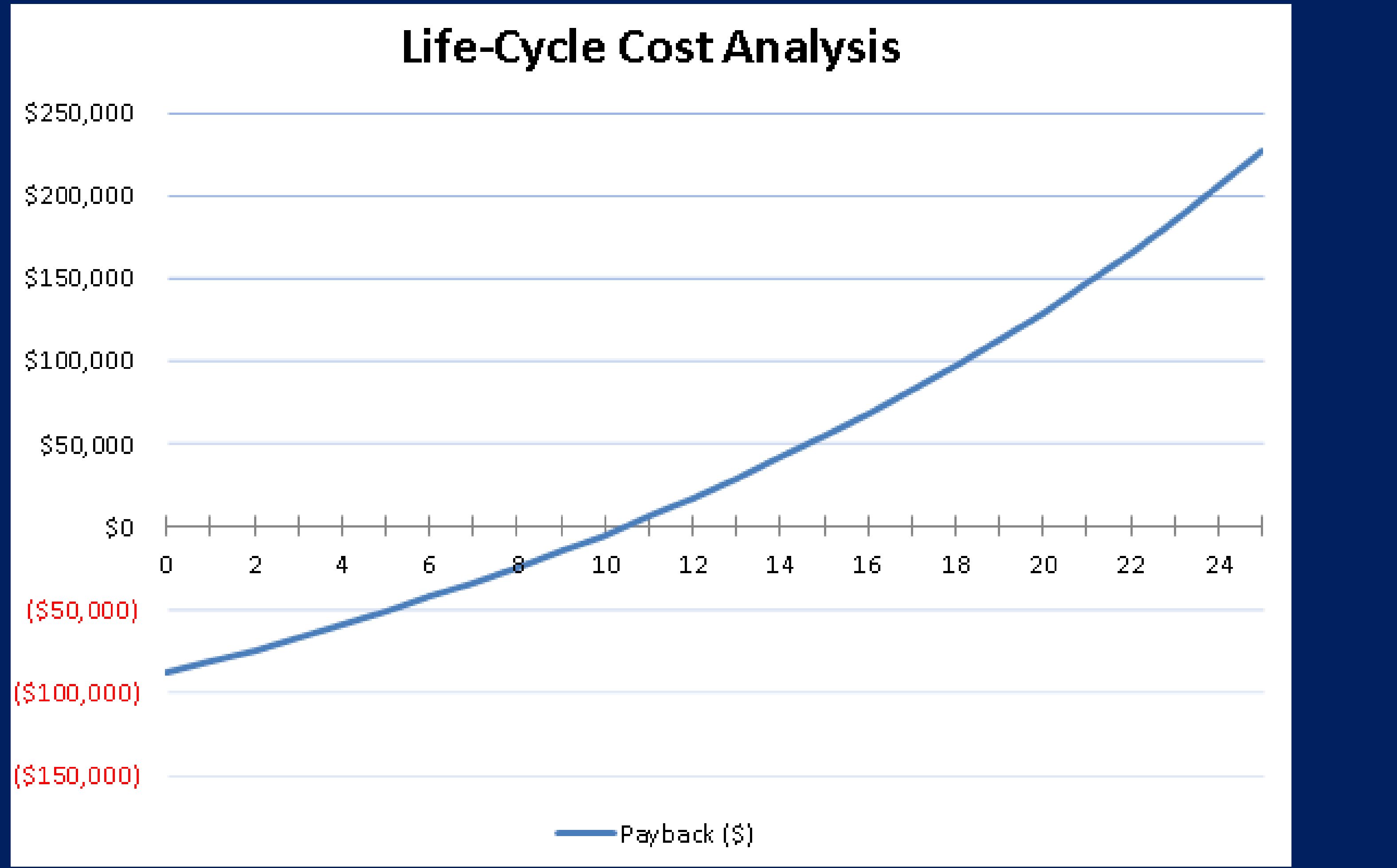
Census Region 1 (Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont)

Projected April 1 Fuel Price Indices (April 1, 2010 = 1.00)

COMMERCIAL

	Electricity				Distillate Oil				Residual Oil				Natural Gas				Coal			
	Inflation Rate				Inflation Rate				Inflation Rate				Inflation Rate				Inflation Rate			
Year	2 %	3 %	4 %	5 %	2 %	3 %	4 %	5 %	2 %	3 %	4 %	5 %	2 %	3 %	4 %	5 %	2 %	3 %	4 %	5 %
2011	0.92	0.92	0.93	0.94	1.03	1.04	1.05	1.06	1.02	1.03	1.04	1.05	1.09	1.10	1.11	1.12	1.00	1.01	1.02	1.03
2012	0.96	0.98	0.99	1.01	1.11	1.14	1.16	1.18	1.15	1.17	1.19	1.21	1.17	1.20	1.22	1.24	1.02	1.04	1.06	1.08
2013	1.00	1.03	1.06	1.09	1.21	1.24	1.28	1.32	1.30	1.34	1.38	1.42	1.20	1.23	1.27	1.31	1.04	1.07	1.10	1.13
2014	1.00	1.04	1.08	1.12	1.29	1.34	1.39	1.45	1.43	1.49	1.55	1.61	1.20	1.25	1.30	1.35	1.06	1.10	1.15	1.19
2015	1.02	1.07	1.12	1.18	1.36	1.43	1.50	1.57	1.52	1.59	1.67	1.75	1.23	1.29	1.35	1.42	1.08	1.13	1.19	1.25
2016	1.05	1.11	1.18	1.25	1.45	1.53	1.63	1.72	1.61	1.71	1.81	1.92	1.26	1.34	1.42	1.50	1.09	1.16	1.23	1.30
2017	1.09	1.16	1.24	1.33	1.53	1.64	1.75	1.87	1.71	1.83	1.96	2.09	1.28	1.37	1.47	1.57	1.11	1.19	1.27	1.36
2018	1.12	1.21	1.31	1.41	1.61	1.74	1.88	2.03	1.81	1.95	2.11	2.28	1.31	1.42	1.53	1.65	1.13	1.22	1.32	1.42
2019	1.14	1.25	1.36	1.49	1.68	1.83	2.00	2.18	1.92	2.09	2.28	2.49	1.34	1.47	1.60	1.74	1.14	1.24	1.36	1.48
2020	1.18	1.30	1.43	1.58	1.74	1.92	2.12	2.33	2.00	2.20	2.42	2.67	1.38	1.52	1.67	1.84	1.16	1.28	1.41	1.55
2021	1.22	1.36	1.51	1.67	1.79	2.00	2.22	2.47	2.06	2.30	2.56	2.84	1.42	1.58	1.76	1.95	1.17	1.30	1.45	1.61
2022	1.25	1.41	1.58	1.77	1.85	2.08	2.34	2.62	2.13	2.40	2.70	3.02	1.47	1.65	1.85	2.08	1.20	1.35	1.51	1.70
2023	1.30	1.47	1.67	1.89	1.91	2.17	2.46	2.78	2.21	2.51	2.84	3.22	1.51	1.72	1.95	2.21	1.23	1.39	1.58	1.79
2024	1.33	1.53	1.75	2.00	1.96	2.25	2.57	2.94	2.28	2.62	3.00	3.43	1.55	1.77	2.03	2.32	1.26	1.44	1.65	1.89
2025	1.35	1.57	1.81	2.09	2.02	2.34	2.71	3.13	2.36	2.73	3.16	3.65	1.58	1.83	2.12	2.45	1.28	1.48	1.71	1.97
2026	1.39	1.62	1.89	2.20	2.09	2.44	2.85	3.32	2.42	2.83	3.31	3.85	1.63	1.91	2.23	2.60	1.31	1.53	1.79	2.08
2027	1.42	1.68	1.98	2.33	2.15	2.54	2.99	3.52	2.50	2.95	3.48	4.09	1.69	1.99	2.34	2.76	1.33	1.57	1.85	2.18
2028	1.47	1.75	2.08	2.47	2.22	2.65	3.15	3.74	2.58	3.08	3.66	4.35	1.75	2.08	2.48	2.95	1.36	1.62	1.93	2.30
2029	1.53	1.84	2.21	2.65	2.30	2.77	3.33	3.99	2.67	3.21	3.86	4.63	1.82	2.19	2.63	3.16	1.39	1.68	2.02	2.42
2030	1.58	1.92	2.33	2.82	2.37	2.88	3.49	4.23	2.76	3.36	4.07	4.93	1.90	2.30	2.80	3.39	1.43	1.74	2.11	2.56
2031	1.64	2.02	2.47	3.02	2.45	3.01	3.69	4.51	2.87	3.52	4.32	5.28	1.98	2.43	2.98	3.64	1.46	1.80	2.20	2.69
2032	1.71	2.11	2.61	3.23	2.54	3.15	3.90	4.81	2.97	3.68	4.55	5.62	2.05	2.54	3.14	3.88	1.49	1.85	2.29	2.82
2033	1.76	2.20	2.75	3.43	2.63	3.29	4.11	5.13	3.05	3.82	4.77	5.95	2.10	2.63	3.29	4.10	1.53	1.91	2.39	2.98
2034	1.81	2.29	2.89	3.64	2.73	3.44	4.34	5.46	3.18	4.02	5.07	6.37	2.17	2.75	3.46	4.36	1.56	1.98	2.49	3.14
2035	1.87	2.38	3.04	3.86	2.82	3.60	4.59	5.83	3.28	4.19	5.33	6.77	2.24	2.86	3.64	4.62	1.60	2.05	2.60	3.31
2036	1.92	2.47	3.18	4.08	2.92	3.76	4.83	6.20	3.40	4.38	5.63	7.22	2.31	2.97	3.82	4.90	1.64	2.11	2.72	3.49
2037	1.97	2.56	3.33	4.31	3.01	3.92	5.09	6.59	3.52	4.58	5.95	7.71	2.38	3.10	4.02	5.21	1.68	2.19	2.84	3.68
2038	2.02	2.65	3.48	4.55	3.11	4.09	5.35	7.00	3.66	4.80	6.30	8.23	2.46	3.23	4.23	5.53	1.71	2.25	2.95	3.86
2039	2.07	2.75	3.64	4.80	3.21	4.26	5.64	7.44	3.79	5.03	6.66	8.79	2.54	3.37	4.45	5.88	1.76	2.33	3.08	4.07
2040	2.13	2.85	3.81	5.07	3.31	4.44	5.93	7.91	3.94	5.27	7.05	9.39	2.62	3.51	4.69	6.24	1.80	2.41	3.22	4.29

The Analysis showed a payback period of 10.5 years for the changes to the original design.



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   1. Initial Difference
   2. LCC
6. Pros versus Cons

The increase indoor environment is a major benefit of the proposed redesign.

Pros

- Increased IAQ
- Contaminant Control
- Warm Floor for Kindergarten
- Increased Thermal Comfort
- 6% Energy Reduction
- 30% Increased Ventilation
- Decreased Mechanical Noise
- 225K Payback over 25yrs
- Reduced Absences
- Increased Test Scores

The redesign is considered to be feasible and is recommended.

Questions?

Presentation Outline

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    1. Radiant Heating and Cooling
    2. Low Velocity Displacement Ventilation
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5. Overall Cost
    1. Initial Difference
    2. LCC
6. Pros versus Cons

The increase indoor environment is a major benefit of the proposed redesign.

Con's

- 5% Increased Initial Cost
- Increased Construction Time

The redesign is considered to be feasible and is recommended.

Questions?