Date of Report: July 1, 1998.

LCMR Work Program Update

I. Project Title and Project Number: Energy Improvements in Public Ice Arenas, no. P3

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A. Legal Citation: ML 95, Chp. 220, Sec. 19, Subd. 11(e)
Total biennial LCMR appropriation: $470,000
Balance: $9,198

Appropriation Language: This appropriation is from the oil overcharge money to the commissioner of administration for an agreement with the Center for Energy and Environment to assess, install and evaluate energy and indoor air quality improvements in at least 25 publicly owned ice arenas located throughout Minnesota. Projects receiving funding from this appropriation must be in compliance with the indoor ice facilities prime ice time and gender preference requirements in Minnesota Statutes, section 15.98. This appropriation must be matched by at least an equal amount of nonstate money for the actual retrofit activities.

ML 1997, Chp. 216, Sec. 15, Subd. 26. Carryforward
(a) The availability of the appropriations for the following projects is extended to June 30, 1998: Laws 1996, chapter 407, section 8, subdivision 3, paragraph (c), local grants; Laws 1995, chapter 220, section 19...subdivision 11, paragraph (e) energy improvements in public ice arenas.

B. Status of Match Requirement:

Match Required:	$232,000
Amount Committed to Date:	$373,675
Match Spent to Date:	$222,802

II. Project Summary: This project will accelerate the installation of energy and indoor air quality improvements in publicly owned ice arenas. Typical energy costs for the 127 public facilities in Minnesota range from $30,000 to $70,000, which represents a significant portion of total arena operating costs. There are a variety of existing and emerging technologies which can reduce energy costs by as much as 50%, improve ice conditions, improve indoor air quality, and extend the number of months per year that the arenas can operate. This project will directly result in the installation of improvements in at least 25 arenas and provide the information necessary for other arena managers to properly identify the most beneficial retrofit measures.

All Minnesota public ice arenas will be surveyed to identify the most broadly applicable and beneficial retrofits. An assessment of these retrofit technologies will then be conducted to determine their expected costs and savings. Energy and indoor air quality (IAQ) audits will generate a prioritized list of cost effective retrofits for a sample of ice arenas. Selected

improvements will be installed and evaluated in ice arenas using project funds and matching funds from the arena owners.

III. Final Six Month Work Program Update Summary: July 1, 1998
The remainder of the 28 energy audits were completed and 13 of the arenas committed to installing a total of $649,000 worth of retrofit work with annual energy cost savings of $128,000. Despite having worked closely with arenas that decided to implement energy saving improvements, a number of arenas are just completing the retrofit work in the last few weeks of the project, and three to five arenas did not fully meet the project timeline. The result is that 10 arenas have completed $455,000 worth of retrofit work with matching energy grant funds. An additional $116,195 worth of work was ineligible for matching funds or is in process and will be completed after the project ends. The total energy costs savings that will results from all of these retrofits is $106,500 annually.

IV. Statement of Objectives:

A. Survey public ice arenas: All 127 publicly owned ice arenas in Minnesota will be surveyed in order to identify the most broadly applicable and beneficial arena retrofits.

B. Conduct technology assessment of potential improvements: Available information from a variety of sources will be used to conduct cost and benefit estimates for all potential improvements. These estimates will provide a basis for cost/benefit analysis performed as part of the arena audits. Fact sheets will be developed for arena managers describing the retrofit and outlining methods to estimate cost and benefits.

C. Perform energy and indoor air quality audits: Extensive energy and IAQ audits will be performed on 25 to 30 arenas. The ice arenas selected will be representative in terms of geographic location, construction, equipment, operations, and energy use. The audits will identify and prioritize cost effective improvements based on the installation cost and the energy, indoor air quality, and ice sheet benefits.

D. Specify and install arena improvements: Cost effective retrofit opportunities will be implemented in appropriate ice arenas. The specific set of improvements installed in each arena will be selected to emphasize and showcase those most cost effective and generally applicable, distribute benefits over a large number of facilities, and guarantee the ability to analyze benefits.

E. Evaluate improvement benefits: The benefits and drawbacks of each installed improvement will be evaluated. These evaluations will consider energy savings, effect on indoor air quality, effect on ice conditions, reliability, effect on operation maintenance costs, and manager/occupant acceptance.

Timeline for Completion of Objectives:

		7/95	1/96	6/96	1/97	6/97
Objective A.	Survey arenas	X				
Objective B.	Technology assessment	X X				X X
Objective C.	Arena audits	X	X X X X X X			
Objective D.	Install improvements			X X X X		
Objective E.	Evaluate benefits			X X X X	X X X X	

V. Objectives/Outcome:

A. Title of Objective/Outcome: Survey public ice arenas

A.1. Activity: Conduct facility survey of ice arenas and summarize results

A.1.a. Context within the project: The surveys will gather information on important facility characteristics in order to determine which improvements are likely to be most beneficial and broadly applicable. The results will be used to help prioritize the types of arenas to be audited and improvements to be installed.

A.1.b. Methods: All public ice arenas will be included in the survey. A survey instrument will be developed using mostly closed ended questions to obtain information about the ice arenas including: type of construction, mechanical systems, lighting, ice resurfacing equipment, recent retrofits and use of the facility. The appropriate respondent for these mail surveys, typically the rink manager, will be verified via telephone contacts. The initial list for the phone contacts will be developed from a Minnesota Department of Health list of registered ice arenas and a membership roster from the Minnesota Ice Arena Managers Association. Cover letters from organizations such as the Minnesota Amateur Hockey Association and the Minnesota Ice Arena Managers Association will be used to encourage rink managers to respond to the survey. In addition, the respondents will be informed that they can not participate in the remainder of the program if they do not complete and return the survey.

Survey responses will be compiled into a data base program such as Paradox for Windows. A double entry method will be used to insure proper coding of responses. Survey results will be tabulated using the statistical functions of the data base program and, when necessary, a statistical program such as SPSS for Windows.

A.1.c. Materials: This activity will require about 150 surveys to be printed and mailed to arenas in Minnesota.

A.1.d. Budget

Total Biennial LCMR Budget:	$12,500
LCMR Balance:	$0
MATCH:	**N/A**
MATCH BALANCE:	**N/A**

A.1.e. Timeline

	7/95	1/96	6/96	1/97	6/97
PRODUCT 1. Survey summary results	X				

A.1.f. Workprogram Update:
January 1, 1996. This task is nearly complete. A summary report of survey results will be sent to LCMR by mid-January. A 47 question written survey was developed and mailed to over 150 ice arenas on

October 31st. A total of 75 arenas have responded to the survey. The survey data has been entered into a data base and preliminary statistical analysis has been conducted.

July 1, 1996. This task is complete. A 47 question, seven page written survey was developed and mailed to 151 ice arenas on October 31st, 1995. A total of 81 arenas responded to the survey. The survey data has been analyzed and summarized in a 38 page report. The report has been sent to important ice arena contacts in Minnesota and an executive summary was sent to all respondents.

B. Title of Objective/Outcome: Conduct technology assessment of potential improvements

B.1. Activity: Conduct technology assessments of potential improvements

B.1.a. Context within the project: The assessments will be used to provide a basis for the cost/benefit analysis performed as part of the arena audits. They will also be used to determine the facility characteristics which indicate whether specific improvements are appropriate.

B.1.b. Methods: Published information from manufacturers, trade associations, utilities, engineering journals, and previous evaluations will be used to conduct cost and benefit estimates for potential improvements. In some cases system modeling will be used to properly estimate benefits and establish design guidelines. Retrofit descriptions and information about where the improvements can best be applied will also be summarized.

The improvements which will be considered will include: low-emissivity ceiling, higher efficiency lighting, variable speed brine pump and ice sensor, desiccant dehumidification, fuel conversion of ice resurfacer, improved ventilation controls, de-mineralize flood water, added building insulation, add/modify energy management system, heat recovery and higher efficiency water heating, added heat exchange surface to allow close approach, and adjustable speed drive for compressor and cooling tower

B.1.c. Materials: Selected reference materials will be purchased in order to obtain the most current information on ice arena energy and IAQ technologies. Annual fees for membership in selected professional organizations will also be required. A personal computer will be purchased at a cost of approximately $3,500 (actual amount = $2,900). This computer will be used to conduct the assessment analysis and fact sheet layouts. The computer will also be used by project staff for Objective C to produce arena audit reports and for Objective E to conduct the analysis of improvement benefits. It is expected that at the completion of this project, CEE will continue its efforts towards improving the energy efficiency of ice arenas and that this computer will be used in that work. If these efforts do not continue, CEE will negotiate with LCMR staff either the return of the equipment or purchase the computer at fair market value.

B.1.d. Budget

Total Biennial LCMR Budget:	$24,500
LCMR Balance:	$0
MATCH:	**N/A**
MATCH BALANCE:	**N/A**

B.1.e. Timeline

		7/95	1/96	6/96	1/97	6/97
PRODUCT 1.	Assessment summaries	X	X			

B.1.f. Workprogram Update:

January 1, 1996. CEE staff have started the process of gathering information on ice arena technologies from manufacturers, technical literature, and appropriate contractors. Preliminary versions of cost savings models have been developed for a number of technologies including: low-e ceilings, demineralized water, and dehumidification systems. A program has also been developed to analyze and display monthly energy costs. This task is currently two to three months behind schedule and is expected to be completed in the first quarter of 1996.

July 1, 1996. CEE staff have gathered information on promising ice arena energy improvements and developed preliminary cost savings models for a number of technologies. A detailed, hourly model of arena thermal and moisture loads is being developed to more accurately estimate savings. A program has been developed to analyze and display skating and non-skating season monthly energy costs. This task is currently behind schedule and is expected to be completed by August 1996.

January 1, 1997. CEE staff have gathered information on promising ice arena energy improvements and developed cost savings models for a number of technologies. A utility bill analysis of annual energy use for participating ice arenas is nearly complete. A detailed, hourly model of arena thermal and moisture loads is being developed to more accurately estimate savings. Significant progress has been made on the arena energy model and it is expected to be completed by February 1997. This task is currently behind schedule.

July 1, 1997. This task is complete. Information was gathered on promising ice arena energy improvements and a detailed model of arena loads and energy use was developed. The arena model is being used for arena audits (task C) to determine baseline energy use and savings estimates for proposed improvement measures. A utility bill analysis of annual energy use has been completed and summary reports generated for each participating ice arena.

B.2. Activity: Develop preliminary and final versions of retrofit fact sheets

B.2.a. Context within the project: The preliminary fact sheets will be used in audit reports to describe the recommended improvements to arena managers. The final version fact sheets will be sent to all managers of Minnesota public ice arenas and will be made available to all interested utilities and associations.

B.2.b. Methods: Retrofit summary descriptions and cost/benefit analysis from the technology assessments will be compiled into preliminary two to four page fact sheets. The final versions will be updated using photographs, evaluation results, and cost information from the actual retrofits. The fact sheets will also list arenas where the retrofit has been installed and contact information for those arenas.

B.2.c. Materials: This activity will require 200 to 250 copies of the final version of the fact sheets to be printed and distributed to interested parties in Minnesota. Development of the graphics and text layout of the final version of the fact sheets will also require the purchase of current presentation software and expenses for graphics processing.

B.2.d. Budget

Total Biennial LCMR Budget:	$10,000
LCMR Balance:	$0
MATCH:	**N/A**
MATCH BALANCE:	**N/A**

B.2.e. Timeline

		7/95	1/96	6/96	1/97	6/97
PRODUCT 1.	Preliminary fact sheets	X				
PRODUCT 2.	Final fact sheets					X X

B.2.f. Workprogram Update:

January 1, 1996. Draft versions of fact sheets for selected technologies have been written. This task is currently two to three months behind schedule and is expected to be completed in the first quarter of 1996.

July 1, 1996. Draft versions of fact sheets for selected technologies have been written. This task is currently behind schedule and is expected to be completed by August 1996.

January 1, 1997. Preliminary fact sheets for selected technologies have been written for use in the energy audit reports. Final versions will be completed at the end of the project when the evaluation of improvement measures is complete.

July 1, 1997. Fact sheets for selected technologies have been written and compiled into a report titled *Cost-Effective Energy Efficient Improvements for Minnesota's Public Ice Arenas: Overview of 20 Options*. This report and an arena specific utility cost report have been distributed to all participating ice arenas. Final versions of the fact

sheets will be completed at the end of the project when the evaluation of improvement measures is complete.

January 1, 1998. There has been no additional activity on this task.

July 1, 1998. This task is essentially complete. The fact sheets and report titled *Cost-Effective Energy Efficient Improvements for Minnesota's Public Ice Arenas: Overview of 20 Options* have been updated to reflect the audit analysis results and information about installations that have been completed. This report is in the process of being mailed to all ice arenas in Minnesota.

C. Title of Objective/Outcome: Perform energy and indoor air quality audits

C.1. Activity: Conduct arena audits and write audit reports

C.1.a. Context within the project: The audit reports will be produced from data collected during site visits and information obtained from technology assessment summaries. This process will provide a more detailed characterization of Minnesota arenas and identify possible retrofit installations for Objective D.

C.1.b. Methods: Extensive energy and IAQ audits will be performed on 25 to 30 ice arenas. The audits will include site inspection of the building envelop and energy systems. Site visits will also include diagnostic measurements of equipment performance and building conditions. In many cases, unobtrusive data loggers will be used for periods of one to three weeks to collect data on hours of operation for critical equipment. All recent building audits or recommendations for improvements will be reviewed and the arena manager will be consulted about typical operation patterns, maintenance practices, and identified improvement opportunities. When necessary, contractors or manufacturers will be asked to provide cost estimates for likely retrofits.

Before an arena receives an audit the arena operators will be required to sign a statement which specifies that the arena is in compliance with the indoor ice facilities prime ice time and gender preference requirements in Minnesota Statutes, section 15.98. The operators will also be notified of the record keeping procedures needed to verify compliance and given references for additional information about the Statute.

A arena audit report will be written which will include an executive summary, prioritized table of retrofits with cost and savings data, summary retrofit descriptions, and detailed savings calculations. A preliminary report will be sent to the arena managers for their review. The audit report will be modified based on arena manager feedback and a final version of the report will be sent to the manager. The audit report executive summaries and retrofit tables will also be included as an appendix in the project final report.

CEE intends to supplement LCMR funds for this task by requesting reimbursement from utility programs when the audit meets the utility's eligibility criteria. When CEE receives reimbursement for an audit, the amount of the reimbursement will be recorded as program income thereby freeing up LCMR funds to perform additional program activities. Upon receipt of reimbursement from the utility, CEE will estimate the additional activities that will be performed and will document these changes in future workprogram updates.

C.1.c. Materials: A power analyzer will be purchased for an approximate cost of $6,500 (actual amount = $6,405) in order to perform short-term electric demand measurements of motors, heaters, and other electric devices. Ten motor run time loggers, eight CT run time loggers, five lighting loggers, and two lighting occupancy run time loggers will be purchased to perform one to three week measurements of equipment run time. The total cost for this equipment is approximately $4,150 (amount to date = $3,585). Two optical filters will be purchased at a cost of $3,100 (one filter and calibration gas = $2,207) to be used in a opto-acoustic infrared analyzer to measure concentrations of carbon monoxide. A contact/non-contact digital tachometer will be purchased at a cost of $350 (no longer required) in order to evaluate motor loading conditions. A continuous output combustion analyzer will also be purchased at a cost of $3,500 (actual amount = $3,952) in order to measure the steady state efficiency and carbon monoxide vent gas concentration of arena gas appliances. A non-contact infra-red temperature sensor has been purchased at a cost of $892 in order to properly evaluate ice sheet radiation losses and to streamline other arena audit measurements.

It is expected that at the completion of this project, CEE will continue its efforts towards improving the energy efficiency of ice arenas and that this equipment will be used in that work. If these efforts do not continue, CEE will negotiate with LCMR staff either the return of the equipment or purchase the equipment at fair market value.

C.1.d. Budget

Total Biennial LCMR Budget:	$75,000
LCMR Balance:	$0
MATCH:	$25,291
MATCH BALANCE:	$0

C.1.e. Timeline

		7/95	1/96	6/96	1/97	6/97
PRODUCT 1.	Arena audit reports	X	X X X X X			

C.1.f. Workprogram Update:
January 1, 1996. A preliminary audit has been completed for three ice arenas. Additional ice arena audits will start in early March.

July 1, 1996. This task is behind schedule by three months. It is expected that at least 25 to 30 audits will be completed by November 1996. The primary selection criteria have been to include at least four arenas from five geographic regions of the State with each region representing equal populations. The arenas have also been ranked by: (1) interest in energy improvements, (2) ability to achieve energy savings, and (3) ability to fund improvements.

A total of 30 arenas have been selected for participation and others will be included if funds are available. Audits have been completed for three ice arenas and they are in process for 11 others. Leveraged utility funds are expected to allow the audit completion goal of 25 to 30 arenas to be exceeded by 10 to 15. The final paragraph of subsection C.1.b specifies the method that will be used to incorporate leveraged funds into the project budget and activities.

January 1, 1997. This task is behind schedule by six to nine months. Audits have been completed for four ice arenas and they are in process for 11 others. Computations for the first four arenas show an expected annual savings of $45,603 for total installation costs of $213,605. It is expected that 25 to 30 audits will be completed by April 1997. Leveraged utility funds are expected to allow the audit completion goal of 25 to 30 arenas to be exceeded by 10 to 15.

July 1, 1997. Audits have been completed for seven ice arenas. The field portion of the audit and portions of the savings analysis is complete for seven others. Computations for the first seven arenas show a potential annual savings of $102,00 for total installation costs of $458,000. It is expected that 25 to 30 audits will be completed by December 1997.

January 1, 1998. Audits have been completed for 18 ice arenas at 12 facilities. The field portion of the audits for 8 of the remaining 10 arenas have been started and it is expected that all of the audits will be completed by mid-February. The completed audits have identified potential annual savings of $304,000 for total installation costs of $1,443,000. Implementation of all the recommended improvements would result in average energy cost savings of 34% for the audited arenas.

It is expected that utilities will reimburse CEE $50,000 for energy audits. As previously described (see last paragraph of methods section), the utility reimbursements are being used to perform additional audit activities. The $50,000 has been included as an expected match for this task. This matching amount has not been specified as a required program match.

July 1, 1998. Audits have been completed for 28 ice arenas at 22 facilities. The last of these audits was completed during the first week in March. Utility reimbursements totalling $29,291 were obtained and allowed for more extensive audits and for the program to serve more

than the minimum number of 25 arenas. The completed audits identified potential annual savings of $358,000 at total installation costs of $1,814,000, plus $30,000 savings potential at virtually no cost. Implementation of all the recommended improvements and adjustments would result in average energy cost savings of 29% for the audited arenas.

D. Title of Objective/Outcome: Specify and install arena improvements

D.1. Activity: Install improvement measures

D.1.a. Context within the project: Appropriate retrofit measures identified in Objective C will be installed in 25 to 35 public ice arenas. The retrofit installations will serve to "show case" technologies and provide sites for field monitoring and evaluation which will be conducted in Objective E.

D.1.b. Methods: Retrofit opportunities which appear to be cost effective will be implemented in appropriate ice arenas. The specific set of improvements installed in each arena will be selected to achieve several objectives: emphasize and showcase those most cost effective and generally applicable, distribute benefits over a large number of facilities, and guarantee the ability to analyze benefits. Participating arenas will provide an average of 50% of the total retrofit cost. Whenever possible, utility and state rebate and loan programs will be used to offset the cost of the project, thus allowing more funds to be provided to a greater number of arenas.

Project staff will work with arena managers and contractors to specify recommended improvements. CEE will also conduct post installation quality control inspections of the installations.

D.1.c. Materials: N/A

D.1.d. Budget

Total Biennial LCMR Budget:	$265,000
LCMR Balance:	$9,198
MATCH:	$232,000
MATCH BALANCE:	$9,198

D.1.e. Timeline

		7/95	1/96	6/96	1/97	6/97
PRODUCT 1.	Improvement installations			X X X X		

D.1.f. Workprogram Update:
January 1, 1996. As scheduled, there have been no activities for this task.

July 1, 1996. This task is behind schedule by three months. The first set of three audited arenas will install many of the recommended

improvement measures, but the specific measures have not yet been determined. Work during the summer of 1996 will focus on completing the 11 audits presently in progress so that those arenas can install measures in the fall and winter. Draft criteria have been developed to determine the level of the "energy grants" that will be provided by the project for energy improvement measures.

January 1, 1997. This task is behind schedule by six to nine months. Criteria and an application form for project grants have been developed. Generic bid specifications for selected improvements are also being developed. One of the first three audited arenas will install additional improvements than initially expected because the floor is being replaced in that arena. The installed cost of the improvements that have approved for the first four arenas is $213,605. A total of $78,099 will be supplied by project grants and $135,506 by matching funds. The cost per arena is higher than what is expected for future arenas. After additional audits are completed in 1997, project staff will work closely with arena managers to obtain funding approvals.

July 1, 1997. CEE staff assisted with the development of bid specifications and identification of appropriate contractors for 11 improvement measures in the first four arenas. A total of $78,100 will be supplied by project grants and $140,900 by matching funds for the $219,00 worth of improvements in these arenas. Over $150,000 worth of improvements have been installed. The remaining improvements are in the process of being implemented and should be completed by September 1997. The cost per arena is higher than what is expected for future arenas. After additional audits are completed in 1997, project staff will work closely with arena managers to obtain funding approvals.

January 1, 1998. CEE staff have assisted with developing bid specifications and identifying appropriate contractors for nine arenas. These facilities have committed to installing $592,900 worth of energy improvements, with $173,008 of the funds supplied by the program and $419,893 by the arenas. Deadlines have been established for the remaining interested arenas to commit to installation measures and to have contractor bids in place so that all the LCMR program and matching funds are spent by the end of the program.

July 1, 1998. CEE staff continued to work with a total of 18 arenas that committed to making improvements worth a total of $649,000, and 88% of these improvements have been or will soon be implemented. These improvements will provide a total of $106,500 in annual energy cost savings. However, two facilities with large retrofit projects are not receiving any energy grant funds so the total cost of improvements made with the support of energy grants is $455,000. One of these facilities installed improvements with funds from other state funding sources and the other facility is in the process of going ahead with improvements, but actual on-site work has not yet begun. Because these projects did not receive grants and other arenas completed less work than expected,

$9,200 of the $232,000 appropriated matching energy grants funds will remain unspent by this project.

E. Title of Objective/Outcome: Evaluate improvement benefits

E.1. Activity: Monitor operation and analyze cost and benefits

E.1.a. Context within the project: The benefits and drawbacks of all the improvements installed in Objective D will be evaluated. The results of this evaluation will be used to update the final version of the fact sheets developed for Objective B.

E.1.b. Methods: The evaluation of retrofit measures will be conducted using diagnostic measurements, continuous monitoring, utility bills, manager surveys, on-site log sheets, and analytic modeling. These evaluations will consider energy savings, effect on indoor air quality, effect on ice conditions, reliability, effect on operation maintenance costs, and manager/occupant acceptance.

E.1.c. Materials: Continuous monitoring of system performance will require the purchase of four to five data loggers at a cost of $6,750 (amount spent to date = $0). A computer will be required for analysis of utility bills and field data. The computer will also be used to access the data loggers specified in Objective E and C and will cost $2,900 (amount spent to date = $2,638).

E.1.d. Budget

Total Biennial LCMR Budget:	$83,000
LCMR Balance:	$0
MATCH:	**N/A**
MATCH BALANCE:	**N/A**

E.1.e. Timeline

		7/95	1/96	6/96	1/97	6/97
PRODUCT 1.	Monitor measures and analyze results			X X X X X X X X		

E.1.f. Workprogram Update:

January 1, 1996. As scheduled, there have been no activities for this task.

July 1, 1996. One arena is being extensively monitored for the project duration. Many of the other audited arenas were continuously monitored for 3 to 21 days. This information is being used to determine baseline energy use before measures are installed and to better understand arena loads and system performance.

The computer purchase for this task has been changed from a laptop to a desktop computer. A more complicated utility bill and field data analysis process has resulted in greater need for a desktop computer.

The field portable laptop computer requirements has been served by a computer borrowed from another CEE project.

January 1, 1997. One arena has been extensively monitored since June 1996 and the monitoring will continue for the project duration. Many of the other audited arenas were continuously monitored for 3 to 21 days. This information is being used to determine baseline energy use before measures are installed and to better understand arena loads and system performance. A series of energy improvements are planned for the arena that is being extensively monitored. An analysis of the data from that arena will provide detailed information on the effectiveness of those improvements.

The computer purchase for this task has been changed from a laptop to a desktop computer. A more complicated utility bill and field data analysis process has resulted in greater need for a desktop computer. The field portable laptop computer requirements has been served by a computer borrowed from another CEE project.

July 1, 1997. One arena has been extensively monitored since June 1996 and the monitoring will continue through the winter of 1997/98. A series of energy improvements are planned for that arena and an analysis of the data will provide detailed information on the effectiveness of those improvements. Many of the other audited arenas were continuously monitored for 3 to 21 days. This information is being used to determine baseline energy use before measures are installed and to evaluate the potential savings associated with various improvements. Evaluation of that data will also serve to streamline future arena audits.

Short-term data has also been collected in a number of arenas to better understand the fuel use and emissions from different types of ice resurfacers. This data has allowed a more accurate comparison of the indoor air quality benefits and fuel costs for LP, natural gas, and electric resurfacers.

January 1, 1998. Extensive monitoring at one of the arenas has continued over the past six months. This data has been used to compute the summer operation savings for the replacement chiller. Additional monitoring was also included to help determine the space heating savings from the installation of a low-e ceiling. Short-term indoor air monitoring was also conducted at two arenas to better understand the impact of resurfacer operation on arena air carbon monoxide concentrations.

July 1, 1998. Most of the improvement installations were completed very recently so complete follow-up evaluations of the installations has not been possible. For the earlier installations, information about satisfaction and performance have been obtained through discussions with arena staff. No reliable analysis of post-installation utility bill data was possible because of the timing of the installations. Although extensive monitoring at one of the arenas continued with the expectation

that energy savings from a low-e ceiling could be measured, the installation was post-poned until the end of June.

VI. **Evaluation:** The effectiveness of the implemented retrofits will be evaluated by Objective E. The long-term project success will be judged by the number of improvement measures that are properly implemented in ice arenas that are not part of this project. This will only be evaluated on a limited basis during the two year duration of this project. It is expected that the additional improvements resulting from this project will largely occur after the fact sheets are distributed at the end of the project.

VII. **Context within field:** The equipment and system improvements to be installed by this project are classic examples of energy efficient technologies that are proven to varying degrees in the manufacturing and engineering communities, but have received little market penetration and acceptance. Some of the technologies, such as variable flow pumping systems, are relatively new and have not been studied by independent researchers. In other cases the technologies are more proven, but the available performance information has not stirred the market. Independent evaluations of the technologies and "show case" sites are necessary to demonstrate the benefits of the measures to Minnesota ice arena managers and owners.

This project will build upon the previous experience of Center for Energy and Environment (CEE) staff with ice arena energy use. CEE is presently conducting field monitoring and evaluations of two desiccant dehumidification systems installed in Minnesota ice arenas and has completed a market and technology assessment of ice arena refrigeration systems. CEE has also completed numerous commercial building energy audits.

VIII. **Budget context:** CEE has conducted two projects in the past two years which relate to this project. The first was a market and technology assessment of industrial refrigeration performed for Northern States Power. The total budget was $55,000, for which a small portion was allocated for work related to ice arenas. The second project was a field monitoring evaluation of commercial cooling systems conducted for Minnegasco. Approximately one half of the total budget of $140,000 was used for field monitoring of two desiccant dehumidification systems installed in local ice arenas. Results of earlier monitoring were presented at an ASHRAE (engineering society) meeting.

There are presently no additional related projects that will be conducted by CEE during the two year project duration.

IX. **Dissemination:** The final version of the fact sheets will be sent to all managers of Minnesota public ice arenas and will be made available to all interested utilities and associations. Each fact sheet will include a list of arenas where the retrofit has been installed and contact information for those arenas. This will allow managers who are considering implementing retrofits to speak first hand to other managers of arenas which have already installed the measure.

The project final report will be sent to all interested Minnesota utilities and associations involved with ice arenas. Results will be presented at meetings for groups such as the Minnesota Ice Arena Managers Association. Specific project results will also be presented at a ASHRAE conference or another appropriate energy systems conference.

X. **Time:** An extension of 12 months may be required in order to meet all the project objectives.

XI. **Cooperation:** The cooperating agencies will have no formal responsibilities. However, CEE will be working with the Minnesota Amateur Hockey Association and the Minnesota Ice Arena Managers Association to solicit the support of their members and aide in the distribution of the project results. CEE will also identify and incorporate all applicable utility and state energy conservation program offerings.

XII. **Reporting Requirements:** Semiannual six-month workprogram update reports will be submitted not later than January 1, 1996, July 1, 1996, January 1, 1997, and a final six-month workprogram update and final report by June 30, 1997.

XIII. **REQUIRED ATTACHMENT:**
1. **Qualifications:**
2. **Project Staffing Summary:**

ENERGY IMPROVEMENTS IN PUBLIC ICE ARENAS

FINAL REPORT

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Executive Summary

There are approximately 270 indoor ice arenas in the state of Minnesota which spend a total of $13.5 million annually on energy costs. This project's technology assessment and on-site engineering analyses have demonstrated the potential to cost-effectively reduce ice arena energy costs by an average of 30 percent. After completing a technology assessment and survey of publicly owned arenas, the Center for Energy and Environment (CEE) then worked aggressively with 28 publicly owned ice arenas in Minnesota with the resulting implementation of $575,000 worth of energy efficiency and air quality improvements in 16 arenas. The improvements provide an energy cost savings of $106,500 annually. Educational promotion of energy efficiency and air quality improvements was also carried out.

Both site-specific engineering analyses and matching grants proved to be critical components of the project's efforts to encourage the installation of cost-effective improvements. The site specific engineering analyses proved to be invaluable for the following reasons:

1. the appropriate combination of technologies and their cost-effectiveness varied significantly from arena to arena
2. the audit reports provided clear recommendations along with supporting information that could be used by arena managers as tools both for decision making and to get buy in from key administrators and city council members
3. very detailed engineering specifications were necessary for proper implementation of a number of the measures

The low priority typically given to energy saving improvements was one of the barriers to the success of this project and it made the one-for-one matching grants a key component. A total of $222,900 worth of grants were provided and this amount was matched by local funding sources on a one for one basis. An additional 20 percent of the work was funded by local sources without a match. In addition to the state's matching grants, utility sponsored no-interest loans provided financing for about half of the improvements.[1] With this financial support and follow-up engineering services, one-third of the recommended, cost-effective improvements were installed. The number of completed improvements was partly limited by the ability of the municipalities to devote the necessary budget and administrative time necessary to complete the improvements within the project timeline. Because of competing funding and city staff priorities, a majority of the improvement work was completed in only the last two months that the matching grant funds were available, and three planned retrofit projects were not started.

The amount of post-retrofit verification of energy savings has been limited by the late completion of most of the energy saving improvements. However, on-site monitoring of a number of facilities has provided verification and valuable performance insights for a limited number of the energy and air quality improvements.

[1] These utility sponsored no-interest loan programs are being phased out in 1998.

Ice Arena Survey Results

Ice arena managers were surveyed in the fall of 1995 to gather information that would be useful for project phases that followed. The main objectives for conducting the survey were to:

1. Determine the typical characteristics of Minnesota arena energy systems and operation.
2. Identify the present degree of saturation and arena manager's level of interest in energy efficient technologies to aide in the prioritization of measures.
3. Compile information on arenas interested in participating in the program in order to select the most appropriate arenas for energy audits.

A 47-question survey and program information were mailed to the 151 publicly owned arenas in Minnesota. Follow-up phone calls were made to those arenas that did not respond within the specified time period. Over half of the arenas responded to the survey and 71 of those qualified for the program. Some key results of the survey are described below, while the survey instrument and a summary of the responses to each question can be found in **Error! Reference source not found.**.

While there has recently been increased interest in building more ice arenas in Minnesota, only 8% of the qualified arenas responding to the survey were built in the previous five years. Another quarter were 6 to 20 years old, and two-thirds were more than 20 years old. It is possible that this distribution is not representative of all arenas in Minnesota since managers of newer arenas may have been less likely to believe that energy improvements would provide significant benefits in their facilities and they were less interested in participating. However, the Minnesota Ice Arena Managers Association (MIAMA) 1995 annual survey of 96 single and multiple sheet arenas[2] found an average opening year of 1977, which is fairly consistent with the results from this survey. The high percentage of older arenas indicates that a significant number of arenas are likely to have older equipment that is in need of replacement or upgrades.

Figure 1 shows the percentage of arenas with various operating season lengths. This distribution is consistent with the results from the 1995 MIAMA survey which found the arenas to be open for ice activities an average of 7.8 months per year. Thus, only a little over a third of the arenas are presently operating in the summer months when arena air dehumidification is required. A cross-correlation of responses verified that dehumidification is used in all arenas that operate for at least 9 months and that very few of the arenas which operate for only half of the year have dehumidification equipment. These arenas will need to install dehumidification equipment if they choose to extend their operating seasons significantly. There is, however, a strong trend for newer arenas to have a longer operating season and dehumidification equipment. Figure 2 demonstrates the trend towards using dehumidification equipment in newer arenas. It also shows that although energy efficient gas-fired desiccant equipment has become common in new arenas, it has only been installed in a fraction of the existing arenas with longer operating seasons.

[2] The large majority of MIAMA members are located in Minnesota.

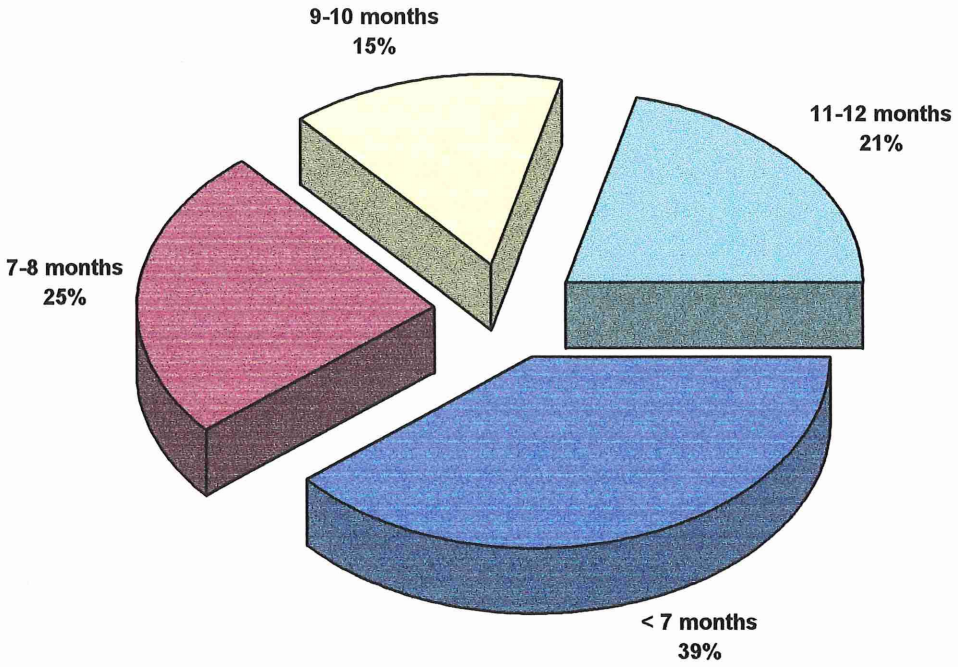

Figure 1. Arena Operating Seasons Lengths

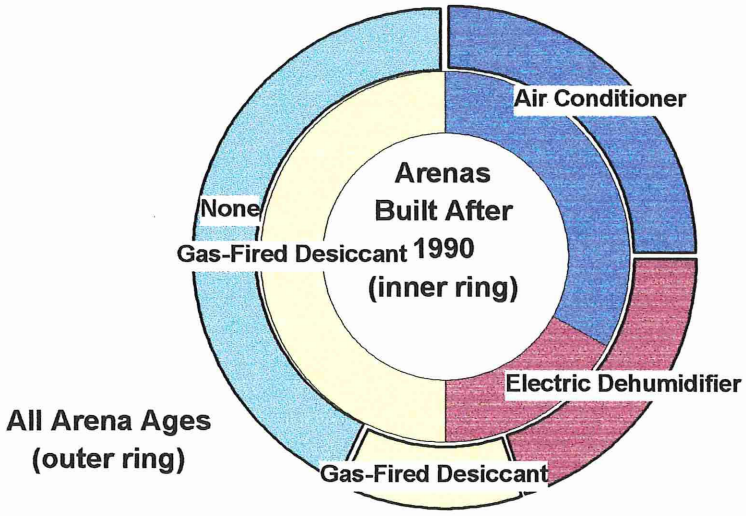

Figure 2. Usage of Dehumidification Equipment Types

Mechanical ventilation is almost always used to dilute resurfacer pollutants and other indoor air contaminants. The ventilation is manually controlled in three-quarters of the arenas. A limited number of arenas use automated controls based on time of day, resurfacer operation, and pollutant levels. About 12% of the arenas are using electric resurfacers to eliminate concerns about exhaust pollutants and to reduce ventilation requirements.

The problems related to energy using equipment and indoor air quality reported in the survey are summarized in Figure 3. More than half of the arenas reported problems with fogging or structural moisture condensation, which is caused by higher-than-desired arena air humidity. It is clear that even some of the short-season rinks and rinks that already have dehumidification equipment are having problems with humidity control. The next most common problem was high energy costs followed by poor arena light quality or control and difficulty maintaining arena air temperature. The concerns with energy costs confirm the need for this program and problems with air temperature and humidity point to improvements in heating and dehumidification as an area that should be emphasized. There are some opportunities to solve some of these arena problems with technologies that will also cost-effectively save energy.

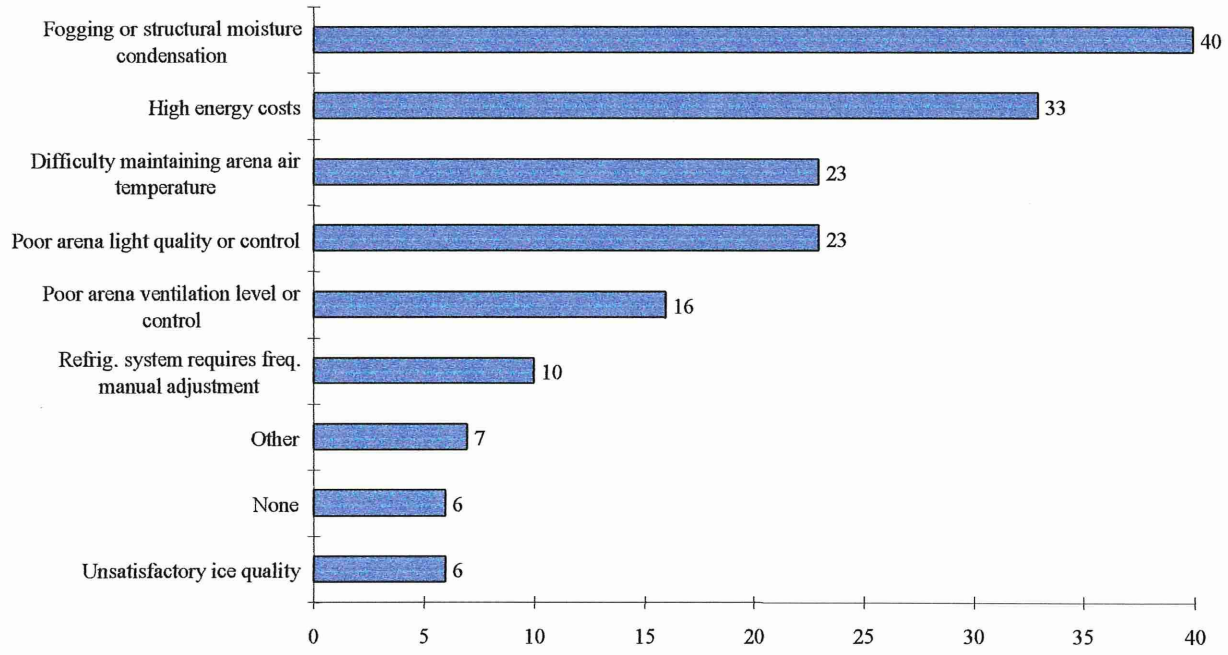

Figure 3. Number of Arenas Reporting Energy/IAQ Problems

Arena managers were asked to specify their level of interest in 13 different technologies. Almost all of the technologies have 10% to 30% market penetration, indicating that they are good candidates to be included in the program. A high level of arena manager interest was found for chiller waste heat recovery, improved chiller controls, high efficiency motor replacement, and electric resurfacers.

The managers were also asked the length of time required to fund an improvement that would pay for itself in five years or less. Over 70% of the arenas could fund an improvement costing

less than $2,500 within three months. For improvements costing more than $10,000, only half of the arenas would be able to fund the work in six months or less while three-fourths would be able to fund the work in one year or less.

This survey was not intended to provide a comprehensive market assessment of energy improvement technologies. However, a number of valuable insights were made about potential energy improvement technologies:

1. A significant number of arenas could be improved by using a multiple pump or multi-speed coolant pumping system.
2. A high percentage of arenas could save energy by varying the ice temperature setpoint according to arena use.
3. There may be a large potential for energy savings and reduced compressor wear from reducing head pressure settings.
4. Snow pit melting, and other uses of heat reclaim, are promising opportunities for reducing energy use in older arenas.
5. Since 95 % of arenas use hot or warm water for flooding the ice sheet, there is a large potential for saving energy through the use of flood water demineralization or other means to lower the flood water temperature.
6. Automated ventilation controls are being used in only a limited number of arenas and may be better able to balance the need for acceptable indoor air contaminant levels and minimized energy costs.
7. In 87% of the arenas individual banks of light fixtures can be switched on or off to vary light levels over the ice sheet. Better light quality and energy savings may be achieved in many arenas using multi-level output fixtures.

Additional relevant information that was used to characterize the refrigeration equipment and the opportunities to reduce its energy use are listed below:

1. Indirect and direct cooling of the ice sheet are used to about the same degree and half of the systems with a mechanical pumping system have a single coolant pump that runs continuously.
2. Three-fourths of the compressors are open-reciprocating (industrial grade), 20% are semi-hermetic reciprocating (commercial grade), and 4% are rotary screw (industrial grade).
3. About one-half of the arenas use coolant temperature for compressor control and most of the rest use a temperature sensor under or in the ice sheet.
4. Most of the arenas use either a water-cooled condenser with cooling tower or evaporative condenser and the remaining one-quarter use air-cooled condensers.
5. About two-thirds of the arenas are using heat reclaim from the chiller for either snow pit melting (30%), subfloor heating (27%), space heating (26%), and/or water heating (14%).
6. R-22 is used as a refrigerant in all of the arenas built in the past ten years and 81% of all surveyed arenas.

These results were used to focus efforts on technologies that are widely applicable to the most common equipment variations.

Assessment and Promotion of Energy Saving Technologies

A thorough assessment of energy saving retrofit technologies that were potentially appropriate for existing ice arenas was conducted early in the project. CEE's engineers contacted a wide variety of local, national, and international industry professionals that included arena designers, refrigeration system designers, and equipment manufacturers. Relevant published information from sources such as trade associations and engineering journals was also reviewed as part of the technology assessment. After objectively reviewing the available information on each technology's expected cost-effectiveness for the variety of ice arenas in Minnesota, CEE's engineers then pared down the list to include those technologies that are worthy of promotion and arena-specific evaluation as part of the energy audits.

Preliminary technology fact sheets were then prepared for technologies that would be cost-effective for a number of arenas in Minnesota. The preliminary technology fact sheets were then distributed to arenas that would be receiving an audit to help familiarize them with the options that would be evaluated. The preliminary fact sheets also served as a starting point for technology specific information that was included in each arena's audit report.

After the completion of the audits and subsequent retrofits, the technology fact sheets were updated and a summary report entitled *Cost-Effective Energy Efficient Improvements for Minnesota's Public Ice Arenas: Overview of 20 Options* was mailed to all the managers of public ice arenas in Minnesota. This report appears in **Error! Reference source not found.** and it will be sent to interested parties upon request. Other efforts to promote the benefits of energy efficiency and indoor air quality retrofits included leading a roundtable discussion at a meeting of the Minnesota Ice Arena Managers Association and a presentation at an engineering conference.

Arena specific energy savings analysis procedures were also developed for the most viable technologies. For each arena, a site-specific, detailed arena model was developed to perform energy cost savings analyses for most of the promising technologies for each arena.

Utility bill analysis of a number of arenas was also carried out as part of this task to better characterize the typical variation in energy costs among arenas in Minnesota. This helped with preliminary evaluations of the potential energy cost savings for a number of technologies. Insights gained through this analysis also helped guide the development of the energy savings calculation procedures.

Energy Audits

Based on the written survey results (described previously) and follow-up contacts, 28 ice arenas were selected for energy audits.[3] The criteria used in selecting these arenas included considerations of the following factors:

1. Technical potential energy savings based on operation
2. Likelihood that funding and implementation could be realized within the timeline
3. Level of interest in the project and energy saving technologies
4. Even distribution throughout the state

The audited arenas are listed in Table 1 along with a summary of the key audit results. More information about specific arena audits can be found in the individual audit executive summaries that appear in **Error! Reference source not found.**.

Table 1. Summary of Arena Audits

Arena Name	Location	Ice Sheets	Annual Energy Cost	Annual Savings		Retrofit Cost
				Potential	% of Total	
Babbit Arena	Babbitt	1	$20,822*	$4,230	20%	$28,286
Bloomington Ice Gardens	Bloomington	3	$195,176	$49,343	25%	$212,186
Bud King Arena	Winona	1	$34,157	$8,021	23%	$72,233
Chaska Community Center	Chaska	1	$45,539*	$11,799	11%	$64,584
Columbia Arena	Fridley	2	$126,932	$70,170	55%	$346,452
Cottage Grove Ice Arena	Cottage Grove	2	$60,930	$28,252	46%	$167,322
Dave Skenzich Memorial Arena	Gilbert	1	-	$596	-	$3,210
Eagan Civic Arena	Eagan	1	$77,970	$23,205	30%	$95,530
Farmington Civic Arena	Farmington	1	$41,077	$15,114	37%	$85,722
Hodgins Berardo Arena	Coleraine	1	$39,710	$11,148	28%	$66,899
Hoyt Lakes Arena	Hoyt Lakes	1	$44,712	$11,726	26%	$92,164
Hutchinson Civic Arena	Hutchinson	1	$36,283	$8,538	24%	$47,634
Lee Community Center	Morris	1	$16,567	$1,218	7%	$10,854
Lily Lake Arena	Stillwater	1	$30,002	$2,972	10%	$20,373
Litchfield Civic Arena	Litchfield	1	$21,025	$2,815	13%	$23,668
Mankato Civic Arena	Mankato	1	$83,255	$7,397	9%	$51,000
Multipurpose Sports Building	Duluth (UMD)	1	$63,466*	$11,020	17%	$65,649
Parade Ice Garden	Minneapolis	3	$199,190	$58,639	29%	$238,879
Riverside Arena	Moose Lake	1	$30,002*	$651	2%	$6,841
VFW Memorial Ice Arena	E Grand Forks	1	$45,539	$2,142	5%	$13,858
Victory Memorial Ice Arena	Minneapolis	1	$50,671	$27,115	54%	$82,185
West St. Paul Arena	West St. Paul	1	$31,879	$2,116	7%	$18,796
Total	22	28	$1,294,904	$358,227	28%	$1,814,325
Per Ice Sheet	-	-	$46,247	$12,794	-	$64,797

*Because of limited utility data, these values are estimates based on the energy costs of similar arenas.

[3] Each of these arenas was required to verify compliance with Minnesota's prime ice time and gender preference requirements by submitting the Ice Arena Compliance Form that is found in **Error! Reference source not found.**.

Annual arena energy costs for the audited arenas average about $46,000 with significant site to site variances. Although a number of factors affect energy use, the two most dominant factors were operating season and indoor space temperature.

The energy audits identified a total of $358,000 worth of annual energy savings that could be realized by implementing all energy saving retrofits with a payback of 10 years or less. The average payback for the measures identified in the audits is 5 years. This amounts to a 28% potential reduction in energy costs or about $13,000 annually for a typical ice arena with the project group's average energy cost of $46,000. In addition, the energy audits found that over $30,000 in annual energy cost savings could be realized through simple adjustments to equipment controls without any substantial up-front costs. Although a variety of factors, such as operating season and degree to which an arena is heated, affected the amount of cost-effective energy savings that could be achieved for the various arenas, it was interesting that age of the arena was generally not a key factor.

Installations of Energy Efficiency and Air Quality Improvements

Following the delivery of the energy audit reports to 28 arenas, CEE staff worked with the arenas to select and implement improvements with both engineering support and energy grants. The audits and follow-up support has resulted in the installation of $575,000 worth of energy efficiency and indoor air quality improvements in 16 arenas. The total annual energy cost savings from these improvements is $106,500, which represents 15% of the previous annual energy costs of these arenas. The gross simple payback for the improvements averaged 5.4 years. In terms of avoided energy consumption, the savings total 2,100 megawatt-hours of electricity and 6.75 million cubic feet of natural gas per year. Table 3 summarizes the resulting improvement installations by arena while Figure 4 and Figure 5 show the breakdown of expenditures and energy costs savings for the various types of improvements.

Table 3. Installations of Energy Efficiency and Air Quality Improvements

Arena Name	Location	Ice Sheets	Annual Savings		Improvement Cost	Energy Grant
Bloomington Ice Garden	Bloomington	3	$38,858	20%	$195,774	$93,273*
Cottage Grove Ice Arena	Cottage Grove	2	$19,905	33%	$135,291	$67,646
Farmington Civic Arena	Farmington	1	$10,099	25%	$55,308	$25,937*
Hutchinson Civic Arena	Hutchinson	1	$3,793	10%	$28,675	$14,338
Lily Lake Arena	Stillwater	1	$750	2%	$10,345	$5,173
Litchfield Civic Arena	Litchfield	1	$2,129	10%	$15,500	$7,750
Parade Ice Garden	Minneapolis	3	$7,570	4%	$59,174	$0**
Riverside Arena	Moose Lake	1	$651	2%	$6,841	$3,421
VFW Memorial Ice Arena	E Grand Forks	1	$0†		$5,587	$2,794
Victory Memorial Arena	Minneapolis	1	$20,926	41%	$57,021	$0***
West St. Paul Arena	West St. Paul	1	$1,854	6%	$5,138	$2,569
Total	11	16	$106,535	15%	$574,654	$2,569.00

†No energy cost savings is occuring at VFW Memorial Arena because only air quality improvements were installed.
*Energy grants are less than 50% for these facilities because not all improvements were completed by the project's end.
**Improvement work is planned, but has not yet begun at this site.
***Most of this work was completed when the project ended, but other sources of state funding were used to partially pay for the improvements.

Each arena that completed eligible retrofits was provided a one-for-one matching grant. These matching grants totaled $222,900, or 96 percent of the $232,000 that was appropriated for matching grants. The completion of audits and original offers of grants were spread over the course of 21 months. It was therefore deemed appropriate to establish various grant requirements and limitations in addition to the requirement of a one-for-one non-state match to try and distribute the grant money evenly while still having the flexibility to provide significant support for unique savings opportunities. The additional limitations that CEE initially established are listed below:

1. A maximum of $25,000 per ice sheet.
2. Improvements made to save energy must have a payback of 10 years or less.
3. The grant is limited by the amount that will reduce the arena's payback to 2 years.

The arenas that were audited relatively early in the project committed to completing large improvement projects at a much greater rate than was expected so additional limitations were required later in the project to ensure that each arena would have a chance to obtain a grant.

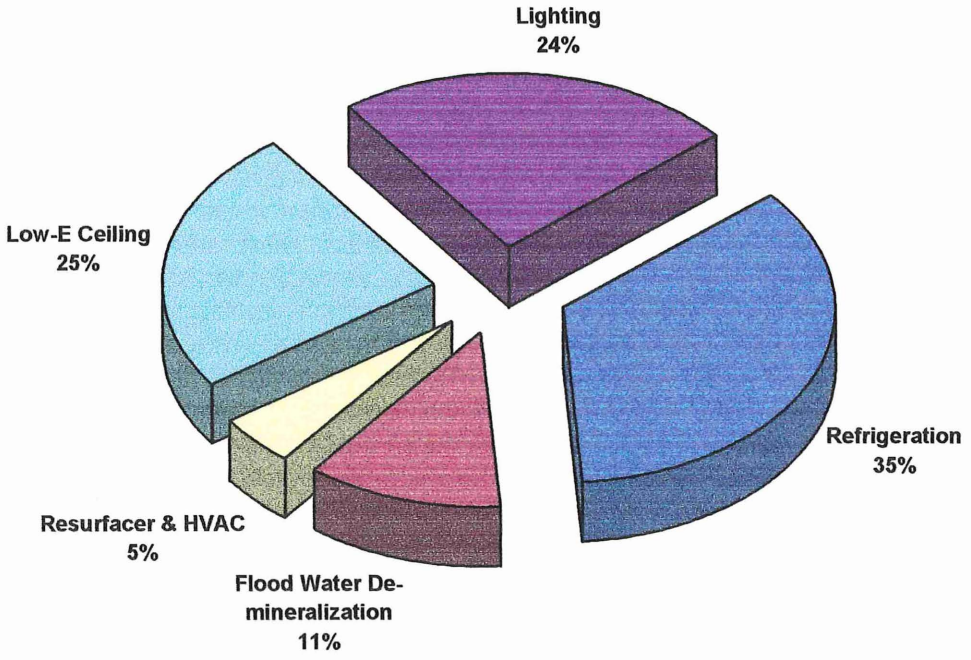

Figure 4. Improvement Breakdown by Installation Cost

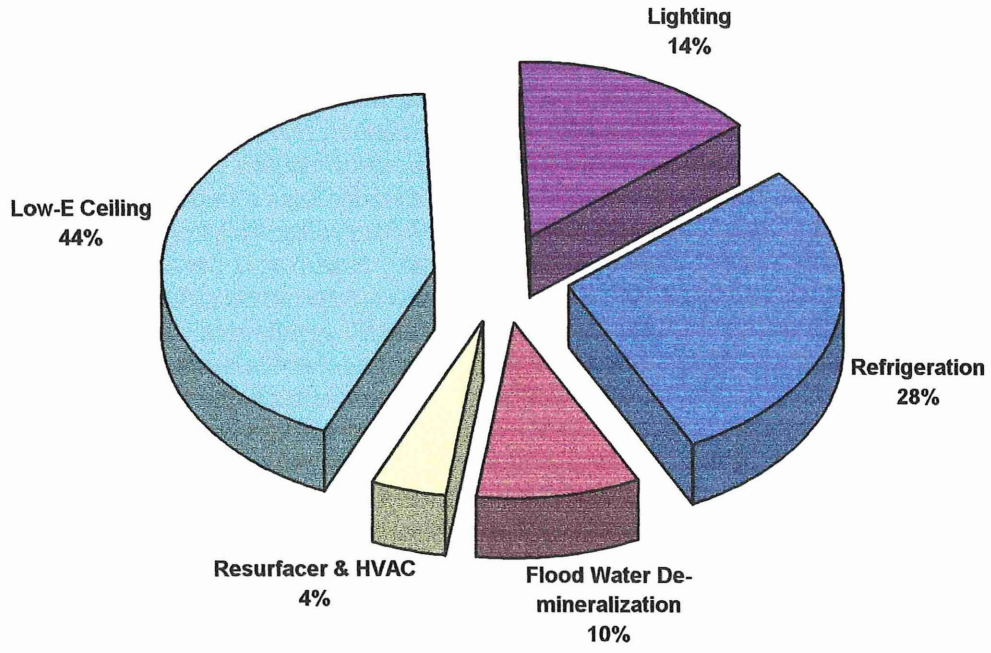

Figure 5. Energy Savings Breakdown by Type of Improvement

Therefore, when the audit reports were delivered to the last 15 arenas, they were only guaranteed grants of at least $5,000 each for eligible improvement projects. Deadlines for turning in Energy Grant Applications were then established, and those arenas that applied for a grant of more than $5,000 were subsequently guaranteed larger grant amounts after other arenas decided not to apply. Some arenas then completed less work than was originally committed to, and three arenas did not complete any of the work committed to within the timeframe of the project. The matching grant funds that were freed up by these unmet commitments were distributed to the arenas that were completing the improvements within the project timeline. Since there was then enough grant money to provide a full one-for-one match to each participating arena that applied for and completed eligible improvement projects, some exceptions to the three previously listed requirements were granted. Table 4 shows how the original commitments to complete improvement projects translated into actual project completions and how the individual energy grants were effected. The "Original" grant amount reflects the minimum grant that was guaranteed after all applications were received, while the "Limited" grant amount reflects the arenas' energy grants according to a strict application of the three limitations that were temporarily established to make sure that the energy grant funds were not exhausted by the first participating arenas.

Table 4. Arena Follow-Through on Improvement Commitments

Arena	Location	Ice Sheets	Improvement Cost		Energy Grant Amount		
			Committed	Completed	Original	Limited	Final
Bloomington Ice Garden	Bloomington	3	$207,407	$195,774	$75,000	$75,000*	$93,273
Chaska Ice Arena	Chaska	1	$16,500	$0	$7,560	$0	$0
Cottage Grove Ice Arena	Cottage Grove	2	$144,322	$135,291	$50,000	$50,000*	$67,646
Eagan Civic Arena	Eagan	1	$9,530	$0	$4,765	$0	$0
Farmington Civic Arena	Farmington	1	$68,422	$55,308	$20,000	$15,906*,**	$25,937
Hutchinson Civic Arena	Hutchinson	1	$47,634	$28,675	$20,000	$14,338	$14,338
Lily Lake Arena	Stillwater	1	$10,345	$10,345	$5,000	$0**	$5,173
Litchfield Civic Arena	Litchfield	1	$15,500	$15,500	$7,750	$7,750	$7,750
Parade Ice Garden	Minneapolis	3	$59,174	$59,174†	$29,587	$0†	$0†
Riverside Arena	Moose Lake	1	$6,841	$6,841	$3,421	$3,421	$3,421
VFW Memorial Ice Arena	E Grand Forks	1	$7,400	$5,587	$3,700	$2,794	$2,794
Victory Memorial Arena	Minneapolis	1	$43,600	$57,021†	$0†	$0†	$0†
West St. Paul Arena	West St. Paul	1	$12,600	$5,138	$5,000	$338***	$2,569
Total	13	16	$649,275	$574,654	$231,783	$169,547	$222,901

†Ineligible for grants because improvements completed outside of the project timeline or with other state funding.
*Grants limited by $25,000 per ice sheet.
**Grants limited by higher actual costs leading to a payback > 10 years.
***Grant limited by payback of < 2 years.

Although some individual projects were delayed or dropped, the overall expenditures were 89 percent of the original commitments. Competing priorities for administrative and financial municipal resources was the biggest barrier to completion. Improvements at one site were postponed because the allotted budget was used for an emergency refrigeration equipment replacement, while two other improvement projects were delayed because key arena administrators could not take time away from the oversight of building addition projects. Some specific parts of other improvement projects were dropped when CEE's follow-up engineering

services provided for project specification and construction oversight led to a change in the recommendations for those arenas. Variations between original cost estimates and actual installed costs also affected the ratio of project completions to commitments. Although various factors led to improvement project delays and cancellations, the fact that energy savings for actual improvements is 84 percent of what was projected for all improvement commitments indicates that these were not a major hindrance to the project's success once an arena actually made a commitment.

While follow-through on commitments was high, there were significant barriers to securing commitments to install cost-effective energy efficiency and air quality improvement measures. Only about 30 percent of potential cost-effective energy savings identified by the audits was actually implemented. The most important barrier preventing arenas from installing these improvements was the inability and low priority of municipalities to set aside funds for these improvements. This was exacerbated by the number of arenas that only had a window of from 4 to 9 months between receipt of the audit and the end of the project. One key to overcoming these barriers was by promoting the multiple benefits of many of the improvements beyond the primary energy efficiency or air quality improvement. Some examples of how other benefits helped to encourage energy saving improvements are listed below:

1. The installation of flood water demineralization equipment improves both the clarity and durability of the ice sheet, besides saving energy.
2. Lighting upgrades often lead to improved lighting levels while saving energy.
3. Lighting, motor, and refrigeration control upgrades allow arenas to install new equipment that will have reduced maintenance needs.
4. Low-emissivity ceiling installations improvedthe distribution of light and reduced ceiling moisture condensation while saving energy.
5. One of the condenser fan adjustable speed drive installations is expected to solve significant refrigeration equipment problems.

Because of these multiple benefits, many arenas made significant investments in improvements with energy savings paybacks on total costs of up to 10 years—even beyond 10 years in some cases. Because of grants and rebates, the actual payback periods for the municipal investments is less than or equal to half of the payback on total costs. Figure 6 shows the number of arenas that invested in each type improvement while Figure 7 energy savings payback time.

Another factor that helped many arenas overcome the funding priority barrier was the offer of zero interest financing by Northern States Power Company (NSP) and rebates from various utilities. This project leveraged more than $60,000 in energy improvement rebates from utilities, which helped reduced the arenas' net installation cost. A total of $252,000 worth of improvement work was also financed through NSP's no-interest loans that are paid back over the length of the energy savings payback period. In this way, the municipalities do not have to allocate any funds for improvements—they simply pay back the loan with the money that is saved on utility bills. While many arenas have benefited from NSP's Local Government Program, NSP has phased it out as of July 1998.

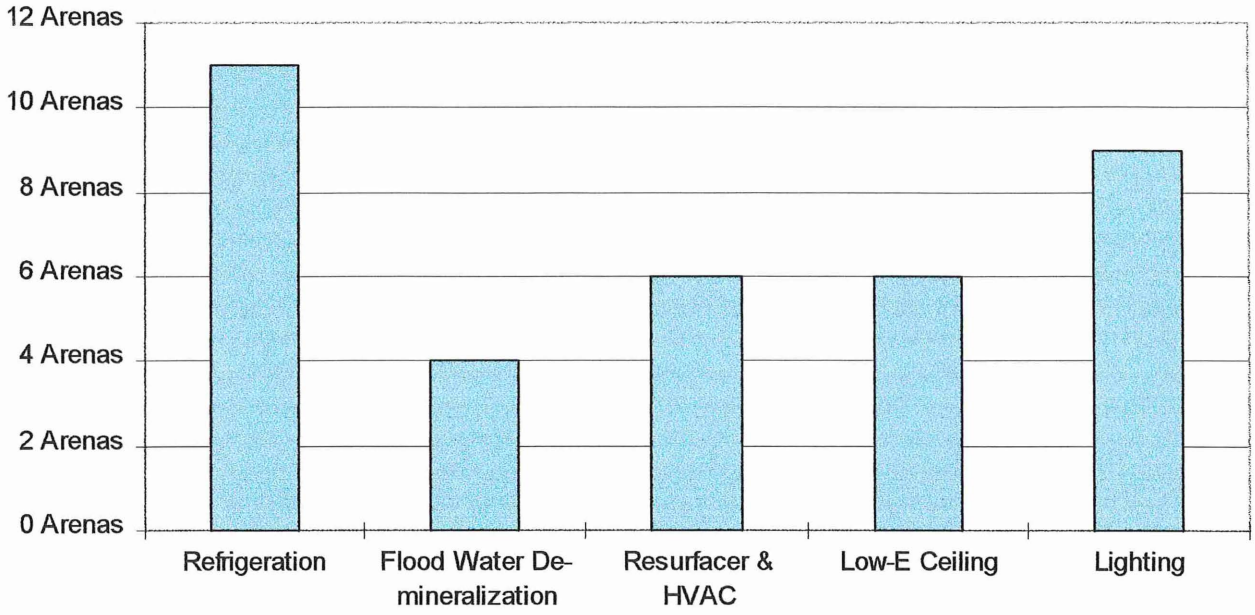

Figure 6. Installation Frequency by Type of Improvement

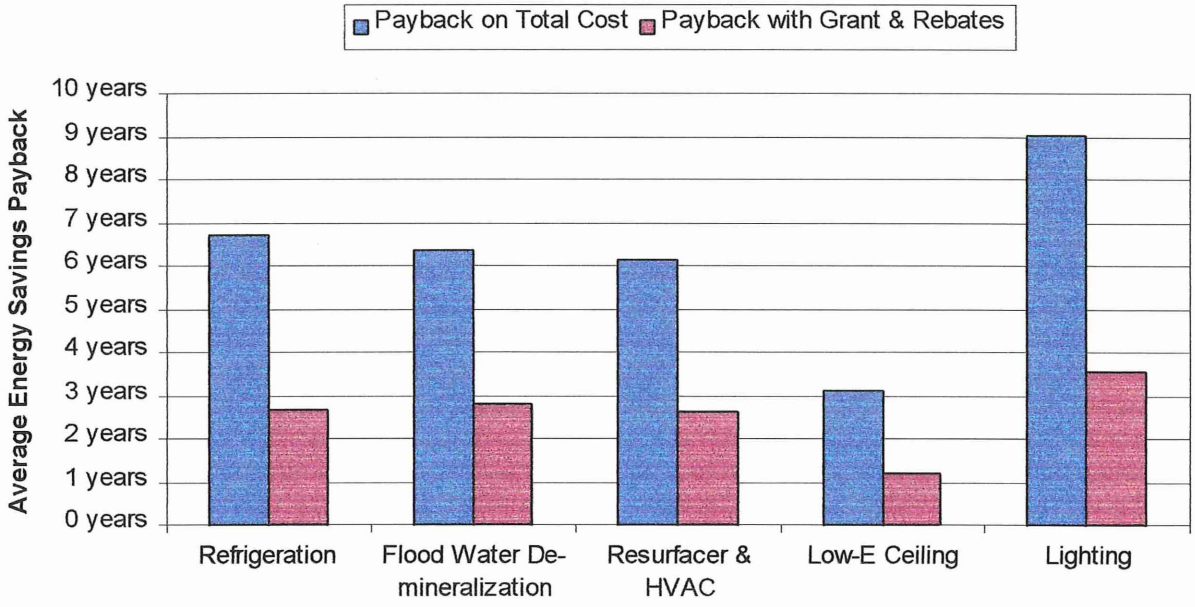

Figure 7. Energy Savings Payback by Type of Improvement

Field Performance Evaluation

Field performance evaluation efforts focussed primarily on detailed measurements in a few arenas. This approach was taken because the completion of improvements near the end of the project did not make a thorough post-installation evaluation of each arena possible. Most arenas did not have improvements in place long enough for arena managers to provide meaningful feedback on performance, and there was not enough post-installation data to make a meaningful comparison of pre and post retrofit utility bills. Instead, more detailed (and often short-term) measurements were used to verify the engineering analysis methods used to estimate energy savings.

Monitoring of refrigeration equipment serving eight ice arenas has provided verification and new information for key performance calculation algorithms. Important results of short-term refrigeration system measurements include:

1. Quantification of the magnitude and daily variation of refrigeration loads.
2. Characterization of the short-term fluctuations in ice temperature and their impact on compressor operation.
3. Verification of the effects of compressor capacity control on performance.
4. Characterization of the load profile for snow-melt pit heat reclaim.

Detailed long-term measurements also provided verification of the energy savings from a major refrigeration system improvement at Bloomington Ice Gardens. At this one site, the measured energy savings with the new refrigeration equipment was even higher than the engineering estimate.

Measurements of indoor air pollutant levels and their variations were conducted in four arenas to study the effect of ice resurfacer and edging equipment on pollutant levels, and the potential for reducing pollutant levels through ventilation control and resurfacer improvements. The measurements also provided information on actual ventilation rates. Limited measurements of the variations in temperature and humidity in several arenas also provided insight that guided the refinement of energy saving calculation algorithms.