The figures above seem to prove that the existing system is simpler at first glance. However, the existing system is comprised of four totally independent systems. The redesigned system integrates all sections of the HVAC requirements as well as other building systems. The only independent system in the redesign is the back-up supplemental boiler which is still in series with the chiller-heater system. So while the existing system's concept is simpler, the redesign's complexity is used to save as much energy as possible compared to the original.

9.0 MECHANICAL SYSTEM REDESIGN CONCLUSIONS

The proposed mechanical system redesign for the Milton Hershey School New Supply Center focused on building system integration and energy savings. Integrating different building systems with the HVAC system is essential in the redesign to save as much energy as possible. The redesign system utilizes more expensive equipment than in the existing system, therefore, this integration process is even more important in an effort to receive reasonable pay back periods (about 2-4 years).

The initial cost of each system is required for the economic calculations as well as the results from a yearly energy simulation. Carrier's Hourly Analysis Program (HAP) is used to perform load calculations as well as energy simulations for both the redesigned system and the existing system. The HAP's load results for the DOAS and water source heat pumps are imported in a chiller-heater model performed in Microsoft Excel. An extensive yearly energy simulation model of the supply center using a chiller-heater and the energy recovery system is also created using Excel. The model calculates the total energy consumed by the chiller-heater and the energy savings created by using the heat recovery system. HAP is used to calculate the energy consumed by AHU fans, terminal unit fans, cooling towers, and pumps.

9.1 ECONOMIC ANALYSIS

The yearly energy simulations prove that the supply center's existing and redesigned mechanical systems have much different results. Table 9-1 indicates the natural gas rates that are provided by H.F. Lenz Company and are used for each simulation. The electric rate for the supply center used in the analysis is $0.06/kwh

Table 9-1 Natural Gas Monthly Rates

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
$/Therm	1.13	1.13	.85	.85	.85	.50	.50	.50	.50	.85	1.13	1.13

Table 9-2 illustrates the comparison of results between the existing and redesigned mechanical system.

Table 9-2 Annual Operating Cost Summery

	Existing System	Redesign w/ Chiller-Heater
Cooling Cost	$67,577	N/A
HVAC Heating Cost	$23,016	N/A
Hot Water Heating Cost	$58,371	N/A
Combined Heating and Cooling Cost	N/A	$117,370
Air System Fan Cost	$21,303	$12,318
Pump Cost	$29,274	$20,480
Cooling Tower Cost	$9,920	$16,440
Total	**$209,461**	**$166,608**

The table indicates that the redesigned system using the direct fired chiller-heater plant is the least expensive to operate per year. The greatest cost savings come in the pumps, air system fans, and cooling operational cost. Also, since the chiller-heater is able to simultaneously cool and produce hot water, there is a $31,600 savings per year compared to the existing system in heating and cooling cost.

Overall, using the redesigned system with the direct fired chiller-heater plant is $43,000 per year to operate cheaper than the existing system. The first cost of the system now comes into consideration for pay back calculations. Also, a 20 year life cycle cost analysis is required for a long term comparison between systems. Table 9-3 compares the initial cost of the two design options.

Table 9-3 Initial Cost Comparison

Equipment (Quantity and Type)	Existing System	Redesign Chiller-heater Option
Chillers (2 Centrifugal)	178,000	-
Chiller-Heaters (2)	-	450,000
HVAC Boiler (1 4500 MBH)	21,800	-
HW Boiler (2 6500 MBH)	61,000	-
Supplemental Boiler (1 9000 MBH)	-	85,000
Heat Exchangers (for HW system)	10,000	-
DOAS AHUs (2)	-	47,840
VAV AHUs (10)	309,310	-
Plate-Frame HX	10,000	20,000
VAV Boxes w/reheat	32,730	-
Heat Pumps	-	60,045
TOTAL	**$622,840**	**$682,885**

Table 9-3 indicates that the redesigned mechanical system is $60,000 more than the existing system. The costs of absorption chiller-heaters are the most expensive portion of the redesign, but due to the DOAS configuration, first cost is saved in the air handling unit category. The water source heat pumps also drive the cost of the redesign upward.

The 20 year life cycle cost (LCC) analysis provides more evidence in proving why the redesign is practical from an economic stand point. Table 9-4 illustrates the life cycle cost analysis. The table indicates that the redesign has a lower 20 year LCC with a difference of approximately $376,601. The assumed interest rate used in the calculation is 6%. Appendix B includes detailed cost spreadsheets for the entire project.

Table 9-4 LCC Analysis

i = 0.06	Existing System	Chiller-Heater Option
yr 1	209461	169108
yr 2	209461	169108
yr 3	209461	169108
yr 4	209461	169108
yr 5	209461	169108
yr 6	209461	169108
yr 7	209461	169108
yr 8	209461	169108
yr 9	209461	169108
yr 10	209461	169108
yr 11	209461	169108
yr 12	209461	169108
yr 13	209461	169108
yr 14	209461	169108
yr 15	209461	169108
yr 16	209461	169108
yr 17	209461	169108
yr 18	209461	169108
yr 19	209461	169108
yr 20	209461	169108
NPW	**$2,266,510**	**$1,829,863**
Initial Cost	$622,840	$682,885
20 Yr LCC	**$2,889,350**	**$2,512,748**

A side note to the life cycle cost analysis that needs addressed is the subject of maintenance cost. Water source heat pumps, as described above, require more maintenance than VAV boxes. However, according to absorption chiller-heater manufactures, new chiller-heaters have maintenance cost comparable to vapor compression chillers. Therefore, that cost difference per year is negligible. Overall, it is calculated that the chiller-heater option is approximately $2,500 more per year to maintain.

The remaining factor in proving if the redesigned mechanical system is beneficial is determining the pay back period. Table 9-3 indicates that the redesign must prove to payback its extra $60,000 in initial cost, and do so in a reasonable time period (2-4 years). Including interest in the calculation, yearly cost savings created by using the redesign helps pay the system back in 1.48 years. This is well within the desired time frame which makes redesign worth considering as long as the Milton Hershey School is willing to spend a little more money upfront.

9.2 MECHANICAL REDESIGN CONCLUSIONS

The mechanical redesign analysis incorporates a DOAS with water source heat pumps and integrates this air side system with other building systems. Heat is recovered from the walk-in freezer's condenser water loop to pre-heat domestic water and acts as the heat source for the water source loop that serves the heat pumps. Taking advantage of the natural gas service at the supply center, and its competitive prices compared to the electric grid, a direct fired absorption chiller-heater plant is implemented in the supply center. The redesigned plant replaces the separate vapor compression chiller and boiler plants the supply center currently utilizes. The concept keeps to the theme of the redesign of building system integration.

Economic analysis of the initial and yearly cost of each design option paves the way for a life cycle cost analysis. The LCC proves that the least expensive redesign has significant savings compared to existing system over 20 years, and it pays itself back in less than 2 years. Therefore, the proposed mechanical system redesign is a good design option.

Finally, the entire redesign incorporates the idea of system integration. Each piece of the redesign plays an important role, and is necessary to see the significant cost savings. The DOAS system alone will produce energy savings. However around half of the energy savings is seen from the simultaneous production of chilled water and hot water. The energy recovery also lowered the hot water demand and the cooling base load during peak hours. Overall, the entire redesign is required for optimal energy savings.