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RETA CRES Initiative: Market Characterization, Baseline Study, and Forecast Report

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Executive Summary

The Northwest Energy Efficiency Alliance (NEEA), an alliance of more than 100 Northwest utilities and energy efficiency organizations, recently partnered with the Refrigerating Engineers & Technicians Association (RETA) to develop a new energy efficiency certification for industrial refrigeration operators across the northwest and the US: Certified Refrigeration Energy Specialist (CRES). The initiative seeks to transform industrial refrigeration operations and maintenance (O&M) practices by offering an ANSI-accredited operator certification in system energy performance.

NEEA contracted with Research Into Action to create a 20 year estimate of energy savings that will result from the initiative. This report provides the savings projections, as well as providing key findings concerning market characteristics. Additionally, the research team delivered to NEEA energy consumption and intervention savings estimation modeling tools that NEEA may refresh as new information become available.

The findings in this report follow from analysis of surveys with refrigeration operators, interviews with RETA staff and regional contracted refrigeration service providers, examination of databases containing information on northwest industrial facilities, and development of energy and savings estimation modeling tools. This research delivered the following key findings and deliverables, described in greater detail in sections that follow:

- Current number and forecast of industrial refrigeration *facilities*, *systems*, and *operators* in the market
- Baseline of energy efficiency O&M *practices*
- Current and forecast *baseline energy consumption* from industrial refrigeration
- Current and forecasted regional *savings from NEEA's intervention through its RETA CRES initiative*
- Current and forecasted O&M *efficiency savings* from local utilities, BPA and ETO's intervention in the refrigeration market
- Forecasts of industrial refrigeration *energy use with and without NEEA's* RETA CRES initiative
- Documented a *model for NEEA's ongoing use* for estimating industrial energy efficiency O&M savings

Market Characteristics

Roughly 740 refrigeration operators work in the region across 185 facilities[1]; on average, each facility contains two and a half refrigeration systems. A number of factors favorable to market adoption of a refrigeration operator certification in energy performance characterize NEEA's region. These factors include:

- High proportions of operators with technical knowledge in refrigeration systems, which is essential for pursuing CRES certification. Many operators have received system training from a prior NEEA initiative, and from regionally funded programs.
- Increasing willingness of industrial customers to invest in energy management, as evidenced by growth in the number of regional efficiency programs requiring participant capital investments.
- Strong professional ethic indicated by high proportion of operators pursuing RETA CARO and CIRO[2] certifications and holding membership in professional organizations.

Baseline Energy Consumption

The average industrial refrigeration facility consumes nearly 11,400 MWh per year[3]. Roughly 10% of this energy is consumed by inefficiencies from either less efficient O&M practices or less efficient equipment configurations; the research team estimate that over 600 MWh per facility could be saved annually from improved O&M practices alone.

Baseline Energy Savings Forecast & Total Regional Savings Forecast

This report provides savings forecasts for more efficient operation of refrigeration systems absent NEEA's RETA CRES initiative (baseline energy savings forecast) and savings forecast with NEEA's intervention through its NEEA's RETA CRES initiative (Total Regional Savings). The Total Regional Savings forecast includes savings resulting from other regional industrial programs, such as utility programs, in addition to NEEA's CRES initiative. The current baseline energy consumption for industrial sector refrigeration is just over 240 aMW. Baseline annual energy consumption will rise to just over 284 aMW by the twentieth year and the CRES intervention will likely drive total energy consumption down to just over 281 aMW. On average,

[1] The research team estimated for the number of RSOs and industrial facilities across the market by performing multiple calculations throughout this report. Estimates for the count of RSOs are within ranges provided by NEEA's initiative and RETA, and energy consumption estimates documented in the Northwest power and Conservation Council's estimates for energy consumption from industrial refrigeration sources documented in the Council's *Sixth Northwest Conservation and Electric Power Plan*. http://www.nwcouncil.org/media/6284/SixthPowerPlan.pdf

[2] Certified Assistant Refrigeration Operator (CARO) and Certified Industrial Refrigeration Operator (CIRO)

[3] Figures estimated from analysis in this report; see Section 3.

NEEA's CRES intervention will likely deliver roughly 2 aMW per year and produce about 40 aMW of savings in 20 years[4].

Modeling Tools

The research team delivered two modeling tools to NEEA. Using the first tool, NEEA will be able to estimate facility-level energy consumption for future baseline studies from any subsequent research conducted. The research team developed this tool – a model – from engineering savings estimates of O&M practices and capital investments.

The second tool produces estimates for baseline energy consumption and total regional energy consumption with NEEA's RETA CRES initiative. NEEA may use the model in support of their cost-effectiveness model development for this initiative.

[4] Estimates were derived from baseline calculations for the average energy consumed by the industrial refrigeration sources per facility, assumptions provided by NEEA's initiative concerning the proportion of energy savings per facility with initiative trained staff, modeled savings outcomes attributable to the initiative in situations where RSOs participate in both regional programs and NEEA's initiative, and estimates for the number of facilities across the market.

1. Introduction

The Northwest Energy Efficiency Alliance (NEEA), an alliance of more than 100 Northwest utilities and energy efficiency organizations, recently partnered with the Refrigerating Engineers & Technicians Association (RETA) to develop a new energy efficiency certification for industrial refrigeration operators across the northwest and the US: Certified Refrigeration Energy Specialist (CRES). NEEA's RETA CRES initiative ("Initiative") seeks to transform industrial refrigeration operations and maintenance (O&M) practices by offering an ANSI-accredited operator certification in system energy performance.[5]

NEEA designed the initiative to accelerate the use of energy performance techniques in the operations and maintenance (O&M) practices of industrial refrigeration service operators (RSOs). NEEA's initiative seeks to transform industrial refrigeration O&M practices by both increasing the supply of instructors offering training appropriate for CRES certification exams, and stimulating market demand for RSOs with energy performance accreditation.

NEEA contracted with Research Into Action to help it reasonably estimate 20 year savings projections for the initiative. Research presented in this report provides the basis for estimating initiative savings by: 1) describing market factors influential to the industrial refrigeration market's acceptance of the CRES certification, and 2) estimating key market parameters helpful to estimating the number of facilities and RSOs in the market. This research focuses on industrial sector refrigeration and further research may be necessary to determine the potential for savings from refrigeration operators in other sectors, such as agriculture and commercial sectors.

1.1. CRES Certification and Development

CRES certification verifies that refrigeration operators, technicians, managers and other refrigeration professionals are knowledgeable about and capable of identifying and implementing low-and no-cost O&M activities that generate energy savings. NEEA and RETA recently developed CRES learning objectives to guide the development of course instruction. As an option to help them prepare for CRES certification exams, RSOs will take course instruction in energy efficiency, energy management techniques (course work is not required to sit for the exam). CRES certification exams require applicants to safely demonstrate an understanding of the basic refrigeration concepts and maintenance practices pursuant to better energy performance. For initial certification the RSO must pass the exam and successfully complete five documented energy savings activities. The CRES initiative has features to ensure CRES-certified RSOs continue to pursue efficiency activities, such as completing and reporting six low- and no-cost energy efficiency activities within three years, and renewing their certification every three years.

5 Industrial refrigeration systems are large, complex systems that are custom engineered and field assembled from individual components, in contrast to smaller packaged systems that are factory engineered and manufactured.

1.1.1. CRES Certification Sponsoring Organizations and Background

NEEA is working jointly with RETA to achieve ANSI accreditation for RETA CRES learning objectives, and to promote the certification in NEEA's region.[6] These two organizations have furthered the process toward an ANSI accreditation by holding demonstration pilot trainings with RSOs from local facilities in Central Washington, the Puget Sound area and Boise. Additionally, NEEA and RETA have contracted with a psychometrician[7] to help develop exams that test RSOs' energy management knowledge. These exams are critical to the acceptance of the CRES certification by the ANSI Committee on Education.

NEEA has worked with regional utilities and local RETA chapters to generate the RSO cohort comprising the CRES demonstration pilot. NEEA will help promote the certification, and will work to transition the initiative to RETA, and to interested training organizations to instruct CRES training courses. RETA will continue as the sponsoring advocate for the certification and will eventually promote the certification on a national level to its members and other RSOs.

In 2004, NEEA contracted with an engineering firm to develop an industrial refrigeration best practices guide (IRBPG)[8] and to deliver best practices training to refrigeration operators throughout NEEA's territory[9]. The contractor presented these trainings, focused on energy efficient operation of industrial refrigeration systems, through 2011. Subsequently, NEEA released its rights, or ownership of the IRBPG manual, to the contractor with the expectation that the contractor would have more incentive to drive training and improve practices by owning its intellectual property in the manual. By the end of 2012, 533 people had taken the best practices training course; many of these attendees were refrigeration operators.[10]

RETA is a national organization with a mission to promote the safe operation of industrial refrigeration systems and develop the abilities of industrial refrigeration operators. It oversees certification of refrigeration operators in the safe operation of refrigeration systems. Nationally RETA has 5,733 members[11], and between 200 and 250 are located in the northwest. RETA

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6 Article on RETA's website describing their collaboration with NEEA to launch the CRES certification. *http://www.reta.com/news/neea-and-reta-launch-certification-program*; downloaded September 30, 2013.

7 An expert versed in measuring psychological attributes such as intelligence or understanding, and ensuring tests measuring these attributes are reliable and test results are valid.

8 The manual—now a proprietary resource of the firm offering training—continues to be used in the region for training in industrial refrigeration best practices: Cascade Energy Engineering, Industrial Refrigeration Best Practices Guide, Third Edition, November 2010.

9 This was NEEA's first initiative to focus on O&M measures in the industrial refrigeration market, and prior initiatives focused on promotion of efficient technologies in this market.

10 The evaluation team reviewed a spreadsheet maintained by NEEA that tracks refrigeration best practices attendees between 2005-2012. The evaluation team unduplicated contacts based upon attendees first and last name, and included attendees who had participated in either the "Industrial Refrigeration Energy Management: 90-Day Collaborative Cohort," or the "Industrial Refrigeration Systems Energy Management" trainings.

11 Figures presented at the RETA National Conference, 2013, Bellevue Washington.

supports continued education for refrigeration operators through its local membership chapters.[12] Additionally, RETA offers two certifications, and both are ANSI-accredited in safe refrigeration operation and maintenance: Certified Assistant Refrigeration Operator (CARO) and Certified Industrial Refrigeration Operator (CIRO).

1.1.2. CRES Learning Objectives

NEEA and RETA finalized the CRES learning objectives in January 2013.[13] Training organizations may use these objectives to help ensure that they develop new curricula – or adopt existing programs and curricula – that adequately address knowledge essential to the effective energy management of industrial refrigeration systems. Additionally, RETA can use these learning objectives to develop the certification program and examinations. The training objectives target the operations and maintenance decisions of personnel responsible for operating industrial refrigeration systems. NEEA and RETA designed the learning objectives to apply to the majority of industrial refrigeration systems.[14]

NEEA anticipates that the training[15] leading to CRES certification will include classroom-based sessions, observation and activities on-site at a host refrigeration plant when possible, and hands-on exercises in participants' own plants between training sessions. To obtain their certification, training participants will need to pass the CRES exam and complete five energy efficiency projects or activities. Table 1. describes some of the topics training organizations may include in their curricula and reasonable training hours indicated.

Table 1. Training Components and Allocated Instruction Hours*

RETA CRES Training Component	% of Total Training Time	Hours Training Time
Refrigeration System Basics	10%	2.4
Energy Efficiency Basics	10%	2.4
Refrigeration Best Practices	60%	14.4
Best Practices for Other Systems	10%	2.4
Overall Facility Energy Management	10%	2.4
Total	**100%**	**24.0**

* Training components are described in detail in Appendix D.

[12] RETA has five chapters in the northwest

[13] Appendix D provides the CRES certification learning objectives.

[14] The CRES learning objectives do not include content on Process Safety Management (PSM) and Risk Management (RM). These content areas are covered in course offerings by RETA and other organizations.

[15] Training is not required by persons interested in taking certification exams.

1.1.3. Training Market Development

Currently the supply of training contractors is limited; only one contractor is active in the industrial refrigeration efficiency training market in the region. The contractor who helped develop NEEA's industrial best practices guide also delivered the CRES trainings to the demonstration pilots. New training organizations may feel more comfortable entering the market once ANSI-accreditation of the CRES certification learning objectives and exam instruments are completed. By helping to achieve an ANSI certification for CRES, NEEA will have effectively helped to create a market product towards which training firms can develop curricula. Therefore, additional training firms—beyond the contractor NEEA currently relies on—will be able to offer courses. These additional training firms will help to increase market supply-side offerings to the level of market demand.

1.2. Research Goals

NEEA contracted with Research Into Action to conduct research that will support its RETA CRES initiative by providing: 1) Market characterization – an assessment of the structure and dynamics of the RSO market, including the supply of and demand for energy efficient refrigeration and operations training; and 2). Baseline determination– an estimate of the current and future energy consumption from industrial refrigeration sources without interventions via NEEA's RETA CRES Intiative and similar programs offered by local utilities, BPA and ETO[16].NEEA will use findings from this research to help estimate energy savings potential for the initiative, and to inform the assumptions providing the basis of its Alliance Cost Effectiveness (ACE) model for this initiative. After this research was underway, NEEA expanded its scope to include estimation and projection of CRES initiative savings. The research team and NEEA's initiative managers determined this additional focus was pertinent because the CRES initiative overlaps with and interacts with existing programs. In order to control for this interaction in its estimates, the research team also modeled CRES intervention activities and savings estimates. By modeling estimates for the initiative and regional programs jointly, the model more accurately estimates regional program savings in years when the initiative operates in the market.

1.2.1. Market Characterization

NEEA requested a market characterization to identify baseline energy efficiency practices, help describe the contexts influencing market acceptance and demand for the RETA CRES certification, and illustrate how key market factors influence the energy savings potential for the CRES initiative. In order to achieve these objectives the market characterization describes: the current level of adoption of efficiency practices, the market offerings related to energy performance O&M practices of industrial refrigeration systems; the common level of RSO system training and their application of knowledge to routine system maintenance activities; and

[16] See page 19 for a more complete description.

facility level characteristics including refrigeration system types, RSO staffing levels and energy use.

1.2.2. Baseline Determination

NEEA applies a market wide approach to estimating savings, where NEEA forecasts savings from two perspectives: 1) Change in the market with NEEA's intervention via its initiative; 2) Change in the market without NEEA's initiative, often delivered by regional programs. The goal of the RETA CRES initiative is to create a market for RSOs certified in energy efficient system operation, and thereby to accelerate the practice of energy efficient O&M practices in the industrial refrigeration market. Estimations for CRES savings are intertwined regional programs, as both the initiative and these programs will likely influence RSOs. Therefore, the research team modeled energy savings estimates for both regional programs and the CRES initiative.

2. Market Characterization

This chapter describes key market factors that NEEA may use to inform its implementation strategies for the CRES initiative, and provides key metrics to inform the assumptions of its CRES ACE model, which NEEA uses to forecast initiative savings. Key factors described in this section include estimation of market size by number of facilities, systems, and refrigeration operators; factors likely to influence market participation in the initiative; and qualitative descriptions of the types and uses of refrigeration systems, and the level of refrigeration system training of RSOs throughout the region. Additionally, the research team used market characteristics described in this chapter to inform the forecast model, which estimates savings projections with and without NEEA's initiative.

2.1. Research Objectives and Questions

Table 2. describes the research objectives, associated questions and targeted data sources the research team developed to guide its activities. The table organizes the objectives and questions into topical domains, including: *market factors* – market characteristics that may influence the overall implementation and progress of the initiative; *facilities* – descriptions of the number, characteristics, and operational patterns of facilities across the region; *systems* – characteristics and operation of industrial refrigeration systems; and *RSOs* –estimates for the number of RSOs in the market and their level of systems training.

Table 2. Research Objective and Questions

Domain	Research Objectives	Research Questions	Data Sources
Market Factors	Initiative launch challenges	What are some common challenges faced when implementing new certifications in the northwest?	RETA staff in-depth interviews (IDIs)
	Outreach barriers	What are the characteristics of RSOs / facilities that are resistant to participating in refrigeration training / certification? How common are these resistant RSOs / facilities in the northwest?	
	Progress of parallel initiatives	What current or future initiatives implemented in the northwest also focus on energy management from O&M training/certification? What are the projected market penetrations of these initiatives? How likely is it that RETA would have developed similar certification without NEEA support, and during what timeframe?	IRBP Db Initiative sponsor correspondence RETA staff IDIs
	Promotional channels	How can the CRES initiative leverage RETA resources in the northwest to promote its certification?	RETA staff IDIs
	RSO / business motivations	What motivations would RSOs and their employers have for pursuing CRES certification or hiring CRES certified employees?	

Continued

Domain	Research Objectives	Research Questions	Data Sources
Facilities	Industry segmentation	How are northwest facilities distributed by industry?	RSO survey DNMNW[17]
Facilities	Facility characteristics	On average, how many refrigeration systems do northwest facilities operate? On average, how many RSOs are located at each facility?	RSO survey DNMNW
Facilities	Facility operating characteristics	How do facility operations vary on a weekly and seasonal basis?	RSO survey
System	Typical system characteristics	What is the distribution of systems by refrigerant type? What are systems' average horsepower? On average, how many compressors does each system have? What is the average horsepower per compressor? What is the distribution of system controls types across refrigeration systems in the region (manual, set point, and computer)?	RSO survey
System	Contracted system maintenance	What refrigeration systems maintenance is contracted out? How frequently do contractors run systems' controls and maintain equipment?	RSO survey Contracted service provider IDIs
System	System operations	How many hours per year are refrigeration systems operated? Is there seasonal variation in systems operations?	RSO survey
System	Number of RSOs in the market	How many RSOs operate in the region?	RSO survey DNMNW
System	Energy controlled by RSOs	How many RSOs maintain each refrigeration systems? How many systems do RSOs maintain?	RSO survey
System	RSOs O&M knowledge	What refrigeration O&M training and certifications have RSOs taken? How likely are they to renew their training and certifications?	RSO survey IRBP Db
RSOs	Number of RSOs in the market	How many RSOs operate in the region?	RSO survey DNMNW
RSOs	Energy controlled by RSOs	How many RSOs maintain each refrigeration systems? How many systems do RSOs maintain?	RSO survey

[17] Database of Northwest Manufactures, Nurseries, and Wineries; described in Section *2.2.1*.

Domain	Research Objectives	Research Questions	Data Sources
	RSOs O&M knowledge	What refrigeration O&M training and certifications have RSOs taken? How likely are they to renew their training and certifications?	RSO survey IRBP Db

2.2. Methodology

The research team employed both primary and secondary research approaches in order to estimate the size and frequency of key market characteristics. The team accessed NEEA databases to help estimate the number of facilities operating in the territory, surveyed refrigeration operators concerning their refrigeration system characteristics and their level of system training, and interviewed contracted refrigeration service providers and RETA staff to elicit additional market intelligence.

2.2.1. Secondary Research

In an effort to help estimate the number of refrigeration facilities and RSOs in the region, the research team accessed market and NEEA databases that contained information of facility locations.

- **Database of Northwest Manufacturers, Nurseries, and Wineries (DNMNW)[18]**: NEEA maintains a database of northwest industrial facilities, which includes information on both the facilities and the industrial organizations occupying them. The research team accessed this database to develop a list of northwest facilities identified as operating in industries often requiring industrial refrigeration. [19] A consulting refrigeration engineer—with over 20 years of experience in the region, and who is under contract with NEEA—reviewed the list and identified industries likely to include facilities most likely to operate industrial refrigeration systems.

- **NEEA's list of Industrial Refrigeration Best Practices (IRBP) attendees**: NEEA maintains a list of contacts who have attended IRBP classes designed to provide RSOs with a fundamental understanding of refrigeration systems and O&M practices for

18 The DNMNW was prepared by Evergreen Economics (2013): *http://neea.org/docs/default-source/reports/database-of-northwest-manufacturers-nurseries-and-wineries.pdf?sfvrsn=9*

19 The list of primary industries used to include facilities in this analysis included: Winemakers, Carbonated Beverages, Brewers, Sugar & Sweeteners, Canned & Frozen Foods, Candy & Confections, Bottling & Distribution, Bakery Products, Meat Products, Canned & Frozen Fruits & Vegetables, Fish & Seafood Products, Seasoning & Dressing Manufacturing, Dairy Products, Snack Foods, Animal Production, Water & Ice.

improving system energy performance. The research team accessed this list to estimate market penetration of this initiative and to produce a sampling frame for a survey of RSOs.

2.2.2. Primary Research

The research team performed target market surveys with RSOs and contracted refrigeration service providers, and conducted in-depth interviews with initiative administrators. The team developed target market surveys to collect data concerning market wide refrigeration system and RSO characteristics, and system operation and maintenance activities. The team conducted in-depth interviews to collect information concerning the planned design and implementation of the CRES initiative, and to describe factors influencing the market's acceptance of the CRES certification.

- **Survey of refrigeration service operators**: The research team conducted phone surveys with 32 industrial refrigeration service operators to learn about the characteristics of their refrigeration systems and operation and maintenance practices for these systems. The survey instrument explored facility refrigeration system features, characteristics of the refrigeration operators – including their trainings and certifications, and a number of operational choices that affect system energy consumption. The team drew the sampling frame from NEEA's IRBP participant database; many of these participants are practicing RSOs. The research team contacted all of the facilities in the sampling frame, and 130 contacts either passed screening or were not available for screening.[20]

  Prior to this effort, the research team drew a sampling frame from market data that comprised facilities identified from their NAICS codes.[21] The team fielded the survey with this sample, yet attained only one completed survey. NEEA directed the team to develop a new sample from the IRBP participant database, described above. The team subsequently estimated that drawing samples based upon NAICS codes would likely yield a population of facilities where only 5% contained industrial refrigeration.

- **Interviews with contract refrigeration service providers.** As another source of information concerning refrigeration system market, the research team interviewed five contracted service provider (CSP) firms who service industrial refrigeration systems. The research team generated the list of CSP firms from our survey with RSOs; the team's only other source of contact data for this population was a list of six names provided by a refrigeration engineer who works in the region. The RSO survey yielded ten unique CSP firms in the northwest. Structured questions for these CSP firms explored organizational

[20] Exact disposition counts for the 130 contacts are: Completes (32), Refusal/Soft refusal (15), Left message (65), Not reached (18)

[21] The North American Industry Classification System (NAICS) classifies businesses according to their type of economic activity. The classification relies on a system of codes used to aggregate businesses into related industries. *http://www.census.gov/eos/www/naics/*

capacity, industries served, their customers' system characteristics, services offered, and CSP employee characteristics. The second half of the interview collected O&M information consistent with information collected from the RSO survey.

- **In-depth interviews with RETA staff and executives**: The research team held two in-depth interviews with NEEA staff and executives concerning the level of activities RETA has in the northwest, RETA's interest and ability to take the CRES certification to market, and anticipated stages and timing for the development of the CRES certification, and to gather estimates of market characteristics – such as the number of RSOs in the market, RSOs level of training in O&M practices, and the willingness of RSOs to pursue O&M training.
- **In-depth interviews with NEEA staff**: The research team interviewed NEEA staff about the stages and timing for the CRES certification, planned CRES certification training objectives – critical to understanding the sources of O&M savings – and specific aspects of the ACE model.

2.3. Market Sizing: Facility Count

The research team estimates that NEEA's service territory contains roughly 185 facilities with industrial refrigeration systems.[22] The research team arrived at this estimate by analyzing the DNMNW database—which includes industrial facilities in Washington, Oregon, Idaho, and Montana from every industry. The database identifies facilities by NAICs codes and estimated annual electricity consumption.

The research team classified facilities in this database by developing a selection criteria based on facility NAICs codes and estimated minimum annual electricity consumption, described in the steps subsequently delineated. The research team developed minimum consumption criterion in order to estimate relevant facility counts from a database that also contains out-of-target facilities – those lacking industrial refrigeration. The team recognizes the program targets facilities of any size, and that refrigeration-using firms below the minimum consumption threshold specified for the selection criteria will likely pursue CRES certification. The team also recognizes the counterpart: many facilities within the selection criteria do not have industrial refrigeration and thus will not pursue certification.

The team believes the specified threshold results in an estimated population size appropriately descriptive of the target market, considering the qualitative information obtained from

[22] Estimates for the number of RSOs and industrial facilities across the market were derived from multiple calculations throughout this report. Estimates are within ranges provided by NEEA's initiative and RETA, and energy consumption estimates documented in the Sixth Power Council's Plan. This estimate may be lower than the actual market figure because the research team relied on the DNMNW database as a census of NW industrial facilities; NEEA has since explained that this database may be lacking in completeness with respect to the all facilities in the region, and the quality of assessed facility energy usage data is not determined.

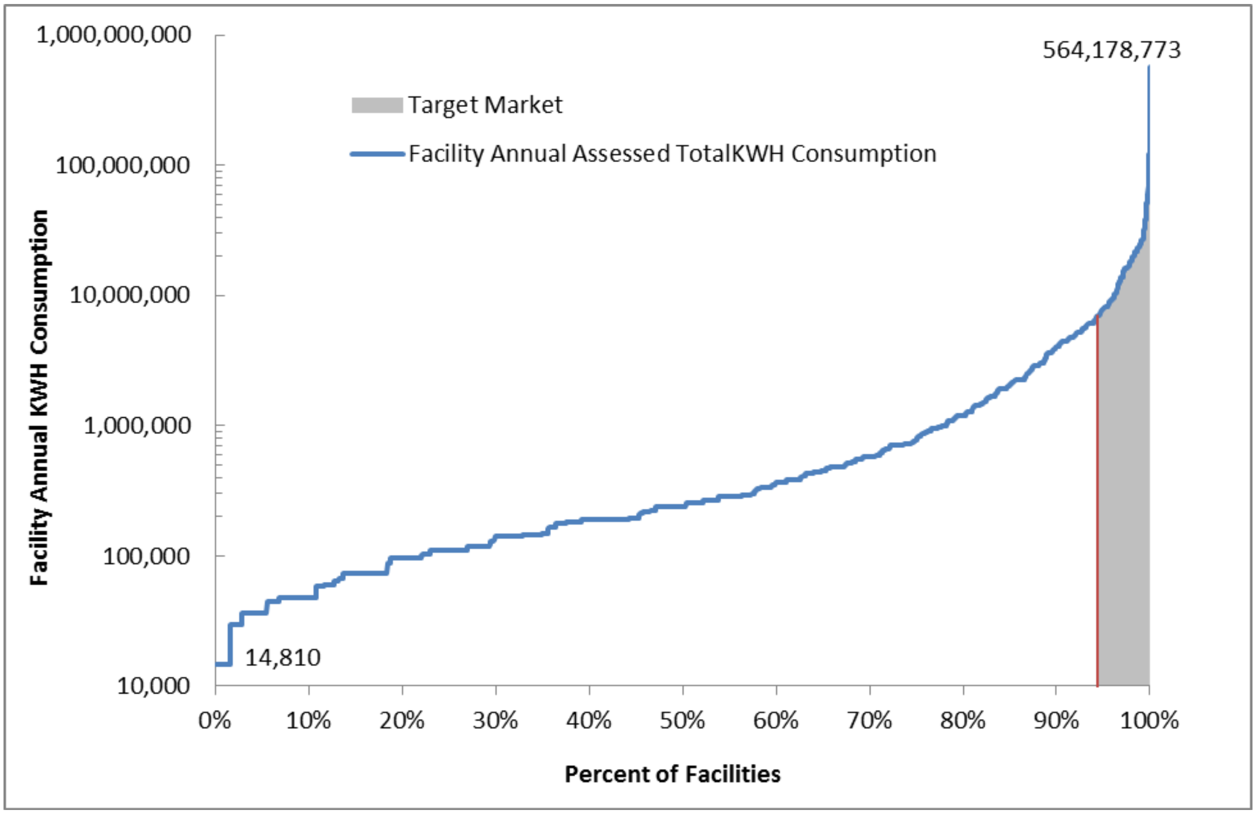
interviewed contacts, the survey results on number of systems per facility, the model results on energy consumption per system, and regional estimates of industrial refrigeration load.

1. **Included facilities by specific NAICs codes:** The research team included industries from the NEEA Industrial Database based upon their primary NAICS codes. Facilities targeted for inclusion in the final list had NAICS codes associated with industries that typically have facilities containing industrial refrigeration. A consulting refrigeration engineer, with over 20 years of experience in the region and under contract with NEEA, reviewed the database for these targeted NAICS codes targeting the following industries: The list of primary industries used to include facilities in this analysis included: Winemakers, Carbonated Beverages, Brewers, Sugar & Sweeteners, Canned & Frozen Foods, Candy & Confections, Bottling & Distribution, Bakery Products, Meat Products, Canned & Frozen Fruits & Vegetables, Fish & Seafood Products, Seasoning & Dressing Manufacturing, Dairy Products, Snack Foods, Animal Production, Water & Ice.

2. **List refinement based on assessed facility electricity consumption:** The research team conducted additional list filtering based on assessed facility annual electricity consumption. Some facilities identified by the NAICS code process in step one do not operate refrigeration systems. Industrial refrigeration is an electric intensive process. Therefore, the research team created a facility-level energy threshold for inferring the presence of refrigeration systems for facilities on NEEA's list. The research team identified a minimum annual facility consumption threshold of 7,000,000 kWh; this figure was produced from a simultaneous equation controlling for market wide energy consumption from industrial refrigeration sources consistent with moderately conservative initiative estimates provided by the initiative, and conforms to the range of estimates for market wide RSOs given by RETA and the initiative. Additionally, the figure conforms to reasonable bounds of the population surveyed for the baseline estimate and is roughly two times the average refrigeration consumption of the lower half of sample population used in this study's baseline energy assessment study.

   Refrigeration drives a high proportion of facility energy usage; this figure is moderately conservative with respect to the level of energy consumption the research team would expect to find for facilities with industrial refrigeration. Using assessed facility electricity consumption, the research team derived a cut-off point for including facilities in the target market. Figure 1 demonstrates the distribution of facilities identified in step one by facilities' annual total kWh consumed. The upper 5% of energy using facilities consume at least 7,000,000 kWh per year.

Figure 1. Proportion of Facilities Identified by NAICS Codes (X) by Facility Annual KWH Consumption (Y); Target Market (Grey Area)



The research team selected facilities from the DNMNW database described in the two analysis steps described above; 3,287 facilities were initially selected by meeting the primary NAICS code criterion, and 185 facilities were selected from this set of facilities by satisfying the minimum 7,000,000+ kWh of annual electricity consumption (per DNMNW).

2.4. Market Characteristics

The following section summarizes key features of industrial facilities, refrigeration systems, and RSOs which characterize the market. The Initiative may use findings from this section to help target their efforts at key industries, better predict operators' experiences with typical system configurations in the region, and understand operators' typical level of training with respect to refrigeration systems operation.

2.4.1. Facilities

The research teams, through its survey of RSOs, found that on average Northwest facilities employ four refrigeration operators to one and a half refrigeration systems; refrigeration is typically associated with food processing and storage.

The research team surveyed RSOs concerning the number of refrigeration systems located in their facilities, the features of those systems, and the primary refrigeration use for their facility.

Average counts of refrigeration systems and RSOs per facility are important to NEEA's ACE model.

2.4.1.1. Count of Refrigeration Systems per Facility

On average, there are one and a half refrigeration systems per facility. Most RSOs (66%) reported that one or two systems operated at their facility (Table 3..). Fewer than 10% of facilities contacted had four systems, and a similar fraction had ten or more systems.

Table 3. Refrigeration Systems per Facility

Number of Systems	Frequency	Percent (n=31)
One	15	48%
Two	6	19%
Three	4	13%
Four	3	10%
Ten or more	3	10%
Total	**31**	**100%**

Non-response cases not included in this table.

2.4.1.2. Count of RSOs per Facility

On average, four RSOs work at each facility; most facilities rely on one to six RSOs (Table 4.). Additionally, all surveyed RSOs stated that their facilities occasionally rely on services from an outside firm for maintenance to deal with emergency and non-routine situations. Contract service providers mentioned by more than one respondent include Permacold (7), McKinstry (2), and Kemper (2).

Table 4. Number of Operators per Facility

Number of RSOs	Frequency	Percent (n=32)
1	5	16%
2	7	22%
3	5	16%
4	4	12%
5	4	12%
6	4	12%
9, 12, 17	3	9%
Total	**32**	**100%**[23]

[23] Figures may not add to 100% because of rounding-error; instances of non-response not included in tables.

2.4.1.3. Purpose for Refrigeration Facilities

Most RSOs (82%) reported their facilities provide refrigeration for food processing or (cold) storage (Table 5.); additionally, 9% of facilities provide refrigeration for the hospitality industry, with the remaining 9% of facilities operating in memory chip industry, heavy industry, or ice arena industry.

Table 5. Count of Facilities' Main Purpose

Facility Purpose	Frequency	Percent (n=31)
Food Processing & Storage	26	82%
Memory Chips	1	3%
Other	4	15%
Total	**31**	**100%**

Non-response cases not included in this table.

Most of the refrigeration activities performed by RSOs concern food processing and storage, as well as creation of controlled atmospheres (Table 6.). CSPs describe a similar landscape of the facilities they primarily support. All five CSPs describe supporting food processing or storage; one supports industrial processes as well.

Table 6. Refrigeration Activities Performed by RSOs (multiple responses allowed)

RSO Refrigeration Activities	Number	Percent
Food processing	15	47%
Food storage/distribution	19	59%
Controlled atmosphere	13	41%
Beverage	3	9%
Ice arena	1	3%
Controlled atmosphere for fabrication	1	3%

2.4.2. Systems

Industrial refrigeration systems in the region annually average 4,500,000 kWh of energy consumption.[24] System energy consumption is driven by an average of four compressors with a combined 1,180 horsepower per system. According to surveyed RSOs, the typical system uses ammonia (68% of cases) and is operated by computer controls (69% of cases). Systems' physical characteristics are important to understanding refrigeration energy consumption and the opportunity for savings encouraged by the initiative.

[24] See the section *Baseline Determination* for system energy consumption findings.

This section summarizes survey results about system operating contexts, from questions on quantity of elements, horsepower, and load size.

2.4.2.1. System Characteristics

Of the 57 systems described by surveyed RSOs, over two-thirds (68%) of the systems use ammonia refrigerants; refrigerants such as R-22, 404A, or R-44 are used by 7% or less of systems (Table 7.).

Table 7. System Refrigerants (multiple responses allowed)

Type	Count
Ammonia	39
R-22	3
404A (from other text)	4
R-44 (from other text)	3
Other*	7
Don't know	1
Total	**57**

* "Other" refrigerants in use by facilities: 134A, 414B, 502, 402A, 414B, 507, and "two-stage."

Over two-thirds (69%) of system controls are PLC or computerized (Table 8.); manual controls operate 20% of systems, and set point controls are less common (9%).

Table 8. Type of Controls (multiple responses allowed)

Controls Type	Cumulative Frequency	Percent
Manual controls	11	20%
Set point controls	5	9%
PLC or computer controls	38	69%
Don't know	1	2%
Total	**55**	**100%**

Seasonal Use of Systems

Typically, facilities operate the refrigeration system year-round and all hours of the week; hours of system operation affect energy consumption. Eighty-five percent of surveyed operators reported they operate systems 8,760 hours per year (Table 9.); reductions in operating hours, if any, typically occur in response to slowed activity in food harvesting. Four facilities reported running less than 8,760 hours per year; three of these facilities indicated reasons related to the agricultural growing season, and one mentioned the size of fishing catches.

Table 9. Year-Round Operation

Estimated Hours of Operation	Number (%[25])
8760 (365 X 24) hours per year	23 (85%)
Fewer than 8760 hours per year	4 (15%)
Don't know / Missing response	5

2.4.2.2. Energy O&M Practices

Refrigeration operators demonstrated moderate involvement with energy management activities at their facilities. Less than half (44%) of operators reported seeing their system's energy bill. Cumulatively, about 70% of operators reported that someone at their companies is responsible for managing energy costs.

Additional opportunity exists for energy savings from optimal refrigeration operations and maintenance. To assess the energy performance of regional O&M practices, the research team included O&M topics in the survey with RSOs; the team developed these survey items in conjunction with a refrigeration engineer.

Table 10. describes the frequency of O&M practices consistent with maintenance of systems for optimal energy performance. The table organizes these activities by system performance areas. These figures describe the sources of O&M opportunity, and to document the baseline of O&M practices.

[25] Percent based on valid responses only

Table 10. Prevalence of Optimal O&M Practices (n=32)

Discharge Pressure	Engaged in Practice (%)	Respondent did not know if facility is engaged	Affected System Area
Absence of glycol heating	69%	6%	Discharge Pressure
Presence of direct expansion (DX) evaporators	47%	9%	Discharge Pressure
Absence of liquid injection oil cooling	41%	9%	Discharge Pressure
Floating wet bulb approach control strategy used for the condensing set point	25%	16%	Discharge Pressure
Lower the condensing pressure when not defrosting	22%	16%	Discharge Pressure
Presence of condenser water treatment process	66%	19%	O & M
Absence of scale when water treatment in place, for 21 facilities	90%	19%	O & M
Calibrate temperature sensors, pressure sensors, and slide valves at least once per year	59%	25%	O & M
Presence of automatic purgers	47%	19%	O & M
Clean condenser nozzles, water distribution trays and strainers at least once per year	47%	34%	O & M
Monitor and remove non-condensables at least once per year	31%	38%	O & M
Compressor motors that are of preferred type VFD	28%	19%	Part-load Performance
Evaporator fans cycle “off” with temperature	25%	69%	Part-load Performance

2.4.3. RSO Characteristics

A typical refrigeration system operator is likely to have more than three years of tenure at a single facility, is a member of RETA, and runs each ammonia-based refrigeration system with at least one other operator. Typically, operators control and maintain refrigeration systems; outside service contractors perform emergency maintenance, repair, or upgrade work.

2.4.3.1. Organization of Operator within Facilities

Operators tend to have a long history with the facilities at which they work. Fifty-nine percent of surveyed RSOs have worked at their facilities for eleven or more years, 19% for six to ten years, and 13% have two to five years of experiences at their facilities. Additionally, 78% of RSOs work at one facility, while 22% of RSOs reported operating additional systems at one to six other facilities.

2.4.3.2. Professional Training, Membership, and Certification

Surveyed refrigeration operators demonstrated high levels of activity with regard to refrigeration training, certification, and membership in professional organizations. Additionally, most industrial companies (as indicated by 53% of RSOs) consider operator certification when hiring operators and encourage operators to pursue additional system training.

Table 11. describes surveyed operators' participation in various regional and national initiatives related to energy programs, membership in professional organizations, and system training or certification. Membership in RETA and International Institute of Ammonia Refrigeration (IIAR) are common among operators; 44% and 28% of surveyed RSOs are members of RETA or IIAR respectively. Participation in system training is more common than certification. Almost half (47%) of RSOs surveyed have attended a RETA Certified Industrial Refrigeration Operator (CIRO) class, and 28% have attended a NEEA Industrial Refrigeration Best Practices (IRBP) class. In certification programs, RETA shows the most prevalence, 38% of RSOs have had CIRO certification at one time and 13% have had Certified Assistant Refrigeration Operator (CARO) certification.

Table 11. RSO Participation in Regional and National Membership, Training, and Certification

Organization	Offering	Membership / Participant Count (%)	Training Count (%)	Certification Count (%)
RETA	CIRO		n=15 (47%)	n=12 (38%)
	CARO		n=6 (19%)	n=6 (13%)
	Membership	n=14 (44%)		
International Institute of Ammonia Refrigeration (IIAR)	Membership	n=9 (28%)		
International Association of Refrigeration Warehouses (IARW)	Membership	n=1 (3%)		
Global Cold Chain Alliance (GCCA)	Membership	n=1 (3%)		
Industrial Refrigeration Best Practices	Training		n=9 (28%)	
Energy Smart Industrial (BPA) Refrigeration Training	Participant	n=8 (25%)		
Energy Trust Refrigeration Operator Coaching	Participant	N=5 (16%)		
Other	Classes		n=6 (19%)	
	Certifications			n=3 (9%)

*Other classes and certifications include: city-sponsored ammonia safety training, continuing education classes including in-house trainings, university or community college courses, and classes by National Technology Transfer Organization, NW Food Processors, and Refrigeration Service Engineers Society (RSES).

2.5. Market Factors Affecting Energy Management

This section evaluates the factors that may impact the rate of market participation in the CRES certification. As with most initiatives, higher rates of adoption help to drive economies of scale. And in the case of the CRES certification, increased RSO participation will provide an economic base for more trainers to offer the certification, which increases the supply side ability to scale up to increased demand for CRES certification. Generally, factors can be viewed as either favorable – conducive to driving market participation – or restraining – slowing or preventing participation.

2.5.1. Favorable Factors

NEEA's region is characterized by many factors favorable to market adoption of the CRES certification. Several regional and national initiatives have fostered technical understanding among RSOs of industrial refrigeration systems, and a working understanding of refrigeration systems is required of those wanting to pursue CRES certification. Positive indications of RSOs' willingness and ability to pursue CRES certification include:

- The market has a sufficient base of technical knowledge to pursue CRES certification, suggested by the high proportion of RSOs achieving CARO or CIRO certification. RETA's estimates for the number of regional certification holders indicate that roughly one in four RSOs has at least one of these certifications, which requires a fundamental understanding of refrigeration systems. And roughly 200 certification holders would equate to one certified RSO per facility in the region.

- Nearly half of RSOs have taken an IRBP course; this demonstrates broad market knowledge of refrigeration system fundamentals and perceived value for refrigeration system training—market participation in IRBP was estimated by comparing the count of RSOs contained in a list of IRBP participants with the estimate of RSOs market wide.

- The market evidences an increasing willingness by market actors and regional stakeholders to invest in industrial refrigeration energy performance, as indicated by growth of refrigeration operator coaching programs implemented by the Energy Trust of Oregon, Bonneville Power Administration, Idaho Power, and other utilities. These programs provide up to nine months of on-site refrigeration training for RSOs and technical support.

- Professional ethic typifies the RSO market, evidence by high proportion of membership in professional organizations. During our survey, RSOs described their membership in professional organization: 44% are RETA members and 28% are International Institute of Ammonia Refrigeration members. In addition, one respondent each are members of the International Association of Refrigeration Warehouses members, and the Global Cold Chain Alliance.

- Fifty-three percent of surveyed RSOs stated their company considers professional certifications when hiring refrigeration operators.

2.5.2. Restraining Factors to Adoption of Energy Management

Various restraining factors influence the adoption of energy management in the absence of NEEA's CRES initiative. Most significantly, none of the existing market services, programs or initiatives integrate energy management with operators' activities toward professional credentials. Regional programs focus their activities on operator training tailored to specific facility systems and do not offer professional certification. A professional certification focused on energy management may better align with companies' emphasis in hiring RSOs with professional certification.

3. Baseline Determination

This chapter answers fundamental questions concerning market wide energy consumption from industrial refrigeration, and estimates energy savings in absence of NEEA's CRES initiative. This chapter presents findings in two distinct sections:

1) *Current Baseline Energy Consumption*: This section synthesizes survey data to estimate the current facility's average level of energy consumed from refrigeration sources.
2) *Forecast Baseline and Total Regional Savings:* This section synthesizes findings from the *Market Characterization* chapter and *Current Baseline Energy Consumption* section to produce 20 years of estimates for the amount of energy savings generated in absence and with NEEA's CRES intervention.

Additional deliverables from this chapter include spreadsheet files containing models used to produce this chapter. These models may be used by NEEA in the future to perform related surveys and estimate facility refrigeration energy usage, as well as adapt the forecast model for use in NEEA's RETA/CRES ACE model.

3.1. Current Baseline

To estimate the current market wide energy consumed by industrial refrigeration systems the research team conducted an investigation into the average refrigeration systems and the RSO behaviors affecting the energy consumption of those systems. Findings from this section provide the basis for projecting the current baseline into the future in the *Forecast Baseline and Total Regional Savings* section. This section presents the findings first, followed by the methodology.

3.1.1. Summary of Current Baseline Findings

The research team estimated that the average facility consumes 11,392,291 kWh, including rejected energy – energy lost to inefficiencies[26]. The model estimates that the average facility can save 10.5% of total energy usage, or over 1,200 MWh, by addressing the modeled O&M measures (

[26] Rejected energy is a common term used by the US Department of Energy to describe the effect that energy inefficiencies have at diverting energy from its intended end use.

Table 12).

Table 12. Estimated Refrigeration Savings Potential per Facility

System Component	Estimated Energy Consumption In Annual kWh	Estimated Savings Potential in Annual kWh	Savings Potential (% of system component kWh)
Compressor	6,773,000	404,000	6.0%
Evaporator	1,940,000	29,000	1.5%
Condenser	2,106,000	195,000	9.3%
Balance of System	573,000	573,000	--
Total	**11,392,000**	**1,201,000**	**10.5%**

One of the biggest sources of rejected energy in the system is the absence of direct expansion. Installing direct expansion can save around 10% of total facility energy use; about half of the sample did not have direct expansion. The next biggest source of rejected energy is overcooling, which results in an average 4.8% rejected energy from compression load.

Table 13. Estimated Refrigeration Savings Potential

System Component Associated O&M Activities (% of sample engaging in behavior)	Average savings potential by facility in annual kWh
Compressor • Not running lower suction when not in production (4%) • Overcooling (44%) • Over-pressurizing (20%) • Not lowering condensing pressure when not defrosting (8%)	404,000
Evaporator • Cycling evaporator fans off with temperature (8%)	29,000
Condenser • Use floating wet bulb strategy (56%) • Clean nozzles, trays, and strainers (24%) • Absence of scale (8%) • Pumps cycle off with temperature (8%)	194,000
Capital Investments* • Install direct expansion (52%) • Install condenser VFDs (8%)	553,000
Balance of System • Calibrate sensors and valves (20%)	22,000
Total	**1,202,000**

* There is potential for capital investment savings through installing evaporator VFDs but the research design was not able to control for interactions.

3.1.2. Methodology

The baseline study examined the basic components of a refrigeration system and identified energy saving O&M measures. The research team worked with an experienced engineer to make estimates of the energy impacts of those O&M measures and conducted a survey of refrigeration system operators to see how prevalent these O&M practices were. The team input the frequencies of these practices into the model to estimate the technical potential for energy savings.

3.1.2.1. Data Sources

The research team consulted with two engineers from Cascade Energy to develop this approach, identifying the O&M activities that have the largest impact on energy usage in a refrigeration system, as well as features of systems that can significantly impact the energy use in that system. To collect information for this model, the research team developed a survey instrument that asks about these features and activities.

The research team collected data through phone surveys from 32 refrigeration service operators between August and September of 2013. From these surveys, 25 RSOs provided information in enough detail to be used to inform the model.

3.1.2.2. Engineering Model

The baseline model provides a preliminary look at the potential impacts of key O&M activities that have significant consequences in terms of energy used in a refrigeration system. There are three main components to all refrigeration systems: compressors, evaporators, and condensers. These are the three components that use the vast majority of energy in a refrigeration system. The compressors take up a larger share of the energy usage. It is fairly easy to determine the size of the compressor component and to estimate the energy use. The evaporators and condensers use less than two thirds of the energy used by the compressors.

The research team associated O&M measures with one of these three components, or with the balance of system load. For each facility, the research team assigned a percentage of rejected energy for each applicable O&M measure determined to be performing at less than optimally performed at that facility. The research team then aggregated these results to find the average rejected energy in kWh and percentage load per facility, and per RSO.

3.1.2.3. Limitations

The baseline model represents a preliminary look at the energy used by refrigeration systems and relevant O&M activities. The research team spoke with two engineers from the same organization to identify O&M opportunities and estimate the potential savings from those opportunities. While the research team spoke with experts, it would be ideal to have a wider range of estimates to rely upon.

This report does not provide statistical estimations for confidence and precision due to difficulties in contacting RSOs. The research team used a list of IRBP participants to develop the sample frame; a sample frame representative of the entire industrial refrigeration market was not available.[27] While the research team had enough information to make estimates, the sample may contain bias, as the surveyed RSOs are more likely to have been contacted for O&M training than the population at large. The research team inferred that the sample may contain bias by findings from an inspection of sample characteristics. One of the engineers consulting to the research team held the opinion that market wide there are far fewer facilities lacking direct expansion evaporators than suggested by the sample of RSO survey respondents. To pursue this claim further, NEEA would need to conduct a more thorough survey of facilities or a Delphi panel of experts.

The model does not account for more complicated interactions between measures and for other interactions outside of the measures. Certain interactions, such as the impact of VFDs on the ability to cycle off with temperature, may have significant impacts on energy saving estimates.

The research team did not conduct any measurement and verification to assess the initial energy usage or the potential impacts of the surveyed O&M activities. To get a better estimate of baseline usage, it would be ideal to meter or to use facility energy bills. To get a better estimate of energy savings for activities would require pre and post metering or billing analysis.

3.2. Baseline and Total Regional Savings Forecast

The research team developed a model to provide 20 years of estimates for a baseline of market wide energy consumption from industrial refrigeration sources, and estimated savings in absence of NEEA’s RETA CRES initiative. These estimates support NEEA’s market transformation approach to estimating savings. For NEEA to claim savings for its initiatives, it must estimate the natural baseline – both an estimation of current and future energy use factoring in savings from in absence of NEEA’s initiative. The savings forecast with NEEA’s RETA CRES initiative (Total Regional Savings) includes baseline savings, and both sources will likely influence RSOs. Therefore, the research team modeled baseline energy savings and savings with CRE initiative.

This section presents the findings first, followed by the methodology. As explained in more detail in the methodology, the savings analysis differentiates between a NEEA-led CRES initiative and a hypothetical CRES certification led at some future date by RETA without NEEA’s involvement, termed CRES $_{NEEA}$ and CRES $_{RETA}$, respectively.

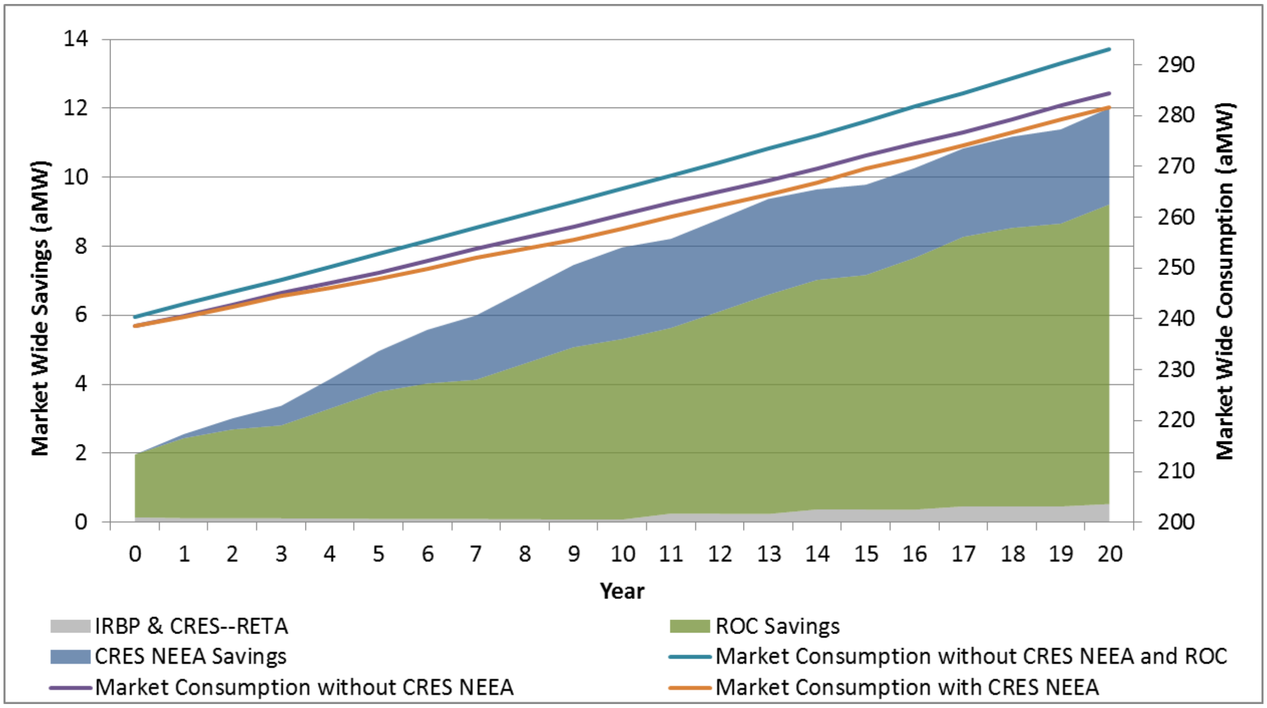
3.2.1. Baseline and Total Regional Savings Estimations

The research team forecasted market wide energy consumption from refrigeration sources and savings estimates in absence and with NEEA’s intervention via RETA CRES initiative (Figure

27 A market wide list of RSOs was not available for this research. NEEA provided the research team with a contact list of participants from the Industrial Refrigeration Best Practices trainings.

2). In the absence of the CRES $_{NEEA}$ intervention, modeled projections for market wide refrigeration system energy consumption are 240.5 aMW in year 1 and 284.3 aMW in the 20th year of the intervention. The same projections for the market including the CRES $_{NEEA}$ intervention are 240.4 and 281.5 aMW for years 1 and 20 respectively. These estimates for market wide refrigeration energy consumption are slightly conservative with respect to regional load planning estimates, as suggested by the following. NEEA's upper estimates for refrigeration as a percent of industrial sector energy consumption is 9%,[28] and this study's estimate of 240.5 aMW (absence of CRES $_{NEEA}$) represents 6.5% of the Northwest Power and Conservation Council's estimates for regional industrial energy consumption, suggesting a somewhat conservative estimate.[29]

Figure 2. Projected Savings from Regional Programs, Interventions and RETA $_{NEEA}$ Intervention



Annualized modeled savings estimates for the CRES NEEA intervention are approximately 2 aMW per year or 40.2 aMW over 20 years. Modeled estimates of the number of RSOs in the market range from 747 in the first year of the CRES initiative to 903 RSOs in the 20th year[30], and in the first and 20th years, 13 and 327 RSOs respectively will hold CRES $_{NEEA}$ certificates (

[28] http://neea.org/neea-newsroom/press-releases/2013/07/16/neea-and-reta-develop-new-efficiency-certification-for-industrial-refrigeration-operators

[29] Estimates for regional industrial sector energy demand was 3,724 aMW in 2010, published in The Northwest Power and Conservation Council *Sixth Northwest Conservation and Electric Power* (February 2010), 3-6. http://www.nwcouncil.org/media/6284/SixthPowerPlan.pdf

[30] The market's growth rate was estimated from NEEA initiative supplied estimates of one percent per year.

Table 14).

To estimate the number of RSOs with a CRES $_{NEEA}$ certificate for each of the first twenty years of the initiative, the forecast model produced estimates for the total number of RSOs across the market. The model factored the count of CRES $_{NEEA}$ certificates as a proportion of the size of the RSO market and maturity of the initiative[31]. Additionally, the model's assumptions account for the number of RSOs who would renew their CRES $_{NEEA}$ certificates or allow them to lapse. Lastly, the research team subtracted from the count of CRES $_{NEEA}$ certificate holders the penetration of the hypothesized naturally occurring CRES $_{RETA}$ certificates. (Note that the model assumes CRES $_{RETA}$ enters the market in the 10th year[32].) Model estimates savings for CRES $_{NEEA}$ based upon the likelihood that a CRES $_{NEEA}$ certificate holder also participated in regional programs.

[31] Model assumptions for the penetration of CRES $_{NEEA}$ were supplied by the initiative's management.

[32] RETA estimates for entering the market with an energy certificate are 6-8 years; conservative estimates are 10 years and accounts for other certificates RETA would have developed before an energy certificate.

Table 14. Estimates for Number of RSOs in the Market and with $CRES_{NEEA}$ Certification; and Total Savings Estimates for Regional Programs and $CRES_{NEEA}$ Initiative

Year	Count of Total Market RSOs	Count of RSOs with $CRES_{NEEA}$	Regional Programs (aMW)	$CRES_{NEEA}$ Savings (aMW)
0	740	-	1.97	-
1	747	13	2.44	0.12
2	755	34	2.69	0.32
3	762	61	2.81	0.57
4	770	93	3.29	0.85
5	778	129	3.78	1.18
6	786	171	4.02	1.55
7	793	205	4.13	1.86
8	801	236	4.60	2.12
9	809	267	5.07	2.38
10	817	298	5.31	2.66
11	826	290	5.63	2.58
12	834	303	6.11	2.68
13	842	316	6.60	2.78
14	851	300	7.02	2.62
15	859	299	7.17	2.62
16	868	300	7.66	2.60
17	876	297	8.27	2.56
18	885	307	8.53	2.64
19	894	318	8.66	2.73
20	903	327	9.21	2.79

3.2.2. Methodology

The research team developed an assumption-based model for forecasting savings from regional programs and NEEA's CRES initiative. A summary figure for the average energy controlled per RSO – produced by the baseline model – and estimates for the number of facilities and RSOs operating in the region – described in the Mar*ket Characterization* – informed the model. The research team developed additional assumptions to help approximate intervention savings and persistence parameters, intervention market penetration, and broader market effects from NEEA's CRES initiative. This report specifies the mathematical calculations for intervention savings assumptions and persistence; the spreadsheet tool delivered to NEEA embeds additional market penetration assumptions.

3.2.2.1. Intervention Savings Allocations and Persistence

In order to allocate savings to both regional programs and NEEA's initiative, the research team developed a savings and persistence matrix (Table 15.). The model assumes savings from each intervention result from the increase in energy performance of systems operated by RSOs receiving one or more of the interventions (Industrial Refrigeration Best Practices (IRBP), Refrigerator Operator Coaching (ROC), and CRES certification). The model estimates intervention savings as a percent of energy controlled by RSOs; persistence assumptions provide the number of years the intervention will produce savings. The research team held discussions with ROC and CRES program/initiative managers to verify average savings and persistence estimates used by these programs/initiatives. The model provides savings and persistence estimates for IRBP as a portion of CRES figures due to a lack of alternative estimates for IRBP savings.

Interactions between interventions potentially occur when the combined effect of interventions produce RSOs whose systems' perform at a higher energy performance than if the same RSOs had only received one intervention. Initiative interaction effects are reasonable to expect for the following reasons. CRES certificate exam preparation causes RSOs to review their systems' energy performance. CRES also requires documentation of savings activities, which help to motivate RSOs to take action. As facility management comes to value CRES certification they will be more likely to support RSOs' recommendations concerning improved system energy performance.

Table 17 identifies these interactive effects in the far right columns under the *Enhanced Interventions* title. In both enhanced scenarios, CRES involvement prolongs savings – CRES certification extends savings by requiring three years of savings activities. The model also credits CRES with extending the persistence of ROC savings because ROC activities are also likely continued; the model allocates the savings from the extended persistence evenly to CRES and ROC. Conversely, no savings are assigned to IRBP in the additional years produced by CRES because CRES savings sources completely overlap with and supersede IRBP savings sources. In both enhanced scenarios, the model assumes enhanced savings to be greater than savings from IRBP-only or ROC-only. CRES savings in the overlap years are the difference between the enhanced savings and IRBP and ROC savings in isolation – CRES savings are 1.5% of refrigeration consumption for IRBP+ CRES, and 1% for ROC+ CRES. CRES savings increase in the additional years due to CRES persistence; savings rise to 3% for IRBP+ CRES, and 4% for ROC+ CRES.

Table 15. Intervention Savings and Persistence Assumptions

	Basic Interventions			Enhanced Interventions	
Intervention	**IRBP**	**ROC**	**CRES**	**IRBP+ CRES**	**ROC+ CRES**
Savings as Percent of Refrigeration Consumption*	1%	7%	3%	3%	8%
Persistence (Years)**	1.5	3	5	5	5
Additional Persistence from Enhancement (Years)	--	--	--	3.5	2
Baseline Intervention Savings from Additional Enhanced Years	--	--	--	0%	4%
CRES Savings in Overlap Years				1.5%	1%
CRES Savings from Additional Enhanced Years	--	--	--	3%	4%

* Energy Trust estimates 5-10% system energy savings from its ROC; and NEEA's assumptions for CRES certification savings are 3%; IRBP savings are not known – the model calculates IRBP savings as a fraction of the estimated CRES savings.

**Energy Trust claims savings for 3 years of its ROC; CRES requires certified RSOs to report activities for 3 years; IRBP persistence is not known – the model calculates IRBP savings as a fraction of the estimated CRES savings.

3.2.2.2. RETA Led CRES Initiative

From interviews with RETA staff the research team learned that RETA would likely at some future date establish an energy management certificate on its own. The model accounts for such a certificate and precludes $\text{CRES}_{\text{NEEA}}$ from claiming savings from RSOs that would have taken the RETA lead CRES ($\text{CRES}_{\text{RETA}}$) certification. The research team began allocating savings to $\text{CRES}_{\text{RETA}}$ 10 years into the forecast period, and assumed a moderate NW region penetration for the $\text{CRES}_{\text{RETA}}$ certificate. Reasons for these assumptions include:

- RETA is currently developing a different certificate, which would have delayed its development of $\text{CRES}_{\text{RETA}}$ certificate without support from NEEA
- RETA would focus their efforts on a national level beyond the NW region focus of $\text{CRES}_{\text{NEEA}}$
- $\text{CRES}_{\text{RETA}}$ marketing channels are less effective in NW region compared to additional NEEA-supported promotion. RETA has approximately 153 CARO and CIRO certificate holders in the NW region generated over 11 years of offering these certificates.[33]

[33] Figures shared by NEEA with the research team for the number of CARO and CIRO certificates held in the NW region estimate approximately 230 for both certificates combined. However, some certificate holders hold both a CIRO and a CARO certificate, there are approximately 153 certificate holders assuming one-third of certificate holder have both a CIRO and CARO certificate.

3.2.2.3. Spillover

The CRES initiative will likely lead to increased activity in other energy performance market offerings – an outcome generally referred to as *spillover*. However, the forecast model does not assign spillover savings to NEEA because it is just as likely that other market offerings, such as regional efficiency program, are themselves generating spillover that increases the uptake of $CRES_{NEEA}$; that is, it may be generally assumed that the spillover effects from the different interventions will cancel each other out.

3.2.2.4. Government Involvement in CRES Market Transformation

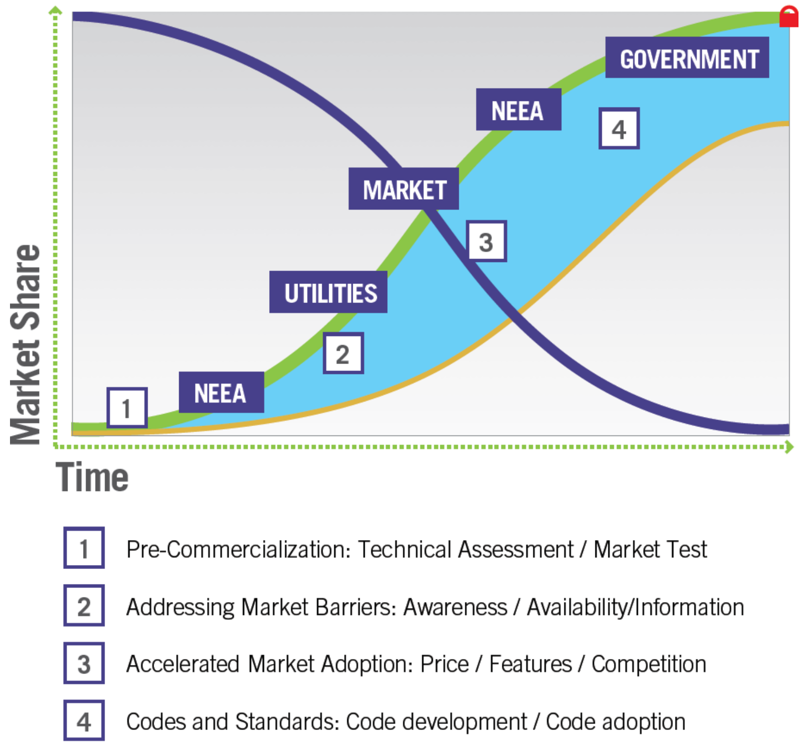
The research team did not model government involvement in market transformation outcomes for the CRES initiative; NEEA's general model for market transformation assumes government involvement in long-term outcomes. NEEA's model is based on technology diffusion theories and assumes that government agencies participate at the end of market transformation efforts by enacting codes/standards to establish a minimum level of product performance. Figure 3 demonstrates this model.

The research team did not include government intervention in codes/standards during the forecast period because:

- Historic government actions indicate little focus on requiring operator certification for this market. The federal government instituted standards for the safe operation of industrial refrigeration systems, but has not required operator safety certification. Government involvement in safety is more likely than in energy performance. For over 25 years RETA has offered voluntary operator certification in the safe operation of systems.

- The CRES initiative is a standard of practice rather than a performance standard associated with a product. Government requirement for operator certification would likely involve an ANSI standard, which would in effect, result in the government requiring operators to achieve CRES certification. The model estimates remain unchanged were the government to require a standard.

Figure 3. NEEA's Market Diffusion Model for Market Transformation*



* Adapted from an undated document NEEA provided entitled *NEEA's Definition of Market Transformation*.

3.2.2.5. Market Growth

The research team adopted a market growth factor of 1% annually from NEEA's suggested estimates and applied it to the forecast model. This factor applies to the estimates of both number of facilities and RSOs in the market annually. This factor compounds and drives the overall change in projected market wide energy consumption and number of RSOs estimated by the model.

4. Conclusions

This research delivered the following key findings and deliverables:

- Estimated current number and forecast of industrial refrigeration *facilities*, *systems*, and *operators* in the market
- Estimated baseline energy efficiency O&M *practices*
- Estimated current and forecast *baseline energy consumption* from industrial refrigeration
- Estimated current and forecasted O&M *efficiency savings for RETA CRES*, as it interacts with regional programs (including those resulting from other regional initiatives)
- Estimated current and forecasted O&M *efficiency savings from regional programs*
- Developed forecasts of industrial refrigeration *energy use with and without NEEA's* RETA CRES initiative
- Developed and documented a *model for NEEA's ongoing use* for estimating industrial energy efficiency O&M savings

Appendices

A. Appendix A: Baseline Model

A.1. O&M Activities by Refrigeration System Component

Our baseline model assesses the energy savings potential of O&M activities associated with the three main components of the refrigeration system: the compressor, the evaporator, and the condenser. These three components use the vast majority of all energy consumed by refrigeration systems. These components are the same regardless of the controls or cooling agents used in the system. Each O&M activity impacts one of these three components, or the efficiency of the balance of system load. Maintaining equipment and adopting certain practices will lead to a reduction in energy for that component, or for the system as a whole.

A.2. Model Parameters

The model's outcome produces whole refrigeration system estimates for rejected energy[34], and includes estimates for O&M savings opportunities. Capital measures are included in this section because the presence or absence of these measures influences the baseline estimate for average energy consumed by industrial refrigeration sources. The model produced estimates by:

- Calculating refrigeration system energy use by counting compressor units and compressor horsepower. The number of compressors and the compressor horsepower is used to estimate the energy used by the compressor. The compressor size is also used to estimate the condenser and evaporator energy usage.
- Estimating O&M savings as a proportion of total system and system component energy use. O&M activities can reduce either the energy usage of the compressor, condenser, evaporator, or in some cases the entire system. The table below lists the O&M activities by the impacted component. It also lists some of the capital equipment that has a significant impact on energy use.

The research team combine this information with the number of RSOs and the size and number of systems they are responsible to estimate what savings potential exists by training an RSO in these O&M activities. Information collected through the survey to inform the baseline model can also be used to better understand the overall market.

[34] In the case of refrigeration, rejected energy is energy consumed in excess of the most efficient equipment, configuration, and operation and maintenance.

Table 16. Data Collection Items

Component	Type	Measure	Estimated Savings Impact, (*Rejected Energy* in Italics)	Average Annual kWh Savings by Facility
Entire System	O&M	Calibrate sensors and valves annually	1% of total load	20,000
Compressor	O&M	Not overcooling	2% of compressor load per degree	303,000
	O&M	Not over-pressurizing	1.5% of compressor load per degree	87,000
	O&M	Lowering suction pressure when not in production	20% of compressor load	13,000
	O&M	Lowering condensing pressure when not defrosting	1.5% of compressor load per degree	3,000
Evaporator	Capital	Direct expansion evaporators installed	*(10% of total load)*	*(530,000)*
	O&M	Cycle evaporator fans off with temperature	25% evaporator load	38,000
Condenser	O&M	Use floating wet bulb control strategy	10% condenser load	107,000
	O&M	Clean nozzles, trays, strainers annually	10% of condenser load	46,000
	O&M	Absence of scale	25% condenser power	38,000
	Capital	Condenser VFDs installed	*(20% of condenser load)*	*(16,000)*
	O&M	Pumps cycle off with temperature	5% of condenser load	1,000

A.2.1. Entire System

- Calibrate sensors and valves annually: This has an impact on the balance of system load. Our estimate of 1% is very rough; the amount of savings could easily be up to 3%. Given the reach of this O&M activity, it will be hard to predict the exact impact across a system.

A.2.2. Compressor

- Not overcooling: there are interactions with other compressor based activities that would modify this number which the research team have not accounted for, so while the savings seem to be large for this measure, caution should be used.
- Not over-pressurizing: opportunity and savings depend on what temperature a system can attain.
- Lowering suction pressure when not in production: opportunity and savings depend on what temperature a system can attain.
- Lowering condensing pressure when not defrosting: opportunity and savings depend on what temperature a system can attain, pertains more to systems that are not operating 24/7.

A.2.3. Evaporator

- Direct expansion evaporators installed; this capital measure has a large impact on the balance of system load.
- Cycle evaporator fans off with temperature: this is much easier O&M activity to maintain with the presence of VFDs. This measure would interact with savings from the presence or absence of VFDs and their use.

A.2.4. Condenser

- Use floating wet bulb control strategy
- Clean nozzles, trays, strainers annually
- Absence of scale: this only applies to systems that have a water program. There is probably some variation based on the amount of scale in the system as well.
- Condenser VFDs installed: pertains more to systems that are not operating 24/7.
- Pumps cycle off with temperature: pertains more to systems that are not operating 24/7.

B. Appendix B: Contracted Service Providers

All surveyed RSOs reported that their facility has a contract with a specialized firm for system repairs, installation of equipment, and emergency maintenance. The research team interviewed five CSP firms regarding the work they provide to industrial refrigeration facilities in the northwest. Interview questions concern the staffing characteristics of CSP firms, and the types of services they provide to refrigeration facilities.

B.1. CSP Firm Characteristics

A typical CSP firm employs technicians to provide repairs, conduct scheduled maintenance beyond the everyday, and design and install refrigeration systems in the Industrial Refrigeration Industry . These firms vary in terms of employee count and employee training levels. Two firms have 25 employees, one has seven, and one 60 to 80 employees who directly provide refrigeration services. The typical CSP technician has 10 to 15 years of refrigeration experience. CSP firms generally do not require certification by RETA or other institutions; one CSP firm in our sample required professional certifications.

B.2. Services Provided

CSP firms provide a range of services to northwest facilities (described in detail in Table 17., below). A majority of these services relate to system installation, equipment replacement and dealing with emergency situations. Additionally, four of five firms the research team interviewed reported helping their customers' to reduce energy costs; three of these four firms perform energy audits, or work with a partnering firm to perform audits, and implement audit recommendations.

Table 17. Services Provided by CSPs

	Number (of 5)
System Design	4
Installation	5
Retrofits & Upgrades	5
Equipment Replacement	5
Managing System Controls	3
Regular Maintenance	4
Reducing Energy Costs	4
Emergency Situations	5

C. Appendix C: Survey Instruments

C.1. Contracted Service Providers (CSP) Survey Instrument

Introduction: Thank you for agreeing…

Code:

Market Characterization

Baseline

Both

C.1.1. Introduction

Hello. My name is [name] with Research Into Action and the research team are conducting research for the Northwest Energy Efficiency. Our research concerns the operations and maintenance activities of the Northwest's industrial refrigeration market; and the research team are surveying firms who provided contracted refrigeration services to this market. I would like to talk to someone at your company who can discuss the types of firms your company works with, and the types of services your company generally provides.

Who would be the best person for me to talk with at your company?

[**If someone else**]: Can you give me his/her contact information?

[**If person on phone is best contact**]: Great. Is now a good time for this survey?

[**If yes**]: Do you have 20 minutes to take a survey?

[**If no**]: When should I schedule a time to call back?

C.1.2. General Information

C.1.2.1. Refrigeration System

1. What industries does your company primarily support?

    a. Do you target specific industries?

2. What are the main uses for the refrigeration systems your company primarily services? PROBE: Do you specialize in any of these systems?

   a. food processing

   b. food storage / distribution

   c. controlled atmosphere storage

   d. beverage

   e. other ________

3. What states do you serve?

4. Why do your customers come to your company for refrigeration services? PROBE: Are there skills they lack? Are they specialized systems? Specific refrigerant types?

5. What refrigerant types is your company often asked to support?

   a. Ammonia

   b. CO_2

   c. Hybrid

   d. R-22

   e. Other

6. On average, how many refrigeration systems does your company service in a typical month?

7. The research team would like to understand what size of refrigeration systems your company supports. What is the range of system sizes you support in terms of compressor horsepower? What is the typical system size?

   a. Could you give me a guess at the total horsepower of all the systems your company provides services for? [**use answers to 5 and 6 to give estimate to compare and adjust estimates if needed**]

8. Considering the types of controls on the systems your company typically supports, what percent have…

   a. set point

   b. PLC or computer controls

c. manual

d. Other

9. Which of these services do you support?

 a. System design?

 b. Installation?

 c. Retrofits and upgrades?

 d. Equipment replacements?

 e. Managing refrigeration system controls?

 f. Regular maintenance?

 g. Reducing energy costs? What does that entail?

 h. Emergency situations? What does that entail?

10. Other than the services I just mentioned, what other refrigeration services does you company provide?

11. Typically, how frequently do you visit each customer to perform maintenance on their refrigeration systems?

12. If your customer does not produce year-round or all day long, do you play a role in preparing for going into production or out of production?

13. Typically, what refrigeration related work do your customers do on their own without your help?

Now I have some questions about your employees.

14. How many employees at your company directly provide refrigeration services?

15. Are the specialized or do they all provide the same services? If specialized, how?

NOTE: Ask how many employees have the following memberships, classes, and certifications they attained, and which ones are required by the company:

Certification	Required? (y/n)	# that are Certified
RETA (Refrigeration Engineers and Technicians Association)		
IIAR (International Institute of Ammonia Refrigeration)		
GCCA (Global Cold Chain Alliance)		
IARW (International Association Refrigeration Warehouse)		
Other ___________		

Organization	Required?	# that took Class	# Certified	Notes
RETA (Refrigeration Engineers and Technicians Association) CIRO				
RETA (Refrigeration Engineers and Technicians Association) CARO				
NEEA Industrial Refrigeration Best Practices				
ROC (Refrigerator Operator Coaching)				
Refrigeration Training offered by BPA				
Other ___________				

16. How many years of experience does your typical employee have with industrial refrigeration?

17. How does your company's workload change throughout the year?

C.1.3. Refrigeration System

C.1.3.1. Reducing Lift: Suction Pressure

18. In general, what recommendations do you give your customers on setting their suction pressure?

    a. How often do they take your advice?

    b. How often do you set the suction pressure for them?

19. What factors do you consider when you are setting the system's suction pressure?

    a. In general, what recommendations do you give to your clients on setting their suction level when they are not in production?

    b. How often do they take your advice?

    c. How often do you set the suction pressure for them?

C.1.4. Reducing Lift: Discharge Pressure

20. What is your strategy for setting the pressure for defrosting?

21. Do you lower the condensing pressure when not defrosting?

22. What percent of your customers have direct expansion (DX) evaporators or other DX loads in their system?

23. What percent use liquid injection oil cooling?

24. What percent use glycol heating?

25. Do you use a floating wet bulb approach control strategy for the condensing set point?

C.1.4.1. Improving Part Load Performance

26. Concerning your customers' facilities, what percent of compressor motors are of the following types?

    a. Constant

    b. VFD

c. 2 speed

27. For those customers without constant speed motors, what percent of customers' evaporator fans cycle off with temperature?

C.1.4.2. O&M

28. What percent of your customers have a condenser water treatment program?

    a. Of those, what percent of condensers does your company service?

        i. How often are these systems completely free of scale?

29. How often do you recommend that your customers clean condenser nozzles, water distribution trays and strainers for ammonia, or hybrid systems?

    a. Less than once a year

    b. Once a year

    c. More than once a year

    d. Don't know

    e. Refused

30. How often do they take your advice?

31. Do you conduct this maintenance for them or is that something they do on their own?

32. How often do you recommend that your customers calibrate temperature sensors, pressure sensors, and slide valves?

    a. Less than once a year

    b. Once a year

    c. More than once a year

    d. Don't know

    e. Refused

33. How often do they take your advice?

34. Do you conduct this maintenance for them or is that something they do on their own?

35. What percentage of your customers have automatic purgers?

36. Of those customers that do not have automatic purgers, how often do you recommend that your customers monitor and remove non-condensables?

    a. Less than once a year

    b. Once a year

    c. More than once a year

    d. Don’t know

    e. Refused

37. How often do they take your advice?

38. Do you conduct this maintenance for them or is that something they do on their own?

Thank you for your time. Those are all the questions I have.

C.2. Refrigeration Service Operators (RSOs) Survey Instrument

Code:

Market Characterization

Baseline

Both

C.2.1. General Information

Hello. My name is [name] with Research Into Action. The research team are performing a survey of industrial refrigeration service operators for the Northwest Energy Efficiency Alliance. NEEA wants to learn about current industry practices so that they can better provide energy efficiency services. This is not a sales call - I have a few questions for someone directly responsible for the maintenance and operation of your company's primary refrigeration system.

Do you perform this role?

[**If yes**]: Great. Is now a good time for you – this should take about 20 minutes?

[**If yes**]: Let's begin.

[**If no**]: When should I schedule a time to call back?

[**If no**]: Can you give me the name and number of the best person to answer my survey questions?

We'd like to start with some questions about the facility and the type of operation you run there.

[**NOTE TO INTERVIEWER:** At a minimum, the research team need enough information to get an estimate of the system size of the largest system. That is mainly through compressor horsepower. The research team also need an idea of how many refrigeration operators are at the facility. The research team need someone who can, and will, answer give us at least an idea.]

[Probe as required to get estimates if they are unwilling or unable to provide a number. The research team want numbers when possible, estimates if necessary.]

[Code for DON'T KNOW and REFUSED separately throughout survey.]

C.2.1.1. Refrigeration System

1. Does this facility have an industrial refrigeration system? [SCREENING]
    a. Yes

b. No → [Terminate survey]

c. Don't know → [Terminate survey]

d. Refused → [Terminate survey]

2. How long have you been working at this facility? [MARKET CHARACTERIZATION]

3. Do you run or maintain systems at other facilities? (in a given month) (Yes/no) (I**f no, skip to 5**) [TO GAUGE REACH OF EACH INDIVIDUAL RSO]

4. How many facilities? [TO GAUGE REACH OF EACH INDIVIDUAL RSO]

5. How many systems does this facility have? [TO IDENTIFY LARGEST SYSTEM]

   a. # systems

   b. Don't know

   c. Refused

6. For each system, ask: refrigerant type, number of compressors, compressor horsepower, and system control type. [TOTAL SYSTEM SIZE AND IDENTIFY LARGEST SYSTEM]

System	Refrigerant Type	# of Compressors	HP of Compressors	System Control Type	Notes
	[see Refrigerant types] Column 1	Column 3	Column 4	Column 6	Column 7

***Column 2 = other response, described. Column 5 = Estimate Y/N for the HP?

   a. Refrigerant types: [OPTIONS FOR ABOVE]

      i. Ammonia

      ii. R-22

      iii. CO_2

      iv. hybrid (incl. ammonia)

      v. Other ____

      vi. Don't know

      vii. Refused

b. If horsepower not known, probe to code a category: [IF EXACT NUMBER NOT KNOWN]

i. OR AT LEAST total HP (probe for <200, 200-500, 500-1000, >1000)

7. Do you work with the refrigeration system? [SCREENING]

8. How many operators run and maintain the refrigeration system at this facility in total? [Probe for: 1? 2? 5? 10?] [NUMBER OF RSOS PER FACILITY]

a. Exact number of PEOPLE

b. or 1, 2, 3-5, 6-10, >10 if they aren't sure

9. Does your company contract out any work on the refrigeration systems? [MARKET CHARACTERIZATION OF CONTRACT WORK AND TO KNOW WHAT RSOS ARE RESPONSIBLE FOR]

a. Yes

b. No

c. Don't know

d. Refused

i. [**If Q9=yes**] Do they operate the controls?

1. Yes

2. No

3. Don't know

4. Refused

ii. [**If Q9=yes**] Do they maintain the equipment? [RSO RESPONSIBILITY]

1. Yes

2. No

3. Don't know

4. Refused

iii. [**If Q9=yes**] How often do they visit the facility?

10. What is the main purpose for this facility? (probe for an industry or activity) [MARKET CHARACTERIZATION]

[DO NOT READ LIST. RECORD ONE RESPONSE. PROBE TO CODE.]

School (K-12)

College/University

Retail – Big Box only

Retail – all other

Office – large [over 10,000 square feet of office space]

Office – small [10,000 square feet or less]

Restaurant – full service

Restaurant – fast food

Hotel or Motel

Medical

Grocery or Convenience Store

Warehouse

Industry - Light

Industry - Heavy

Public Assembly, Churches

Apartments, Condominiums, Coops

Municipal

Agriculture

Miscellaneous, please describe _________

88. DON'T KNOW

99. REFUSED

11. Which of these refrigeration activities do you perform there: [MULTIPLE RESPONSE ALLOWED] [MARKET CHARACTERIZATION]

    a. food processing

    b. food storage / distribution

    c. controlled atmosphere storage

    d. beverage

    e. other ________

C.2.1.2. Individual Questions RSO

12. Ask what memberships, classes, and certifications the respondent attained: [MARKET CHARACTERIZATION]

Organization		**Membership (y/n)**
RETA (Refrigeration Engineers and Technicians Association)		
IIAR (International Institute of Ammonia Refrigeration)		
GCCA (Global Cold Chain Alliance)		
IARW (International Association Refrigeration Warehouse)		
Other ___________		

13. Ask what memberships, classes, and certifications the respondent attained: [MARKET CHARACTERIZATION]

Organization	Class (Y/N/DK)	Certification [MULTIPLE RESPONSE ALLOWED] (currently certified, planning to remain certified, previously certified (but not currently), planning to recertify, N/A)	Certification Date	Notes
RETA (Refrigeration Engineers and Technicians Association) CIRO				
RETA (Refrigeration Engineers and Technicians Association) CARO				
NEEA Industrial Refrigeration Best Practices				**IF YES, TERMINATE**
ROC (Refrigerator Operator Coaching)				**IF YES, TERMINATE**
Refrigeration Training offered by BPA				**IF YES, TERMINATE**
Other ___________				

Terminate if any if NEEA, ROC, or BPA conditions are met

14. Does your company consider any kinds of certification when hiring refrigeration service operators? [MARKET CHARACTERIZATION]

    a. No

    b. Yes: Which certificates?

15. Does your organization encourage its refrigeration service operators to pursue a refrigeration training or certification? [MARKET CHARACTERIZATION]

    a. No

    b. Yes: Which certificates?

C.2.2. Refrigeration System

I want to focus the rest of this survey on your largest refrigeration system at this location:

16. Does this facility operate year round? [ESTIMATE HOURS THE SYSTEM OPERATES]

17. [If not year round] During which months is your facility not operating? [List months] [ESTIMATE HOURS THE SYSTEM OPERATES]

18. Do you run production during weekends? [ESTIMATE HOURS THE SYSTEM OPERATES]

19. How many production shifts do you operate during a week? [ASK FOR HOURS A WEEK IF UNCLEAR] [ESTIMATE HOURS THE SYSTEM OPERATES]

20. Do you see your energy bill? [GAUGE AWARENESS OF ENERGY USE]

    a. Yes, I see the bill

    b. No, I rarely or never see the bill

    c. Don’t know

    d. Refused

21. Do you have anyone responsible for managing energy costs at your facility? [Probe for Energy Manager, Sustainability Manager, etc.] [DETERMINE IF THERE IS RESPONSIBILITY FOR SAVING ENERGY]

    a. Yes

    b. No

c. Don’t know

d. Refused

C.2.2.1. Reducing Lift: Suction Pressure

22. Do you know the suction pressure of your largest system? [**If yes**, what is the system's suction pressure?]] [TO FIND OUT IF SUCTION PRESSURE CAN BE IMPROVED]

23. What is the average space temperature of the refrigerated air? [TO FIND OUT IF SUCTION PRESSURE CAN BE IMPROVED]

24. When you are not running production, can you run at a higher suction level? [TO FIND OUT IF AND HOW MANY HOURS SUCTION CAN BE TURNED OFF/DOWN]

    a. [**If Q18= No**] Do you run at a higher suction level during weekends? [TO FIND OUT IF AND HOW MANY HOURS SUCTION CAN BE TURNED OFF/DOWN]

C.2.2.2. Reducing Lift: Discharge Pressure

25. Do you know the system’s discharge pressure? [**If no, skip to Q27**] [USED TO CALCULATE POTENTIAL SAVINGS FROM REDUCING LIFT IF POSSIBLE]

26. What is the lowest condensing pressure? [USED TO CALCULATE POTENTIAL SAVINGS FROM REDUCING LIFT IF POSSIBLE]

27. What is your peak condensing pressure? [USED TO CALCULATE POTENTIAL SAVINGS FROM REDUCING LIFT IF POSSIBLE]

28. What pressure do you need for defrosting? [USED TO CALCULATE POTENTIAL SAVINGS FROM REDUCING LIFT IF POSSIBLE]

29. Do you lower the condensing pressure when not defrosting? [WHETHER OR NOT THEY ARE SAVING ENERGY BY REDUCING LIFT WHEN NOT DEFROSTING]

    a. Yes

    b. No

    c. Contractors are responsible for this

    d. Don’t know

    e. Refused

30. Do you have direct expansion (DX) evaporators or other direct expansion loads in your system? [PRESENCE OR ABSENCE IMPACTS ENERGY USE]

a. Yes

b. No

c. Don’t know

d. Refused

31. Do you have liquid injection oil cooling? [NEEDED TO CALCULATE POTENTIAL SAVINGS FROM REDUCING LIFT]

a. Yes

b. No

c. Don’t know

d. Refused

32. Do you have glycol heating? [NEEDED TO CALCULATE POTENTIAL SAVINGS FROM REDUCING LIFT]

a. Yes

b. No

c. Don’t know

d. Refused

33. Do you use a floating wet bulb approach control strategy for the condensing set point? [WHETHER OR NOT THIS ENERGY SAVING APPROACH IS USED]

a. Yes

b. No

c. Contractors are responsible for this

d. Don’t know

e. Refused

C.2.2.3. Improving Part Load Performance

I only have a few more questions before the research team wrap this up…

34. Are your compressor motors primarily: [VFDS PERMIT CERTAIN ACTIVITIES]

a. Constant

b. VFD

c. 2 speed

d. Other: please describe

e. Don't know

f. Refused

35. [**If none=constant**] Do your evaporator fans cycle off with temperature? As in, do they cycle off when you don't need to run at full speed? [TO DETERMINE IF THEY ARE TAKING ADVANTAGE OF VFDS]

a. Yes

b. No

c. Don't know

d. Refused

C.2.2.4. O&M

36. Do you have a condenser water treatment process? [SCREENING FOR THE SCALE QUESTION]

a. Yes

b. No

c. Don't know

d. Refused

i. Are your condensers free of scale? [**If there is any scale, the answer is no**] [THE PRESENCE OF SCALE RESULTS IN SIGNIFICANT INEFFICIENCY]

a. Yes

b. No

c. Contractors are responsible for this

d. Don't know

e. Refused

37. How often do you clean condenser nozzles, water distribution trays and strainers?

    a. Less than once a year
    b. Once a year
    c. More than once a year
    d. Contractors are responsible for this
    e. Don’t know
    f. Refused

38. How often do you calibrate temperature sensors, pressure sensors, and slide valves?

    a. Less than once a year
    b. Once a year
    c. More than once a year
    d. Contractors are responsible for this
    e. Don’t know
    f. Refused

39. Do you have an automatic purger?

    a. Yes
    b. No
    c. Don’t know
    d. Refused

40. [**If No**] How often do you monitor and remove your non-condensables?

    a. Less than once a year
    b. Once a year
    c. More than once a year

d. Contractors are responsible for this

e. Don't know

f. Refused

41. Is there anything else you would like to add before I let you go?

Thank you for your time. Those are all the questions I have.

C.3. RETA Staff Interview Guide

C.3.1. Research Objective

NEEA's consultants have recognized expertise with energy efficiency in industrial refrigeration applications; and have a strong understanding of NEEA's RETA-CRES initiative. Through our interviews with these contacts, the research team will achieve the following research objectives:

- Identify key factors affecting the market, market segments and participation in the initiative
- Describe the initiative's major assumptions
- Identify key secondary research sources to help characterize the current market conditions and forecast future conditions
- Evaluate approaches for conducting RSO surveys

C.3.2. Interview Steps

The interview will be held on-site or completed by telephone. The interviewer(s) will have prepped by reviewing initiative documents and kick-off meeting notes.

C.3.3. Consultants Role

The research team would like to get a better sense of your experience with industrial refrigeration, and understand more about your role with the RETA-CRES initiative.

1. First, please describe your experiences and responsibilities as a consultant to NEEA; please comment on your involvement with other NEEA initiatives as well.
2. Please summarize your experiences and background with industrial refrigeration as it relates to the CRES initiative.
3. When did you first become aware of, or involved with the RETA-CRES initiative?
4. As NEEA's consultant, how will you be involved with, or interact with this initiative?

C.3.4. Market Factors

Before the research team discuss the initiative at length, the research team would like to get a better sense of the industrial refrigeration market as a whole.

5. First, when you think about the industrial facilities with refrigeration systems targeted by this initiative, how would you segment or classify them? Why?

6. As it relates to our research, what are the strengths and weaknesses of using the following segment categories? The research team are interested in segments that allow us to better understand variations in both O&M practices and energy use.

    a. NAICs / SIC codes

    b. Sectors (refrigerated warehouse, frozen food, etc.)

    c. Weather zone

    d. System configuration / age

    e. Plant management style (i.e. implementation of SEM, lean, etc.)

    f. Others described in Q5

    g. In-house RSO vs. contracted RSO

7. What are the largest sources of potential energy savings from O&M practices for this sector? And how has the industry been addressing these opportunities?

8. What are the key areas of energy saving O&M opportunities in most facilities? And what practices address these opportunities? Which of these practices are addressed by the RETA-CRES initiative? Which are not?

9. Please discuss the types of O&M practices you've seen used by RSOs who have not been exposed to training by an ETO, NEEA or BPA program.

    a. Are there any segment or region based variations in these practice?

    b. Is there variation between 'in-house' versus contracted RSO

10. Where do RSOs typically learn O&M practices, if any?

11. Who generally determines if an RSO pursues certification? What are their motivations?

12. How would you characterize the trend over the past 10 years in the proportion of RSOs with either CARO or CIRO certifications?

    a. Would you say it is: increasing; decreasing; or staying about the same?

    b. Do you have an idea of the percentage of change?

C.3.5. Clarify Program Assumptions

NEEA described the initiative to us in a kick-off meeting, and the research team reviewed their concept approval document. The research team would like to know from your industry experiences how you view the reliability of some of the initiative's assumptions and your thoughts on what strategies will be required for the initiative to achieve its goals.

13. First, the initiative's concept approval document suggests the initiative will generate 13.2 aMw in 20 years, and generate an average 0.94 aMw / year in the later 10 years.

    a. What kinds of discussions and information shaped these figure?

    b. What kinds of discussions and information shaped this figure?

    c. Are you aware of any strong opinions in favor of revising this projection?

    d. 70% of the initiatives savings will be generated in the last 10 years. Did those savings anticipate future standard energy efficient levels? How so?

14. The concept approval document states 86% of RSO will take the training courses, and 73% will maintain level 1 certification, 41% will maintain level 2 certification.

    a. What are level 1 and level 2 certifications?

    b. How would you characterize these participation and certification persistence levels (aggressive, optimistic, …)? Why?

    c. Can you think of any relationship between achieving a RETA CARO or CIRO certification and pursuing CRES certification?

    d. Can you think of any relationship between participating in Energy Trust's ROC or Cascade's IRBP and pursuing CRES certification?

    e. Were any assumptions made about the expected cost of achieving a CRES certification or the effectiveness of incentives to drive participation?

15. Are there any elements of the CARO or CIRO training that may lead to more energy efficient system operations?

16. Can you think of any points in CARO or CIRO trainings that might have similarity to the CRES trainings? How do those trainings differ from the CRES trainings?

17. The initiative assumes each RSO controls an average 2.5 MW of load, and certified RSOs will reduce load by 3.3% annually for an average of 107,000 kWh/year. What assumptions went into this figure?

    a. Is 107,000 kWh 1/20th of the 20-year savings value of a CRES RSO?

    b. How do annual savings differ for level 1 and 2 CRES certification?

c. Are there any technology or business trends that could change these assumptions? [**If yes**] To what degree?

18. The initiative assumes an investment of $2.7M over 20 years, what are the major investment costs in this figure?

C.3.6. Secondary Research

The research team would like to use various databases and reports to characterize the Northwest's industrial refrigeration market (in terms of number of facilities and RSOs, average number of RSOs per facility, average load controlled by RSOs, load use by facility, key business and energy practices trends)

19. Can you think of any databases or reports the research team should be using?

    a. The research team have access to…

        i. The 6th NW Power Plan

        ii. Hoover's Data used by NEEA consultants

20. For each of the mentioned data sources…..

    a. Are you familiar with key assumptions helpful for us to understand?

    b. Do any assumptions between these databases make it difficult to use these sources in the same analysis?

    c. Is there any reason you chose the Hoovers data set over others (Info USA)?

C.3.7. RSO Survey Ideas

Considering your industry experience, and knowledge of the RETA-CRES initiative, the research team would like your input on the RSO survey the research team will be fielding. It will be helpful to better understand the level of detail the research team might expect from the RSOs the research team survey, and the best language the research team should use with them. Also, keep in mind the survey targets two separate RSO segments: Those with ammonia based systems, and those without.

21. First, the research team will be contacting RSOs directly. What are some good strategies for identifying and working with RSOs through a phone survey that will likely begin at companies' switchboard?

22. Are you aware of any variations in the RSO population that may affect the way the research team work with RSOs?

    a. Language (Spanish) – which regions / sectors?

b. Regions – urban versus rural; east versus west

c. Sectors – refrigerated warehouses, food processing, dairy, …

d. Education – engineers, technicians…

23. The research team intend to ask the RSOs about their familiarity with, and participation in RETA, as well as that of their co-workers. Are there some ways RSOs refer to RETA?

24. The research team would like to discuss the amount of load controlled by each RSO. How should the research team go about this conversation? (conditioned sq./cubic foot, horsepower, …)

25. The research team will need the RSOs to identify energy efficiency O&M practices they pursue on their refrigeration system. Can you suggest survey questions that will help to get at this information? As a model it may be helpful to review these similar questions used in a Building Operator Certification survey (interviewer to provide survey questions).

D. Appendix D: Learning Objectives to Support a Program for CRES

D.1. Overall Learning Objectives

Participants in CRES will be able to:

- Describe the basic parts of an industrial refrigeration system, the purpose of each part, and how the parts work together as a system. Define basic refrigeration terms. (Section 2.0)
- Define and use basic energy efficiency concepts and terms; perform basic calculations and conversions with energy units; understand basic approaches for tracking energy use and measuring energy savings. (Section 3.0)
- Prepare a facility "energy map" showing (1) how energy is used in an industrial refrigeration facility, and (2) identifying the type and magnitude of potential energy efficiency opportunities in operations & maintenance, equipment upgrades, and new system design. (Sections 3.0 and 6.0)
- Use a logical process to prioritize identified energy efficiency opportunities (based on energy savings, although there may be other criteria). (Sections 4.0 and 5.0)
- Optimize and maintain the energy efficiency of compressors, condensers, evaporators, and associated refrigeration equipment by optimizing both individual components and the refrigeration system as a whole,[35] using part-load performance, and implementing operation & maintenance strategies (Sections 4.0 and 5.0).
- Optimize and maintain the energy efficiency of non-refrigeration loads: lighting, compressed air, pumps, fans, and more. (Section 6.0)
- Understand the relationship between implementing specific energy efficiency opportunities and maintaining (and potentially improving) production, temperature control, product quality, plant reliability, and safety. Describe other potential non-energy benefits from energy efficiency. (Sections 3.0, 4.0, 5.0)
- Select and use measurement units, processes, and methods to establish a baseline for energy use and intensity, set energy reduction goals, and measure progress towards those goals. (Sections 3.0, 4.0, 5.0)

35 A systems-based look at efficiency can reveal constraints at particular places in the systems that reduce overall system efficiency, even if individual components are efficient. Similarly, sometimes an improvement in the efficiency of one part of the system can actually reduce the efficiency of another part.

- Perform simple energy savings calculations and understand the economic analysis concepts that their company management uses to evaluate energy efficiency opportunities. (Section 6.0)

- Prepare a plan (examples: staffing, funding, timeline) for implementing the activities/projects and maintaining the savings over time. (Section 6.0)

- Obtain management support, approval, and recognition for implementing these opportunities and for an overall energy management plan (Section 6.0).

D.2. Refrigeration System Basics

This section provides learning objectives for refrigeration system basics. This content could be covered in an introductory seminar prior to the main CRES training. (Sections 3.0-7.0)

Participants in CRES will be able to:

D.2.1. Basics

- Draw a diagram of the four major elements of the basic refrigeration cycle and associated equipment components.

- Describe the purpose within the system of each equipment component; the physical change in the refrigerant in that equipment component; and what the physical change achieves and how in terms of the underlying principles of heat transfer.

- Describe the meaning of "system lift." [36]

- Define "suction pressure."

- Define "condensing pressure."

- Name three common types of industrial refrigerants and identify the one most frequently used in industrial systems.

- Name the two principal ways an operator can determine what is occurring inside the various parts of the refrigeration system (for example, sight gauges, pressure gauges and thermometers).

- If gauges or instrumentation are not available, give two examples of other sensory cues to determine what is occurring within the system.

[36] The relationship of system lift to energy efficiency is covered in subsequent sections of this document.

D.2.2. Evaporators

- Describe the purpose of the evaporator in the refrigeration cycle.
- Name the two main types of evaporators and identify which is most common (refrigerant-to-air coils (also known as evaporator fan coils) and heat exchangers; refrigerant-to-air coils most common).
- Name the three major methods of supplying liquid refrigerant to evaporator coils (recirculated or overfeed, flooded, direct expansion).
- Describe how a VFD can be applied to an evaporator fan.
- Describe the purpose of defrost and the factors that influence the need for defrost
- Describe the most common types of defrost (hot gas, water, air and electric) and how they work

D.2.3. Compressors

- Describe the purpose of the compressor in the refrigeration cycle.
- Name the three main types of compressors and identify which is most common (reciprocating, rotary screw, rotary vane; reciprocating and rotary screw most common).
- Describe the capacity control method for a reciprocating compressor.
- Describe the capacity control methods for a rotary screw compressor.
- Describe methods of compressor cooling and the types of compressors for each method may be applied.
- Describe how a VFD can be applied to a compressor.

D.2.4. Condensers

- Describe the purpose of the condenser in the refrigeration cycle.
- Name the three main types of condensers and identify which is most common in industrial applications (evaporative, water-cooled, air-cooled; evaporative most common).
- Describe capacity control methods for an evaporative condenser (airflow control, cycling, variable speed drive).
- Describe how a VFD can be applied to a condenser fan.

D.2.5. Valves

- Describe the types and function of valves commonly used.

D.3. Energy Efficiency Basics

This section covers learning objectives for the fundamental elements of energy efficiency.

Participants in CRES will be able to:

D.3.1. Definitions and Calculations

- Define basic energy terms (kW, MW, kWh, MWh, kVAR, horsepower, BTU).
- Perform basic calculations and conversions with energy units (example, hp to kW).
- Define "energy efficiency." (Examples: using less energy to provide the same or better level of performance; the percentage of electrical power that is converted to mechanical power.)
- Define "energy intensity" (Example: Energy consumed per unit of production)
- Give examples of good overall measurements of energy efficiency for an industrial plant. (Examples: energy used per unit of production; kWh versus average ambient temperature, kWh per cubic foot of storage per month by space type normalized by wet bulb temperature.)
- Describe what a VFD is, how a VFD saves energy, or how it might increase energy use.

D.3.2. The "big picture" for efficiency opportunities. Note: More detailed learning objectives for energy efficiency are covered in later sections.

- List major categories of energy efficiency opportunities in refrigeration systems. (Examples: reduce system lift; improve part-load performance; improve system operation and maintenance including defrost management; upgrade equipment; improve system design where/when feasible; reduce refrigeration loads; install/program automated controls.)
- Identify the central driving goal that relates to a majority of efficiency opportunities (reduce system lift) and give examples.

D.3.3. Measurement and tracking of energy use

- Use utility bills to track energy use.
    - Identify and understand different components of utility bills. (kW, kWh, time of use, meter access fees, power Factor charge (kVAR), local taxes and other charges)

  - Know how much energy your plant uses and how much you spend each year for the facility as a whole and roughly for each end-use.
  - Calculate cost impacts of wasteful energy practices.
  - Describe the benefits and issues with using billing data to identify energy use trends.
- Use “energy intensity” to track energy use.
  - Calculate energy intensity using billing and production data or storage capacity.
  - Describe benefits and issues with energy intensity (for example, what are you comparing current intensity with (the baseline).
  - Set a reasonable goal for energy intensity reduction based on industry averages or your best experience.
- Outline an overall plan for tracking energy and production including: type and quantity of data to be collect and analyzed; type, frequency, and audience(s) for internal reports.

D.3.4. “Energy mapping”

- Define “energy map” and prepare a mock example of how energy is used in a facility and a description of the type and magnitude of usage. Could include a comprehensive list of products and cooling processes, and their specific cooling requirements to help you:
  - Estimate the annual energy use of your refrigeration system. (See page 103 of the 2004 IRBPG.)
  - List which processes dominate your cooling energy consumption.
  - Identify unwanted heat gains.

D.4. Refrigeration Best Practices

This section describes learning objectives for the operation and maintenance of refrigeration systems to increase and maintain energy efficiency.

D.4.1. Understand and apply, safely and appropriately, the following rules of thumb for efficient refrigeration practices and activities

- Increasing suction pressure provides more capacity: 2 percent improvement per ºF.
- Decreasing head pressure decreases energy use: 1.5 percent improvement per ºF.
- Overall, reduced lift provides higher efficiency and greater capacity.
- A VFD reduces power (approximately) proportionally for constant torque loads such as conveyors and compressors.

- A VFD reduces power (approximately) cubically for centrifugal loads such as fans and pumps. Understand other affinity laws including flow and pressure.

- Fifty percent of condenser capacity is lost when there is a 1/16 inch of scale on the condenser coil.

D.4.2. Managing system lift

- Define system lift and describe implications for overall system efficiency.

- Minimize head pressure to improve efficiency while maintaining plant safety and respecting barriers such as hot gas defrost, heated zones, oil separator performance, liquid injection oil cooling.

- Maximize suction pressure to improve efficiency while maintaining plant safety and respecting barriers such as oil separation, production requirements.

D.4.3. Understand the value of calibrating instrumentation (proper measurement of system operating conditions).

- Know what instrumentation should be regularly calibrated and why (pressure and temperature transducers and indicators; slide valve position indicators).

- Know how incorrect instrumentation calibration can compromise safe, proper, and efficient system operation.

- Outline a plan for effective regular calibration of plant instrumentation. What is the proper frequency for what instruments, and who should perform the work

D.4.4. Automated controls

- Program automated optimization of suction pressure set point

- Program automated optimization of condensing pressure set point

- Program automated sequencing of compressors, including VFD

- Program automated sequencing of condenser staging, including VFD

- Automate defrost cycles and settings

- Accurately control evaporator operation and zone temperature

- Better anticipate problems

- Maintain more consistent temperatures

- Monitor system remotely

D.4.5. Interpretation of system data

- Gather sources of data including automated control system data, engine room logs, utility bills and weather data.
- Convert data into a useful form as needed (for example, an Excel spreadsheet)
- Interpret the data to determine how the system is operating from a production, safety, and efficiency perspective; this is often done in conjunction with service providers
- Trend one or more variables over a selected range and period (for example, compressor amps, plant kWh, head pressure, freezer space temperature)
- Use techniques such as graphing, statistical analysis (average, minimum maximum, total), and comparison of two variables to determine whether your system is operating as intended

D.4.6. Document system and equipment set points

- Find information in system's original design documents to help operate the system efficiently and diagnose problems (for example, original as-designed set points, operating parameters, and sequences of operation).
- Document the set points that should be reviewed quarterly, seasonally, and annually.
- Formalize and post the appropriate parameters for operating the system under a range of conditions; inform or train operators, management, and production staff as needed.

D.4.7. Compressor efficiency opportunities

- Describe some of the design and sizing characteristics for an efficient compressor.
  - Interpret compressor manufacturer power and capacity ratings.
  - Identify opportunities in equipment purchase and retrofit to apply part-load efficiency approaches and VFD.
  - Understand screw compressor slide valve to capacity relationship.
  - Compare the full- and part-load efficiency of a compressor using slide valve, unloading, or VFD.
  - Describe how the oil separator sizing can affect the energy efficiency of a system.
- Identify opportunities in operation and maintenance to improve compressor efficiency and operation.

- Resolve barriers and increase suction pressure as appropriate and safe.
- Determine approaches for compressor staging when multiple compressors are available.
  - Use the most efficient compressor base loading and trim combination for each operating load range.
- Identify ideal volume index (VI) for each compressor operating condition.
  - Understand the consequences of over- and under-compression.
  - Use both manually adjusted and variable volume index (VI) to optimize compressor efficiency.
  - Recognize the symptoms of malfunctioning volume index (VI) controls.
- Use a compressor economizer as appropriate in situations where it might be beneficial to energy efficiency.
- Describe different compressor cooling approaches and their relative impact on system efficiency; select and implement best approaches for your plant.
  - Recognize the symptoms and consequences of improper oil cooling calibration.
- Recognize the symptoms of improper slide valve calibration.
- Understand the causes and recognize the symptoms of compressor current limiting.

D.4.8. Condenser efficiency opportunities

- Describe some of the design and sizing characteristics for an efficient condenser.
  - Interpret condenser manufacturer power and capacity ratings.
  - Identify opportunities in equipment purchase, sizing, and retrofit to apply part-load efficiency approaches, fan and pump staging, and VFD.
- Identify opportunities in operation and maintenance to improve condenser operation.
- Resolve barriers and reduce condenser pressure as appropriate and safe
- Define floating head pressure
  - Understand condenser refrigerant-to-air temperature difference rating and its effect on condensing pressure. Understand minimum possible condensing pressure for a given air temperature.
  - Use appropriate ambient temperature and humidity sensor location
- For multiple condensers, use the most efficient combination for a particular load
  - Use the most efficient pump and fan staging

- Understand the benefits of condenser grouped fan VFD operation

〉 Water delivery

- Spray nozzle maintenance and the benefits of larger orifice nozzles
- Pump operation, sequencing, and impeller trimming
  - Identify symptoms of poorly performing or improperly sized pumps
  - Identify throttled pumps
- Identify water piping issues

〉 Purging of non-condensables

- Check for the presence of non-condensables
- Troubleshoot purger operation

〉 Water treatment

- Properties of water
- Impurities present in water
- Cycles of concentration
- Scale
- Corrosion
- Microbiological
- Impact on condenser performance
- Identifying symptoms and addressing causes

〉 Identify condenser refrigerant piping configuration issues

- Explain the purpose of an equalizer line.
- Explain the proper use of drop leg pressure trap

〉 Maintaining belt drives

〉 Cold weather operation

D.4.9. Evaporator efficiency opportunities

〉 Describe some of the design and sizing characteristics (including fan blade design and motor efficiency) for an efficient evaporator.

- Interpret evaporator manufacturer power and capacity ratings.

  - Understand evaporator refrigerant-to-air temperature difference rating and its effect on suction pressure.
  - Describe the trade-offs between fan power and coil size when selecting coils.
  - Describe the energy implications for the three types of evaporator coils – direct expansion, liquid overfeed, and flooded.
  - Identify opportunities in equipment purchase and retrofit to apply part-load efficiency approaches and VFD.
- Identify opportunities in operation and maintenance to improve evaporator efficiency.
  - Coil cleaning
  - Understand the impact of water in the refrigerant or cooling water, and oil contamination, on evaporator performance.
- Capacity control
  - Fan cycling
  - VFD operation
    - Minimum and maximum speed settings
    - Grouped fan VFD control
  - Suction BPR operation
  - Direct expansion
    - The effect of excess superheat on system energy consumption
- Valve commissioning
  - Identify the symptoms of malfunctioning valves
  - Hand expansion valves and liquid feed balancing
    - Measure evaporator performance using inlet and outlet air temperature
  - Address valve commissioning systematically

D.4.10. Defrost

- Understand the costs associated with defrost
- Understand the extent of defrost heat lost to the room
- Understand defrost piping and valving layouts
- Understand the phases of defrost and identify potential issues impacting energy use
  - Pump down

- Hot gas
- Bleed down
- Refreeze (or “fan delay.”)

〉 Given system equipment and conditions, determine (1) which defrost approaches are to be used and why (hot gas, water, electric resistance, air); (2) how defrost cycles are to be scheduled and managed under a range of operating conditions such as season and operating mode.

- Defrost staging between evaporators
- Times of day to defrost
- Run time based defrost
- Defrost sensors
- Defrost termination controls

〉 Use pressure regulators safely and appropriately for evaporator operation and evaporator defrost.

〉 Identify the symptoms of malfunctioning defrost valves.

D.4.11. Effectively manage refrigeration loads

〉 Door management (dock, freezer, etc.)

- Communicate the cost of leaving doors open to production
- Effective use of strip curtains
- Minimize the use of electric door heat
  - Use door fans as an alternative
  - Use heater cycling where electric heating must be applied

〉 Lighting in refrigerated spaces

- Effective use of lighting controls in refrigerated spaces

〉 Under-floor heating

- Identify appropriate floor temperature settings and controls
- 4.11.3.2 Glycol under-floor heating
  - Understand the impact on condensing pressure
- Electric under-floor heating

D.4.12. Energy opportunities for packaged Freon units

- Evaporator fan control
- Direct expansion and superheat
- Condensing pressure control
- Defrost control

D.5. Best Practices for Other Systems

On average across refrigeration plants, non-refrigeration end-use can comprise about 50 percent of the total facility energy use.

D.5.1. Be aware of the dominance of energy and maintenance costs in life-cycle costs.

D.5.2. General best practices to achieve energy efficiency in the O&M of non-refrigeration systems

- Minimize loads
- Process once, not twice
- Eliminate leaks
- Turn it off
- Maintain cleanliness
- Minimize pressure drops
- Calibrate instrumentation and controls
- Run your most efficient equipment first
- Use your best part load option
- Establish standards

D.5.3. Lighting best practices

- Effective use of lighting controls

D.5.4. Compressed air

- List inappropriate compressed air end-uses and potential alternatives (example: open blowing to keep sensors clean)
- Describe safe and appropriate compressed air rules of thumb
- Develop and implement a compressed air leak management program. Use efficient part-load methods: load/unload, start/stop, variable displacement, variable speed

D.5.5. Pumps

- Identify and address "symptoms" of an unreliable and inefficient pump system
- Identify opportunities to control pump flow and increase efficiency
- Identify opportunities to reduce the frictional component of your pumping

D.6. Overall Facility Energy Management

This section describes organizational elements and activities that help optimize and sustain energy use reduction such as management support, team building, and regular reporting of success. Participants will be able to:

D.6.1. List the key elements of energy management

- Executive sponsor
- Energy goal
- Energy champion
- Trained staff
- Assessment
- Activity documentation and reporting
- Continuous Energy Improvements

D.6.2. Describe how management support is the first key element in an ongoing energy management program. What are the key elements for getting management support?

D.6.3. Outline measurement approaches for energy management.

D.6.4. Tap into resources for incentives, consulting services, education and certification (utilities, vendors, RETA, etc.).

- How can vendors assist in implementing activities and projects at your facilities? What are elements you should be prepared to do and what do they do?

E. Appendix E: Market Characterization Secondary Data

In order to target facilities with industrial refrigeration, the research team selected facilities from the Database of Northwest Manufacturers, Nurseries, and Wineries. The research team queried facilities identified by primary NAICS codes associated with industries that rely on industrial refrigeration. A consulting refrigeration engineer, with over 20 years of experience in the region and under contract with NEEA, reviewed the database for these targeted NAICS codes. The following NAICS codes were used to target these facilities

311320, 311330, 311340, 311411, 311412, 311421, 311422, 311423, 311511, 311512, 311513, 311514, 311520, 311611, 311612, 311615, 311711, 311712, 311811, 311812, 311821, 311930, 311941, 311942, 311991, 311999, 312111, 312113, 312120, 312130, 334413, 424930, 493120.