Commercial and Industrial Refrigeration Market Assessment

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Executive Summary

This study was undertaken to generate information about the medium and large commercial and industrial refrigeration market in Minnesota that will help programs increase the savings realized in this sector. For the purposes of this study, the market was defined as consisting of three subsectors of large refrigeration-dominated facilities — grocery, industrial (including food processing and cold storage), and ice arenas. The value of a current statewide study of the refrigeration-dominated facilities market in Minnesota was indicated by a combination of:

1. low Conservation Improvement Program (CIP) savings relative to energy use and reported potential;
2. numerous technology and facility ownership changes;
3. the influence of key market players across utility service territory boundaries;
4. the importance and specific opportunities of local factors like climate and the prevalence of indoor ice arenas; and
5. that two decades had passed since large-scale local and national market studies had last been undertaken.

To effectively address the challenges and opportunities in Minnesota's large refrigeration-dominated facilities, a project team was assembled from organizations that have expertise in each of the three key subsectors of the refrigeration-dominated facilities market, as well as an organization with a strong background in market studies and two organizations with a long regional history with utility efficiency programs.

A key characteristic of large refrigeration systems that this team took into account during this market study is that they are largely field-assembled, with the way that the different key components are matched and controlled as a system typically having more energy impact than the selection of efficiency options for any one component. While there are some important efficiency opportunities associated with individual components, CIP programs have historically underrepresented many significant, cost-effective opportunities that fall into the general categories of: (1) reducing load, lowering head pressure (a.k.a. saturated condensing temperature); and (2) raising suction pressure (a.k.a. saturated suction temperature). The energy impacts of many system and control issues makes the influence of contractors, designers, and operators critical to maximizing efficiency. With these background considerations in mind, the project team employed the following market investigation approaches to gather information that would be useful for CIP program planners, implementers, and regulators in Minnesota:

- Reviewed Minnesota CIP program refrigeration efficiency efforts, successes, and challenges through document review and interviews with program staff
- Reviewed seven programs outside of Minnesota that exemplified successful and progressive program approaches in refrigeration through document review and interviews
- Identified national industry trends and technologies through interviews with 20 key industry contacts and literature review

- Identified the number of facilities and key characteristics within each subsector through a combination of secondary sources and primary survey research
- Estimated the rates of new construction and refrigeration system replacement projects within each subsector by reviewing data on construction project tracking existing equipment age
- Evaluated local market issues through interviews with 41 key contacts
- Further characterized existing facility opportunities and new system practices through detailed plans and site reviews for 15 facilities
- Estimated the potential for increased program impact for more than 25 measures that are not consistently addressed by current Minnesota CIP programs using documented savings and engineering calculations

The key results that these efforts yielded and subsequent recommendations for Minnesota CIP programs are outlined in the following sections.

Current Utility Programs

Minnesota utilities have had some success with equipment rebates using a variety of program approaches. Most utilities have reported their greatest success in the refrigeration market with prescriptive rebates that are easy for end users to participate in, coupled with outreach primarily through regular service representative contacts. These prescriptive rebates are generally limited to specific pieces of equipment in grocery stores and the use of variable frequency drives (VFDs) as applicable to refrigeration equipment. On the other hand, the utility with the largest refrigeration savings relative to its customer base uses custom rebates with a third-party implementer that regularly checks in with key contractors and has very quick turnaround times for rebate evaluations for custom projects.

Interviews with local industry contacts suggested that prescriptive rebates are seen as easy to work with, but that many opportunities for retrofits or upgrades don't fall within the current prescriptive lists. They reported that custom programs are often so difficult that efficiency measures are not pursued or are pitched without an attempt to get a custom rebate. A few contractors were even unaware of relevant prescriptive measures that are offered in much of the territory they serve. Most utilities' CIP program outreach to key refrigeration contractors is limited to an invitation to an annual event.

While the Minnesota programs generally did not emphasize on-site evaluations by refrigeration efficiency experts as a key component of their program strategies, this is the cornerstone of a number of programs outside the state that have successfully achieved significant savings in existing facilities that did not otherwise have plans for system upgrades. While most of these programs tend to work more like custom or recommissioning programs, there are some examples of programs that have developed prescriptive measure lists beyond the limited rebates, like grocery store equipment and VFD rebates, that most programs offer.

Market Overview

One key factor that is common to all three of the large refrigeration subsectors included in this study is the very significant influence of a relatively small number of contractors. First of all, only a small number of dominant contractors install most of the large refrigeration systems in Minnesota, and their influence on the system design is often larger than that of other specialties because large refrigeration systems tend to be design–build projects. Especially when it comes to new system installation, contractors tend to specialize, and there is relatively little crossover between the three market subsectors (e.g., grocery, industrial, and ice arenas). However, there is a larger degree of contractor crossover between subsectors when it comes to service work and installation of components (as opposed to whole-system installations). While there are more service contractors serving large refrigeration systems than there are contractors performing major system installations, the number of dominant players is still small, and their influence on customer decisions for refrigeration equipment is hard to overstate. Facility decision makers count on their refrigeration service contractors to keep their system running well (typically with monthly service visits) and to respond quickly when there is a problem so as to avoid large financial business losses. A facility decision maker generally values the relationship with their service contractor and would be very hesitant to make any changes to their refrigeration system without that contractor's input. There are also very few specialty designers within each of these subsectors, such that a handful of regional and national contacts a large influence over the design choices for new large-refrigeration systems.

The estimated number of facilities in Minnesota within each subsector are shown in Table 1 along with the estimated annual refrigeration system energy use for a typical large facility. Note that some of the ice arenas have multiple sheets, so there are 268 ice sheets total. It is also believed that at least half of the number of industrial facilities have a substantially smaller refrigeration load than a typical large facility in this category.

Table 1. Summary of Refrigeration Dominated Facilities in Minnesota by Subsector

Value	Grocery	Industrial	Ice Arenas
Number of Facilities	979	223	208
Refrigeration Use for a Typical Large Facility	970,000 kWh	4,500,000 kWh	636,000 kWh

Each of the market subsectors has a different set of facility-owner characteristics. One of the few things they tend to have in common is a great concern for reliable, continued operation of the refrigeration system. Besides concern about the possibility of any change compromising reliability, most facilities have little to no down time during which a complete refrigeration system shutdown could occur to carry out a retrofit. Decision-making for the grocery store market tends to be controlled by a few key contacts at local, regional, or national chains. On the other hand, most industrial refrigeration and ice arena facilities in Minnesota are controlled by owners with two or fewer facilities in the state. For industrial facilities, high-level decision-making may be at a regional or national corporate level, while most ice arenas are controlled by local governments.

Measures and Savings Potential

This study identified a number of refrigeration system measures not previously targeted by Minnesota programs that have the potential to increase statewide program impact by an estimated 26,000 megawatt hours over a three-year program implementation cycle. The estimated potential program impact is outlined in Table 2 with a breakdown by subsector and applicability to existing versus new refrigeration systems.

Prescriptive programs in Minnesota have had most of their success with grocery sector measures aimed at particular display equipment load reduction items (e.g., high-efficiency doors, high-efficiency fan motors, display case lighting, and antisweat heater controls) that are often only cost-effective as an incremental upgrade at the time that equipment is replaced. However, the study identified 13 cost-effective measures that optimize energy use in existing facilities that have not been widely recognized or targeted by CIP program efforts in Minnesota.[1] Many of these system optimization measures are consistently applicable across the different sectors, while others — especially the load reduction measures — are limited to only one or two sectors. Six measures that are applicable to new systems and currently not well addressed in Minnesota by prescriptive rebates were also identified as potential growth areas.

In addition, seven other measures applicable to new systems were identified as having significant promise for future inclusion as a prescriptive rebate for new construction, but were not included in the total potential presented here because further technology evaluation (which was beyond the scope of this market study) is recommended prior to widespread program promotion. These measures recommended for further evaluation most notably include items that are uniquely suited to maximizing the efficiency of transcritical CO_2 refrigeration systems. Although this new system type does not have a long history in Minnesota, it appears likely that transcritical CO_2 systems will soon be the most popular choice for new grocery store refrigeration systems in Minnesota.

Table 2. Three-Year Increased Program Savings Potential by Sector and Application (MWh)

Application	Grocery	Industrial	Ice Arenas
Optimization of Existing Systems	12,612	7,297	5,545
New/Replacement Refrigeration Systems	209	243	132
Sector Total	12,821	7,540	5,677

It is also noteworthy that both federal equipment efficiency standards and the 2020 Minnesota Energy Code have established baseline requirements that render some historically rebated refrigeration measures inappropriate for rebates as part of a new system installation.

[1] Three of these thirteen measures are partially addressed through VFD rebates, but the savings provided in these applications is not fully reflected in VFD program savings assumptions and corresponding rebate levels.

Recommendations for Minnesota CIP Programs

The recommendations listed below will maximize the cost-effective program impact within refrigeration-dominated facilities in Minnesota. Many of these recommendations are aimed at tailoring program approaches to better optimize the efficiency of existing refrigeration systems.

- Conduct frequent outreach to the small number of dominant contractors and other key industry contacts that influence many facilities.
- Develop and aggressively promote program services that will provide assessments and optimization assistance by a refrigeration efficiency expert with sector-specific expertise, who will work closely with the on-site or service contractor technician(s). While this could be similar to traditional recommissioning, it is important that programs promote and get credit for low-cost operational changes and work very closely with contractors. Remote access to refrigeration system controls could also be leveraged as a more effective and cost-effective way to provide expert assistance.
- Develop more prescriptive rebates to overcome barriers to program participation and measure awareness for the top priority measures detailed in Table 27 within the Conclusions and Recommendations section of this report — especially for retrofit and control optimization measures. While savings and cost can vary in these situations, rebates that scale with system size and the degree of control change (i.e., a set $ per ton per 1°F change in saturated suction temperature) could strike a more progressive balance between the rigor of cost-effectiveness protections for each rebate and the ease of program use for participants.
- Minimize barriers to custom program participation — especially for smaller-scale retrofit and limited equipment replacement situations. The two key custom program developments that could have the most impact are: (1) shifting as much of the burden as possible for performing savings calculations from the end users, contractors, and vendors to the utility or program implementer; and (2) evaluating project rebate requests within one week. TRM measure development could also provide benefits.
- For utilities that have a significant number of industrial refrigeration facilities, consider providing operator training workshops along with the means for follow-up encouragement and tracking of subsequent control optimization actions.
- Undertake further technical review and market tracking for the measures identified in Table 28 within the Conclusions and Recommendations section of this report — especially for the measures that are uniquely applicable to transcritical CO_2 refrigeration systems.

Conclusion

This market study of refrigeration-dominated facilities in Minnesota identified specific opportunities and CIP program development actions that could provide as much as a 26,000 megawatt hour increase in statewide savings over a three-year CIP program implementation cycle. This savings potential is primarily achievable through aggressive program approaches aimed at optimizing existing refrigeration systems in grocery stores; industrial refrigeration facilities (i.e. food processing and cold storage facilities); and ice arenas. The savings arrive primarily through the implementation of measures that have not previously been featured as prescriptive refrigeration measures within Minnesota CIP programs.

Background

Introduction

Before the project team undertook this market study, numerous factors pointed to the time being ripe for a comprehensive, statewide commercial and industrial (C&I) refrigeration market assessment in Minnesota that would focus on large, refrigeration dominated facilities:

1. Refrigeration accounts for about 17.5% and 10% of commercial and industrial electric load, respectively. CEE's recent potential study (2018) showed that refrigeration represents nearly 20% of the potential electric C&I program savings in Minnesota through 2029. Yet, in 2017, refrigeration represented less than 2% of the combined total electric C&I Conservation Improvement Program (CIP) savings achieved by Minnesota's three largest electric investor-owned utilities (IOUs). These contrasting numbers suggest significant potential for growth in CIP program impact in this sector.
2. There were numerous dramatic changes happening in the refrigeration industry, including federal equipment efficiency standards, refrigerant phaseouts, increased national chain market share, changes in regional chain ownership, changes in distribution networks, and changes in store designs. All of these factors could impact appropriate program baseline assumptions and rebate measures, present significant one-time opportunities to piggyback on required capital upgrade projects and change the effectiveness of specific program marketing and delivery approaches.
3. Small commercial refrigeration had recently been addressed through a new IOU pilot program and two CARD-funded pilots for niche markets (convenience stores and restaurants). However, there had not been effective, substantial commercial refrigeration program changes addressing grocery stores, ice arenas, cold storage warehouses, or food/beverage processing in Minnesota for more than 15 years.
4. The last comprehensive national technology study was in 1996, so it did not reflect current equipment or technologies (Arthur C. Little, Inc., 1996). The last commercial, industrial, and ice arena refrigeration market assessments in Minnesota were completed by CEE in 1993, 1993, and 1995, respectively.
5. Many of the dominant refrigeration contractors, grocery chains, and food wholesalers in Minnesota operate across utility service territory boundaries. Moreover, many of the systems and technologies are complex. This makes it more difficult for each utility to justify the level of effort to take a comprehensive look at this market and makes it potentially beneficial for utilities to design programs based on a consistent understanding of the market opportunity and barriers.
6. While studies more than two decades old could provide a starting point, a current Minnesota-specific refrigeration market study would be valuable from both a technical and market perspectives for many reasons. Notable among these were that: (a) The market penetration of efficient refrigeration technologies varies over time and from one area to another; (b) Minnesota's cold climate creates specific efficiency opportunities; and (c) The high number of ice arenas is very unusual. Moreover, the relatively large impact of a small number of key

industry contacts (e.g., chain store decision makers and a few dominant equipment manufacturers and refrigeration contractors) makes it critical to understand the factors driving these key players in the Minnesota market. This relevance was underscored by proprietary reporting from one of Minnesota's three largest utilities, which found that refrigeration contractor resistance is a key issue limiting program impact in grocery stores.

To effectively address these issues, a project team was assembled from organizations that have expertise in each of the three key subsectors of the refrigeration-dominated facilities market in Minnesota — grocery stores; industrial refrigeration (including cold storage warehouses and food processing); and ice arenas. The team also included an organization with a strong background in market studies and two organizations with a long regional history with utility efficiency programs.

Overview of Large Refrigeration Systems

This section provides a summary of the project team's general knowledge of refrigeration systems and local trends at the start of the market study. It is meant to provide a shared context and better understanding of the study findings and program implementation implications. More information regarding key measures and issues appears in the Study Findings and Discussion of Results sections.

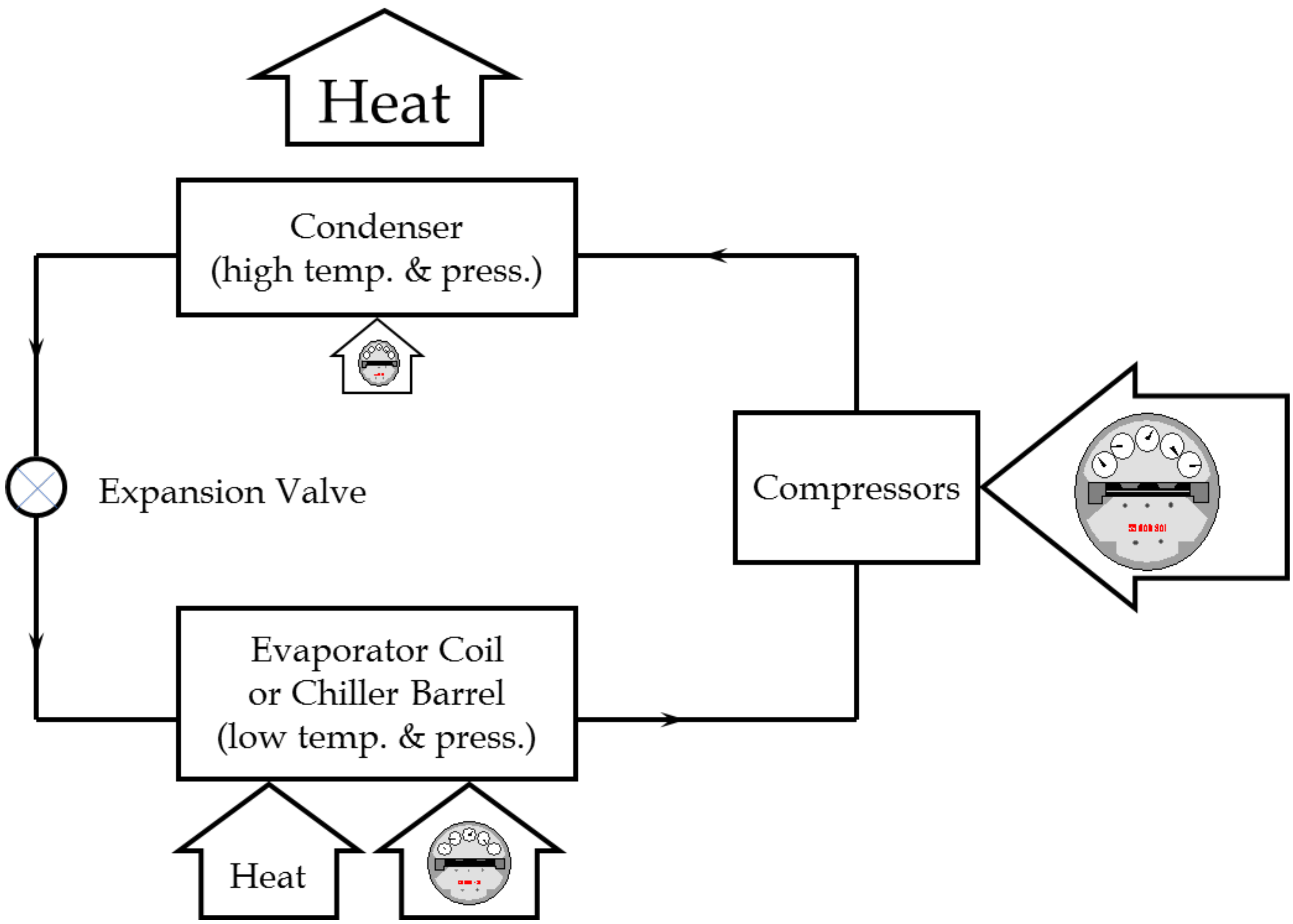
Large Refrigeration System Energy Considerations

The refrigeration systems within the three targeted subsectors of refrigeration-dominated facilities have a number of common characteristics that provide a set of efficiency challenges and opportunities. Key characteristics that differentiate the energy efficiency issues of these refrigeration-dominated facilities from most other CIP program measures are:

- Each of the three main refrigeration system components — evaporators, compressors, and condensers — are selected and packaged separately for field assembly into a complete system.
- Differences in the rated energy performance of each of the three key system components typically have less impact on the system's overall energy performance than do a number of the details in how the three main components are matched up, piped, valved, and controlled together as a system.
- Interactions between the system components will often amplify or reduce the apparent savings achieved by making a change to the performance or control of one component. For example, reducing fan power within a freezer also reduces the heat load on the refrigeration system. On the other hand, being too aggressive with reducing the fan power of the outdoor condenser can lead to an increase in the energy use of the compressors that eclipses the fan energy savings.
- The savings of many measures are dependent on the combination of an upgrade to one component and an associated change in how another component is controlled.
- Often, a limited incentive or expertise for technicians and operators to focus on energy performance, combined with the system's great sensitivity to a number of control methods and settings, leads to systems operating with higher energy use than can be achieved with the installed equipment and system configuration.

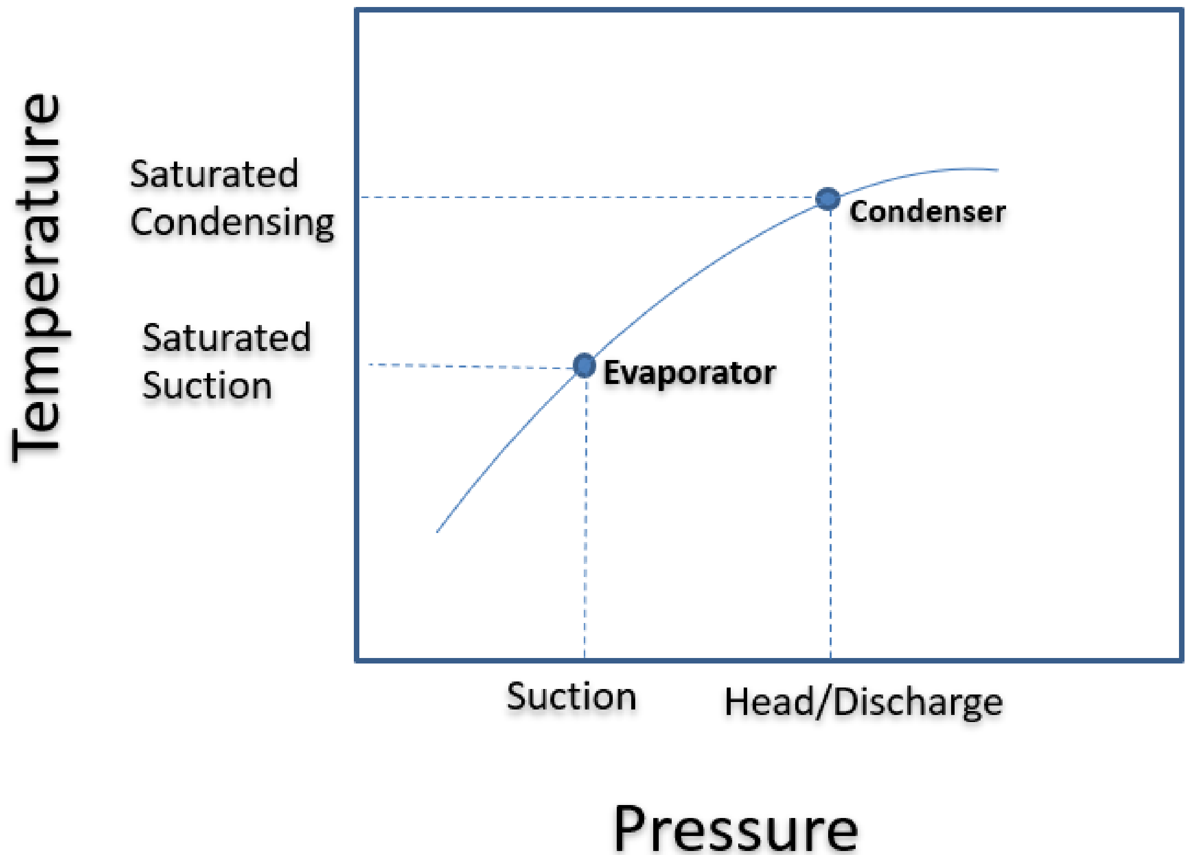
A basic outline of what the key refrigeration system components are and how they work together is presented in Figure 1. This information can help CIP program planners, implementers, and regulators understand the general categories of refrigeration efficiency measures and the opportunities associated with taking a whole-system approach to realizing energy savings in refrigeration systems. The basic purpose of a refrigeration system is to take heat from something cold and remove it, typically into the ambient air. The heat is absorbed into a refrigerant within the evaporator and disposed of (a.k.a. "rejected") from the refrigerant at the condenser. The small meter arrows show that both the evaporator and condenser use fans or pumps to blow air or pump water or a water-antifreeze solution over a metal surface that has refrigerant on the other side. The refrigerant moves through a complete cycle to and from the evaporator and condenser through the compressor(s) and expansion valve(s), with the majority of refrigeration system energy consumed by the compressor. The compressor sucks in refrigerant that is at low pressure and temperature refrigerant that has been boiled or evaporated in the evaporator, and then the compression process raises the refrigerant's pressure and temperature before the hot, high-pressure refrigerant is sent to the condenser.

Figure 1. Key Refrigeration System Components



The compressor uses a lot of energy because it has to dramatically raise the pressure of the refrigerant so that the heat removed in the evaporator can be rejected from the condenser at a much higher temperature. Figure 2 shows how the refrigerant pressure must be increased so that the heat absorbed as the refrigerant boils in the cold evaporator can be rejected to higher-temperature outdoor air as the refrigerant condenses. After condensing, the refrigerant flows through the expansion valve where its pressure drops back down so that it can again be boiled at the low temperature of the evaporator, which is typically either a cooling coil with cold air blowing over it or a chiller barrel with cold antifreeze pumped from under a sheet of ice.

Figure 2. Refrigerant Pressure Change to Change Boiling/Condensation Point



A useful analogy is to think of the refrigeration system as moving water uphill from a low temperature (near the bottom of the hill) to a high temperature (near the top). The amount of energy required to move the water upward goes up as the height of the hill increases. Similarly, refrigeration compressor energy use goes up as the temperature difference between the low temperature where the heat is absorbed and the high temperature where the heat is rejected increase. The refrigerant pressures at the inlet and outlet of the compressors are referred to as the suction pressure and the discharge or head pressure (because this pressure occurs at the heads of traditional reciprocating compressors where refrigerant is discharged). These pressures have a big impact on the energy use and capacity of the compressors and of the entire system. Each of these key pressures has a corresponding temperature (on the line in Figure 2) that is commonly referred to as the saturated suction temperature, which corresponds to the compressor suction pressure, and the saturated condensing temperature, which corresponds to compressor discharge or head pressure. When applying the water up the hill analogy, the saturated suction temperature dictates how far down the hill the water is coming from and the saturated condensing temperature dictates how close to the top of the hill the water has to be moved to. Anything that can bring these two temperatures closer together saves energy by bringing down the distance that the heat must be moved "uphill".

Table 3 outlines how each of the key categories of refrigeration system energy efficiency measures saves energy. It gives examples of measures within each as well as notes on how interactions between key components come into play. The categories are listed in the high-to-low priority order that is generally agreed upon within the industry. Note that prescriptive rebate programs have generally addressed measures in the "Reduce Refrigeration Load" and "Increase Efficiency of a Component" categories, as these items can often be defined in terms of the performance or control of a singular piece of equipment without much consideration of its interaction with other components. It is noteworthy that although compressors are the component of refrigeration systems that use the most energy, the differences in full-load efficiencies of currently available compressor options are relatively small compared to the energy use and the potential savings of other measures.

Table 3. Categories of Refrigeration Efficiency Measures

Category	Water & Hill Analogy	Example(s)	Notes
Reduce Refrigeration Load	Moves less water	• Put glass doors on an open display case • Increase an ice rink's temperature overnight • Cycle cooling coil fans off	The energy use of fans and lights in a refrigerated space adds to the refrigeration load. The same is true of glycol/brine pumps for ice arenas.
Increase Suction Pressure (a.k.a. Saturated Suction Temperature)	Starts with water that is farther up the hill	• "Float" the suction pressure up during low load conditions that don't require as low of refrigerant temperatures in the evaporator to maintain a freezer's air temperature • Improve the matching of compressor capacity to the load • Operating at a higher than needed compressor capacity	Grocery stores and industrial refrigeration facilities often have refrigeration loads at multiple temperature levels with one load dictating what suction pressure a whole system operates at. Sometimes separating out or making changes to one load will allow the rest of the loads to be handled much more efficiently at a higher suction pressure.

Category	Water & Hill Analogy	Example(s)	Notes
Reduce Head Pressure (a.k.a. Saturated Condensing Temperature)	Doesn't bring the water as close to the top of the hill	• Control the condenser fans so that the head pressure floats down when cooler outdoor air lets the system reject the head with a lower condensing saturation temperature • Choose or replace components that reduce the minimum head pressure needed for proper operation of the system	The choice between air-cooled condensers and the alternative of evaporative or adiabatic condensers has a big impact on the head pressure — especially during annual summertime maximum temperatures. Evaporative cooling from letting water evaporate into the air allows either of these other designs to reduce the temperature on the outside of the condenser from ~95°F to ~ 78°F during summertime peak design conditions.
Increase Efficiency of a Component	Uses a better pump or bucket	• Use more efficient fan motors or variable speed operation of fans or pumps • Increase the part-load efficiency of a screw compressor with a variable speed drive	Improvements in fans or pumps on the evaporator side also reduce the refrigeration load. The same is true of glycol/brine pumps for ice arenas. However, overly aggressive reductions in power at the evaporator or condenser can increase compressor power by lowering the suction pressure or raising the head pressure.
Provide Subcooling at the Expansion Valve	Gets some water from partway up the hill	• Use a mechanical subcooling system • Use cold, outdoor air to cool the refrigerant further after it condenses	Subcooling of refrigerant between when it condenses and goes through the expansion valve reduces the low temperature refrigeration load. It essentially takes care of the load with a system that either operates at a much higher saturated suction temperature or with some other way of cooling down high-pressure liquid without using a compressor. The piping configuration and/or insulation of high-pressure liquid lines must be considered in many cases.

It is also important to consider the degree to which certain cost-effective energy savings opportunities are available only at the time that a refrigeration system is installed and the degree to which savings can be achieved through cost-effective retrofits to existing systems or low- to no-cost control adjustments to existing equipment. While all of the categories in Table 1 offer opportunities to decrease energy use through building in capabilities, it also noteworthy that the energy performance of all measures across categories is impacted by how well the refrigeration system components are controlled individually and as a system. Refrigeration controls impact operating efficiency and generally provide a number of cost-effective opportunities. These may take the form of simple control adjustments or reprogramming, or they may need to be carried out in combination with retrofits that modify components to allow the suction pressure to be raised or the head pressure to be lowered during off-design operating conditions.

Key Refrigeration System Differences by Subsector

Grocery Store Refrigeration Systems

Large grocery stores in Minnesota have a long history of using refrigeration system rack systems that have multiple compressors packaged together with a controller. Each rack serves a number of display case line-ups and walk-in boxes at similar temperature levels, with the piping connections for each group of loads made to a pre-piped manifold and sets of valves at the rack. The flow of refrigerant through each load is controlled by a combination of thermostatic expansion valves at each cooling coil and an evaporator pressure regulator that is typically located at the rack. Typically, each store has at least one low temperature rack serving freezers and one medium temperature rack serving coolers. Each rack automatically controls the staging of its compressors to maintain a suction pressure setpoint. Grocery stores in Minnesota have traditionally used air-cooled condensers with separate piping from each rack to a condenser (or dedicated portion of the tubes within a condenser).

Grocery store racks systems have traditionally used artificial refrigerants, with the selection of refrigerants changing over time due to the historic and anticipated regulatory phasing out of production for different refrigerants. There is a small but increasing number of systems following the national trend of using carbon dioxide or other natural refrigerants. The use of carbon dioxide necessitates some significant changes in the systems that could potentially make some measures related to head pressure reduction and subcooling much more cost-effective while creating opportunities for brand new measures to handle part of the load with a separate, higher saturated suction temperature system.

The compressors in traditional grocery store rack systems have generally been semi-hermetic, meaning that the compressor motor is cooled by refrigerant gas flowing right over the compressor motor that is housed within a sealed compressor unit. These compressors are sometimes provided with unloading capability that allows the compressor to operate at one or two different stages of reduced capacity (e.g., two-thirds and one-third of full load) with a fairly small part-load efficiency penalty. A newer “digital” compressor design uses this traditional unloading capability and quickly changes the compressors degree of unloading back and forth to provide a time-averaged capacity that is between the fixed stages of unloading. There is generally no more than one compressor on a rack with unloading capability, because having just one allows the controller to better match the number of compressors to load and avoid an unnecessary reduction in suction pressure from running compressors at a higher capacity than the load.

Frost build-up on the evaporators in the freezers is most typically dealt with by running hot compressor discharge gas through the coils periodically, although electric resistance heaters are used for defrosting in some stores. Achieving effective hot gas defrost may require a head pressure that is higher the system would otherwise need to maintain it in cool weather.

While grocery store refrigeration systems have loads on them year-round on a 24/7 basis, the loads and energy use do tend to go up with warm, humid weather — especially if the humidity in the store is not well controlled.

Industrial Refrigeration Systems

Industrial refrigeration systems in Minnesota have a strong tendency toward central refrigeration systems with large screw compressors that are packaged individually with all piping and control coordination between multiple compressors installed in the field. The compressors are piped together into different suction groups, similar to the grouping of compressors in a grocery store rack system. Also like grocery store rack systems, the staging and capacity control multiple compressors are controlled to maintain a suction pressure setpoint. Facilities with large freezer loads often have two stages of refrigeration with a low-temperature (a.k.a. booster) suction group and high temperature (a.k.a. high pressure) suction group that operates at an intermediate suction pressure. The refrigerant from the low temperature compressors is pressurized to the intermediate pressure and cooled by higher temperature liquid refrigerant in an intercooler before it goes to the high temperature compressors where the pressure is raised to the point at which the heat can be rejected outside through the condenser. These two-stage systems essentially subcool the refrigerant going to the low-temperature evaporators, and this subcooling load is handled by the high-stage compressors.

Many industrial refrigeration systems also often have swing compressors that are piped and valved so that they can be used for either low-temperature or high temperature loads. An often-used approach is to use a single stage for the freezers and handle the subcooling and a moderate amount of medium-temperature load through the side port of screw compressors. Efficiencies are dependent upon the refrigeration loads and part-load efficiencies of the compressors and need to be considered carefully. This side port is an intermediate pressure inlet into the compressor that allows one compressor to handle loads at two different suction levels (although the maximum load and suction pressure at the side port is dictated by the low-temperature load).

Industrial refrigeration systems generally use a liquid overfeed system to push the liquid refrigerant out to the individual evaporator coils. The flow through each evaporator coil is controlled by valves located near each coil. Large industrial refrigeration systems use evaporative condensers exclusively and tend to continue the use of water spray over the condenser coils through much of the winter.

Screw compressors have little difference in efficiency from large reciprocating compressors, but they have very different part-load characteristics and needs for oil. Both screw and reciprocating compressors are used in central industrial refrigeration systems, but all use part-load capacity control and all are open compressors with the motor being separated from the compressor and driven by a shaft or belt. Reciprocating compressors reduce their capacity by unloading two cylinders at a time. While this has a relatively small part-load efficiency penalty, there are fairly large, finite steps between the stages of unloading. Screw compressors can reduce their capacity with a slide valve that has very fine stages of capacity control. Unfortunately, the slide valve also has a much larger part-load penalty than unloading of reciprocating compressors. Another key characteristic of screw compressors is that the close tolerances between the interlocking screw gears requires much more oil use and oil cooling. This oil cooling is often achieved by injecting liquid refrigerant into the compressor and having it evaporate as it cools this oil, which adds to the compressor’s refrigeration load.

Large industrial refrigeration systems have traditionally used either R-22 or ammonia as the refrigerant. The difference in efficiency between the two refrigerants is small compared to the other commonly cost-effective measures. Although most aspects of system design are very similar between these two refrigerants, different material compatibility and pipe sizing issues make it impractical to switch an existing system to the other of these two refrigerants. The production of new R-22 has been completely phased out, which may force major system retrofits or replacements.

While large industrial refrigeration systems generally trend toward central ammonia or R-22 systems, there is also a significant number of smaller cold-storage facilities that use packaged refrigeration systems to cool spaces and product. These facilities often have several generally have several smaller packaged refrigeration units serving one or several evaporator coils for space or process cooling. These individual refrigeration units use various artificial refrigerants, tend to run at high condensing saturation temperatures year-round, and tend to be more difficult to cost-effectively improve efficiency through retrofits or control improvements.

The refrigeration load and energy use of cold storage facilities is generally highly temperature dependent. Cold storage facility loads may also be affected by periodic blast-freezing or other product loads that need to be cooled after being brought in. Depending on the type of facility, the refrigeration load variation in food processing may be driven more by daily or seasonal variations in product throughput (e.g., vegetable harvest season).

Ice Arena Refrigeration Systems

Both commercial- and industrial-style packaging of compressors and their controls are common in arenas. A number of semi-hermetic compressors (typically four) may be provided together on a single skid with piping and controls already connected between the compressors and ancillary components. In most of these cases, the glycol (or brine) chiller and pumps are provided by the same packager, with these components being packaged together on a separate skid, or sometimes on the same skid as the compressors. Alternatively, a smaller number of open compressors (typically two for a single ice sheet) may be packaged individually with all piping and control connections between compressors and other components put together in the field. While some legacy “direct” systems recirculate refrigerant directly in tubes under the ice, most existing and all newer systems are “indirect,” whereby a chiller is used to cool an ethylene glycol (or calcium chloride) solution that is pumped under the ice sheet. The vast majority of energy that goes into pumping this solution under the ice sheet ends up being a heat load on the refrigeration system. The compressor staging is most commonly controlled to maintain a set temperature of the glycol (or brine) solution coming back from the ice sheet, but some systems use an ice sensor imbedded underneath the ice for compressor staging control. Few control systems run individual ice rink compressors at partial capacity — even when large industrial-style compressors that have unloading capability are installed.

Evaporative condensers are most commonly used to reject heat from ice arena refrigeration systems, but the use of air-cooled condensers is not uncommon — especially for systems in arenas that don’t have ice in the summer and for packaged systems with semi-hermetic compressors. Most arenas also have a small amount of the heat recovered from the refrigeration system for the melting of “snow” that is generated during resurfacing and for heating glycol that is circulated deeper in the ground to prevent the formation of permafrost and subsequent heaving of the floor. A minority of systems have a much larger amount of heat recovered for space heating and dehumidification. It is common for head pressures to run higher than otherwise necessary to facilitate the recovery of this “free” heat.

Nearly all ice arena systems more than 10 years old were built with R-22 as the refrigerant, but there is more inconsistency in newer systems. As R-22 has been phased out of production, some older R-22 systems have been retrofitted with newer alternative artificial refrigerants. While newer, artificial refrigerants are being used in some new ice arena refrigeration systems, there is also a trend toward the use of ammonia as the refrigerant in newer systems.

Although many newer ice arenas maintain an ice sheet for 10 or more months a year, there are also a large number of seasonal ice rinks that have limited summer ice time or only operate for as few as six to seven months each year (September/October through March). Arenas that do operate in the summer have significantly higher refrigeration system loads associated with warmer temperatures and higher levels of humidity in the summer.

Overview of Market Structure

Trade Allies

One key factor that is common to all three of the large refrigeration system market subsectors included in this study is the very large influence of a relatively small number of contractors. First of all, there is only a small number of dominant contractors that install most of the large refrigeration systems in Minnesota, and their influence on the system design is often larger than other specialties because of a greater tendency for large refrigeration systems to be design–build projects. There even tends to be a high degree of specialization within each of the subsectors with few installation contractors doing much crossover between these three parts of the large refrigeration system market. However, there is a larger degree of crossover of contractors between subsectors when it comes to service work and the installation of components (as opposed to complete system installations). While this is partially necessitated by the need to be located closer to a facility to provide responsive service, it is also limited for industrial refrigeration facilities using ammonia because of the high level of specialization required.

While the number of refrigeration service contractors servicing a significant number of large refrigeration systems in Minnesota is much larger than the number performing major system installations, there is still a relatively small number of dominant players, and their influence on customer decisions for refrigeration equipment is hard to overstate. The impact of even a short-term refrigeration system failure can be catastrophic for these facilities and the facility decision makers count on their refrigeration service contractors to keep their system running well (typically with monthly service visits) and to respond quickly when there is a problem. They value the relationship with their service contractor and would be very hesitant to make any changes to their refrigeration system without their service contractor’s input.

The very limited number of specialty designers within each of these subsectors also gives a handful of regional and national contacts a large influence over the design choices for new large-refrigeration systems.

Facility Decision Makers

Each of the market subsectors has a different set of facility-owner characteristics. One of the few things they do tend to have in common is a great concern for continued operation of the refrigeration system in a reliable manner. Besides possible concern about any change having an impact on reliability, most facilities have little to no “down time” during which a complete refrigeration system shutdown can occur to carry out a retrofit. Even short shutdowns risk a great financial loss in terms of lost product, or ice downtime if the arena flooding process has to start over. Key sector-specific facility ownership characteristics are outlined the following paragraphs.

First of all, decision-making for the grocery store market tends to be controlled by a few key contacts at local, regional, or national chains. Besides the varying geographic scale of each chain, the level of corporate direction for issues related to refrigeration systems also varies greatly among the chains. Some will specify all system components while others will only provide direction on very specific items, such as whether the display cases are open or have doors. While there are obvious challenges with getting the attention of large chain decision makers, a successful result can lead to many similar projects within a utility’s service territory. It is also noteworthy that even among chains dictating the refrigeration system design in great detail, local operators tend to have a degree of control over system service and refrigeration control settings that can allow for savings without reaching higher-level corporate decision makers.

While industrial refrigeration facilities are also often controlled by larger corporations, each owner tends to have very few facilities in Minnesota, let alone within one utility’s service territory. Corporate decision makers for these facilities are notorious for having very low payback thresholds for energy-saving projects, as they tend to be more focused on investments that will impact product output. On the other hand, the larger size of each facility can yield significant cost-effective savings for each project that is undertaken.

Like industrial refrigeration facilities, the vast majority of ice arena owners and operators manage no more than two ice sheets. However, nearly all ice arenas are owned by local government units, where it tends to be easier to reach key decision makers than it is within large corporations. While limited short-term budget availability is often an issue in these facilities, the local governments tend to embrace longer payback thresholds for energy-saving projects than do most corporations.

Market Study Objectives

The goal of this project was to generate comprehensive information about the medium and large commercial and industrial refrigeration market in Minnesota, to determine potential savings and to inform program planners and implementers about opportunities to increase refrigeration system savings realized through CIP program efforts over the next several years.

The market study's efforts included addressing the following specific objectives noted in the Department of Commerce's request for proposals:

1. Determine the applicability, current market penetration, and site-level savings of specific commercial and industrial refrigeration technologies in Minnesota.
2. Understand market barriers for refrigeration efficiency measures and identify program approaches that can be used to overcome them, enabling refrigeration programs in Minnesota to achieve their maximum potential.
3. Identify the best market channels to increase refrigeration technology adoption and program impacts.
4. Establish a base-case reference for the updating and future development of utility programs in Minnesota that target medium and large commercial and industrial refrigeration.
5. Refine estimates of the technical, economic, and achievable energy (and carbon) savings potential through energy efficiency in medium and large commercial refrigeration systems. This will build upon the results of the statewide potential study by taking a closer look at a targeted range of refrigeration measures and facility types with significant refrigeration.

This study focused on energy efficient refrigeration measures applicable to Minnesota's grocery stores, ice arenas, cold storage warehouses, and food/beverage processing facilities. Because these facilities have refrigeration systems made of multiple components that are special ordered and assembled in the field into a system with complex controls, many efficiency opportunities go beyond simple packaged equipment efficiency ratings. We sought to assess both new construction/equipment upgrade opportunities (e.g., increasing efficiency when display cases are replaced or refrigerant change-outs occur), and cost-effective savings opportunities that do not require major refrigeration equipment replacement (e.g., control adjustments or fan motor replacement).

Market Investigation Approaches

The project team carried out the first four investigation efforts described here — Utility Program Review, National Market Characterization, Characterization of Existing Facilities, and New Construction and System Replacement Rates — concurrently before undertaking the last three — Local Market Interviews, Facility Reviews, and Savings Potential Analysis — sequentially. This was done so that the critical local interviews and site reviews could be focused on addressing important questions that weren't answered through earlier efforts.

Utility Program Review

Programs in Minnesota

The project team comprehensively assessed existing utility programs in Minnesota that include refrigeration measures to develop a baseline of addressed and unaddressed opportunities and obtain utility feedback on the successes and disappointments of different facility types, measures, and program approaches. We identified these programs by reviewing the 2021–23 triennial plans for electric IOUs and the Energy Savings Platform for the electric municipal and cooperative utilities. Then, we interviewed representatives from five different utility programs (including all three electric IOUs) to better understand the successes and barriers of their commercial refrigeration programs.

Programs Outside of Minnesota

Slipstream, in collaboration with CEE, kW Engineering, and Cascade Energy, identified promising and exceptional programs throughout the country that might be applicable to the Minnesota refrigeration-dominated facility market. We identified these programs by combing through DSMdat (an E Source database of more than 5,000 demand-side management in the United States and Canada), reviewing ACEEE Exemplary Program Awards, and considering suggestions from the project team. We then narrowed the list to focus on programs that provide a more comprehensive or unique approach to this market that might provide valuable examples for programs in Minnesota. We made special efforts to look for refrigeration programs that have features consistent with the recommendations in the statewide potential study, such as comprehensive program design for larger, harder-to-reach customers; upstream incentives; operations savings; segment-specific strategies; and deeper trade ally engagement (CEE 2018).

A stepwise approach in narrowing focus led to the detailed review of seven programs outside of Minnesota through a combination of program data review and interviews. While the DSMdat database review yielded a list of 39 programs specifically targeting refrigeration measures, the vast majority of these programs are traditional rebate programs. We were most successful in identifying relevant programs by reviewing ACEEE's Exemplary Program Awards and by mining the market sector expertise and program awareness already present on the project team. Based on reviewing readily available information for the initial list, Slipstream identified 15 programs for serious consideration. The project team worked in collaboration to set priorities for narrowing down the list of 15 programs. Slipstream ultimately gathered detailed program information and conducted program staff reviews for seven of these programs. Among those seven prioritized programs, there was only one instance where Slipstream's email and phone outreach failed to secure an interview, and a slightly lower priority program was reviewed instead.

Interviews with program staff focused on the rationale for measures included or excluded, approaches to marketing and sales, trade ally engagement, project review, and program logistics. We also asked program staff what they hear from their end users and trade allies about requests for rebates on equipment that is not already prescriptively rebated, as well as positive responses or pushback to specific measures or program approaches.

National Market Characterization

The project team's considerable knowledge about large C&I refrigeration technologies was supplemented with a literature review and interviews of key national industry contacts. The goal was to gather accurate information about the latest technologies and to ensure that the local market data collection focused on the most relevant questions for guiding Minnesota CIP program refinement. These semi-open-ended interviews were conducted by individuals with a working knowledge of refrigeration efficiency issues. The national-level industry experts interviewed included manufacturers of key refrigeration system components and refrigeration system designers and consultants for each of the major facility types addressed by this study, as well as end-user decision makers for a number of large organizations.

These interviews gathered up-to-date information about national-level industry technologies, market penetrations, practices, and trends with an eye toward technologies and approaches that are especially relevant to Minnesota's climate and markets. The expected trends related to the phaseout of production of R-22 refrigerant at the end of 2019 were addressed as part of these interviews. For promising measures identified that were not part of refrigeration programs in Minnesota, information about energy savings potential was researched through follow-up interviews; literature review (including Technical Resource Manuals (TRMs) in other states); and expert engineering estimates of savings potential conducted by the project team.

The number of completed interviews for each subsector and contact types is summarized in Table 4. The number of different types of contacts varied among the subsectors based on differences in the most pressing information needs or verification of the team's initial impressions.

Table 4. Summary of National Level Contacts Interviewed by Subsector

Contact Type	Grocery	Industrial	Ice Arena
Vendor [a]	1	2	6 [b]
Contractor	—	2	1 [b]
Designer	1	—	—
Energy Consultant or Program Implementer	2	1	—
End User	1	2	—
Trade Industry Organization Leader	1	—	—
Subsector Total	6	7	7 [b]

a) The vendor category includes refrigeration equipment, controls, and products that reduce refrigeration load.

b) One contact interviewed for ice arenas is both a packaged system supplier and combination installation/service contractor.

Counts and Characterization of Existing Facilities

The team counted and compiled lists of existing grocery stores, ice arenas, cold storage facilities, and food/beverage processing facilities in Minnesota from a variety of public, industry association, and fee-for-service sources.

For grocery stores, a large number of individual facilities were identified through grocery store chain website searches, the Minnesota Grocer's Association membership directory, and the Minnesota Department of Agriculture's list of food retail and wholesale licenses. Cross-referencing between these sources provided a more complete picture of the key chains operating in different areas of Minnesota. However, the most definitive statewide estimate of the number of grocery stores came from the Census Bureau's data on county business patters (US Census Bureau 2019). Using the contact information in the Minnesota Grocer's Association membership directory, an invitation to a short online survey was also conducted. This was emailed to a list of 285 contacts — 198 emails were delivered (87 bounce backs) and 13 surveys were completed. Finally, the most detailed information about store size and refrigeration equipment patterns came from a review of seven grocery stores that participated in a Midwestern utility's energy efficiency program.

In the industrial refrigeration subsector, the definitive identification of facilities proved to be more challenging. The food manufacturing industry includes facilities that process raw materials, animal, vegetable, and dairy products into food that is typically sold to wholesalers or retailers, not directly to consumers. It is a broad category that also includes grain milling, confectioneries, and bakeries. To focus on those facilities likely to have high refrigeration loads, we highlighted animal, dairy, and fruit and vegetable processing. We also included refrigerated warehouses (i.e., cold storage) in this sector. The data on this sector comes from the county business pattern data (US Census Bureau 2019), which does not include facility square footage information. Most of the lists used from the Census Bureau, the

Minnesota Department of Labor and Industry's boiler and pressure vessel inspection database,[2] the Minnesota Department of Agriculture's list of food retail and wholesale licenses, and the Minnesota Grocer's Association membership directory included many of the targeted facility types, but refrigerated warehouses were included among hundreds or thousands of other facilities that do not have industrial refrigeration equipment. The closest approximation of a complete list came from picking out facilities in the state's boiler and pressure vessel list that were reported as having a manufacturer from among the few compressor manufacturers that dominate the industrial refrigeration market and do not make compressors for air conditioning or compressed air applications. While this was known to exclude some makes of compressors, they were believed to represent a small fraction of industrial refrigeration facilities with central refrigeration systems. It is noteworthy that cold storage (or other) facilities with a number of scattered individual condensing units would not have been included in this count. None of the industrial refrigeration facility lists the project team pulled together had contact information that could be used for short online surveys.

For ice arenas, we believe that the Department of Health's list of indoor ice arenas identified all ice arenas in the state (and is expected to generally omit curling rinks, which were not a key focus of this study). We also used the Minnesota Ice Arena Managers Association directory for contact information to send invitations to a short online survey. Invitations were sent to 182 contacts — with 145 emails delivered (37 bounce backs) and 23 surveys completed.

New Construction and System Replacement Rates

Grocery

Dodge Construction Data for 2015–2019 for counties in the Twin Cities area, Rochester, and Duluth (Hennepin, Ramsey, Washington, Anoka, Carver, Scott, Dakota, Sterns, Olmsted, St. Louis, and Blue Earth counties) was used to determine the number of new construction and retrofit projects. Then the proportion of total state population that these counties represent (65%) and the reported construction rates was used to scale the new construction and renovation trends to the entire state.

Industrial

Dodge Construction Data on food manufacturing and cold storage facilities for 2015–2019 and for counties in the Twin Cities area, Rochester, and Duluth (Hennepin, Ramsey, Washington, Anoka, Carver, Scott, Dakota, Sterns, Olmsted, St. Louis, and Blue Earth counties) was used to identify the number of projects within each of those categories. Then the proportion of total state food manufacturing (around 40%) and cold storage facilities (around 60%) located in the above counties and the reported construction rates were used to scale the new construction trends to the entire state.

[2] The boiler pressure vessel database was useful because large refrigeration system components are often included in the list of pressure vessels.

Data on equipment age from the Minnesota Department of Labor and Industry's boiler and pressure vessel inspection database also was used as a proxy for the total number of new construction and equipment replacement projects. This database included the manufacturer date for each piece of equipment, so the age range of equipment could be used to get an idea of how often existing equipment is replaced, and the rate of addition of new entries in recent years provided an indication of how many systems are added per year.

Ice Arenas

Dodge Construction Data on indoor arenas for 2015–2019 and for counties in the Twin Cities area, Rochester, and Duluth (Hennepin, Ramsey, Washington, Anoka, Carver, Scott, Dakota, Sterns, Olmsted, St. Louis, and Blue Earth counties) was used to count how many ice arenas were constructed or had ice systems replaced, as well as the number of arenas that had alterations within those counties. The total number of ice arenas located in the above counties and the reported construction rates were used to scale the construction trends to the entire state. Data on equipment age from the Minnesota Department of Labor and Industry's boiler and pressure vessel inspection database was also used as a proxy for the total number of new construction and equipment replacement projects.

Local Market Interviews

Interviews with 41 key decision makers at local and regional levels were conducted to provide valuable market information for program development. The number of each type of contact interviewed is summarized by market subsector in Table 5 and a full list of interviewees can be found in Appendix A: Local Refrigeration Industry Interviewees. Interviews with all of these industry representatives gathered both general market intelligence and measure-specific data related to energy efficiency, such as the impacts of various parties on design and operations; information about the prevalence of individual measures; why these parties aren't implementing specific measures; what is limiting their participation in utility programs; what measures they are implementing regardless of whether a rebate is available; and operational practices with respect to energy efficiency (e.g., head pressure controls, suction pressure controls, defrost scheduling, and anti-sweat heater control). Plans related to the phaseout of R-22 refrigerant were also addressed as part of the interviews — especially for contacts of ice arenas and industrial refrigeration facilities, where a higher percentage of existing systems use R-22. The primary goal was to get an understanding of statewide practices and opportunities. Observations of differences between utility service territories will generally not have a statistically significant sampling basis. These interviews were expected to provide the study's most valuable information for guiding the program enhancements to maximize CIP energy savings in the local commercial and industrial refrigeration market.

Table 5. Summary of Local & Regional Contacts Interviewed

Contact Type	Grocery	Industrial	Ice Arena
Vendor	4	4	1
Contractor	1	6	4
Designer	—	—	1
Energy Consultant or Program Implementer	1	1	1
End User	7	5[a]	5
Subsector Total	13	16	12

a) The industrial end users interviewed represent two food processing and three cold storage facility contacts.

Across all three subsectors of the refrigeration-dominated facilities market the refrigeration contractors tend to have a very strong influence on both system design and operation. Therefore, a critical initial focus of the interview was in-depth discussions between refrigeration contractors and the project team's industry experts. These interviews explored contractors' opinions on the barriers and opportunities around individual measures and program approaches — especially approaches that might engage them more effectively. In the grocery sector, some of the focus on contractors was transferred to interviews with key contacts at a majority of large retail grocery chains with a significant number of stores in Minnesota, as many of these contacts had an usually high level of knowledge about refrigeration system details.

Facility Reviews

The project team reviewed plans, conducted on-site visits, or both, for 15 facilities to further evaluate technology practices and measure market penetration for items that were not adequately clarified through the previous efforts outlined previously. Since large refrigeration systems are often supplied on a design–build basis, detailed plans were often unavailable. Thus, plan review provided adequate information for only a fraction of facilities, and site visits were conducted at all facilities reviewed. The facility reviews had the following key goals:

- Assess refrigeration system design features and control characteristics for recently built or upgraded facilities to evaluate practices at the time of equipment installation or replacement. This identified the measures missed at the time of system installation and any retrofits that might still be cost-effective.
- Review a number of representative older refrigeration systems to evaluate the potential for cost-effective retrofits that could be performed without replacing the existing system.
- Review operational practices to evaluate the potential to achieve savings through no- or low-cost control changes, such as head and suction pressure control strategies, defrost scheduling, case/process temperature control, and anti-sweat heater operation.

Table 6 summarizes the facility types reviewed and highlights some of the most important characteristics that went into each facility's selection. The final selection of sites was driven by a combination of striving to find the most representative facilities to best inform program development and cooperation from facility staff during times of COVID-19 pandemic concerns.

Table 6. Summary of Sites Selected for Review

Site #	Grocery	Industrial	Ice Arena
1	• Recently built transcritical carbon dioxide system	• Food distribution center	• Typical moderate age system • Recently converted to R-449A • Implemented customized control measures
2	• Typical moderate age system	• Cold storage	• Older system • Implemented customized measures
3	• Typical moderate age system	• Cold storage	• Typical moderately new system • Designed with R-507
4	• Older system	• Cold storage	• Typical older system • Still using R-22
5	• Recent remodel • Conversion to R-449A	• Food processing	• Recent refrigeration system rebuild

Savings Potential and Cost-Effectiveness Analysis

The project team sought to expand on the commercial and industrial refrigeration measure analysis conducted in the 2018 Minnesota DSM Potential Study. We identified promising technologies not included in the study or in current Minnesota utility programs and then characterized their cost-effectiveness and overall potential. The list of measures characterized was determined after dozens of interviews with industry experts (e.g., program managers, contractors, facility managers), review of existing Minnesota utility programs, and internal discussion by the project team's refrigeration efficiency experts.

Cost-Effectiveness Analysis

We calculated cost-effectiveness by measure using the Societal Cost Test (SCT) and Utility Cost Test (UCT) in a manner consistent with Department of Commerce's approved practice for Minnesota utilities. We also used a simple payback calculation to indicate the return on investment from the customer's perspective. The general assumptions used within this framework were drawn from the Commerce Decision: CIP Gas and Electric Utilities 2021–2023 Cost-Effectiveness Review, EIA state level energy price data, and the 2018 Minnesota DSM Potential Study (CEE 2018). These assumptions are all statewide averages and were not customized by utility service territory. The details of these assumptions are presented in Appendix B: Assumed Inputs for Cost-Effectiveness Evaluation.

For each measure, savings estimates were determined by first calculating an average baseline energy use (kWh/year) by facility type for the component(s) of the refrigeration system to which the measure was applicable. An average savings potential by measure was then calculated by multiplying this baseline by the percentage savings for each measure relative to the baseline non-efficient measure. Both the energy-use baselines and the measure savings percentages were determined from engineering estimates using data from projects previously completed by the project team, internal estimating software, and publicly available studies. The measure costs were determined in a similar manner and were based extensively on experience from actual efficiency upgrade projects completed previously by project team members. Finally, the measure lives were set at 15 years for capital improvements and seven years for recommissioning measures (e.g., making controls adjustments). Although there is some variation within the industry, this is broadly consistent with typical utility program assumptions.

Potential Calculations

Although this study did not seek to comprehensively assess the energy savings potential for commercial and industrial refrigeration measures in Minnesota, the project team did characterize technical and program potential by measure to provide a reference for the relative impact each measure could achieve. After calculating the average savings potential by measure for each facility type, we multiplied those savings averages by the number of existing facilities in Minnesota and the rate of new construction by facility type (e.g., Industrial, Grocery, and Ice Arenas) as outlined in the General Characterization of Existing Facilities and New Construction and System Replacement Rates subsections of this report. The percentage of these facilities in which a measure was technically applicable was determined through a combination of the team's previous experience and information gathered during the interviews conducted for this project (both for new construction and existing facilities).

All of these assumptions were then used to calculate technical and program potential. The technical potential reported assumes that the measure is deployed in 100% of the facilities in which it is technically applicable. The program potential was determined by taking the technical potential and multiplying it by a penetration curve typical of a measure newly introduced to a program portfolio (Year 1 = 1%; Year 2 = 2%; Year 3 = 4%; three-year total = 7%). The program potential is not intended to represent the maximum potential achievable for each measure by Minnesota utilities, but rather a more realistic estimate of actual program potential as compared to the technical potential estimates.

Study Findings

Utility Program Review

Programs Within Minnesota

All of the utility programs identified in Minnesota offer prescriptive rebates that are either refrigeration specific or can apply to refrigeration measures (e.g., efficient motors). Although most utilities also have custom rebate programs through which refrigeration efficiency projects can qualify for rebates, most of the savings come from prescriptive offerings. Only one of the utilities interviewed (Minnesota Power) employs a third-party implementor that handles the majority of their refrigeration offerings. The other utilities typically use a combination of in-house program managers, account representatives, and trade ally liaisons to deploy their refrigeration offerings.

In general, there are few eligibility requirements a commercial customer must meet to participate in Minnesota utility programs that deal with refrigeration measures. For custom programs, project preapproval is typically required, but otherwise a customer usually just needs to install a rebate-eligible piece of equipment to qualify. Despite eligibility requirements being fairly simple, the burden of determining what equipment qualifies for rebates typically falls on the customer. Few Minnesota utilities take a more proactive role in identifying efficiency opportunities for the customer.

One notable absence in Minnesota utility efficiency portfolios are active program efforts focused on no-cost/low-cost refrigeration control optimization (e.g., lowering head pressure setpoints, reducing defrost frequency, increasing suction pressure setpoints, etc.). This is an offering that utilities should consider, as it is an opportunity for significant cost-effective energy savings.

For all utilities, grocery stores are the most common participants in refrigeration offerings. Large storage warehouses and food processing facilities are also relatively common participants. However, most interviewees cited little to no participation by ice arenas.

Minnesota Investor-Owned Utilities' Prescriptive Refrigeration Program Offerings

As mentioned above, prescriptive rebates are typically the primary way that utility programs promote their refrigeration offerings. Table 7 shows the utility rebates offered by the three electric IOUs in Minnesota.

To quantify the impact and relative effectiveness of each Minnesota utility's approach to their refrigeration program offerings, we reviewed the IOU status reports and triennial plan filings, as well as the Energy Savings Platform, where municipal and cooperative utilities in Minnesota submit their program performance data. This data, which is summarized in Table 8 and Table 9, shows a wide range of refrigeration program savings as a percentage of total utility sales. Minnesota Power recorded the highest percentage in 2019, followed by Otter Tail Power.

Table 7. Prescriptive refrigeration measures offered by IOU (2021–23 triennial plan)

Measure Name	Xcel Energy	Otter Tail Power	Minnesota Power[a]
Preventative maintenance: 1–30 HP	No	Yes	No
Preventive maintenance: 31–100 HP	Na	Yes	No
Preventive maintenance: 101–200 HP	No	Yes	No
Anti-sweat heater controls	Yes	Yes	No
Conversion to parallel-rack system	No	Yes	No
Conversion to solid state controller	No	Yes	No
Solid-state condenser fan control	No	Yes	No
Floating head pressure controls	Yes	Yes	No
High evaporator temperature cases	No	Yes	No
LED display case lighting (low temp)	Yes	Na	No
LED display case lighting (med temp)	Yes	Yes	No
Medium-temp Enclosed Reach-In Case	Yes	No	No
High-efficiency motors	Yes	Yes	Yes
No heat case doors	Yes	Yes	No
Outdoor air cooling	No	Yes	No
Preservation of condenser subcooling	No	Yes	No
Retrofit of open cases with doors	Yes	No	No
VFDs	Yes	No	No
Walk-in freezer defrost controls	Yes	No	No
Custom refrigeration project	Yes	Yes	Yes

a) Minnesota Power has historically provided their commercial offerings through a single custom program, which is why they have few prescriptive refrigeration measures.

Table 8. Refrigeration Program Participation and Savings by IOU (2019)

Utility	Participants	Commercial refrigeration savings (kWh, at generator)	Adjusted average 2017-19 baseline sales (kWh, all sectors, minus CIP opt-outs)	Commercial refrigeration savings as % of total sales
Xcel Energy	192	897,658	27,807,301,870	0.0032%
Otter Tail Power	83	929,927	1,689,628,350	0.0550%
Minnesota Power	N/A	1,969,263	2,646,854,358	0.0744%

Table 9. Refrigeration Program Participation and Savings by Municipal and Cooperative Utility (2019)*

Utility*	Participant Count	Commercial refrigeration savings (kWh, at generator)	2019 baseline sales (kWh, all sectors, minus CIP opt-outs)	Commercial refrigeration savings as % of total sales
Alexandria Light & Power	2	25,420	281,812,000	0.0090%
Bagley Public Utilities Commission	1	245	24,014,791	0.0010%
Barnesville Municipal Power	1	1,915	21,704,441	0.0088%
Beltrami Electric Coop, Inc.	5	36,000	492,653,402	0.0073%
Benson Municipal Utilities	1	3,041	34,418,000	0.0088%
Blooming Prairie Public Utilities	1	5,000	25,999,020	0.0192%
Breckenridge Public Utilities	1	3,330	36,998,941	0.0090%
Detroit Lakes Public Utility	2	16,463	189,741,000	0.0087%
Fairmont Public Utilities	1	7,500	144,834,429	0.0052%
Fosston Municipal Utilities	1	245	30,140,167	0.0008%
Grand Marais Public Utilities	1	2,000	20,882,239	0.0096%
Hutchinson Utilities Commission	10	90,000	270,873,597	0.0332%
Jackson, City of	2	4,099	45,292,000	0.0091%
Lake City Utility Board	1	20,000	130,442,381	0.0153%
Litchfield Public Utilities	1	5,000	129,088,220	0.0039%
Luverne, City of	1	7,695	73,566,000	0.0105%
Marshall Municipal Utilities	2	5,000	558,720,581	0.0009%
Melrose Public Utilities	2	10,173	120,955,000	0.0084%
Moorhead Public Service	2	38,975	437,035,000	0.0089%
Mora Municipal Utilities	1	5,000	50,470,417	0.0099%
New Prague Utilities Commission	1	5,000	74,770,613	0.0067%
North Branch Municipal Water & Light	1	5,000	25,914,029	0.0193%
North Star Electric Coop	4	11,650	111,159,290	0.0105%
Ortonville Light Department	1	2,456	27,596,000	0.0089%
Preston Public Utilities	1	5,000	13,102,691	0.0382%
Princeton Public Utilities	1	5,000	52,192,683	0.0096%
Redwood Falls Public Utilities	1	25,000	63,882,591	0.0391%
Roseau Electric Coop	7	15,000	153,314,361	0.0098%
Sauk Centre Public Utilities	2	5,380	60,936,000	0.0088%
Spring Valley Public Utilities Comm	1	5,000	19,553,882	0.0256%
St. James Municipal Light & Power	1	4,884	53,428,000	0.0091%
St. Peter Municipal Utilities	2	20,000	96,108,880	0.0208%
Staples, City of	1	2,078	25,370,000	0.0082%
Wadena Light & Water	2	6,095	67,478,000	0.0090%
Waseca Utility	1	5,000	57,431,808	0.0087%
Wells Public Utilities	3	5,000	21,058,077	0.0237%
Willmar Municipal Utilities	1	18,797	279,868,000	0.0067%
Worthington Public Utilities	2	23,291	221,993,000	0.0105%

*This table only includes data for the minority of utilities that specifically reported refrigeration program savings.

Interview summaries

Utilities Interviewed

- Xcel Energy
- Minnesota Power
- Otter Tail Power
- Great River Energy
- Connexus

High-level takeaways

Similarities

- Prescriptive and custom refrigeration rebates are offered as part of broader commercial efficiency programs.
- Offerings are most commonly promoted through utility account managers and trade ally representatives.
- Grocery stores are the most common program participants. Relatively few ice arenas take advantage of utility rebates.
- Contractors are often wary of the additional time and complications resulting from participating in utility programs. This is especially true of custom programs.

Differences

- Minnesota Power relies primarily on their commercial custom program to provide refrigeration rebates compared to all other utilities interviewed, which focus on their prescriptive offerings.
- Otter Tail Power is the only Minnesota utility known to offer a preventative maintenance program for refrigeration contractors and customers to use, which is used both as a savings measure itself and as a way to identify additional savings opportunities.

Xcel Energy — HVAC+R Program

The HVAC+R program combines Xcel Energy's commercial heating, cooling, refrigeration, and motors and drives products into a single program that is available to all commercial customers. The program focuses on capital upgrades that a customer can make by providing prescriptive and custom rebates, as well as technical information and support. Participants are primarily recruited by Xcel Energy's Business Solutions Center representatives and account managers. In addition, bill inserts, emails, mailings, and engagement with trade allies are all used to increase program participation.

For the refrigeration portion of the HVAC+R offering, assessments are available at no cost to the customer to eliminate a participation barrier. The most common participants that implement refrigeration measures are grocery stores, school districts with large central cold-storage facilities, food banks, hospitals, and industrial cold-storage facilities. For those facilities, food safety and product reliability are typically their top concerns and must be addressed when implementing energy-saving measures.

Minnesota Power — Custom and Prescriptive Business Efficiency Programs

Minnesota Power is unique among large Minnesota utilities in that its primary commercial efficiency delivery platform is a custom program called the Custom Business Efficiency Program. A field representative works directly with each customer to identify opportunities specifically tailored to the individual customer's needs, while also developing long-term relationships through regular interaction to encourage ongoing efficiency upgrades. Like other custom programs, project preapproval is required, but Minnesota Power and its program implementer take project information and perform the energy savings calculations while typically being able to get that approval in 24–48 hours. This lowers the most commonly cited barriers to customer participation in a custom efficiency program. This intensive approach to working with customers appears to be effective, as Minnesota Power has reported the highest commercial refrigeration program savings as a percentage of total electricity sales of any Minnesota utility (Table 8). In addition to the custom program, the Prescriptive Efficiency Program was recently introduced to streamline program participation for small to medium-sized customers, but the custom program remains the primary focus.

Typical customers with large refrigeration loads that participate in Minnesota Power's refrigeration offerings are convenience stores and ice arenas. These customers' interest in the program has helped Minnesota Power develop contractor relationships, which, in many cases, have been built over years of repeated interactions with the program as well as contractor trainings that Minnesota Power hosts multiple times per year.

Otter Tail Power Company – Refrigeration

Otter Tail Power's refrigeration program is designed to promote high-efficiency commercial refrigeration technologies by offering rebates for new and retrofit installation of equipment. In addition to the rebates offered for capital improvements, Otter Tail Power is unique in offering a preventative maintenance measure that covers the majority of the cost for a contractor to conduct activities such as coil cleaning and system setpoint verification. Contractors and customers have consistently provided positive feedback about this offering, as it covers the cost of making sure their current refrigeration system is operating efficiently. Otter Tail Power is able to claim energy savings from the preventative maintenance visits themselves as well as use the visits as a regular opportunity to discuss efficient capital improvements.

The primary method used to promote the refrigeration program are Otter Tail Power's geographically placed account representatives, who they train on their refrigeration and other offerings to be able to discuss them with customers. Overall, larger customer with a facilities manager are the most likely customers to retrofit existing equipment through the program. Smaller, independent grocery stores typically only take advantage of rebates when they are doing a new build or complete equipment changeout.

Great River Energy and Connexus

The project team interviewed Great River Energy (GRE), a generation and transmission cooperative, and one of its largest members, Connexus Energy. GRE supports the efficiency programs of its member utilities, but the programs themselves are implemented by each individual utility. For GRE and its members, general prescriptive measures (e.g., motors and VFDs) compose the majority of the refrigeration-related measures in their programs. There is also a custom efficiency path, but as with the investor-owned utilities, the prescriptive path is typically preferred by customers since there is usually significantly less work involved.

Grocery stores are the most common large refrigeration facilities that participate in GRE's members' programs. However, one unique aspect of GRE's refrigeration offerings is that they have provided a significant number of rebates to ice arenas for resurfacer electrification. Although part of the refrigeration offerings, this resurfacer electrification does not have a significant impact on refrigeration system energy consumption. This measure was introduced when ice arenas managers indicated their interest in replacing existing resurfacers that used other fuels such as propane, primarily driven by concerns about indoor air quality.

Barriers and Successes Identified

Out of the interviews, two related issues emerged that program representatives consistently deal with when promoting refrigeration offerings. The first issue, difficulty engaging refrigeration contractors, was the primary barrier to increasing refrigeration savings cited by program representatives. The second issue, convincing customers of the value of participating in refrigeration programs, was also prevalent, and often stemmed from the contractor engagement difficulty.

Contractor Engagement

All utility representatives we interviewed talked about the importance of engaging with refrigeration contractors to promote their refrigeration offerings to end-user customers. However, many noted that, unlike lighting contractors, many refrigeration contractors do not actively work with their programs. In fact, many reported contractors actively recommending that their customers not implement refrigeration efficiency upgrades recommended by utilities. Below are some common themes identified by the utility representatives that we interviewed, many of which came from feedback the utility representatives themselves had received from customers and trade allies.

Common issues contractors have with utility refrigeration offerings include the following:

- The participation process and documentation requirements are too onerous. This is particularly true for custom projects, where customers and their contractors must seek preapproval before starting a project.
- Food safety and product reliability are the primary concerns for contractors and their customers, not efficiency.
- Contractors may not be willing to use a more efficient technology if they have not used it extensively before or doubt its performance and reliability.

The following are some ways the utility representatives can or do address those contractor concerns:

- Although none of the utilities interviewed have official refrigeration contractor networks, many work with contractors to educate them about their program offerings, which is important due to relatively low contractor awareness of refrigeration programs. Having a program representative

who knows refrigeration systems well, and can meet with key contractors regularly, is critical to increasing contractor participation in utility refrigeration programs.
- None of the utilities interviewed have trainings specific to efficient refrigeration technologies, which may be a way to help contractors overcome their hesitance.
- The utilities which have successfully built relationships with contractors have done so over a long period of time (several years or more) both through personal relationships and by having customers put pressure on contractors to participate.
- “Trade incentives” for contractors (e.g., an additional 10% of the rebate total goes to the contractor) compensate contractors for the time they spend navigating utility programs.
- Preventative maintenance programs like the one offered by Otter Tail Power give contractors an avenue to interact with their customers on a regular basis and potentially sell them additional upgrades.

Program Participation

Program representatives reported generally positive feedback from end-user customers. Customers appreciate the programs for the rebates and information they provide. However, there are some common issues that may prevent customers from participating.

Barriers to participation:

- Rebate applications are often complicated and unclear, making it difficult for customers and contractors to determine what equipment qualifies for a rebate. Utility account managers and field reps may help, but the customer or contractor is usually responsible for completing rebate application and providing supporting documentation.
- Custom programs requirements, including extensive project documentation and program approval before work commences, are often considered so onerous that customers and contractors chose not to participate.
- Payback time for investment in efficient measures can be too long.
- Typically, a customer must wait 4–8 weeks to receive their rebate check after submitting completed application.

How programs might increase participation:

- Higher rebates may be necessary to cover a larger portion of the up-front costs.
- A common way for utilities to streamline program participation is by creating prescriptive measures to replace formerly custom offerings. The typical route for that transition is for the utility to see a customer offering come through their program frequently enough that it decides to consider adding it as a regularly available offering. Some also look at other utility programs and TRMs across the country for common offerings. Unless a concerted effort is made to streamline custom programs, developing prescriptive rebates for as many measures as possible may be the most effective way to simplify customer participation in refrigeration programs.

Programs Outside of Minnesota

Programs Identified and Chosen for Review

A wide range of programs targeting commercial or industrial refrigeration measures were identified. A review of programs in the DSMdat database yielded nearly 40 programs that target refrigeration measures, with the vast majority having very traditional rebate program approaches. However, a number of programs with more progressive approaches were identified from among this list as well as through both the project team's refrigeration subsector experts and a review of programs that received ACEEE Exemplary Program Awards.

Table 10. Short List of Energy Efficiency Programs Outside Minnesota

Name of Program	Implementing Entity	Source
Strategic Energy Management	Energy Trust of Oregon	Project Team
Strategic Energy Management; component of the Energy Smart Industrial program*	Bonneville Power Administration*	ACEEE Exemplary Program & Project Team
Industrial System Optimization Program*	Puget Sound Energy*	Project Team
Commercial Strategic Energy Management	Puget Sound Energy	ACEEE Exemplary Program
Efficiency Vermont Commercial Refrigeration	Efficiency Vermont	Project Team
Industrial Refrigeration Study*	ComEd*	Project Team
Small Business Program Offering	ComEd	ACEEE Exemplary Program
Pilot Program: Monitoring Based Commissioning*	NYSERDA*	Project Team
Commercial Refrigeration Efficiency	Xcel Energy Colorado	Project Team
EnergySmart Grocer*	PG&E and National Grid*	Web Search
C&I Direct Install	New Jersey Office of Clean Energy	ACEEE Exemplary Program
Large Energy Users Program*	Wisconsin Focus on Energy*	ACEEE Exemplary Program
Continuous Energy Improvement	AEP Ohio	ACEEE Exemplary Program
Municipal Ice Rink Program*	SaskPower*	Project Team
Burlington (Canada) Ice Rink Energy Competition	City of Burlington	Web Search

Table 10 lists the 15 programs that were identified as having features that are likely to provide valuable examples that could potentially be duplicated in Minnesota, along with an indication of how the program was identified for consideration. Based on project team prioritization, seven of these programs were reviewed in detail — those seven programs are noted in the table with asterisks. While the C&I

Direct Install program by New Jersey Office of Clean Energy was originally targeted, we were unable to obtain detailed enough information from implementation staff to carry out the review.

Characteristics of Programs Reviewed

Most of the programs we reviewed do not specifically target refrigeration systems. They take a comprehensive approach to energy management that includes refrigeration. All the programs reviewed have a scoping study or audit component. Three of the programs include a mix of prescriptive and custom rebates, three are custom incentives only, and one is prescriptive only. Measure categories include motors, controls, sensors, and floating head pressure control, among others. Table 11 identifies these program characteristics, and Table 12 provides additional details on program recruiting processes and financial incentives.

Table 11. Program Characteristics

Program	Incentives	Utility	Administrator	Common Participants	Measure Categories
Energy Smart Industrial	Prescriptive/ Custom	Bonneville Power Administration	Cascade Energy	Food processors and pulp & paper	Motors, Controls, Strip curtains
Industrial System Optimization Program	Custom	Puget Sound Energy	Cascade Energy (now managed by Puget Sound)	Cold storage	Measures identified through scoping study including lower head pressure, raise suction pressure, cycle evaporative fans, optimize VFD fans, optimize defrost.
Industrial Refrigeration Study	Custom	ComEd	Franklin Energy	Food processors and cold storage	Measures identified through audit
Large Energy Users	Prescriptive and Custom	Various Wisconsin utilities	Focus on Energy	Food processors and cold storage	Compressors, Controls, Equipment reconfiguration, Commissioning
Municipal Ice Rink	Prescriptive and Custom	SaskPower	SaskPower	Indoor ice rinks	Motors, Pumps, Sensors, Controllers, Ventilation
Pilot: Monitoring Based Commissioning	Custom	NYSERDA	KW Engineering	Grocery stores	Measures identified through data collected
EnergySmart Grocer	Prescriptive	PG&E and National Grid	CleaResult	Grocery stores	Motors, Cases, Anti-Sweat Controls, Floating Head Pressure Control, Refrigeration Controls, HVAC (destratification fans)

Table 12. Program Details

Program	Utility	Recruitment	Most Successful Recruiting Method	Contractor Network?	Contractor Recruiting Method	Contractor Training?	Incentive Process	Paperwork Prepared By	Time to get Incentive
Energy Smart Industrial	Bonneville Power Authority	Field staff, case studies, vendor outreach and lunch and learn events targeted to specific market segments	Field staff	TSPs (technical service pool)	Application process, companies submit work samples	TSP manager conducts annual safety training and general program policies and M&V protocol.	Implementer creates a submittal package (with TSP help); submits package to local utility	Implementer and TSPs	Average time from submittal to incentive payment is two months
Industrial System Optimization Program	Puget Sound Energy	Implementer customer base and targeted list from utility	Targeted customers	No	N/A	N/A	Customer completes Action Item Completion Report; implementer completes M&V report	Implementer completes project packet and submits to utility	Average = 15 months
Industrial Refrigeration	ComEd	Third-party outreach	Service providers bring customers to the program	Yes	Application process — companies submit their qualifications	Classroom events	Incentives awarded after project M&V	Service Provider and Customer	Comprehensive study 3–6 months up to 1–2 years; Fix It Now 2–4 months
Large Energy Users Program	Leidos, Inc.	Energy Advisors	Energy Advisors	Yes	Through the customer — the company they are already working with to service/install equipment	Has paid UW Madison to provide trainings on commercial refrigeration in the past	Application confirming installation dates, measures installed, final paperwork submitted	Energy Advisor completes most paperwork with help from customer and trade ally	12–18 months
Municipal Ice Rink Program	SaskPower	Marketed program through Saskatchewan Parks and Recs, hockey and curling leagues, ads in journals of those	Saskatchewan Parks and Recs	No	N/A	N/A	Prescriptive: Submit application and proof of install	Customer	Vary depending on the size of project.

Program	Utility	Recruitment	Most Successful Recruiting Method	Contractor Network?	Contractor Recruiting Method	Contractor Training?	Incentive Process	Paperwork Prepared By	Time to get Incentive
		groups and direct mailers to municipalities.					Custom: Engineering review of project, check-in at project milestones; 75% of the incentive released at proof of install; remainder after M&V.		
Pilot: Monitoring Based Commissioning	NYSERDA	Implementer identifies and recruits participants	N/A	No	N/A	N/A	Unknown	Implementer	Unknown
EnergySmart Grocer	PGE and National Grid	Implementer recruits participants	N/A	Yes	Implementer recruits contractors	Unknown	Application	Account Manager	Unknown

Program Staff Interview Findings

The key takeaways from program staff interviews are noted below.

Energy Smart Industrial — Bonneville Power Authority. Energy Smart Industrial Program (ESI) has several program components: custom projects, strategic energy management (SEM), and a trade ally-driven component. For the purposes of this project, we focused on ESI custom and SEM. ESI custom achieves 80% of the savings and SEM achieves 20%. SEM addresses organizational practices and projects that will provide persistent savings, while custom projects address new or retrofit measures that require custom measurement and verification.

The measures included in this program were derived from the implementer's experience — measures they've seen to be successful in projects over the years. They are seeing more advanced controls (lots of specialty process controls) that are not technically on the measure list for the program, but which fit into some broader measure categories and allow them to include those measures in the program.

Industrial Systems Optimization Program — Puget Sound Energy. Industrial System Optimization (ISOP) targets industrial facilities with most of their electric load associated with process systems or manufacturing, or with subsystems that have long run-hours, use industry-standard technology, and maintain stable control setpoints and loads. The requirements preclude retail sites (such as grocery stores). Many of the businesses participating in this program are cold storage facilities.

The program focuses on identifying and implementing low-cost or no-cost operation and maintenance improvements. Program staff work on-site with facility staff (or their refrigeration contractor) to immediately implement no-cost changes while identifying actions the facility can take within four months. Program staff generally spend two to four days (depending on facility size) on-site. The primary refrigeration measures implemented are lower head pressure, raise suction pressure, cycle evaporative fans, optimize VFD fans, and optimize defrost schemes. A measure the program generally doesn't pursue is regulating refrigerant flow. If it has been done correctly, there is little cost-effective savings to be gained.

A result of ISOP was Puget Sound's implementation of their Strategic Energy Management program. Graduates of ISOP are targeted for participation in SEM.

Industrial Refrigeration Study — ComEd. The Industrial Refrigeration Study is a component of ComEd's Industrial Systems Optimization Program but specifically targets industrial refrigeration systems, primarily industrial manufacturing (chemical, plastic, fabrication) and food processing and storage facilities. A refrigeration study includes a two-week period of baseline monitoring, an engineering review, and recommendations for projects to implement. Common measures include floating head pressure controls; controlling speed drives, fans, evaporators and VFDs; defrost controls; and envelope measures (doors, insulation and infiltration). ComEd's also implemented a "Fix It Now" program that addresses compressed air leaks — a program service provider visits the facility and identifies and repairs compressed air leaks on the spot.

The program is delivered through a closed network of primarily engineering-based service providers. These service providers generally bring participants into the program as well. Participants receive incentives in three to six months, though the process can take longer for more complicated projects. The incentives for the comprehensive refrigeration study are paid to the service provider, while incentives for "Fix It Now" go to the customer, though these end up being paid back to the service provider for the work performed. The introduction of the "Fix It Now" program filled a gap in the program, and both service providers and customers have provided positive feedback on it.

Large Energy Users — Wisconsin Focus on Energy. The Large Energy Users program targets commercial, industrial, educational, healthcare, and government facilities with average monthly electricity demand greater than 1,000 kW (or monthly natural gas demand greater than 100,000 therms). Industrial refrigeration participants in the program tend to be food processors (cheese and milk) and cold storage facilities.

Participants are assigned an Energy Advisor who helps participants identify savings opportunities in their facilities. The Energy Advisor also works directly with utility account managers and trade allies through the implementation of participant's projects. Participants are recruited into the program through established relationships with Energy Advisors, utility representatives, and Trade Allies, as well as through the Focus on Energy website. The program has a high participant retention rate, that is, roughly 84% of program participants had participated in the program in previous years. About 16% of participants are new to the program each year (Cadmus 2019).

Municipal Ice Rink — SaskPower. SaskPower has had an ice rink program for decades with funding and interest waxing and waning through the years. Currently, there is no financial support for the program. Our interview focused on the program as it functioned about three to four years ago when it was more active. The program followed an audit model but tailored specifically to indoor ice rinks. The auditor would complete an ASHRAE Level 1 audit, review energy bills, and identify some savings opportunities. The savings opportunities that delivered the best returns were programmable controllers with infrared or slab sensor inputs to control compressors and pumps; brine loop sensing to slab or infrared sensing system; and high-efficiency motors on circulation pumps.

Pilot: Monitoring Based Commissioning — NYSERDA. This pilot program targets grocery stores and uses remote monitoring to connect with their refrigeration, lighting, and HVAC control systems to quickly find energy savings opportunities. In addition to identifying energy savings, the data link to the store's control systems provides fault detection and diagnostic capabilities that add a non-energy benefit to the grocer.

The program focuses on regional grocery chains with facilities that are 30,000 to 60,000 square feet. It was designed to be a streamlined approach to traditional retro-commissioning programs that are heavy on reporting and site visits. Program staff approach energy savings from the grocer's perspective — identifying ways to reduce electricity use while keeping the ice cream frozen. An example of this approach is to monitor freezer case temperatures rather than electricity use, and then raise the case temperature as high as possible while keeping the contents frozen.

Typical successful measures include floating suction pressure controls, floating head pressure controls, upgrades to case lighting controls, and upgrade and recommissioning of anti-sweat heater controls. However, the program implementer notes that, while there is a typical set of measures for all grocery stores, the details in implementing those measures differ by facility.

EnergySmart Grocer. The EnergySmart Grocer program serves mid- to large-sized grocery stores with peak demand greater than 60 kW. It provides a no-cost energy assessment that identifies savings opportunities and financial incentives for implementing standard measures. These measures include motors, cases, anti-sweat controls, floating head pressure control, refrigeration controls, and HVAC (destratification fans).

The program was originally designed to target small, independent grocers who were less likely to have in-house operations managers and had little to no refrigeration expertise. Early on, though, program implementers discovered that mid- to large-sized grocers were good candidates as well. While they had operations managers, they didn’t really understand their building and refrigeration systems or how to make them work efficiently.

The lynchpin of the program design was a simple building energy model that allowed the energy auditor to conduct a four-hour assessment of the store and immediately deliver a report to the facility manager/owner showing savings opportunities. Additionally, the auditor would install some savings measures as part of their walk-through (e.g., LED exit lights).

National Market Characterization

Grocery Refrigeration

There was considerable diversity in points of view in the industry, but there are some clear trends that can be identified around several concepts.

Experience from Prior EE Programs

Experience from prior energy projects suggests that many similar energy efficiency measures have been installed in the grocery sector. Common measures that have been installed with help from utility incentives include:

- LED lighting (general area lighting and refrigerated cases);
- doors on open-deck cases;
- commissioning of controls;
- replacement of old controls; and
- electrically commutated motors.

All the interviewees had experience participating in or running utility energy efficiency programs. A common thread in response to taking part in those programs is that they are often “too much hassle.” Some reported that, in some jurisdictions, the incentives available were not worth the effort to obtain them, especially for measures such as new controls, where a customized approach was required to estimate energy savings. Most prefer "deemed" incentives or simple rebates when those are available. This barrier to participation is a clear problem that the sector needs to address if policies are to truly incentivize changes in adoption of energy efficient technologies. There are also clear financial barriers to adoption of new technologies such as updated controls, which are expensive to install. A trend towards financial decisions being driven to shorter and shorter payback periods make efficiency a "tough sell" in organizations that are capital constrained, risk averse, and have very low profit margins that average 1.2% (FMI 2018).

Regulatory Trends will Drive Investments

Market participants all noted important changes in regulations of refrigerants that will drive investments in this sector during the coming decade. Phase-outs of ozone-depleting refrigerants is still ongoing, and interviewees noted that "there is still a lot of R-22 out there." R-22 is an example of a common refrigerant that can no longer be purchased legally in the United States (except as a recycled refrigerant) due to its ozone depletion potential. The expense of retrofitting these systems to newer refrigerants is further complicated due to proposed regulations in many states, including Minnesota, to phase out HFC refrigerants due to their high global warming potential (GWP). Although regulatory action has yet to be implemented in Minnesota, the state is a member of the U.S. Climate Alliance, members of which have agreed to implement policies that align with the Paris Climate Agreement. Meeting these goals implies adopting lower GWP refrigerants such as ammonia, carbon dioxide, and hydrocarbons. Since these refrigerants have vastly different engineering requirements compared to traditional HCFCs and HFCs, conversion to this new generation of refrigerants will require complete replacements of refrigerated cases, walk-in evaporators, compressors, and heat rejection — essentially the entire refrigeration system in each store. Due to the expense of these conversions, market adoption, as existing HFC options are phased out and become increasingly rare, will be a slow and expensive process.

Interviewees indicated that Minnesota has a favorable climate for transcritical carbon dioxide (CO_2) refrigeration systems. These systems have efficiencies that are on par with traditional systems when outdoor air temperatures are low enough to keep the refrigerant below its critical point of 87.8°F (31°C). The cooler annual average weather in the state can lead to these CO_2 systems operating efficiently most of the time, but they are expected to have increased usage during summer peak demand periods.

The 2020 Minnesota Energy Code requires that new refrigeration system installations will need to incorporate a number of energy efficiency features that have been rebated by some programs. The key code requirements (which may not apply to the replacement of like equipment, depending on the project's energy code path) include:

- ECM or three-phase motors on condenser fans and evaporator fans within walk-in or larger coolers and freezers
- Automatic control of display case lighting
- Variable speed control of condenser fans (on units with motors totaling ≥ 5 HP)
- Floating head pressure setpoint based on ambient air down to 70°F or lower condenser saturation temperature

- Floating suction pressure control on rack systems
- Mechanical subcooling on low-temperature racks with ≥100,000 BTU/hour load
- Antisweat heater control
- Temperature termination of defrost
- Limitations on the ratio of condenser fan HP to heat rejection capacity

There are also multiple federal minimum standards that have impacted refrigeration systems. The most notable affecting the large refrigeration-dominated facilities are the minimum performance requirements for display cases. While this standard does not directly require or disallow specific display case features, it may significantly push the market toward certain technologies (such as no-heat glass doors) to meet the required performance level. A more definitive determination of the effect on the appropriateness of continuing rebates for display case features would require an in-depth technology assessment that was beyond the scope of this market study.

New Technologies

Interviewees reported interest in many emerging technologies, but there was no clear trend of which were found to be the most promising. They indicated interest in the following:

- Ammonia cascade systems
- Transcritcal CO_2 systems
- Parallel compression and ejectors on transcritical CO_2 systems
- Adiabatic / hybrid condensers
- New “medium GWP” refrigerants such as R-448 and R-449 (with Global Warming Potentials below 1500)
- Micro-distributed systems (often with propane as the refrigerant)
- “Eco blades” — airfoil blades to reduce the infiltration in open display cases
- Thermal Storage Phase Change Materials (e.g., Viking Cold)
- Battery storage
- Switched-reluctance motors (e.g., Software Motor Company)

Opportunities

Interviewees had greater agreement upon the current most promising opportunities for retrofits to existing stores. Many of them agreed on the following as promising measures for the short term:

- Adding doors to existing open cases or replacing existing open cases with new cases with doors
- Commissioning of existing controls systems
- LED lighting (although that market has partially been transformed — many have already been done)

All of these measures can be done with existing utility incentives, to varying degrees of effectiveness.

Industrial Refrigeration

All interviewees contacted have extensive experience in industrial refrigeration, and most have implemented numerous efficiency projects with the support of various utilities throughout the country. Together, the interviewees provided a broad perspective on efficiency projects, including factors that foster implementation and barriers that impede it.

Effective Energy Efficiency Projects

The interviewees have implemented efficiency projects throughout the entire system, from reducing refrigeration loads to more efficient heat rejection. A common denominator for project implementation is the speed of a return on investment (ROI), which generally takes two to three years, with a trend towards higher ROIs. Common measures that have been implemented with utility support include:

- Variable speed drives (VFDs) on condensers, compressors, and evaporators
- Lowering head pressure and floating head pressure controls
- Replacing liquid injection oil cooling
- Envelope improvements including fast-acting doors and dock humidity control.
- Improved suction pressure control
- Controls and control upgrades, especially to facilitate the control of VFDs
- Tune-ups

Technical support and rebates provided by utilities have been most helpful to the interviewees for project implementation. The interviewees indicated utilities could improve measure implementation by simplifying the process and increasing customer awareness. Contractors are often unaware of utility offerings, and the offerings themselves can require too much time from end users and contractors. Many measures are complicated and require a customized approach, and end users and contractors do not have the time and expertise to pursue them. Furthermore, the energy savings impact of projects could be improved with utility program support for additional technical expertise in the design phase of the project, rather than just through a rebate at the end.

New Technologies

The interviewees are interested in a wide range of new technologies including:

- Thermal energy storage
- Low refrigerant charge packaged systems
- Smart controls — adjusting setpoints through a weather forecast model

The general trend of new smaller systems (such as cold storage) is toward packaged low-charge ammonia or other synthetic refrigerant systems. This trend is driven by the high cost of compliance with safety requirements for larger-charge ammonia refrigeration systems. However, the larger systems, notably food processing, are unlikely to be influenced.

Phaseout of R-22

The interviewees showed no urgency towards the phaseout of R-22. The general attitude is that R-22 will be phased out gradually enough to not have significant negative effects. Most owners are electing to wait until equipment needs to be replaced and then install new equipment, rather than retrofit existing equipment with R-22 alternatives. The cost of R-22 will impact the pace at which existing equipment that uses it will be replaced or converted.

Opportunities for Minnesota Market

The interviewees provided modest input about opportunities for the Minnesota market. The predominant theme was using the cold climate to operate at lower condensing pressures. Some believed that there are fewer VFD installations in the Midwest because the region has fewer efficiency implementors. During the winter, variable speed control of condenser fans and evaporator fans can reduce energy use.

The effective energy projects implemented by the interviewers are also applicable to the Minnesota market. Successful implementation often requires a custom, technical approach to understand the whole system, as opposed to discrete deemed-type measures. Given the complex interactions of these large refrigeration systems, interviewees held the tune-up offering for cost-effective energy savings in high regard.

New Energy Code Implications

The 2020 Minnesota Energy Code requires that new refrigeration system installations will need to incorporate a number of energy efficiency features that have been rebated by some programs. The key code requirements (which may not apply to the replacement of like equipment, depending on the project's energy code path) relevant to cold storage areas and other industrial refrigeration applications include:

- ECM or three-phase motors on condenser fans and evaporator fans within walk-in or larger coolers and freezers
- Limitations on the ratio of condenser fan hp to heat rejection capacity

Ice Arena Refrigeration

Effective Energy Efficiency Projects

Interviewees mentioned numerous energy efficiency opportunities when selecting a system or for retrofits. These are listed below in order of those mentioned most often to least often:

- Variable speed drives (VFDs) on glycol pumps
- VFDs on condenser fans
- Floating head pressure
- Low-emissivity ceiling

- Brazed plate and frame heat exchangers (allow lower minimum flow through chiller and reduces charge; new system only)
- Adiabatic fluid cooler or condenser
- ECM motors on condenser fans (air-cooled condensers only)
- Heat reclaim (for space heating with heat pump and thermal storage)
- Infrared ice temperature control
- Flooded chiller (instead of direct expansion to lower minimum head pressure; new systems only)
- Use of ammonia as a refrigerant instead of synthetic refrigerants (new systems only)
- Use of open compressors instead of semi-hermetic (new systems only)

Utility Support

Interviewees reported that the measure most frequently supported by utility programs is rebates for variable frequency drives, and three reported working with custom rebates. Those that had seen custom rebates reported working with the utilities very early on in the process and having to provide savings calculations to the utilities. Some of those interviewed said that more prescriptive rebates or "custom or TRM" type rebates would be helpful for things like EC motors on condenser fans and low-emissivity ceilings. It was also noted that outreach through trade associations (e.g., Minnesota Ice Arena Managers Association and Ice Skating Institute) and trade shows is an effective method for this market.

New Technologies

Interviewees reported interest in a wide range of new technologies including:

- Direct CO_2 system with the refrigerant pumped under the ice sheet (which was reported as requiring a mechanical code change)
- Adiabatic condensers (or fluid coolers)
- Permanent magnet compressor motors
- Aqueous ammonia solution as a secondary fluid under the ice (in place of glycol or brine)

Refrigerant Phaseout and Selection

The interviewees showed no urgency towards the phaseout of R-22. The general attitude is that R-22 will be phased out gradually enough to not have significant negative effects. Most owners are electing to wait until equipment needs to be replaced and then install new equipment, rather than retrofit existing equipment with R-22 alternatives. The cost of R-22 will impact the pace at which existing equipment that uses it will be replaced or converted.

It appears that about 80% of new ice arena refrigeration systems installed in Minnesota use ammonia as the refrigerant, and the other 20% use synthetic refrigerants. A number of energy efficiency design implications are impacted by this basic choice of ammonia as the refrigerant. Ammonia systems almost universally have the following features that increase energy efficiency over alternatives:

- flooded chillers, which are not possible with newer synthetic refrigerants, allow for a lower minimum head pressure than direct expansion chillers

- Open compressors that tend to have more efficient motors and don't put the motor heat load onto the system
- Evaporative condensers, which have lower summertime head pressures that air-cooled
- Calcium chloride solution is often used instead of ethylene glycol (which reduces pump power, but at the cost of possible corrosion problems if it is not well maintained)

While the last three of the above options can be used with synthetic refrigerants, there is much less of a tendency towards their use in synthetic refrigerant systems than there is in ammonia systems. It was also noted that Minnesota has more service companies that are familiar with ammonia than many other parts of the country, so it is easier to owners to choose to install an ammonia system in Minnesota.

Detailed Information Related to Specific Measures

The interviews also provided further insights into a number of ice arena energy efficiency measures and issues. The most notable were:

- Variable frequency drives on glycol pumps (or the alternate use of a small and large pump) are common but by no means universal.
- Low-emissivity ceilings are used on at most half of arenas in Minnesota (despite their near universal use in the western part of the country). They are more often installed as a retrofit in Minnesota instead of during the initial construction (often because of budget constraints).
- Head pressure is generally controlled with a fixed minimum setpoint rather than floating it with ambient conditions. The minimum condensing saturation temperature reported varied widely form 60°F to 88°F, and multiple interviewees reported not knowing off-hand. Reasons given for the minimums included: expansion valves, heat reclaim, and the compressor's minimum oil pressure.
- Many arenas manually turn off the water for their evaporative condensers for the winter season (which can cause much higher head pressures and condenser fan energy use).
- Screw compressors are coming into common use in arenas — especially in ammonia or multi-sheet facilities.
- Different refrigeration system packagers have different preferred compressor and glycol/brine pump control schemes.
- There is a growing practice of compressors being shut down overnight when there is low load.

New Energy Code Implications

The 2020 Minnesota Energy Code requires that new refrigeration system installations will need to incorporate a number of energy efficiency features that have been rebated by some programs. The key code requirements (which may not apply to the replacement of like equipment, depending on the project's energy code path) include:

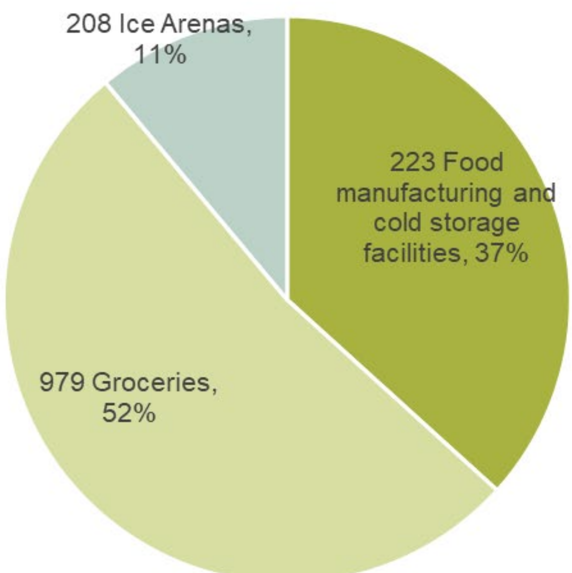
- Variable speed control of condenser fans (on units with motors totaling ≥ 5 HP)
- Floating head pressure setpoint based on ambient air down to 70°F or lower condenser saturation temperature

- Floating suction pressure control
- Limitations on the ratio of condenser fan hp to heat rejection capacity

Counts and Characterization of Existing Facilities

Figure 3 shows the estimated total number of large refrigeration-dominated facilities in Minnesota broken out by subsector – grocery stores; industrial (food manufacturing, processing, and cold storage); and indoor ice arenas.

Figure 3. Estimated Number of Refrigeration-Dominated Facilities in Minnesota



The most inclusive estimate of the total number of grocery stores and industrial refrigeration facilities presented in Figure 3 is based on US Census Bureau data (US Census Bureau 2019). Other sources provided positive identification of a lesser number of specific facilities within the grocery and industrial refrigeration sectors. Table 13 shows the number of specific facilities of each subsector type within various utility service territories in Minnesota.

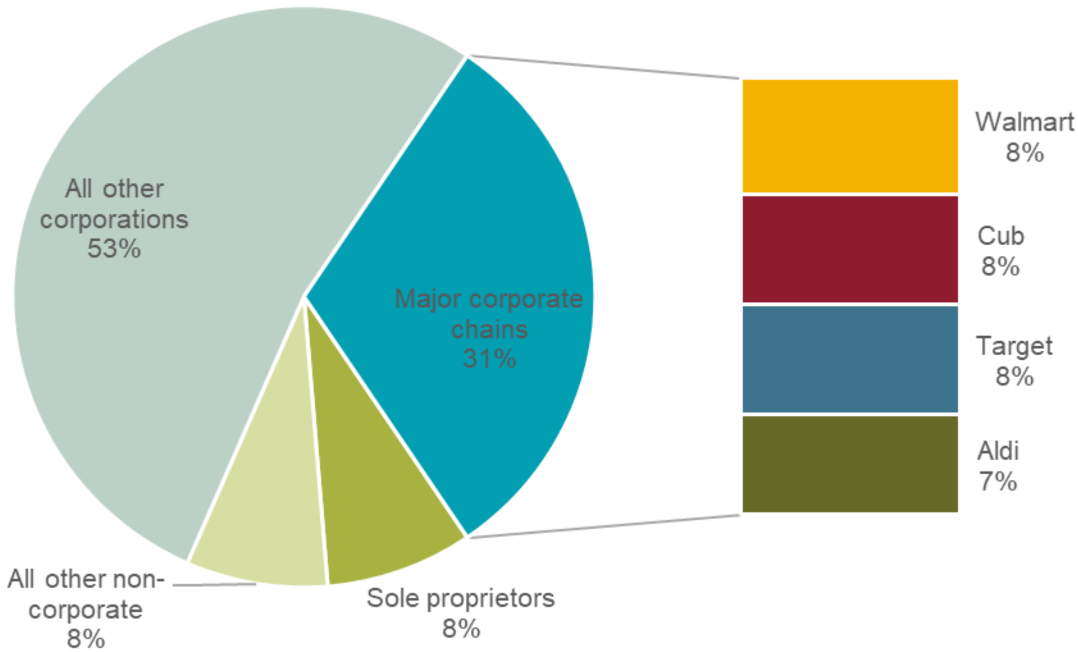
Table 13. Identified Facility Counts by Utility and Subsector

IOU or Aggregator Group	Grocery	Industrial	Ice Arenas
IOUs			
Minnesota Power	38	15	23
Otter Tail Power Company	25	4	7
Xcel Energy	228	79	90
IOU Total:	***291***	***98***	***120***
Cooperative Utility Aggregators			
Dairyland Power Cooperative	5	7	1
East River Electric Cooperative	0	2	0
Great River Energy	68	12	17
Minnkota Power Cooperative	1	0	6
Other Cooperatives	0	1	0
Cooperative Total:	***74***	***22***	***24***
Municipal Utility Aggregators			
Central Minnesota Municipal	13	9	5
Heartland Consumers Power District	4	6	1
Minnesota Municipal Power Agency	7	9	6
Missouri River Energy Services	22	7	10
Northern Municipal Power Agency	7	2	10
Other Municipals	33	5	19
Southern Minnesota Municipal Power Agency	29	17	13
Municipal Total:	***115***	***55***	***64***
Total Identified:	**480**	**175**	**208**

Grocery Stores

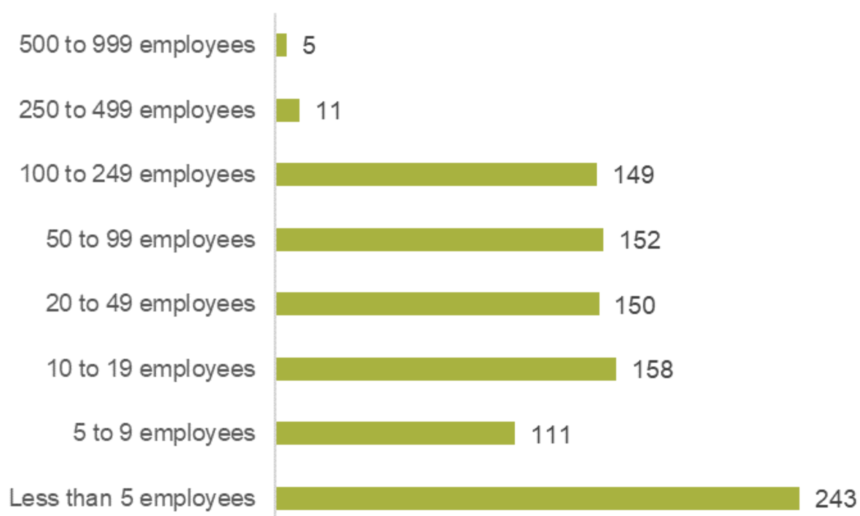
There are an estimated 979 grocery stores in Minnesota. Grocery store ownership is predominantly corporate — only 16% are sole proprietors, partnerships, or other noncorporate structures (154 establishments) or nonprofits (three establishments). The largest chains that all have more than 60 stores in Minnesota are Walmart (Walmart 2020), Cub, Target, and Aldi. Of those, Cub and Aldi are primarily grocery stores, while Walmart and Target are department stores with grocery departments. Cub stores range from 60,000 to 95,000 square feet, while Aldi stores are significantly smaller at 10,000 to 12,000 square feet (StarTribune 2019). Several other national, local, or regional chains also have at least a number of stores in Minnesota. Those with more than 20 stores include: Coborns, HyVee, Lunds & Byerlys, and SuperOne Foods. Others with six or more stores include: Whole Foods, Costco, Kowalski's Market, Fareway, IGA, Supervalu, Fresh Thyme, County Market, Trader Joe's, Sam's Club, and Festival Foods.

Figure 4. Grocery Store Ownership Structure



Groceries in Minnesota employ slightly more than 47,000 people. Figure 5 shows that few groceries employ more than 250 people — most facilities are clustered in ranges between 10 and 250 employees.

Figure 5. Number of Groceries by Size as Indicated by Number of Employees per Store



Data from seven grocery stores that participated in a Midwestern utility's energy efficiency program to collect information on store size and refrigeration equipment was reviewed to identify detailed characteristics of individual stores. The average area of the stores ranged from 28,100 to 71,900 square feet.[3] Table 14 and Table 15 show mean, median, minimum, and maximum for eight key areas within large and small grocery stores: total store area; total refrigeration capacity; compressor horsepower; total wattage of evaporator fans (only for walk ins); total area of both freezer and cooler walk ins; and total length of open and closed cases. Generally, in older buildings (10–15 years old), freezer cases are closed, and cooler cases are open. Closed cases are becoming more common in new construction.

[3] Specifications collected from major grocery chains for typical newer Midwestern stores.

Table 14. Key Characteristics of Larger Grocery Stores

	Store Area (in ft²)	System Cap (in tons)	Compressor Size (in HP)	Freezer Walk-In Area (in ft²)	Cooler Walk-In Area (in ft²)	Open Case Length (in feet)	Closed Case Length (in feet)	Evaporator Fan Power (in watts)
Mean	71,885	83	198	997	4,219	564	589	6,271
Median	72,390	84	193	943	4,185	545	404	6,271
Min	63,110	71	185	624	3,549	301	207	4,047
Max	79,652	93	221	1,479	4,957	864	1,340	8,494

Table 15. Key Characteristics of Smaller Grocery Stores

	Store Area (in ft²)	System Cap (in tons)	Compressor Size (in HP)	Freezer Walk-In Area (in ft²)	Cooler Walk-In Area (in ft²)	Open Case Length (in feet)	Closed Case Length (in feet)	Evaporator Fan Power (in watts)
Mean	28,122	50	83	475	3,078	312	338	1,953
Median	28,552	46	88	480	2,189	357	240	1,953
Min	22,813	39	56	438	2,008	140	148	1,639
Max	33,000	65	106	506	5,038	440	625	2,266

Industrial Refrigeration Facilities

There are an estimated 689 facilities in Minnesota that fit into the food processing business sector, and it is estimated that 223 of these facilities have industrial refrigeration systems. The food manufacturing industry includes facilities that process raw materials, animal, vegetable, and dairy products into food that is typically sold to wholesalers or retailers, not directly to consumers. It is a broad category that includes grain milling, confectioneries, and bakeries. To focus on those facilities likely to have high refrigeration loads, we've highlighted animal, dairy, and fruit and vegetable processing. We've also included refrigerated warehouses (i.e., cold storage) in this sector. The data on this sector comes from the public data on county business patterns (US Census Bureau 2019), which does not include facility square footage information.

Figure 6. Food Processing Business Sectors

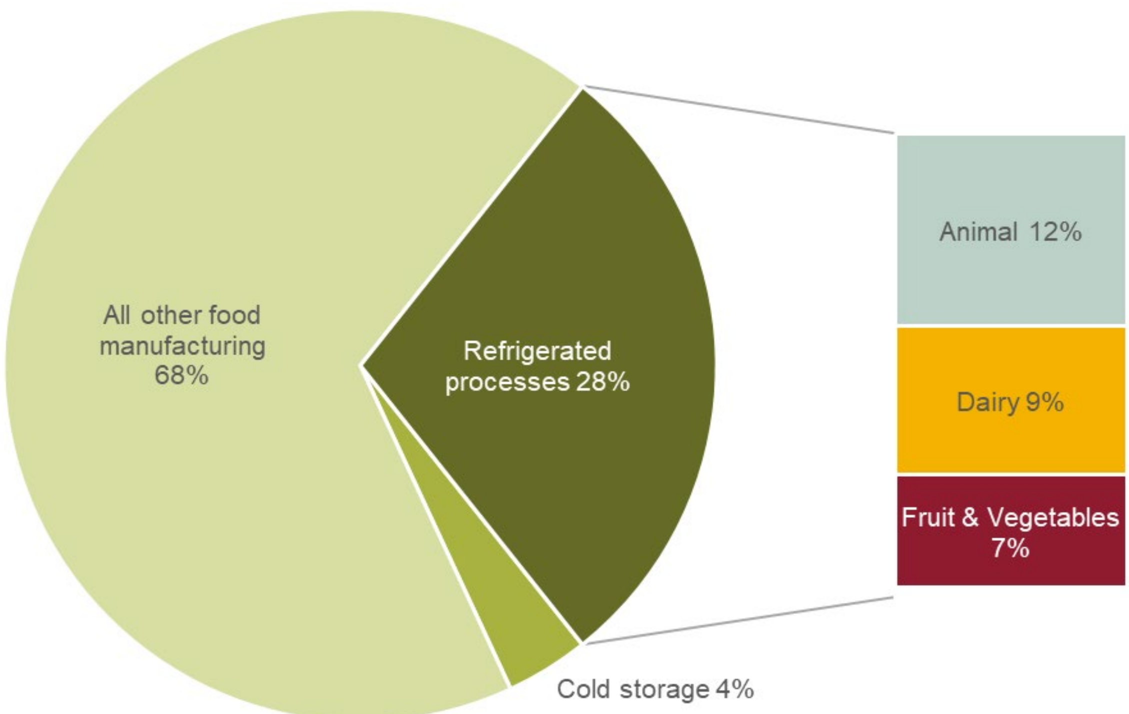
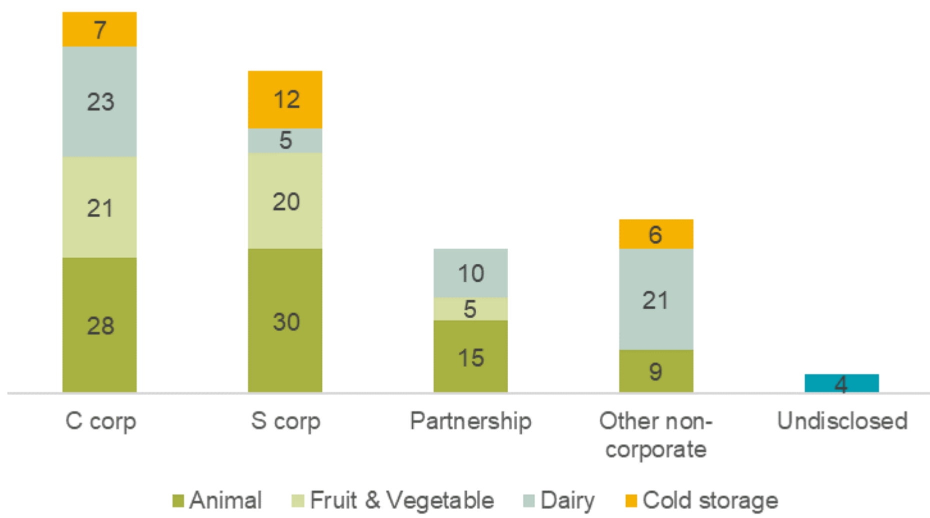


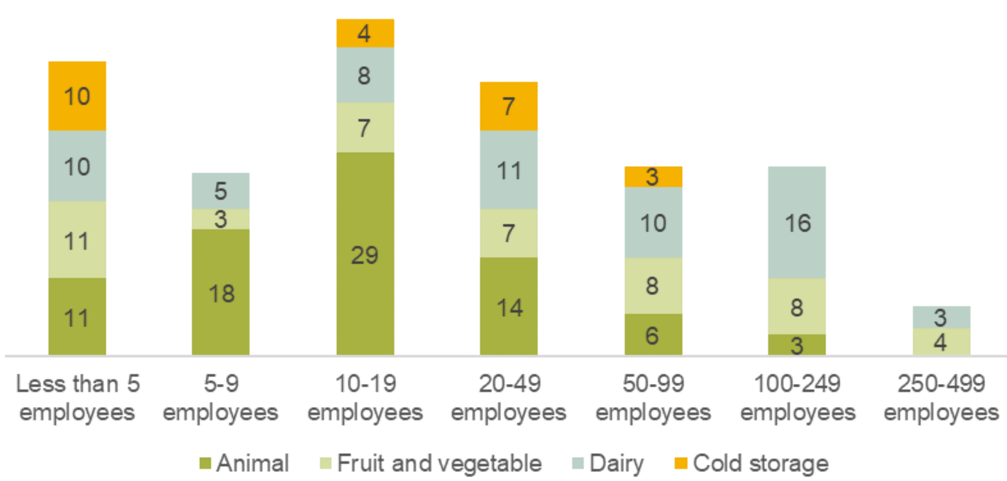
Figure 7 shows that animal, fruit, and vegetable food manufacturing and cold storage are primarily corporate enterprises in Minnesota, while dairy food manufacturing is more evenly divided into corporate and non-corporate ownership.

Figure 7. Industrial Refrigeration Facility Count by Ownership Type



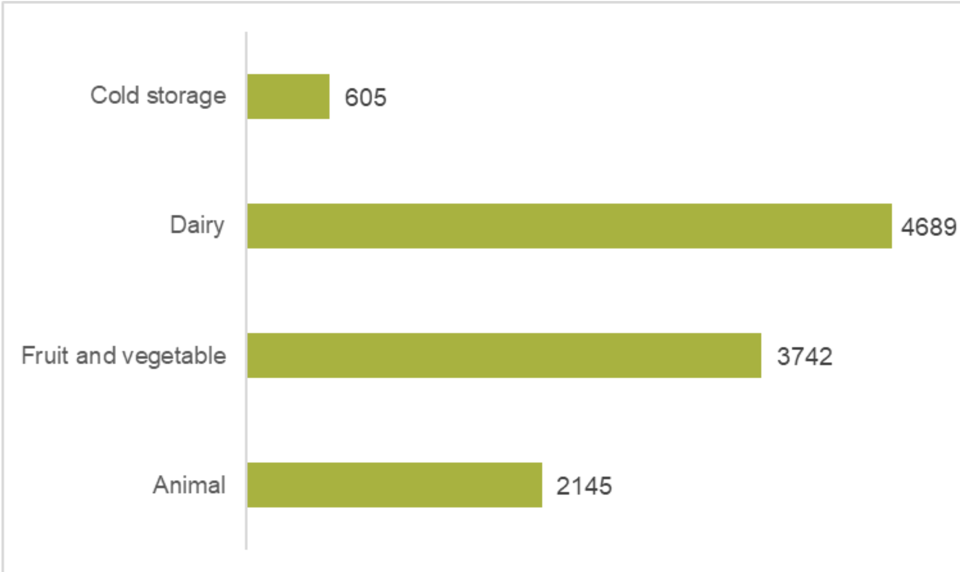
Few facilities employ more than 100 people, with the exception of the dairy food manufacturing sector.

Figure 8. Facilities by Employment Size Range



The dairy food manufacturing sector also employs the most people overall.

Figure 9. Employment by Industrial Refrigeration Facility Type



Ice Arenas

There are 208 indoor ice arenas and a total of 282 ice sheets in Minnesota. The standard ice rink size in North America is 200 by 85 feet, or 17,000 square feet. The estimates of total building and ice sheet square footage in Table 16 are based on the extrapolation of survey results from a limited number of facilities. That data is represented below in a range calculated using the average and median value of one facility and a low, average, and high value for an ice sheet. Of these 208 facilities, 16 are believed to use ammonia refrigeration systems in light of them each having a permit to store anhydrous ammonia.

Table 16. Ice Rink Characteristics

Characteristic	Value
Number of indoor ice arenas	208
Number of ice sheets	282
Total facility square footage	11.5–15.5 million sq. ft.
Total ice sheet square footage	4.8–5.6 million sq. ft.

Survey respondents reported that they use the refrigeration installation and service contractors noted in Table 17.

Table 17. Ice Arena Contractors Reported in Survey of Arena Managers

Refrigeration Installation Contractors	Refrigeration Service Contractors
Commercial Refrigeration	Cool Air Mechanical
NewMech	Gartner Refrigeration
Rink Systems	Rink Systems
CIMCO	Carlson and Stewart Refrigeration
Total Mechanical in Cottage Grove	Facility Staff
Harris Services	Harris Services
Rinktec	Rinktec
SCR {St. Cloud Refrigeration}	Commercial Refrigeration & Cool Air Mechanical
Holmstein	SCR {St. Cloud Refrigeration}

New Construction and System Replacement Rates

The estimated new construction and renovation trends for the state of Minnesota are show in Figure 10. Note that much of the variability in the trends is believed to be related to chains undertaking periodic waves of expansion into new markets or fleet-wide renovation programs. These new construction and renovation projects provide unique opportunities for building in efficiency at a relatively low incremental cost, but the modest numbers in comparison to the number of existing stores suggests that programs that are only focused on new equipment are limited in their savings potential.

Figure 10. New Construction/Renovation Trends in Grocery Stores

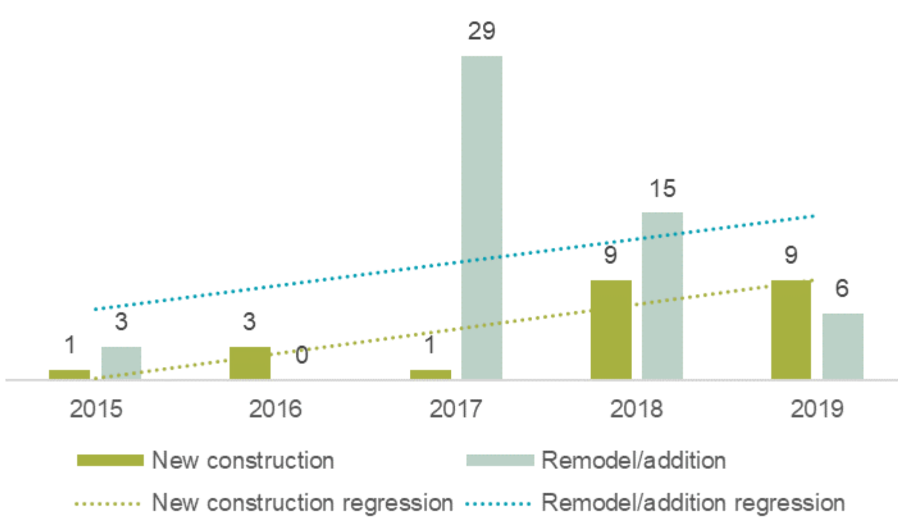
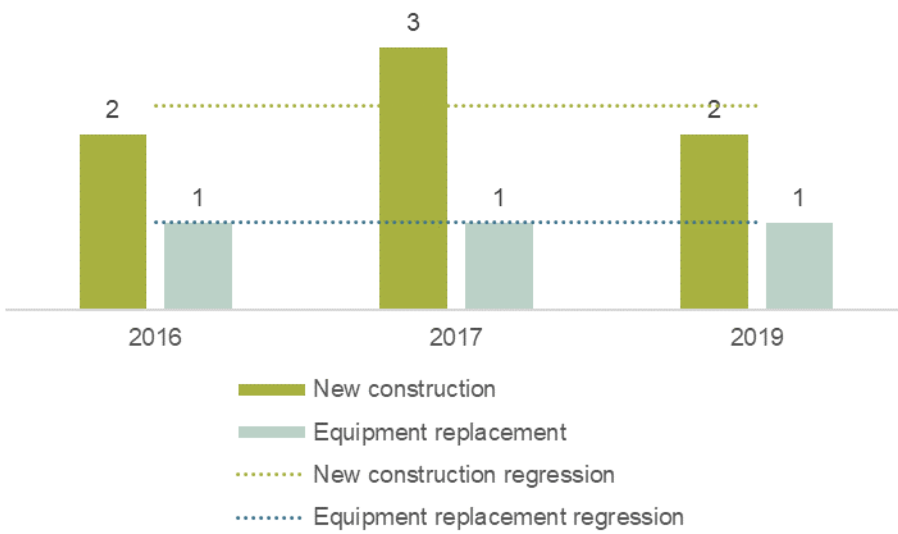


Figure 11 shows the estimated statewide new construction and major refrigeration equipment replacement rates for the indsutrial refrigeration subsector. Data on the age of active industrial refrigeration compressors in Minnesota indicates that most equipment has a very long service life. The vast majority of the compressors are more than 20 years old, and there are more than 100 operating compressors that are at least 50 years old. The very low rates of major equipment installation or replacement suggest that programs should focus most of their efforts on cost-effective retrofits to existing equipment (e.g., controls) and operational savings opportunites (e.g., changing setpoints) to consistently achieve substantial savings in this subsector.

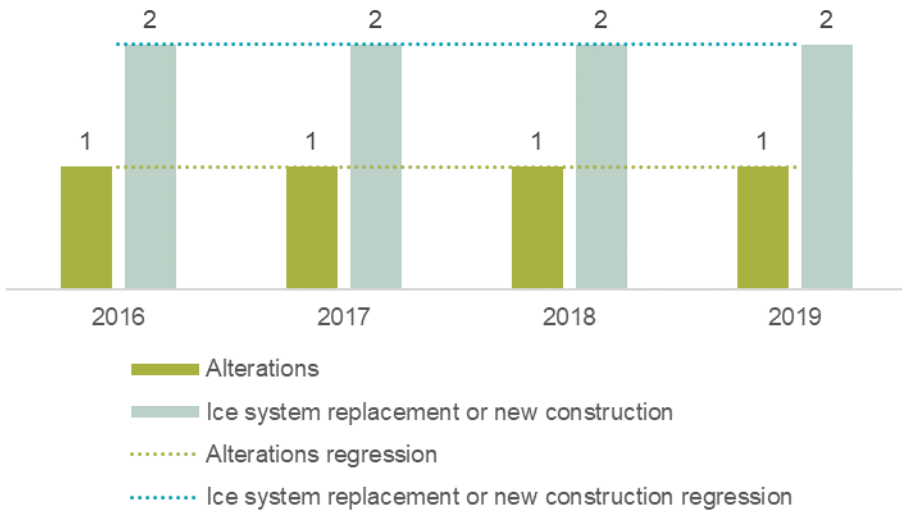
Figure 11. New Construction Trends for Food Manufacturing and Cold Storage



Source: Data on equipment replacement derived from the Minnesota Department of Labor and Industry boiler and pressure vessel inspection database.

Figure 12 shows the estimated annual rate of ice arena refrigeration system installation and major retrofit. It is estimated that two new ice sheet refrigeration systems are installed annually in Minnesota (as part of new construction or equipment replacement). The relatively low rates of major equipment installation or replacement suggest that programs should focus most of their efforts on cost-effective retrofits to existing equipment (e.g., controls) and operational savings opportunites (e.g., changing setpoints) to consistently achieve substantial savings in this subsector.

Figure 12. New Construction, Ice System Replacement, and Remodeling Trends for Indoor Arenas



Source: Data on equipment installations derived from the Minnesota Department of Labor and Industry boiler and pressure vessel inspection database (two projects annually) and Dodge data (one new construction project and three ice system replacement projects).

Local Market Interviews

Grocery Refrigeration

Utility Program Experiences

Prescriptive energy efficiency rebate programs generally see good participation and are appreciated by both regional and national chains. Custom incentive projects are typically seen as overly burdensome and not worth the effort. Some interviewees indicated that technical assistance for incentive application prep and analysis (especially new construction) was of value. However, one other interviewee reported that he had many meetings with different utility staff before he finally got an answer and rebate that was worth a fraction of the otherwise billable time he spent getting it.

Effective Energy Efficiency Projects

The interviewees reported a wide range of successful energy efficiency projects in Minnesota, indicating potential in many areas of these facilities and systems. These measures include:

- Adding VFDs to condenser fans and compressors
- Floating head pressure controls
- Floating suction pressure controls
- Anti-sweat heater controls
- Adding doors to open cases
- Updating case lights to LED (some with occupancy sensors)

- Strip curtains
- Air curtains
- Heat reclaim
- Night shades
- Liquid pressure amplification

While many of these technologies have been around for years, some (like floating head and floating suction) have had lackluster adoption with poor persistence. To maximize the gains of these measures, we recommend more emphasis on whole-building performance with measured results at the meter, rather than piecewise rebates for individual approaches. Site visits confirmed that adoption of these measures is partial at best, and implementation and persistence are often poor.

Both national chains interviewed have in-house staff that make decisions about refrigeration and have energy teams that develop projects and work with utilities to pursue incentives. Regional chains may have an in-house refrigeration specialist but tend to rely on refrigeration contractors for operational decisions and on vendors or consultants to help with the rebate process.

Prescriptive rebates and technical support provided by utilities have been most helpful for project implementation. There is a common desire for the rebate application process to be simplified. The difficulty of custom incentives was often stated as an impediment to projects. Two of the regional chains stated difficulty navigating the application process of multiple smaller municipal utilities.

New Technologies

The interviewees are interested in a wide range of new technologies including:

- CO_2 and natural refrigerants
- Adiabatic condensers
- SkyCool radiative cooling
- Shelf-edge technology
- Storage/batteries

There was a high degree of interest in learning about which refrigerants to use going forward, specifically CO_2.

One interviewee mentioned the SkyCool radiative cooling system as a potential for energy savings. This product is in an early deployment stage and applicability for the Minnesota market is to be determined. It uses the night-sky as a heat sink for radiative cooling – an idea that has resurfaced a number of times over the years in various forms. The technology is likely more appropriate to warmer climates.

Another interviewee noted the EcoBlade® "shelf edge technology" currently offered by Hillphoenix. This option for open multi-deck cases reduces infiltration by improving the aerodynamics of the supply air curtain on these cases. While they are reported to offer energy savings, it is doubtful that in-situ performance is better than cases with doors, which are becoming widely accepted elsewhere.

Installing cases with doors, or retrofitting doors on cases might be more appropriate for direct regulation rather than incentives. Many grocery retailers are fundamentally opposed to having doors on cases voluntarily as they fear customer push-back and losing customers to their competition. However, mandating doors on new case installations would alleviate these concerns with a level playing field.

Refrigerant Use and R-22 phaseout

All grocery chains interviewed operate with a mix of refrigerant types across their portfolio and are in various stages of phasing out R-22. Three of the chains (one national and two regional) have completely phased out R-22. The remaining four chains operate with some R-22 stores and are in the process of retrofitting either a scheduled number of stores per year or as leaks develop. Most stores are currently using R-404, 407, 507, 448, or 449 (last two to a much lesser extent). Most new stores are being installed with either R-448 or R-449, although CO_2 is gaining traction. Most chains interviewed have at least one CO_2 system installed.

Opportunities for Minnesota Market

Due to Minnesota's climate with extended cool weather, transcritical CO_2 systems are widely considered for new construction and will gain market penetration as other options are phased out. CO_2 systems are most efficient when they don't exceed the transcritical operating point of 87.8°F, which only happens about 100 hours of the year in Minneapolis. For this reason, CO_2 is likely to be a market leader in Minnesota. Other options for reducing refrigerant GWP include coupling propane with CO_2 distribution — especially systems that use micro-distributed propane options with small charges.

Many interviewees recognized that existing stores could likely benefit from retro-commissioning. Most have newer controls systems, many of the capabilities of which go untapped. For example, most stores use neither floating head pressure nor floating suction pressure controls — technologies that have been widely available for decades. In this case, lack of adoption is due to most operators being responsible for many stores and opting for simple controls over more sophisticated options that require time to set up and maintain.

Replacing thermostatic expansion valves (TXVs) valves with electronic expansion valves (EEVs) and mechanical evaporator pressure regulator (EPR) valves with electronic stepper valves aid in suction pressure management. The TXV to EEV replacement also often reduces the minimum head pressure that must be maintained, which can provide more significant annual savings benefits in Minnesota than in other climates. These measures were of interest to interviewees, and some of the stores have already implemented valve replacements. The relatively high cost of these measures is an impediment to implementation that could be mitigated by incentives.

Industrial Refrigeration

All interviewees have extensive experience in industrial refrigeration, but limited participation in utility programs. Equipment vendors generally expressed that they strive to meet the contractor's and owner's specifications and are hesitant to offer more expensive and efficient options, as equipment is often selected based on first costs. The general attitude of contractors is that reliability and production rates are paramount to their customers and energy efficiency is not a major consideration

Effective Energy Efficiency Projects and Attitudes

The interviewees indicated a wide range of successful energy efficiency projects in Minnesota, indicating potential in many areas of these facilities and systems. These measures include:

- Variable speed drives (VFDs) on condensers, compressors and evaporators, supply/exhaust fans
- Lowering head pressure and floating head pressure controls
- Space supply air/exhaust optimization (space pressure and economizer controls)
- Heat recovery
- Anhydrators (water and oil removal)
- Flywheeling (i.e., overcooling the space and night and letting it drift back up during daytime peak rate periods)
- Defrost optimization
- Envelope improvements
- Improved suction control
- Controls and control upgrades, especially to facilitate the control of VFDs
- Tune-ups
- Compressor sequencing

Technical support (primarily utility studies and tune-ups) and rebates provided by utilities have been most helpful for project implementation. Several contractors and vendors indicated that energy efficiency engineers do not understand industrial refrigeration systems. The general attitude of the contractors is that energy efficiency is not needed to sell their projects and that the calculations are too complicated and time consuming to provide without payment for that service. Most interviewees indicated that the rebate and measurement and verification process is too burdensome. ROI and budget constraints are also key barriers. Generally, a payback of three years or less is required, and the sector trend is toward higher returns on investment. Corporate owners often believe that projects that increase throughput will provide a better return on their investment.

When it comes to making operational changes, people tend to do what has worked for them (i.e., if it is not broken, don't fix it). Most operators are not incentivized to make energy savings improvements but see repercussions when something fails. In general, contractors that operate refrigeration systems on behalf of a business are risk-averse and err on the side of reliability as opposed to using the full efficient capabilities of control systems to maximize efficiency.

New Technologies

The interviewees are interested in a wide range of new technologies, including:

- IoT; Data monitoring
- Smart controls and artificial intelligence
- Demand defrost
- Thermal energy storage

- Packaged and low-charged systems
- CO_2 and natural refrigerants
- Adiabatic condensers (for water and water treatment cost savings more than for energy savings)

Phaseout of R-22

The interviewees showed no urgency towards the phaseout of R-22. The general attitude is that R-22 will be phased out gradually. R-12 was phased out, and now they are going through the same process with R-22. Cost will impact the pace at which existing equipment with R-22 is replaced. Low-charge ammonia and modular systems are good, more efficient options to replace R-22. Units with variable speed evaporator fans, compressors, and condenser fans, as well as demand-based defrost and operation at low condensing pressures should be considered when purchasing new equipment.

Opportunities for the Minnesota Market

The interviewees were not aware of any specific market factors making Minnesota a more favorable climate for energy efficiency. One interviewee indicated that he sells the same projects in Minnesota as elsewhere. Two interviewees indicated that Xcel Energy provides large incentives for thermal energy storage, and, as a result, they are pursuing projects in Xcel Energy's service territory.

In the Minnesota region, most condenser fans are axial type with a forced draft configuration. Centrifugal-type fans are generally rare and used when high static pressure and sound attenuation is required. While there is one further energy upgrade available to axial draw-through fans, there is less savings potential than is associated with making the jump from centrifugal fans to axial fans.

One interviewee indicated that this region of the country has older technology, and modernization of controls would improve energy efficiency. However, high costs can be a barrier for installing new control systems. When replacing piping for mechanical integrity, piping can be better sized for energy efficiency cost-effectively.

The Minnesota climate, with long, cold winters, provides an opportunity to run refrigeration systems at lower condensing pressures. Numerous factors can result in running artificially high condensing pressures during the winter, which generally include defrosting coils; cooling of compressors (liquid injection oil cooling); and oil carryover issues. Some of these barriers can be addressed cost-effectively on existing systems. Opportunities should be reviewed during the design process for new equipment and replacement.

Given the cold climate, most condenser sumps are remote, requiring more pumping energy. Condenser manufacturers offer condensers with fin coils. These units are often able to run dry when temperatures are above freezing, thus reducing freeze issues, pumping energy, and water use.

Ice Arena Refrigeration

Effective Energy Efficiency Projects

Interviewees mentioned numerous energy efficiency opportunities when selecting a system or for retrofits to existing equipment. The measures that were reported as having been rebated in Minnesota are listed in Table 18 with key notes associated with each. It was generally reported that the use of variable frequency drives is nearly universal, sometimes with a caveat that a rebate can help a customer get "over the hump." While use of the REAL ice device was reported by two facility representatives, there is much skepticism in the industry about the device's effectiveness. (This skepticism is shared by the project team.) It is also noteworthy that one designer reported that most arena refrigeration systems are design–build jobs, where lowest first cost is much more important than life-cycle cost. It was also noted that the few private firms with ice arenas tend to be more interested in efficient systems than municipalities.

Table 18. Ice Arena Measures Reported by Industry Contacts as Having Received Rebates

Measure	Frequency	Other Key Notes
VFD on Glycol/Brine Pump	Highest	—
VFD on Condense Fans	Highest	—
Low-Emissivity Ceiling	Mid-level	• Custom, if the manufacturer does the extra work to provide the rebate calculations • This reduces the heat gain associated with radiation from the ceiling to the ice sheet and provides heating savings • Common, but not universal in the facilities represented
ECM Motors on Air-Cooled Condensers	Low	• One contractor reported that it is easier and cheaper to wire and control than condenser fan VFDs.
REALice Water Treatment Device	Low	• Custom Rebate • Reportedly eliminates the need to heat resurfacing water

Local interviewees reported several additional energy-saving measures that are effective, but for which they are not aware of rebates being available in Minnesota. These are listed in Table 19 with some clarifying notes. One trade ally suggested that rebates may not be needed for variable speed drives in some motor sizes because they cost no more than a soft-start control.

Table 19. Ice Arena Measures Reported by Local Contacts as Not Having Received Rebates

Measure	Other Key Notes
Flooded Plate and Frame Heat Exchanger	• Was reported as being useful with synthetic refrigerants to allow lower head pressures than DX chillers, with the added bonus of low refrigerant charge • One trade ally reported hearing that they are hard to control, while another has seen it work well in one arena and suspects rumors about control problems are from competitors "guessing."
Computer/Electronic Controls	• Tighter control of ice temperature allows for higher average ice temperature • Can allow for ice temperature setback (although one facility representative noted that energy engineers often want to set back the ice temperature, which ruins the ice quality) • Can float the head pressure setpoint based on outdoor air conditions
Air-Cooled Condenser Instead of Evaporative	• This trend is seen to save on water treatment more than on energy. • Can have an energy benefit in a seasonal rink (and summer demand penalty)
Adiabatic Condenser	• Either as alternative to evaporative with less water and water treatment cost or as an energy-saving alternative to air-cooled
Replace TXV with EEV	• For DX (direct expansion) chillers an Electronic Expansion Valve (EEV) can operate with a lower minimum head pressure than a thermostatic expansion valve (TXV)
Aqueous Ammonia (or Calcium Chloride) Secondary Fluid	• Aqueous ammonia requires much less pumping power that the fluids currently used in Minnesota. • Calcium chloride solution requires less pumping power than the more commonly used ethylene glycol, but with a risk of corrosion problems if it is not well treated and maintained.
Oversize the Condenser	• This allows the head pressure to be somewhat lower — including at summer design conditions — and allows fans to run at lower speed.
R-22 to Ammonia Conversion	• The decision to replace a system is generally driven by factors other than energy efficiency, and the savings achieved is generally small compared to the project cost.
Reclaim Heat from Subcooler Instead of Desuperheater	• This reduces the refrigeration load, but provides heat at a lower temperature, which could be an issue if pit piping isn't sized accordingly.

Utility Support

The most often reported support from utility programs was for variable frequency drive rebates, and three interviewees reported working with custom rebates. It was noted that VFD rebates often don't capture the full savings in refrigeration systems because of either the reduction in heat load on the refrigeration system or the additional savings that can be achieved because of the tighter control. It was reported that prescriptive VFD rebates are easy to work with across most utilities in Minnesota, but that the custom rebate process experience varies dramatically between utilities.

One contractor reported that Minnesota Power is by far the easiest to work with, and that they have received incentives that have helped them sell projects. Energy Insight, the program administrator, did all of the rebate calculations for them and processed the rebate quickly. Another trade ally reported that the paperwork required for recommissioning programs is too much for the money — especially with Xcel Energy. He noted that Otter Tail Power and Minnesota Power are easier to work with. Most trade allies reported that rebates are usually initiated by the contractor or end user bringing the project information to the utility. Trade ally responses generally indicated that other than perhaps an invitation to an annual event, Minnesota Power is the only utility that is in contact with them on a regular basis. The following items were reported as desired support that utility programs are not currently providing:

- Making it easier to get rebates for controls and monitoring combinations of upgrades that provide savings; perhaps giving rebates based on monitored savings instead of having to explain how each widget saves energy
- Demonstration sites for new technologies (e.g., adiabatic condensers or water treatment to avoid heating resurfacer flood water)
- Taking a detailed look into plate and frame chillers to try to get more designers and contractors on board (i.e., see if the competing manufacturers' claims of issues have merit)
- Figuring out the right balance between condenser fan(s) and compressor power
- Proactive outreach to the end user to promote and help with programs
- A mechanism allowing a rebate to provide a third party with the cost benefit (e.g., for the situation where a hockey association pays for improvements to a building owned by a city)
- Get designers on board, as there are maybe six engineers in the United States that design systems

New Technologies

In response to a question about what new technologies they are interested in learning more about, interviewees offered the responses outlined in Table 20.

Table 20. New Technologies That Local Arena Contacts Would Like to Know More About

Reported by Contractors & Engineers	Reported by Facility Representatives
CO_2 systems (most reported)	R-22 to CO_2 conversions (most reported)
Aqueous ammonia as a secondary fluid under the ice sheet	Potential drop-in refrigerants (to replace R-22 or R-404a)
Ways to avoid or reduce heating of resurfacer water	Heat recovery
Corrugated ice sheet tubing that can reduce pumping power	Computer/Building Automation System Controls
Permanent magnet motor — especially paired with a variable frequency drive	—
Variable frequency drive on lead compressor	—
Generators for peak shaving	—

The use of aqueous ammonia as the secondary fluid that is circulated under the ice sheet has become standard practice in Sweden over the last decade. There are material compatibility issues with copper, brass, and galvanized metal that must be considered in the design or retrofit. There is reportedly a pending system installation in Minnesota.

Refrigerant Phaseout and Selection

The interviewees showed no urgency towards the phaseout of R-22. The general attitude is that R-22 will be phased out gradually enough to not have significant negative effects. Most owners are electing to wait until equipment needs to be replaced to then install new equipment, rather than retrofit existing equipment with R-22 alternatives. However, a significant minority are doing drop-in refrigerant conversions and sometimes pairing that with additional scope that provides energy savings. The cost of R-22 will impact the pace at which the existing equipment that uses it will be replaced or converted. The phaseout has led to a number of different synthetic refrigerants being used in different systems, with R-449 and R-407 being the most common. However, R-22 is probably still the most common refrigerant in existing systems, with ammonia being the second most common.

Ammonia was reported as being used much more than all other refrigerants combined in new ice arena refrigeration systems in Minnesota. There was reported knowledge of one arena using CO_2, but its usage in arenas has lagged behind the trend in grocery stores.

Detailed Information Related to Specific Measures

The interviews also provided further insights into a number of ice arena energy efficiency measures and issues. The most notable were:

- Both flooded and DX (direct expansion) chillers are common, with evaporative condenser being more so — especially in “built-up” systems with open, industrial compressors.
- There is great variability in condenser/head pressure control strategies reported: Multiple contractors indicated that the head pressure setpoint is floated with outdoor air temperature (or wet-bulb temperature if an evaporative condenser is used); multiple contractors reported the use of water in evaporative condensers down to 10°F–15°F, while another said 35°F–40°F is the lowest; and most facility representatives didn’t know the head pressure control strategy.
- Older systems universally have reciprocating compressors, while screw compressors are used commonly in newer systems. In synthetic refrigerant systems, these are commonly Bitzer semi-hermetic screw compressors with two or three slide valve positions, while ammonia systems most typically have twin screw open compressors.
- Reports of typical minimum condensing saturation temperatures varied significantly: Two trade allies noted 60°F–70°F as the lower limit with flash gas formatting before the expansion valve being the limiting factor; three reported values ranging from 75°F–90°F; and two reported running air-cooled condensers as low as 40°F–50°F.

Facility Reviews

Grocery

The results of plan and site reviews of five grocery stores in Minnesota are detailed in Table 21. Four of the facilities are regional chains and one is a national chain. Four are located in the Twin Cities metropolitan area and one is in Central Minnesota. All facilities have opportunities to improve energy efficiency, ranging from low-cost controls updates to capital measures.

Facility Overview

Store construction ranged in time from the early 1980s to 2018. Each of the five stores uses a different refrigerant: R-22, R-404a, R-449, R-507, and R-744 (CO_2). Four of the stores have one compressor rack for medium and one for low temperature loads, while one store has multiple racks for each temperature level. Medium and low temperature compressors share a common discharge header in three of the systems. All stores have a central digital controller.

Compressors

All compressors were reciprocating type. One store has VFD control. None of the stores are floating suction pressure, even though most of them have the control capability to do so. Most EPR valves were electronic stepper type. Three stores reclaim heat for domestic hot water, while one store has had space heating reclaim capability disabled, and the fifth has no reclaim.

Condensers

Four of the stores use air cooled condensers, one store uses adiabatic gas coolers (CO_2 system). Two of the store's condensers have VFD control. Only one store is floating the head pressure setpoints, even though most of them have the control capability to do so.

Refrigerated Cases

Refrigerated cases are a mix of type and vintage. There are many multideck cases without doors or night covers. Open island and coffin-style cases are also still being used. Most medium-temperature case lighting has been updated to LED. Low-temperature case lighting is LED except for one store. Anti-sweat controls are used in two of the stores.

Walk-In Coolers

None of the walk-in coolers have automatic door closers, however all but one store uses strip curtains. Lighting is a mix of fluorescent and LED. Most evaporator fan motors are EC/PM type.

Lighting

Most store area lighting is fluorescent; one store has updated to LED.

Table 21. Detail of Reviewed Grocery Stores

Type	Grocery	Grocery	Grocery	Grocery	Grocery
Year Installed	2018	2008	2009	1980	2018 (remodel)
Store Area	50,000	49,000	38,000	140,000	180,000
Control Brand	RDM	Emerson	Emerson	Altech	Emerson
Refrigerant(s)	R744	R404a	R507	R22	R449A
LT STPT (psi,°F)	216, -16	15.3, -22	18, -19	6, -28	8, -22
MT STPT (psi,°F)	400, 19	48.5, 16	57, 19	—	B: 46,24 BS: 42,18
LT Defrost Type	Electric	Hot Gas	Hot Gas	Hot Gas	Hot Gas
Compressors					
Type	Reciprocating	Reciprocating	Reciprocating	Reciprocating	Reciprocating
# of LT	2	5	3	6 (2 racks)	5
# of MT	4	6	3	15 (5 racks)	8
LT HP	11	115	40	68 (2 racks)	96
MT HP	100	125	45	153 (5 racks)	130
Floating Suction	No	No	No	No	No
VFD	1 MT Compressor	No	Yes	No	No
EPR Valve Type	Electronic Stepper	Electronic Stepper	Electronic Stepper	Mechanical	Electronic Stepper
Heat Reclaim	DHW	DHW	DHW	Heat Disabled	None
Condensers					
# of Fans	3	10	10	12 LT and 23 MT	20
Type	Adiabatic, water above 75°F	Air cooled	Air cooled	Air cooled	Air cooled
Total Fan HP	9.6		30	18 LT, 30 MT	
Min Head-psi,°F	955, 80	180, 82	135, 66	195, 100	43, 75
VFD	Yes—All Fans	No	Yes	No	No
Split Condensers	No	Yes	Yes	Yes, below 60°F LT	Yes
Floating Head	No	No	No	No	Yes
PM/EC Fans	EC	No	No	PM reported	
Cases					
Cases w/o Doors	Lunchmeat, Produce		Produce, Dairy, Lunchmeat	Produce, Dairy, Meat	Produce, Dairy, Lunchmeat
Anti Sweat Controls	Yes			Yes	Yes
Night Covers	?	No	Yes	No	No
MT Case Lights	LED	LED	LED	Fluor. Mt/Dairy	LED
LT Case Lights	LED	LED	LED	Fluorescent	LED
No Heat Drs LT	?	Yes	Yes	No	No
Walk-ins					
Door Closure	?	No	No	No	No
Strip Curtains	?	Yes	Yes	Yes	No
Lighting	?			Fluorescent	LED
EC/PM Motors	EC	No	Yes	PM	Yes
Area Lighting					
Front of House	?	Fluorescent	Fluorescent	Fluorescent	LED
Back of House	?	Fluorescent	Fluorescent	Fluorescent	LED
Control	?			None	Central

Industrial

The project team conducted plan and site reviews of five industrial refrigeration systems in the Minneapolis area. All operators were knowledgeable of their systems, and the systems were well maintained and in good working order. All facilities have opportunities to improve energy efficiency, but innovative solutions are needed for those changes to be cost-effective. Details of the observations for these sites are presented in Table 22.

Facility Overview

All five facilities use ammonia as the refrigerant, and all facilities have computer control systems. The cold storage and food distribution facilities have central control systems, and the food processing facility uses the compressor panels to control compressors and condensers. All cold storage and food distribution facilities have two temperature systems (low/high temperature). Two cold storage and the food distribution facilities are piped for two stage operation. One facility is only able to operate as two-stage, while the other two facilities can operate single-stage economized, which is the operation about 90% of the time. The remaining cold storage facility has two independent economized suction systems.

Evaporators

All evaporators are liquid recirculation type (i.e., pumped), and coils were generally designed for a temperature difference of 10°F. Evaporator fans of one facility cold storage facility are mostly VFD control, while two other facilities were a mix of constant speed and VFD. One cold storage facility uses the VFDs as soft starts, and facility operators are in favor of installing more VFDs. The food processing facility uses VFDs in the processing areas, but the blast and spiral freezers are constant speed.

Three facilities have a hot gas main regulator set to a reasonable pressure (~110 psig). Three facilities use liquid runtime to initiate defrost, and the runtimes are seasonally adjusted. The defrost durations of these facilities is reasonable, generally about 20 minutes. One cold storage facility was using significantly longer defrost times, 30 to 60 minutes. In general, defrosts for freezers in this facility are initiated with a schedule, and defrosts for the coolers and docks are initiated with liquid runtime.

Compressors

All (operational) compressors are screw type. The two-stage only system has VFDs on the trim compressors, with liquid injection oil cooling using a mix of thermal expansion valves and electronic valves. The thermal expansion valves and the need for one of the compressors to maintain oil circulation (no internal pump, this is the one with the VFD) are barriers to reducing condensing pressure. Two cold storage facilities use thermosyphon oil cooling (i.e., TSOC) with economized operation. One facility has a VFD on the economized compressor, and the other facility's compressors manage capacity control with slide valves. The largest cold storage facility has two compressors controlled with VFD compressors in one engine room and the compressors in the other engine room are all controlled with slide valves.

Condensers

All condenser fans are axial type with VFD control and fixed setpoint (i.e., no ambient wet-bulb controls). Two facilities have a mix of forced draft and induced draft condensers, and all have remote sumps. Three facilities run dry at freezing outdoor air temperatures and maintain minimum condensing pressures. Another cold storage facility struggles to maintain minimum condensing pressure when ambient temperature exceeds 25°F. This same facility was operating at a condensing pressure of about 172 psig (92°F) when the ambient wet-bulb temperature was about 68°F. The operator believes the condensers are scaled due to hard water in the area.

Underfloor Heat and Heat Reclaim

The underfloors of four out of five freezers are heated with glycol. The heat for the glycol is recovered from the refrigeration system. The fifth freezer has electric heat. There was no heat reclaim for any facility beyond underfloor heating.

Lighting

Most lighting is LED with motion controls. Digital Lumens appears to be a popular brand.

Table 22. Details of Reviewed Industrial Refrigeration Facilities

Facility	Southeast Metro	Southeast Metro	North Metro	Central MN	Central MN
Type	Food Distribution	Cold Storage	Cold Storage	Cold Storage	Food Processing
Energy Use	6,300,000	4,700,000	7,300,000	11,300,000	5,600,000
Cooler Area	51,000		28,600		16,000
Freezer Area	88,400		160,555		
Ice Cream Freezer	700		0		
Cold Dock Area	27,600		37,711		
Blast Freezing					2,000
Under Floor Heat	To 49°F w/Glycol	To 48°F w/Glycol	To 48°F w/Glycol	To 55°F w/Glycol	To 32°F w/Elect.
Controls					
Type:	Computer/Central	Computer/Central	Computer/Central	Computer/Central	Local Micros
Fly wheeling	Yes	Yes	No	No	No
Refrigerant	Ammonia	Ammonia	Ammonia	Ammonia	Ammonia
Room Temps	-10 F/ 33 F	-20 F/ 38 F	-20/-5/38 F	-30/-5/35 F	-48/4 F
Refrig . Temps	-17.3 F/ 16 F	-25 F/ 21 F	-26 F/24 F	-40/-21/5 F	-40/-10/50 F
Suction Systems	2	2	2	2	1
Stages	2	2	2	1	1
Evaporators					
Type	Liquid Recirc.	Liquid Recirc.	Liquid Recirc.	Liquid Recirc.	Liquid Recirc.
Design DT	10	10	10	10	10
Fan VFDs	Yes	Some, LT	Yes-Soft Starts	50%, most LT	Some-Prod. Area
Fan Cycling	Yes	Yes	Yes	No	No
Defrost Type	Hot Gas	Hot Gas	Hot Gas	Hot Gas	Hot Gas
Main HG Reg	Yes, 110 psig	Yes, 115 psig	Yes, 110 psig	No	No
Def. Schedule	Liq. Run Time	Liq. Run Time	Liq. Run Time	Sch/Liq Runtime	Scheduled
Def. Adjustment	Seasonally	Seasonally	Seasonally	No	No
Def. Duration	15-20	20	20	30-60	30-45 min
Compressors					
Type	Screw	Screw	Screw	Screw	Screw
Control	Trim VFD, Each	VFD on Trim	Slide	Slide	Slide
Float Suction	Seasonally	Seasonally	Seasonally	None	None
Oil Cooling	LI, TXV & Motor	TSOC	TSOC	LI, 2 with TSOC	(2) TSOC, (1) LI
Economized	No	Yes	Yes	Yes	No
No. LT Comps	2	1	2	5	1
LT HP	350	250	400	1800	300
No. Swing Comps	2	1	3	3	1
Swing HP	700	300	1250	650	200
No HT Comps	1	2			1
HT HP	350	1000			450
Condensers					
# Forced Draft	2	1	2	3	0
# Induced Draft	2	—	—	1	1
Sump Type	Remote	Remote	Remote	Remote	Remote
No. Pumps	2	1	2	4	1
Total Fan HP	50	60	60	100	20
Total Pump HP	50	25	40	65	20
Dry Operation	34 F	When it gets cold	25 F	30 F	35 F
Fan Control	VFD	VFD	VFD	VFD	VFD
Min Cond Press	130	115	115	145	130
Total MBH	20,932	17,346	19,404	29,179	9,110
Twb Approach	No	No	No	Not Used	No
Heat Reclaim	Floor Heat	Floor Heat	Floor Heat	Floor Heat	None
Lighting					
Type	LED, some T8	LED	LED, Some T8	LED	LED
Control	Motion, 1 min	Motion, 15 Sec	Motion		

Ice Arenas

The results of plan and site reviews of five ice arenas in Minnesota are detailed in Table 23. Two are located in the Twin Cities metropolitan area, two in Northeastern Minnesota, and one in Southeastern Minnesota. Although some have undergone refrigeration or control improvements within the last 10 years, all facilities have opportunities to improve energy efficiency ranging from low cost controls updates to capital measures. The key findings from these site reviews are noted in the following paragraphs.

Facility Overview

The construction date of the arenas reviewed ranges from the 1960s to 2010 with the most recent building being a two-sheet facility. Two of the older facilities have replaced evaporative condensers within the last 10 years, and one reported “rebuilding” the compressors within the last several years. Two of the facilities use R-22, while three other synthetic refrigerants are used in one each of the other arenas. The use of glycol as the secondary fluid was consistent across all five facilities.

Compressors and Compressor Controls

The compressors systems were a good representation of the mix of systems that are 10 years old or older. All compressors were reciprocating type, with three facilities having open compressors and two having semi-hermetic. The use of some degree of unloading control in two of the facilities suggests a greater acceptance and use of unloading controls than was previously observed.

It was noteworthy that two of the five facilities reported using significant ice temperature setback overnight and during most noncompetitive events, and they reported no complaints about ice quality. It was also noted that at least one of the facilities has sequentially offset setpoints for the compressors that allows the glycol return temperature to drift up 1°F before another stage is brought online, and two others appear likely to have similar logic. With this logic, the ice temperature tends to be kept colder than necessary much of the time so that the ice temperature is adequately cold when the load increases, which causes an increase in ice and glycol temperature.

Condensers and Head Pressure Control

Two of the arenas use evaporative condensers and two use air-cooled condensers, while the other has a legacy system that uses a cooling tower and water-cooled shell and tube condenser. Only one of the arenas has a flooded chiller, which is matched with air-cooled condensers. All other arenas have DX (direct expansion) chillers. Even though flooded chillers generally have much lower minimum head pressure requirements than DX chillers, the site with a flooded chiller was one of three sites that appeared to have minimum condensing saturation temperatures of around 100°F. That leads to much higher compressor energy use (and wear) than operating at the 75°F minimum condensing saturation temperature that one of the sites with a DX chiller uses. This lower level is more consistent with what most industry professionals indicate and implies that three of these arenas could achieve dramatic energy savings with improved condenser/head pressure control.

Glycol Pump Control

Although only one of the reviewed arenas is not using any form of reducing pump power during off-design conditions, with most of those taking advantage of unequally sized pumps that are built into the systems. Even the two facilities with variable frequency drives (VFDs) are using them more as a two-speed controller rather than a close to infinitely variable speed control. The use of the VFDs in these facilities was still very valuable in allowing the contractor to correct for capacity mismatches between the pump(s) and the system requirements. There appears to be significant savings potential from adding variable speed or another form of automatic glycol pump control both in the facility that manually switches between different pumps on a seasonal basis and in the facility that exclusively uses its largest pump.

Load Reduction Measures

None of the arenas reviewed have a low-emissivity ceiling, and only one of the five uses unheated water for resurfacing along with the use of the REALice device (which is purported to make oxygen bubbles coalesce so that ice quality is improved). This is being used in the only two-sheet facility reviewed, where the savings can effectively be doubled with the same installed cost. The facility owner had moved this from a different single-sheet facility where it was originally installed. Those facilities that do heat the resurfacing water use temperatures ranging from 120°F to 140°F. None of the arenas appeared to be heating the subfloor substantially more than necessary. The reviewed arenas generally appear to operate with relatively low arena space temperatures during most of the year. One facility uses aggressive, scheduled setback of arena space temperatures while a number of the others appear to manually limit the operating time of infrared heaters above the spectator areas to a minimal amount.

Table 23. Details of Reviewed Ice Arenas

Location	Northeast	Northeast	Twin Cities	Twin Cities	Southeast
Year Built	1999	1972	2010	Mid 1960's	1976
Controls Type	Refrigeration – Emerson E2 HVAC – BAS	Refrigeration/HVAC - Standalone	Refrigeration - Emerson E2 HVAC-BAS	Refrigeration/HVAC - Standalone	Refrigeration-CPC HVAC - Standalone
Renovation History	2010 evap. condenser; Recent conversion to R-449A & controls	VFD's on glycol pumps and cooling tower fan	None	Not for refrigeration system	2017 LEDs; 2014 rebuilt comps. & evap. condenser to air-cooled
Operation	Year Round	Seasonal	Year Round	Seasonal	Seasonal +3 wks
Refrigerant	R-449A	R-404A	R-507	R-22	R-22
Secondary Fluid	Glycol	Glycol	Glycol	Glycol	Glycol
Rink Size	85'X200'	85'X200' sand floor	2@85'X200' 1 sand floor	85'X200'	85'X200'
Low-e Ceilings	No	No	No	No	No
LED Lighting	No, Fluorescent	No, Fluorescent	No, Fluorescent	No, Fluorescent	Arena area only
Resurfacer Fuel	Electric	Propane	Electric	Electric	Propane
Resurfac. Water	140F	120F	Cold Water; Use	125F+	130F
Condenser					
Type	Evaporative, Forced	Cooling Tower	Evaporative	Air Cooled	Air Cooled
Fan Type	Axial	Axial	Axial	Propeller	Propeller
Fan #/Motor HP	15 hp	5 hp	20 hp	6 @ 1.5 hp each	8 @ 1.5 hp each
VFD on Fans	Yes	Yes	Yes-Cycles 60Hz	No	No
OAT to operate	15F - 20F	N/A	Below Freezing	N/A	N/A
Minimum CST (F)	75F	Control condenser water inlet to 70F	235 psig (98F)	200 psig (101F)	200 psig (101F)
Control Method	Pump on first, then fan VFD	Pump first, then fan VFD	Pump first above 32F	Individual fan pressure switches	Individual fan pressure switches
Condenser Pump	2 hp	5 hp	5 hp	N/A	N/A
Heat Recovery	Snow pit & subfloor	None	Snow pit &	Snow pit	Snow pit
Subfloor Control	28F, 30F; Pit 90F	NA	35F	NA	Heat Disabled
Inlet Pressure	Yes, set at 125 psig	No	No	No	N/A
Compressors					
Type	Open reciprocating	Semi-hermetic reciprocating	Open reciprocating	Open reciprocating	Semi-hermetic reciprocating
# of Compressors	2	3 (2 circuits)	4 (2 per rink)	2	6 (on 2 circuits);
Compressor HP	100 hp each	20-25 hp each	75 hp each	100 hp, 125 hp	35 hp each
Part-Load Control	Unloading at 50%	None	None	Unloading	None
Suction Press.	30-35 psig	-	-	25 psig - 30 psig (1F	30 psig (7F)
Discharge Press.	150 psig	225 psig	-	160 psig - 200 psig	200 psig - 225
Ice/Glycol & Setting (F)	Ice: 22F; 25F night; 19F game	Glycol: 17F, drifts up 1F each stage	Glycol: 15F, 16F Seasonal change	Glycol: 15F to 18F	Glycol: 14F to 17F
Chiller/Glycol					
Chiller Type	DX	DX	DX, 2 circuits	Flooded	DX
# of Chillers	1	2	1	1	1
# of Glycol Pumps	2	2	4 (2 for each rink)	2	2
Glycol Pump HP	10 hp--VFD; 20 hp	15 hp--VFD	15 hp, 7.5 hp	30 hp, 40 hp	7.5 hp, 15 hp
Pump Control	10hp runs @2 speeds; 20hp games	15 Hz @ 0 com.; 40 Hz @1+ comps.	Manual--small in cold months	Manual--40 hp continuous	7.5 hp @1 comp; 15 hp 2+ comps
HVAC					
Dessicant	Yes	Yes	Yes, 1 for each	No	Yes, (1)
Heating	Infrared Heaters	No other heating	Infrared Heaters,	None besides	IR in seating area
Arena Air	49F Occupied	NA	55F for AC	40F - 50F	No Setpoint

Savings Potential and Cost-Effectiveness

The cost-effectiveness and savings potential for refrigeration measures that have not been well-addressed in Minnesota through prescriptive rebate programs is detailed in Table 24. Note that some essentially identical measures are repeated across multiple market subsectors.

Table 24. Measure Cost-Effectiveness and Savings Potential by Subsector

Measure description	Cost per site (retrofit)	Cost per site (new construction, incremental)	First-year savings (kWh)	Demand savings (kW)	Simple payback w/o rebates (years, retrofit)	Simple payback w/o rebates (years, new construction)	Estimated number of applicable existing facilities	Estimated number applicable new facilities constructed annually (new construction)	Technical savings potential (first-year, kWh, retrofit)[a]	Technical savings potential (first-year, kWh, new construction)	3-year program savings potential (first-year, kWh, retrofit)	3-year program savings potential (first-year, kWh, new construction)	SCT (retrofit)[b]	UCT (Electric, retrofit)[c]	SCT (new construction)	UCT (Electric, new construction)
GROCERY MEATURES																
New controls to schedule suction temperature setback	50,000	N/A	34,550	0.0	13.00	N/A	490	N/A	16,912,225	N/A	1,183,856	N/A	0.52	1.06	N/A	N/A
Replace TXVs with EEVs	20,100	3,015	20,730	2.4	8.70	1.30	734	17	15,221,003	357,593	1,065,470	25,031	0.92	2.05	6.11	13.67
VFD condenser fan control	14,300	N/A	35,100	2.0	3.70	N/A	49	N/A	1,718,145	N/A	120,270	N/A	2.02	4.32	N/A	N/A
Digital capacity modulation	10,800	1,600	41,460	2.4	2.30	0.30	245	9	10,147,335	381,432	710,313	26,700	3.16	6.76	21.30	45.66
Adiabatic condensers	N/A	6,200	61,165	17.5	N/A	0.90	N/A	21	N/A	1,266,105	N/A	88,627	N/A	N/A	10.71	26.28
Case lighting controls	6,200	N/A	62,500	7.1	0.9	N/A	294	N/A	18,356,250	N/A	1,284,938	N/A	9.0	20.0	N/A	N/A
Passive PCM TES for walk-in freezers	20,100	20,100	6,000	3.4	30.1	30.1	930	23	5,580,300	138,000	390,621	9,660	0.4	1.1	0.4	1.1
Replacing island cases w/ multideck cases w/ doors	21,000	N/A	8,199	0.9	23.0	N/A	392	N/A	3,210,615	N/A	224,743	N/A	0.4	0.8	N/A	N/A
RCx existing refrigeration controls	11,000	N/A	271,600	31.0	0.4	N/A	323	N/A	87,745,812	N/A	6,142,207	N/A	10.2	24.5	N/A	N/A
Permanent magnet (PM) fan motors	15,500	2,300	29,000	4.0	4.8	0.7	734	21	21,293,250	600,300	1,490,528	42,021	1.7	3.9	11.5	26.2
Low speed condenser fans (& larger condenser)	N/A	45,000	88,400	20.2	N/A	4.6	N/A	3	N/A	238,680	N/A	16,708	N/A	N/A	2.0	4.8
GROICERY SUBTOTAL	-	-	-		-	-	-	-	180,184,934	1,872,125	12,612,945	208,748	-	-	-	-

Measure description	Cost per site (retrofit)	Cost per site (new construction, incremental)	First-year savings (kWh)	Demand savings (kW)	Simple payback w/o rebates (years, retrofit)	Simple payback w/o rebates (years, new construction)	Estimated number of applicable existing facilities	Estimated number applicable new facilities constructed annually (new construction)	Technical savings potential (first-year, kWh, retrofit)[a]	Technical savings potential (first-year, kWh, new construction)	3-year program savings potential (first-year, kWh, retrofit)	3-year program savings potential (first-year, kWh, new construction)	SCT (retrofit)[b]	UCT (Electric, retrofit)[c]	SCT (new construction)	UCT (Electric, new construction)
INDUSTRIAL MEASURES																
Reduce Minimum Condensing Pressure	30,240	N/A	216,000	0.0	1.30	N/A	151	N/A	32,562,000	N/A	2,279,340	N/A	2.52	5.47	N/A	N/A
Floating head pressure – wetbulb, Central Systems	9,240	6,930	33,000	0.0	2.50	1.90	151	2	4,974,750	74,250	348,233	5,198	2.70	5.49	3.60	7.32
Raise Compressor Suction Pressure	9,450	N/A	135,000	15.4	0.60	N/A	101	N/A	13,567,500	N/A	949,725	N/A	5.89	14.16	N/A	N/A
Evaporator fan cycling	50,400	25,200	360,000	20.5	1.30	0.60	50	1	18,090,000	270,000	1,266,300	18,900	5.87	12.58	11.74	25.17
Evaporator fan cycling of packaged systems	44,100	31,500	180,000	10.3	2.20	1.60	6	1	990,000	135,000	69,300	9,450	3.35	7.19	4.70	10.07
Floating head pressure - drybulb, packaged systems	107,100	N/A	170,000	0.0	5.70	N/A	11	N/A	1,870,000	N/A	130,900	N/A	1.20	2.44	N/A	N/A
Advanced packaged freon systems (Freezers)	N/A	175,000	500,000	42.8	N/A	3.10	N/A	3	N/A	1,500,000	N/A	105,000	N/A	N/A	2.44	5.36
Advanced packaged freon systems (Coolers/Docks)	N/A	193,200	345,000	29.5	N/A	5.00	N/A	3	N/A	1,035,000	N/A	72,450	N/A	N/A	1.53	3.35
Compressor Sequencing	28,350	18,900	135,000	7.7	1.90	1.30	60	1	8,140,500	121,500	569,835	8,505	1.82	4.18	2.73	6.28
LIOC to TSOC Upgrade	105,840	52,920	216,000	24.7	4.40	2.20	80	1	17,366,400	194,400	1,215,648	13,608	1.81	4.06	3.62	8.11
High Speed Doors	27,000	27,000	50,000	5.7	4.90	4.90	112	2	5,575,000	112,500	390,250	7,875	1.64	3.68	1.64	3.68
Truck Seals	5,000	5,000	10,000	1.1	4.50	4.50	112	2	1,115,000	22,500	78,050	1,575	1.78	3.97	1.78	3.97
INDUSTRIAL SUBTOTAL	-	-	-		-	-	-	-	104,251,150	3,465,150	7,297,581	242,561	-	-	-	-

Measure description	Cost per site (retrofit)	Cost per site (new construction, incremental)	First-year savings (kWh)	Demand savings (kW)	Simple payback w/o rebates (years, retrofit)	Simple payback w/o rebates (years, new construction)	Estimated number of applicable existing facilities	Estimated number applicable new facilities constructed annually (new construction)	Technical savings potential (first-year, kWh, retrofit)[a]	Technical savings potential (first-year, kWh, new construction)	3-year program savings potential (first-year, kWh, retrofit)	3-year program savings potential (first-year, kWh, new construction)	SCT (retrofit)[b]	UCT (Electric, retrofit)[c]	SCT (new construction)	UCT (Electric, new construction)
ICE ARENA MEASURES																
Controls capital upgrades	30,000	20,000	85,048	10.0	3.2	2.1	125	1	14,390,122	63,786	1,007,309	4,465	2.5	5.7	3.8	8.5
Plate & Frame Flooded vs Shell & Tube	N/A	5,000	14,195	0.0	N/A	3.2	N/A	1	N/A	10,646	N/A	745	N/A	N/A	2.2	4.4
VFD/ECM on Condenser Fan	7,000	5,000	50,172	5.7	1.3	0.9	125	2	8,489,102	75,258	594,237	5,268	6.4	14.2	8.9	19.9
Compressor Controls (Unloading or VFD)	12,000	8,000	29,593	0.0	3.6	2.4	104	150	4,172,613	4,438,950	292,083	310,727	1.9	3.8	2.8	5.7
Adiabatic condensers (vs Air-cooled)	N/A	26,100	76,397	0.0	N/A	3.1	N/A	1	N/A	57,298	N/A	4,011	N/A	N/A	2.2	4.5
VFD on Glycol/Brine Pump	7,000	5,000	70,674	8.1	0.9	0.6	52	1	4,982,517	84,809	348,776	5,937	9.0	20.1	12.6	28.1
Controls on Glycol/Brine Pumps	5,000	3,000	70,674	8.1	0.6	0.4	52	1	4,982,517	84,809	348,776	5,937	12.6	28.1	20.9	46.8
Low speed condenser fans	N/A	38,000	69,073	21.4	N/A	4.9	N/A	1	N/A	72,527	N/A	5,077	N/A	N/A	2.0	5.0
Ammonia-Water Secondary Fluid	22,400	15,600	50,629	9.1	4.0	2.8	52	2	3,569,345	106,321	249,854	7,442	2.2	5.1	3.1	7.3
ReCx/Optimizing Existing Controls	10,000	N/A	66,549	0.0	1.4	N/A	208	N/A	18,766,818	N/A	1,313,677	N/A	2.3	5.1	N/A	N/A
Reduced Flood Water Temperature	20,000	20,000	34,848	4.0	4.0	4.0	166	1	7,861,709	20,909	550,320	1,464	1.2	1.7	1.2	1.7
Subcooling reclaim for pit/subfloor	15,000	7,500	35,692	4.1	3.8	1.9	177	3	8,555,372	91,015	598,876	6,371	2.1	4.7	4.2	9.5
Optimizing subfloor heating	7,000	N/A	10,901	0.0	5.8	N/A	42	N/A	614,816	N/A	43,037	N/A	1.2	2.4	2.8	5.6
Low emissivity ceiling	50,000	50,000	64,311	0.0	5.4	5.4	104	2	9,067,851	154,346	634,750	10,804	1.7	2.0	1.7	2.0
ICE ARENA Subtotals	-	-	-		-	-	0	0	79,217,247	1,889,056	5,545,207	132,234	-	-	-	-
Totals	-	-	-		-	-	-	-	363,653,332	7,226,331	25,455,733	583,542	-	-	-	-

a) Technical potential includes all technically achievable efficiency potential without regard to cost-effectiveness, market barriers, and program constraints.

b) The Societal Cost Test (SCT) divides the total benefits by the total costs of each measure. Benefits and costs are determined from the combined perspective of the utility, customer, and society (which benefits from avoided emissions). An SCT result greater than 1 indicates cost effectiveness.

c) The Utility Cost Test (UCT) divides the total benefits by the total costs of each measure from the utility perspective alone. A UCT result greater than 1 indicates cost effectiveness.

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Discussion of Results

Market & CIP Program Design Issues

While there is some overlap in the key industry contacts and applicable measures, each of the three refrigeration-dominated facility types — grocery, industrial, and ice arenas — has its own network and characteristics. Most notably, while the grocery sector is the largest, with nearly 1,000 facilities, most of them are controlled by a small number of retail chains. On the other hand, for the smaller industrial and ice arena sectors, most of the facilities are controlled by owners that have fewer than three facilities each. One thing that is common across all of the sectors is that just a few contractors have a very significant impact — especially regarding ongoing operations and small retrofit or equipment replacement projects.

While the CIP programs in Minnesota have some effective measures, there are key approaches that have been shown to be effective, within Minnesota or elsewhere, that are not consistently used in the state's programs. The most notable of those are:

- frequent personal outreach to key industry contact — especially contractors; and
- detailed on-site assessments by experts in the particular refrigeration subsector.

Because the most significant potential for achievable savings exists through retrofits and operational changes to existing facilities, it seems apparent that these approaches should be emphasized more consistently across Minnesota, along with other approaches that can proactively harvest savings from existing refrigeration-dominated facilities. Local proof of the effectiveness is seen in that the only utility that was reported as being in touch with key refrigeration contractors every couple of months has much larger total refrigeration savings in relation to utility size than all of the others in Minnesota.

One particular challenge in program design and implementation is capturing the savings from low- and no-cost operational and control changes. While one Minnesota utility has taken the step of including contractor tune-ups, programs outside of Minnesota have gone much further, with refrigeration efficiency experts working on-site alongside the regular service technicians and providing operator training workshops to reach larger facilities that have on-staff experts. While some sites in Minnesota have accomplished some of the same end results with co-funded recommissioning studies, the number of refrigeration-dominated facilities reached in Minnesota to date has been relatively small compared to the market size. Monitoring-based recommissioning, the use of refrigeration market sector experts, and partnering closely with contractors in these efforts are some approaches that could overcome barriers to greater participation and savings among existing facilities that are not otherwise undertaking a refrigeration project. There is a growing use of refrigeration system controllers with remote access capabilities, with this feature often being used by service contractors or facility staff. Leveraging remote data collection capabilities can increase the effectiveness and lower the cost of expert support for controls optimization in existing refrigeration systems.

One common finding among the different study efforts is that prescriptive programs are better received by trade allies and customers, easier to use, and provide the greatest savings when compared to custom-measure programs in Minnesota. While the state's current prescriptive programs are effective at addressing a number of options for new equipment and a limited number of retrofit opportunities (e.g., variable frequency drive installations), a number of the measures with the greatest potential for program savings growth in Minnesota are not currently addressed in a prescriptive manner. The barriers associated with custom programs — uncertainty, the effort and cost to provide savings calculations, the time to wait for approval — must be addressed to significantly increase the uptake of these measures. These barriers may seem less worth the effort just to deal with making low-cost control changes that can provide substantial savings, but even those are not being effectively encouraged by current program models.

Refrigerant Phaseout Impacts

The evolving impact of refrigerant phaseouts and regulation is clearly on the minds of key contacts in all three market sectors. Minnesota is a member of the U.S. Climate Alliance, through which the state has committed to significant reductions in the greenhouse gases with high global warming potential (GWP). Currently, the Alliance is considering additional greenhouse gas reductions, which may include the phaseout of high-GWP refrigerants, to align with the Kyoto Amendment to the Montreal Protocol. Interviewees are all aware of these regulatory pressures, which are in flux, and each subsector has its own set of issues and current market direction with regard to refrigerants. One common theme across the market sectors is that there is not a flurry of current or expected future activity around proactive changeouts of systems.

Grocery

A range of refrigerant types are being used in existing systems. Drop-in replacements and other low-scale refrigerant changeouts have been occurring, but most owners are generally maintaining their existing equipment until it would otherwise need to be changed. Therefore, there is not expected to be a rush on equipment replacement projects through which CIP programs could "piggyback" equipment efficiency upgrades. Among those that are making changes, the type and scope of projects is not consistent. On the other hand, there appears to be a growing coalescence around the use of transcritical CO_2 systems in most new and future systems. This has important implications with Minnesota's climate and the emergence of new technologies to maximize the efficiency of these systems.

Due to Minnesota's climate with abundant cold weather, transcritical CO_2 systems are often considered for new construction and will gain market penetration as other options are phased out. CO_2 systems are most efficient when they don't exceed the transcritical operating point of 87.8°F, which only happens about 100 hours of the year in Minneapolis. For this reason, CO_2 is likely to be a market leader in Minnesota. Other options for reducing refrigerant GWP include coupling propane with CO_2, especially in systems that use micro-distributed propane options.

We did not hear much feedback from participants pertaining to measures to improve the efficiency of CO_2 systems. However, based on our market research elsewhere, we would recommend consideration of the approaches that improve the efficiency of CO_2 transcritical systems, beyond basic design. First, parallel compression should be considered as an incentive due to its overall higher efficiency compared to a simple transcritical CO_2 system. Furthermore, a larger incentive might be considered for the application of multi-ejectors with parallel compression systems as an additional means to improve overall system efficiency. Thirdly, mechanical subcooling could be considered independent of, or in conjunction with, parallel compression and multi-ejectors. In the CO_2 market, adiabatic coolers are also used to provide more versatile heat rejection compared to simple air-cooled models. It is worth further investigating the relative costs and benefits of adiabatic gas coolers as a technology that might provide increased savings if it is more widely adopted in Minnesota. However, given the humidity of the state's climate, the relative annual energy savings compared to air-cooled condensers may be more marginal than the demand benefit it can provide.

To gain the full advantage of CO_2 systems, we would also recommend increased use of heat reclaim from these systems. Due to the high operating pressures and high discharge temperature from CO_2 systems, they have much greater heat reclaim potential than traditional synthetic refrigerant systems. To take advantage of this fact, we encourage electric and gas utilities to coordinate to provide the most appropriate incentives for reclaiming heat in conjunction with system retrofits or installations. This heat can potentially be used to preheat domestic water as well as for defrost heat and to provide space heating when needed.

In existing stores, retrofitting to CO_2 is not feasible with existing equipment using HCFC or HFC refrigerants. CO_2 operating pressures are very different than refrigerants currently in use, and it will be cost prohibitive to retrofit, except in stores where complete remodels are proposed for compressors, heat rejection, and refrigerated cases. For existing stores, owners and operators are likely to opt for "near drop-in" replacements such as R-448 (GWP = 1386) and R-449 (GWP = 1396), as long as those refrigerant options are available. Other states, such as California, have moved to phaseout new applications of these refrigerants in favor of others with GWPs less than 150.

Industrial

In Minnesota, the locally wide range of qualified ammonia service contractors tends to make the use of R-22 less common than it is in many other areas. Therefore, refrigerant phaseout issues have had less impact on industrial refrigeration than on other sectors. Even so, regulations surrounding ammonia and other refrigerants have pushed the market toward some use of packaged systems with more limited refrigerant charge, and to generally favor other technologies that reduce the amount of refrigerant in the system.

As packaged systems are gaining popularity, some are including measures to make them more efficient than condensing units have been historically. This could provide an opportunity for incentivizing the most efficient packaged systems, but such program design must also consider whether this would be incentivizing an option that is less efficient than the more typical central system.

Ice Arenas

Like other facility types, ice arenas are not rushing to swap out all of the existing R-22 systems or refrigerant. One issue that complicates the options for replacement refrigerants in ice arenas is that flooded chillers are common. In a flooded chiller, the refrigerant sits in a large vessel and is boiled off with a relatively slow velocity. Most new synthetic refrigerants that might otherwise be used as near drop-in replacements are actually blends of multiple refrigerants, and should not be used with flooded chillers because the slow-velocity boiling off tends to separate the different refrigerants from the other mixture components. That factor is contributing to prolonged use of R-22 in existing ice arena systems compared to other sectors. Even so, most arenas appear to be planning to continue to use their R-22 equipment until replacement would be needed regardless of refrigerant phaseout issues. Even so, a number of existing systems — especially those with DX (direct expansion) chillers — are operating with various other synthetic refrigerants, while the majority of those built in the last 5–10 years use ammonia. CO_2 has also been discussed within the industry, but there does not appear to be a strong trend toward its use in Minnesota ice arenas. The trend toward ammonia refrigeration systems in Minnesota ice arenas has pushed the market more toward the use of somewhat more efficient, industrial-style, built-up systems with flooded chillers that can be operated efficiently at low head pressures. However, there still is a significant market niche for synthetic refrigerants in new systems with a baseline design that is closer to a grocery store rack system design and its corresponding options for air-cooled condensers.

Individual Measures

This study generally focused on potential program growth areas among measures that have not already been systematically addressed in Minnesota, and we found a number of relatively consistent opportunities across all sectors, with a degree of specialization within each. A key theme common across all sectors is that the greatest potential for additional savings is by optimizing a large number of existing refrigeration systems with a variety of control adjustments, control upgrades, and load reduction measures. This trend is much more significant than the savings associated with any single measure or the savings that can be harvested when new refrigeration systems are installed. The most important system optimization and control improvements that apply across all refrigeration-dominated facility sectors are listed in Table 25. While the concept behind each measure is consistent across sectors, the exact mode of its execution may vary.

Table 25. Existing System Optimization Measures That are Consistent Across Sectors

Optimization Measures
Reduce minimum head pressure
Float head pressure with ambient temperature or wet-bulb
Raise suction pressure or ice/glycol temperature
VFD, cycling or staging of evaporator fans or pumps
Condenser fan variable speed control
Recommission existing controls
Upgrade controls

It is important to note that in addition to the direct control changes, replacing thermostatic expansion valves (TXVs) with electronic expansion valves (EEVs) and mechanical evaporator pressure regulator (EPR) valves with electronic stepper valves can aid in suction pressure management. The TXV to EEV replacement also often reduces the minimum head pressure that must be maintained, which can provide more significant annual savings benefits in Minnesota than in other climates. These measures were of interest to interviewees, and some of the stores have already implemented valve replacements. The relatively high cost of these measures is an impediment to implementation that could be mitigated by targeted incentives.

Beyond primary refrigeration system controls, a number of measures can provide additional savings in existing systems by reducing the refrigeration load. The most important of these are outlined in Table 26. Compared to the control opportunities, there is more variation between the sectors in the cost-effective load reduction measures that can be applied.

Table 26. Important Load Reduction Measures for Existing Facilities

Subsector	Measure
Grocery and Industrial	Improved freezer defrost control
Ice Arenas	Low-emissivity ceiling over the ice
Grocery	Display case lighting controls
Industrial	Thermosiphon oil cooling
Ice Arena	Aqueous ammonia secondary fluid
Ice Arena	Reduce resurfacer flood water temperature

Although the number of refrigeration systems built or replaced in a given year is small, there are several promising measures specifically applicable to new system installations that are not currently addressed by Minnesota programs. They include the following:

- Low fan speed condensers
- Adiabatic condensers

- Parallel compression in transcritical CO_2 systems
- Multi-ejectors in combination with parallel compression in transcritical CO_2 systems
- Mechanical subcooling in transcritical CO_2 systems
- Advanced packaged synthetic refrigerant systems for cold storage facilities
- Aqueous ammonia as a secondary fluid in ice arenas
- Plate and frame chillers

The measures above are generally only cost-effective when a program can take advantage of the infrequent chance to piggyback incremental efficiency improvements onto a planned refrigeration system installation or replacement. While there was reported interest and apparent potential for significant savings for the above measures, most of these new construction items should receive more detailed technology evaluation before widespread inclusion in CIP programs.

Conclusions and Recommendations

While each of the utility programs reviewed in Minnesota has some effective refrigeration program aspects, there is potential for all of the programs to dramatically increase cost-effective impact with new approaches or measures. The estimated statewide potential savings that could be achieved over a three-year CIP program cycle is about 26,000 megawatt hours. The most important program approaches for maximizing savings are:

1. frequent outreach to the small number of dominant contractors and other key industry contacts that influence a large number of facilities;
2. tailoring program approaches to better harvest the opportunities for operational improvements and cost-effective retrofits in existing facilities (e.g., more prescriptive rebates, TRM custom); and
3. minimizing program barriers for measures that are not currently included as prescriptive measures.

Greater harvesting of the savings potential from the large refrigeration-dominated facilities sector also depends on the development of new prescriptive or TRM measures that represent the common operational and cost-effective retrofit savings opportunities for existing refrigeration systems as well as measure updates to reflect current market conditions for new refrigeration systems.

CIP Program Approaches

Frequent Outreach to Key Industry Contacts

A relatively small number of key industry contacts influence the design, operation, and retrofits of the vast majority of facilities within each of the subsectors of refrigeration-dominated facilities. This makes it both practical and critical for program implementers to build relationships with these contacts and leverage them to get appropriate credit for projects that are happening and, more importantly, to increase the efficiency achieved in these facilities.

Table 27 summarizes the recommended avenues of key industry contact outreach, with the highest priorities listed first. Note that frequent personal contact with specialized refrigeration contractors is critical in all subsectors of this market to maximize program impact in existing systems and new refrigeration systems. While all outreach is most effective if done by individuals that understand refrigeration efficiency measures and the market, a good technical knowledge base is especially critical when talking with contractors and designers. The most effective methods of personal engagement vary within each subsector depending on whether facility-level decision-making is dominated by individual owners that each control a large number of facilities (e.g., grocery chains) or whether owners typically control only a small number of facilities (e.g., cities that own a single ice arena).

Table 27. Recommendations for Outreach to Key Contacts

Subsector	Key Contact Type	Recommended Outreach
All	Service and Installation Contractors	Personal contact every other month to discuss potential projects
All	Service Contractors and ESPs[a]	Engage in the development and delivery of approaches targeting operational savings and retrofits to existing systems
All	Designers and Vendors	Personal contact semiannually to increase program awareness and as needed to address issues or conflicts with individual measures
Grocery	Retail Chain Decision Makers	Personal contact 2–6 times per year to ask about potential projects
Ice Arenas	Ice Arena Managers	Join MIAMA[b] and participate in trade shows
Industrial	Facility Operators	Work with RETA[c] Northern Plains chapter to develop and promote approaches targeting operational savings measures
All	Other End Users	Regular project marketing and annual personal outreach

a) ESPs include energy service providers such as recommissioning providers, industry consultants, and shared-savings contractors.

b) MIAMA is the Minnesota Ice Arena Managers Association.

c) RETA is the Refrigerating Engineers and Technicians Association.

Expand Approaches Targeting Operational and Retrofit Measures

No- and low-cost operational and existing system retrofit measures represent about 90% of the additional potential savings in this sector, and these have not been effectively addressed by most refrigeration programs in Minnesota. In addition to removing program participation barriers for individual measures in these categories (which is addressed in more detail in the following section), expanding program approaches that are proactively aimed at improving the efficiency of existing systems is critical to significantly increasing program impact. A number of approaches that have successfully affected efficiency improvements in existing facilities, beyond what would occur absent program interventions, include:

- Having a refrigeration efficiency expert work on-site with staff operators or service contractors to make low-cost control changes;
- Providing reduced cost on-site assessments by experts in refrigeration efficiency for the specific market subsector;
- Leveraging remote refrigeration system monitoring to lower the cost of assessments and control optimization guidance; and
- Providing refrigeration operator training workshops (ACEEE 2016), which could be coupled with documentation of control changes or energy use monitoring to document program impact.

Minimize Barriers for Measures Without Prescriptive Rebates

A consistent message from industry contacts was that prescriptive rebates are easier to take advantage of than custom rebates. Numerous contacts indicated that the hassle of custom rebates often either got in the way of an efficiency measure getting sold or led to efficiency upgrades happening outside of CIP programs (and thus without utility credit for the savings). Most equipment replacement and upgrade projects in this sector occur without the involvement of a design engineer that has the expertise (or appropriate fee) to quantify the energy savings benefits of various upgrade options. Therefore, the detailed documentation of savings commonly required for custom projects would typically add significantly to the expense, effort, and timeline. Minimizing these barriers for potential custom projects can add substantially to the number of projects impacted by CIP programs and the number that participate. Recommendations for minimizing these custom program barriers include:

- Add to the list of prescriptive program measures wherever practical to make it easier for contractors and customers to participate in CIP programs, including measures for ice arenas and industrial refrigeration systems. This has the added benefit of increasing the awareness of measures among end users and trade allies.
- For measures that continue to fall under a custom approach, shift as much of the effort and responsibility for determining savings for proposed retrofit and small-scale equipment replacement projects away from the contractors, vendors, and end users. This typically requires a refrigeration efficiency expert to represent the program implementer in conversations with the contractor or vendor. If such conversations happen early enough in the process, they can have the added benefit of identifying additional upgrades that are appropriate for the proposed project's scope of work.
- Further develop TRM measures and other methods of expediting the calculation of savings and subsequent custom rebates (e.g., have standard savings that are scaled based on system size and the amount that a controlled condition changes, like degree Fahrenheit change in saturated suction temperature).
- Provide one week or less turnaround times for reviews of retrofit and smaller scale custom equipment replacement projects.

Recommendations for Specific Measures

The recommendations presented focus largely on recommended changes that are not necessarily comprehensive regarding measures that were already being regularly addressed by Minnesota CIP programs in the 2019–2020 time frame.

Top Priority Growth Measures

The top priority measures for increasing CIP program impact in large, refrigeration-dominated facilities are outlined in Table 28. It is recommended that utilities offer prescriptive rebates for as many of these as is practical and take other steps to promote these measures and streamline CIP participation as much as possible. Note that the most significant potential for program growth exists in measures related to control improvements that can provide savings in existing facilities, including both operational changes (e.g., changing a setpoint or enabling an advanced function on an existing controller) and retrofits (e.g., new controllers, rewiring, adding temperature sensors, or replacement of valves to allow for a change in setpoints). It is also noteworthy that a single control upgrade or recommissioning project may address a number of these control opportunities at the same time.

Table 28. Top Priority Program Measures for Refrigeration Dominated Facilities

Subsector	System Type	Measure	Comments
All	Existing	Reduce Minimum Head Pressure	Implementation cost and degree of possible head pressure reduction varies greatly.
All	Existing	Raise Suction Pressure or Ice/Glycol Temperature	Could be accomplished by: an increase in fixed setpoint, scheduled, floating, through improved suction grouping, or improved compressor capacity control.
Industrial and Grocery	Existing and New	Evaporator Fan Cycling or VFD	Fan power savings are amplified by the reduction in refrigeration load.
All	Existing	Condenser Fan VFD Control	Improved head pressure control makes the savings larger than typical VFD applications.
Ice Arenas	Existing (or New)	VFD or Staging of Glycol Pumps	Unequally sized pumps or large fixed steps of VFD control are more common than infinitely variable speed control. Extra heat on the system makes savings larger than typical VFD applications.
Ice Arenas	Existing and New	Low-Emissivity Ceiling	Also provides substantial heating savings
Grocery	Existing	Case Lighting Controls	—
All	Existing	Ambient Approach Control of Condenser	Capability is often present, but not enabled. Largest opportunity on industrial.
Industrial and Grocery	Existing	Improved Freezer Defrost Control	Appreciable savings only occur in freezers.
Grocery and Ice Arenas	New	Low speed Condenser Fans	Provides demand savings that condenser fan ECM or VFD control does not.
All	Existing	Recommission Existing Controls	Often includes reducing minimum head pressure, ambient approach control, raising suction pressure setpoints, floating suction pressure, and VFD control optimization.
All	Existing	Upgrade Controls	Typically includes a combination of reducing minimum head pressure, ambient approach control, raising suction pressure, evaporator fan cycling, glycol pump control, and VFD control optimization.
Industrial	Existing (and New?)	Thermosyphon Oil Cooling	Alternative to liquid injection oil cooling of screw compressors.
Grocery (and Ice Arenas)	New	Adiabatic Condenser	Provides demand savings vs. air-cooled and annual savings depends greatly on controls.
Industrial	Existing & New	High Speed Doors	Automatic doors reduce infiltration of warm, moist air.

The cost to implement a number of these control measures can vary substantially across facilities, and the expected savings may also vary depending on facility-specific conditions and seasonal operating schedules for ice arenas and food processing facilities. Despite the challenges presented by degrees of variability between facilities and bundling of measures, it is critical that CIP programs promote these items and make it easy for contractors, end users, and energy service providers to obtain rebates for their implementation.

The high priority measures list includes two items related to condensers that have a higher ratio of demand to energy savings than many refrigeration program measures. One savings opportunity applicable to the selection of new condensers that is widely available but has received little attention relative to the demand and energy savings it can provide, is low speed condenser fans. National and local energy code changes have recently focused more attention on the condenser fan power at design conditions, while programs and the industry have historically focused more on variable speed control of condenser fans with VFDs or ECMs. Starting with a lower fan speed to begin with yields both demand savings and a similar level of energy savings. In some situations, the 2020 Minnesota Energy Code will force a change from previous standard practice. In all cases, there are opportunities for significant improvement over the baseline condenser selection. However, it is expected that a significant amount of effort will be required to educate contractors and vendors concerning this measure, which is new to utility program offerings.

The other new measure is adiabatic condensers, which use evaporative cooling of air going into the condenser to achieve lower condensing saturation temperatures (and head pressures), compared to air-cooled condensers, during hot weather. While further technical investigation of this measure may be warranted to determine optimal control requirements, it will likely be an important measure for grocery stores and ice arenas.

Measures to Evaluate or Promote to a Lesser Degree

The market study efforts indicated the promise of a number of measures not included in the top priority list, but definitive conclusions were not reached due to the need for more detailed technology assessment work or conflicting information from research and interviews. The measures with the highest priority for further evaluation and program development are shown in Table 29. A number of these measures are exclusively or especially relevant to transcritical carbon dioxide (CO_2) refrigeration systems, which appear to be moving toward market dominance in new grocery store refrigeration systems as the industry adapts to the near-term phaseout of HFC refrigerants.

Table 29. Key Potential Measures Requiring Further Technology Assessment

Subsector	Measure	Notes
Grocery	Adiabatic Condenser/Gas Cooler	Savings will be higher for transcritical CO_2 systems. Control for energy savings vs water savings must be considered.
Grocery	Parallel Compression in Transcritical CO_2 Systems	Is only practical at the time of system installation
Grocery	Multi Ejectors in Transcritical CO_2 Systems	Is only practical at the time of system installation. Two different system configurations are used, and the most common approach is paired with parallel compression.
Grocery	Mechanical Subcooling in Transcritical CO_2 Systems	Could potentially be practical and cost-effective as a retrofit
Grocery and Ice Arena	Space heat reclaim	Transcritical CO_2 systems provider greater potential that previous grocery refrigeration systems and the low temperature of ice arenas makes them an ideal application
Industrial	Advanced Packaged Synthetic Refrigerant Systems	To be compared against a baseline of standard packaged synthetic refrigerant systems.
Ice Arena	Aqueous Ammonia as a Secondary Fluid (Under the Ice)	Material compatibility and product issues are a concern that warrant further investigation prior to widespread promotion.
Ice Arena	Reduced Resurfacer Water Temperature	Various methods to treat resurfacer flood water have been used with greatly varying reports of success in lowering temperature and maintaining ice quality.[a] Cost-effectiveness in single-sheet facilities is questionable
Ice Arena	Plate and Frame Chillers	The glycol side pressure drop impact and minimum flow considerations must be evaluated (with glycol pump VFD control) against any impact on minimum head pressure

a) While a close study of the REALice device was unable to document its effectiveness (Makhnatch 2011), the authors recognize potentially large opportunities for refrigeration and water heating savings if a better industry understanding of how various resurfacer water variables (e.g., dissolved oxygen, hardness, purity, and temperature) impact ice quality can lead to no cost operational changes or better targeted water conditioning methods.

The measures in Table 30 were investigated in this market study, and are recommended for consideration or promotion, but with a lower priority than the other measures evaluated. It would be worthwhile to include these measures in a list of possible custom measures and in discussions with industry contacts, but taking steps towards providing prescriptive rebates is probably not warranted at this time.

Table 30. Other Measures to Consider

Subsector	Measure	Notes
Grocery	Permanent Magnet Fan Motors	Currently is a viable measure, but savings are lower than for top priority measures.
Industrial and Grocery[a]	Phase Change Material Thermal Energy Storage	Effective demand response measure, but energy savings are minimal — especially in Minnesota's climate.[b]
Ice Arena	Subcooling Heat Reclaim for Snow Pit and Subfloor	Primarily applicable to new systems as an alternative to desuperheating reclaim. Adequate heating of the snow melt pit may be a challenge and must be considered in heat exchanger and snow pit design.
Ice Arena	Optimizing Subfloor Heat Control	Provides low savings and is infrequently applicable as an operations or retrofit opportunity with variable costs.
Industrial	Truck Dock Seals	Relatively low savings and cost compared to other measures.

a) Within the grocery sector, Phase Change Thermal Energy Storage can only be applied to walk-ins.

b) The documented savings study (ASWB 2016) did not isolate the savings of phase change material from extensive control upgrades that were made at the same time. Also, day–night refrigeration efficiency differences are minimal for much of the year in Minnesota (because systems are already down to their minimum head pressure in the daytime for the majority of the year). The opportunity for phase change materials to be cost-effective will likely increase with additional renewable energy sources being added to the grid, and there will be a resulting increased difference in energy prices over different times of the day.

Measures No Longer Appropriate for Rebates as Part of New Systems

Both the 2020 Minnesota Energy Code requirements for refrigeration systems and the federal code requirements include a number of items that have historically been rebated by CIP programs in Minnesota (ICC 2020). Based on the current code requirements, it is recommended that rebates for the items clearly required by code no longer be provided as part of the installation of a new refrigeration system. Table 31 outlines the state energy code requirements and includes notes about applicable federal standards that went into effect in 2009, 2017, and 2020 (CFR 2020). Because the display door, display cases, and refrigeration equipment performance requirements are expressed differently than most CIP program measure descriptions that tend to identify specific features, a more detailed technology evaluation is recommended to clearly establish a current baseline for any ongoing refrigeration program rebates based on those features in new refrigeration equipment and systems.

Table 31. Measures Currently Required by the Minnesota Energy Code or Federal Standards

Applies To	Measure
Walk-Ins and Larger Storage Areas[a]	Minimum insulation requirements
Equipment for Walk-Ins and Larger Storage Areas[a]	ECM or three-phase evaporator and condenser fan motors
Glass Freezer Doors for Walk-Ins[a]	Triple pane with inert gas or heat reflective glass
Glass cooler Doors for Walk-Ins[a]	Double pane with inert gas and heat-reflective glass
Walk Ins and Larger Storage Areas[a]	Antisweat heat control and limit on uncontrolled antisweat heat
Site Assembled Display Cases	Lighting Control by Timer or Motion Sensor
Site Assembled Display Cases	Antisweat heater control
Various Display Cases	kWh/day energy use limits as tested per AHRI 1200[b]
Display Doors for Walk Ins	Federal standard limits on kWh/day went into effect in 2017 [b]
Unit Coolers & Condensing Units for Walk-Ins	Federal standard minimum AWEF requirements went into effect in July of 2020
Condensers[c]	Fan motors 1 HP or less must be ECM, PSC (permanent split-capacitor), or three-phase
Condensers[c]	Variable speed control of all fans in unison
Condensers[c]	Float head pressure with ambient (dry-bulb or wet-bulb) down to 70°F or less
Compressor Control[c,d]	Floating suction pressure based on temperature(s)
LT Systems with ≥100,000 BTU/hr load[c]	Mechanical subcooling and liquid line insulation
Compressors[c]	Crankcase heater must cycle off when compressor runs

a) These requirements are in the 2020 Minnesota Energy Code and have been required by federal minimum equipment manufacturing standards since 2009.

b) Federal standards for the manufacturer of commercial refrigeration equipment that went into effect in 2017 use the same quantitative scale, but are even more stringent than the 2020 Minnesota Energy Code requirements (CFR 2020). A detailed technology evaluation of the impact of this on the baseline for historically rebated display case features (e.g., no heat doors) is recommended, but was beyond the scope of this market study.

c) Transcritical CO_2 and ammonia systems are exempt from these particular requirements.

d) This is not required for single compressor systems lacking compressor capacity control.

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Appendix A: Local Refrigeration Industry Interviewees

Role	Grocery	Industrial	Ice Arena
Contractor	1. Ryan Welty, Sales and Operation St. Cloud Refrigeration (SCR) 2. Joe Berger Installing Coolers ETC 3. Chris Braun, Project Manager Refrigeration Coborns Inc	1. Kevin Vwieselhoser, Mechanical Engineer Harris Company 2. Marks Worms, Sales Engineer Cool Air Mechanical 3. Mark Fitch, Sales Engineer Justin Zembo, Lead Mech. Technician St. Cloud Refrigeration (SCR) 4. Mike Warne, Vice President Engineering Gartner Refrigeration 5. Erik Hansen, P.E., VP of Engineering Carlson & Stewart Refrigeration	1. Art Sutherland, President & CEO Accent Refrigeration 2. Mark Fitch, Sales Engineer Justin Zembo, Lead Mech. Technician St. Cloud Refrigeration (SCR) 3. Mike Warne, Vice President Engineering Gartner Refrigeration 4. Bruce Pylkas, President Total Mechanical
Vendor	1. Brooks Rajala, Sales Representative RAC Sales 2. Skip Lindback, CEO Applied Sales 3. Eric Wickberg, Sales Representative Crown Tonka	1. Nathan Bartlett, Controls-Programming Manager AEC 2. Neil Thompson, Senior Sales Engineer Evapco 3. Jim Spade, Sales Engineer Frick (Johnson Controls) 4. Dave Deroche, Principal FES Midwest	1. Jerry Lazno, Business Development Engineer Baltimore Air Coil (BAC)
Designer		1. Jo Annepu, Energy Systems Engineer DualTemp Companies	1. Jim Maland, Senior Associate Stantec
Energy Consultant	1. Abtar Singh, Owner Singh360	1. Dr. Doug Reindl, Director IRC University of Wisconsin	1. Mark Rasmussen, P.E., Owner Apex Engineering
End User	1. Wally Lindeman, Store Development Director Lund and Byerlys 2. KC Kolstad, Lead Mechanical Ref. Engineer Target 3. James McClendon, Director of Energy Efficiency Walmart Energy 4. Jon Scanlan, Assistant VP, Store Development Hy-Vee 5. Scott Vancamp, VP Operations Hugos Family Marketplace 6. James Saboe, Project Manager Fareway Stores	1. Robert Gray, Plant Engineer West Central Turkeys 2. Dale Radueg, Maintenance Manager Russ Sather, Refrigeration Lead Trident Foods 3. Ted Royals, Facility Service Manager Americold 4. Scott Kerfoot, Maintenance Manager Sysco 5. Brad North, Sales and Business Leader Viking Cold Storage	1. Ryan Ries, Facilities Director, Ramsey County Parks and Recreation 2. Paul Froman, Maintenance Foreman Faribault Ice Arena 3. Daryl Fieck, Building Operation Manager Olmsted County 4. Ed Staiert, Recreation Center Manager Rochester Parks and Recreation Administration 5. Wayne Roehrich, CAC Maintenance Supervisor Brooklyn Park Ice Arena

Appendix B: Assumed Inputs for Cost-Effectiveness Evaluation

Description	Assumed Value	Annual escalation rate	Source
Avoided costs (Electric)			
Marginal cost of energy ($/kWh)	$ 0.0266	3.59%	Commerce Decision: CIP Gas and Electric Utilities - 2021-2023 Cost-Effectiveness Review (2/11/2020, Docket Nos. G999/CIP-18-782 and E999/CIP-18-783)
Avoided capacity cost, summer ($/kW)	$ 65.99	3.59%	Minnesota Energy Efficiency Potential Study: 2020–2029
Avoided capacity cost, winter ($/kW)	$ -	-	N/A
Avoided T&D cost ($/kW)	$ 9.89	2.40%	Minnesota Energy Efficiency Potential Study: 2020–2029
Environmental damage factor ($/kWh)	$ 0.0198	2.30%	Commerce Decision: CIP Gas and Electric Utilities - 2021-2023 Cost-Effectiveness Review (2/11/2020, Docket Nos. G999/CIP-18-782 and E999/CIP-18-783)
Other inputs (Electric)			
Electric line loss factor (%)	7.70%	N/A	Commerce Decision: CIP Gas and Electric Utilities - 2021-2023 Cost-Effectiveness Review (2/11/2020, Docket Nos. G999/CIP-18-782 and E999/CIP-18-783)
Retail electric rate ($/kWh) (Blended rate that includes demand charges)	$ 0.1113	3.59%	EIA Minnesota Statewide August 2020 (Commercial)
Avoided costs (Gas)			
Commodity cost ($/Dth)	$ 3.250	4.69%	Commerce Decision: CIP Gas and Electric Utilities - 2021-2023 Cost-Effectiveness Review (2/11/2020, Docket Nos. G999/CIP-18-782 and E999/CIP-18-783)
Demand cost ($/Dth/year)	$ 0.540	4.69%	Xcel Energy 2021-23 Triennial Plan Filing (General Inputs for the Gas CIP BENCOST Model)
Variable O&M ($/Dth)	$ 0.041	4.69%	Xcel Energy 2021-23 Triennial Plan Filing (General Inputs for the Gas CIP BENCOST Model)
Environmental damage factor ($/Dth)	$ 2.070	2.30%	Commerce Decision: CIP Gas and Electric Utilities - 2021-2023 Cost-Effectiveness Review (2/11/2020, Docket Nos. G999/CIP-18-782 and E999/CIP-18-783)
Other inputs (Gas)			
Retail gas rate ($/Dth)	$ 5.03	4.69%	Xcel Energy 2021-23 Triennial Plan Filing (General Inputs for the Gas CIP BENCOST Model)
Peak reduction factor (%)	1.00%	N/A	Commerce Decision: CIP Gas and Electric Utilities - 2021-2023 Cost-Effectiveness Review (2/11/2020, Docket Nos. G999/CIP-18-782 and E999/CIP-18-783)
Discount Rates			
Electric Utility	5.38%	N/A	(Xcel Electric) Commerce Decision: CIP Gas and Electric Utilities - 2021-2023 Cost-Effectiveness Review (2/11/2020, Docket Nos. G999/CIP-18-782 and E999/CIP-18-783)
Gas Utility	5.34%	N/A	(Xcel Gas) Commerce Decision: CIP Gas and Electric Utilities - 2021-2023 Cost-Effectiveness Review (2/11/2020, Docket Nos. G999/CIP-18-782 and E999/CIP-18-783)
Societal	3.02%	N/A	Commerce Decision: CIP Gas and Electric Utilities - 2021-2023 Cost-Effectiveness Review (2/11/2020, Docket Nos. G999/CIP-18-782 and E999/CIP-18-783)

Description	Assumed Value	Annual escalation rate	Source
Commercial Participant	6.47%	N/A	Commerce Decision: CIP Gas and Electric Utilities - 2021-2023 Cost-Effectiveness Review (2/11/2020, Docket Nos. G999/CIP-18-782 and E999/CIP-18-783)
Government Participant	3.02%	N/A	Commerce Decision: CIP Gas and Electric Utilities - 2021-2023 Cost-Effectiveness Review (2/11/2020, Docket Nos. G999/CIP-18-782 and E999/CIP-18-783)