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Optimized Operation of Indoor Public Pool Facilities

Guidance for Utilities, Technicians and Recommissioning Providers
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Executive Summary

Background

Indoor public pools represent an opportunity for significant energy savings in Minnesota. The Environmental Protection Agency's (EPA's) Target Finder indicates that indoor public pools have an energy use intensity that is at least 3 times that of the other parts of buildings within which they reside (EPA 2014). They have energy intensive, specialized conditioning requirements and equipment. Optimized operation of these facilities requires careful balancing between pool temperature and the combination of air temperature and humidity. Modest changes in any one of these can throw off the balance and have large energy and comfort impacts. Operational issues with HVAC equipment can also cause excessive energy use that goes unnoticed. These complex HVAC systems can have a problem with one component and have another part of the system make up for it in a way that uses much more energy, but still keeps the pool temperature and space conditions comfortable. Based on our market research conducted as part of this project, we estimate that there are approximately 600 indoor public pools in Minnesota larger than 2,000 square feet, about 1,500 smaller indoor public pools, and about 900 spas. We found that all of these had a combination of high energy use, complexity and prevalence, making indoor public pools a ripe opportunity for energy savings.

Although indoor public pools are common high energy users with optimization opportunities, CIP program efforts in Minnesota have generally underserved this portion of the commercial building market. Most large public pools are in schools and fitness centers that may be served by recommissioning (and other) programs, but recommissioning of these facilities often doesn't fully address the indoor pool area--or is very expensive. This is because of both the specialized nature of the facilities and inconsistencies of their tie-ins with central building automation systems. Moreover, we found a gap in CIP programs when it comes to serving hospitality and multifamily buildings with smaller indoor public pools, missing opportunities to adequately address optimization.

This project was undertaken to develop specialized guides designed to provide energy savings through quality maintenance and operation of indoor public pool facilities, and to investigate their energy impact. The focus is on making the best use of existing HVAC equipment, as well as low to moderate cost upgrades (e.g. control optimization). One guide is designed for recommissioning providers working with CIP programs to help them maximize the savings achieved while minimizing the cost of the recommissioning services. This guide (requiring the high level of expertise associated with the recommissioning engineer) encompasses a wide range of improvements for comprehensive one-time investigations. The second guide is designed for service technicians. This guide is for use by technicians that deal with a facility on a regular, ongoing basis as well as serving as a complement to the recommissioning guide. The service technician guide has the potential to impact a larger number of facilities at a lower cost than the recommissioning service provider guide because of the cost and relative infrequency of recommissioning services.

Goal & Methodology

The key goals were the development of guides and quantification of the savings potential associated with specific operational improvements in Minnesota's indoor public pools. The steps taken towards these aims are outlined below.

1. <u>Baseline Characterization.</u> The first step was to establish a detailed definition of the common range of baseline conditions for indoor pool facilities in Minnesota. After gathering preliminary information about the quantities of various pool sizes and the building types in which they are found, we performed a field observation survey of pool area, equipment and baseline operating conditions (critical operating temperatures, air flows, and humidity) for 30 facilities chosen to be representative of the important segments of the market. This included a total of 15 hospitality and multifamily buildings with small pools (and spas in many cases), and a total of 15 schools and fitness centers with at least one large pool. The survey was also designed to provide preliminary identification of the applicability of specific energy improvement measures. In addition, the survey results helped refine the use of information from a variety of sources so that more accurate best estimates of statewide counts of facilities and pools by type could be compiled.

2. <u>In-Depth Evaluations and Improvement Implementation.</u> More in-depth investigation and implementation of improvements was targeted for 6 of the facilities surveyed. This included one hospitality building, one multifamily building, two schools, and two fitness centers. At these sites detailed spot observations and long-term monitoring was used to guide the implementation of operational improvements and to measure the subsequent energy savings achieved. The monitoring and analysis was carried out using a variety of approaches based on the site and measure-specific situation. For example, data collection used a combination of existing building automation system trend data and research grade data logging equipment. Similarly, approaches such as simple regression analysis, piecewise regression analysis, and temperature bin data analysis were used as appropriate for the available data set and relationships.

3. <u>Guide Development & Refinement.</u> The lessons learned from earlier project activities guided the development of two guides aimed at improving the efficiency of indoor public pool facility operations. The first guide provides operators (facility staff or contractors) a checklist of items to verify periodically, and correct as needed to improve efficiency. For a limited number of these items—chosen based on a combination of savings magnitude and the level of expertise needed to address them—a set of detailed step-by-step directions was developed. A draft of the technician's guide was sent to 12 operators and contractors that agreed to review and provide feedback, and final revisions were made after making follow-up contacts. A second, recommissioning provider's guide built upon the technician's guide with additional measures and technical guidance aimed at engineers that are less familiar with pool systems and issues.

This guide was similarly sent to two recommissioning providers for review and feedback before finalization.

4. Savings Quantification and Guidance. Based on the results of the surveys and implementation, two different savings estimation efforts were undertaken. First of all, the results from the test sites and other engineering calculations were used to estimate the statewide savings potential for systematic implementation of operational improvements to indoor public pools in Minnesota. Secondly, recommendations were developed to guide future pool system energy savings calculations for utility program purposes.

Results

Baseline Characterization

In the 30 buildings surveyed on-site, there were strong relationships observed between the building types with pools and the sizes and types of pools in those buildings, and other trends related to key equipment characteristics. The most important building and equipment asset characteristic findings are:

- Pools in schools & fitness centers averaged six times the size of pools in hospitality and multifamily buildings
- Multiple pools were seen in all fitness centers and ¼ of schools
- Spas appeared in all hospitality buildings and fitness centers, and more than ¼ of multifamily buildings
- Sand filters and constant speed pumps were nearly universal
- All pool water heating was gas-fired
- Pool water heating was through a secondary heat exchanger in most buildings, with packaged pool heaters only used for 1/3 of small pools.
- Each of these three secondary heat sources was common: a dedicated boiler (or water heater), a central whole-building boiler systems, and seasonal changeover between the former two.
- 2/3 of large pool rooms used dehumidifiers with compressor(s) and the remaining 1/3 used "dry" outdoor air ventilation only to dehumidify
- All hospitality buildings used compressorized dehumidifiers while none of the multifamily buildings did
- Boiler system coils provided space heating for all large pool rooms and 1/3 of small pool rooms
- Other common space heat sources for small pool rooms were direct-fired heaters, and electric resistance supplemented with dehumidifier hot-gas reheat
- Large pool area HVAC systems had heat recovery ventilation (HRV) in 1/3 of buildings and reclaim of heat from the dehumidifier for pool water heating was designed into ½ of the compressorized dehumidifiers.
- The above two features were much less common in small pool room HVAC systems

The most important operational observations and interview findings from the survey are noted here:

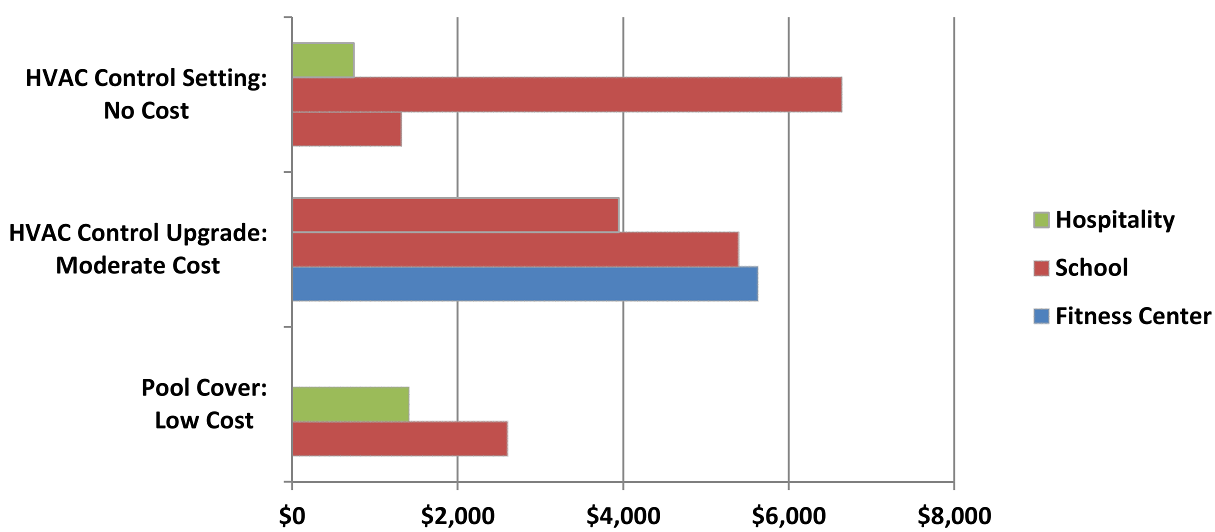
- Control problems and insufficient understanding of controls was very common.
- Many sites had space temperatures well below the industry recommended values
- Half of the sites with pool covers don't use them
- Pool water recirculating rates were typically much higher than code requirements in small pools
- Significant valve throttling was observed in nearly all secondary pools in schools and fitness centers, and more than a quarter of the primary pools in these facilities.

Each of the above observations is an indicator of a likely cost-effective opportunity to improve operations. The likely opportunities include HVAC control upgrades and fixes, HVAC control setting adjustment, increased use of existing pool covers, balancing of pool water recirculation rates, and the use of a variable speed drive to balance pool water flow rates.

Detailed Investigation of 6 Sites

The energy saving operational improvement opportunities identified at the six sites that received recommissioning style evaluations are summarized in Figure 1. All of the items presented have a payback of less than three years and most have been successfully implemented at the sites and had the savings validated. The average annual savings per measure identified was 29,000 kWh and 3,700 therms (when the increased gas use associated with fixing one heating equipment problem is ignored). These savings average 6.5% of electrical usage and 12% of gas usage for the mechanical equipment serving the pool spaces and the pools. The most important opportunities for cost-effectively achieving energy savings in these facilities were HVAC control setting and control system changes while pool covers offer more modest opportunities.

Figure 1. Energy Saving Measures Found at 6 Recommissioned Facilities



These energy cost saving control opportunities had some noteworthy traits. The two largest saving measures, plus the 4th largest, included outdoor ventilation air flow reduction as a primary feature. The two lowest saving no-cost control setting changes could be made without accessing a building automation system, while the top 4 saving measures require changing settings and/or programming of a building automation system (BAS) or similarly sophisticated individual HVAC unit controller. While a number of problems with existing control systems provided opportunities for improvements, these problems also included problems with communication between BAS systems and pool area HVAC units or BAS trend logging that made thorough investigation of opportunities challenging.

While pool covers are one of the most-cited energy saving measures for pools in pool and energy efficiency industry literature, their savings potential was much less than the HVAC control opportunities in the facilities with large pools. The one cost-effective pool cover opportunity identified in a large building was for repairing an existing cover, rather than for the full price of purchasing and installing a cover. The pool cover opportunity noted for the hospitality building is for the use of an invisible liquid pool cover material that reduces evaporation when the water is still. The savings shown and (and less than one year payback) is based on an engineering estimate of savings, while the actual savings observed through monitoring was only a small percentage of this projected savings. While this liquid pool cover technology appeared to have the potential to be the largest impact measure for a number of small pools, it is unclear now indicative the disappointing result at the one site is of the potential savings in other Minnesota indoor public pools. Both traditional and liquid pool covers may provide important savings opportunities in Minnesota that this small sample size does not reveal even though the potential per site savings is less than what most of the HVAC control operational improvements can provide.

Energy Efficient Operations & Recommissioning Guides

Two guides focused on energy efficient operation of existing indoor public pool facilities were successfully developed—one for operators and contractor technicians, plus a second for recommissioning engineers that may not have extensive experience with pools. The guide development process included detailed review and feedback from 10 local industry professionals. Each guide is built around a one-page checklist of specific energy efficient operation items. The main checklist includes either an indication of how often to check an item (for operators) or what investigation approach is needed to identify the opportunity (for recommissioning engineers), plus a specific reference to the location of further information. Many of these references lead the user to other portions of the guide where clear, detailed direction is given in a format that is specific to the type of user. The operator's guide primarily uses a consistent visual layout with step by step instructions while the recommissioning provider's guide includes an additional text section that provides guidance for every measure on the checklist. The recommissioning guide also has sections that provide valuable background on pool facilities, mechanical equipment, and methods for both spot measurements and long-term monitoring. These guides are being made publicly available as a resource for pool operators, building owners, recommissioning engineers, and CIP program staff.

Statewide Savings Potential

Table 1 shows the statewide savings potential available in indoor public pool facilities in Minnesota by category of measure or service. HVAC recommissioning type activities show the largest potential for savings of both gas and electricity. No cost control adjustments and liquid pool covers provide significant secondary opportunities for gas savings while variable speed pool pumping provides about one-third of the electric savings potential. The one-third of buildings that have large pools represent about two-thirds of the overall savings potential.

Table 1. Summary of Statewide Savings Potential

	# of Applicable Buildings	CCF/ Building	kWh/ Building	MCF Statewide	MWh Statewide
No Cost Changes*	907	853*	3,878*	77,394*	3,517*
HVAC Recommissioning/Audits	2,029	2,545	8,788	516,302	17,832
Liquid Pool Cover	1,394	221	1,453	30,755	2,026
Variable Speed Pool Pumping	907	0	9,789	0	8,879
Total	2,029	2,696	14,163	547,057	28,736

*Values for no-cost changes were not added to the totals because the savings associated with this measure is mutually exclusive with the recommissioning audits (within the same building).

Recommendations

CIP Programs Recommendations

Based on the results of this study, our key recommendations for CIP programs are:

- Direct recommissioning efforts towards indoor public pool facilities with guidance to providers based on the *Recommissioning Guide for Indoor Public Pool Facilities in Minnesota,* (which is one of two companion documents prepared as part of this project).
- Develop prescriptive or similar, simple rebate options for a variable speed pool pumping
- Consider offering pilot or custom rebates for liquid pool covers with measurement and verification of the first few participants before undertaking wide promotion of this technology.
- Promote the use of the *Operator's Guide to Energy Efficient Indoor Public Pool Operations* (which is the second companion document prepared as part of this project) among on-staff operators, HVAC contractors, and pool water system contractors.

TRM and Savings Calculation Recommendations

Based on a review of other states' TRM measures and a number of resources we have developed six measure specific recommendations for incorporation of TRM measures and/or CIP program calculation approaches for use in Minnesota. These recommendations address some assumptions in commonly used calculation approaches that we have found to be frequently inaccurate for Minnesota's climate and commonly used HVAC systems.

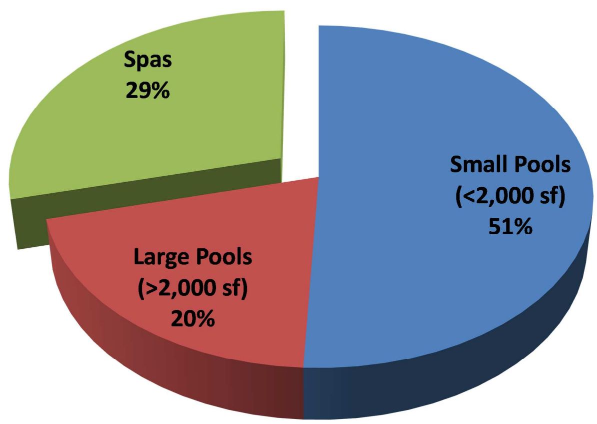
Conclusions

There is a large potential for energy cost savings by turning more focused attention to optimized operation of indoor public pool facilities in Minnesota. HVAC recommissioning activities provide the majority of the savings potential. Variable speed pool pumps, no-cost HVAC control setting changes, restoring pool covers, and liquid pool covers also provide secondary opportunities for energy savings. A recommissioning provider's guide and an operator's guide developed as part of this project can aid with CIP program activities.

Introduction

The potential for cost-effectively achieving energy savings in indoor public pool facilities through optimized operation appears to be very large. We found that there are about 1,900 buildings in Minnesota with indoor public pools, and these are primarily hospitality, multifamily, school and fitness center facilities. Figure 2 categorizes the roughly 3,100 public pools found in these buildings by pool size and type. While the intent of this project was to focus on pool facilities, the presence and operation of spas (i.e. hot tubs) in a significant fraction of the pool rooms has a significant impact on the pool room and should be addressed alongside of efforts to address pool operations.

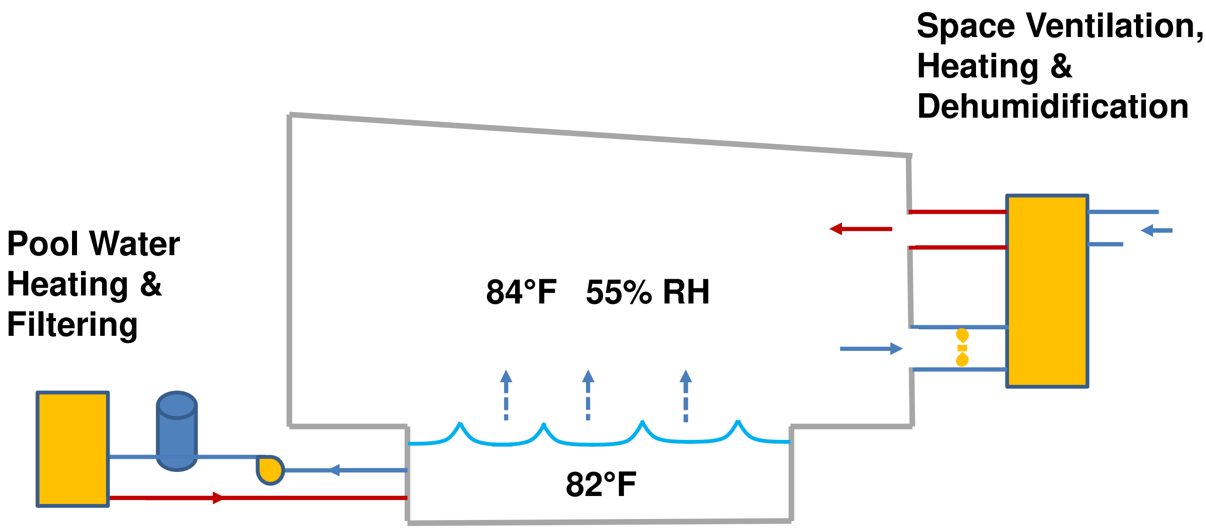
Figure 2. Indoor Public Pool Categories in Minnesota



The indoor pool facilities have energy intensive, specialized conditioning requirements, but in practice equipment is often not operated and maintained in a way that is optimal with respect to energy performance. Optimized operation of these facilities requires careful balancing between pool temperature and the combination of air temperature and humidity. Modest changes in any one of these can throw off the balance and have large energy and comfort impacts. The key system components in a public pool facility are illustrated in Figure 3. There are a number of other ways that excessive energy use can be caused by HVAC equipment operational problems that may easily go unnoticed. The control systems for HVAC systems for swimming pool areas compensate for many problems by using excessive energy without the pool temperature and space conditions being affected. Two common problems that are not “self-alerting” include using excessive amounts of outside air and the failure of heat-recovery equipment.

The achievable cost-effective savings potential is significant because of the combination of the number of facilities, energy-intensity, and sensitivity of energy use to a number of maintenance and operation issues. While public pool operators are required to have extensive training and certification, this training primarily focuses on pool water treatment systems and maintaining water quality, with very little guidance regarding energy efficient operations and the unique HVAC operations challenges encountered in indoor public pool facilities. While CIP recommissioning programs theoretically include indoor public pools in their scope, the specialized space conditioning requirements, specialized equipment, and frequent disconnect between pool equipment and a central building automation system (BAS) often cause recommissioning providers to overlook opportunities in the pool area. Therefore, it appears that improved quality maintenance and operations program for indoor pools in Minnesota has the potential to create pool water heating, space heating, cooling and fan energy savings.

Figure 3. Diagram of Key Pool Area Equipment



To address this opportunity, CEE undertook this project to develop two specialized guides designed to provide energy savings through quality maintenance and operation of indoor public pool facilities, and to estimate their energy impact. One guide is designed for CIP program recommissioning providers to help them maximize the savings achieved while minimizing the cost of the recommissioning services. This guide (requiring the high level of expertise associated with the recommissioning engineer) encompasses a wide range of improvements for comprehensive one-time investigations. It also includes guidance for quality installation, maintenance, and operations improvements. The second guide is designed for service technicians. This is meant for technicians that deal with a facility on a regular, ongoing basis as well as serving as a complement to the recommissioning provider guide. It is anticipated that the service technician guide has the potential to impact a larger number of facilities at a lower cost than the recommissioning service provider guide, because the cost of recommissioning services is a barrier to program delivery, especially for smaller buildings with indoor public pools.

Goals and Methodology

The key goals of the project were:

- Development of an effective energy efficient operations guide for commercial indoor public pool operators and contractors
- Development of an effective guide for recommissioning providers that increases the subsequent savings achieved in facilities with pools through cost-effective investigation efforts
- Give CIP program planners and providers guidance for quantifying the magnitude of savings that can be achieved through operations and maintenance improvements in indoor public pool facilities.

Given the variety of operations improvements that can be undertaken, the field study efforts did not aim to achieve statistically significant proof of savings for each item as much as they were intended to provide lessons that would improve the quality of the guides and to give a general indication of the magnitude of savings that should be expected. The following task subsections detail the efforts and approaches that we undertook to achieve these goals.

Baseline Facility Characterization

Statewide Facility and Pool Count Estimation

Information was gathered from a variety of sources and synthesized to make a best estimate of the number of various types of facilities with indoor public pools in Minnesota, the number and general size of pools within them, and the number of spas within the pool rooms of these facilities. Based on previous in-house knowledge and discussions with a number of industry professionals, we used various approaches to estimate the state-wide quantities associated for each building type. Preliminary estimates were generated prior to the contracted work, and then improved upon within the course of this project. Multiple estimates were generated for most building types, and a type-specific approach was applied to choose one of these as a best estimate, or combine multiple estimates to yield our best estimate.

Extrapolation of Suburban County Data

The most important single source of information for estimating statewide counts of facilities and pools was a list of every indoor public pool and spa regulated by one county in the Twin Cities (Ramsey County 2014). While facility name and corporate license holder information was all that was provided for each of these pools (and spas), the facility name gave a clear indication of building type and duplication of addresses frequently gave a clear indication of a second pool/spa at a facility. The individual counts for this jurisdiction were translated into statewide estimates by multiplying by 28.6, which is the ratio of state-wide population in 2010 to the population of the jurisdictions regulated by the county in 2010

(U.S. Census Bureau, 2016). This data was used provide an estimate of facility and pool/spa counts for all of the facility types noted in the following subsections.

Hospitality Count Estimation

The best estimate counts of facilities with pools and the count of spas is directly from a voluntary, self-reported list of hospitality buildings in Minnesota that provided information to the state of Minnesota's office that promotes these facilities through a state tourism website (Explore Minnesota 2014). Additionally, based on a separate list of facilities with water parks, we estimated that 5% of the pool hospitality facilities have a large pool as part of a water park, and that half of these (2.5% of all hospitality) have a second pool that fits into the small pool category. The extrapolation of suburban county data to the entire state gave a hospitality building with indoor pool Minnesota-wide estimate hat was just 3.5 percent below the count provided by the state's tourism office.

Multifamily Count Estimation

The extrapolation of suburban county data was the only estimate of statewide facility count available for multifamily buildings. The on-site survey findings and spot checking of multiple pool licenses in the suburban county all suggested that 2nd "pools" in multifamily facility are nearly all spas. When all 2nd "pools" in the suburban county's multifamily buildings are assumed to be spas, it appears as though this county has a proportion of multifamily buildings with spas that is moderately higher than what was observed in the on-site survey. To arrive at the estimate of multifamily building spas we applied the average of the percentages from the suburban county and the on-site survey to statewide count of multifamily buildings with pools estimated from extrapolation of county license data, yielding a State-wide count of 570.

School Count Estimation

The total number of public schools with indoor public pools was calculated by taking the total number of middle and secondary schools in Minnesota (Education Bug 2015) and applying a factor of 0.42. The 0.42 factor is based on a phone survey we conducted on a random sample of middle and high schools in Minnesota (selected from a list of schools that have entered their utility billing data into a Minnesota specific energy benchmarking database). This resulted in an estimate of 418 for Minnesota.

Fitness Center Count Estimation

One estimate of the number of fitness centers, pools and spas came from adding up the fitness centers identified through fitness center chain and internet searches for fitness centers with pools throughout Minnesota websites (Foss Swim School, LA Fitness, LifeTime Fitness, YMCA 2014, 2017). Each fitness center was assigned an estimated pool count based on the "standard" facility amenities for that chain (as determined from information from a subset of each subset). This resulted in facility and pool count estimates that were only about 1/3 of the value estimated from the extrapolation of the license data from one county. This was despite the license data for the one county showing a much lower average number of pools per fitness center (1.2) than what was observed in the fitness centers surveyed (3 per site). The value reported for fitness center facility count (with an indoor public pool) was calculated as a weighted average between the extrapolated data and the facilities identified through on-line searches, with the lower, search value numbers receiving twice the weight of the extrapolated data estimates. The on-line search trends of number of pools and spa per site was applied to this facility count. The fitness center count estimates (100 state-wide) are considered to be somewhat more conservative than the estimates for the other facility types.

Other Count Estimation

The best estimates of counts for the sum of all other building types was made in a similar way as the fitness center counts. The one difference is that we used simple averages of all values obtained from the two estimation approaches.

On-Site Surveys and Interviews

Field observations and an operator interview survey were used to provide detailed definition of the common range of baseline characteristics for indoor pool facilities in Minnesota. Data elements were chosen to provide direction for subsequent guide development, energy savings magnitude quantification and calculator tool development. The field survey and interviews were used to refine the preliminary prioritized list of improvement measures and equipment types for indoor public pools developed by CEE initially through first-hand experience and interviews with local equipment suppliers in Minnesota as well as literature research.

Field staff gathered three categories of information during the on-site surveys:

- Facility and equipment data (e.g. the count, size and type of pools, pool room size, HVAC system types, design flow rates, pool heater type, and motor horsepower)
- Observed operating conditions (e.g. pool temperature, space temperature and humidity, outdoor air ventilation rate, and pump system operation)
- Staff Interviews (e.g. pool area schedule, equipment operating schedules, service technician type [in-house vs contracted], and known problems). These interviews were generally conducted with on-site staff at the time of the field visit.

The field surveys were conducted at 30 facilities chosen to be representative of the two size ranges of pools found in the four key building types with a large number of indoor public pools in Minnesota.

Table 2. Preliminary Facility Counts and Survey Sampling

Building Type	Pool Size Category	Preliminary Estimate in Minnesota	Number Targeted
Hospitality	Small	390	4 to 8
Multifamily	Small	570	7 to 11
Category Total	Small	960	15
Public School	Large	418	10 to 13
Fitness Center	Large	100	2 to 5
Category Total	Large	518	15
Survey Total	All Sizes	1478	30

Table 2 shows the building type and pool size categorization, along with preliminary estimates of state-wide counts in each category, and the number targeted for field surveys and interviews. Pool size is the primary determinant of the type of pool heat and HVAC equipment, as well as the subsequent applicability of specific energy savings improvements. The sample size within each size category was chosen to provide 95% confidence that a characteristic or condition present in only 20% of the buildings in a size category would be observed at least once in the sample set of buildings.

Individual survey site selection was based on random sampling within each building type. (The sources of facility lists are detailed in the next subsection.) After target buildings were selected, recruitment was aided by the offer of small financial incentives to survey participants. No more than two buildings operated by the same organization were to be included in the public school, fitness center, and multifamily building survey groups. However, this limit was not intentionally applied to hospitality as it was feared that this could lead to underrepresentation of dominant chains. However, specific buildings within a chain were to be chosen to represent different groups of maintenance and operation technicians.

Detailed Investigation of Operations Improvements in 6 Buildings

Six of the 30 sites receiving on-site surveys were chosen for more detailed field investigation and subsequent implementation of maintenance and operations improvements. These six were chosen to represent the important combinations of facility type, pool size, equipment type, technician type, and opportunities for maintenance and operations improvements that were identified in the baseline characterization. The ability to perform long-term monitoring was an additional consideration in site selection. The goal of these detailed investigations and implementation was to further inform both the development of the guides and the estimation of energy savings that can be achieved through public pool facility operations improvements.

The primary focus of the detailed investigation was related to the most common and significant improvement opportunities in the following general areas:

- Reducing evaporation load with improved temperature control
- Reducing evaporation load with covers
- Reducing over-ventilation with outdoor air that must be heated
- Correcting improper operation of energy saving features (e.g. heat recovery ventilation)

Table 3. Key Characteristics for Sites Receiving Detailed Investigation

ID	Building Type	Pools	Dehumid-ifier Type	HVAC Notes	Special Item(s)
HP4	Hospi-tality	Small, Spa	Compressor	Common Complex System	Temperature Imbalance; Combined Electric Heat, Reheat & Outdoor Condenser
MF14	Multi-family	2 Small, Spa	Outdoor Air	Common Direct-Fired Unit	Temperature Imbalance; Variable Speed Exhaust
SC17	School	Large	Outdoor Air	Likely Excessive Outdoor Air	Unused Cover; Temperature Imbalance
SC23	School	Large	Compressor	Common Newer Complex System	Heat Recovery Ventilation
FT28	Fitness	2 Large, Spa	Compressor	Common Older Complex System	Heat Recovery Ventilation; Moderately Low Humidity
FT30	Fitness	2 Large, Spa	Outdoor Air	Two Units with 100% Outdoor Air; Common Newer Type	Overnight Reduction in Ventilation; Heat Recovery Ventilation

A more comprehensive listing and description of measures is presented in a companion document, *Recommissioning Guide for Indoor Public Pool Facilities in Minnesota* (CEE 2017A).

Site-specific information for the facilities included in the detailed investigations appears in Table 3 above. More facilities with large pools were chosen because these specific sites appeared to have the best opportunities for operational improvements. These investigations were expected to fulfill the need for further information on measures that could have a large energy impact on the population of public pools in Minnesota.

Comprehensive evaluations for these facilities included a recommissioning study approach that was supplemented with additional field data monitoring and in-depth discussions with the facility's technicians. The investigation efforts included:

- Detailed review of plans,
- Detailed on-site observations of the pool area and systems,
- Spot measurements of conditions and performance (e.g. HVAC system air flow),
- Long-term monitoring of key operating parameters,
- Long-term monitoring of system energy use indicators,
- Repeated discussions with operators and management about pool operations issues.

The long-term monitoring approach was tailored to each site's combination of equipment, building automation system (BAS) logging capabilities, and expected operations improvements. This was done to both maximize the number of sites that could be addressed within the project budget, and to emulate the experiences and challenges that a recommissioning provider would encounter. More resources were invested where it was necessary to obtain a more definitive long-term monitoring of the energy impact of operational changes (e.g. BAS upgrades to allow for trend logging or long-term use of multiple channel research grade data loggers). A site by site summary of those parameters monitored for the long-term appears in *Appendix A. Long Term Data Monitored at Detailed Investigation Sites*.

After initial investigation efforts and preliminary long-term monitoring results were compiled and analyzed, we worked the facilities to implement specific operational improvements at the test sites. For improvements that involved contractor expenses, we covered the cost up to $5,000. This incentive was to allow us to learn from the implementation. By expediting the implementation we were able to observe follow-up operation, and to collect adequate post-implementation data over a range of conditions to allow for a meaningful comparison of pre and post implementation performance and energy use.

The comparative analysis of pre and post implementation performance and energy use for each site and measure was chosen to provide the most representative comparison possible. Differences in performance were then used with typical meteorological year (TMY) data to estimate the annual energy savings achieved for each measure at each site. The analysis approach was guided by the range of data and form of the relationships between equipment energy use and outdoor temperature for each particular site and measure. For example, when both pre and post sets had a wide range of outdoor temperatures and the relationship between energy use indicators (e.g. pool heater runtime) was linear, a linear least-squares regression model was applied. On the other hand, when the physics and observed data showed non-linearity, BIN analysis was used (i.e. relationships were determined by averaging data points within each 5°F span of outdoor temperature).

Development and Refinement of Two Guides for Energy Efficient Operation

Separate quality maintenance and operations guides were prepared for two different audiences: technicians; and recommissioning providers. The technician audience includes facility maintenance staff and outside contractors. This is both because of the variation in responsibility between on-site staff and outside contractors, and also because of the importance of having owners and operators be able to have a common language and tools for communicating with contractors about operations issues. Similarly, the recommissioning guide will be valuable to both recommissioning providers with little expertise in pool equipment or datalogger monitoring, and amongst other CIP program staff. Each of these guides, listed below, was developed to include measures and equipment specific guidance for understanding, diagnosing and correcting suboptimal maintenance and operation.

- Operator's Guide to Energy Efficient Indoor Pool Operations

- Recommissioning Guide for Indoor Public Pool Facilities in Minnesota

Each document was tailored to the expected needs of the intended audience. For example, the technicians guide was developed to mirror the design and flow of the Sustainable Buildings 2030 Energy Efficient Operations (EEO) manual approach (CSBR 2017), while keeping as much as practical within a single document. The EEO is based on a master list of items to check at various intervals with a clearly directed list of steps to take to check and make corrections for each item, with as much consistency in look and steps between items as is practical. The technician's guide was also designed to supplement widely distributed pool operator resources used in training pool operators for certification (NRPA, NSPF). In contrast, the development of the recommissioning providers guide aimed to provide an engineering level understanding for applying a technology, as well as guidance for field measurements and analysis approaches. The technical scope and improvement measure list was also intended to be more comprehensive in the recommissioning provider's guide. This guide is written for professionals with the capability to understand and diagnosis complex issues. The guide also is intended to ensure that the engineers consider low to moderate cost capital upgrades at the time of engineering study. In contrast, the technician's guide was meant to focus primarily on operational improvements that do not involve upgrades (beyond repairing improperly operating equipment).

The clarity and practicality of the guides was tested and refined with a number of pool facility technicians and recommissioning providers that were not involved in the creation of these guides. These professionals were provided with the guides and time allowed to review in the guide detail and/or to try applying it to a facility in the pilot phase of the project. The targeted number of individuals and facilities for inclusion in the testing and review is noted in Table 4 below.

Phone recruiting of facility staff was from the set of sites surveyed, excluding those facilities where detailed investigations were performed. Individuals were asked if they would commit to going through the guide within a few weeks, and a phone interview was also immediately scheduled in most cases. Feedback from facility staff operators was limited to phone interviews, except for one site where the operator expressed interest in going through the manual in more detail. When operators were not prepared or available at the time of scheduled phone interviews, at least three follow up attempts were made by phone and/or email in an effort to solicit the maximum amount of feedback.

Contractors and recommissioning providers were recruited based on recommendations of local professionals that deal with facilities that have indoor public pools. They were also offered nominal incentives (paid to professional's employer) to review the guides and provide feedback at a face-to-face meeting. Similarly, at least 4 phone calls and/or follow-up emails to reach out to the individual when original plans for feedback did not work out.

Table 4. Draft Guide Distribution for Testing & Feedback

Guide	Type of Professional	Number Targeted
Technician	Facility Staff	9

Guide	Type of Professional	Number Targeted
Technician	Contractor	3
Recommissioning	Recommissioning Engineer	2

Quantification of Savings Potential and Guidance for CIP Program Calculations

Statewide Impact Potential Estimation

The project's findings were used to develop state-wide energy savings potential for a number of specific, applicable operations improvement measures. This synthesis of information from the baseline characterization findings and detailed site investigation findings was supplemented with additional engineering calculations as needed. The nature of the findings from the characterization and detailed site investigations guided the choice of the most appropriate final calculation methods. The overall calculation results were compiled to provide valuable information about expected savings potential for energy efficient operations improvements in indoor public pool facilities in Minnesota.

Both the on-site surveys and detailed investigations were used to make estimates of the prevalence of specific measures for improving operations. The on-site surveys collected data from a larger sample of buildings, and were able to capture applicability and prevalence information for a few, easy to identify measures. On the other hand, while the detailed investigations were able to identify some specific opportunities that the surveys did not, they were only conducted at six sites. Therefore, extrapolation of the frequency of occurrence of these harder to identify measures to a larger population of buildings will have more significant uncertainty. Similarly, the energy impact realized at the few test sites gives only a rough indication of the savings that would occur across a full-scale program population.

The small number of investigated buildings within each category (small and large pool facilities) also led to some cross-over in the use of findings. For example, while none of the large pool buildings had HVAC setpoint changes that provided electric savings, the presence of electric savings in one of the small pool buildings—along with a review of setpoints in the survey—suggest that with a larger sample, some large pool buildings would be able to achieve savings by making HVAC setpoint adjustments that reduce the load on the dehumidifier, thereby providing electric savings. The per site electric savings from the small pool buildings was then doubled to conservatively account for the size increase and then assumed to apply to only 1 in 4 large pool facilities. In a similar manner, the average large pool facility savings potential was scaled to estimate the impact of recommissioning and/or detailed audits of small pool facilities. The savings values for each fuel were first divided by 4 (the ratio of average pool room size between the two categories), and then cut in half to account for the lower likelihood of finding as many cost-effective opportunities since transactions costs for measures typically don't scale down as much as measure savings when looking at smaller systems.

Calculation Guidance for Specific Measures

Information from available resources and the current study were used to develop specific technical guidance for energy saving calculations of six indoor pool energy saving operational improvements in Minnesota. This included 3 measures that are addressed by other TRMs and 3 measures for which no TRM precedent was found. The review of available resources included existing TRM manuals, publicly available calculation tools, pool calculators, and standard recommissioning approaches to savings estimation. The development of recommendations focused on areas where existing approaches were suspected of having significant inaccuracies or limitations, or where important opportunities were not already adequately addressed.

Results

Baseline Characterization

Facilities and Equipment

Basic information about the surveyed buildings and HVAC equipment is summarized in Table 5, while physical information about the individual pools and their water-side equipment appears in Table 6. These two tables provide information about building and equipment assets without regard to how they are currently operated. The complete details of all the sites and pools from the on-site survey data is presented in *Appendix B. Detailed On-Site Survey and Interview Data.*

The field survey validated the general categorization of pools and buildings suggested by local pool industry professionals. The pools in the hospitality and multifamily buildings were all well below the 2,000 square foot upper limit for “small” that was suggested, with an average size of 630 square feet. Likewise, the primary pool in each of the education and fitness center facilities were well above the 2,000 square foot lower limit for “large” that was suggested, with an average size of about 3,800 square feet. Therefore, the general expectation of finding small pools in hospitality and multifamily buildings and large pools in schools and fitness centers was confirmed.

Besides the primary pool, many of the facilities had an additional pool or spa in the same room. All hospitality and fitness center sites visited had a spa in addition to the pool, while only 2 of 7 multifamily buildings had a spa. One-quarter of the schools also had a diving pool that fell into the “small” pool size range while the fitness centers each had a second “large” pool (i.e. one lap pool and one recreational/leisure pool).

All of the sites visited used natural gas to heat the pool water with variations in the equipment used. At least one-third of the large buildings use high efficiency condensing equipment for pool heating, while only about 1 in 7 of the small buildings does. One-third of the small pool buildings use packaged pool heaters designed with the pool water flowing right through them. All of the other buildings use heat exchangers with hot water or steam to heat the pool water. Among the buildings using heat exchangers, there is a roughly even mix of the following:

1) hot water is provided by a boiler (or water heater) that only serves pool area equipment
2) hot water or steam is provided by a central boiler system that serves the entire building
3) both of the above exist with seasonal switchover between systems

Nearly all surveyed facilities use sand filters. We also found one each of an open sand filter and regenerative filter, as well as two replaceable cartridge filter systems. The latter two filter types greatly reduce the dumping of heated pool water during the periodic backwashing that is required for sand filters.

Table 5. Summary of Assets in Facilities Surveyed

Building Type	# Survey-ed	# of Pools per Site	Pool Room Area [sf]	Total Fan hp	Fan VFD s%	Pool Space Main Heat Source	Space Heating Fuel Natural Gas	Natural Gas Eff.	Compress-orized Dehumid.	Condenser Reheat %	Heat Reclaim to Pool Water %	Heat Recovery Ventilatio n %
Hospitality	8	2.0	2,431	2.9	25%	2 hot water; 2 electric; 3 direct-fired; 1 none	78%	91%	100%	25%	25%	0%
Multi--family	7	1.4	2,403	3.6	43%	2 hot water; 3 direct-fired; 1 none; 1 unknown	100%	87%	0%	-	-	14%
School	11	1.4	8,038	33	64%	6 hot water; 5 steam	100%	87%	82%	45%	27%	27%
Fitness Center	4	2.5	9,689	41	50%	4 hot water; 1 also direct fired	100%	91%	50%	25%	0%	25%

A key defining factor in the pool area HVAC equipment is whether dehumidification is only provided by ventilation with "dry" outdoor air, or whether the system uses at least one compressor to dehumidify the pool room air. The small pool buildings showed a clear split with the hospitality buildings using compressorized systems and the multifamily buildings using outdoor air only systems. For the large pool buildings there was consistency between the education and fitness centers with both types having compressorized systems in two-thirds of the buildings.

Table 6. Summary of Assets in Pools Surveyed

Building Type	#	Area	Cove r%	Filter Type % sand	Heat Source-dedicate d %	Seaonal swtich between sources	Pool Heat Eff-dedicate d	NG as Pool Heating Fuel %	pump hp
Hospitality	8	639	0%	88%	75%	0%	85%	88%	2
Multifamily	8	569	0%	100%	50%	0%	80%	88%	2
School	15	3,032	40%	80%	33%	33%	86%	67%	14
Fitness Center	7	3,626	0%	100%	43%	0%	86%	100%	12
All Small	20	670	0%	95%	55%	10.0%	83%	75%	3
All Large	16	3,741	25%	81%	44%	25.0%	84%	88%	17

While the main heat source for all large pool buildings is a hot water or steam coil, the heat sources are much more diverse for the air handling systems serving small pool areas. Three of these small pool room systems use electric resistance as the primary heat source, although they were designed with supplemental heat also provided by dehumidifier heat recovery. Three small pool rooms are heated by hot water coils while six are heated by direct-fired make-up air units.

Heat recovery ventilation was found in one-third of the large pool buildings, but in only 1 of the 15 small pool buildings. Similarly, about half of the large pool buildings were designed to heat pool water with heat recovered from the dehumidifier, but this feature was only designed into 2 of the small pool buildings.

Operations and Opportunities

Key operating conditions observed during the 30 on-site pool surveys are summarized in Table 7 and Table 8. Some of the most important findings from operating conditions observations are highlighted in the list below

- Control problems and misunderstanding of HVAC controls was very common. Although there wasn't one specific survey question regarding this, the high frequency of issues noted led to the addition of this category.
- A significant fraction of facilities have what industry standards regard as improper relationships between pool and space temperature.
- One-third of the buildings with large pools have covers (or had at one time), but only half of those that currently have a cover are using it.
- Although nearly half of the sites with large pools were designed to recover heat from the dehumidifier to heat pool water, most sites have disabled this feature due to problems.
- The space heating was not operational in two of the small buildings, leading to heating of the space by the pool itself (and the pool water heat source).
- The pool water flow rate was often much higher than code requirements in small pools, and moderately higher a small fraction of larger pools
- Significant valve throttling was observed in nearly all secondary pools in schools and fitness centers, and more than a quarter of the primary pools in these facilities.

More detail regarding the pool water flow rate control findings are noted in the following paragraphs.

Table 7. Summary of Operating Conditions in Facilities Surveyed

Building Type	Number Surveyed	Occupied Hours	Measured Air Temp [F]	Measured RH	Conden--sation Signs %	Supply Flow [cfm]	Control Problem	Odors
Hospitality	8	53%	78	50	50%	3,200	38%	33%
Multifamily	7	28%	77	51	29%	2,142	57%	0%
School	11	39%	78	53	45%	17,712	18%	9%
Fitness Center	4	73%	83	31	25%	25,985	75%	0%

Elevated Flow Rates. A large number of pools have opportunities to save some of the energy used to pump the continuously recirculated water through the filter, disinfection system, and heat source. Two thirds of the small pools were found to have pool water circulation rates at least 25% higher than the pool code requirements (i.e. a pool volume turnover time of 6 hours). As a group, these pools with significantly elevated flow rates had averaged flows that were 67% above the code-required flow. Similarly 4 of the 9 spas in small buildings had flow rates more than 30% above the code-required flow, and these averaged 35% above the code required flow rate. On the other hand, only about 30% of the larger pools have flow rates that exceeded the code required flow by more than 15%. Those pools with flows significantly above the required flow can achieve savings by adjusting balancing valves to bring the flow down.

Table 8. Summary of Operating Conditions in Pools Surveyed

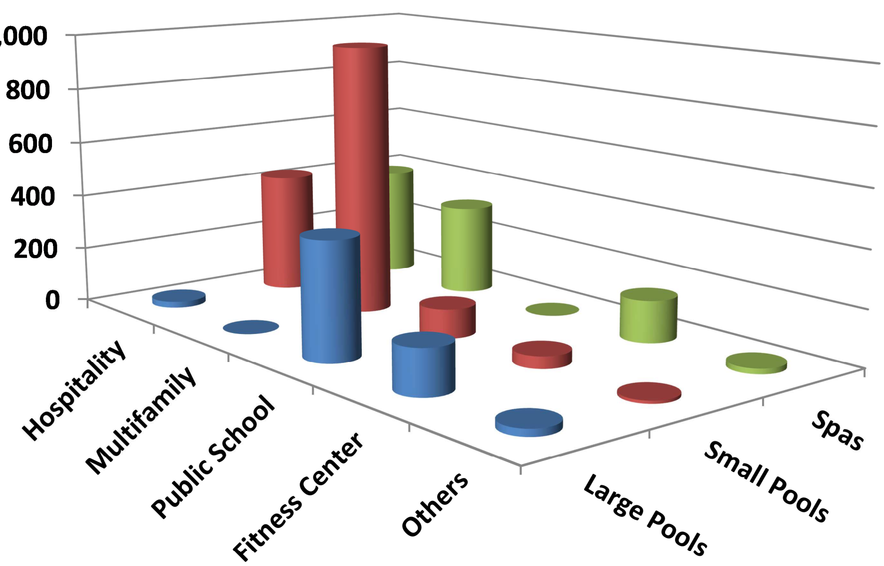
Building Type	Pool Probe Temp [F]	Pool 1 Return Sensor Temp [F]	vfd %	Valves Throttled %	Pool ValveThrottle Angle	Pool Cover Used %	Observed Turnover [hrs]	Flow % of Design
Hospitality	83	84	0%	0%	-	-	4.4	96%
Multifamily	83	80	0%	13%	30	-	4.2	106%
School	82	81	7%	33%	33	50%	5.3	106%
Fitness Center	85	84	29%	43%	65	-	4.0	104%
All Small	83	82	0%	20%	30	-	4.3	102%
All Large	83	82	19%	19%	60	50%	5.1	106%

Excessive Throttling. Another factor contributing to excess pool pumping use is a consequence oversized pumping systems that are then regulated with balancing valves. Excessive throttling of balancing valves was observed as a way to compensate for the excessive capacity. This is an inefficient way to achieve the proper flow rate. While this situation was only found in a small fraction of the pools, it could be the case in more of them after balancing the flow down to the current code requirement as noted in the previous paragraph. In these cases, achieving the proper flow rate by operating the pump at a lower speed (or using a properly sized pump) uses much less energy than forcing the pump to work against the extra pressure drop caused by pinching the flow down with balancing valves.

Statewide Facility and Pool Counts

Our best estimates of the statewide count of indoor public pools by facility and pool category is presented below in Figure 4 and Table 9. The total of about 2,200 pools and about 900 spas represent a significant population of pools for CIP program targeting. The highest populations of large pools are in public schools and fitness centers, and many of these buildings also have a secondary pool (and/or spa in fitness centers). Overall the highest total count of pools is estimated to be in multifamily buildings, while both hospitality and multifamily buildings also house a large number of spas.

Figure 4. Statewide Estimates of Indoor Public Pool Counts by Building and Pool Type *



*The categorization of pools between small and large is based on a 2,000 ft^2 breakpoint.

Table 9. Statewide Estimates of Indoor Public Pool Facility and Pool Counts *

Building Type	# of Buildings	Total # of Pools	# of Large Pools*	# of Small Pools*	# of Spas	Total # of Pools + Spas
Hospitality	444	455	22	433	395	839
Multifamily	972	972	0	972	324	1,296
Public School	418	522	418	104	0	522
Fitness Center	160	203	160	43	150	353
Others	35	35	25	10	19	54
Total	2,029	2,176	625	1,562	888	3,064

*The categorization of pools between small and large is based on a 2,000 ft^2 breakpoint.

Detailed Investigation and Implementation at 6 Sites

Detailed investigations found significant opportunities for energy savings through a variety of no-cost to moderate cost operational improvements. The savings associated with specific measures at specific sites is detailed in Figure 5 and Table 10.[1] The figure and table also clearly note which values are based on engineering calculations and which are based on observed, long-term performance over similar operating conditions. The majority of energy savings potential was found in HVAC control setting changes and/or upgrades, with pool covers having the second most common significant opportunity.

HVAC Control Measures

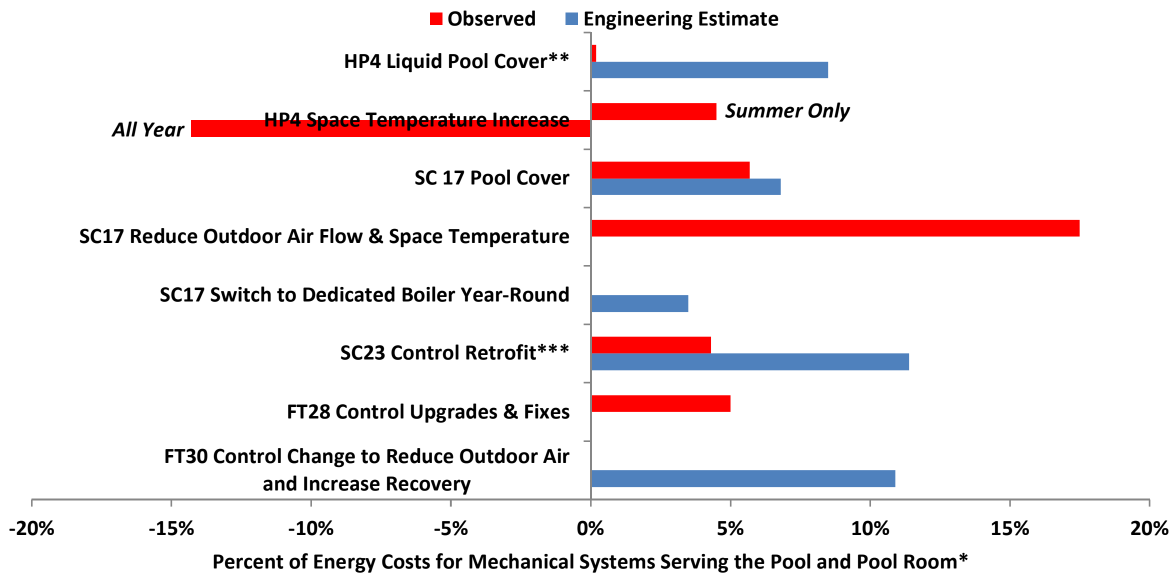
Opportunities to reduce energy costs through HVAC control changes were found in all six sites, and these HVAC control changes were also the largest potential savings opportunity for five of the six sites. The HVAC control change measures can be categorized according to no and low cost set point changes, and moderate cost control upgrades.

HVAC Setpoint Changes

Space temperature changes were identified as an opportunity for three facilities based on the general industry recommendation that air temperature be kept 2°F to 4°F above the pool temperature (up to a maximum of 86°F) to save energy through reduced evaporation (ASHRAE 2011). At SC17 this led to a reduction in space temperature and was coupled with other setpoint changes that reduced the outdoor air ventilation rate significantly for most of the year. These control setting adjustments at SC17 had the largest savings for any measure both in terms of energy cost savings and savings as a percentage of the facility's energy costs. In two other sites space temperature setting increases were recommended to get the space temperatures 2°F to 4°F above the pool temperature. This was not implemented at MF14, but implementation at HP4 showed disappointing results. While we observed a modest savings in the summer months from this change, we also saw energy cost increases in cooler weather that went far beyond the savings seen in the summer so that he annual energy costs increased significantly with this change.

[1] Site MF14 also had HVAC control adjustment and liquid pool cover savings potential similar to those for HP4, but these were not implemented and/or reported in the table due to a lack of follow-through by facility staff, property management changes, and HVAC equipment failures that affected results. Similarly, additional HVAC control changes were identified for HP4 and FT28, but observed savings was not reported due to limited data and/or gross inconsistencies in pre/post conditions.

Figure 5. Savings for Measures Found at Detailed Investigation Sites



*Annual energy costs are based on assumed effective billing rates of $0.60/therm and $0.11/kWh.

**It appears as though unplanned changes in the operating conditions (most notably outdoor air ventilation rate) may have unduly impacted the results for this measure.

***The observed performance was dramatically impacted by an error in the new controls program that caused severe overheating and with a large energy penalty. This was identified and corrected, but not until after detailed monitoring had ended at this site.

It appears that the disappointing result is based on some simplifications behind the standard recommendation that did not hold true in the case of HP4. First of all, the expected reduction in evaporation is based on an assumption that the pool area's relative humidity would stay constant with the change in temperature, while our monitoring shows that this is not the case—especially during swing and heating season weather or very hot weather. Moreover, this recommendation appears to focus on pool water heating and dehumidifier energy use without considering the additional energy needed to heat the large amount of fresh outdoor ventilation air up to the higher room temperature. The space heating energy penalty was also amplified for HP4 because of the high fuel cost for the electric resistance heat source that the HVAC system used. The results from the various investigated sites led us to conclude that reducing elevated space temperatures down to the level of the pool temperature can provide significant savings in some cases, but that space temperature increases to a few degrees above the pool temperature are not recommended during the heating season.

An alternative approach to minimize evaporation—without increasing the ventilation air heating load—is to increase the humidity setpoint. While low humidity may be needed in very cold winter weather to prevent condensation problems (e.g. on windows, door frames and the ceiling), higher humidity can be tolerated during much of the year. A temporary inadvertent relative humidity setpoint change during long-term monitoring at FT28 suggested significant energy benefits (although variability in outdoor air and other operating conditions made it impossible to reliably estimate the annual savings that would have been realized).

Table 10. Savings for Measures Found at Detailed Investigation Sites

Site	Measure	Annual Energy Cost Savings**	% of Energy Cost	Gas Savings [therms]	% of Gas*	Electric Savings [kWh]	% of Electric*	Measure Cost	Payback Period
HP4	Liquid Pool Cover (Engineering Estimate)	$1,410	8.5%	590	22%	9,599	7%	$1,000	0.7 years
HP4	Liquid Pool Cover (Observed)***	$28	0.2%	-254	-9%	1,639	1%	$1,000	36 years
HP4	Space Temperature Increase—All Year	-$2,363	-14.3%	-474	-17%	-18,893	-14%	$0	Never
HP4	Space Temperature Increase—Summer	$744	4.5%	76	3%	6,352	5%	$0	Immediate
SC17	Pool Cover (Engineering Estimate)	$2,604	6.8%	4,340	13%	0	0%	$2,500	1.0 years
SC17	Pool Cover (Observed)	$2,160	5.7%	3,600	11%	0	0%	$2,500	1.2 years
SC17	Reduce Outdoor Air Flow and Space Temperature	$6,644	17.5%	11,074	33%	0	0%	$1,500	0.2 years
SC17	Switch to Dedicated Boiler Year-Round	$1,316	3.5%	2,194	7%	0	0%	$0	Immediate
SC23	Control Retrofit (Engineering Estimate)	$3,946	11.4%	1,300	6%	28,780	12%	$9,000	2.3 years
SC23	Control Retrofit (Observed)****	$1,638	4.3%	-2,487	-12%	28,453	12%	$9,000	5.5 years
FT28	Control Upgrade & Fixes	$5,392	5.0%	-23,507	-67%	177,242	23%	$15,700	2.9 years
FT30	Control Change to Reduce Outdoor Air and Increase Recovery	$5,623	10.9%	6,613	12%	15,048	9%	$3,500	0.6 years

*Percent of gas and electric use are reported based on the energy use of mechanical systems serving the pool and pool room.

**Annual energy costs are based on assumed effective billing rates of $0.60/therm and $0.11/kWh.

***It appears as though unplanned changes in the operating conditions (most notably outdoor air ventilation rate) may have unduly impacted the results for this measure.

****The observed performance was dramatically impacted by an error in the new controls program that caused severe overheating and with a large energy penalty. This was identified and corrected, but not until after detailed monitoring had ended at this site.

*****Site FT28 is also estimated to save >$15,000 per year in maintenance costs from not having to replace a compressor every 1-2 years under the previous control conditions.

It is believed that the most significant component of control setting savings at SC17 was from bringing the outdoor flow down from its previous excessive level. While many pool HVAC unit controllers do not make the outdoor air settings readily apparent and changeable, adjusting outdoor air setpoints to appropriate levels is expected to be the single biggest no-cost opportunity for energy savings when available.

Another no-cost savings opportunity at SC17 was to stop doing seasonal changeover of pool area HVAC and water heating source. They have historically use the central boiler system during most of the school year, and then switched to a smaller, dedicated boiler system to serve all of the pool area mechanical equipment when the central boiler system was not needed for the remainder of the building. However, the dedicated seasonal boiler is a high efficiency condensing boiler that is about 10% more efficient than the central boilers. This no-cost change in operations is expected to save more than $1,300 per year.

HVAC Control Upgrades

Cost-effective control upgrades with significant savings were identified in three of the four large pool buildings investigated. In two of these cases, better control of outdoor air was a key contributor to energy savings, and both of these sites had opportunities to realize both gas and electric use savings. Unfortunately one of these sites, SC23, initially saw a dramatic increase in gas use due to an error in the new program for the HVAC unit controller (that was corrected at the end of the monitoring period). The control upgrades undertaken at SC23 were the addition of a variable speed drive to the HVAC supply fan for overnight reduction in flow and a detailed factory start-up (which had never happened when it was first installed) to correct a number of minor issues.

Site FT30 also had a large savings opportunity identified, which called for bringing the normal occupied mode outdoor air ventilation down from excessive levels to the code requirement and making better use of the existing heat recovery ventilation. This would provide savings in both fan power and outdoor air heating, although it was not implemented due to a long-term inability of the existing pool area HVAC unit to interface with the new BAS that was installed.

The third site with significant savings from a control upgrade achieved most of the savings through the correction of a problem with hot water coil heating control. Net cost savings was achieved through a combination of dramatic electric savings and an increase in gas use. This is because improper control limited the hot water coil capacity to only 20% of its design and the HVAC unit made up for this inadequate heat by running the dehumidifier compressor continuously throughout the heating season. The coil and air flow configuration made this compressor’s heating efficiency closer to that of an electric resistance heat source than that of a typical heat pump, and the long operating hours contributed to the need to replace the compressor at least once every two years. Correcting this problem while upgrading the connectivity between the BAS and pool area HVAC unit provided energy savings and more reliable control over the unit at the same time.

While cost-effective HVAC control upgrades were identified in three of the four large buildings receiving detailed investigations, engineering expertise was required for the identification and/or implementation of these upgrades in a way that would not negatively impact indoor air quality. Monitoring beyond a one-time site visit ended up being important for identifying the opportunity or correcting implementation issues in two of these three facilities.

Current issues with controls and equipment operations had a significant impact on most sites investigated. In some cases, improvements in control systems were able to provide energy cost savings and collateral benefits at the same time. On the other hand, challenges with building automation systems (BAS) and complex HVAC unit controls impeded the identification and implementation of measures at other sites. Examples of significant problems (beyond the energy saving opportunities described above) at the investigated sites include:

- HP4 had suboptimal coordination between external electric resistance heaters and the control of heat reclaim from the dehumidifier.
- Failure of an electric outdoor air heater led to long-term failure to provide adequate space temperatures at HP4
- Improper control of combustion air supply and its heating led to pool heater back-drafting concerns and severe overheating of the mechanical room at HP4
- Outdoor air damper actuator failure at MF14[2]
- Water fill procedure and pool heater control combination led to frequent, temporary overheating of the pool at MF14
- Failure of a pool heater to heat over the course of a season was not recognized at SC17
- Pool area depressurization was improperly controlled at SC23
- When the manufacturer upgraded the HVAC unit program, improper control of the steam heat dramatically overheated the pool area at SC23
- Inadequate connection between the BAS and HVAC unit required a local controller upgrade to allow for the collection of data needed for investigation at SC23
- Improper damper control and failures at FT28 led to below code outdoor air ventilation rates
- Inadequate connection between the BAS and HVAC unit required the use of dataloggers for investigation at FT28
- Repeated relative humidity sensor failures and the original BAS systems's inadequate BAS connectivity and trending capability both resulted in poor control and limited investigation efforts at FT30

Although the outdoor air damper actuator at MF14 failed in a minimum air position that did not increase energy use (but may have limited the ability to adequately dehumidify for part of the year), if it had instead failed in a position that provided a higher outdoor air fraction it would have dramatically increased energy costs in a way that likely would not have been noticed by on-site staff. Therefore, the absence of an energy saving control upgrade or repair opportunity at the two small pool sites receiving detailed investigations does not necessarily indicate that they would not be commonly found in a larger sample of buildings.

[2] This was repaired early in the long-term monitoring period, and then failed again later in the monitoring period.

Although improved operation of heat recovery ventilation (HRV) was not included in the title of any of the improvement measures presented above, there were opportunities for improvements in HRV operation at two of the three investigated sites where they are present. Recent field research in Minnesota has highlighted how common it is for heat recovery ventilation systems to have opportunities for improving operating efficiency by simply correcting relatively low-cost control problems (Quinnell 2017). The specific opportunities for operational improvements at the two sites are described below:

- Investigation at SC23 found that the HVAC unit's HRV was not operating at its full capacity because of severe imbalances in airflow in spaces adjacent to the pool room. Inadequate or no flow through locker room HVAC systems caused significant air flow between these spaces and pool room through intentional air openings between these spaces. Correction of these adjacent HVAC systems led to more effective use of the HRV because it had more balanced flow of fresh outdoor air and exhaust air. The interactive effects between the spaces made it difficult to quantify the net energy impact of these changes, which were made for both indoor air quality and proper control than for energy savings.
- Investigation at FT30 suggested that very little outdoor air was being brought in through the HVAC unit with an HRV, but it was instead being over-supplied by a make-up air unit without an HRV. The control change presented in the analysis includes some improved HRV usage savings accomplished by reducing the air flow of the make-up air unit and increasing the amount of outdoor air brought in through the unit with an HRV so that the code-required ventilation level would be provided.

While the specific upgrades needed and their savings potential by fuel vary substantially between sites, it is clear that detailed review of pool room HVAC equipment operation through recommissioning can regularly find opportunities to cost-effectively save energy. Better control of outdoor air is a key factor in most of these opportunities, and when HRVs are present improvement in their usage is also a common area of opportunity. Problems with HVAC controls present both challenges and opportunities with this specialized equipment and application.

Pool Covers

After improved HVAC control, pool covers were the second most important energy savings opportunity among the sites receiving detailed investigations. These provide energy savings by blocking the evaporation of pool water into the pool room. Evaporation is by far the biggest heating load on public pool heaters (ASHRAE 2011), and also increases energy use by the HVAC unit when dehumidification is needed. We looked at opportunities to use either a traditional pool cover or a liquid pool cover.

At the start of investigation, a traditional pool cover was in place at SC17, but not used because of a need for repair. Over the course of long-term monitoring, it was repaired and the staff then alternately went through periods of using and not using it overnight to allow for data collection under both conditions. The monitored data showed that the pool's water heating heat exchanger did not function during most of the school year, so observed energy savings was actually in the form of reduced HVAC system heating energy use (as the water was indirectly heated by the air in the pool area). Review of short-interval trend data showed a marked drop in humidity when the cover was used during cold weather, but the data also showed that the cover was not used every night during periods that it was supposed to be used nightly. In warmer weather when the outdoor air was more humid this data review was not able to reliably distinguish between nights that the pool was covered and those when it wasn't. Therefore our analysis of energy savings conservatively ignored any potential summertime savings associated with the use of the pool cover. Even so, this conservative annual savings estimate of 3,600 therms savings is only about 20% less than the engineering estimate of annual savings.

The use of a liquid pool cover product was also evaluated for the small pool buildings that received detailed investigation. This is a product that spreads out in a thin, invisible layer over the top of the pool water to slow down water evaporation. Although it only partially reduces evaporation instead of completely stopping it like a traditional pool cover, the liquid pool cover is effective whenever the pool surface is calm. This allows it to provide savings in between periods of intermittent pool use. Recent CARD funded research (Michaels Energy 2015) and engineering calculations both suggest substantial energy savings with a good payback for this technology. While our long-term monitoring did show a moderately lower pool room humidity with the use of the liquid pool cover, the energy savings were much less than anticipated. Spot observations confirmed that the automatic feeders that add this product to the pool daily were drawing down the level of the product in the containers, although this was not tracked closely enough to confirm that the supplier's recommended dosage was being followed. While our investigation approach more directly measured energy usage and more rigorously addressed consistency between pre and post outdoor air, pool and space conditions than the Michaels Energy study, we do have some small doubt about whether unintentional changes to outdoor air ventilation were consistent across the primary comparison periods as well as some uncertainty about whether or not dramatic increases in mechanical room temperature observed during the liquid pool cover usage period may have biased the results in some way (e.g. causing errors in pool temperature or HVAC unit controllers). While our monitored findings were disappointing for the site we tested, the combination of high theoretical potential savings and numbers of possible program participants suggests that further evaluation of this technology is needed before a definitive recommendation can be made regarding its inclusion in a regular CIP program.

Operations and Recommissioning Guides

A cornerstone of this project was the successful development of two indoor public pool guides focused on energy efficiency in existing facilities. These guides, titled *Recommissioning Guide for Indoor Public Pool Facilities in Minnesota* (CEE 2017A) and *Operator's Guide to Energy Efficient Indoor Public Pool Operations* (CEE 2017B) are provides as separate, companion documents. These recommissioning and operations versions of the guides were completed with features targeted to the separate audiences, and were revised after soliciting feedback from the Department of Commerce, Division of Energy Resources, pool facility staff, contractors, and recommissioning providers.

This variety of feedback was solicited in order to get useful direction for making the guides more useful to the intended audiences. Reviewer feedback on the operator's guide was obtained via phone interviews with six facility staff and two contractors. Feedback on the recommissioning guide was obtained from two recommissioning engineers, one in-person meeting with an engineer experienced in pool facilities, and a combination of phone and email feedback from a second engineer that was less experienced with pool facilities.

While the feedback on the draft guides was generally positive, there were some common misunderstandings that were highlighted along with an indication that a number of operators were overwhelmed. For example, two facility staff made comments to the effect that, "We're not planning to make any changes soon." These were indicative of either a basic misunderstanding of the purpose of the operator's guide (i.e. to make sure that the equipment you have is operating optimally), or of the respondent generally being overwhelmed by the document and trying to find a face-saving reason to say that they didn't look through it in detail. In either case, this shows a possible need for the document to

- be more thoroughly introduced to technicians (a brief in-person explanation of the guide and orientation to its use),
- have a clearer up front description of its purpose, and/or
- be more user-friendly.

Some minor modifications addressed these issues in the hard copy version of the document, and a pdf version will be made available with numerous hyperlinks throughout to make it easier for a user to navigate while using it as a working reference document. While most updates to the draft involved clearer presentation of various items, there were also a small number of technical additions based on reviewer feedback or updated information from the other study activities. Based on the comments from reviewers, we are confident that both guides will be valued resources for local pool industry and recommissioning professionals.

The centerpiece of the technician's guide is a one-page "Energy Efficient Pool Operations Checklist" that pairs very brief summaries of 15 items with recommended frequencies for checking and references where further direction regarding the item can be found. Where other pre-existing resources already provide adequate guidance for some of these items, the checklist page directs guide users to the resource and specific page number. For six key items where adequate, readily available reference guidance was not available, detailed, step-by-step instructions are provided for the checklist item. Even more useful information for two of these checks is provided in additional reference pages included in the guide. The idea is that the user starts with the shorter reference information that does not look as overwhelming, and then jumps to additional reference information if need. It is expected that after a user goes through this a second or third time, there will not be a need to reference the deeper levels. While the hard copy version of the document may still be somewhat overwhelming to some operators, the use of live links to help with quick navigation to various parts of the pdf document should make the electronic version easier to use.

The recommissioning guide is built around a similar checklist, but addresses more opportunities and provides more direction that is specific to recommissioning providers. The recommissioning provider's measure checklist includes 17 items with brief summaries, an indication of how to identify the existence of the opportunity, and the same references to detailed information that is available in other resources or within the guide. The first additional section that is specific to recommissioning providers gives general information about the HVAC and water-side systems in pool facilities, the special operating condition requirements, and guidance for measurements and monitoring of systems. Another section provides a summary description, technical direction and tips for each individual measure.

Energy Savings Potential and Calculation Guidance

Statewide Savings Potential

The total statewide potential for savings from low to moderate cost operational improvements in Minnesota's indoor pool facilities is detailed in Table 11 below.[3] These are categorized by type of measure and maximum pool size in the applicable building. (The buildings with only small pools are multifamily and hospitality while the buildings with large pools are primarily schools and fitness centers.) The savings achieved through no-cost adjustments (noted with * in the table) are not added to the total for each category because each is followed by a measure or service that would capture the same savings. Also note that for HVAC setpoint change and recommissioning measures, the per building savings are already averaged across a sample of buildings that included some where no specific setpoint change opportunity exists. The percentage where the measure applies in these cases indicates the expected percentage of facilities where staff would have the technical capability to identify and implement this operational improvement through the use of the operator's guide that was developed through this project. For pool pumping measures, this percentage denotes the fraction of buildings where the current operating condition makes this measure applicable.

While variable speed pumps represent a significant fraction of the potential savings within each category, recommissioning and/or audits have the largest potential savings overall—especially for gas savings and for large buildings. Adjustment of outdoor air flow was a key focus of many of the recommissioning measures. While less expensive to deliver, the no-cost operations savings potential appears to be relatively small compared to the savings that can be achieved with high quality recommissioning of buildings with large pools, and perhaps a scaled down similar service for buildings with small pools.

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[3] One measure in particular that had a dramatic mismatch between engineering estimates and observed savings was the liquid pool cover. The statewide potential calculation is based on assuming savings that is half of the expectation of engineering estimates. See page 35 within Pool Covers subsection for more detailed discussion.

Table 11. Statewide Savings Potential for Public Pool Facility Operational Improvements

Measures	Max Pool Size in Building	# of Buildings in Category	% Measure Applies	# of Buildings Measure Applies	Gas Savings/ Building [CCF]	Electric Savings /Building [kWh]	Statewide Potential Savings [MCF]	Statewide Potential Savings [MWh]
HVAC Setpoint Changes*	Small	1,394	50%*	697*	111*	3,176*	7,737*	2,214*
HVAC Audit or ReCx	Small	1,394	100%	1,394	798	2,754	111,172	3,840
Liquid Pool Cover	Small	1,394	100%	1,394	221	1,453	30,755	2,026
Pool Flow Balancing with Valves*	Small	1,394	50%*	697*	0	913*	0	636*
Variable Speed Pump(s)	Small	1,394	50%	697	0	5,820	0	4,057
Building Type Total	**Small**	**1,394**	**100%**	**1,394**	**1,018**	**7,117**	**141,927**	**9,922**
HVAC Setpoint Changes*	Large	635	33%*	210*	3,317*	3,176	69,657*	667
HVAC Recommissioning	Large	635	100%	635	6,380	22,035	405,130	13,992
Variable Speed Pump(s)	Large	635	33%	210	0	22,963	0	4,822
Building Type Total	**Large**	**635**	**100%**	**635**	**6,380**	**29,613**	**405,130**	**18,804**
Total All Buildings	**Large**	**2,029**	**100%**	**2,029**	**2,696**	**14,158**	**547,057**	**28,726**

*Values for these line-items were not added to the totals because the savings associated with each of these measures are mutually exclusive with the measure immediately following (within the same building).

Guidance for Individual Measure CIP Calculations

Other states have a very limited number of TRM items addressing indoor public pools. Specific recommendations for incorporating or adapting other states' TRM approaches for the following three measures into Minnesota's TRM are provided in *Appendix C. Recommendations Regarding TRM Manual Additions & Savings Calculation Approaches:*

- variable speed pool pumping
- high efficiency pool heater
- pool cover

Based on the absence of previous TRM guidance for other measures that provide significant potential for savings in indoor public pools, we also developed recommendations for CIP program calculations to use in program planning, recommissioning studies, and custom rebates for the following three measures:

- reducing outdoor air
- modifying pool room temperature control
- modifying pool room humidity control

The interactive effects between evaporation from the pool surface and space conditions makes analyzing these measures more complicated than in most applications. We also found that one particular common industry practice for calculating energy impacts for indoor public pool systems is seriously flawed when applied to facilities in Minnesota. In particular, the assumption that the pool area relative humidity stays at the setpoint year-round is flawed due the combination of high fresh air ventilation and our cold weather. With the high continuous outdoor air flow needed to dilute contaminants, the “dry” outdoor air in cold weather months usually brings the pool area relative humidity below typical controller setpoints. Properly dealing with this issue, and other recommendations for savings calculations approaches for the measures listed above are detailed in *Appendix C. Recommendations Regarding TRM Manual Additions & Savings Calculation Approaches.*

Discussion of Results

The large number of pools in specific building types makes it relatively easy for CIP programs to target facilities with pools. Also, programs that target hospitality, multifamily or school buildings could enhance their achieved savings by addressing energy saving indoor pool operations improvements as part of their regular program offering.

The potential for significant savings through well-informed recommissioning of indoor public pool facilities was demonstrated through this project's efforts. Additionally, the potential to achieve modest savings through no-cost operations improvements that can be identified by operators was also confirmed. While this was generally expected, many of the details we found regarding specific opportunities were enlightening.

First of all, industry standard recommendations for space temperatures in pool facilities do not appear to be optimal for Minnesota. In hindsight, we concluded that space temperatures should generally not more than 1°F above room temperature if a constant setpoint is used. We believed that a seasonal (warm weather) increase in relative humidity (or space temperature) setpoint is a better approach to minimize the combination of pool heating, dehumidication system, and ventilation air heating energy use (as opposed to having the space temperature a few degrees above the space temperature year-round).

We also found that some of the most often touted pool efficiency design features were not achieving their expected potential for savings. The first example of this was that complex dehumidifier designs that reclaim a portion of the refrigeration system heat for pool water heating have almost universally been abandoned within the first few years of operation (reportedly to do operational problems). At one site the pool water heating reclaim condenser built in to the unit had never even been piped to the pool system. Pool covers were another area where the field reality was often not matching the expectation. Most importantly, only half of the traditional pool covers that were found at facilities were being used. The high cost and inconsistency in both durability and usage (reported by operators and observed in our monitoring) makes the effective measure life of a pool cover hard to reliably estimate. However, pools that already have covers not being used because of a repairable or institutional issue that can be overcome can provide very cost-effective opportunities for achieving significant energy cost savings at low cost. Besides the challenges seen with traditional pool covers, the trial of a promising liquid pool cover technology also did not appear to show the expected energy cost savings at the one study site where it was observed. This technology does not depend on the daily actions of pool users and would be cost effective at all small pool facilities—especially those with compressorized dehumidifiers—if the savings are actually close to engineering estimates. Additional research or measurement and verification of early adopters is recommended before rolling out a full-scale rebate program offering for this technology.

While improved operation of complex dehumidifier heat reclaim equipment was expected to provide key opportunities, most of the energy savings potential was found in optimally controlling outdoor air and fixing more basic control system features that were not operating correctly (e.g. a heating valve actuator that was only ever controlled to be 20% open and a failed humidity sensor). Just getting optimal outdoor air control was a key item. While the variations in outdoor air control are different in pool facilities than other applications, the focus on outdoor air is similar to recommissioning activities in other facilities and does not necessarily require a high level of expertise in the dehumidifier refrigeration system details. The absence of pool water heating reclaim also reduced the effort needed to track the refrigeration operation while analyzing the systems for energy saving opportunities. While more optimal use of heat recovery ventilation equipment did contribute some savings, this was not a major contributor in the sites that we monitored in detail. The ability to capture most of the savings opportunities by focusing primarily on outdoor air and other air-side control—as opposed to complex refrigeration system operation that many recommissioning providers are not as familiar with—makes it more likely that adequate recommissioning of pool facilities can be accomplished by a wide population of engineers.

Conclusions and Recommendations

There is a large potential for energy cost savings by turning more focused attention to indoor public pool facilities in Minnesota. The largest energy savings opportunities in Minnesota's indoor public pools are a combination of items that are simple to define (e.g .pool cover), and operational changes that are more inconsistent between individual sites. The recommissioning provider guide developed through this project can effectively support getting more savings from recommissioning efforts for indoor public pool facilities. The operator's guide can also be used by on-staff operators and contractors to improve the operational efficiency of indoor public pools—including smaller pool that are located in facilities not typically reached by recommissioning programs. Promotion of a variety of program measures and approaches will achieve the most portfolio wide savings in these facilities.

Significant cost-effective energy savings can be achieved in indoor public pool facilities through no-cost, low-cost and moderate cost operational improvements. Modest savings can be achieved through no-cost HVAC and pool pumping control changes that many operators could implement through the use of the operator's guide prepared as part of this project. More substantial electric savings can be achieved through targeted installation of variable speed pool pump capabilities where flows are either substantially higher than needed, or where the appropriate flow rate has been achieved by excessive throttling of a valve. Moderate cost-effective savings may also be achieved in many instances by restoring a pool cover or using a liquid pool cover technology. However, the lion's share of savings potential is associated with recommissioning of indoor public pool facilities and subsequent implementation of control problem fixes and/or control upgrades—especially those addressing proper control of outdoor air.

CIP Program Recommendations

Based on the analysis performed and lessons learned in the this study, we have compiled the following recommendations for addressing indoor public pool facilities with CIP programs

- When recommissioning programs address buildings with indoor public pools, have recommissioning providers use the following guide developed as part of this project: *Recommissioning Guide for Indoor Public Pool Facilities in Minnesota* (CEE 2017A).
- Develop prescriptive or similar, simple to process rebate options for a limited number of items: packaged variable speed pool pumps (up to 3 hp), and the addition of variable frequency drives to larger pool pumps VFD [a nearly single-speed application].
- Direct recommissioning efforts towards indoor public pool facilities with guidance to providers based on the recommissioning provider's guide.
- Consider offering pilot or custom rebates for liquid pool covers with measurement and verification of the first few participants before undertaking wide promotion of this technology.
- Promote the use of the operator's guide among on-staff operators, HVAC contractors, and pool water system contractors.

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Appendix A. Long Term Data Monitored at Detailed Investigation Sites

Long Term Data Monitored at Detailed Investigation Sites

Site	Collection Method	Pool Heating Energy	Space Heating Energy	HVAC Electric	Conditions	Outdoor Air Flow	Other HVAC Data
HP4	HVAC Unit Logging, Multi-channel logger with cellular modem	Burner on-site for fixed firing rate pool heaters	Current transformers on electric heaters	Current transformers on entire unit and outdoor condenser	Pool water return temperatures (insulated outside of plastic pipe), Return air temperature and humidity	Temperature rise across heater (on/off damper)	Operating mode log, intermediate temperatures, and supply temperature
MF14	Multi-channel logger with cellular modem	Burner on-site for fixed firing rate pool heaters	Burner on-time and control signal indication of input rate**	Current transformer on exhaust fan	Pool water return temperatures (insulated outside of copper pipe), Return air temperature and humidity	Damper control signal**	Supply air temperature and humidity
SC17	BAS Trends*	Temperature change across pool side of heat exchangers	Temperature rise across heating coils	None (fixed fan speed and no compressor)	Pool water return temperature well; Return air temperature and humidity	Damper control signal, Combination of mixed air, return, and outdoor temperatures	Supply air temperature
SC23	BAS Trends,* Loggers with on-site data collection	Temperature change across pool side of heat exchangers	Temperature rise across heating coil	Power of supply fan, exhaust fan and unit	Pool water return temperature well; Return air and space temperatures and humidities	Damper control signal, Combination of mixed air, return, and outdoor temperatures	Operating mode log, HRV and other damper signals, fan VFD signal, pressure, intermediate temperatures
FT28	Multi-channel loggers with cellular modem and local link	Temperature change across pool side of heat exchangers	Temperature rise across heating and reheat coil combination, valve control signal**	Current transformers on supply fan and compressor	Pool water return temperature well; Return air temperature and humidity	Damper control signal, Combination of mixed air, return, and outdoor temperatures	Intermediate temperatures including for glycol heat recovery coil, refrigerant line temperatures
FT30	BAS Trends,* Logger with on-site data collection	None	None	None	Return Air Temperature, Space Temperature and Humidity***	Operation status of one unit via temperature sensors	Discharge air temperatures

*Building Automation System (BAS) trend data was collected by an existing building automation system. This required an upgrade to the local controller that interfaces with the pool area HVAC unit in the case of site SC23. At site FT30, limited BAS data was available at the beginning of the monitoring before a BAS system replacement was to take place, then the new BAS system was never successfully integrated with the existing pool area HVAC units.

**These instances of efforts to capture control signals with dataloggers did not accurately reflect the system behavior due to various problems (e.g. actuator failures, poor control signal reading).

Appendix B. Detailed On-Site Survey and Interview Data

Basic Site Information

Site Name	Facility Type	Year Built / Renovated	# of Pools	Pool Room Area [sf]	Pool Room Height [ft]	Exposed Interior Wall Area [sf]	Exposed Exterior Wall Area [sf]	Pool Room Volume [ft3]	HVAC Supply Height [ft]	HVAC Return Height [ft]	Exhaust Height [ft]	Ext. Window Area[sf]	Supply Washes Windows	Area Lighting Wattage	Underwater Lighting Wattage
HP1	Hospitality	1998/2012	2	2,379	17	2,668	1,560	40,435	0	13	8	360	Yes	1,847	300
HP2	Hospitality	2006	2	2,252	19.1' (Pool	3,721	1,299		0	8	8	711.5	Yes	1,200	300
HP3	Hospitality	2008/NA	2	2,987	15.49	-	621	46,264	Ceiling	Ceiling	no exhaust	498.15	Yes	number: (26*2	0
HP4	Hospitality	2009	2	2,555	11.3	549	2,182	28,872	Ceiling	Ceiling	Ceiling	497	Yes	2,500	unknwn
HP5	Hospitality	1999/2011/2014	2	1,384	10.86	941	579	15,029	Ceiling	Ceiling	Ceiling	267.87	No	1,600	200
HP6	Hospitality	2001	2	2,741	14.6	895	1,736	40,019	Floor Grills	Ceiling	Ceiling	429.36	Yes	2,200	0
HP7	Hospitality	2011	2	3,414	16.8	2,043	2,043	57,362	Ceiling	Wall - Low	nonw	1976.92	Partially	900	0
HP8	Hospitality	1996-1997/2012	2	1,739	8.46	1,149	419	14,713	Floor Grills	Ceiling	NA	280.179	Yes	312	400
MF9	Multifamily	1979/2014	1	1,833	17.1	2,686	334	31,339	NA	NA	7.1 ft	82.08	no	1,425	150
MF10	Multifamily	1968/2009	1	2,360	15.333	1,093	1,789	36,181	Floor Grills	0	Ceiling and	592.4342	Partially	975	0
MF11	Multifamily	1968(1986?)/ NA(exhaust fan seems	1	1,169	11.96	1,642	-	13,985	Ceiling	Ceiling	with RA	0	No Windows	978	100
MF12	Multifamily	mid 80/2014	2	1,922	9.833333	2,345	-	18,895	Ceiling	Ceiling	0	0	No Windows	3600+32 F lan	2 underwa
MF13	Multifamily	1997/1983/1993	1	1,936	20.22431	2,361	923	39,151	Ceiling	NA	Ceiling	323.4924	Yes	don't know	one not w
MF14	Multifamily	2002	3	5,633	13	698.75	2,556	73,227	Floor Grills	Ceiling	Ceiling	561	Yes	2,176	500
MF15	Multifamily	1964	1	1,968	31	480	5,345	61,008	8' hgt	0	Ceiling	306	No	338	0
SC16	School	2007	2	13,616	24	9,290	9,990	326,787	24	1	Return?	0	No Windows	19,850	None
SC17	School	1981/1990(?)	1	6,209	26.4	-	-	163,912	17.69	17.69	0	0	0	8,000	0
SC18	School	1996/?	3	-	0	-	-	0	0	0	0	0	0	-	0
SC19	School	1951 / 2004/5	1	7,458	25	8,758	6,500	186,455	25	25	Ceiling	533.75	Yes	4,224	1430
SC20	School	1968 / 2004/5	1	7,094	25	8,570	6,200	177,344	20	22	Ceiling	480	No	3,584	1430
SC21	School	2000	1	9,949	25.42	10,143	1,262	252,891	20-22	18-20	0	0	No Windows	6,912	2400
SC22	School	1968/2012	1	7,960	29.1	10,550	-	231,636	0	0	0	0(?)	No	3136~3584	0
SC23	School	1961 / 1967, 2009	1	6,626	?	?	?		Ceiling	Ceiling	Ceiling	0	No Windows	3,968	5100
SC24	School	1965/2012	1	6,728	22	2,050	5,137	148,005	Ceiling	0	4 @ 4', 4 @	300	No	4,352	2100
SC25	School	1969 / 1997	1	7,836	20.13	7,151	808	157,748	Ceiling	Wall - Low	-	0	No Windows	6,912	6000
SC26	School	1964/2009	2	14,945	18.25	4,270	4,416	272,746	Ceiling	Ceiling	na	573	Partially	10,914	0
FT27	Fitness center	1989/2006	1	12,835	22.45	10,183	-	288,149	Floor Grills	Ceiling	Ceiling	0	No Windows	3,000	0
FT28	Fitness center	0	3	10,919	29.01	-	(3 of 4 are e	316,774	Floor Grills	Ceiling	Ceiling	973.68	Yes	5,672	0
FT29	Fitness center	0	3	15,000	63.5	-	-	952,502	Ceiling	15 - 20 ft	0	0	No	9,312	0
FT30	Fitness center	2006	3	-	0	-	-	0	0	0	0	0	0	-	0

Additional Facility Asset Information

Site Name	HVAC Unit Location	Supply Fan hp	Exhaust/Relief Method	Return/Relief Fan hp	Fan VFDs	Pool Area Main Heat Source	Space Heating Boiler Fuel	Space Heating Efficiency	Cooling/Dehumidification	Condenser Reheat	Heat Reclaim to Pool Water	Heat Recovery Ventilation	HVAC Controls Approach
HP1	Same Room as Water Side Equipment	2	Separate Exhaust Only	-	No Fan VFD	Hot Water Coil	Natural Gas	94%	DX Coil with Compressors in Packaged Unit--Separate Condenser	Yes	Yes	None	Local Controller No BAS Monitoring
HP2	Same Room as Water Side Equipment	2	Separate Exhaust Only	0	No Fan VFD	Electric Resistance	Electric Resistance	100%	DX Coil with Compressors in Packaged Unit--Separate Condenser	Yes	Yes	None	Local Controller No BAS Monitoring
HP3	Separate Room Far From Water Side Equipment	5	0	0	0	0	0	0	0	0	0	0	0
HP4	0	2	Separate Exhaust Only	no access to	No Fan VFD	Electric Resistance	na	1	DX Coil with Compressors in Packaged Unit--Separate Condenser	Don't Know	No	None	Local Controller No BAS Monitoring
HP5	Separate Room Near Water Side Equipment	1.5	Separate Exhaust Only	don't know	No Fan VFD	Direct Fired Burner (in air stream)	Natural Gas	don't know	Outdoor Air Only	No	No	None	Local Controller No BAS Monitoring
HP6	Outside Near Water Side Equipment	0	Separate Exhaust Only	0	0	Direct Fired Burner (in air stream)	0	0.9	None or Packaged DX with HGR & separate condenser	Yes, but may be	No	None	Local Controller No BAS Monitoring
HP7	Oustide Far From Water Side Equipment	3	0	0	No Fan VFD	Direct Fired Burner (in air stream)	Natural Gas	0.9	DX Coil with Separate Condensing Unit	No	No	None	Local Controller No BAS Monitoring
HP8	Same Room as Water Side Equipment	1	through window	0.5	No Fan VFD	pool water/aux heat by electric	Electric Resistance	0	DX Coil with Compressors in Packaged Unit--Separate Condenser	No	No	use pool water to heat the air	Local Controller No BAS Monitoring
MF9	Oustide Far From Water Side Equipment	0	Separate Exhaust Only	0	0	NA	NA	0	NA	0	0	0	Local Controller No BAS Monitoring
MF10	Outside Near Water Side Equipment	3	Separate Exhaust Only	NA	No Fan VFD	Direct Fired Burner (in air stream)	0	0.9	None	No	No	None	Local Controller No BAS Monitoring
MF11	Same Room as Water Side Equipment	don't know	Separate Exhaust Only	don't know	No Fan VFD	Hot Water Coil	Natural Gas	80%	None	no	no	None	Local Controller No BAS Monitoring
MF12	Separate Room Far From Water Side Equipment	1	Return Fan with Relief in AHU Only	1	Supply & Return/Exhaust	Hot Water Coil	Natural Gas	0	Outdoor Air Only	No	No	Wheel	Local Controller No BAS Monitoring
MF13	Oustide Far From Water Side Equipment	3	Separate Exhaust Only	NA	don't know	Direct Fired Burner (in air stream)	Natural Gas	0.9	Outdoor Air Only	No	No	None	Local Controller No BAS Monitoring
MF14	Separate Room Near Water Side Equipment	3	Separate Exhaust Only	0	No Fan VFD	Direct Fired Burner (in air stream)	Natural Gas	0.9	Outdoor Air Only	No	No	None	Local Controller No BAS Monitoring
MF15	Same Room as Water Side Equipment	1.5	Separate Exhaust Only	1.5	No Fan VFD	Other--Apparently Pool (HW coils cut out)	Natural Gas	0.85	Outdoor Air Only	No	No	None	Local Controller No BAS Monitoring
SC16	Oustide Far From Water Side Equipment	50	Exhaust Fan in AHU Only	30	Supply & Return/Exhaust	Hot Water Coil	Natural Gas	0.93	DX Coil with Compressors & Condenser in Packaged Unit	Yes	Don't Know	Heat Exchanger	Local Controller with BAS Monitoring Only
SC17	Separate Room Far From Water Side Equipment	7.5	0	5	No Fan VFD	Steam Coil; hot water	Natural Gas	0	Outdoor Air Only	No	No	None	BAS Control of Everything
SC18	Separate Room Far From Water Side Equipment	15	0	15	0	Hot Water Coil(?)	0	0	0	might be	0	0	0
SC19	Outside Near Water Side Equipment	20	Both Return Relief in AHU & Separate Exhaust	10	No Fan VFD	Hot Water Coil; Perimeter radiation (hot water)	Natural Gas	96.9% (Central Plant) / 84%	DX Coil with Compressors & Condenser in Packaged Unit	Yes	Yes	None	Local Controller with Limited BAS Control As Well
SC20	Oustide Far From Water Side Equipment	20	Both Return Relief in AHU & Separate Exhaust	10+1 (EF)	No Fan VFD	Hot Water Coil	Natural Gas	98% "Possible" w Aerco /	DX Coil with Compressors & Condenser in Packaged Unit	Yes	Yes	None	Local Controller with Limited BAS Control As Well
SC21	Separate Room Far From Water Side Equipment	25	Separate Return	7.5	Supply & Return/Exhaust	Hot Water Coil	Natural Gas	0.8	DX w/ no known condenser. DH line to pool water, however.	Yes	Yes	None	AHU - Local, Pool Heating - on BAS and minimal control
SC22	Same Room as Water Side Equipment	20	10	use the same one	Return/Exhaust Only	Steam Coil	0	0	DX Coil with Compressors in Packaged Unit--Separate Condenser	Don't Know	Don't Know	0	Local Controller with BAS Monitoring Only
SC23	Separate Room Far From Water Side Equipment	20	Return Fan with Relief in AHU Only	7.5	Return/Exhaust Only	Steam Coil	Natural Gas	Unknown. Boiler	DX Coil with Compressors in Packaged Unit--Separate Condenser	Yes	Don't Know	Heat Exchanger	Local Controller with Limited BAS Control As Well
SC24	Separate Room Near Water Side Equipment	20	Separate Exhaust Only	10	Supply & Return/Exhaust	Steam Coil	Natural Gas	0	Outdoor Air Only	No	No	None	Local Controller with Limited BAS Control As Well
SC25	Same Room as Water Side Equipment	3hp (2 pool units)	Separate Return AND Exhaust	3 (2 pool units)	No Fan VFD	Hot Water Coil	Natural Gas	0.8	None	No	No	None	BAS Control of Everything
SC26	0	30	Both Return Relief & Exhaust Fan in AHU	15	Supply & Return/Exhaust	Steam Coil	Natural Gas	0.83	DX Coil with Compressors in Packaged Unit--Separate Condenser	0	No	Heat Exchanger	BAS Control of Everything
FT27	Separate Room Far From Water Side Equipment	25	Return Fan with Relief in AHU Only	15+15	No Fan VFD	Hot Water Coil	Natural Gas	don't know	Outdoor Air Only	No	No	None	BAS for AHU only
FT28	Separate Room Near Water Side Equipment	20	Return Fan with Relief in AHU Only	25	Supply & Return/Exhaust	Hot Water Coil	Natural Gas	0	DX Coil with Compressors in Packaged Unit--No Outdoor Condenser	Yes	In manual, but abandond	None	Local Controller No BAS Monitoring
FT29	Separate Room Near Water Side Equipment	50?	Return Fan with Relief in AHU Only	15?	No Fan VFD	Hot Water Coil	Natural Gas	0	DX Coil with Compressors & Condenser in Packaged Unit	No	Built into unit,	Heat Exchanger w/glycol loop	BAS Control of Everything
FT30	Oustide Far From Water Side Equipment	10hp & 5hp	Exhaust Fan in AHU Only	15	0	Hot Water Coil & Direct Fired Burner (in air stream)	Natural Gas	0	Outdoor Air Only	No	No	Heat Exchanger	AHU - Local, Pool Heating - on BAS and minimal control

Facility Operations Information

Site Name	Hours Occupie d/Week day	Hours Occupie d/Week end	Measure d Air Temp [F]	Measure d RH	Condensation Signs	Supply Flow [cfm]	Max OA Flow [% of Supply]	HVAC Fan On 24/7	HVAC Pressure Control	Setpoint Temp [F]	Control Temp Reading [F]	Setpoint RH	Control RH Reading	RH Control Method	Min OA Flow [% of Supply]	OA Control Approach	Problems	Odors
HP1	16	32	79.7	67.4	Multiple--	3000	0	Yes--Constant Speed	Don't Know	86	81	50-55%	41	DX/Condensing Unit	Unknown	Unknown	AHU was tripped off during site visit. Notable condensation in window sills, and signs of moisture at roof/wall connections.	Strong chlorine smell
HP2	12	24	74.2	65.3	None	3000-4525	Unknown	Yes--Constant Speed	Don't Know	Unknown, thermost at in	74	Unknown, thermost at in	71%	DX/Air-cooled condenser/ Water-	Unknown	Unknown	DHU was in alarm. Major corrosion on spa heat unit (suspect dielectric fitting issues). Had been very humid before new mechanical unit was installed.	0
HP3	16	32	82.4	52.1	None	5500	27%	0	0	0	0	0	0	0	0	0	Particulate build-up. Looks like salt particles. This is considered a saline pool.	0
HP4	15	15	79.3	44.1	Peeling paint	3400	0	Yes--Constant Speed	No Direct Measurement & Control	80	0	53	0	DX/Condensing Unit	0	Min unless Economize. Dehumidify too.		Minimal
HP5	5.50	15//7	79.2	29.4	None	2000 scfm	1	Yes--Constant Speed	Don't Know	82	~82	40~60	cannot read	Outdoor Air Only	no min value. Based on	Space/Return RH Setpoint	Sometimes in summer have issue maintain the humidity since there's no cooling.	Moderate Chlorine Smell
HP6	17	17	74.3	56.9	Droplets on door o	0	1	0	0	0	0	0	0	0	0	0	AHU on roof freezes up in winter	Minimal
HP7	17	17	83.8	36.8	None	4100	0	Yes--Constant Speed	No Direct Measurement & Control	83	0	25	88	DX/Condensing Unit	0	Min unless Economize. Dehumidify too.	Humidity/Moisture	Minimal
HP8	5	30	74.3	45.4	only on the exterio	don't know	0	Yes--Constant Speed	Don't Know	86	74	35	35 or 50	DX/Condensing Unit	0	NA	Sometimes have trouble maintaining the humidity. However they set the humidity setpoint to 35%, which is normally 40% to 60%.	Moderate Chlorine Smell
MF9	3	6	73.7	41.3	None	0	0	Yes--Constant Speed	0	no set point	73.7	None	0	0	0	0	no moisture problem. Saw pipe leakage on site(filter), circulation pump leak so they changed the pump yesterday	Minimal
MF10	4.5	9.25	69.2	45.4	None	3850	unknown	Yes--Constant Speed	Don't Know	80	0	NA	NA	NA	1	0	poor insulation, three exterior walls and big window/doors on each side	Minimal
MF11	3	6	81.5	45.1	None	don't know	don't know	Yes--Constant Speed	Don't Know	don't know	no access	no cooling coil, don't know	NA	don't know	don't know	don't know	all equipment is very old, no cooling, can feel cold air coming from the SA inlet but we didn't find the OA inlet, only one exhaust fan.	Minimal
MF12	4	8~28	80.9	70.3	None	0	0	yes-vfd control	Don't Know	80	83	80	100	Outdoor Air Only	Unknown	Space/Return RH Setpoint	None	Minimal
MF13	4.5	12	75.1	54	None	5000	unknow	Yes--Constant Speed	Don't Know	80	broken	0	NA	Outdoor Air Only	don't know	Space/Return RH Setpoint	temp. control of the AHU doesn't working. Operator just keep the switch in the Temp. control at the same position as when it was working, and notice no problem of mantaining the room temperature,	Minimal
MF14	18	18	81.8	48.4	Droplets on door o	4000	0	Yes--Constant Speed	Don't Know	0	0	0	0	Outdoor Air Only	0	Fixed Mixed Air Temperature	None	Minimal
MF15	13	13	77.2	51.8	Droplets on door o	0	0	No--Hours Off per Wk=____	None	unknwn	unknwn	unknwn	unknwn	Outdoor Air Only	0	0	Chilly winter air temps	Minimal
SC16	11.5	6	75.7	56.6	None	35000	51%	0	Don't Know	0	0	0	0	DX/Condensing Unit	0	Other--Complex Built Into Unit	Dive pool level was low	Minimal
SC17	12	5	78.4	49.8	Peeling paint	17000	0	Yes--Reduced Overnight	0	0	0	None	0	None	0	Fixed Mixed Air Temperature	Humidity/Moisture	0
SC18	13.5	13.5	88.4	47.9	0	18000	0	0	0	0	0	0	0	0	0	0	0	0
SC19	15.5	10	75.4	61	None	18000	100%	Yes--Constant Speed	Don't Know	72 +/- 2	75	50%	Unknown	DX/Condensing Unit	10%	Min unless Economize. Maintain DAT setpoint.	0	0
SC20	6	6	79.5	71	None	18000	100%	Yes--Constant Speed	Don't Know	73-74 per Operator	81.06	60%	97.80%	DX/Condensing Unit	30%	0	AHU tripps off, resulting in condensation/temperature, etc. Sheaves/belts are an issue. Aerco boiler appears to be losing glycol hot water.	0
SC21	13.5	7	71.7	58.1	None	24410	100%	Yes - VFDs and apparent DCV via CO2 (operator)	Don't Know	79 cooling 75 heating	0	43%	61.90%	DX w/ pool water condenser	40%	Unknown	Some corrosion, etc. Previuosly had been losing water out of pool basin. 3 repairs in last 5 years. Audio jacks are corroding and require replacement every few years. Chlorine metering system water temp sensor is reading incorrectly.	Minimal
SC22	10	Sat:10; Su	78.6	42	None	19000(?)	0	Yes--Constant Speed	0	0	0	0	0	0	0	0	0	no chlorine smell due to the new
SC23	6	2	83	48.8	None	15000	0.5	Yes--Constant Speed	Controlled vs Adjacent Space--Setpoint?	Unknown	84.9	Unknown	35.23%	DX/Condensing Unit	0.25	Min unless Economize. Dehumidify too.	Previously had cloudy water, poor ventilation before new Innovent AHU. Separated pool from locker rooms.	0
SC24	13	13	68.9	56.8	severe according to	14000	1	Yes--Reduced Overnight	Don't Know	73/60(unoc)	72	NA	No control	None	1	Constant	moisture drive through walls is a big problem, rebuilt east wall because of structural moisture damage.	Minimal
SC25	12	4	77.3	39.3	Peeling paint	Between 3000-9500 CFM	3000 X2	Yes--Constant Speed	No Direct Measurement & Control	80	78.4-79.6	Unknown	Unknown	None	Unknown	Unknown	Equipment Life--, Moisture, etc.	Moderate Chlorine Smell
SC26	16	8	78	51	na	0	0	Yes--Reduced Overnight	Don't Know	80	80.2	46	45.6	DX/Condensing Unit	Unknown	Space/Return RH Setpoint	0	Minimal
FT27	16.5	33	80.3	37.5	None	don't know	100%	Yes--Constant Speed	Don't Know	84	82	NA	NA	Outdoor Air Only	15%	Space/Return RH Setpoint	building new pools and the existing one will not be used from next spring. New system has VFD for water and cooling coils in AHU	Minimal
FT28	17	30	84.4	44	none	25985	0	Yes - VFDs and apparent DCV via CO2 (operator)	0	0	0	0	0	DX/Condensing Unit	21%	don't know	summer fully based on OA (no other dehumidification?)	Minimal
FT29	17	30	84.6	41.6	none	9400 cfm OA, 10400 cfm	0	Yes--Constant Speed	0	84	84	50	50	DX/Condensing Unit	0	consttant on or off	Dehumidifier controls hadn't work right, they replaced them all.	Minimal
FT30	24	24	83.4	0	0	8,000 & 8,000	75%	Yes--Reduced to 1/2 OA 11pm - 5am	0	0	79.5 - 84 drift	0	0	Outdoor Air Only	100% / 50%	MAU & Innovent Most/Innovent only overnight	BAS & Innovent won't communicate; perhaps daily water additions to the lap pool	Minimal

Individual Pool Information (Page 1 of 2)

ID	Pool Type	Pool Area [sf]	Cover	Pool Filter Type	Pool Heat Source	dedicated Pool Heat Effi.	Pool Heating Fuel	Pool Pump hp	Pool Probe Temp [F]	Variable Speed Pump	Valve Closed	Pool Valve Angle	Pool Observed Turnover [hrs]	Pool Flow % of Design
HP1_P1	Rec	550	None	Sand Closed	HX, Dedicated Boiler	94%	Gas	2	81.0	No	No		2.9	89.6%
HP1_P2	Spa	120	None	Sand Closed	HX, Dedicated Boiler	94%	Gas	2	103.0	No	No		0.5	85.8%
HP2_P1	Rec	488	None	Sand Closed	HX, Dedicated Boiler	93%	Gas	2	83.3	No	No		2.5	
HP2_P2	Spa	79	None	Sand Closed	HX, Dedicated Boiler	93%	Gas	2	98.9	No	No		0.4	
HP3_P1	Rec	888	None					1.5	83.9	No	No		7.4	
HP3_P2	Spa	148	None						102.0		0			
HP4_P1	Rec	647	none	Sand Closed	Pool Heater	82%	Gas	1.5	83.8	No	No		4.0	81.6%
HP4_P2	Spa	187	none	Sand Closed	Pool Heater	82%	Gas	3.6	102.0	No	No		0.7	101.4 %
HP5_P1	Rec	458	None	Sand Closed	HX, Dedicated Boiler	82%	Gas	1	84.8	No	No		4.6	
HP5_P2	Spa	67	None	Sand Closed	HX, Dedicated Boiler	78%	Gas	2	100.1	No	Yes	70	0.4	
HP6_P1	Rec	820	none	Sand Closed	HX, Central Boiler		Gas	5	75.4	No	No		3.1	42.5%
HP6_P2	Spa	133	None	Sand Closed	HX, Central Boiler		Gas	13.5	104.0	No	No		0.5	108.1 %
HP7_P1	Rec	785	none	Sand Closed	Pool Heater	82%	Gas	2	82.2	No	No		5.9	
HP7_P2	Spa	61	none	Sand Closed	Pool Heater	82%	Gas	1	104.1	No			0.5	63.5%
HP8_P1	Lap	473	None	Sand Closed	HX, Dedicated Boiler	78%	Gas	3	89.4	No	No		4.7	170.3 %
HP8_P2	Spa	67	None	Sand Closed	HX, Dedicated Boiler	78%	Gas	1	104.0	No	No		0.4	140.0 %
MF9_P1	Lap	510	None	Sand Closed	Pool Heater	80%	Gas	1	69.3	No	No		4.8	46.9%
MF10_P1	Lap	624	None	Sand Closed	Pool Heater	78%	Gas	2	81.1	No	Yes	30	3.6	100.0 %
MF11_P1	Lap	547	None	Sand Closed	HX, Central Boiler	80%	Gas	2	90.0	No	No		4.4	136.2 %
MF12_P1	Lap	424	None	Sand Closed	HX, Central Boiler		Gas	2	81.4	No	No		3.3	122.1 %
MF12_P2	Spa	82	None	Sand Closed	HX, Central Boiler		Gas	2	102.0	No	No		0.4	1048.3 %
MF13_P1	Lap	543	None	Sand Closed	HXs with Seasonal Switch	80%	Gas	2	87.1	No	No		7.6	158.7 %
MF14_P1	Rec	1,143	None	Sand Closed	Pool Heater	81%	Gas	2.5	85.6	No	No		4.7	58.7%
MF14_P2	Spa	129	None	Sand Closed	Pool Heater	81%	Gas	1.5	100.5	No	No		0.4	135.1 %
MF14_P3	Wade	189.0625	None	Sand Closed	Pool Heater	81%	Gas	2	80.3	No	0		0.3	100.0 %
MF15_P1	Rec	571	None	Sand Closed	HXs with Seasonal Switch	82%	Gas	1.5	88.7	No	No		5.3	121.6 %
SC16_P1	Lap	4,505	None	Sand Closed	HX, Dedicated Boiler	93%		20	83.9	No	Yes	45	5.3	104.5 %
SC16_P2	Dive	1,332	None	Sand Closed	HX, Dedicated Boiler	93%		15	87.1	No	Yes	45	5.0	115.3 %
SC17_P1	Lap	3,513	Yes, not used	cartridge	HXs with Seasonal Switch	93%	Gas	20	79.6				5.7	
SC18_P1	Lap	4,481	Yes & used	Sand Open				17.5	85.7	No				

ID	Pool Type	Pool Area [sf]	Cover	Pool Filter Type	Pool Heat Source	dedicated Pool Heat Effi.	Pool Heating Fuel	Pool Pump hp	Pool Probe Temp [F]	Variable Speed Pump	Valve Closed	Pool Valve Angle	Pool Observed Turnover [hrs]	Pool Flow % of Design
SC18_P2	Dive	800	Yes & used	Sand Closed				5	81.8	No	Yes	45		
SC18_P3	Wade	533	Yes & used	Sand Closed				1	86	No				
SC19_P1	Lap	3,496	Yes, not used	Sand Closed	HXs with Seasonal Switch	85%	Gas	15	80.1	No	No		5.2	102.3%
SC20_P1	Lap	3,404	No longer	Sand Closed	HXs with Seasonal Switch	80%	Gas	15	83.3	No	No		5.7	98.2%
SC21_P1	Lap	5,017	None	Sand Closed	HX, Central Boiler	80%	Gas	23	81.8	No	No		4.7	128.3%
SC22_P1	Lap	3,462	None	automatic regenerative medea filter	HX, Dedicated Boiler	93%	Gas	20	80.0	Yes--Used	No		6.6	
SC23_P1	Lap	3,268	None	Unable to access	HX, Dedicated Boiler		Gas	NA	82.7	-				
SC24_P1	Lap	2,625	None	Sand Open	HXs with Seasonal Switch	78%	Gas	10	83.1	No	No		3.7	119.6%
SC25_P1	Lap	3,476	Yes & used	Sand Closed	HX, Dedicated Boiler	80%	Gas	15	80.9	No	Yes	25-30	4.7	
SC26_P1	Lap	4,484	None	Sand Closed	HXs with Seasonal Switch	83%	Gas	15	80.4	No	No		7.7	91.7%
SC26_P2	Dive	1,080	None	Sand Closed	HXs with Seasonal Switch	83%	Gas	10	80.3	No	Yes	30	4.4	87.3%
CC27_P1	Lap	5,742	None	Sand Closed	HX, Dedicated Boiler	don't know	Gas	21	83.1	No	Yes	70	5.2	105.0%
FT28_P1	Lap	3,235	None	Sand Closed	HX, Central Boiler		Gas	10	83.2	Yes--Used	no			
FT28_P2	Rec	2,580	None	Sand Closed	HX, Central Boiler		Gas	10	89.9	Yes--Used	no			89.0%
FT28_P3	Spa	200	None	Sand Closed	HX, Central Boiler		Gas	9	102.418	No	Yes	45		
FT29_P1	Rec	4,144	None	Sand Closed	HX, Dedicated Boiler	78%	Gas		82.0				1.2	120.3%
FT29_P2	Lap	2,428	None	Sand Closed	HX, Dedicated Boiler	78%	Gas	20	90.0	No	Yes	65	5.8	100.0%
FT29_P3	Spa	190	None	Sand Closed	HX, Dedicated Boiler	78%	Gas	8	103.948	Yes--Used	No		0.4	100.9%
FT30_P1	Lap		None	Sand Closed	HX, Central Boiler	93%	Gas	5	81.0	No	Yes	80		
FT30_P2	Rec		None	Sand Closed	HX, Central Boiler	93%	Gas	5	87.4	No	Yes	45		
FT30_P3	Spa		None	Sand Closed	HX, Central Boiler	93%	Gas	5	103.7	Waterslide	Yes	60		

Appendix C. Recommendations Regarding TRM Manual Additions & Savings Calculation Approaches

The following pages provide detail regarding recommendations related to energy savings calculation recommendations for the measures listed below:

Recommended Minnesota TRM Manual Additions

1) variable speed pool pumping
2) high efficiency pool heater
3) pool cover

Recommended Savings Calculation Approaches

4) reducing outdoor air
5) modifying pool room temperature control
6) modifying pool room humidity control

RECOMMENDED MINNESOTA TRM MANUAL ADDITIONS

1) Variable Speed Pool Pumping (Commercial)

Basis for TRM Recommendation

Minnesota does not currently have a TRM measure that includes commercial pool pump variable speed control within its scope.[i] Closely related measures in Version 2.1 of the Minnesota TRM include *Residential Variable Speed Pool Pump, C/I HVAC - Variable Speed Drives,* and *Electric Utility Infrastructure - Variable Speed Drives (non-HVAC)*. Based on our review of these measures and commercial pool pump variable speed drive TRMs for 5 other states, we developed two variants of calculations already in the Minnesota TRM, and recommend using one of those variants.

While 3 states have fixed savings values for variable speed pumps serving commercial pools, we found many assumptions that are not appropriate for Minnesota in the other TRMs.[ii,iii,iv] The chief of these is an assumption that the pump is turned off or has the flow reduced dramatically below industry standard values for extended periods of time. These are in conflict with the Minnesota Pool Code, which requires public pools to continuously circulate water through the treatment system at a typical industry standard flow rate. Similarly, the *Residential Variable Speed Pool Pump* measure in Minnesota's TRM includes assumptions about pool pump runtime and flow that are not appropriate for public pools in Minnesota. Inappropriate and undocumented assumptions lead us to recommend against using any of these fixed savings values.

In addition, the importance of taking into account site to site variations in conditions was also highlighted by both the review of the basis for other TRMs and the results of our study. The Wisconsin and California TRMs both call for detailed calculations of pool pump variable speed drive applications that are designed for more complex process variable speed drive applications than the actual situation encountered in Minnesota's public pools[v,vi] [similar to Minnesota's *Electric Utility Infrastructure - Variable Speed Drives (non-HVAC)* calculation]. A field study of the installation of variable speed pumps on five public pool sites also concluded that the site to site variations make it inappropriate to use a single deemed savings value.[vii] (The standard deviation of savings for these sites was larger than the average savings.) Similarly, our field survey of indoor public pools in Minnesota found wide variations in the degree to which individual pools have excessively high flow rates and/or significant throttling of valves. Many of the surveyed sites would not have significant savings from the installation of a variable speed drive, while the savings per pump motor horsepower for those with opportunities varies significantly.

While some site to site variations are important to consider, the most common pump variable speed drive savings calculators in TRMs can be simplified for public pools in Minnesota. This is because the vast majority of savings in this application comes from efficient balancing of the flow rate to constantly provide the code required level, rather than from varying the flow rate based on variations in load. This allows calculations to be simplified from the summation of multiple calculations in a table to a comparison of two values. The continuous operation at a lower power level also means that the savings are fully coincident with the peak demand period for the building. In order to simplify the savings calculations, we propose the use of a procedure that modifies the calculations in *Electric Utility Infrastructure - Variable Speed Drives (non-HVAC)* by changing the naming in one table, and replacing a large table with a single calculation.

We found that combining this approach with representative findings from our field survey yielded results that match strikingly well with other TRM variable speed pump measures. This includes a close match to Michigan's 0.28 kW/hp fixed value[ii] and the pump savings factor values in the Minnesota TRM's *C/I HVAC - Variable Speed Drives* measure. This led us to believe that despite misgivings about large site to site variations a variation, a variation of this Minnesota HVAC measure may provide a reasonable program level savings estimate.

<u>TRM Savings Calculation Recommendation: Site Specific Savings</u>

For site-specific estimates of savings for variable speed pool pumps, follow the energy savings calculation procedure for the measure *Electric Utility Infrastructure - Variable Speed Drives (non-HVAC)* in version 2.1 of Minnesota's TRM with the following modification.

a) Calculate the Energy Savings Factor as the difference between the current and proposed conditions in the Table of PLR Values below. (This replaces the use of the TRM's Table 5 with multiple load factor and % of design flow values per the format of the TRM's Tables 1 and 2.)

Table of PLR Values

Min % of Wide Open Flow		Max % of Wide Open Flow	Throttle Valve PLR	Variable Speed Drive PLR
0%	To	10%	0.8	0.05
10%	To	20%	0.81	0.06
20%	To	30%	0.82	0.09
30%	To	40%	0.83	0.12
40%	To	50%	0.85	0.18
50%	To	60%	0.87	0.27
60%	To	70%	0.9	0.39
70%	To	80%	0.93	0.55
80%	To	90%	0.96	0.75
90%	To	100%	1	1

b) The following equations will apply with Wide Open Flow being defined as the pool water flow rate at full pump speed with any throttling valves wide open

$$ESF = PLR_{Throttle\,Valve,current} - PLR_{VSD,proposed}$$

$$\%\ of\ Wide\ Open\ Flow_{proposed} = \%\ of\ Wide\ Open\ Flow_{current} \times \frac{Code\ Required\ Flow}{Current\ Flow}$$

$$Code\ Required\ Flow[gallons\ per\ minute] = \frac{Pool\ Volume[gallons]}{60\left[\frac{minutes}{hour}\right] \times Code\ Turnover\ Time[hours]}$$

c) Reference the current Minnesota Swimming Pool Code for the maximum time to run the pools entire volume through the filtering and treatment system. The table below summarizes the maximum turnover time requirement in the code volume published in 2009 and in force as of December of 2017.[viii]

Table of Code Turnover Time

Pool Type	Max Turnover Time
General	6 hours
Wading	2 hours
Spa	0.5 hours
Dedicated Plunge	1 hour
Zero Depth	2 hours (for area < 3 feet deep)

d) For indoor pools in hospitality buildings, fitness centers, and other buildings that keep the pool open year-round, assume 8,760 operating hours per year and a coincidence factor of 1. For schools and other facilities with seasonal pool shutdown, base the hours and coincidence factor on the facility's reported schedule.

<u>TRM Savings Calculation Recommendation: Preliminary Program Level Savings Estimate</u>

For building type-specific estimates of savings of variable speed pool pumps, follow the energy savings calculation procedure for the measure *C/I HVAC - Variable Speed Drives* in version 2.1 of Minnesota's TRM with the following modification.

a) Use the following values for Energy Savings Factor (ESF) in place of the TRM's Table 3.
$ESF_{hospitality,\ multifamily} = 0.45$
$ESF_{school,\ fitness} = 0.51$

The potential number of applicable facilities should be based on an assumed 35 percent of pools (same value for all building types).

b) For indoor pools in hospitality buildings, fitness centers, and other buildings that keep the pool open year-round, assume 8,760 operating hours per year and a coincidence factor of 1. For schools assume 7,665 operating hours [i.e. pool shut down for 1 ½ months] and a coincidence factor of 0.78.

2) High Efficiency Pool Heater (Commercial)

<u>Basis for TRM Recommendation</u>

Minnesota does not currently have a TRM measure that addresses pool heaters,[i] and Michigan is the only Midwestern state that has a pool heater TRM measure to draw from.[ii,ix] However, the Michigan TRM gives a fixed savings value regardless of the pool heater efficiency even though there is about a 2:1 range of savings given the range of pool heater efficiencies available that meet the rebate requirement (85% to 95%+). A much more accurate site-specific estimate of savings can be achieved by using a formula that takes into account the new heater efficiency. This approach is already used in the Minnesota TRM for Commercial HVAC - Boilers, Space Heating Only and Commercial Hot Water - Gas Water Heater.

Besides taking into account the project-specific efficiency of the pool heater, an assumption of pool heating load must also be made. If based on the minimum efficiency required for a heater, the Michigan TRM savings would be based on an average load of 39% of the heater's maximum capacity (or 16% if 95% heater efficiency was assumed). This range of average percent of design load is greater than was measured in the accompanying study's detailed investigations of two indoor public pool facilities with dedicated, gas-fired heaters. CEE's findings suggest that an assumed burner on-time (for a fixed firing rate pool heater) of 12% gives a much better representation than the Michigan TRM's apparent assumption of 16% to 39%. The low annual average pool heating load (12% of design) is caused by dramatic oversizing of indoor pool heating equipment. This dramatic oversizing tends to occur in pool heaters more than in other mechanical heating equipment because they are typically sized according to the ability to heat up the pool's volume of water at a certain rate (typically 1°F to 2°F per hour) rather than the peak steady-state load for a pool that is already at the normal operating temperature. This sizing criteria leads to pool heaters that are several times larger than the maximum load during normal operation (i.e. excluding any initial heat-up after a fill). It is reasonable to expect that this oversizing is typically greater in Minnesota that in milder climates because of the colder water inlet temperatures. Therefore, a 12% of pool heater design load is recommended.

The potential added accuracy and complication of using site-specific schedule information is not recommended. A survey of 30 facilities in the companion study found that packaged, commercial pool heaters are generally only found in hospitality and multifamily facilities that operate their pools year-round.

TRM Savings Calculation Recommendation

For indoor public pool heater savings in Minnesota, the following savings calculation should be used.

$$Savings\ [therms] = BTUH\_In \times \left[\frac{1}{Eff_{Base}} - \frac{1}{Eff_{High}}\right]$$

Where:

BTUH_In = maximum input rating of the new pool heater [in units of BTU per hour]

Eff_{base} = Baseline pool heater efficiency (78% [0.78] code minimum for new heater)

Eff_{High} = Efficiency of the new high efficiency pool heater efficiency [as a decimal value (e.g. 0.95 for 95% efficiency)]

3) Pool Cover (Commercial)

Basis for TRM Recommendation

Minnesota does not currently have a TRM measure that addresses pool covers,[i] but 3 other Midwestern states do have TRMs to draw from.[ii,ix,x,xi] While Michigan and Iowa have per unit (square foot of pool surface) savings estimates that are within about 20% of each other, Illinois has a savings value that is more than twice these other two. This is despite Iowa and Illinois both reportedly to be based on the same software. CEE's engineering estimate (based on more recent industry research of pool evaporation rates) and observed savings for one site are fairly consistent with each other and fairly consistent with the Michigan and Iowa savings values. We recommend using the same calculation as Michigan because of its greatest consistency with our observations and the ability to take into account the pool heater efficiency. Although based on more complex engineering calculations with assumptions about operating conditions and hours, it is simplified into a single, representative factor (which was field-verified as a reasonable savings estimate for one site in Minnesota).

We could find no instances of the liquid pool cover technology being addressed by any TRM,[ix,xii] and provide only a preliminary suggestion that should be validated further. Data from the manufacturer and engineering calculations suggest that liquid pool cover annual savings would be about 80% of the savings of traditional pool covers. However, the single site included in this study showed negligible savings while two Minnesota hospitality buildings included in a separate CARD-funded study showed savings that are 50% of the savings expected for traditional pool covers (as calculated per the approach recommended below).[xiii]

TRM Savings Calculation Recommendation

For indoor public pool cover savings, the following savings calculation should be used for Minnesota.

$$Savings\ [therms] = \frac{0.9\ [therms/ft^2]}{Pool\ Heater\ Efficiency} \times Pool\ Area\ [ft^2]$$

If the pool heater efficiency is not known, it should be assumed to be 80% (0.80).

For the use of a liquid pool cover, the preliminary suggestion is to assume 50% of savings for a traditional pool cover—as calculated above. However, it is recommended that additional measurement and verification be conducted before using this assumption for large-scale program implementation.

Recommended Savings Calculation Approaches

4) reducing outdoor air
5) modifying pool room temperature control
6) modifying pool room humidity control

For these last 3 measures addressed by this appendix, we recommend a particular, rigorous approach for CIP program savings calculations (e.g. custom rebates or recommissioning savings estimates). In particular we recommend that savings estimates be based on detailed hourly or BIN calculation models that address the real interactions between these factors—plus the pool evaporation rate—with assumptions that have a sound basis in the actual design and operating conditions. A degree of iteration needs to be used to accurately estimate the savings from changing any one of these factors because each of these key pool room or HVAC system parameters has an impact on the others. Because of these interactions, some assumptions that have commonly been used in engineering calculations can cause misleading savings estimates. For example, the actual relative humidity may be higher or lower than the setpoint leading to a poor estimation the pool heating and dehumidification loads. Thus, setpoints should be used as a starting point for iterative analysis of the actual conditions as they are influenced by the other operating conditions and system limitations. The key interactive effects that need to be taken into consideration are outlined below, as well as guidance and references to detailed formulas and tables from Chapter 1 of the 2017 ASHRAE Fundamentals Handbook.[xiv]

Key Interactive Effects

a) Impact of Pool Room Temperature & Relative Humidity on Pool Room Humidity Ratio. While relative humidity is the most commonly used indicator of moisture level in the air for purposes of comfort discussions, humidity ratio is the measure of the amount of water in air that is ultimately used in most engineering calculations. This is because humidity ratio gives a direct indication of the amount of water vapor in air. It is defined simply as the ratio of the mass of water vapor to the mass of dry air. On the other hand, relative humidity indicates the ratio of how much water is in the air compared to the maximum amount of water vapor that air can hold at its current temperature.

   The humidity ratio of air can be calculated from the relative humidity, temperature, and atmospheric pressure. As one might expect, increasing the relative humidity for a given temperature increases the humidity ratio proportionally. However, the humidity ratio also goes up with the air temperature if the relative humidity is held constant. The warmer the air is, the more sensitive the humidity ratio is to changes in temperature (if the relative humidity stays constant). Below are the steps for calculating humidity ratio using equations in Chapter 1 of the ASHRAE Fundamentals Handbook.
   i. Using the temperature, calculate the partial vapor pressure of water vapor in air at saturation [the point where water starts to condense out of the air], p_{ws}, using Table 3 or equation (6).
   ii. Using this pressure, p_{ws}, and relative humidity, ø, calculate the actual partial vapor pressure of water in the air, p_w, using equation (22) [$ø=p_w/p_{ws}$ given here due to a handbook error in some versions].

iii. Using this p_w and the atmospheric pressure [in units of psia and can be estimated from Table 1 in the handbook], p, calculate the humidity ratio, W, using equation (20).

b) Impact of Pool Temperature, Pool Room Humidity, and Pool Room Temperature on Pool Evaporation Rate. Pool water evaporation rate is a key determinant of a pool facility's energy use for both pool heating and dehumidification. Although it happens in a less intense process, evaporation of water at any temperature draws about as much energy from the surrounding water as boiling water does from its heat source. This energy needs to be made up via the pool water heater. Likewise, the water vapor that evaporates must be removed from the pool room with a dehumidifying HVAC unit to keep the room's humidity in check. Therefore, the evaporation rate is the primary determinant of the loads on the both pool water heating and pool room dehumidification equipment.

The two key inputs for calculating the evaporation rate of an indoor pool are pool temperature and pool air moisture level. Here the steps for calculating the pool water evaporation rate following the ASHRAE Fundamentals Handbook and the Natatoriums section within Chapter 5 of the ASHRAE Applications Handbook.[xv]
i. Using the pool water surface temperature, calculate the saturated vapor pressure of water at the pool surface, p_w, using Table 3 or equation (6) from Chapter 1 of the ASHRAE Fundamentals Handbook [ignore the difference in subscript for p].
ii. Find the pool room's partial vapor pressure of water in the air, p_a, calculated from ii in a) above (using pool room temperature and relative humidity).
iii. Based on the pool type and activity, choose an appropriate activity factor, F_a, from the table right after equation (2) in the Natatoriums section of the ASHRAE HVAC Application Handbook. (This ranges from 0.5 for an unoccupied pool to 1.5+ for special water features.)
iv. Using the above vapor pressures and activity factor--along with the pool area--to calculate the pool water evaporation rate, w_p, using the equation below [equation (2) in Natatoriums section of handbook].

$$w_p\left[{}^{lbs}/_{hr}\right] = 0.1 \times Pool\ Area\ [ft^2] \times (p_w - p_a)F_a$$

This pool evaporation rate can be used directly to calculate the evaporation impact on pool water heating rate [in units of Btu/hr] by multiplying the evaporation rate by 1,000 [BTU/lb.]

c) Outdoor Air Flow and Humidity Ratio Impact on "Free Dehumidification" and Pool Room Humidity Ratio. In Minnesota's climate the outdoor air is usually much dryer than pool room air. This means that the high, continuous outdoor air ventilation needed to dilute and remove pool off-gassing provides significant "free" dehumidification throughout most of the year. The amount of dehumidification provided by the outdoor air flow can be calculated using the steps outlined below.
i. Using the outdoor temperature and humidity, calculate the outdoor air humidity ratio, W_{OA}, following the calculation steps i through iii outlined in a) above.
ii. Using the outdoor air flow rate along with pool room and outdoor humidity ratios, calculation the moisture removal rate with the equation below.

$$Moisture\ Removal\ Rate\left[{}^{lbs}/_{hr}\right] = Outdoor\ Air\ Flow\left[\frac{ft^3}{min}\right] \times 0.075\left[\frac{lb_{dry\ air}}{cubic\ foot}\right] \times 60\left[\frac{min}{hr}\right] \times (W_{room} - W_{OA})$$

If the above calculated dehumidification provided by outdoor air (i.e. moisture removal rate) is greater than the pool water evaporation rate, then the assumed pool room humidity level should be lowered until these two values match. If, however, the calculated dehumidification provided by outdoor air is less than the pool water evaporation rate, then the remaining dehumidification load will be the difference between these two. If outdoor air ventilation is the only (or first, economized) source of dehumidification, then the outdoor air flow rate would be increased (up to the system's maximum outdoor air flow rate) so that the calculated moisture removal rate matches the pool water evaporation rate. If the moisture removal rate calculated from the outdoor air, plus any compressorized dehumidifier at its maximum capacity, is less than the calculated pool evaporation rate, then the pool room humidity level must be assumed to increase until these two calculated values match.

Note that as outdoor air flow increases to provide dehumidification, the energy needed to heat the outdoor air also increases. The relationship between outdoor air flow and energy used to heat the outdoor air can be reasonably approximated with the equation below.

$$Outdoor\ Air\ Heating\ Energy\left[{}^{Btu}/_{hr}\right] = 1.08 \times Outdoor\ Air\ Flow \times (T_{room} - T_{OA})/Eff$$

where *Eff* = heating efficiency (90% for a gas direct-fired make-up air unit)

The above relationships often need to be used iteratively to find what the actual conditions and loads will be. Depending on how the HVAC system capacity and operation matches the loads, the modeling will generally use the pool room setpoints as a starting point, and then adjust them where outdoor air flow and system limitations will lead to a drift above or below the setpoint. Note that while it only happens for very few hours in the year, the pool room temperature may similarly increase above the setpoint due to outdoor air being brought in that is warmer than the pool room temperature.

References for Appendix C

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