The Importance of Integrated Design, Commissioning, and Building Tuning: A Grocery Store Case Study

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ABSTRACT

Significant savings in heating energy can be achieved through proper application of refrigeration heat recovery techniques with minimal increases in refrigeration energy. However, barriers exist to widespread adoption due to the current specialization in the construction industry. We will detail the process needed to achieve modeled natural gas savings through direct condensation of refrigerant in the main air handler, and the resulting energy impacts on refrigeration energy and heating energy.

The grocery store construction industry for regional chains and independents in the Pacific Northwest region is compartmentalized into refrigeration, electrical, and HVAC specialties. The most effective refrigeration heat recovery involves integrated knowledge and work that affects the scope of each of those trades, and is difficult to achieve without integrated design support, careful commissioning, and tuning of the building during actual operations.

Primary barriers faced by the project described in this paper included the limited understanding of refrigeration by the design build HVAC team and the narrow focus of refrigeration contractors for optimizing the operation of only the refrigeration equipment. The inexperience of the HVAC team led to improperly sized heat recovery coils and serious problems integrating control of the heat recovery and gas heating.

Early modeling indicated that the vast majority of heating energy could be offset through use of heat recovery. However, it took more than a year of on-site commissioning, billing analysis, and building tuning to get all systems setup as originally intended to achieve modeled savings.

Introduction

A grocery store was designed by a small, local chain for a speculative development in the suburbs of Seattle in early 2006. The store was designed and had a contractor and design-build team of subcontractors hired when the original grocery store chain backed out of the planned development. The plans were sold to another small, local chain with a marketing focus on energy efficiency and sustainable building design. This new client hired their own architect and consultant team to alter the original design to achieve a LEED® Gold rating from the U.S. Green Building Council, and to create an energy efficient store. The original design and design-build subcontractor team were retained by the new client.

Ecotope was brought in with funding from the *Better Bricks* program of the *Northwest Energy Efficiency Alliance* to make recommendations to improve the energy efficiency of the design. A model of the building was created by VaCom Technologies using the DOE2.2R program and a range of measures to improve the base design were evaluated.[1] These included

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[1] DOE-2.2R (Release 46a) was used for building simulation work. DOE-2.2R is a sophisticated hourly energy simulation program that can accurately model the hourly interaction between building envelope, HVAC systems,

measures to improve: building envelope; HVAC equipment; lighting and daylighting; refrigeration cases; refrigeration compressors and condensers; and refrigeration heat recovery to the main HVAC unit. Almost all of the recommended measures were accepted by the client and the design-build team was instructed to alter their designs to incorporate the recommended measures. During the course of design and construction a number of the measures were not achieved due to a combination of a compressed time scale, inexperienced contractors, poor coordination, and mistakes. However, the majority of measures were installed when the store opened. A measurement and verification and re-commissioning study nearly a year after opening found that although they had been installed, a number of the measures had never been fully implemented as a result of a lack of understanding on the part of the contractors, service, and operations staff of the integrated functioning of the entire system. After adjustments the store was finally set up and is operating in a manner which achieves the savings originally modeled. Furthermore, additional improvements were made and are planned that will continue to improve the energy performance of the store.

Energy Efficiency Measures

After the initial store design was analyzed, a range of improvements were evaluated and modeled.[2] The most significant measure was the incorporation of heat recovery from the refrigeration system to the main air handler. This results in a reduction of 70% in the gas used for space heating. A wide range of equipment and control measures result in a predicted reduction of 22% of the electrical energy.

Through negotiations with the client and their design-build team all of the proposed measures were theoretically agreed upon except for cycling of the walk-in fans which was rejected by the client operations manager as potentially damaging to the products. Ecotope put together a description of the measures to be incorporated and made them part of the contract documents. The design-build team accepted those improvements and provided change order budgets to the client.

Design-Build

The design-build approach to building made achievement of the energy efficiency goals very challenging. Features of this approach that presented obstacles included: a compressed time frame for construction; contractors inexperienced with the proposed measures; designers reluctant to change their designs to incorporate the proposed changes; and a lack of clear contract documents spelling out the responsibilities of each subcontractor. To properly function, the proposed design required a level of integrated design that the traditional design-build approach is not well suited to deliver. In a fully integrated design specification project, all the integration points would be worked out ahead of time and contractors would be implementing a fully integrated design. But in a design-build situation each contractor is responsible for designing their portion, which makes integration much more challenging.

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lighting systems, and refrigeration systems. Weather and utility rates for Seattle, Washington were used for the study.

[2] A list of measures and modeled results are shown at the end of this paper, Table A1.

Refrigeration

Ecotope recommended a range of improvements over a standard refrigeration system design including measures associated with the compressors, condensers, and cases. A major refrigeration equipment supplier provided design-build racks and equipment to the refrigeration subcontractor. This national design-build supplier was unresponsive regarding the requested design improvements and a substantial amount of engineering supervision was required to achieve them. The design had to be reviewed and returned to the design-build supplier four times before it was acceptable. This level of detailed review and persistence was only possible because Ecotope was assisted by Doug Scott of VaCom Technologies who has extensive experience with these systems and was able to interpret and critique what the refrigeration supplier was proposing.

HVAC

The mechanical engineer for this project was conscientious but lacked knowledge and experience with refrigeration systems and was unable to accurately account for the refrigeration load in his design. This led to an overly large calculated cooling load. Integration of refrigeration heat recovery requires a certain level of refrigeration knowledge from the HVAC designer that is not common in the industry. Due to perceived time constraints on ordering the equipment he relied on his usual commercial equipment supplier to help him. The equipment supplier was also inexperienced with refrigeration heat recovery. They sold him a standard rooftop VAV unit with an after-market heat recovery coil installed with no means of control. They also included an on-board unit controller set up for VAV operations (the standard controller for that type of unit installed on an office building – variable volume, constant temperature).

This rooftop unit has never been able to be fully integrated into the building control system. Its on-board controls can not be bypassed by the building control system. The selection of this unit and the inability of the HVAC or controls contractor to work out the controls integration have led to an inability to implement a number of the planned energy efficiency measures (CO_2 controls, variable damper operations, variable fan speed). The unit is functioning with a fixed outside air damper and a constant volume continuous fan. Additionally, the cooling has never worked properly, although it has never been needed. During the hottest day of the year when temperatures exceeded 100°F at the make-up air damper, the peak temperature at the indoor temperature sensor 8 feet off the floor was 76°F. The rooftop unit also has full economizer controls which are never used. The outside air damper was designed to be set at 30% outside air to act as make-up air for the kitchen hoods in an attempt by the mechanical engineer to maintain building pressure. After lengthy discussions Ecotope convinced them to reduce this to 10% which improved the comfort and energy efficiency of the space.

There are various ways to accomplish heat recovery in the grocery industry and it remains a poorly understood art. Ecotope's proposed design was for full refrigerant condensing in a coil in the air handler supply, with a hold back valve upstream of the gas furnace. The idea was to condense most of the refrigerant in the air handler so that the majority of the heat is recovered and the rooftop condensers have very little work to do before returning the refrigerant to the compressors. The mechanical engineer did not know how to design the heat recovery coil, and so relied on help from his equipment supplier. The equipment supplier did not know how to design the coil and so they relied on the after-market coil manufacturer. They in turn provided a coil with very small piping connections not designed for the full flow of the refrigerant. Ecotope discovered this coil during an early commissioning walk-through and it was removed and replaced at significant cost to the client.

The HVAC engineer designed near-floor return ducting in the frozen food isles to improve comfort by reducing cold air stratification in that area. Unfortunately the near-floor return ducts were never installed due to time constraints on the design and difficulty incorporating the ducts into the display shelving. They were eliminated from the design by the client without fully consulting the design team.

Lighting

Lighting design was assisted by the Lighting Design Lab and the Daylighting Lab. Lighting fixture selection and design were driven by a desire for “sparkle.” This limits the number of fixtures that can be turned off from daylight sensors. Skylights were added to allow for about 40% of fixtures to be turned off during daylight hours.

Three-level switching (100%, 50%, 0%) was implemented as the most economical way to achieve daylight control. The intent was to have two circuits to each daylight controlled fixture so that ½ of the lamps in each fixture could be switched separately. The intent was also to have different retail zones of the store circuited separately so that different zones could have their lights controlled at different levels and times. Unfortunately, the design-build electrical contractor simplified the circuiting without regard to retail zones, so that different zones could not be controlled separately. Furthermore, they wired every-other light to a separate circuit so that at the 50% condition half of the fixtures are off, which does not deliver uniform light to the space. The resultant daylighting control is to turn half of the lamps off during daylight hours only.

Controls

Controls were the responsibility of the refrigeration contractor. This allowed HVAC and electrical contractors to shift all responsibility for sequence of operations to the refrigeration contractor. Integration of these systems was not well planned and the refrigeration contractor was not well-versed in how to control HVAC or lighting systems. The design-build approach led to significant redundancy of controls as every subcontractor provided controls for their equipment even though it was clear in design meetings that a central building control system would be provided. Redundant controls were provided on the main air handler, the lighting panels, and the condensers.

Measurement and Verification

Ecotope returned to evaluate the operation of the store after one year of occupancy. This effort reviewed the Measurement and Verification data and the control system settings to verify that operations were taking place per the original design intent, and to determine the efficacy of the various energy conservation measures. As a result of findings during this study a number of changes were made which significantly improved the energy efficiency of the store.

The primary comfort issue remaining in the store at that time was low temperatures near the floor in the main sales area (~60^{o}F). This was due to the large amount of open refrigerated cases in the store and exacerbated by the fact that only a small amount of the return air was being taken from near the floor. During construction one of the two near-floor returns was deleted from the scope. When this happened no attempt was made to balance the airflow and as a result nearly all of the return air was drawn from near the ceiling. This resulted in extreme stratification in the store (over 20°F difference between floor and ceiling). The HVAC contractor was asked in February 2007 to return to balance the return ducts to draw ½ of the return air from the remaining near-floor returns. To accomplish this the HVAC contractor "temporarily" placed a piece of cardboard over a portion of the upper return opening to force more of the air to be drawn from below. It is not clear how the HVAC contractor determined how much of the upper duct opening to block off. The piece of cardboard was discovered six months later during further building tuning efforts. As a result of this study the HVAC contractor returned and extended the high return opening to the floor in the coldest corner of the store.

Control settings for heat reclaim at the main air handler were poorly adjusted resulting in reduced efficacy of the heat recovery. The settings turned off the heat reclaim when a setpoint of 73°F was reached. This setpoint for heat reclaim was raised to 76°F to keep the heat reclaim on continuously and allow the store to warm up more during the day to reduce gas usage at night.

The HVAC units in the perimeter spaces (Classroom, Deli, and Office) had a very conservative schedule. The occupied settings for these units were 3:15AM to 11:15PM. These settings were changed so that occupied periods for these spaces more closely matched the actual usage. (8:00AM-10:00PM for the classroom, 8AM-8PM for the office, and 5:00AM-10:00PM for the deli).

The refrigeration system was not set up according to the Basis-of-Design documents. Floating suction pressure was only implemented on some compressor groups, a fixed setpoint was being used to float head pressure, and the holdback valve on the heat recovery coil was never set.

The refrigeration system veered from the Basis-of-Design documents as follows:

- Floating Suction Pressure: The Basis-of-Design documents called for: "All suction groups except for +35°F SST and single compressor satellites shall be controlled with floating suction pressure control, with the suction pressure setpoint adjusted to maintain fixture temperature on the most demanding branch circuit. Negative float limit shall be zero and positive float limit shall be no less than equivalent of 5°F SST. Verify operation by using historical graphs to confirm float is operating during non-peak load periods." This was only implemented on a single compressor group. The contractor set this up correctly following the re-Cx study.
- Floating Head Pressure: The Basis-of-Design document states: "The condenser shall utilize floating head pressure control to 70°F or lower and ambient following control logic. System shall use variable setpoint control with mechanical subcooling. Variable speed drive on each condenser shall control all motors in unison down to a minimum speed of 15% (±5%), with low-limit pressure maintained by holdback/bypass valve set below the condenser fan control setpoint." This control algorithm was not implemented. To implement this, the refrigeration contractor added a pressure sensor at the condenser and reprogrammed the condenser control to vary the fan speed based on a constant temperature difference (TD) between the condensing temperature and the ambient

temperature. The logic for this control methodology was available through the installed control system.

- Holdback Valve: The refrigeration contractor needed to return to set the holdback valve on the medium temperature rack to condense at about 95°F (as noted in the Refrigeration Basis of Design). This caused the refrigerant to condense in the heat reclaim coil and raised the supply air temperature to about 90°F, effectively doubling the amount of heat reclaim taking place.

When asked why the holdback valve was not set, the refrigeration contractor replied that setting the valve would only increase the energy use of the refrigeration system. The contractor made this statement even though he had attended numerous meetings in which the heat recovery concept and design were discussed and significant gas savings were presented. This illustrates the fact that integrated thinking is very difficult to accomplish. After another meeting with the refrigeration contractor, the O&M manager, and the facilities director, the contractor finally understood that the gas savings would more than offset the small increase in electrical load caused by the hold back valve.

The daylighting and lighting control strategy was found to be yielding only small electrical savings. Traces from the lighting submeters indicated approximately a 10% or 4KW reduction in lighting loads during the daylight hours. This was significantly lower than the original goal of approximately 40% of the lights turned off during the day. This was primarily due to aesthetic decisions of the client. Note that since this store is almost continuously in heating mode, savings associated with lighting reductions are not fully realized as reductions in lighting energy lead to an increase in the need for heating energy.

The control system has a limited capability to capture and store data. The client's O&M team never intended to use the data tracking capabilities of the system, so it was not set up for effective Measurement and Verification. It can track any input or output point; however, each data point must be set up for tracking in the control system. As part of that setup, the frequency to record data for that point and the number of data points to accumulate before they are over-written must be entered. It appears that the default setup is to record data every 5 minutes with a maximum of 6000 data points before the data is overwritten. This only yields about 20 days of data which is useless for trying to evaluate seasonal effects of various measures. These settings were adjusted so that we were only logging data as frequently as needed to extract useful information. Although the capability for monitoring and diagnosis are available through the control system, the client's O&M personnel are not capable of this level of building analysis and tuning.

Billing and Data Analysis

Ecotope evaluated billing data to determine the effectiveness of the various energy efficiency measures. Hourly billing data was available through the utility's website. In addition, Ecotope obtained submetered data via the building control system. These included two lighting panel submeters collecting total energy use for electric lighting, two refrigeration rack submeters collecting total electrical energy use for the refrigeration racks, a gas submeter collecting gas usage for the kitchen, and a flow meter collecting volume data for the domestic hot water.

Table 1 presents data on natural gas consumption. The total gas consumption was estimated from the last six months worth of actual bills from PSE. The cooking gas was taken from the gas submeter and assumed to be constant throughout the year. The DHW gas usage was calculated from the flow data and temperature data at the preheat tank and assumed to be constant throughout the year. The remainder of the gas was assumed to be for space heating and is shown as "HVAC Inferred." Note that the actual gas usage for HVAC is somewhat higher than the amount of gas usage predicted by the model for the baseline building, and nearly four times the amount predicted for the store with a fully operational heat recovery system.

Table 1. Estimated Annual Gas Usage (in Therms)

Total Gas Use from Bills	Cooking from Submeter	DHW from Submeter	HVAC Inferred	Baseline HVAC Modeled	Proposed HVAC Modeled
35,900	900	1,100	33,900	30,000	9,200

Table 2 presents data on electricity consumption. The total was estimated from the last six months worth of actual bills from PSE. Lighting and compressor energy was estimated from submeter data. The condenser energy was calculated from data logged by the control system. Additional refrigeration energy associated with the case work fans and doors was estimated. HVAC fan and cooling energy was calculated from data logged by the control system. The remainder of the energy is included in the "Other" category. This includes all office energy such as computers, printers, phones, and cash registers, and all kitchen and deli electricity associated with the exhaust fans, cooking equipment, dishwashers, coffee makers, and plug-in refrigerators, and any other miscellaneous electricity use in the store.

Table 2. Estimated Annual Electrical Usage in kWh.

Total Electric from Bills	Lighting from Submeter	Compressor from Submeter	Condenser Calculated	Refrigerated Cases Estimated	HVAC Calculated	Other Calculated
1,021,000	261,000	374,000	126,000	78,000	55,000	127,000

The lighting energy use is significantly higher than predicted primarily due to the fact that there are somewhat more lights in the store than modeled, the model assumed that most of the lights would be turned off for a longer period of time at night, and the model assumed that 40% of the retail lights would be turned off during daylight hours.

Table 3 presents modeled electrical use for the store as actually configured by the contractors. The combined HVAC and refrigeration electrical use of 650,000 kWh/yr compares favorably with the sum of refrigeration and HVAC usage from Table 3 above (633,000 kWh/yr).

Table 3. Modeled Annual Electrical Usage in kWh

Baseline Lighting	Proposed Lighting	Baseline Refrigeration and HVAC	Proposed Refrigeration and HVAC	Model prediction of actual set-up (fixed setpoint condenser control, no VAV or CO2 on air handler)
188,000	157,000	751,000	571,000	650,000

Final Building Tuning

The recommended changes from the Measurement and Verification study were made and led to an insignificant increase in electrical usage and a significant decrease in gas usage. The electrical increase is expected to increase bills by about $30/yr, while the decrease in gas usage is predicted to save about $21,000/yr. Submeters were used to collect energy use data for a period of two weeks before and after the changes. Time periods evaluated were defined as: "Before" = September 14 – September 27, 2007; and "After" = October 1 – October 14, 2007.

The changes made related to the methodology for controlling the refrigeration condenser fans and the setting of the holdback valve at the heat recovery coil in the main air handler to raise the condensing temperature. The conditions of these items are described below for the two periods:

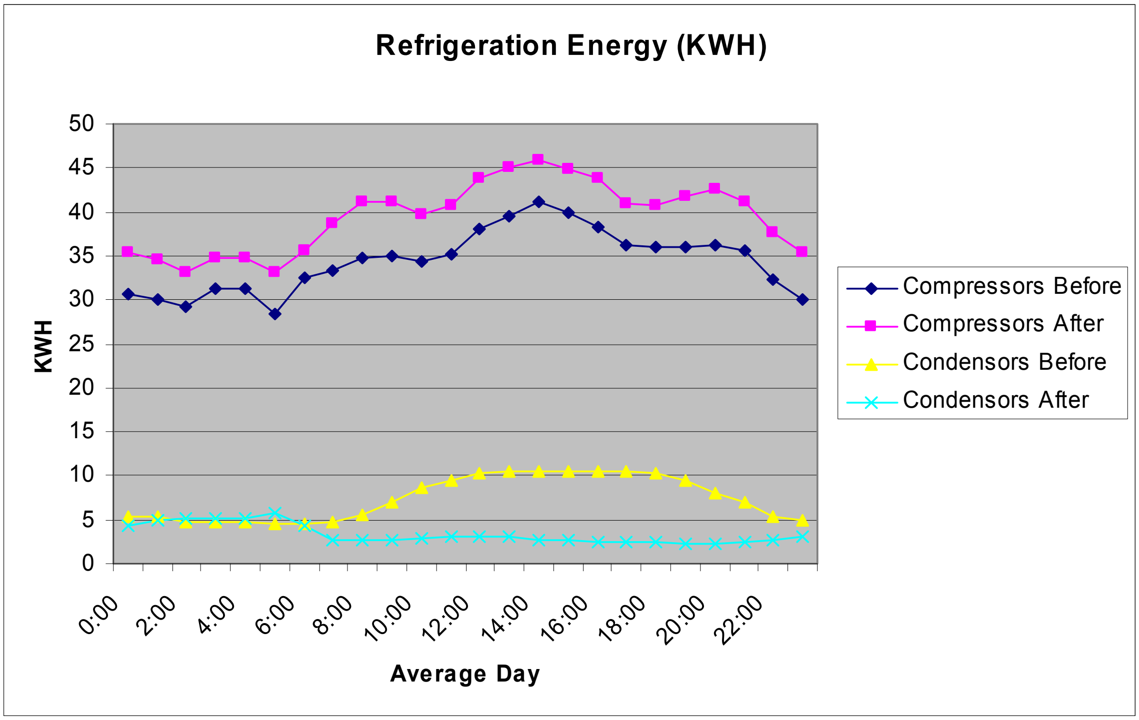
Before: The condenser fans were operating to maintain a fixed pressure setpoint at the discharge of the compressors. The holdback valve was in the wide open position. This kept compressor energy to a minimum, but caused the condenser fans to run more than necessary. A wide open holdback valve led to relatively low condensing temperatures in the coil and recovery of only the superheat portion of the available heat of rejection.

After: On September 28th the refrigeration contractor added a pressure sensor at the condensers on the roof. They then changed the logic controlling the condenser fans to "Ambient Following." This logic runs the condenser fans to maintain a fixed temperature difference of 10°F between the ambient air temperature and the condensing temperature of the refrigerant. This significantly reduces the runtime of the condenser fans when paired with heat recovery. At the same time the holdback valve on the heat recovery coil was set to raise the pressure in the coil to achieve a condensing temperature of 95°F. This resulted in more energy being used by the compressors, but caused the refrigerant to condense in the heat recovery coil, extracting a much higher percentage of the heat of rejection.

Data collected after building tuning indicated that the actual energy use for refrigeration and HVAC is very close to what was predicted by initial modeling. The following graphs and tables show the conditions before and after the changes.

The refrigeration equipment behaved very much as predicted after the final building tuning. The compressor racks used approximately 15% more energy after the switch, and the condensers used about 55% less energy. These two effects nearly balanced each other with an overall increase of about 1KWH per day in electrical usage. The data were condensed to an average day and are shown in Figure 1.

Figure 1. Condenser and Compressor Energy Use for an Average Day



The dramatic drop in condenser electricity usage can be seen Figure 2. Note that the energy use for the condensers serving Rack A is much lower and relatively unchanged, while the energy use for the condensers serving Rack B (with the heat recovery coil) are reduced significantly. Figure 3 shows the small increase in electricity usage for the compressor system.

Figure 2. Condenser Energy Use Before and After Adjustments

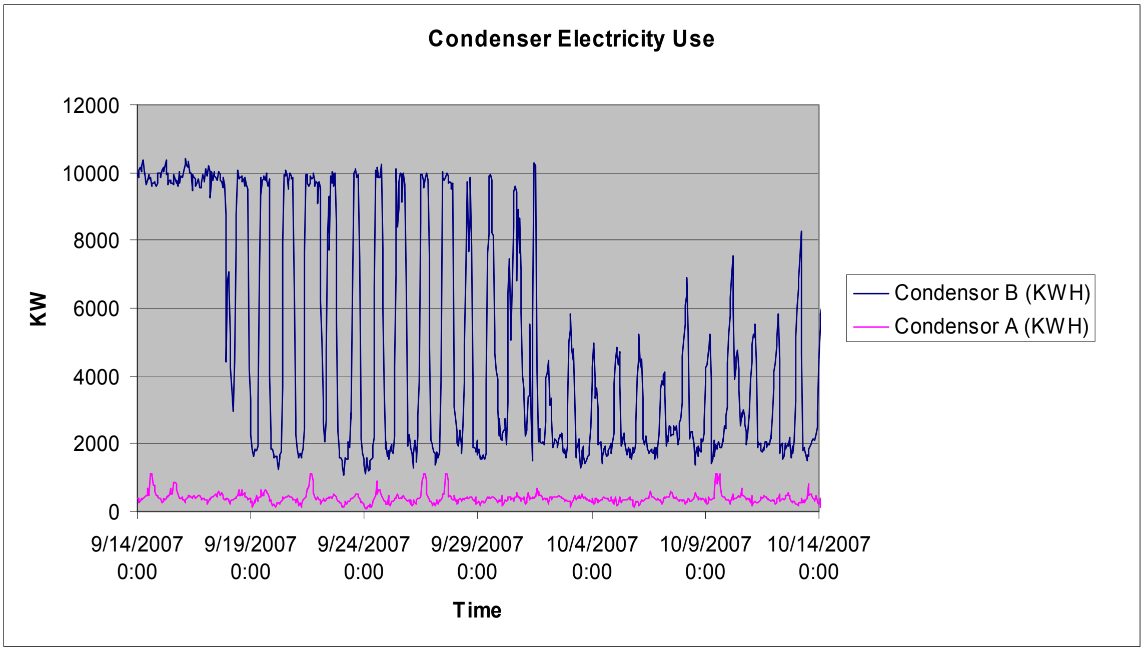
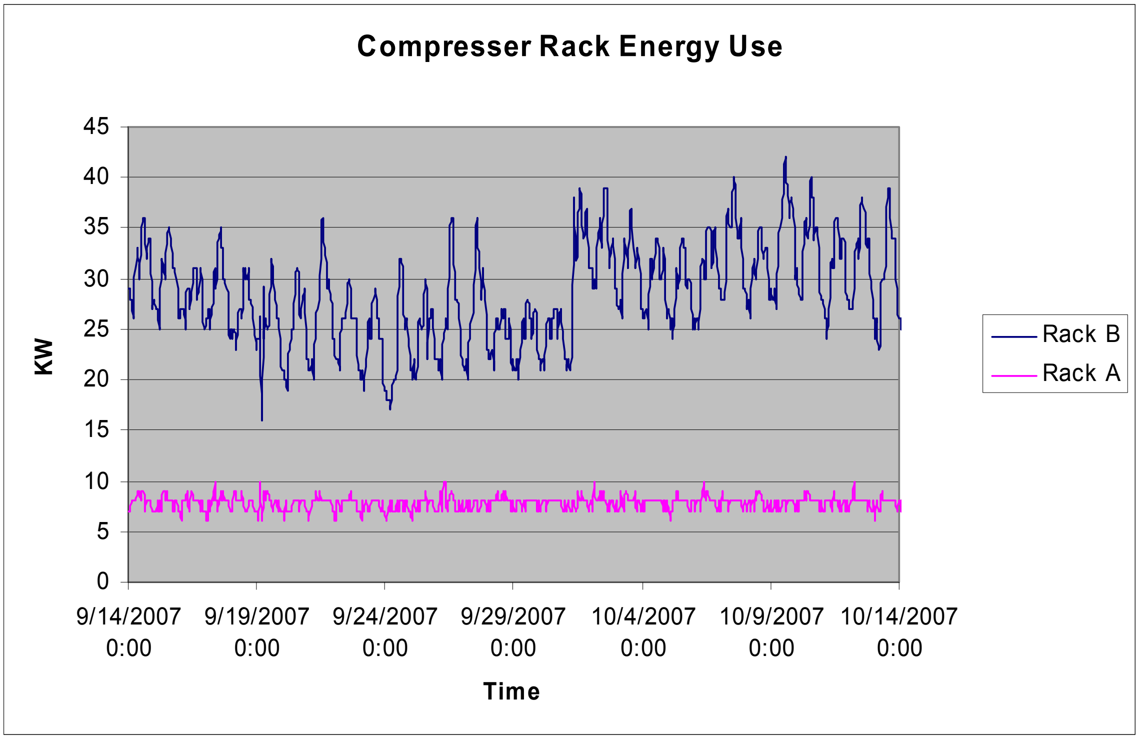


Figure 3. Compressor Energy Use Before and After Adjustments



The data show a dramatic improvement in the efficacy of the heat recovery system and a consequent reduction in gas usage. Evaluation of the gas usage was somewhat more complicated than the electrical usage. Total gas usage was determined from the PSE website. Gas used for cooking was subtracted from this amount on an hourly basis for the period of interest. Gas usage for hot water was estimated based on readings of hot water volume and temperature for each hour of the period of interest, including an estimate of standby losses associated with the tank and recirculation loop. Hours of space heating for each of the other three rooftop units was then determined from log files and gas usage calculated for those units. The remaining natural gas use was assumed to be the space heat for the main sales floor.

Gas usage for space heating on the main sales floor dropped by about 35% for the two week period following the changes compared to the two week period before the changes. During this same time the average outdoor air temperature also dropped by an average of 4°F. Ecotope used a regression analysis to estimate the impact of these savings on an annual basis using a temperature adjustment. Seattle TMY temperature bin data was used to calculate long-term outdoor temperature. The regression used the observed outdoor and indoor temperature difference in the two study periods and the heating energy used in each period. For this purpose the data were summarized hourly.[3] Separate coefficients were generated for the "before" and "after" periods and these coefficients were applied to the long-term temperature record. The result was two separate estimates of the required space heat: the heating required by the initial configuration and the space heat required by the altered configuration. Using these analyses we estimated annual heating energy before the changes to be about 36,000 Therms/yr, and an energy use of about 16,400 Therms/yr after. This indicates a savings of about 19,600 Therms/yr in gas

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[3] Seattle TMY bin data indicates 164,147 base 70 degree-hours, with regression analysis yielding correlations of 0.22 Therms/hrF before and 0.10 Therms/hrF after the changes.

usage. This compares to our earlier estimate of 34,000 Therms/yr for heating in the last billing analysis, and a savings prediction of 12,000 Therms/yr.

The last improvement that was made to the store as a result of our analyses was the addition of the near-floor return air ducting. The effect of this change was to lower the average return air temperature by 10°F with no measurable change to the average supply air temperature. This indicates a significant increase in the rate of heat recovery due to the fact that the air through the air handler has a higher capacity to carry heat to the store. On an annual basis this represents a reduction in gas usage of about 9400 Therms. This leads to an annual predicted natural gas usage of only about 7000 Therms/yr. Table 4 shows the modeled and calculated gas usage for the store in its various configurations:

Table 4. Natural Gas (Therms) Used for Space Heating Under Various Conditions

Initial Design (Modeled)	Proposed Design (Modeled)	Initial Set-up (Measured / Inferred)	After Setting Holdback Valve (Measured / Calculated)	After Adding Low Return (Calculated)
30,000	9200	33,900	16,400	7000

Conclusion

The construction industry in the Pacific Northwest is not yet well positioned to deliver optimal energy efficiency in new grocery stores for regional chains and independents. This is due to inexperience, lack of integrated understanding, and limitations of the design-build approach to construction. Building commissioning can improve the situation by ensuring that the building is nominally set up to function per the intent of the designers. However, even with building commissioning the systems can not be expected to deliver optimal energy efficiency. This is due to the fact that "design intent" is developed before the actual building is constructed and operating and is typically very conservative by nature. Optimal energy efficiency can only be attained by detailed analysis and "building tuning" by trained energy efficiency analysts. This is true in all building types, but especially in energy intensive buildings such as grocery stores where a correctly operating system requires close integration across a number of building trades.

APPENDIX A: Modeled Energy Efficiency Measures

Table A1. Modeling Results

		Site Energy				Baseline Source Energy		Peak Demand (kW)	Lighting Electric (kWh)	HVAC/Refrig. Energy			Peak Cooling (Tons)	Energy Reduction (kWh)
		Electric (kWh)	N. Gas (Therms)	Total (MBtu)	Index (kWh/ sf/yr)	Total (MBtu)	EUI (kBtu/sf/yr)			Electric (kWh)	N. Gas (Therms)	Total (MBtu)		
Run 1	Standard Practice Base	1,023,472	28,093	6,302	45	13,289	582.1	156	233,207	790,265	28,093	5,506	13	
Run 2	EEM 1: Initial Design	938,248	29,993	6,202	41	12,606	552.2	146	187,572	750,676	29,993	5,561	14	
	EEM 1 vs Std. Practice Base													85,224
Run 3	EEM 5a: Alternate refrigeration system	892,116	30,039	6,049	39	12,138	531.7	141	187,588	704,528	30,039	5,408	14	
	EEM 5a vs EEM 1													46,132
Run 4	EEM 5b: EEM 5a with floating head pressure (fixed setpt.)	873,007	30,008	5,980	38	11,939	523.0	141	187,580	685,427	30,008	5,340	14	
	EEM 5b vs EEM 5a													19,109
Run 5	EEM 5c: EEM 5a with FHP (var.setpt.) and variable speed control	826,234	29,992	5,819	36	11,459	501.9	125	187,576	638,658	29,992	5,179	14	
	EEM 5c vs EEM 5a													65,882
Run 6	EEM 6: EEM 5c with refrigeration heat reclaim to main HVAC unit	868,785	8,993	3,864	38	9,795	429.0	125	187,578	681,207	8,993	3,224	14	
	EEM 6 vs EEM 5c													-42,551
Run 7	EEM 7: EEM 6 + Efficient roof top units	867,190	8,993	3,859	38	9,778	428.3	124	187578	679,612	8,993	3,219	14	
	EEM 7 vs EEM 6													1,595
Run 8	EEM 8: EEM 7 + Variable speed drive on sales area HVAC	817,726	8,993	3,690	36	9,272	406.1	119	187,578	630,148	8,993	3,050	14	
	EEM 8 vs EEM 7													49,464
Run 9	EEM 9: EEM 8 + CO2 based ventilation control	814,475	8,993	3,679	36	9,239	404.7	116	187,586	626,889	8,993	3,039	14	
	EEM 9 vs EEM 8													3,251
Run 10	EEM 10: EEM 5a + Floating suction pressure	890,386	30,039	6,043	39	12,120	530.9	141	187,588	702,798	30,039	5,403	14	
	EEM 10 vs EEM 5a													1,730
Run 11	EEM 11: Initial Design plus dfficient display case fan motors	902,157	30,110	6,090	40	12,248	536.5	142	187,571	714,586	30,110	5,450	14	
	EEM 11 vs EEM 1													36,091
Run 12	EEM 12: Low wattage reach-in doors	987,158	28,527	6,222	43	12,960	567.7	152	233,207	753,951	28,527	5,426	13	
	EEM 12 vs. Std. Practice Base													36,314
Run 13	EEM 13: Initial Design plus efficient walk-in fan motors	916,601	29,993	6,128	40	12,384	542.5	143	187,572	729,029	29,993	5,487	13	
	EEM 13 vs EEM 1													21,647
Run 14	EEM 14: Initial Design plus walk-in fan cycling	924,510	29,995	6,155	40	12,465	546.0	144	187,572	736,938	29,995	5,515	14	
	EEM 14 vs EEM 1													13,738
Run 15	EEM 15: Initial Design plus proposed lighting power density	922,596	30,504	6,199	40	12,497	547.4	143	172,359	750,237	30,504	5,611	14	
	EEM 15 vs EEM 1													15,652
Run 16	EEM 16: EEM 15 plus skylights and lighting control	907,083	30,835	6,179	40	12,371	541.9	136	156,897	750,186	30,835	5,644	14	
	EEM 16 vs EEM 15													15,513
Run 17	EEM 17: Initial Design plus domestic water heat reclaim	938,248	27,256	5,928	41	12,332	540.2	146	187,572	750,676	27,256	5,288	14	
	EEM 17 vs EEM 1													0
Run 18	EEM 18: Initial Design plus proposed roof insulation	938,397	29,546	6,157	41	12,563	550.3	145	187,572	750,825	29,546	5,517	14	
	EEM 18 vs EEM 1													-149
Run 19	Combo #1 : Initial Design plus EEMs 11&13	880,501	30,111	6,016	39	12,026	526.8	139	187,571	692,930	30,111	5,376	13	
	Combo #1 vs. Std. Practice Base													142,971
	Combo #1 vs. EEM 1 Initial Design													57,747
Run 20	Combo #2 : Initial Design plus EEMs 5c & 10	824,099	29,992	5,812	36	11,437	501.0	125	187,576	636,523	29,992	5,172	14	
	Combo #2 vs. Std. Practice Base													199,373
	Combo #2 vs. EEM 1 Initial Design													114,149
Run 21	Combo #3 : Initial Design plus EEMs 5c, 6, 7, 8 & 9	814,475	11,540	3,934	36	9,493	415.8	116	187,586	626,889	11,540	3,294	14	
	Combo #3 vs. Std. Practice Base													208,997
	Combo #3 vs. EEM 5c													123,773
Run 22	Combo #4 : Initial Design plus EEMs 15 & 16	907,083	30,835	6,179	40	12,371	541.9	136	156,897	750,186	30,835	5,644	14	
	Combo #4 vs. Std. Practice Base													116,389
	Combo #4 vs. EEM 1 Initial Design													31,165
Run 23	Combo #5 : Initial Design plus EEMs 5c,6,7,8,9,10,11,13,15,16,17,18	727,707	9,178	3,401	32	8,369	366.6	100	156,912	570,795	9,178	2,866	13	
	Combo #5 vs. Std. Practice Base													295,765
	Combo #5 vs. EEM 1 Initial Design													210,541