Optimizing Major Equipment Replacements Using Life Cycle Cost Analysis

Chicago Peer Exchange

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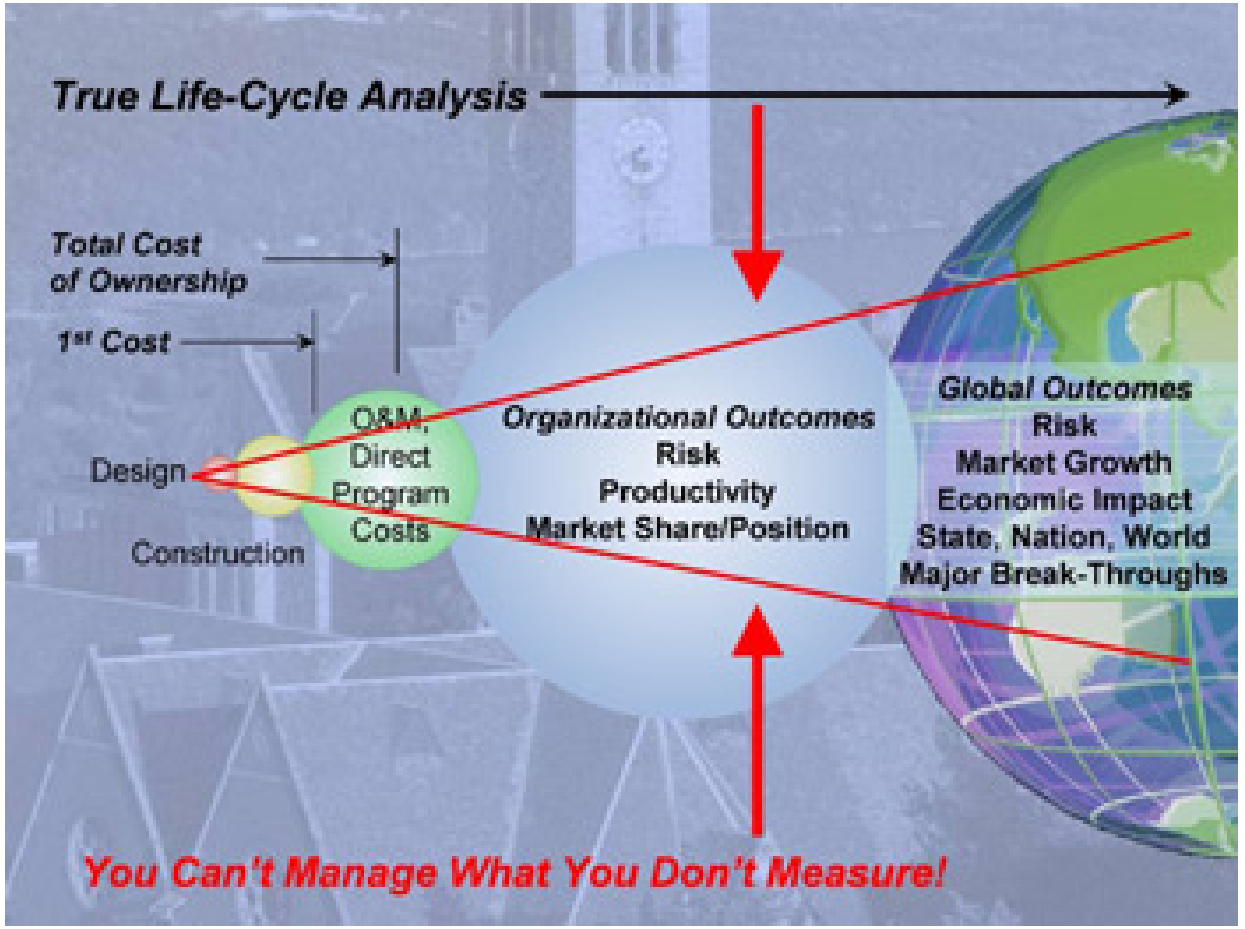
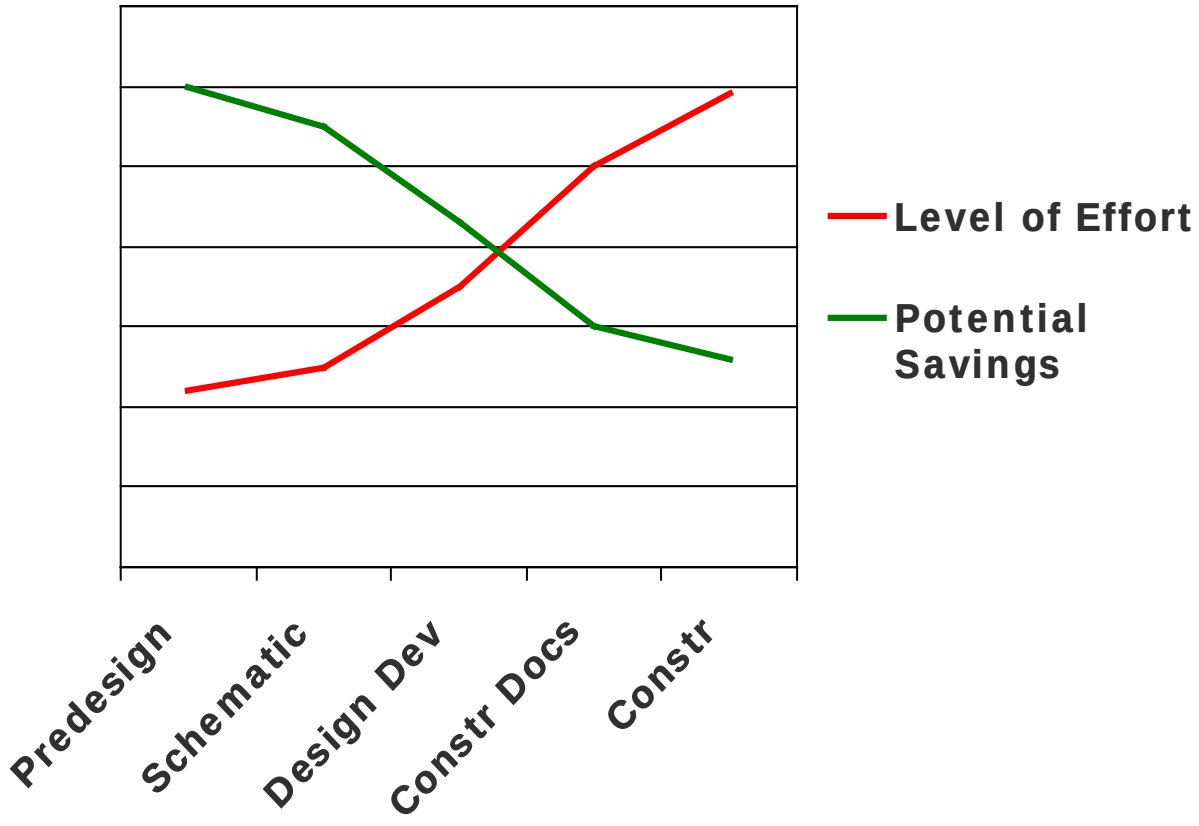
Major Equipment Replacements



Use LCC Techniques Early in the Design Process to Optimize Results

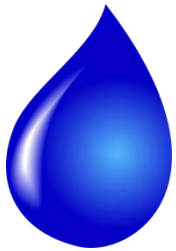


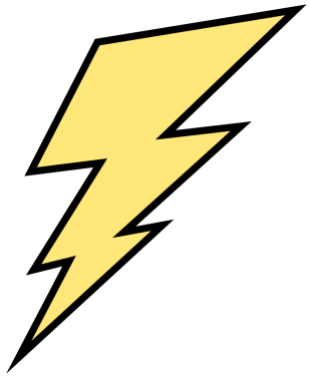
The LCC Analysis Should Include the Following Metrics:

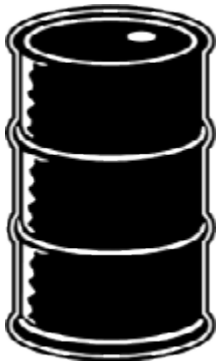
- Construction Cost (including O&P, permits, demolition, waste disposal, etc.)
- Design Fees
- Project/Construction Management Fees
- Maintenance and Operating Costs
  - Regular (sometimes a service contract)
  - Periodic tear downs
- Reinvestment Costs

The LCC Analysis Should Include the Following Metrics:

- Utility/Energy Costs
  - Electric
  - Gas
  - Oil
  - Water
  - Sewer







The LCC Analysis Should Include the Following Metrics:

- Expected Service Life of Various Types of Equipment
  - Use data from ASHRAE Handbook

Estimates of Service Lives of Various System Components

Equipment Item	Median Years	Equipment Item	Median Years	Equipment Item	Median Years
Air conditioners		Air terminals		Air-cooled condensers	20
Window unit	10	Diffusers, grilles, and registers	27	Evaporative condensers	20
Residential single or split package	15	Induction and fan-coil units	20	Insulation	
Commercial through-the-wall	15	VAV and double-duct boxes	20	Molded	20
Water-cooled package	15	Air washers	17	Blanket	24
Heat pumps		Ductwork	30	Pumps	
Residential air-to-air	15 [b]	Dampers	20	Base-mounted	20
Commercial air-to-air	15	Fans		Pipe-mounted	10
Commercial water-to-air	19	Centrifugal	25	Sump and well	10
Roof-top air conditioners		Axial	20	Condensate	15
Single-zone	15	Propeller	15	Reciprocating engines	20
Multizone	15	Ventilating roof-mounted	20	Steam turbines	30
Boilers, hot water (steam)		Coils		Electric motors	18
Steel water-tube	24 (30)	DX, water, or steam	20	Motor starters	17
Steel fire-tube	25 (25)	Electric	15	Electric transformers	30
Cast iron	35 (30)	Heat exchangers		Controls	
Electric	15	Shell-and-tube	24	Pneumatic	20
Burners	21	Reciprocating compressors	20	Electric	16
Furnaces		Package chillers		Electronic	15
Gas- or oil-fired	18	Reciprocating	20	Valve actuators	
Unit heaters		Centrifugal	23	Hydraulic	15
Gas or electric	13	Absorption	23	Pneumatic	20
Hot water or steam	20	Cooling towers		Self-contained	10
Radiant heaters		Galvanized metal	20		
Electric	10	Wood	20		
Hot water or steam	25	Ceramic	34		

Notes: 1. ASHRAE makes no claims as to the statistical validity of any of the data presented in this table.
2. Table lists base values that should be adjusted for local conditions (see the section on Service Life).
3. For updated information on heat pump life, see Lovvorn and Hiller (2002).

Source: Data obtained from a survey of the United States by ASHRAE Technical Committee TC 1.8 (Akalin 1978).
[a] See Lovvorn and Hiller (1985) and Easton Consultants (1986) for further information.
[b] Data updated by TC 1.8 in 1986.

The LCC Analysis Should Include the Following Metrics:

- Timeframe for Analysis (not always the same as equipment life)
- Escalation Factors
  - Discount Rate
  - Inflation
  - Fuel Escalation Rates (from DOE)
- Financial Perspective – usually "present value" dollars, or PV$

Run a *Sensitivity* Analysis

- Simple "what-if" scenarios with different values within estimate range are input into calculations
- Examples:
  - What if gas prices rise twice as fast as assumed?
  - What if discount rate is more or less?
  - What if inflation rate is more or less?

Two Examples

- Replace Rooftop Air Handling Units in an R&D laboratory building near Philadelphia
- Replace Chillers, upgrade Cooling Plant in a local hospital

R&D Facility HVAC Upgrade

- The goals of the project were to:
  - Replace aging building infrastructure supporting on-going business operations
  - Provide better control of comfort conditions and indoor environmental quality
  - Improve system reliability
  - Reduce energy operating and maintenance costs
  - Reduce carbon footprint

Overview of Process

- Create a baseline understanding of system operations
- Evaluate existing building operations and energy efficiency opportunities/applications
- Develop concepts of options for improved energy efficiency and sustainability
- Develop construction cost estimates, energy and operating costs
- Run life cycle cost comparison

HVAC Upgrade Options

- Design and Cost Considerations to be Evaluated:
  - Quality level of new equipment
  - Required level of equipment redundancy
  - Potential locations other than roof
  - Structural capacity for new rooftop equipment
  - Roof curb modifications versus new steel support structure

HVAC Upgrade Options

- Staging/phasing of construction
- Rigging
- Routing of new piping/ductwork
- Condition and configuration of existing electrical distribution
- New controls/compatibility with existing
- Chemical treatment for new water systems
- Lab Type/Criticality/Layout/Consolidation

Summary of Existing Building Energy Usage and Cost

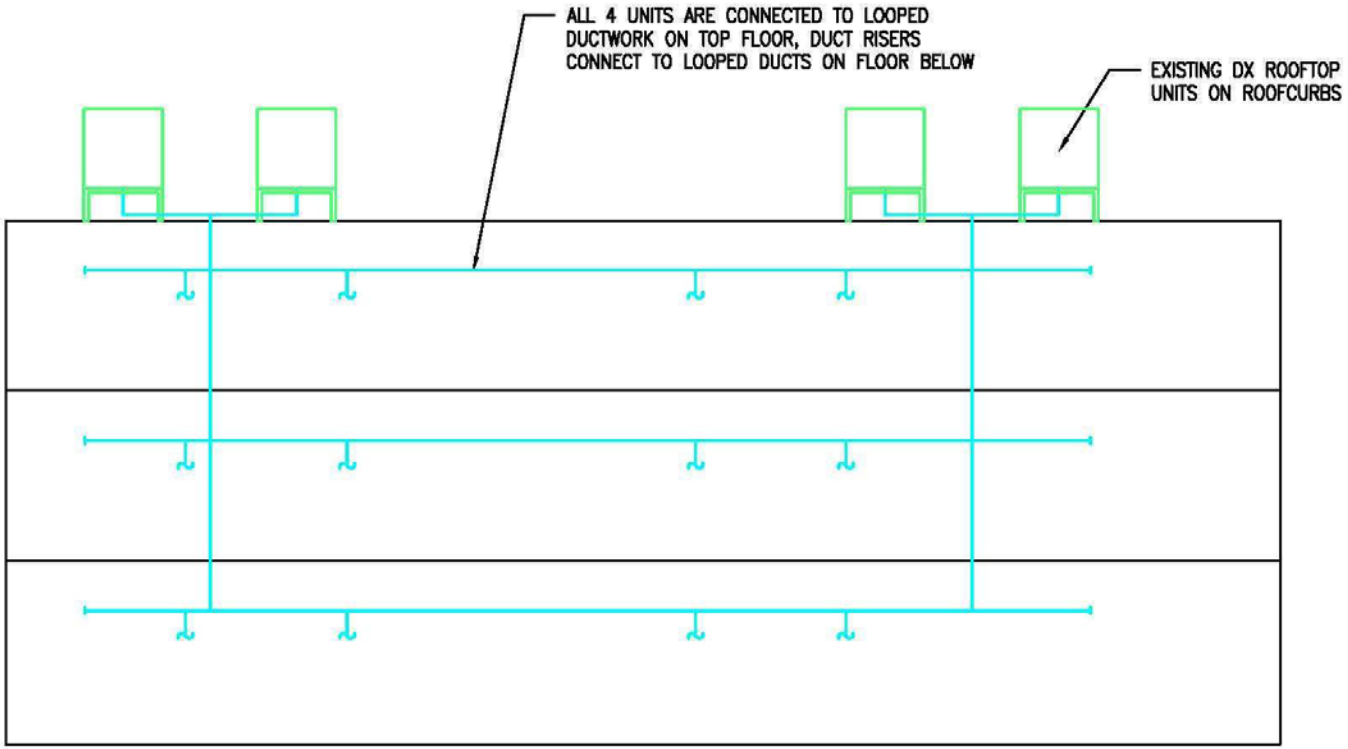
Calendar Year	Energy Usage Intensity (Btu/SqFt/Yr)*	Average Unit Electric Energy Cost ($/kWh)**	Total Energy Cost ($/yr)*	Energy Cost ($/SqFt/Yr)*
2008	225,627	$0.087	$2,232,971	$5.73
2009	217,952	$0.086	$2,141,121	$5.49
2010	208,126	$0.091	$2,163,060	$5.55

*A small amount of natural gas is used for food service and miscellaneous unit heaters. This usage comprises less than 1% of the total building energy.
**Average electric unit costs include all charges, including demand.

- The energy usage intensity for laboratories is typically 5 to 10 times greater than office buildings. – U.S. DOE, Laboratories for the 21st Century (www.labs21century.gov).

Existing HVAC

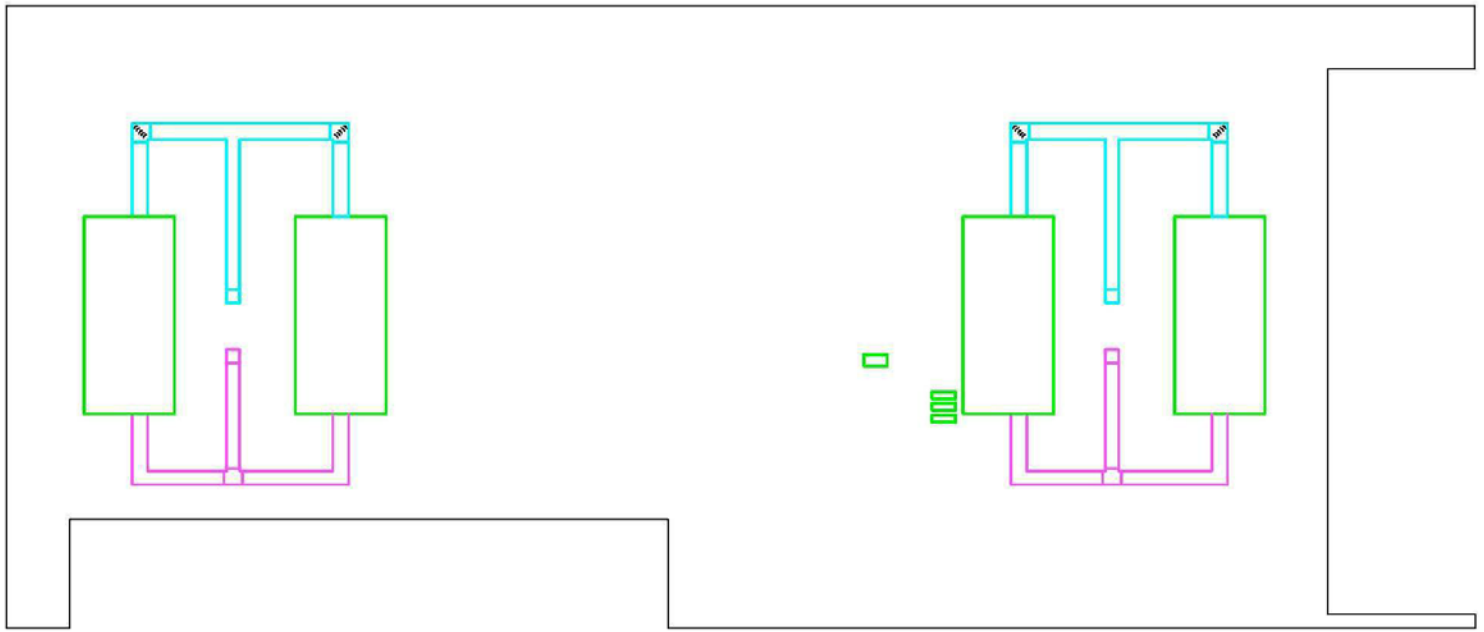
- System Schematic Diagram:



EXISTING HVAC

Existing HVAC

- Existing Roof Plan:

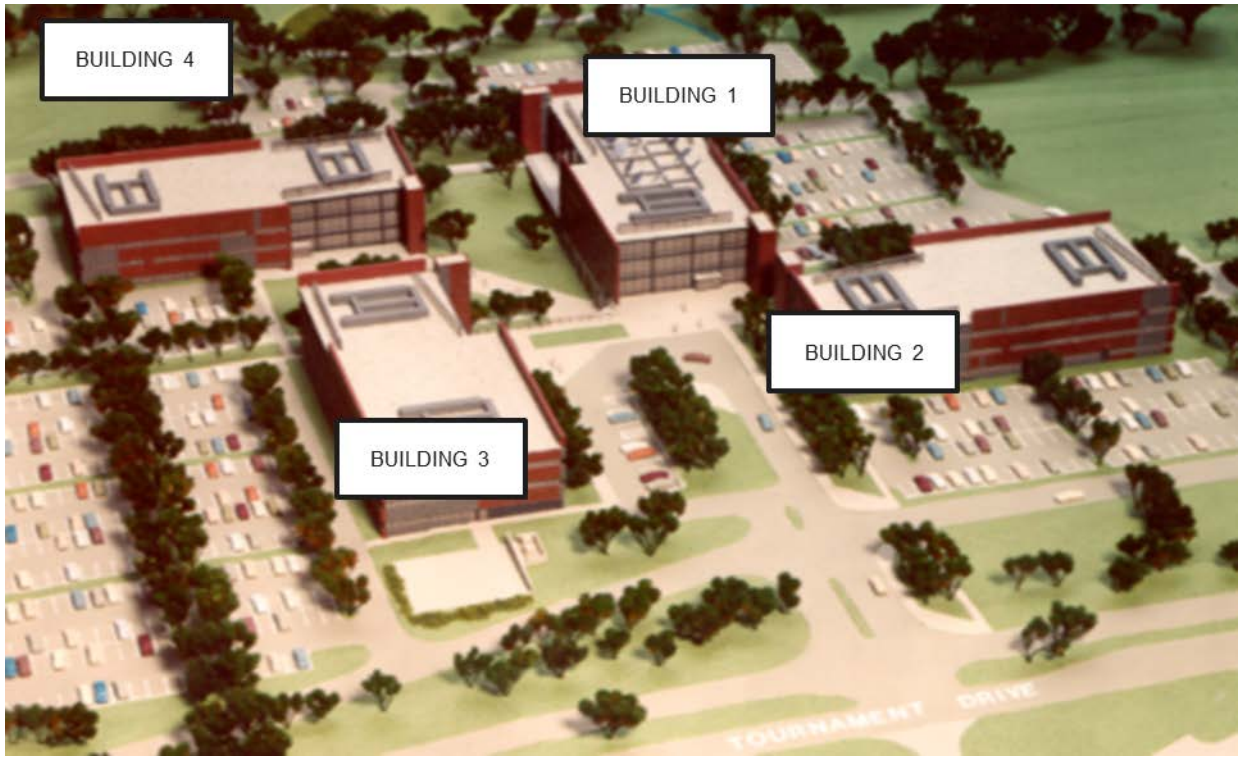


EXISTING HVAC

HVAC Upgrade Options Initially Considered

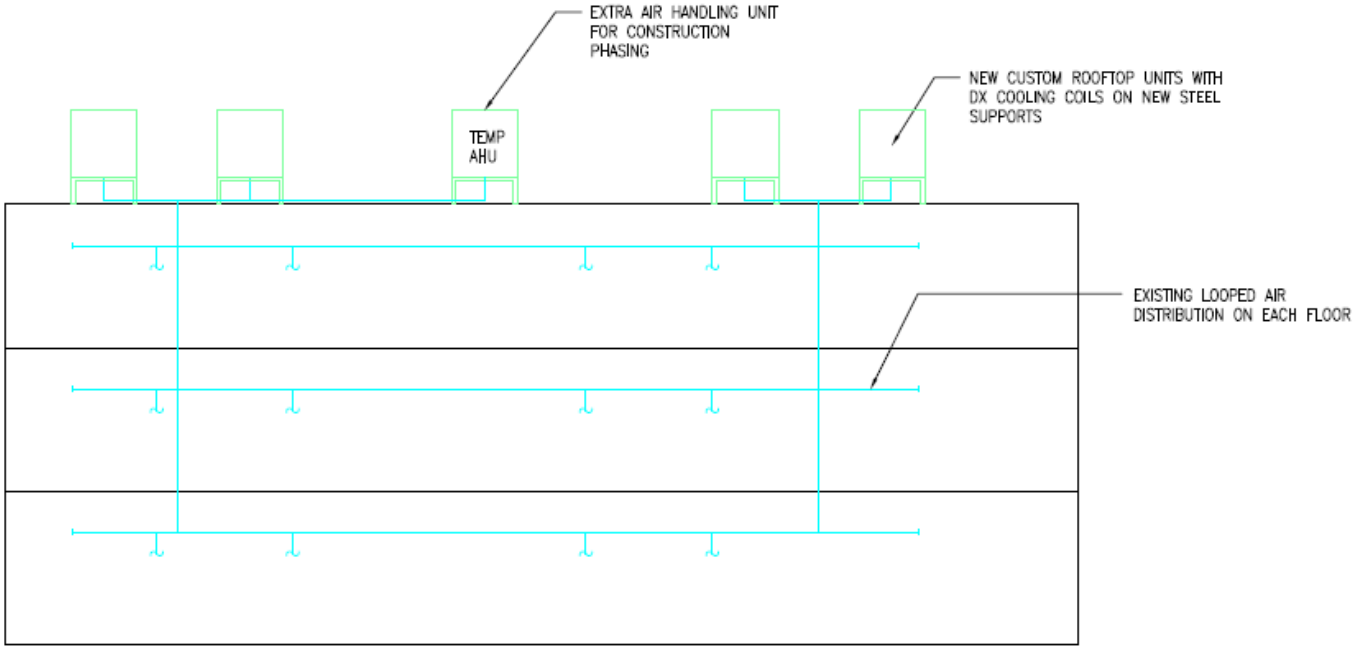
- OPTION 1 – In-kind replacement with Basic DX RTUs (Air-Cooled)
- OPTION 1A – Replace with custom DX Rooftop Units (Air-Cooled)
- OPTION 1B – Replace with custom DX Rooftop Units (Evaporative Cooled)
- OPTION 2 – DX Rooftop Units with Water-Cooled Condensers
- OPTION 3 – Rooftop Units with Chilled Water Coils
- OPTION 4 – Chilled Water System to Directly Serve Labs, AHUs
- OPTION 5A –Condenser Water System to Serve All Labs / Basic DX RTUs
- OPTION 5 – Condenser Water System to Serve All Labs / Custom DX RTUs

Existing HVAC



HVAC Upgrade Options

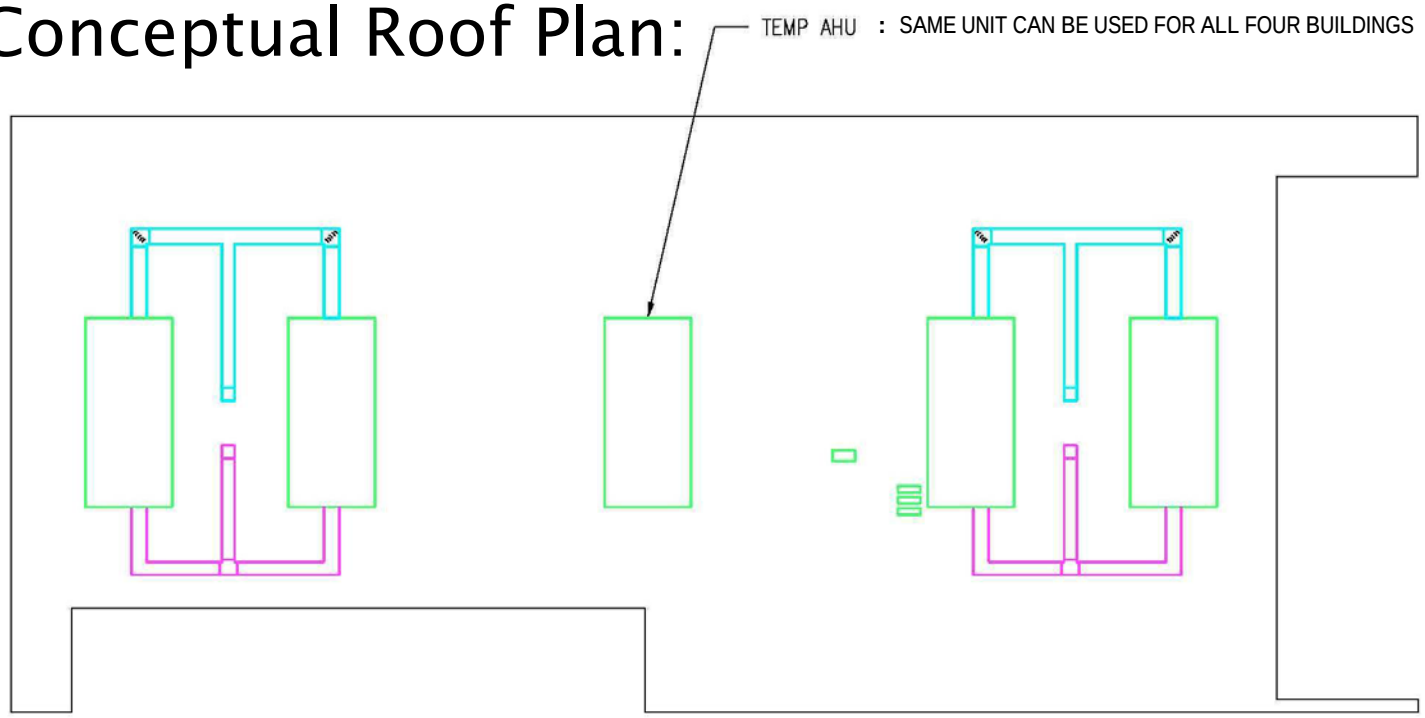
- PROPOSED OPTIONS 1 AND 1A – Replace with new DX Rooftop Units
- System Schematic Diagram:



OPTION 1

HVAC Upgrade Options

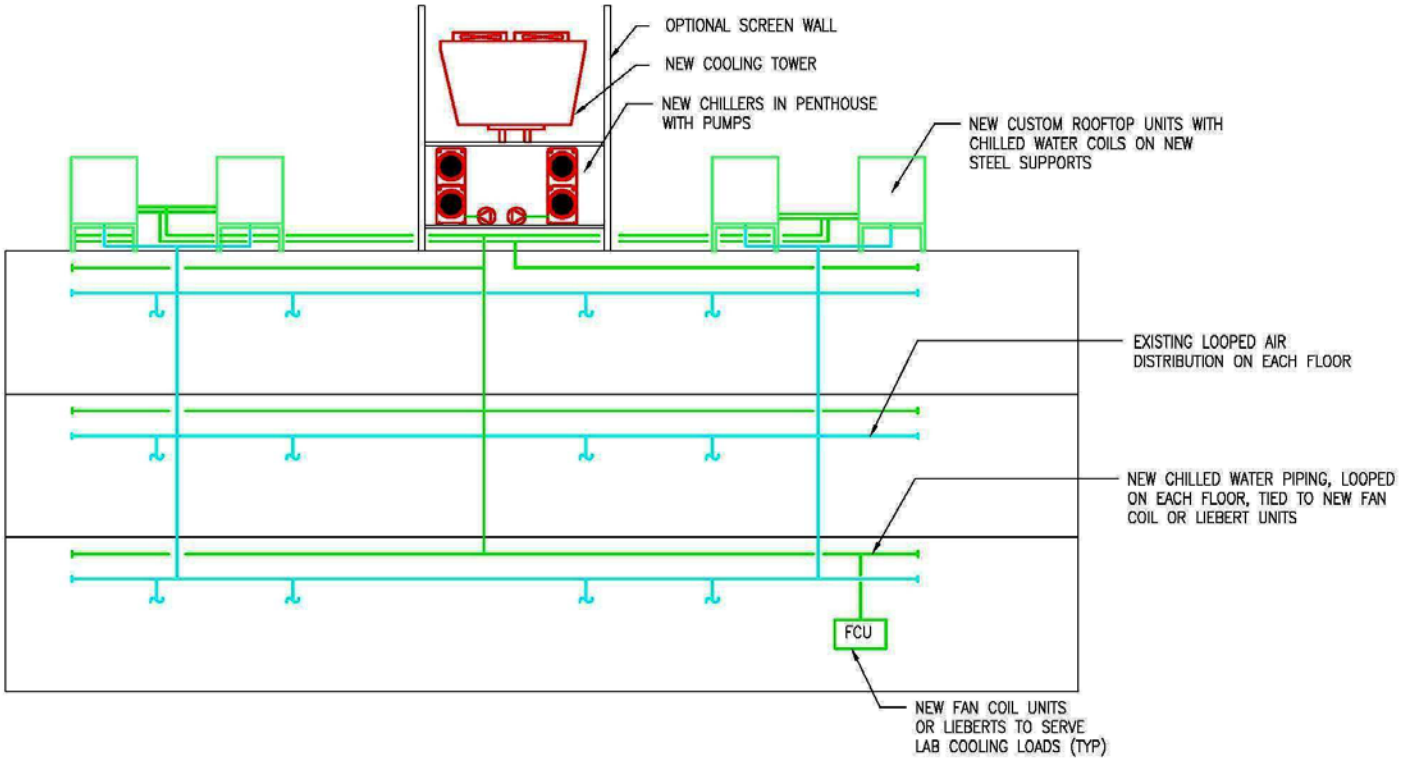
- PROPOSED OPTION 1 AND 1A – Replace with new DX Rooftop Units
- Conceptual Roof Plan:



OPTION 1

HVAC Upgrade Options

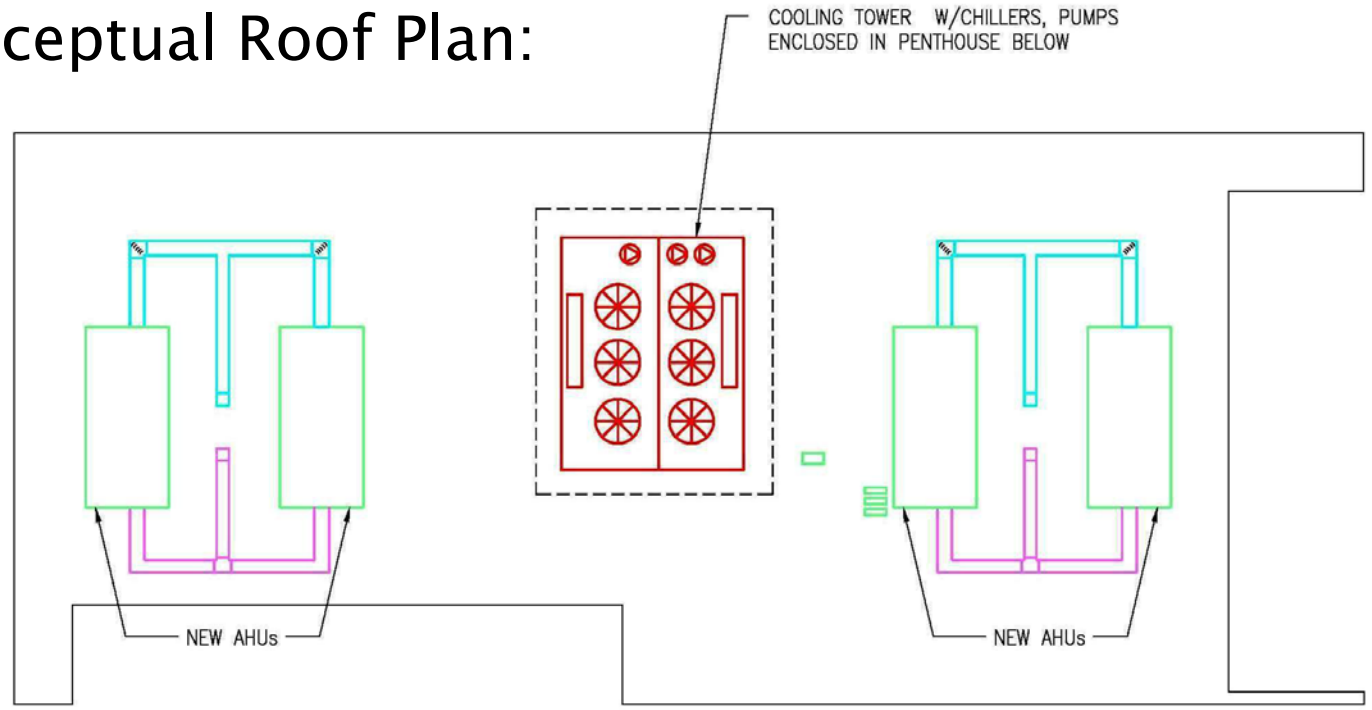
- PROPOSED OPTION 4 – Chilled Water System to Directly Serve Labs and AHU CHW coils
- System Schematic Diagram:



OPTION 4

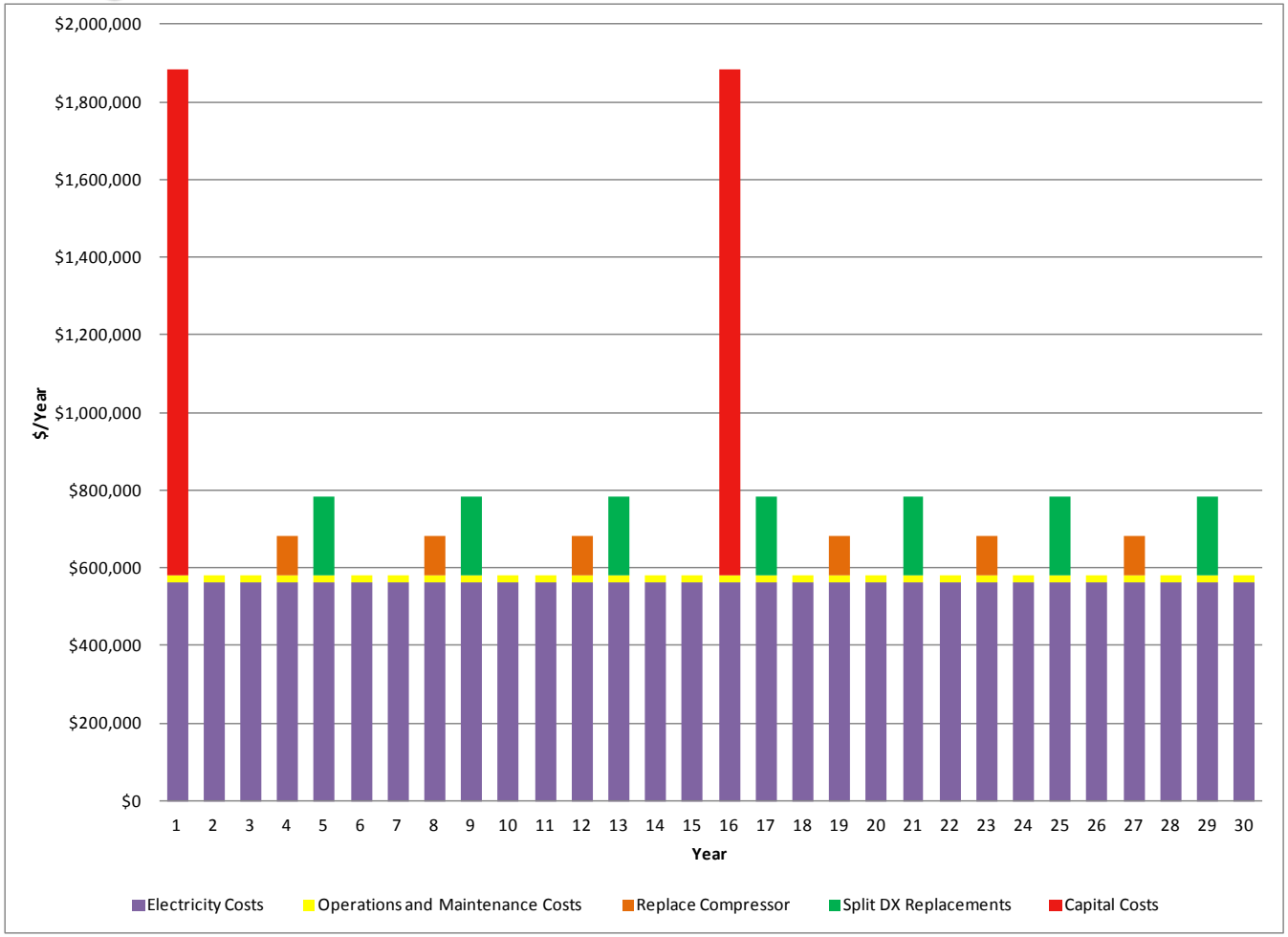
HVAC Upgrade Options

- PROPOSED OPTION 4 – Chilled Water System to Directly Serve Labs and AHU CHW coils
- Conceptual Roof Plan:



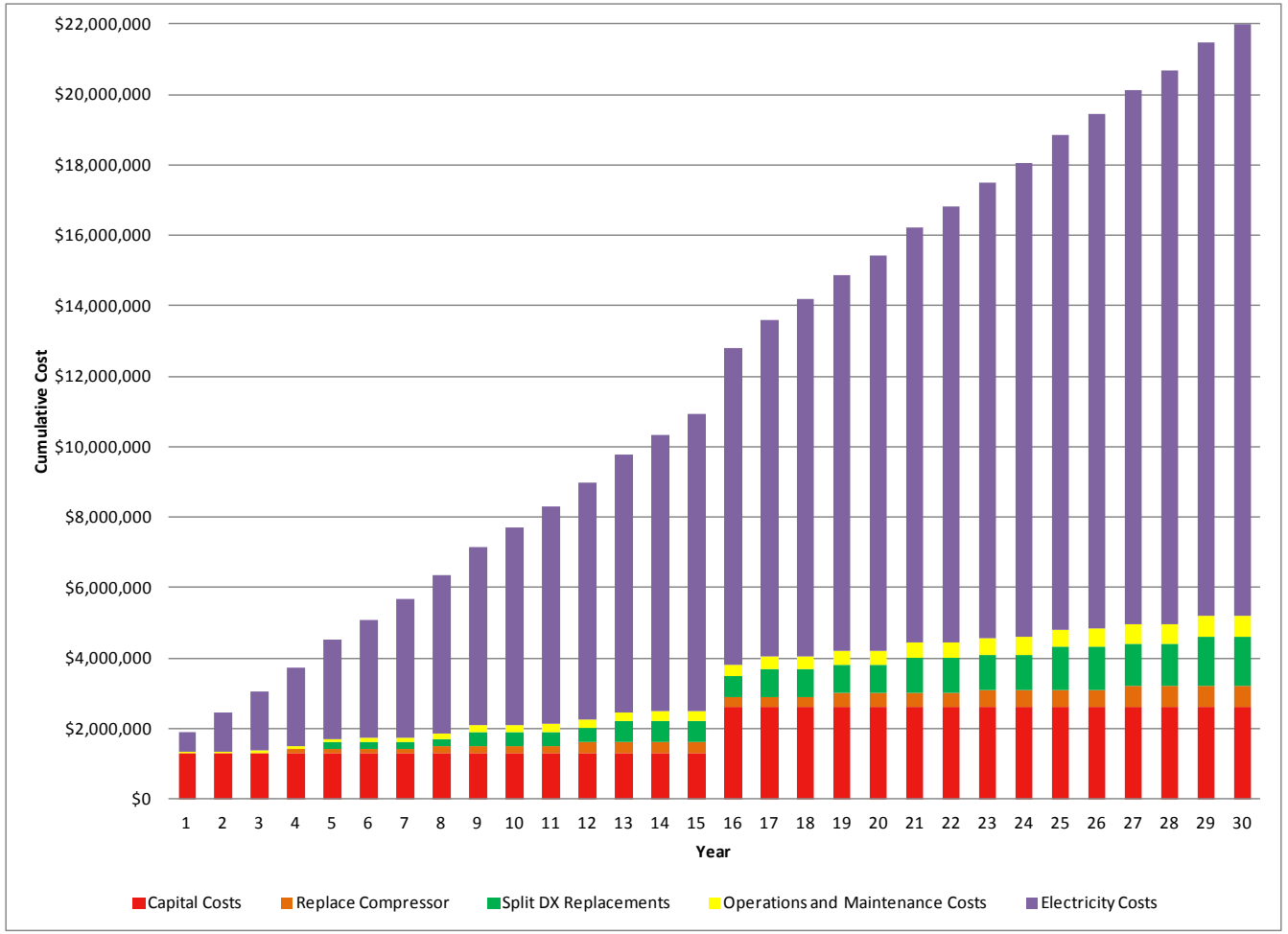
OPTION 4

Proposed Option 1A – Basic Air-Cooled DX RTUs Projected Annual Cash Flows



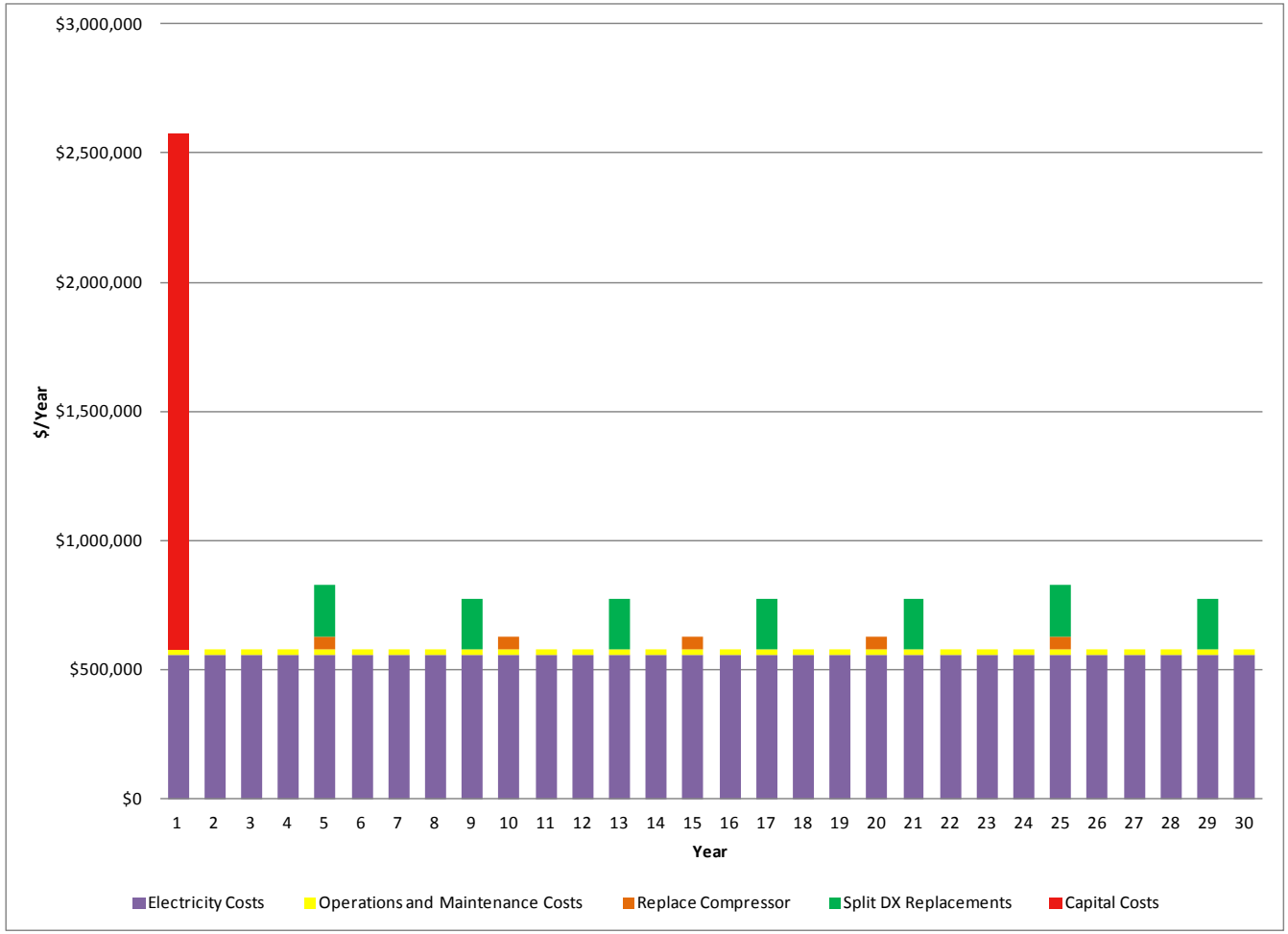
Year 1 includes initial construction expenses and first year operating costs.

Proposed Option 1A – Basic Air-Cooled DX RTUs Projected Cumulative Cash Flows



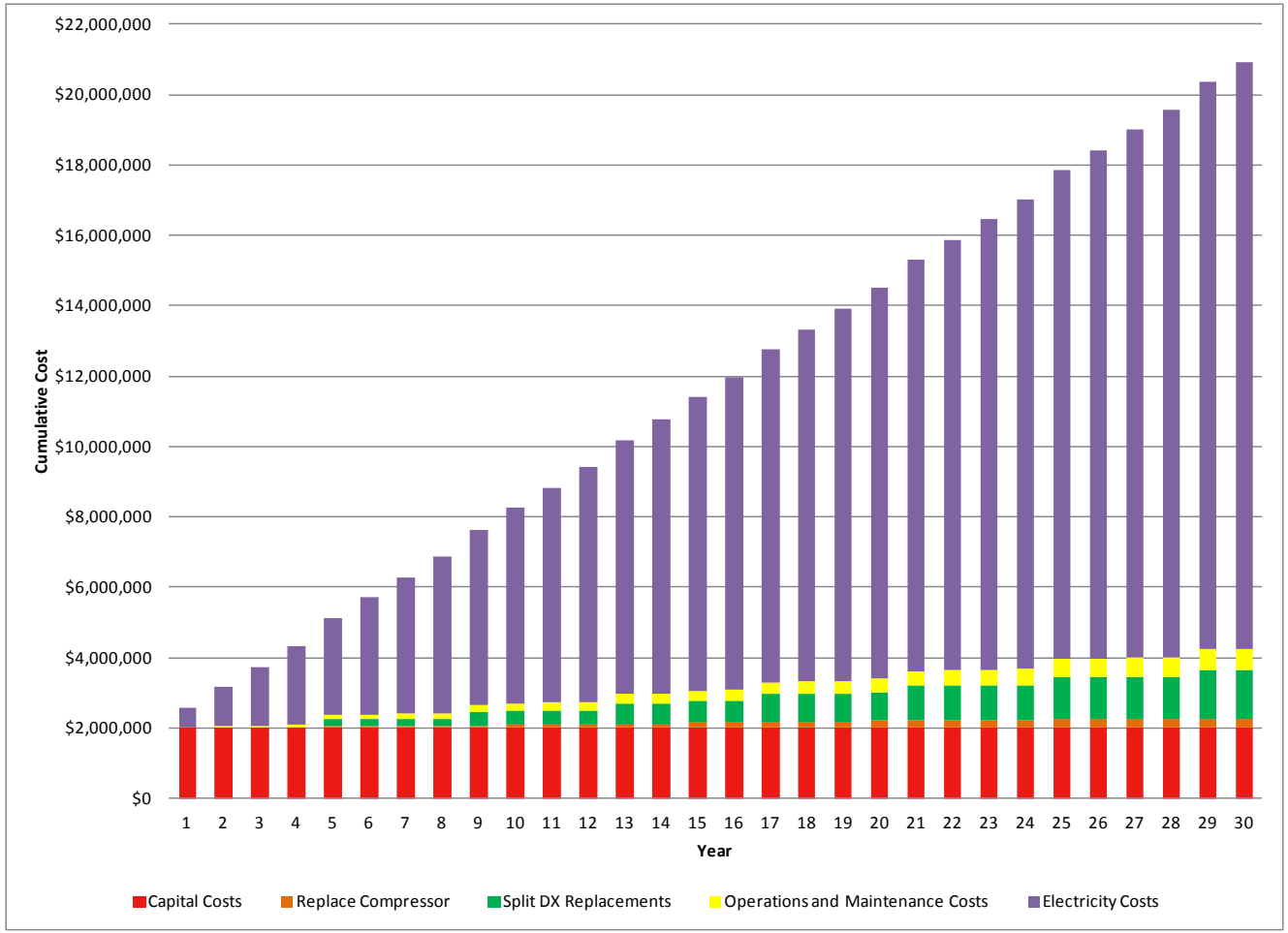
Year 1 includes initial construction expenses and first year operating costs.

Proposed Option 1 – Custom Air-Cooled DX RTUs Projected Annual Cash Flows



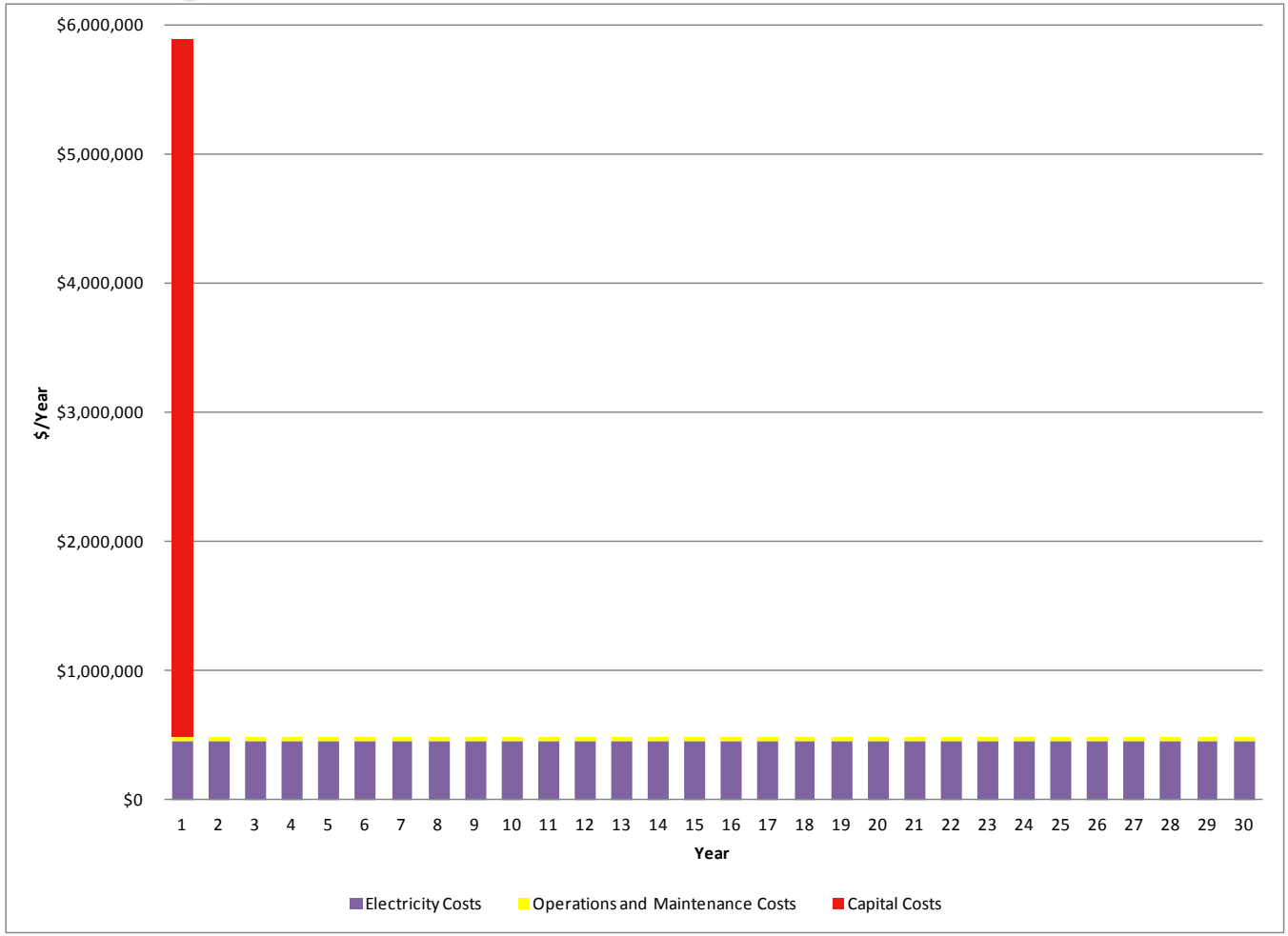
Year 1 includes initial construction expenses and first year operating costs.

Proposed Option 1 – Custom Air-Cooled DX RTUs Projected Cumulative Cash Flows



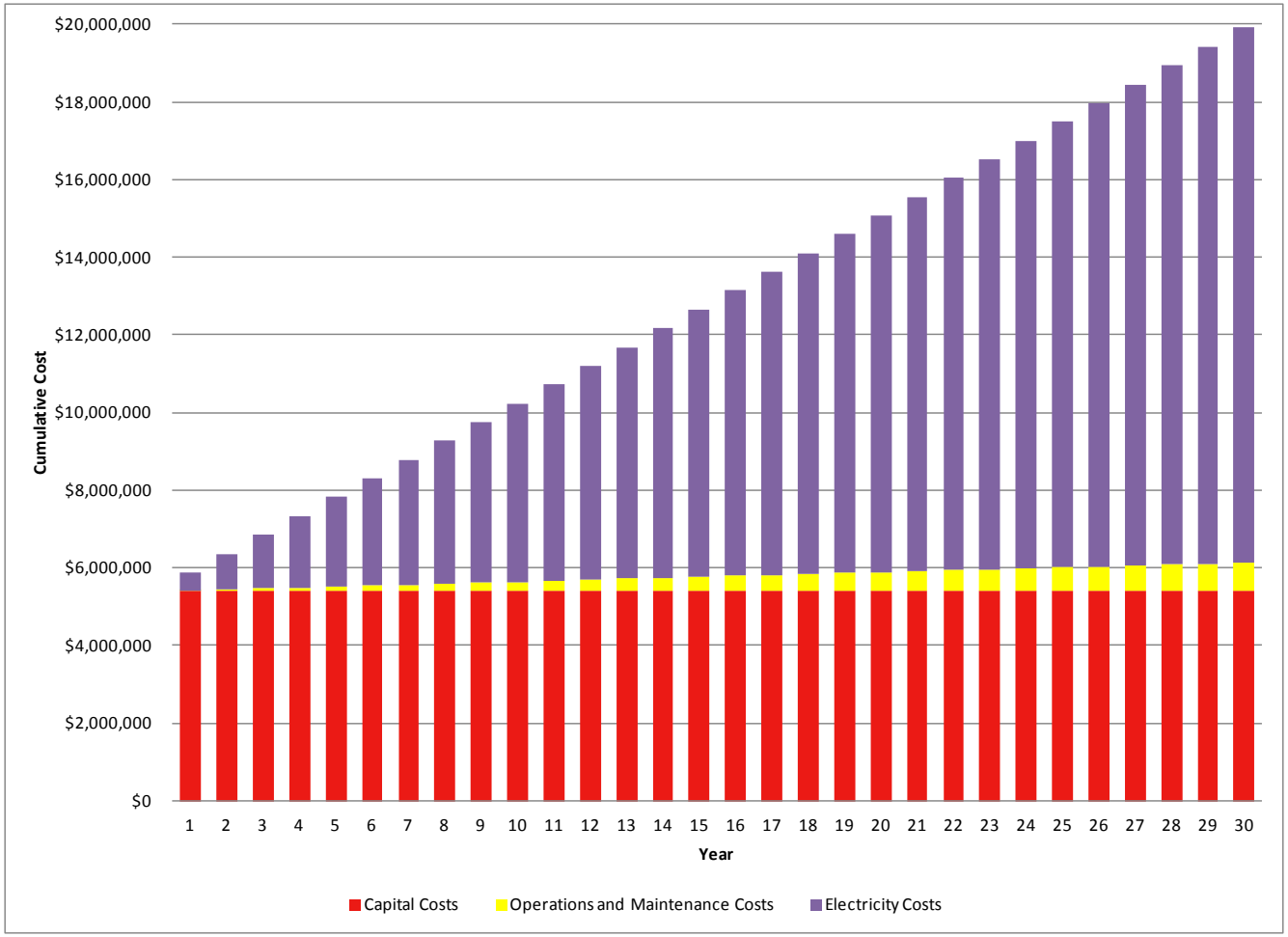
Year 1 includes initial construction expenses and first year operating costs.

Proposed Option 4 – CHW System for RTUs & Labs Projected Annual Cash Flows



Year 1 includes initial construction expenses and first year operating costs.

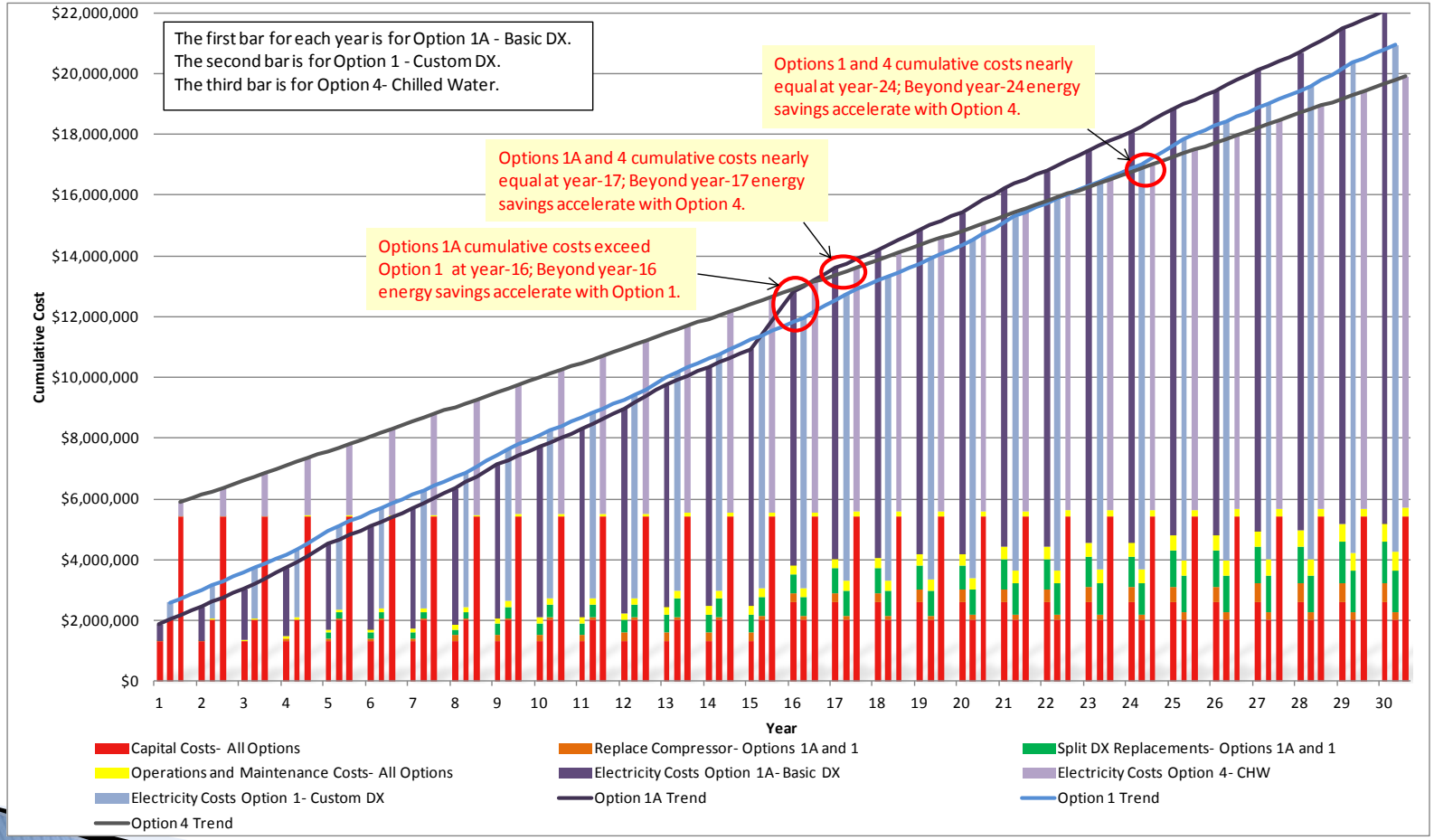
Proposed Option 4 – CHW System for RTUs & Labs Projected Cumulative Cash Flows



Year 1 includes initial construction expenses and first year operating costs.

Proposed Options 1A, 1 and 4 – Projected Cumulative Cash Flows

15-Year Planning Horizon = Option 1A (year-1 capital investment *excludes lab unit modifications/replacements*)
25-Year Planning Horizon = Option 1 (year-1 capital investment *excludes lab unit modifications/replacements*)
30-Year Planning Horizon = Option 4 (year-1 capital investment includes lab unit upgrades/replacements)



Year 1 includes initial construction expenses and first year operating costs.

Example #2: Chiller/Cooling Tower Replacement

- Base Project
  - Replace 3 chillers, cooling towers
- Additional goals
  - Add cooling tower capacity
  - Replace air-cooled chiller serving surgery
  - Convert CHW piping to variable primary configuration
  - Convert CW system to variable flow

Chiller Purchase

- Issued a prepurchase specification directly to four (4) chiller manufactures
- Each manufacturer submits multiple bids
- Award contract based on lowest LCC

Chiller Purchase LLC Components

- Chiller bid cost
- Factory performance test
- Energy usage (modeled)
  - Compressor
  - Pumps
  - Cooling tower
- Maintenance cost
  - Annual maintenance/service contract
- Extended warranty
- ComEd Incentives
  - Chiller
  - Cooling Tower
  - VV pumping

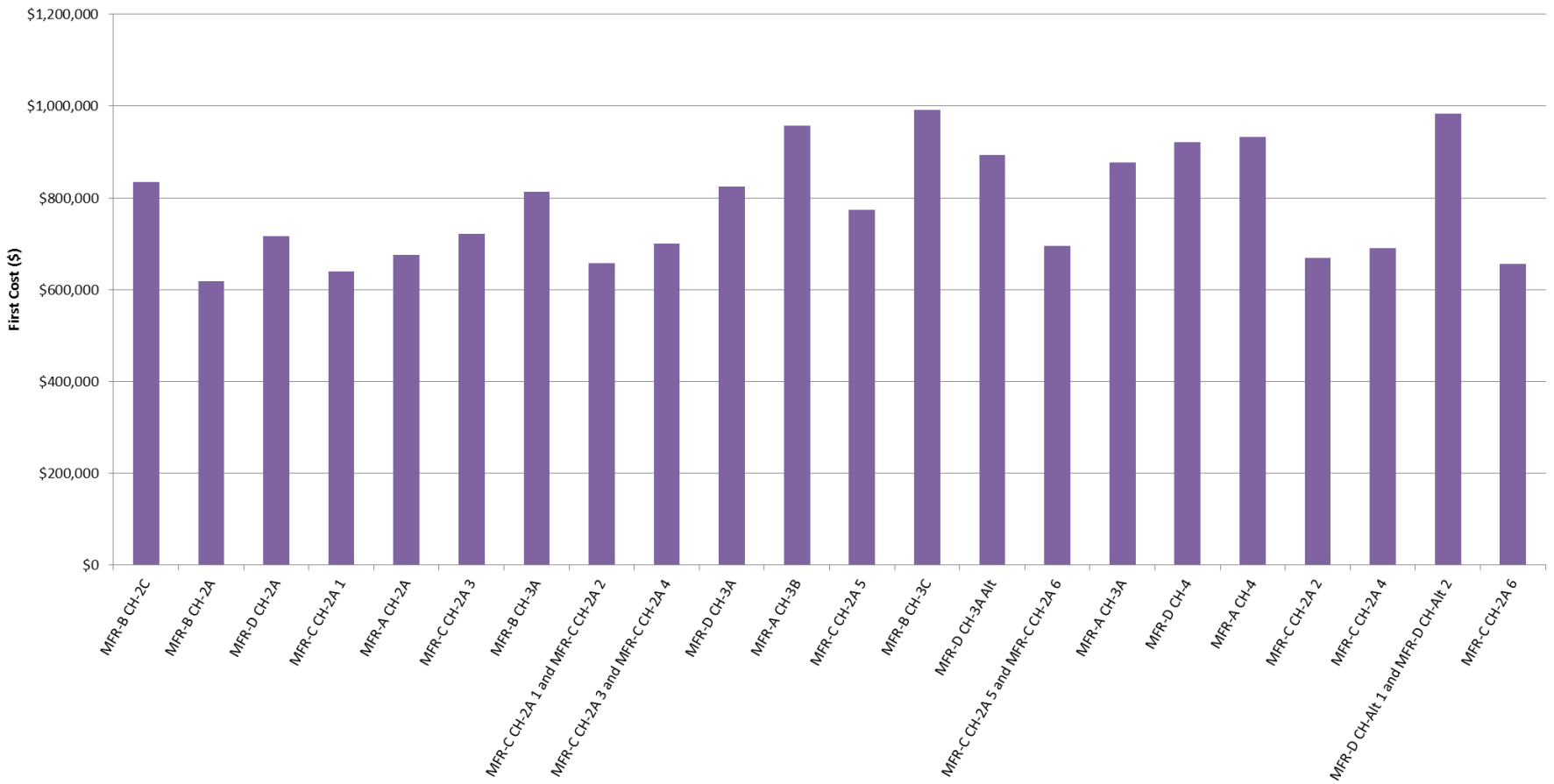
Pros/Cons of Prepurchase Process

- Advantages:
  - LCC Analysis – best long term VALUE
  - You make the decision – not the contractor
  - Delivery
  - Design for installation reflects actual machine purchased
- Dis-Advantages:
  - Early financial commitment

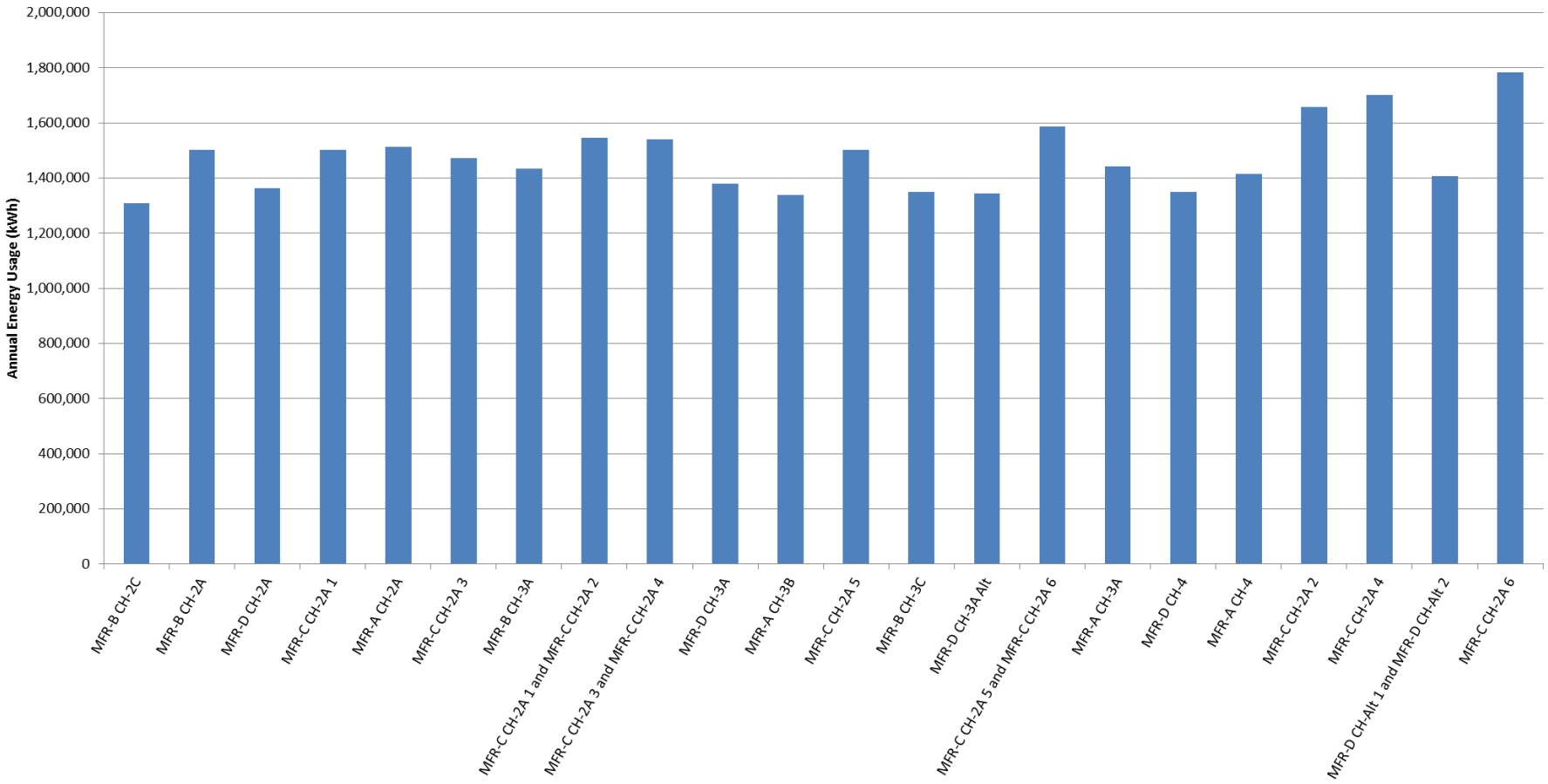
Bid Information																
Chiller	Description	Total Installed Tons	CH Type 1 Full Load (kW/ton)	CH Type 1 Factory NPLV	Base Price ($)	Additional CH HVAC Equip ($)	Factory Performance Test Witnessed by Owner ($)	Extended 5-Year Parts and Labor Warrantee ($)	5-Year Preventative Maintenance and Service ($)	10-Year Preventative Maintenance and Service ($)	Total First Cost ($)	Est. ComEd Incentive* ($)	Adjusted First Cost ($)	First Cost per Ton ($/ton)	Pct of Min Base Price (%)	Base Price Ranking
MFR-B CH-2C	Three 700 Ton Centrifugal Chillers with VFDs and Magnetic Bearings	2,100	0.572	0.339	$820,000	$0	$32,000	$38,000	$33,075	$37,275	$960,350	$126,493	$833,858	$397	135%	15
MFR-B CH-2A	2A - Three 700 Ton Centrifugal Chillers with VFDs	2,100	0.611	0.400	$580,000	$0	$23,000	$42,000	$36,375	$41,100	$722,475	$104,075	$618,400	$294	100%	1
MFR-D CH-2A	2A - Three 700 Ton Centrifugal Chillers with VFDs	2,100	0.569	0.384	$586,450	$20,000	$22,000	$44,175	$63,350	$90,475	$826,450	$109,955	$716,495	$341	116%	10
MFR-C CH-2A 1	700T-8595 - Three 700 Ton Centrifugal Chillers with VFDs	2,100	0.584	0.399	$554,973	$0	$29,485	$13,184	$68,000	$78,500	$744,142	$104,443	$639,700	$305	103%	2
MFR-A CH-2A	2A - Three 700 Ton Centrifugal Chillers with VFDs	2,100	0.583	0.378	$580,000	$0	$25,000	$56,433	$59,410	$66,290	$787,133	$112,160	$674,973	$321	109%	6
MFR-C CH-2A 3	700T-8597 - Three 700 Ton Centrifugal Chillers with VFDs	2,100	0.601	0.409	$632,754	$0	$29,485	$13,184	$68,000	$78,500	$821,923	$100,768	$721,156	$343	117%	11
MFR-B CH-3A	3A - Four 525 Ton Centrifugal Chillers with VFDs	2,100	0.626	0.377	$675,000	$100,000	$27,000	$38,000	$48,500	$54,800	$943,300	$130,903	$812,398	$387	131%	13
MFR-C CH-2A 1 & MFR-C CH-2A 2	700T-8595 - One 700 Ton Centrifugal Chillers with VFD, 2 w/o VFDs	2,100	0.584	0.399	$533,319	$0	$29,485	$13,184	$68,000	$78,500	$722,488	$64,295	$658,193	$313	106%	4
MFR-C CH-2A 3 & MFR-C CH-2A 4	700T-8597 - One 700 Ton Centrifugal Chillers with VFD2 w/o VFDs	2,100	0.601	0.409	$573,310	$0	$29,485	$13,184	$68,000	$78,500	$762,479	$61,845	$700,634	$334	113%	9
MFR-D CH-3A	3A - Four 525 Ton Centrifugal Chillers with VFDs	2,100	0.594	0.363	$555,600	$120,000	$25,000	$54,600	$84,450	$120,630	$960,280	$136,048	$824,233	$392	133%	14
MFR-A CH-3B	3B - Four 525 Ton Rotary Screw Chillers with VFDs	2,100	0.590	0.353	$776,000	$100,000	$30,300	$48,708	$66,490	$75,270	$1,096,768	$139,723	$957,046	$456	155%	20
MFR-C CH-2A 5	700T-85100 - Three 700 Ton Centrifugal Chillers with VFDs	2,100	0.621	0.421	$676,692	$0	$29,485	$13,184	$68,000	$78,500	$865,861	$92,715	$773,146	$368	125%	12
MFR-B CH-3C	3C - Four 525 Ton Centrifugal Chillers with VFDs and Magnetic Bearings	2,100	0.577	0.340	$870,000	$100,000	$33,000	$39,000	$44,100	$49,700	$1,135,800	$144,500	$991,300	$472	160%	22
MFR-D CH-3A Alt	3A Alt- Four 525 Ton Centrifugal Chillers with VFDs	2,100	0.573	0.353	$627,950	$120,000	$25,000	$54,600	$84,450	$120,630	$1,032,630	$139,723	$892,908	$425	144%	17
MFR-C CH-2A 5 & MFR-C CH-2A 6	700T-85100 - One 700 Ton Centrifugal Chillers with VFD, 2 w/o VFDs	2,100	0.621	0.421	$564,488	$0	$29,485	$13,184	$68,000	$78,500	$753,657	$58,905	$694,752	$331	112%	8
MFR-A CH-3A	3A - Four 525 Ton Centrifugal Chillers with VFDs	2,100	0.589	0.400	$655,000	$100,000	$30,300	$72,750	$66,490	$75,270	$999,810	$122,450	$877,360	$418	142%	16
MFR-D CH-4	4 - Four 525 Ton Centrifugal Chillers with VFDs in Series Counter-Flow	2,100	0.549	0.357	$555,600	$170,000	$25,000	$54,600	$84,450	$120,630	$1,010,280	$88,253	$922,028	$439	149%	18
MFR-A CH-4	4 - Four 525 Ton Rotary Screw Chillers with VFDs in Series Counter-Flow	2,100	0.585	0.344	$714,000	$150,000	$30,300	$48,708	$66,490	$75,270	$1,084,768	$151,483	$933,286	$444	151%	19
MFR-C CH-2A 2	700T-8595 - Three 700 Ton Centrifugal Chillers without VFDs	2,100	0.570	0.500	$522,492	$0	$29,485	$13,184	$68,000	$78,500	$711,661	$42,000	$669,661	$319	108%	5
MFR-C CH-2A 4	700T-8597 - Three 700 Ton Centrifugal Chillers without VFDs	2,100	0.597	0.524	$543,588	$0	$29,485	$13,184	$68,000	$78,500	$732,757	$42,000	$690,757	$329	112%	7
MFR-D CH-Alt 1 and MFR-D CH-Alt 2	Alt- One 975 Ton Centrifugal Chiller and Three 365 Ton Centrifugal Chillers all with VFDs	2,070	0.596	0.379	$700,360	$120,000	$27,000	$54,950	$84,450	$120,630	$1,107,390	$124,707	$982,683	$475	159%	21
MFR-C CH-2A 6	700T-85100 - Three 700 Ton Centrifugal Chillers without VFDs	2,100	0.633	0.556	$508,386	$0	$29,485	$13,184	$68,000	$78,500	$697,555	$42,000	$655,555	$312	106%	3

Bid Information		Annual Costs						Total Annual	Life Cycle Cost					
Chiller	Description	Chiller Electricity Usage (kWh)	Pumping Electricity Usage (kWh)	Total Annual Electricity Usage (kWh)	First Year Electricity Cost ($)	Pct of Min Elec Cost (%)	Energy Use Ranking	Cooling Cost ($/ton-hr)	Electricity Cost ($PV)	Maintenance Cost ($PV)	Total Cost ($PV)	Diff From Min Cost ($PV)	Pct of Min Total Cost (%)	LCC Ranking
MFR-B CH-2C	2C - Three 700 Ton Centrifugal Chillers with VFDs and Magnetic Bearings	1,083,049	73,783	1,309,148	$98,186	100%	1	$0.036	$1,478,246	$57,036	$2,369,140	$0	100%	1
MFR-B CH-2A	2A - Three 700 Ton Centrifugal Chillers with VFDs	1,245,617	105,435	1,503,367	$112,753	115%	14	$0.041	$1,697,552	$62,889	$2,378,841	$9,702	100%	2
MFR-D CH-2A	2A - Three 700 Ton Centrifugal Chillers with VFDs	1,145,773	64,549	1,362,638	$102,198	104%	6	$0.039	$1,538,646	$138,440	$2,393,581	$24,441	101%	3
MFR-C CH-2A 1	700T-8595 - Three 700 Ton Centrifugal Chillers with VFDs	1,220,187	130,873	1,503,375	$112,753	115%	15	$0.043	$1,697,561	$120,116	$2,457,377	$88,237	104%	4
MFR-A CH-2A	2A - Three 700 Ton Centrifugal Chillers with VFDs	1,227,839	133,873	1,514,027	$113,552	116%	16	$0.042	$1,709,589	$101,433	$2,485,996	$116,856	105%	5
MFR-C CH-2A 3	700T-8597 - Three 700 Ton Centrifugal Chillers with VFDs	1,254,655	66,822	1,473,792	$110,534	113%	12	$0.042	$1,664,157	$120,116	$2,505,429	$136,290	106%	6
MFR-B CH-3A	3A - Four 525 Ton Centrifugal Chillers with VFDs	1,197,948	84,123	1,434,386	$107,579	110%	10	$0.040	$1,619,662	$83,852	$2,515,911	$146,771	106%	7
MFR-C CH-2A 1 and MFR-C CH-2A 2	700T-8595 - One 700 Ton Centrifugal Chillers with VFD, Two without VFDs	1,265,768	127,126	1,545,209	$115,891	118%	18	$0.044	$1,744,799	$120,116	$2,523,108	$153,969	106%	8
MFR-C CH-2A 3 and MFR-C CH-2A 4	700T-8597 - One 700 Ton Centrifugal Chillers with VFD, Two without VFDs	1,310,296	76,919	1,539,530	$115,465	118%	17	$0.044	$1,738,386	$120,116	$2,559,137	$189,997	108%	9
MFR-D CH-3A	3A - Four 525 Ton Centrifugal Chillers with VFDs	1,168,847	59,553	1,380,715	$103,554	105%	7	$0.041	$1,559,058	$184,581	$2,567,871	$198,732	108%	10
MFR-A CH-3B	3B - Four 525 Ton Rotary Screw Chillers with VFDs	1,126,220	61,673	1,340,208	$100,516	102%	2	$0.038	$1,513,318	$115,174	$2,585,538	$216,398	109%	11
MFR-C CH-2A 5	700T-85100 - Three 700 Ton Centrifugal Chillers with VFDs	1,292,678	58,012	1,503,005	$112,725	115%	13	$0.043	$1,697,143	$120,116	$2,590,406	$221,266	109%	12
MFR-B CH-3C	3C - Four 525 Ton Centrifugal Chillers with VFDs and Magnetic Bearings	1,111,546	86,917	1,350,779	$101,308	103%	5	$0.037	$1,525,255	$76,048	$2,592,603	$223,463	109%	13
MFR-D CH-3A Alt	3A Alt- Four 525 Ton Centrifugal Chillers with VFDs	1,125,449	67,744	1,345,508	$100,913	103%	3	$0.040	$1,519,303	$184,581	$2,596,791	$227,652	110%	14
MFR-C CH-2A 5 and MFR-C CH-2A 6	700T-85100 - One 700 Ton Centrifugal Chillers with VFD, Two without VFDs	1,364,009	69,653	1,585,977	$118,948	121%	19	$0.045	$1,790,833	$120,116	$2,605,701	$236,562	110%	15
MFR-A CH-3A	3A - Four 525 Ton Centrifugal Chillers with VFDs	1,220,129	69,960	1,442,404	$108,180	110%	11	$0.041	$1,628,715	$115,174	$2,621,249	$252,109	111%	16
MFR-D CH-4	4 - Four 525 Ton Centrifugal Chillers with VFDs in Series Counter-Flow	1,115,880	81,028	1,349,224	$101,192	103%	4	$0.040	$1,523,498	$184,581	$2,630,107	$260,968	111%	17
MFR-A CH-4	4 - Four 525 Ton Rotary Screw Chillers with VFDs in Series Counter-Flow	1,095,209	168,608	1,416,132	$106,210	108%	9	$0.040	$1,599,050	$115,174	$2,647,509	$278,369	112%	18
MFR-C CH-2A 2	700T-8595 - Three 700 Ton Centrifugal Chillers without VFDs	1,385,935	119,690	1,657,941	$124,346	127%	20	$0.047	$1,872,092	$120,116	$2,661,870	$292,730	112%	19
MFR-C CH-2A 4	700T-8597 - Three 700 Ton Centrifugal Chillers without VFDs	1,452,832	96,957	1,702,105	$127,658	130%	21	$0.048	$1,921,960	$120,116	$2,732,833	$363,694	115%	20
MFR-D CH-Alt 1 and MFR-D CH-Alt 2	Alt - One 975 Ton Centrifugal Chiller and Three 365 Ton Centrifugal Chillers all with VFDs	1,192,588	61,882	1,406,785	$105,509	107%	8	$0.041	$1,588,495	$184,581	$2,755,759	$386,620	116%	21
MFR-C CH-2A 6	700T-85100 - Three 700 Ton Centrifugal Chillers without VFDs	1,538,685	92,756	1,783,756	$133,782	136%	22	$0.050	$2,014,159	$120,116	$2,789,830	$420,690	118%	22

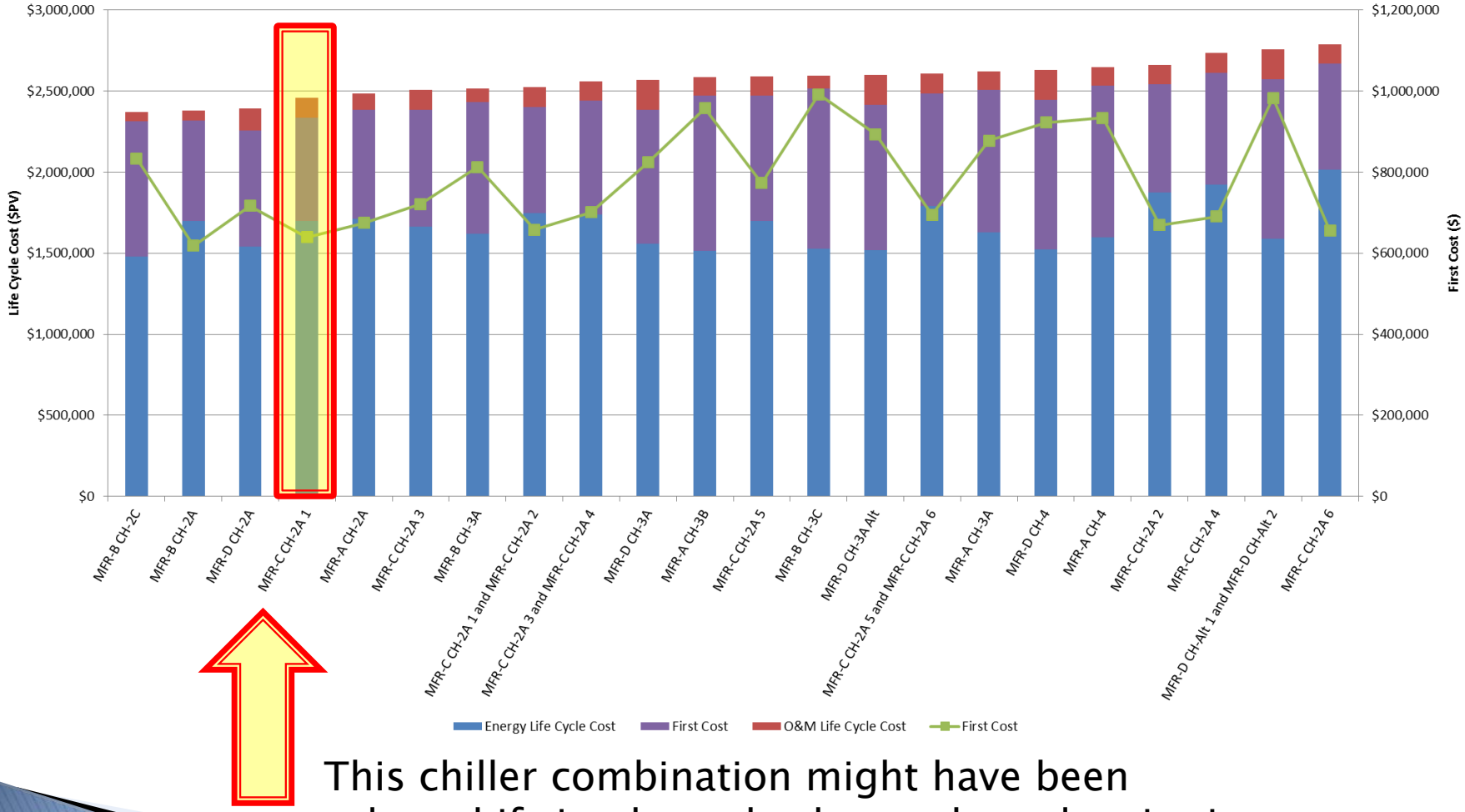
First Cost Summary with Additives



Annual Energy Usage Summary



Life Cycle Costs Summary with Additives



This chiller combination might have been selected if simple payback was the only criteria

Questions?

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