In this report, two common HVAC systems were proposed for grocery store renovation, they are:

1. Roof Top package system
2. Air-source heat pump system

The two types of systems have their own unique features. This report summarized a few criteria that used to compare these two systems. Here, we list some important findings from the study.

1. First Cost: $1500/Tons RTUs Vs. $3500/Tons Air-source heat pump
2. Life Space: 20 years and above RTUs Vs. 15 years and above Air-source heat pump
3. Appearance: RTUs are not pretty Vs. Heat pump looks more appealing
4. Energy Efficiency: RTUs generally consumes more energy than Air-source heat pump

Roof top unit was recommended for grocery store due to it is a system that easy to be installed and maintained. After HVAC system is selected, we went through different manufacturer’s products regarding to the refrigerant each product used. The Carrier WeatherMaster series are using R-410A, which has better environmental-friendly feature than conventional refrigerant such as R-22. However, there is higher requirement on system structure due to its higher operation pressure.

Then, simulation model was built based on the efforts from our design teams. Other critical assumptions such as occupancy, lighting etc. were taken from well-known sources such as IECC 2009, IMC 2009 as well as DOE reference building. A system sizing performed before simulation, which indicates the building requires a 8.5 tons RTU to meet cooling and heating peak load.

From the initial simulation, we found out that picking up wasted heat from refrigeration cases and use it for space heating and domestic hot water system could have significant impact on total energy consumption. This was then applied to the model. The results shows around 10% total energy reduction with 48% from space heating and 63% from domestic hot water.

All the sources used in this report can be found online:

5. TRANE HVAC system products, Available at <http://www.trane.com/COMMERCIAL/Products/Default.aspx?i=876>
1. Proposed System: RTUs and Air-Source Heat Pump System

1.1 Roof Top Unit

A roof top package unit system is recommended for the grocery store. Roof top package unit system is a self-contained, packaged air-conditioning unit system that not only packaged direct expansion cooling coil, condenser, furnace as well as a variable speed fan, but also can be easily customized with heat recovery options for outdoor air heat recovery or refrigeration cases heat recovery, which makes it an ideal system for grocery store.

Currently, RTU’s are available in most of HVAC manufacturers such as Carrier’s weather master series, Daikin’s Maverick series and RoofPak series and Trane’s ICS series. In additions, RTU’s is capable for small and medium size commercial buildings whose cooling load might range from 2 tons to above 100 tons.

Furthermore, as described by some of practitioners in mechanical system industry, RTU is one of the system types that can be easily maintained and operated. Also, the system is so popular that the parts and maintenance cost will be lower than some other newly introduced HVAC systems in U.S.

1.2 Air-Source Heat Pump System

Air to air heat pump system is another recommended HVAC system for this application. Heat pump system has high performance in climates with moderate heating and cooling needs. Therefore, in a heating dominated climate such as Pittsburgh, an additional boiler is required to maintain the loop water temperature, which will increase the first cost of this type of system. However, besides the cost, there are plenty of great features it can offer to make this type of system desirable by mechanical engineers and house owners. As reported by DOE, the air-source heat pump normally can trim the amount of electricity bill for heating by as much as 30% to 40%.\(^1\) In summer, most of heat pump system can dehumidify the outdoor air better than standard central air system, resulting less energy consumption as well as more thermally comfortable indoor space.

Currently, manufacturers such as Lennox, York and Comfort Star etc. are manufacturing both residential and commercial use heat pumps with high efficiency. Also, there are list of Energy Star qualified air-source heat pump products available at the following link: <http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=EP>

As summarize, a design factor table for decision-making was developed in the table at next page.

---

Table 1. Comparison between two Different Systems

<table>
<thead>
<tr>
<th>Factors</th>
<th>RTUs</th>
<th>Air-Source Heat Pump</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Costs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. First Cost</td>
<td>Around $1500/Ton</td>
<td>Average $3500/Ton</td>
</tr>
<tr>
<td>2. Replacement Cost</td>
<td>Parts are not expensive</td>
<td>Parts can last long time</td>
</tr>
<tr>
<td>3. Mount</td>
<td>On Roof</td>
<td>Flexible (wall, basement etc)</td>
</tr>
<tr>
<td><strong>2. Codes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>3. Space Available</strong></td>
<td>Roof</td>
<td>Basement, Roof</td>
</tr>
<tr>
<td><strong>4. Equipment Available</strong></td>
<td>Available at most of time</td>
<td>Available at most time</td>
</tr>
<tr>
<td><strong>5. Equipment Life Span</strong></td>
<td>20 years and above</td>
<td>15 years and above</td>
</tr>
<tr>
<td><strong>6. Flexibility</strong></td>
<td>High flexibility</td>
<td>High flexibility</td>
</tr>
<tr>
<td><strong>7. Appearance</strong></td>
<td>Not Pretty, see figure 1 below</td>
<td>More appealing than RTUs</td>
</tr>
<tr>
<td><strong>8. Noise</strong></td>
<td>Low noise in the zones</td>
<td>Low noise in the zones</td>
</tr>
<tr>
<td><strong>9. Environment Impact</strong></td>
<td>Noisy to the surround environment</td>
<td>Low impact to the environment</td>
</tr>
<tr>
<td><strong>10: Control Level</strong></td>
<td>Simple Control</td>
<td>Simple Control</td>
</tr>
</tbody>
</table>

In this report, we will demonstrate one type of the above two systems with EnergyPlus simulation tool as well as integration of refrigeration cases waste heat recovery option with HVAC system. Although Air-source heat pump has great energy efficiency performance, we would like to use Roof Top Package Unit as our case study due to it is relatively simple to install and it doesn’t require extra work to design and install ventilation system.

2. System Demonstration

The energy efficiency of RTUs in terms of energy simulation is mainly depends on the rated COP and its performance curves. (Total Cooling Capacity Functions of temperature and flow fraction, Energy Input ratio Functions of temperature and flow fraction) These information can be extracted from manufacturer’s product specification documents under performance tables. Beside energy performance, environmental concerns such as refrigerant type and their global warming potential and ozone depletion potential would be another interesting topic that we are looking at. Table 2 below listed some major manufacturer’s RTU unit’s COP under rated conditions and the refrigerant they recommended. Table 3 provides a thoroughly comparison between the most common refrigerants that be used in HVAC system.

Table 2. Product Energy Performance and Refrigerant Type

<table>
<thead>
<tr>
<th>Products</th>
<th>System Performance (Rated COP)</th>
<th>Recommend Refrigerant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrier WeatherMaster 48HC 3-25 Tons</td>
<td>3.8-4.0</td>
<td>R-410A (Puron)/R-22</td>
</tr>
<tr>
<td>Daikin McQuay Maverick II MPS Series</td>
<td>3.4-3.9</td>
<td>R-410A (Puron)</td>
</tr>
<tr>
<td>Daikin McQuay MRT</td>
<td>3.3-3.6</td>
<td>R-407C</td>
</tr>
<tr>
<td>Daikin McQuay Maverick II MPS Series</td>
<td>3.4-3.9</td>
<td>R-410A (Puron)</td>
</tr>
<tr>
<td>Daikin McQuay RoofPak</td>
<td>3.1-3.5</td>
<td>R-407C</td>
</tr>
</tbody>
</table>
Table 3, Environmental Impact Comparison between Refrigerants\(^2\)

<table>
<thead>
<tr>
<th>Properties</th>
<th>R-407C</th>
<th>R-410A</th>
<th>R-22</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ozone Depletion Potential, ODP</td>
<td>0</td>
<td>0</td>
<td>0.055</td>
</tr>
<tr>
<td>(CFC11=1.0)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global Warming Potential, GWP</td>
<td>1700</td>
<td>1890</td>
<td>1700</td>
</tr>
<tr>
<td>(CO(_2)=1.0 [100 yr integrated time horizon])</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occupational Exposure Limit (PPM)</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>Flammable</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Toxicity</td>
<td>Very Low</td>
<td>Very Low</td>
<td>Very Low</td>
</tr>
<tr>
<td>Relative Energy Efficiency Ratio, EER (%) (^a)</td>
<td>-7 to -3</td>
<td>-2 to +2</td>
<td></td>
</tr>
<tr>
<td>Change in discharge temperature (F) (^a)</td>
<td>-15 to -8</td>
<td>-9 to -11</td>
<td></td>
</tr>
<tr>
<td>Change in discharge pressure (psi) (^a)</td>
<td>+15 to +40</td>
<td>+131 to +150</td>
<td></td>
</tr>
</tbody>
</table>

\(a\): the values indicates the comparison results between the refrigerant and R22.

\(b\): All the values are tested under same conditions using the DOE cooling test conditions A and B

The above table indicates that both R-407C and R-410A are less harmful on the environment than R-22 because of their 0 ozone depletion potentials. However, both refrigerants requires higher discharge pressures, which requires thicker walled tubing, high pressure compressors and use of components capable of withstanding these higher pressures. Especially for R-410A, whose discharge pressure requirement is 130 psi higher than R-22, which means all the components used in R-22 and R-407C system has to be completely redesigned. In addition, high operation pressure restricts the use of R-410A to smaller HVAC systems.

According to the above comparison, a relative average RTU product, Carrier WeatherMaster 48HC single-Package Rooftop Unit with COMFORTLIN controls, was selected as a sample to demonstrate how a RTU mounted in grocery store and energy performance of the RTU.

![Figure 1: Carrier WeatherMaster 48HC](image)

The dimension of 48HC is 74” long, 47” height and 41” wide in the drawing. Therefore, it can be easily mounted on the roof of grocery store without taking the majority space. In addition, the roof of this grocery store is connecting direct to the street behind it. Therefore, people who are maintaining this HVAC system can easily access to the equipment. This also encourages people to replace air filter inside the air-handling unit regularly, so that the system can provide a healthier indoor environment. Figure 2 illustrates a possible mounting solution.

![Figure 2: System mounting solution (the yellow box in the figure)](image)

As described in manufacturer’s specification documents, the 48HC-D17 is weighted around 2000 lbs, therefore, for this roof mount application, maximum bearing load must be carefully examined before taking a further action.
3. Simulation Results:

The grocery store for modeling is resides at Hazelwood, Pittsburgh, which is defined as Climate Zone 5 according to IECC climate zones. The total area of this building is around 10000 square foot with 7.92% overall window to wall ratio (include basement). The only glazed the wall of this building is the West façade, which has about 30% window to wall ratio. Below is the grocery building model in EnergyPlus:

![Building model](image)

3.1: Sizing Issues:

Before simulation, we have to size the system of the grocery store first, in order to determine which size of system we need for the grocery store. The importance of sizing could have significant effect on energy performance as well as capital cost. In this report, we build two different models to demonstrate the importance of HVAC system. The first grocery model was built based on proposed designs such as assembly team’s high thermal resistance wall assembly, lighting team’s efficient LED lighting and roof team’s green roof. The second model was created based on IECC 2009 minimum requirements. The different assumptions used for these two models are listed in table 4 below:

<table>
<thead>
<tr>
<th>Categories</th>
<th>IECC Model</th>
<th>Minimum Requirement</th>
<th>Designed Model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Constructions (kBtu/h·ft°F)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Front Façade Hybrid Option</td>
<td>0.047</td>
<td></td>
<td>0.028</td>
</tr>
<tr>
<td>Basement Walls</td>
<td>0.3768</td>
<td></td>
<td>0.07</td>
</tr>
<tr>
<td>Glazing</td>
<td>1.017</td>
<td></td>
<td>0.49</td>
</tr>
<tr>
<td>Glass Door</td>
<td>0.956</td>
<td></td>
<td>0.43</td>
</tr>
<tr>
<td><strong>Lighting (W/ft²)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LPD</td>
<td>1.02</td>
<td></td>
<td>0.675</td>
</tr>
<tr>
<td><strong>HVAC system &amp; Refrigeration Cases</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>System Type</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Packaged Roof Top Unit</td>
<td></td>
<td></td>
<td>Packaged Roof Top Unit with Heat Recovery option</td>
</tr>
<tr>
<td><strong>Refrigeration Cases</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air Cooled</td>
<td></td>
<td></td>
<td>Water Cooled</td>
</tr>
<tr>
<td><strong>Heat Recovery Options</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td></td>
<td></td>
<td>Yes (Space heating and DHW)</td>
</tr>
<tr>
<td><strong>Green Roof</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Green Roof Installed</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
From the simulation results, the peak cooling load of IECC Minimum Requirement Model was around 15 tons compare to 8 tons in the design model. Due to the series we are using is Carrier WeatherMaster HC series, the available models for these two loads are 48HC-D17 and 48HCD09 respectively. Detail manufacturer’s specifications are listed in table 5. The numbers are derived from performance table under manufacturer’s product specification documents, which is required by EnergyPlus input/output document, therefore, a slightly differences between the input rated specifications and the specifications described by the manufacturers.

From the side by side comparison in table 5, we can find that 5 tons RTU has much smaller physical dimension and around 1/2 of weight of 15 tons unit. This implies the installation and maintenance of 5 tons unit will be cheaper and simpler than 15 tons unit. In addition, the rated air speed for 15 tons unit is 6000 CFM. Compare to 5 tons unit, which is only 3400CFM, 15 tons unit requires larger ducts (approx. 26’’) than 8.5 tons unit (approx. 22’’). The reduction on duct size will not only leave more ceiling space for architectural design, but also save a lot of capital costs.

Table 5. Carrier WeatherMaster 48HCD17 and 48HCD09 product specifications

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Carrier</th>
<th>Carrier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rooftop Unit</td>
<td>48HC</td>
<td>48HC</td>
</tr>
<tr>
<td>Model Details</td>
<td>48HC-D17</td>
<td>48HCD09</td>
</tr>
<tr>
<td>Rated Total Cooling Capacity (Ton)</td>
<td>15</td>
<td>8.5</td>
</tr>
<tr>
<td>Speed (CFM)</td>
<td>6000</td>
<td>3400</td>
</tr>
<tr>
<td>Rated EER</td>
<td>12.99</td>
<td>14.47</td>
</tr>
<tr>
<td>Rated Total Cooling Cap (MBH)</td>
<td>169.7</td>
<td>96.2</td>
</tr>
<tr>
<td>Power at rated Capacity (W)</td>
<td>13066</td>
<td>6646</td>
</tr>
<tr>
<td>Sensible Heat Capacity [MBH]</td>
<td>106.1</td>
<td>61</td>
</tr>
<tr>
<td>Rated Volumetric Air Flow Rate (CFM)</td>
<td>6000</td>
<td>3400</td>
</tr>
<tr>
<td>Rated Total Cooling Capacity (W)</td>
<td>49734</td>
<td>28193</td>
</tr>
<tr>
<td>Flow Rate/Ton</td>
<td>400</td>
<td>400</td>
</tr>
<tr>
<td>Sensible Heat Ratio</td>
<td>0.624</td>
<td>0.634</td>
</tr>
<tr>
<td>Rated COP</td>
<td>3.8</td>
<td>4.2</td>
</tr>
<tr>
<td>Rated EIR</td>
<td>0.3</td>
<td>0.2</td>
</tr>
<tr>
<td>Dimension (in.)</td>
<td>128 x 87 x 57</td>
<td>88 x 59 x 41</td>
</tr>
<tr>
<td>Approx. Unit Weight (lb)</td>
<td>1892</td>
<td>925</td>
</tr>
</tbody>
</table>
3.2: Simulation Assumptions:

The model is built based on the inputs from design teams. However, there are still huge amount of assumptions in the EnergyPlus that requires specifying in order to make the model work. Tables below indicate the model assumptions and their sources:

Table 3. Internal Loads Assumptions and Their Respective Data Sources

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Temperature Setpoints / Setbacks</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium Office</td>
<td>Temperature Setpoints / Setbacks</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cooling Setpoint: 76 °F</td>
<td>IECC 2012</td>
</tr>
<tr>
<td></td>
<td>Heating  Setpoint: 70 °F</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cooling Setback: 98 °F</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heating Setback: 54 °F</td>
<td></td>
</tr>
<tr>
<td><strong>Equipment load</strong></td>
<td>Average power density</td>
<td>DOE Reference Building</td>
</tr>
<tr>
<td></td>
<td>0.5 W/ft2</td>
<td></td>
</tr>
<tr>
<td><strong>Occupancy</strong></td>
<td>Occupancy density</td>
<td>IMC 2012</td>
</tr>
<tr>
<td></td>
<td>8/1000 sqft</td>
<td></td>
</tr>
<tr>
<td><strong>Infiltration (ft$^3$/h ft$^2$)</strong></td>
<td></td>
<td>Emmerich and Persily (2005)</td>
</tr>
<tr>
<td></td>
<td>8.65</td>
<td></td>
</tr>
<tr>
<td><strong>Outdoor Air</strong></td>
<td>By Occupants</td>
<td>IMC 2012</td>
</tr>
<tr>
<td></td>
<td>7.5 CFM/person</td>
<td></td>
</tr>
<tr>
<td></td>
<td>By Floor Area</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.06 CFM/ft$^2$</td>
<td></td>
</tr>
<tr>
<td><strong>Misc.</strong></td>
<td>Kitchen Equipment</td>
<td>DOE Reference Building</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Equipment Level</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7000 Watt</td>
<td></td>
</tr>
</tbody>
</table>

Along with assumptions for internal heat gains and systems, schedules were created to adjust the assumptions so that the heat gains and heat loss would reflect the reality as close as possible. Following figures show the schedules (occupancy, equipment and lighting) specified for weekdays and weekends respectively.
Figure 4, Occupants Schedules

Figure 5, Lighting Schedule

Figure 6, Equipment Schedule
We assume that the store will open at 8 am in the morning, and close at 6 pm in the afternoon. After it close, there will still have some customers or people cleaning till 12 pm. Lighting schedule was developed according to occupant’s schedule with a base load of 20% all year long. Equipment schedule was similar to lighting schedule. Considering it’s a grocery store, a high base load (40%) was assumed.

We also developed a kitchen equipment schedule for the kitchen bakery activities. Figure 5 indicates the schedule. We assume the bakery equipment start to operate 2 hours before the store open, and will stop running after store closed.

![Bakery Equipment Schedule](image)

**Figure 7, Bakery Equipment Schedule.**

Other schedules such as case lighting schedules, case defrost and defrost drip down schedules were generated based on DOE reference building and EnergyPlus example files. The schedule can be found in the additional baseline assumption excel files.

HVAC system is developed based on the description of Carrier WeatherMaster 48HC product specifications. The supply air is assumed to be 20 °F difference between zone air temperature and supply air temperature. The supply fan was developed based on DOE reference building supermarket, Chicago with 55.75% efficiency. Figure 8 and table 4 below indicates the simple layout of HVAC connections in EnergyPlus.

![HVAC connection layout](image)

**Figure 8, HVAC connection layout in EnergyPlus.**
Table 4. HVAC system Modules Used

<table>
<thead>
<tr>
<th>HVAC system</th>
<th>Modules Used</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Fan</td>
<td>Fan:VariableVolume</td>
<td>DOE Reference Building, Supermarket, Chicago</td>
</tr>
<tr>
<td>Heating Coil</td>
<td>Coil:Heating:Electric</td>
<td>Manufacturer’s specification</td>
</tr>
<tr>
<td>Cooling Coil</td>
<td>Coil:Cooling:DX:SingleSpeed</td>
<td>Manufacturer’s specification</td>
</tr>
<tr>
<td>Outdoor Air controller</td>
<td>OutdoorAir:Mixer</td>
<td></td>
</tr>
</tbody>
</table>

3.2 Results:

After implement the roof top package unit system, the simulation results are generated in figure 3. The total EUI of grocery store is about 122.66 kBtu/ft². Among all the categories, refrigeration system consumes the most energy in the grocery store, follows by interior equipment and heating. The results imply there is a huge amount of waste heat generated from refrigeration and interior equipment. If we can efficiently extract the waste heat and direct them to space heating and domestic water system, the savings on energy consumption might have significant reduction.

![Figure 9: Energy Consumption of RTU](image)

Therefore, in order to test our hypothesis, we create connections that link the refrigeration condensers to the air handling unit as well as the water heater for heating domestic hot water, detail discussion and results will be shown in the next section.
4. Refrigeration Cases Heat Recovery

In refrigeration cases report, a detail connection diagram has been provided. The EnergyPlus model will be create based on the schema described in refrigeration cases report as close as possible.

EnergyPlus has the capability of modeling supermarket refrigeration including modeling sensible and latent interactions between the refrigerated cases and the building HVAC system along with some basic heat recovery options. Currently, there are two heat recovery options in EnergyPlus, one is using a Coil:Heating:Desuperheater module to add an additional desuperheat coil in air handling unit for space heating, and the other is using Coil:WaterHeating:Desuperheater module that introduce a desuperheat coil in water heater source side for domestic hot water recovery.

There are two simulation models were built in order to test the effect of refrigeration cases heat recovery to the overall energy usage of the grocery store.

1. Model the space heating heat recovery as a preheat coil and will operate all year long when it is needed.
2. From Sept 9 to next year May 31, the waste heat extract from refrigeration cases condenser will be directed to preheat coil, and the rest of time, it will be directed to hot water equipment.

The simulation Results are showed in below:

Figure 10, Design Case Energy Performance Vs. Heat Recovery Option

---

From figure 10, space heating has substantial decrease by adding heat recovery option to HVAC system (48% reduction). Energy usage of refrigeration cases has slight decrease as well, this happens is due to the effectiveness of the heat recovery system that reduce the excessive heat in the condensers, which improve the work efficiency for entire thermal cycle.

In addition, after we added heat recovery loop between refrigeration cases and domestic hot water loop, about 60% of heating energy was reduced, which demonstrated the effectiveness of heat recovery option.

By comparing “RTU+HEATRECOVERY” and “RTU+HEAT RECOVERY(Heating+Hot Water)” cases, we can see that both cases results an increase on cooling energy due to the fact that the space heating option is still available in summer. This is one limitation of simulation software. The cooling energy we expected should be lower than the design case due to the fact that less excessive heat gave out by refrigeration cases. However, in the EnergyPlus, there are two major limitations that causing the cooling energy increase.

1. It assumes all the waste heat was rejected to the outdoor
2. There is no logical control option for heat recovery system.

The first limitation caused the heat, which generated from refrigeration cases condensers, are perfectly rejected to the outside environment. However, in reality, there is always some heat remain in the grocery store. By adding a heat recovery option, we are able to pick up those excessive BTUs and re-cycle them for either space heating or domestic hot water system. Therefore, a reduction on cooling energy should be found in reality by having heat recovery option.

The second limitation is the major reason that caused the cooling energy increase. The lack of logical control of desuperheater coil kept this coil operates 24/7 hours or according to a static operation schedule that is pre-defined in the schedule section. However, we could easily add a simple control logic that turns this desuperheater coil off whenever cooling coil starts working, and turn it back on when heating energy is needed in real building.

In sum, the EUI reduced from simply RTU to “RTU+HEATRECOVERY” case and “RTU+HEAT RECOVERY(Heating+Hot Water)” case is around 8% and 10% respectively.

5. Summary:

In this report, we first explored two possible HVAC systems and their features and potential environmental impacts. We then select a roof top unit to demonstrate how the system is working in the grocery store. A system sizing comparison between IECC 2009 minimum requirements and our proposed design case indicates that the proposed design had great advantage over IECC 2009 minimum requirement model in terms of energy performance and first cost. Later, heat recovery option was added to the system. The alternative shows that RTU works perfectly with heat recovery option that recovers the waste heat rejected from refrigeration cases. The total energy consumptions were reduced from 8% to 10%.