ACKNOWLEDGEMENTS

This project was supported by a grant from the Minnesota Department of Commerce, Division of Energy Resources, through the Conservation Applied Research and Development (CARD) program, which is funded by Minnesota ratepayers.

DISCLAIMER

This report does not necessarily represent the view(s), opinion(s), or position(s) of the Minnesota Department of Commerce (Commerce), its employees or the State of Minnesota (State). When applicable, the State will evaluate the results of this research for inclusion in Conservation Improvement Program (CIP) portfolios and communicate its recommendations in separate document(s).

Commerce, the State, its employees, contractors, subcontractors, project participants, the organizations listed herein, or any person on behalf of any of the organizations mentioned herein make no warranty, express or implied, with respect to the use of any information, apparatus, method, or process disclosed in this document. Furthermore, the aforementioned parties assume no liability for the information in this report with respect to the use of, or damages resulting from the use of, any information, apparatus, method, or process disclosed in this document; nor does any party represent that the use of this information will not infringe upon privately owned rights.
# Table of Contents

Executive Summary .................................................................................................................. 3

Introduction and Background ................................................................................................. 4

Minnesota Context ....................................................................................................................... 5

Conservation Improvement Program ....................................................................................... 5

Statewide Potential Study ......................................................................................................... 6

Publicly Funded Energy Efficiency Technology Research ..................................................... 6

California’s Electric Program Investment Charge ................................................................. 7

White Paper Objectives ............................................................................................................. 8

Methodology .............................................................................................................................. 9

Project Screening ....................................................................................................................... 10

Technology Fact Sheet Development ...................................................................................... 12

EPIC Technology Research Database ..................................................................................... 13

Overview ................................................................................................................................ 13

Summary Statistics .................................................................................................................... 13

Using the Database .................................................................................................................... 14

Technology Fact Sheets and Supplemental Project Information ............................................. 17

Fact Sheet Overview ................................................................................................................ 20

Fact Sheets ................................................................................................................................. 21

Commercial HVAC Technologies and Controls ..................................................................... 21

New Wastewater Treatment Technologies ............................................................................. 26

Emerging Technologies in Food Services and Grocery .......................................................... 33

Assorted Commercial Building Technologies ....................................................................... 37

Program Adoptions Strategies and Insights from Consumer-Oriented Studies ..................... 42

Discussion................................................................................................................................ 46
Executive Summary

Minnesota utilities administer energy conservation programs to help customers save energy. These programs evolve as market forces, consumer adoption, and available technologies change. The Minnesota Department of Commerce administers the Conservation Applied Research and Development (CARD) program, and some utilities investigate emerging technologies internally to keep program portfolios current. The authors of this paper sought to complement the Minnesota-based efforts with an investigation of emerging technologies being developed and studied by publicly funded research in California through the Electric Purpose investment Charge (EPIC) program.

This white paper summarizes 20 emerging technologies and innovations from EPIC studies that may be applicable and of value to Minnesota utilities—nine presented as technology fact sheets and eleven included as supplemental information. These emerging technologies and innovations fall into five general topic areas:

- Commercial HVAC Technologies and Controls
- New Wastewater Treatment Technologies
- Emerging Technologies in Food Services and Grocery
- Assorted Commercial Building Technologies; and
- Program Adoption Insights from Consumer Studies.

These technologies were selected through a screening process to identify EPIC studies with the greatest potential relevance to Minnesota. We also have made available a database of all 296 EPIC studies from the program’s first two triennia of funding.

While applicability of the featured technologies to Minnesota utilities’ Conservation Improvement Programs (CIPs) will vary, those seeking new technologies to add to their portfolios may wish to review and consider the technologies included in this white paper and the attached fact sheets. Those wishing to go further could explore the screening database we developed for consideration of the fuller portfolio of EPIC studies to consider a wider range of emerging technologies and innovations. We note that many of these technologies are evolving and may require some tracking of their development in the laboratory or marketplace before they can be fully considered.

The Minnesota Department of Commerce could assist in tracking EPIC-funded technologies of interest to multiple Minnesota utilities and serve as a repository of secondary information about these technologies as EPIC studies are completed and performance information is published. Further, some of these technologies may warrant Minnesota-specific studies through the CARD program.

Given the comparatively light investment required to screen and summarize technologies funded by other states or public entities, there may be value in examining other large research and development programs in similar ways as this white paper does for EPIC.
Emerging Energy Efficient Technologies
Evergreen Economics

Introduction and Background

This white paper was funded by the Minnesota Department of Commerce’s Division of Energy Resources and developed by Evergreen Economics to identify emerging energy efficiency technologies that are likely to be relevant to energy conservation efforts by the state’s utilities for their customers—the state’s residents and businesses—in future years. To be more specific, the projects presented in this white paper complement on-going work in Minnesota that is already examining emerging technologies through vehicles such as state-funded research and development of specific technologies, energy conservation potential studies that examine near-term emerging technologies that are already available commercially, and research by individual utilities’ conservation improvement programs. While these efforts examine existing technologies that are already available in Minnesota, we sought to fill a gap by examining more future-oriented technology development funded publicly by the state of California that are still being created or demonstrated and evaluated. We screened 296 studies funded in California for technical promise and potential applicability in Minnesota and present the results of our work here.

As detailed in this white paper, our work entailed a screening process for the California-funded projects to identify those with the greatest promise for Minnesota and develop technology fact sheets to introduce the technologies we identified, provide an update on the status of their development, and suggest ways to follow their development as some of them mature or evolve to a point where it would make sense to include them in energy conservation portfolios.

The white paper is organized as follows:

- Introduction and Background—We begin by providing more detailed background to put this work in context.
- Methodology—We present our approach for the secondary research presented in this paper and the associated resources we created.
- EPIC Technology Research Database—We present the database (available separately) that identifies the research we reviewed and presents our screening scores for each. This database may be useful for efficiency professionals and researchers wishing to explore technologies beyond those we chose to highlight as technology fact sheets, as well as for utilities wishing to take a deeper look at potential emerging technologies.
- Technology Fact Sheets—Here, we present the core of our secondary research’s results. We introduce the technologies from the California research that appeared most promising and applicable for Minnesota. We present these technologies in the form of stand-alone technology fact sheets in Appendix B, but incorporate the core information from the fact sheets and supplemental information about additional relevant projects in this white paper as well.
- Discussion—We close with some high-level observations about the emerging technologies we highlighted for Minnesota energy conservation efforts and discuss opportunities to leverage out-of-state research such as California’s EPIC program.
Minnesota Context

Minnesota utilities administer energy conservation programs to help customers save on energy consumed, thereby reducing their bills, and to comply with state statute. These programs evolve as market forces, consumer adoption, and available technologies change. This white paper is intended to help inform these programs and the processes that support them. For readers not fully aware of Minnesota’s efficiency and program context, we provide the following background.

Conservation Improvement Program

The Conservation Improvement Program (CIP) helps Minnesota households and businesses use electricity and natural gas more efficiently—conserving energy, reducing carbon dioxide emissions, and lessening the need for new utility infrastructure. CIP is funded by ratepayers and administered by electricity and natural gas utilities.

The Next Generation Energy Act of 2007 established energy conservation as a primary resource for meeting Minnesota’s energy needs while reducing greenhouse gases and other harmful emissions. The Act also established a savings goal of 1.5 percent of annual retail electricity and natural gas sales for all utilities in the state. The utilities may reach this annual goal directly through the CIP and, indirectly, through energy codes, appliance standards, and behavioral and other market transformation programs.

Typical utility programs for residential customers include:

- Energy audits, where a trained energy consultant examines a home and offers specific advice on energy improvements;
- Rebates on high-efficiency heating, cooling, and water-heating appliances; efficient lighting; and low-flow showerheads and faucet aerators; and
- Air-conditioner cycling programs, which allow the utility to manage its peak energy demand in return for discounted electric bills for participating customers.

Typical utility programs for commercial or industrial customers include:

- Rebates for high-efficiency boilers, chillers, and rooftop units; high efficiency motors and drives; high-efficiency lighting and lighting control systems;
- Building recommissioning studies; and
- Manufacturing process improvements that reduce energy intensity and improve productivity.

---

1 Minnesota Statutes, 216B.241
2 Laws of Minnesota 2007, Chapter 136, SF145
3 A subsequent update to Statute 216B.241 exempts smaller utilities from these requirements (specifically, electric cooperatives with 5,000 or fewer members, electric municipals with 1,000 or fewer retail customers, and natural gas municipals with 1 million cubic feet or less annual throughput sales). See Subdivision 1b in the statute.
Utilities develop and administer their own CIPs and update them as market conditions, technological developments, consumer response, and program cost-effectiveness warrant. Utilities file triennial program plans with the Department of Commerce that include any updates in program measures, approaches, and coverage. Newly included measures and technologies are often based on technological developments and informed by utility-sponsored research, Department of Commerce-funded Conservation Applied Research and Development (CARD) research, and other energy efficiency research.

**Statewide Potential Study**

A recently completed study of statewide energy efficiency potential\(^5\) provides a comprehensive source of information for Minnesota utilities on emerging technologies that are sufficiently developed to be incorporated into some program plans immediately or in the near term.

Emerging technologies included in the study are:

- The application of emerging lighting technology and design principles in new construction, including LEDs, daylighting, advanced lighting controls, and fixture layouts;
- Aerosol envelope sealing to reduce air infiltration from hard to reach areas (like electrical outlets) in newly constructed homes;
- Condensing roof-top units (RTUs) to reduce heating energy in many commercial applications; and
- New approaches to building recommissioning that focus on continuous commissioning of commercial buildings.

**Publicly Funded Energy Efficiency Technology Research**

As noted, the Department of Commerce’s CARD grant program provides for energy efficiency research and development that is particularly relevant for Minnesota. This program funds approximately $2.6 million annually in applied research with a focus on research and demonstrations that could be applied by Minnesota utilities in their CIPs.

Several other research and development funds also support the development and study of applicable technologies nationally or in other parts of the United States that produce results or further technologies with future potential application in the upper Midwest. These funds include:

**National Funds**

- The DOE’s Advanced Research Projects Agency-Energy Program (ARPA-E)
- The U.S. Department of Energy’s (DOE’s) Small Business Innovation Research (SBIR) Program
- The DOE’s Small Business Technology Transfer (STTR) Program

---

\(^5\) Ibid.
State / Regional Funds

- California’s Electric Program Investment Charge (EPIC) program
- California’s Natural Gas Research and Development program
- The New York State Energy Research and Development Authority’s (NYSERDA’s) Technology and Market Development (T&MD) Program

California’s Electric Program Investment Charge

This white paper addresses the EPIC program, which we describe in more detail below.

The Electric Program Investment Charge is an innovation funding program that seeks to advance the frontiers of energy science and technology. The California Public Utilities Commission (CPUC) established and oversees EPIC, while the California Energy Commission (CEC) administers 80 percent of the program’s funds and California’s electric investor-owned utilities (IOUs) administer the other 20 percent. California’s electric IOUs are Pacific Gas and Electric (PG&E), Southern California Edison (SCE), and San Diego Gas & Electric (SDG&E).

Grant-funded studies from the first two triennial funding cycles (covering 2012 to 2017) are at or near completion, marking the availability of research from many of the 296 projects selected for funding with a total authorized budget of $874,099,034 in public investments.

The bulk of the funded projects address energy efficiency or demand side management, while others seek solutions for problems related to grid operations/market design, generation, transmission, or distribution of electricity. Demand-side management projects generally promote new technologies or operational practices that will produce efficiencies in end-use consumption of electricity. Other projects primarily administered by the IOUs look at further understanding and management of end-use consumption, load profiles, or other technology developments (such as smart-charging platforms of plug-in electric vehicles).

Projects are further divided by the nature of the research or market support they are intended to provide to new technologies or solutions for the electricity industry and its users. These categories are:

- **Applied Research and Development (Applied R&D)** – Applied R&D activities support pre-commercial technologies and approaches that are designed to solve specific problems in the electricity sector.
- **Technology Demonstration and Deployment (TD&D)** – TD&D addresses the installation and operation of pre-commercial technologies or strategies at a scale sufficiently large enough and in conditions sufficiently reflective of anticipated actual operating environments to enable appraisal of operational and performance characteristics and financial risks.
- **Market Facilitation** – Market Facilitation refers to a range of activities including program tracking, market research, education and outreach, regulatory assistance and streamlining and workforce development to support clean energy technology and strategy deployment.
As shown in Figure 1, the single largest topic area among funded studies was demand-side management or energy efficiency. Studies that addressed technology demonstration and deployment (TD&D) were more common than either applied research and development (R&D) or market facilitation (MF).

Figure 1. Percentage of Projects by Topic Area Addressed, Project Type, and Administrator (through 2016)

Source: Administrators’ 2016 Annual Reports

**White Paper Objectives**

The objective of this white paper was to identify and describe relevant clean energy technologies and innovations being developed or demonstrated by EPIC-funded grants that would have applicability for Minnesota generally and the CIP more specifically, so their consideration and subsequent adoption can be accelerated as these solutions become viable.
Methodology

Our process for creating this white paper and the technology fact sheets and supplemental information contained herein consisted of:

- Screening EPIC studies for applicability in two separate rounds of scoring and incorporating the scores into the EPIC Technology Research Database we created for this study;
- Identifying preliminary fact sheet topics (linked to specific EPIC studies);
- Conducting more detailed research on the studies associated with the initial fact sheet topics; and
- Developing the fact sheets for technologies being investigated by the EPIC studies that continued to offer indications of future promise for Minnesota.

Figure 2 illustrates this process visually.

Figure 2. Screening and Fact Sheet Development Process

* We refer to 296 projects for consistency. This is the number of projects selected for funding by EPIC’s first two triennia. A small number of projects did not go forward, and we added one study from the third triennium upon stakeholder request. As a result, the net number of studies we screened is 291.
Project Screening

The scope of this effort comprised all 296 EPIC grant-funded studies from the first two triennial funding cycles (covering 2012 to 2017) plus one project from the third triennial funding cycle to address stakeholder-expressed interests. We screened each of these projects for applicability in Minnesota in two separate rounds of scoring.

These rounds of scoring were intended to highlight promising emerging technologies and exclude those that would not apply well to Minnesota based on the state’s energy use, climate, and program infrastructure, while also taking into account the apparent state of the technology being investigated.

The first scoring round was based on a short description of each EPIC grant-funded study. The second scoring round examined a somewhat more detailed description of the studies that had emerged as most promising as well as studies related to the highest-rated studies from the first round. Both rounds of scoring were based primarily on descriptions of the grants created before the studies were initiated and did not include additional inquiry into study findings and results to-date. (We reserved that level of inquiry for the development of fact sheets after promising technologies had been identified.)

Both scoring rounds were based on the same set of criteria and processes. Scoring criteria, which are also listed in Table 1, consisted of a preliminary judgment about the technology’s status and promise; its end-use’s applicability to energy consumption patterns in Minnesota; its fit for Minnesota’s climate; whether it serves to reduce energy demand, support the provision of energy, or both; the potential scale of its impact on reducing demand; the role a utility energy conservation program could play in supporting the technology’s proliferation and adoption; and the degree to which additional vetting would be needed to understand the technology’s impact in Minnesota so it could be included in the state’s technical reference manual.

Table 1. Scoring Criteria

<table>
<thead>
<tr>
<th>Scoring Criterion</th>
<th>Categorical Scoring Options</th>
<th>Total Points Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology Status</td>
<td>Research suggests major limitations</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Research still in progress / unclear results</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Research suggests viability</td>
<td></td>
</tr>
<tr>
<td>End-Use/Energy Applicability</td>
<td>None</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Limited applicability</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Above average</td>
<td></td>
</tr>
</tbody>
</table>
To conduct the scoring, we created a Microsoft Excel workbook that describes each project and contains all the scoring values. This scoring workbook became the EPIC Technology Research Database we discuss in the next section.
Technology Fact Sheet Development

The development of technology fact sheets, which followed the scoring of the EPIC studies, involved three steps:

- Fact sheet topic selection
- Additional information gathering
- Creation of technology fact sheets

We selected fact sheet topic areas based on CARD stakeholder input. After identifying highly rated technologies (studies), we created groupings of fact sheet topic areas that would each be based on one or more EPIC studies and presented these to a group of stakeholders invited by the Division of Energy Resources. Stakeholders representing Minnesota utilities and others interested in the CIP provided input and voted on technology topic areas. We selected the top-scoring five topic areas for development into technology fact sheets (or supplemental project information). Although our initial intent had been to write five to ten technology fact sheets, the manner in which individual fact sheets fell into groupings and the selection of five topic areas that generally contained multiple studies and technologies resulted in a larger number of fact sheets for potential development. This gave us room to drop individual fact sheets if further investigation found them to be of lower value or not sufficiently documented yet (often because the underlying EPIC study had not yet produced results).

Our research team reached out to the individual EPIC study teams working on technologies that were part of the selected fact sheet topic areas to request more information about the current state of the research, preliminary results, and expectations concerning future evolution and availability of the technology being investigated. Responses and the amount of detail available varied greatly. We also obtained data and assumptions about energy consumption in the state by end-use and sector from the Minnesota potential study team at the Center for Energy and Environment. These data, combined with EPIC study team assumptions and results about the degree of energy savings potential per application of their studied technologies, allowed us to develop high-level energy savings estimates. We provide the inputs, sources, and assumptions for these technology-specific potential savings estimates in Appendix A.

Once all these data were gathered, we assembled them into the technology descriptions presented in this white paper and the attached technology fact sheets. Ultimately, we developed technology fact sheets for nine technologies that fall into four of the topic areas and describe an additional eleven technologies covering all five topic areas as “supplemental information” in the body of the white paper.
Overview

Although the EPIC technology research database was created as a screening tool to identify EPIC-supported technology development that showed promise for future application in Minnesota, it may also serve as a useful tool for some interested readers looking for an overview of EPIC-supported technologies, those who are looking for specific types of technologies, or those who wish to create their own screening.

Below, we describe some summary statistics of what we found in our screening process and outline how readers can access and use the database for their own purposes. Please note that this database provides a snapshot of information available to us during our screening project—often about studies that were still in progress. The database is a static tool and not being updated as EPIC studies are completed or new ones are initiated.

For updates on specific projects, we recommend that readers visit the California Energy Commission’s Energy Innovation Showcase at http://innovation.energy.ca.gov and search for individual studies by EPIC project name.

Summary Statistics

We assessed 296 EPIC studies for applicability in Minnesota. Figure 3 summarizes how these EPIC studies performed in conjunction with each of our evaluation criterion in our second round of scoring. For this overview, we collapsed more nuanced rating categories into three simple ones to show whether studies and their underlying technologies appeared generally favorable or unfavorable for future application in Minnesota or whether we could not make even an initial determination.

As shown, some evaluation criteria filtered or downgraded studies and their underlying technologies more than others. Climate fit was not a differentiator, as most studies were developing or demonstrating technologies that would be feasible and applicable in Minnesota’s climate. On the other hand, end-use applicability and the aspect of the energy industry that the studies addressed (supply or demand) did help sort out more and less promising technologies, as our review team identified numerous EPIC studies as not addressing end-uses that are common in Minnesota or that would reduce consumption (as opposed to facilitating or improving efficiency for the supply of energy). Similarly, some technologies also did not have a clear path toward commercialization in a way that utilities could support through conservation improvement programs, which also weighed down their studies’ scores.

Meanwhile, two rating variables proved inconclusive when examining many projects during the screening process. We were often unable to assess the technology’s feasibility or likely impact with the preliminary information we had at the time of the ratings, leaving those assessments unanswered until we reviewed more detailed study information during the fact sheet development process.
Using the Database

The database is available publicly and may be of interest to anyone wishing to explore emerging technologies funded by EPIC that we did not select for our fact sheets. The database can be downloaded at https://eeaps.evergreenecon.com/card-emerging-technology/. Figure 4 illustrates the location on the project website where the database can be downloaded.
The database consists of three worksheets:

1. The worksheet titled Overview describes the database and provides some of the same instructions included here.

2. The Scoring and projects database contains the actual data as a flat file. Each of the EPIC grants we examined is listed in a separate row with groups of columns that include the following:
   - Project basics, including the EPIC grant name (which is useful for searching for more recent updates on not-yet-completed studies) and an official EPIC grant project description. These columns are useful for obtaining a sense of studies conducted or to search for particular projects by keyword.
   - Round 1 scoring fields that show the values we assigned to each parameter used in our scoring and the outputs during the initial scoring round for each EPIC study. These scores were based on preliminary information available from the EPIC project description and consisted of a preliminary judgment about the technology using the criteria described in our discussion of methodology above.
   - Potential applicability of the grant to a series of policy interests identified by the Department of Commerce.
   - Rescoring of each study for the applicable technology’s potential for Minnesota. The rescoring used the same variables and criteria as the initial (round 1) scoring, but was based on an improved understanding of the higher-rated studies. For this round, we examined more detailed descriptions of each study that received more than 70 points initially or that was connected topically with a fact sheet subject we were considering at the time of the scoring.
3. The *Scoring key* lists the various categories we used for scoring and classifying each project and the total number of points associated with each.

We suggest three uses of this database:

1. For users wishing to get a sense of the nature of EPIC projects for further exploration, we suggest simply skimming the description column.
2. For users wishing to identify projects that address particular end-uses or employ particular types of technology, we suggest a free-form search of the project name and the project description for any desired keywords.
3. Users wishing to modify the search criteria or scores to identify a different mix of studies will need to unprotect the applicable worksheets before changing criteria or scoring entries.
Five topic areas rose to the top as offering emerging technologies that show promise for Minnesota. Several of these topic areas include multiple technologies spread across separate EPIC studies. The five topic areas are:

- Commercial HVAC technologies and controls
- New wastewater treatment technologies
- Emerging technologies in food services and grocery
- Assorted commercial building technologies
- Program adoption insights from consumer studies

We developed technology fact sheets for four of these topic areas and described technologies studied by EPIC for all five topics in the body of this white paper. The fact sheets are intended as stand-alone resources for utility conservation improvement program portfolio managers and others tracking emerging technologies. They are attached as Appendix B, but we also summarize fact sheet content in this section.

Table 2 lists the individual technologies associated with each of these topic areas that we think show promise, as well as the EPIC study name. (The official study name is useful for readers who wish to track future developments by these studies.) The table also indicates whether the technology and associated study was developed into a full fact sheet (included in Appendix B) or just summarized in this section for context.

<table>
<thead>
<tr>
<th>Topic Area Technology</th>
<th>EPIC Grant Name</th>
<th>Full Fact Sheet in Appendix B?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial HVAC Technologies and Controls</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultrasonic Anemometer</td>
<td>Very Low-cost MEMS-based Ultrasonic Anemometer for Use Indoors and in HVAC Ducts</td>
<td>yes</td>
</tr>
<tr>
<td>Integrated Building Control Retrofit Package</td>
<td>Pilot-Scale Evaluation of an Integrated Building Control Retrofit Package</td>
<td>yes</td>
</tr>
<tr>
<td>Optimized Hybrid Cooling Controls</td>
<td>Climate appropriate HVAC Systems for Commercial Buildings to Reduce Energy Use and Demand</td>
<td>yes</td>
</tr>
</tbody>
</table>

Table 2. List of Technologies by Topic Area, Including EPIC Grant Name
<table>
<thead>
<tr>
<th>Topic Area</th>
<th>Technology</th>
<th>EPIC Grant Name</th>
<th>Full Fact Sheet in Appendix B?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>New Wastewater Treatment Technologies</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Raw Wastewater Filtration Cloth Depth Filters</td>
<td>Raw Wastewater Filtration to Increase Organic Removal Efficiency and Achieve Significant Electrical Savings</td>
<td>yes</td>
</tr>
<tr>
<td></td>
<td>Biofiltration as an Advanced Primary Treatment Method</td>
<td>Biofiltration as an Advanced Primary Treatment Method to Achieve Substantial Energy Savings</td>
<td>yes</td>
</tr>
<tr>
<td></td>
<td>Biological Double Efficiency Process (BDP)</td>
<td>Biological Double-Efficiency Process as an Advanced Wastewater Treatment Method to Achieve Substantial Energy and Water Savings</td>
<td>yes</td>
</tr>
<tr>
<td></td>
<td>Porifera Forward Osmosis (PFO) Recycler</td>
<td>Advanced Wastewater Treatment Using Forward Osmosis to Produce High Quality Water</td>
<td>no</td>
</tr>
<tr>
<td></td>
<td>Amphiphilic Membrane</td>
<td>Novel Membrane Technology to Improve Energy Efficiency and Water Savings in Wastewater Treatment Operations</td>
<td>no</td>
</tr>
<tr>
<td><strong>Emerging Technologies in Food Services and Grocery</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cost-effective energy efficiency upgrade package for a grocery store</td>
<td>MarketZero: Taking an existing grocery store to scalable near-ZNE</td>
<td>no</td>
</tr>
<tr>
<td>Topic Area</td>
<td>Technology</td>
<td>EPIC Grant Name</td>
<td>Full Fact Sheet in Appendix B?</td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td>Commercial Foodservice Equipment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Porifera Forward Osmosis (PFO) Concentrator</td>
<td>Demonstration of Forward Osmosis to Produce Juice Concentrate, Purify and</td>
<td>Demonstration of Forward Osmosis to Produce Juice Concentrate, Purify and Reuse Wastewater and Reduce Energy Use</td>
<td>no</td>
</tr>
<tr>
<td></td>
<td>Reuse Wastewater and Reduce Energy Use</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assorted Commercial Building Technologies</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Program Adoption Insights from Consumer Studies</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Fact Sheet Overview

We present here summaries of each technology we included in fact sheets and a few additional insights from other EPIC studies and related Minnesota CARD studies. Technology discussions are organized by topic area. For those technologies included in fact sheets (available in Appendix B), we provide:

- A description of the technology and what the EPIC study is seeking to accomplish;
- Discussion of the energy-related problem or opportunity the technology can address;
- Updates on the status of the study and ways to track the progression of the technology’s development; and
- A rough indication of the energy-saving potential of the technology in Minnesota.  

Related technologies include similar, but sometimes more limited, information. Status updates are current as of summer 2019.

---

Note that point estimates for our energy saving estimates are not necessarily based on the midpoints of the ranges shown due to uneven probability distributions.
Fact Sheets

Commercial HVAC Technologies and Controls

Ultrasonic Anemometer

Full fact sheet in Appendix A

Project summary can be found at the California Energy Commission’s Energy Innovation Showcase website (http://innovation.energy.ca.gov). Search for project by EPIC grant project name, which is 'Very Low-cost MEMS-based Ultrasonic Anemometer for Use Indoors and in HVAC Ducts.'

The Center for the Built Environment at the University of California-Berkeley has developed a low-cost ultrasonic anemometer that can be used indoors and in HVAC ducts to measure airflow metrics. This technology is expected to be available for $20 to $100 and offer improved operational data communicated wirelessly to HVAC control systems and operators. Such data could allow for reduced airflow when ventilation requirements have been met, greater temperature setbacks while maintaining comfort, and identification of system anomalies or failures. The project team estimates potential savings of 10% to 15% of a building’s HVAC usage and technology applicability in between 25% and 75% of commercial buildings.

<table>
<thead>
<tr>
<th>Problem Addressed</th>
<th>Status, Next Steps, and What to Watch</th>
<th>Energy Savings Potential</th>
</tr>
</thead>
</table>
| Excess ventilation and operational constraints due to lack of distributed sensor feedback about airflow. | **Status**: The project team completed prototypes of an indoor and duct sensor and was testing them in 2018. A project report is expected in 2019. **Next Steps and What to Watch**: The next step is most likely development of these products for the marketplace. UC-Berkeley had included several industry partners in this effort, at least two of which are active in the HVAC industry (Price Industries and Vigilent). | **Lifetime Energy Savings**:  
  - Point estimate: 0.9 TWh  
  - Range: 0.3-2.8 TWh  
**Assumptions and Inputs**:  
  - Annual commercial HVAC consumption: 2.5 TWh  
  - Tech. applicability: 25%-75%  
  - HVAC energy use reduction: 10%-15%  
  - Adoption rate: 20%-50%  
  - Measure life: 20 years |
Integrated Building Control Retrofit Package

Full fact sheet in Appendix B

Project summary can be found at the California Energy Commission's Energy Innovation Showcase website (http://innovation.energy.ca.gov). Search for project by EPIC grant project name, which is 'Pilot-Scale Evaluation of an Integrated Building Control Retrofit Package.'

The California Lighting Technology Center at the University of California-Davis is developing and testing a retrofit package for commercial buildings that integrates and optimizes control of lighting, fenestration, and space-conditioning systems under a single, unified platform. Initial estimates through computer simulations by the project team show energy savings potential of up to 37% percent of commercial building lighting and HVAC energy use. The control system allows for integration of existing end-use technologies and controls using added sensors and a master controller, and allows for optimization of comfort and energy use based on space occupancy and environmental conditions.

Table 4. Integrated Building Control Retrofit Package Summary

<table>
<thead>
<tr>
<th>Problem Addressed</th>
<th>Status, Next Steps, and What to Watch</th>
<th>Energy Savings Potential</th>
</tr>
</thead>
</table>
| Efficiency losses when HVAC, lighting, and fenestration controls do not coordinate. | **Status:** The UC-Davis research team has tested the system in a laboratory setting and had planned to install it in a UC-Davis building in 2019 for demonstration and performance monitoring and evaluation. Results on energy performance and occupant satisfaction should be available in 2020. Final report expected in 2020 or 2021. | **Lifetime Energy Savings:**
| | **Next Steps and What to Watch:** Key items to watch are the in-field performance of the controller at producing electrical savings and comfort during testing, as well as market response once the study is concluded. The algorithms and system details will be publicly available, but it remains to be seen which market actors will integrate the controller in their offerings or promote the technology to building decision-makers. | • Point estimate: 2.2 TWh
• Range: 0.4-11.1 TWh |
| | **Assumptions and Inputs:**
| | • Annual commercial HVAC and lighting consumption: 3.7 TWh
• Tech. applicability: 25%-75%
• Energy use reduction: 10%-40%
• Adoption rate: 20%-50%
• Savings persistence: 20 years |
**Optimized Hybrid Cooling Controls**

*Full fact sheet in Appendix B*

Project summary can be found at the California Energy Commission’s Energy Innovation Showcase website (http://innovation.energy.ca.gov). Search for project by EPIC grant project name, which is 'Climate appropriate HVAC Systems for Commercial Buildings to Reduce Energy Use and Demand.'

The Electric Power Research Institute is testing the use of an intelligent HVAC controller that processes signals from building sensors and system feedback to maximize system efficiency. This particular study is applying the controller to the optimization of variable refrigerant flow and indirect evaporative cooling for the optimal mix. The control system utilizes cloud-based optimization using weather, grid conditions, and occupancy (CO2) as inputs to optimally operate the hybrid system. (For Midwestern applications, such a controller would need to be configured to optimize hybrid cooling solutions for humid climates.)

<table>
<thead>
<tr>
<th>Problem Addressed</th>
<th>Status, Next Steps, and What to Watch</th>
<th>Energy Savings Potential</th>
</tr>
</thead>
</table>
| Lack of control technology to effectively integrate multiple cooling approaches optimized based on existing conditions. | **Status:** Baseline conditions were being measured in late 2018 at three project sites in California where this system will be tested. The study is scheduled to be completed in 2020.  
**Next Steps and What to Watch:** Key items to watch are the in-field performance of the controller at producing cooling energy savings during testing. A separate analysis for the Midwest may be required to assess its potential to optimize hybrid cooling in humid climates. | **Lifetime Energy Savings:**  
- Point estimate: 0.3 TWh  
- Range: 0.1-0.9 TWh  

**Note:** High uncertainty. A Midwest-specific analysis would be needed to determine savings potential for hybrid systems for humid climates.  

**Assumptions and Inputs:**  
- Annual commercial cooling consumption: 1.2 TWh  
- Tech. applicability: 20%-50%  
- Cooling energy use reduction: 10%-15%  
- Adoption rate: 20%-50%  
- Measure life: 20 years |
### Related Minnesota CARD Studies

<table>
<thead>
<tr>
<th>CARD #</th>
<th>Report Title</th>
<th>Year</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>34452</td>
<td>Advanced Rooftop HVAC Unit Controls Pilot</td>
<td>2014</td>
<td>This study identified clear electrical energy savings, some increase in natural gas usage, and operational issues that would need to be resolved in field tests of three types of advance control optimizers for commercial rooftop unit air handling systems.</td>
</tr>
<tr>
<td>86450</td>
<td>Commercial Roof-top Units in Minnesota: Characteristics and Energy Performance</td>
<td>2017</td>
<td>This study characterized the existing stock of packaged rooftop (HVAC) units in commercial buildings in Minnesota and quantified the energy efficiency savings available from upgrades to newer, more efficient models in most buildings.</td>
</tr>
<tr>
<td>72920</td>
<td>Energy Recovery in Minnesota Commercial and Institutional Buildings: Expectations and Performance</td>
<td>2017</td>
<td>This study characterizes the in-building performance of air-to-air energy recovery ventilators in Minnesota buildings and found savings opportunities from (re)commissioning of the systems to ensure they provide the full energy savings available.</td>
</tr>
<tr>
<td>72625</td>
<td>Energy Savings from Implementing and Commissioning Demand Control Ventilation</td>
<td>2015</td>
<td>This study investigated the energy savings and operational characteristics of existing demand control ventilation systems in Minnesota and their ability to regulate ventilation based on occupancy; this approach was found to save significant ventilation energy, while some existing systems were found to be in need of commissioning for optimal operation.</td>
</tr>
<tr>
<td>73533</td>
<td>The Energy Conservation Potential of Displacement Ventilation Technology in Minnesota Climate Conditions</td>
<td>2016</td>
<td>This study assessed owner satisfaction and energy savings for displacement ventilation in a sample of 26 Minnesota buildings where the technology was already in place; significant savings were realized, primarily from decreased fan and cooling energy; however, considerable variability in savings indicates that design and/operational parameters are critical to achieving potential.</td>
</tr>
<tr>
<td>54682</td>
<td><strong>Duct Leakage and Retrofit Duct Sealing in Minnesota Commercial and Institutional Buildings</strong></td>
<td>2016</td>
<td>This study tested a proprietary product that facilitates retrofit air sealing in commercial and institutional building duct systems; results suggest that such duct sealing provides worthwhile energy savings in about 10 to 15 percent of buildings.</td>
</tr>
</tbody>
</table>
New Wastewater Treatment Technologies

**Raw Wastewater Filtration Cloth Depth Filters**

*Full fact sheet in Appendix B*

Project summary can be found at the California Energy Commission's Energy Innovation Showcase website (http://innovation.energy.ca.gov). Search for project by EPIC grant project name, which is 'Raw Wastewater Filtration to Increase Organic Removal Efficiency and Achieve Significant Electrical Savings.'

The Cloth Depth Filter (CDF) is an emerging water filtration technology that aims to reduce the energy input needed during the secondary biological wastewater treatment process through filtering out biosolids beforehand. The implementation of CDFs as a primary filtration step is projected to result in a higher rate of biosolid removal as well as the reduced need for aeration and activated sludge processing, two steps that when combined account for 40% to 60% of total wastewater treatment plant electricity consumption. The study demonstrated the application of CDFs at three California wastewater treatment plants: the Linda County Water District, the City of Manteca, and the Los Angeles County Sanitation District, as well as a pilot demonstration in the Rock River Water Reclamation District in Rockford, Illinois.

<table>
<thead>
<tr>
<th>Problem Addressed</th>
<th>Status, Next Steps, and What to Watch</th>
<th>Energy Savings Potential</th>
</tr>
</thead>
</table>
| The energy heavy aeration and activated sludge processing steps that account for 40% to 60% of wastewater treatment plant energy consumption. | **Status:** The project team has completed its demonstration of the CDF filters at three California wastewater treatment plants as of March 2019.  
**Next Steps and What to Watch:** A final report is currently in the works. The next step is the introduction of these products to the marketplace. Kennedy/Jenks Consultants is currently developing a website to introduce CDFs to the market as well as track the technology’s progress. | **Lifetime Energy Savings:**  
• Point estimate: 0.2 TWh  
• Range: 0.06-0.5 TWh  
**Assumptions and Inputs:**  
• Annual total energy use for target wastewater treatment plants: 0.127 TWh/yr  
• Secondary aeration accounts for 40%-60% of treatment cycle energy use  
• Electrical savings in secondary aeration stage of 25%-45%  
• Adoption rate: 25%-75%  
• Measure life: 20 years |
**Novel Staged Anaerobic Fluidized Bed Membrane Bioreactor**

*Full fact sheet in Appendix B*

Project summary can be found at the California Energy Commission's Energy Innovation Showcase website (http://innovation.energy.ca.gov). Search for project by EPIC grant project name, which is 'Maximizing Energy Efficiency and Reducing Bio-solids Waste from New Anaerobic Wastewater Treatment Technology.'

The Novel Staged Anaerobic Fluidized Bed Membrane Bioreactor is an emerging technology that uses anaerobic bacteria to filter industrial wastewater. Anaerobic-based facilities require less space than aerobic-based ones and may produce 30% less solid waste. For the study, an anaerobic system was demonstrated at the Silicon Valley Clean Water (SVCW) treatment facility, replacing the aeration step in the filtration process. The system is projected to filter 30% more bio-solids than conventional systems while reducing energy consumption and environmental impact for the wastewater plant. The filtered higher quality water is also being demonstrated as a potential source of local water supply through the employment of reuse treatment trains.

<table>
<thead>
<tr>
<th>Problem Addressed</th>
<th>Status, Next Steps, and What to Watch</th>
<th>Energy Savings Potential</th>
</tr>
</thead>
</table>
| Conventional wastewater systems are based on 100 year-old technology that is energy intensive (3% of electricity nationwide), produces bio-solids, and neglects the value of wastewater as a reliable water supply. | **Status:** Initial reports are currently being reviewed. The study is on track to being completed by March 1, 2021. **Next Steps and What to Watch:** Publication of study's findings in a peer reviewed trade journal and, eventually, market availability through vendors such as Suez. The SVCW website (www.svcw.org) and the Codiga Resource Recovery Center website (https://cr2c.standford.edu) can both be used to follow the progress of this project. | **Lifetime Energy Savings:**
  * Point estimate: 0.2 TWh
  * Range: 0.1-0.5 TWh

**Assumptions and Inputs:**
  * Annual total energy use for target wastewater treatment plants: 0.127 TWh/yr
  * Electrical savings of total treatment energy use: 10-40%
  * Adoption rate: 20%-50%
  * Measure life: 20 years
Biofiltration as an Advanced Primary Treatment Method

Full fact sheet in Appendix B

Project summary can be found at the California Energy Commission's Energy Innovation Showcase website (http://innovation.energy.ca.gov). Search for project by EPIC grant project name, which is 'Biofiltration as an Advanced Primary Treatment Method to Achieve Substantial Energy Savings.'

Raw waste water filtration or biofiltration is an alternative wastewater treatment model that aims to save overall wastewater treatment plant energy consumption through replacing conventional primary wastewater clarifiers with wastewater filters to reduce downstream energy use. This project is quantifying the water savings and electrical energy reduction that can be achieved by biofiltration based on demonstration results at the Linda County Water District wastewater plant. This project will provide the cost and performance data to evaluate the benefits from sustained, full scale validation testing, including quantification of electrical energy savings, determination of water savings, organic solids removal efficiencies, operation and maintenance and design criteria, independent monitoring and verification and technology transfer. According to preliminary results from the pilot study at the Linda County Water District wastewater plant, biofiltration has the potential to decrease later stage aeration energy inputs by 45% to 60% while increasing gas production and treatment capacity.

Table 9. Biofiltration as an Advanced Primary Treatment Method Summary

<table>
<thead>
<tr>
<th>Problem Addressed</th>
<th>Status, Next Steps, and What to Watch</th>
<th>Energy Savings Potential</th>
</tr>
</thead>
</table>
| The energy intensive secondary aeration process in wastewater treatment. | **Status:** Project in progress. Pilot project ongoing at the Linda County Water District wastewater plant. **Next Steps and What to Watch:** Final study report is scheduled to be released in March 2021. | **Lifetime Energy Savings:**  
- Point estimate: 0.3 TWh/yr  
- Range: 0.1-0.7 TWh/yr  
**Assumptions and Inputs:**  
- Annual total energy use for target wastewater treatment plants: 0.127 TWh/yr  
- Secondary aeration accounts for 40%-60% of treatment cycle energy use  
- Electrical savings in secondary aeration stage of 25%-75%  
- Adoption rate: 25%-75%  
- Measure life: 20 years |
**Biological Double Efficiency Process (BDP)**

*Full fact sheet in Appendix B*

Project summary can be found at the California Energy Commission's Energy Innovation Showcase website (http://innovation.energy.ca.gov). Search for project by EPIC grant project name, which is 'Biological Double-Efficiency Process as an Advanced Wastewater Treatment Method to Achieve Substantial Energy and Water Savings.'

The Biological Double Efficiency Process is an alternative to the separate anoxic and aerobic tanks conventionally used in secondary wastewater clarifiers. Combining state-of-the-art aeration technology, airlift circulation/dilution technology, and an integrated all-in-one bioreactor model, the BDP simultaneously achieves nitrification/denitrification and accomplishing the work of two separate anoxic and aerobic tanks. According to initial estimates from a study on BDP technology, the technology has the potential to reduce 50% of aeration required for secondary treatment as well as reduce necessary wastewater treatment plant (WWTP) capital by 30%, necessary land for WWTPs by 50%, and WWTP maintenance costs by 50%.

### Table 10. Biological Double Efficiency Process (BDP) Summary

<table>
<thead>
<tr>
<th>Problem Addressed</th>
<th>Status, Next Steps, and What to Watch</th>
<th>Energy Savings Potential</th>
</tr>
</thead>
</table>
| The high capital costs, land footprint, and energy costs associated with conventional activated sludge processes. | **Status:** Project is ongoing. Final report in the works. **Next Steps and What to Watch:** The recipient is on budget and schedule and is working on securing the air and water permits. Final report is expected in April 2020. | **Lifetime Energy Savings:**  
• Point estimate: 0.25 TWh  
• Savings range: 0.04-0.7 TWh  
**Assumptions and Inputs:**  
• Annual total energy use for target wastewater treatment plants: 0.127 TWh/yr  
• Secondary aeration accounts for 40%-60% of treatment cycle energy use  
• Electrical savings in secondary aeration stage of 25%-75%  
• Adoption rate: 15%-65%  
• Measure life: 20 years |
**Porifera Forward Osmosis (PFO) Recycler**

*No full fact sheet; supplemental information only*

Project summary can be found at the California Energy Commission's Energy Innovation Showcase website (http://innovation.energy.ca.gov). Search for project by EPIC grant project name, which is 'Advanced Wastewater Treatment Using Forward Osmosis to Produce High Quality Water.'

The PFO Recycler has been undergoing demonstration by Porifera Inc. as an advanced wastewater treatment technology for industrial wastewater applications that produces reusable treated wastewater while cutting energy, chemical, and maintenance inputs. The PFO Recycler uses forward osmosis to extract the water from the waste stream and reverse osmosis to extract the water out of the forward osmosis draw solution. If successful, this technology could be used to treat challenging wastewaters to achieve high purity and provide high temperature water for reuse while using less energy than other processes. Initial estimates show 15%-30% energy savings relative to competing technologies while also reusing 50% of treated wastewater for internal use, which in turn reduces operating costs. The technology aims to reduce the energy consumption and greenhouse gas emissions from the wastewater treatment process and, with broad adoption, could enable the reuse of industrial wastewater and minimize the need for fresh water.

Table 11. Porifera Forward Osmosis (PFO) Recycler Summary

<table>
<thead>
<tr>
<th>Problem Addressed</th>
<th>Status, Next Steps, and What to Watch</th>
<th>Energy Savings Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>The potential for Industrial-scale wastewater treatment to save energy, reduce wastewater volumes, and generate pure water streams for on-site re-use has been hindered by the inability to filter high levels of dissolved and suspended solids.</td>
<td><strong>Status</strong>: Porifera has concluded its demonstration of the PFO recycler at a winery, frozen food facility, and soap company. Expected final report submission for review in June 2019. <strong>Next Steps and What to Watch</strong>: Porifera will be commercializing the technology and introducing it to the market.</td>
<td>Energy savings potential was not computed when a full fact sheet was not developed for the technology.</td>
</tr>
</tbody>
</table>
**Amphiphilic Membrane**

*No full fact sheet; supplemental information only*

Project summary can be found at the California Energy Commission's Energy Innovation Showcase website (http://innovation.energy.ca.gov). Search for project by EPIC grant project name, which is 'Novel Membrane Technology to Improve Energy Efficiency and Water Savings in Wastewater Treatment Operations.'

This study demonstrates the use of an “amphiphilic” membrane in wastewater treatment operations to increase water flow and decrease energy use. The amphiphilic membrane maintains properties that retard long-term foulants in wastewater, keeping organic and inorganic foulants from the membrane surface in order to increase water yield, which may lead to potential increased water yield and improved energy efficiency. According to a study by Kennedy/Jenks Consultants, the implementation of this technology would not require significant capital investment and could replace existing conventional hydrophilic membranes at wastewater treatment plants. Based on data provided by the American Membrane Technologies Association (AMTA) in California, the technology was estimated to save facilities 44,000 MWh, assuming 50% market penetration.

<table>
<thead>
<tr>
<th>Problem Addressed</th>
<th>Status, Next Steps, and What to Watch</th>
<th>Energy Savings Potential</th>
</tr>
</thead>
</table>
| Energy intensive conventional low-pressure membrane filtration used in drinking water, wastewater, and industrial water treatment. | **Status:** Ongoing.  
Next Steps and What to Watch: Final report expected to be submitted for review February 2019. | Energy savings potential was not computed since a full fact sheet was not developed for the technology/strategy. |
Related Minnesota CARD Studies

Table 13. Additional CARD Study on Wastewater Treatment Savings Opportunities

<table>
<thead>
<tr>
<th>CARD #</th>
<th>Report Title</th>
<th>Year</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>136952</td>
<td>Driving Wastewater Treatment Energy Efficiency: A Cohort Training and Implementation Plan</td>
<td>2019</td>
<td>This white paper presents a training and energy management-oriented efficiency strategy for small and mid-sized wastewater treatment plants focused on identifying no or low-cost operational and maintenance practices.</td>
</tr>
</tbody>
</table>
Emerging Technologies in Food Services and Grocery

Cost-Effective Energy Efficiency Upgrade Package for a Grocery Store

No full fact sheet; supplemental information only

Project summary can be found at the California Energy Commission's Energy Innovation Showcase website (http://innovation.energy.ca.gov). Search for project by EPIC grant project name, which is 'MarketZero: Taking an existing grocery store to scalable near-ZNE.'

The cost-effective energy upgrade package is a set of innovative strategies and technologies identified and collected by Prospect Silicon Valley that together are designed to create a cost-effective pathway for grocery markets to achieve maximum energy efficiency. The goal of the project is to convert existing grocery stores to near-zero net energy sites through adoption of the upgrade package, and for project sites to serve as models for stores throughout California. So far, two Whole Foods sites are being used as initial implementation sites. The pre-commercial technologies that comprise the package include HVAC, refrigerants, fans, air curtains, phase change materials, occupancy sensing measures, and advanced lighting and controls. The project will also outline new approaches for rapid technology adoption to ensure the most current technologies are implemented in the design. Prospect Silicon Valley estimates that the package could yield a statewide reduction of $400 million if adopted by California groceries, which would suggest potential energy cost savings in the tens of millions of dollars in Minnesota.

Table 14. Cost-Effective Energy Efficiency Upgrade Package for a Grocery Store Summary

<table>
<thead>
<tr>
<th>Problem Addressed</th>
<th>Status, Next Steps, and What to Watch</th>
<th>Energy Savings Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>The high energy consumption of commercial grocery markets, which ranks among the</td>
<td>Status: Ongoing.</td>
<td>Energy savings potential was not computed since a full fact sheet was not developed for the</td>
</tr>
</tbody>
</table>
Electric Plug Load Savings Potential of Commercial Foodservice Equipment

Full fact sheet in Appendix B

Project summary can be found at the California Energy Commission's Energy Innovation Showcase website (http://innovation.energy.ca.gov). Search for project by EPIC grant project name, which is 'Electric Plug Load Savings Potential of Commercial Foodservice Equipment.'

The Electric Plug Load Savings Potential study was a market analysis of the quantity and types of unventilated commercial food preparation equipment in common use in the market and the savings potential from emerging alternatives. The study addressed the lack of knowledge and available energy data within the commercial food service industry that prevent businesses from adopting available advanced appliances, such as smart controls, better insulating materials, advanced headers, and induction. After completion of the study’s monitoring of 10 commercial food service facilities and 52 appliances over 19 appliance types, the research team concluded that smart conveyor toasters, induction soup warmers, and modular insulated hot-food holding cabinets offered the greatest savings potential. The researchers also recommended that utilities sponsor rebate and replacement programs to drive market change specifically for hot-food holding cabinets and conveyor toasters, where energy savings were found to justify early retirement programs.

Table 15. Electric Plug Load Savings Potential of Commercial Foodservice Equipment Summary

<table>
<thead>
<tr>
<th>Problem Addressed</th>
<th>Status, Next Steps, and What to Watch</th>
<th>Energy Savings Potential</th>
</tr>
</thead>
</table>
| Commercial foodservice facilities are among the largest energy consumers within the commercial building sector and consume as much as five times more electricity per square foot than any other commercial building type. | **Status**: Final report complete. Available on Fisher-Nickel website at https://fishnick.com/cecplug/SVP_Plug_Load_Field_Monitoring_and_Replacement.pdf  
**Next Steps and What to Watch**: Utility CIP programs serving commercial foodservice facilities should consider the potential role of such technologies as smart conveyor toasters, induction soup warmers, and modular insulated hot food holding cabinets. | **Lifetime Energy Savings:**  
• Savings estimate: 0.09 TWh  
• Savings range: 0.04-0.15 TWh  

**Assumptions and Inputs:**  
The most prominent foodservice appliance savings potentials:  
• Conveyor Toasters: 1.8-2.2 kWh/day  
• Soup Wells: 0.2-0.6 kWh/day  
• Holding Cabinets: 2.3-6.3 kWh/day  

Market and measure assumptions:  
• Appliance lifespan: 5 years  
• Days of operation a year: 200-300  
• Food service sites in Minnesota in 2019: 10,681 |
Porifera Forward Osmosis (PFO) Concentrator

No full fact sheet; supplemental information only

Project summary can be found at the California Energy Commission’s Energy Innovation Showcase website (http://innovation.energy.ca.gov). Search for project by EPIC grant project name, which is 'Demonstration of Forward Osmosis to Produce Juice Concentrate, Purify and Reuse Wastewater and Reduce Energy Use.'

The Porifera Forward Osmosis Concentrator is a new technology innovation designed to reduce the energy, chemicals, and maintenance required for food and beverage processing. This specific study conducted by Porifera demonstrates the PFO Concentrator’s use of forward and reverse osmosis to dewater fruits and vegetables during the production of food and beverage concentrates and purees. The process could replace energy intensive thermal evaporators and use extracted water as a reusable water source within the production process. The study demonstrates that the PFO Concentrator, when adopted, could lower energy use and costs for food processing and industrial operations through replacement of energy intensive thermal evaporators and reuse of wastewater streams onsite, rather than disposal through the municipal system, resulting in electrical savings of up to 80% per operation. Other benefits include reducing the need for fresh water purchases and the need to dispose of water through the sewer system.

### Table 16. Porifera Forward Osmosis (PFO) Concentrator Summary

<table>
<thead>
<tr>
<th>Problem Addressed</th>
<th>Status, Next Steps, and What to Watch</th>
<th>Energy Savings Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>The need for energy efficient methods to concentrate food and beverage products in the commercial sector.</td>
<td><strong>Status:</strong> Three pilot test programs (Ale Industries, Anheuser-Busch winery, and Los Gatos Tomatoes) are currently complete and still in place. <strong>Next Steps and What to Watch:</strong> Final report is in progress. PFO Concentrators will be available for purchase through the Porifera website.</td>
<td>Energy savings potential was not computed since a full fact sheet was not developed for the technology/strategy.</td>
</tr>
</tbody>
</table>
## Related Minnesota CARD Studies

Table 17. Additional CARD Studies on Food-Related Efficiency and Processes

<table>
<thead>
<tr>
<th>CARD #</th>
<th>Report Title</th>
<th>Year</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>36538</td>
<td>Improving Energy Efficiency in Convenience Stores</td>
<td>2013</td>
<td>A study of convenience store efficiency opportunities in Minnesota identified established lighting improvements, HVAC control, efficient motors, and operational practices as the main energy saving options.</td>
</tr>
<tr>
<td>56702</td>
<td>Cost-Effective Recommissioning of Restaurants</td>
<td>2015</td>
<td>A recommissioning pilot for restaurants found savings potential among established technologies, such as LED lighting, swinging plastic doors for refrigeration equipment, and preventative practices.</td>
</tr>
<tr>
<td>55870</td>
<td>Advanced Heat Recovery System Field Deployment</td>
<td>2016</td>
<td>A demonstration of an advanced heat recovery system on a large boiler at a food processing plant in Minnesota indicated both market and technical energy savings potential through the capture of waste heat and water vapor in boiler exhaust gases.</td>
</tr>
</tbody>
</table>
Assorted Commercial Building Technologies

Flexible, Networked Lighting Control Systems

No full fact sheet; supplemental information only

Project summary can be found at the California Energy Commission's Energy Innovation Showcase website (http://innovation.energy.ca.gov). Search for project by EPIC grant project name, which is 'Developing Flexible, Networked Lighting Control Systems That Reliably Save Energy.'

This project aims to advance lighting control system innovation to help realize California’s Lighting Action Plan goals by 2020. The project is developing a comprehensive strategy based around four new converging lighting trends that open new opportunities for energy savings within lighting control systems: 1) increasing control granularity, 2) increasing sensor availability and use, 3) pervasive communication through wireless networks, and 4) low cost computations. The project strategy involves the development of low-cost lighting components with open communication interfaces that allow seamless integration into whole-building control and automation systems. When applied to commercial buildings, the technology is estimated to reduce energy consumption and costs associated with lighting energy by 40%.

Table 18. Flexible, Networked Lighting Control Systems Summary

<table>
<thead>
<tr>
<th>Problem Addressed</th>
<th>Status, Next Steps, and What to Watch</th>
<th>Energy Savings Potential</th>
</tr>
</thead>
</table>
| The lack of multi-vendor interoperability and standardized user interfaces among lighting control systems. | **Status:** Final report in development.  
**Next Steps and What to Watch:** Final report publication on the Lawrence Berkeley National Laboratory website. | Energy savings potential was not computed since a full fact sheet was not developed for the technology/strategy. |
Flexible Control Strategies for Plug Loads with Context-Aware Power Outlets

No full fact sheet; supplemental information only

Project summary can be found at the California Energy Commission's Energy Innovation Showcase website (http://innovation.energy.ca.gov). Search for project by EPIC grant project name, which is 'Flexible Control Strategies for Plug Loads with Context-Aware Smart Power Outlets to Mitigate Electricity Waste and Support Demand Response.'

This project developed a flexible energy management system (FEMS) that accounts for different types of possible spaces observed in commercial buildings. This integrated control strategy consists of the installation of smart power outlets and integration of various plug load control strategies with building energy management and/or lighting control systems. FEMS is currently being implemented at pilot sites to demonstrate its potential to reduce electricity use in commercial buildings, particularly during low-occupancy times and in user-assigned spaces. The deliverable control strategies will clarify display designs, control settings, and incorporated behavioral considerations. The control strategy is projected to potentially reduce electricity use by 10% from plug loads.

Table 19. Flexible Control Strategies for Plug Loads with Context-Aware Power Outlets Summary

<table>
<thead>
<tr>
<th>Problem Addressed</th>
<th>Status, Next Steps, and What to Watch</th>
<th>Energy Savings Potential</th>
</tr>
</thead>
</table>
| Plug loads are not typically targeted by either utility energy efficiency or demand response programs, yet power consumption from electronic and miscellaneous plug loads account for large load profiles. | **Status:** Final report in progress.  
**Next Steps and What to Watch:** Project completion on track for March 2020. | Energy savings potential not computed since a full fact sheet was not developed for the technology/strategy. |
High Performance Integrated Window and Façade Solutions for Commercial Buildings

No full fact sheet; supplemental information only

Project summary can be found at the California Energy Commission's Energy Innovation Showcase website (http://innovation.energy.ca.gov). Search for project by EPIC grant project name, which is 'High-Performance Integrated Window and Façade Solutions for California Buildings.'

This project aims to develop, validate, and quantify the energy impacts of a new generation of high performance building envelope systems including highly insulating windows, novel window-integrated local ventilation, and dynamic daylight redirection strategies.

Building envelope systems have major impacts on annual energy use, load shape, and peak demand, and better system designs can play a significant role in achieving building energy savings. The project sought to provide a management toolkit for the building industry to aid in accomplishing energy performance goals leading towards zero net energy buildings.

Table 20. High Performance Integrated Window and Façade Solutions for Commercial Buildings Summary

<table>
<thead>
<tr>
<th>Problem Addressed</th>
<th>Status, Next Steps, and What to Watch</th>
<th>Energy Savings Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>High performance window and building envelope technologies and systems have struggled to gain significant market share due to cost and the complexity of providing market-ready business solutions.</td>
<td>Status: Progress includes developing an improved window system prototyping a window-integrated ventilation system to maximize use of natural ventilation, and designing and testing a daylight-redirecting system that increases daylight up to 40 feet from the window. Next Steps and What to Watch: Final report in progress.</td>
<td>Energy savings potential was not computed since a full fact sheet was not developed for the technology/strategy.</td>
</tr>
</tbody>
</table>
The Value Proposition for Cost-Effective, DR-Enabling Nonresidential Lighting System Retrofits

No full fact sheet; supplemental information only

Project summary can be found at the California Energy Commission's Energy Innovation Showcase website (http://innovation.energy.ca.gov). Search for project by EPIC grant project name, which is 'The Value Proposition of Cost-Effective, DR-Enabling Nonresidential Lighting System Retrofits in California Buildings.'

This study quantifies and evaluates the incremental costs and benefits of demand responsive lighting control system requirements in the California Energy Code for existing non-residential building stock, focusing specifically on the additional costs and benefits of adding demand response (DR) functionalities to existing general lighting upgrades. Using over 100,000 individual hourly load profiles, the project forecasts potential DR resources available from commercial lighting in 2025 and the estimated revenue from participation of DR resources in energy markets in California. The study concludes that network lighting controls have large potential to provide flexible energy savings in the coming years.

Table 21. The Value Proposition for Cost-Effective, DR-Enabling Nonresidential Lighting System Retrofits Summary

<table>
<thead>
<tr>
<th>Problem Addressed</th>
<th>Status, Next Steps, and What to Watch</th>
<th>Energy Savings Potential</th>
</tr>
</thead>
</table>
| Advanced lighting controls are a rapidly evolving technology. The value of lighting as a potential demand response (DR) resource is not well understood. | **Status:** Complete.  
**Next Steps and What to Watch:** The project team recommends that utility programs consider research efforts that support these intervention strategies and their eventual integration into programs. | Energy savings potential was not computed since a sheet was not developed for the technology/strategy. |
### Related Minnesota CARD Studies

Table 22. Additional CARD Studies on Assorted Commercial Building Technologies

<table>
<thead>
<tr>
<th>CARD #</th>
<th>Report Title</th>
<th>Year</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>34558</td>
<td>Commissioning for Optimal Savings from Daylight Control</td>
<td>2013</td>
<td>A study of existing daylit buildings in Minnesota and Wisconsin found that daylighting controls only provide about half of their potential savings from reduced electrical lighting; commissioning of the systems can harvest the majority of those unrealized savings.</td>
</tr>
<tr>
<td>72743</td>
<td>Adjusting lighting levels in commercial buildings</td>
<td>2015</td>
<td>A study quantified the energy savings and economics of task tuning of lighting in commercial buildings in Minnesota and Wisconsin.</td>
</tr>
<tr>
<td>87091</td>
<td>Impacts of Office Plug Load Reduction Strategies</td>
<td>2016</td>
<td>A field study characterized the plug load usage of office equipment in a few dozen Minnesota offices and tested the relative energy savings from five plug load energy reduction strategies that comprised plug load-saving devices, changes to computer settings, and a behavioral campaign.</td>
</tr>
<tr>
<td>136863</td>
<td>Field Study of Tier 2 Advanced Power Strips</td>
<td>2019</td>
<td>A field study of Tier 2 advanced power strips in Minnesota office buildings quantified the electrical savings at workstations from two different models available in the market, and identified behavioral factors that influence outcomes.</td>
</tr>
</tbody>
</table>

Additional CARD studies currently in progress include:

- Operation and Control of Lighting, Plug Loads, and other Power over Ethernet Technologies (CARD # 137582)
- Energy Savings potential of Networked Lighting Control Systems in Small Businesses (CARD # 157663)
- Light Level Characterization in MN Commercial Buildings (CARD # 156817)
- Field study of Phase Change Material use for Passive Thermal Regulation (CARD # 159521)
Program Adoptions Strategies and Insights from Consumer-Oriented Studies

**Customer-Centric Approach to Scaling Retrofits in Low-Income Multifamily Buildings**

Full fact sheet in Appendix B

Project summary can be found at the California Energy Commission's Energy Innovation Showcase website (http://innovation.energy.ca.gov). Search for project by EPIC grant project name, which is 'Customer-Centric Approach to Scaling Integrated Demand Side Management (IDSM) Retrofits.'

The customer-centric approach to retrofit projects demonstrates an approach to scale residential retrofits specifically tailored towards low-income multifamily buildings. The approach is based on energy efficient retrofit packages developed for the project that are non-intrusive to occupants and have the potential of reducing energy use by 30% to 40%. The project also provides new data, analysis, and designs for cost-effective integrated demand side management retrofits such as advanced HVAC, smart thermostats, plug load controls, LED lighting, and heat pump water heaters for residential communities, all designed to minimize tenant disruptions. This study is intended to help California reach its goal of reducing energy use in existing buildings by 50% by 2030 through actionable approaches for affordable multifamily buildings.

<table>
<thead>
<tr>
<th>Problem Addressed</th>
<th>Status, Next Steps, and What to Watch</th>
<th>Energy Savings Potential</th>
</tr>
</thead>
</table>
| Low income and Multifamily are two of the most important retrofit targets, yet have been historically underserved. | **Status:** The research team has completed installation of efficiency measures and has begun a 12-month monitoring and commission period in Ontario, CA. **Next Steps and What to Watch:** Final report in progress. Fresno site installations are underway. | **Lifetime Energy Savings:**  
• Point estimate: 0.9 TWh  
• Savings range: 0.1-5.1 TWh  

**Assumptions and Inputs:**  
• 2016 Minnesota Low Income Multifamily building electric load: 1.7 TWh  
• Technology applicability: 25%-75% of buildings  
• Energy savings when applied: 30%-40% of electric consumption  
• Adoption rate: 20%-50%  
• Measure life: 5-20 years |
Examining the Heterogeneity of Energy Efficiency Using a Large Scale Quasi-Experiment

No full fact sheet; supplemental information only

Project summary can be found at the California Energy Commission’s Energy Innovation Showcase website (http://innovation.energy.ca.gov). Search for project by EPIC grant project name, which is 'Examining the Heterogeneity of Energy Efficiency Adoption and Savings across Socio-Economic and Ethnic Groups Using a Large Scale Quasi-Experiment.'

This project used econometric methods to evaluate three research questions. 1) How is participation in energy efficiency programs affected by increased customer incentives? 2) What is the value of energy saved when accounting for the timing of savings? 3) How does participation and savings vary between levels of income, education, racial make-up, and household size?

The study focused on data provided by Southern California Edison’s Quality Installation Program collected from 9,000 smart metered participants. The study findings show that participation is strongly influenced by demographic factors, specifically climate zones.

Table 24. Examining the Heterogeneity of Energy Efficiency Using a Large Scale Quasi-Experiment Summary

<table>
<thead>
<tr>
<th>Problem Addressed</th>
<th>Status, Next Steps, and What to Watch</th>
<th>Energy Savings Potential</th>
</tr>
</thead>
</table>
| Current energy efficiency programs and energy demand forecasts do not account for varying participation across social, cultural, and socioeconomic groups. | **Status:** Complete.  
**Next Steps and What to Watch:** Final report complete. | Energy savings potential was not computed since a full fact sheet was not developed for the technology/strategy. |
Technology Adoption and Behavior Change across Diverse Geographies and Populations

No full fact sheet; supplemental information only

Project summary can be found at the California Energy Commission’s Energy Innovation Showcase website (http://innovation.energy.ca.gov). Search for project by EPIC grant project name, which is 'Fieldwork to Document Technology Adoption and Behavior Change across Diverse Geographies and Populations to Inform Energy Efficiency Program Design.'

This project utilizes empirical research methods grounded in anthropology and behavioral sciences to explore the factors affecting behavior beyond a simple economic rationale. The approach documents and analyzes emerging attitudes, emotions, experience, habits, and practices around technology adoption for purposes of devising predictive indicators for on-going potential studies regarding energy consumption in California. Understanding social, cultural, and behavioral aspects of energy use and technology adoption can help utilities more cost-effectively and efficiently market their energy efficiency programs to hard-to-reach customer groups, resulting in greater participation and lower program implementation costs per kilowatt-hour saved.

Table 25. Technology Adoption and Behavior Change across Diverse Geographies and Populations Summary

<table>
<thead>
<tr>
<th>Problem Addressed</th>
<th>Status, Next Steps, and What to Watch</th>
<th>Energy Savings Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technological innovation has been an impressive driver of efficiency gains; however, over time it has become clear that without a greater understanding of the human factors, potential energy savings will remain untapped.</td>
<td><strong>Status:</strong> The project is on schedule. All deliverables have been submitted. Reviewer comments have been provided on the draft final report. <strong>Next Steps and What to Watch:</strong> Final report in progress.</td>
<td>Energy savings potential was not computed since a full fact sheet was not developed for the technology/strategy.</td>
</tr>
</tbody>
</table>
Analysis of Sociocultural Factors Influencing Customer Adoption of Home Energy Efficiency Retrofits

No full fact sheet; supplemental information only

Project summary can be found at the California Energy Commission's Energy Innovation Showcase website (http://innovation.energy.ca.gov). Search for project by EPIC grant project name, which is 'Home Energy Efficiency Retrofits in California: An Analysis of Sociocultural Factors Influencing Customer Adoption.'

The California Latino Households and Energy Efficiency Upgrades research study was a three-year study that investigated how social, behavioral, and cultural factors affected a household's likelihood to adopt energy efficient measures, specifically investigating Latino single-family households to better understand the demographic group's low participation rate in mainstream energy efficiency programs. The study consisted of a literature review, focus groups, semi-structured interviews, and online and field experiments to inform results.

While some participants in the focus groups reacted negatively towards energy efficiency financing advertisements and the lack of bilingual support for such programs, others who had hired contractors in the past revealed higher than average awareness in energy and water programs. Based on the study results, the research team concluded that small pockets of Latino households are responsive to utility efficiency programs, while the majority have little knowledge of access to such programs. The research team provided a list of recommendations for California utilities including suggestions to partner with community based organizations, to invest in bilingual approaches, and to use imagery in advertisements that resonate more with target audiences.

Table 26. Analysis of Sociocultural Factors Influencing Customer Adoption of Home Energy Efficiency Retrofits

<table>
<thead>
<tr>
<th>Problem Addressed</th>
<th>Status, Next Steps, and What to Watch</th>
<th>Energy Savings Potential</th>
</tr>
</thead>
</table>
| Most energy efficiency programs today geared towards the general public disproportionately serve high income, college educated households. Latino households represent 39 percent of Californian residences but historically, mainstream energy efficiency programs fail to reach this demographic. | **Status**: Final report complete.  
**Next Steps and What to Watch**: The research team recommends follow-up attitudinal and behavioral research across additional household metrics such as spoken language, income level, age, and generations in home. | Energy savings potential was not computed since a full fact sheet was not developed for the technology/strategy. |
Discussion

A review of the emerging technologies being developed and explored by the California EPIC program reveals a few overarching insights and implications for Minnesota’s Conservation Improvement Program and others interested in furthering energy efficiency technology in the state. We share some overall observations and implications here for future consideration by the Minnesota Department of Commerce and Minnesota utilities.

Observations

The EPIC research and development efforts are well-funded and provide a rich set of clean energy development efforts. Only a subset of the studies funded address “demand-side” efficiency opportunities, so the relevant studies can easily be whittled down. Even this subset is substantial and backed by substantial public investments that can be leveraged by Minnesota for insights into emerging technologies. The technologies being developed in this group of studies are not limited to California, and most—especially those addressing the commercial and industrial sectors—are applicable nationwide. (Residentially-oriented studies were more limited in their applicability because the housing stock, climate, and policy considerations driving California residential building tend to be less transferable to Minnesota or the Midwest in general.)

In this context, looking to California for new technologies and innovations is worthwhile both because California policy goals are aggressively pursuing energy efficiency, zero energy buildings, and carbon reductions and because research and development funding dwarfs the resources available in other individual states, including those like Minnesota that fund robust research and development programs. This white paper only examined the first two triennial funding cycles of EPIC, which is now in its third round of grants. It would be worthwhile to continue to track EPIC-funded research.

It should be noted that commercial and industrial technologies being developed with EPIC funding include some creation of unique technologies, but also a substantial amount of innovation where existing technologies are applied in new ways or demonstrations of existing technologies that have not penetrated the market. Other studies provide market and consumer insights. Hence, the EPIC program should not be seen solely as a technology creator, but as a source of new ideas and an opportunity to vet existing ideas for improved energy efficiency.

Furthermore, it is important to recognize that many of the EPIC studies are scheduled to extend for multiple years, and several have run longer than expected. Most of the studies we examined were still on-going, which limited our ability to be as definitive as we might have wished in relaying study outcomes and next steps for the technologies we studied.

Finally, EPIC focuses on the electric sector. Not surprisingly, technologies and innovations spurred by EPIC grants provide electric benefits with occasional incidental benefits for natural gas, other fuels, or water.
Implications

Our review of EPIC studies for potential applicability Minnesota suggests several near- and long-term implications and opportunities. We discuss here our thoughts about what individual Minnesota utilities, the Department of Commerce, and other stakeholders can do to leverage the research completed for this white paper specifically and research and development efforts outside Minnesota generally.

Our discussion takes into account that:

- Technologies and innovations investigated by research and development programs like EPIC are in differing stages of technical development and commercial availability, with some available currently and others still in the laboratory;
- Some of the technologies will require additional performance testing in a Minnesota context, and many need additional investigation to determine their cost and cost-effectiveness;
- Technology applicability and needs will vary by utility based on customer infrastructure, end-uses, efficiency opportunities, and the nature of the CIP portfolio; and
- There are economies of scale to tracking of technological and market developments for emerging technologies and testing of their performance in a collaborative or centralized manner when multiple utilities have potential interest in their application for their CIP portfolios.

With these factors in mind, we consider exploration of individual emerging technologies identified in this white paper or from further examination of research and development programs outside Minnesota to generally follow the process outlined in Figure 5.
Figure 5. Technology Consideration Process

This process implies several near-, mid-, and long-term opportunities – both at the utility and state level.
Near-Term

Portfolio managers for Minnesota utility CIPs may wish to review the technology fact sheets and others featured in this white paper to identify any technologies and innovations with a potential fit for their customer base and program portfolio (and just to stay informed about general insights from these studies). Our screening process suggests that the technologies featured here may be among those with the best fit for Minnesota, and several are already available or represent an innovative application of existing technologies that can be incorporated into programs now. These could be explored for cost-effectiveness and piloted or included in program portfolios. Portfolio managers interesting in exploring emerging technologies more deeply to understand what may be on its way to market could also explore the EPIC Technology Research Database that was developed as part of this project.

Mid-Term

Some technologies and innovations we highlighted in this white paper and many others in the EPIC Technology Research Database are still being investigated by EPIC studies and will continue to evolve as they become commercialized or otherwise are adapted to further energy efficiency. As emerging technologies, they are in various states of development and vetting, but all have been defined sufficiently to allow for initial screening by individual utility programs to determine which are worth tracking as they progress based on their potential fit for utility customers and program portfolios. As noted in the figure above, tracking these technologies could involve one or more of the following:

- Tracking the remainder of the EPIC study for final outcomes on performance and energy savings;
- Tracking the introduction of applicable technologies in the marketplace;
- Tracking the adoption of innovative applications of existing technology by energy efficiency efforts (by programs or market actors);
- Exploring potential cost-effectiveness in Minnesota through further investigation of costs of adoption and benefits in a Minnesota context (through secondary sources or primary research).

Understanding what technologies may be coming and following their progress can help utility portfolio managers plan for the future and permits earlier adoption of technologies once they are available, sufficiently vetted, and cost-effective. Further, targeted investigations by Minnesota utilities or the Department of Commerce play a role in the vetting process for Minnesota and can help advance promising emerging technologies.

For some technologies of interest, individual utilities may be in a position to track progress toward program viability and do some selected vetting on their own. Overall, however, there are economies of scale from collaboration in tracking emerging technologies that are of potential interest to multiple utilities. The Department of Commerce helps explore and advance emerging technologies through its CARD program and could consider serving as a central repository of tracking information for any of these emerging technologies that are of widespread interest among Minnesota utilities. Generally, tracking technology progress requires only a light-level effort of following EPIC studies and reviewing and interpreting study results as they are released, as well as occasional scans of market activity.
Further, independent researchers could suggest future CARD studies to help fill any essential gaps in understanding about the most promising emerging technologies.

**Long-Term**

We believe that the effort behind this white paper demonstrates both the value in tracking large-scale research and development efforts outside Minnesota and some of the challenges in doing so. The potential benefits are meaningful, as there are a few well-funded research and development efforts at the federal and state levels that provide an indication of emerging technologies that are worth tracking. Understanding what technologies are evolving and will be available in the future allows for better portfolio planning by utilities, can help inform field research selections by Minnesota’s CARD program, and provides potentially useful input for updates to potential studies and technical reference manuals. On the other hand, as demonstrated by this white paper effort, studies conducted elsewhere need to be screened for applicability, present moving targets of information, and take some occasional persistence to follow their progress. There are economies of scale in tracking the research centrally—perhaps at the state level—and then disseminating updates to stakeholders in the form of a periodically updated dashboard of technologies worth watching by Minnesota stakeholders.

Among California’s EPIC studies, grants issued by the California Energy Commission are more likely than those issued by California’s investor owned utilities to be relevant to CIP programs. While not explored for this white paper, we note that the California Energy Commission also manages a natural gas-focused research and development program. Outside California and Minnesota, the New York State Energy Research and Development Authority and the United States Department of Energy also provide substantial funding toward the development of energy efficiency technologies.

---

7 The [proposed investment plan for the current triennium](https://efiling.energy.ca.gov/getdocument.aspx?tn=217117), which funds grants not included in this white paper, is available here: https://efiling.energy.ca.gov/getdocument.aspx?tn=217117.

References


## Appendix A: Energy Savings Potential Estimates

### Ultrasonic Anemometer

<table>
<thead>
<tr>
<th></th>
<th>Point estimate</th>
<th>Low</th>
<th>High</th>
<th>Units</th>
<th>Source(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Minnesota statewide base energy use input</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual commercial HVAC consumption</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>TWh</td>
<td>Minnesota potential study baseline data* (sectors: large office, large retail, healthcare, and public assembly; end-uses: space heating, space cooling, ventilation, motors-fans/blowers)</td>
</tr>
<tr>
<td><strong>Technology inputs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tech. applicability</td>
<td>50%</td>
<td>25%</td>
<td>75%</td>
<td>percent</td>
<td>Evergreen Economics estimates based on EPIC project description, fit with sector and end-uses included in baseline value, and professional judgment</td>
</tr>
<tr>
<td>HVAC energy use reduction</td>
<td>13%</td>
<td>10%</td>
<td>15%</td>
<td>percent</td>
<td>EPIC grantee estimates; ranges assigned by Evergreen Economics</td>
</tr>
<tr>
<td><strong>Market and measure life inputs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adoption rate</td>
<td>30%</td>
<td>20%</td>
<td>50%</td>
<td>percent</td>
<td>Evergreen Economics estimates based on EPIC project description and professional judgment</td>
</tr>
<tr>
<td>Measure life</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>years</td>
<td>Typical major equipment measure life</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>0.9</td>
<td>0.3</td>
<td>2.8</td>
<td>TWh</td>
<td>Computation</td>
</tr>
</tbody>
</table>
## Integrated Building Control Retrofit Package

<table>
<thead>
<tr>
<th></th>
<th>Point estimate</th>
<th>Low</th>
<th>High</th>
<th>Units</th>
<th>Source(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Minnesota statewide base energy use input</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual commercial HVAC and lighting consumption</td>
<td>3.7</td>
<td>3.7</td>
<td>3.7</td>
<td>TWh</td>
<td>Minnesota potential study baseline data* (sectors: large office, large retail, healthcare, and public assembly; end-uses: interior lighting, space heating, space cooling, ventilation, motors-fans/blowers)</td>
</tr>
<tr>
<td><strong>Technology inputs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tech. applicability</td>
<td>50%</td>
<td>25%</td>
<td>75%</td>
<td>percent</td>
<td>Evergreen Economics estimates based on EPIC project description, fit with sector and end-uses included in baseline value, and professional judgment</td>
</tr>
<tr>
<td>Energy use reduction</td>
<td>20%</td>
<td>10%</td>
<td>40%</td>
<td>percent</td>
<td>EPIC grantee estimates; ranges assigned by Evergreen Economics</td>
</tr>
<tr>
<td><strong>Market and measure life inputs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adoption rate</td>
<td>30%</td>
<td>20%</td>
<td>50%</td>
<td>percent</td>
<td>Evergreen Economics estimates based on EPIC project description and professional judgment</td>
</tr>
<tr>
<td>Measure life</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>years</td>
<td>Typical major equipment measure life</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>2.2</td>
<td>0.4</td>
<td>11.1</td>
<td>TWh</td>
<td>Computation</td>
</tr>
</tbody>
</table>
## Optimized Hybrid Cooling Controls

<table>
<thead>
<tr>
<th></th>
<th>Point estimate</th>
<th>Low</th>
<th>High</th>
<th>Units</th>
<th>Source(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Minnesota statewide base energy use input</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual commercial cooling consumption</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>TWh</td>
<td>Minnesota potential study baseline data* (sectors: all commercial; end-uses: space cooling)</td>
</tr>
<tr>
<td><strong>Technology inputs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tech. applicability</td>
<td>30%</td>
<td>20%</td>
<td>50%</td>
<td>percent</td>
<td>Evergreen Economics estimates based on EPIC project description, fit with sector and end-uses included in baseline value, and professional judgment</td>
</tr>
<tr>
<td>Cooling energy use reduction</td>
<td>13%</td>
<td>10%</td>
<td>15%</td>
<td>percent</td>
<td>EPIC grantee estimates; ranges assigned by Evergreen Economics</td>
</tr>
<tr>
<td><strong>Market and measure life inputs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adoption rate</td>
<td>30%</td>
<td>20%</td>
<td>50%</td>
<td>percent</td>
<td>Evergreen Economics estimates based on EPIC project description and professional judgment</td>
</tr>
<tr>
<td>Measure life</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>years</td>
<td>Typical major equipment measure life</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>0.3</td>
<td>0.1</td>
<td>0.9</td>
<td>TWh</td>
<td>Computation</td>
</tr>
</tbody>
</table>
## Raw Wastewater Filtration Cloth Depth Filters

<table>
<thead>
<tr>
<th>Source(s)</th>
<th>Point estimate</th>
<th>Low</th>
<th>High</th>
<th>Units</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minnesota statewide base energy use input</td>
<td>Estimated electrical usage by small and medium-sized Minnesota wastewater treatment plants presented in webinar about MN CARD white paper study &quot;A Cohort Approach to Wastewater Treatment Energy Efficiency;&quot; actual baseline may be bigger if large treatment plants are included</td>
<td>0.127</td>
<td>0.127</td>
<td>0.127</td>
<td>TWh</td>
</tr>
<tr>
<td>Technology-specific savings inputs</td>
<td>Provided by an EPIC grantee working on multiple wastewater treatment studies</td>
<td>50%</td>
<td>40%</td>
<td>60%</td>
<td>percent</td>
</tr>
<tr>
<td></td>
<td>EPIC grantee estimates; ranges assigned by Evergreen Economics</td>
<td>35%</td>
<td>25%</td>
<td>45%</td>
<td>percent</td>
</tr>
<tr>
<td>Market and measure life inputs</td>
<td>Evergreen Economics estimates based on EPIC project description and professional judgment</td>
<td>50%</td>
<td>25%</td>
<td>75%</td>
<td>percent</td>
</tr>
<tr>
<td></td>
<td>Typical major system life expectancy, corroborated for wastewater treatment plants by &quot;A comparative life cycle assessment of a wastewater treatment technology considering two inflow scales &quot; by Leonor Patricia Güereca Hernández et al.</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>years</td>
</tr>
<tr>
<td>Total</td>
<td>Computation</td>
<td>0.22</td>
<td>0.06</td>
<td>0.51</td>
<td>TWh</td>
</tr>
</tbody>
</table>
### Novel Staged Anaerobic Fluidized Bed Membrane Bioreactor

<table>
<thead>
<tr>
<th>Source(s)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated electrical usage by small and medium-sized Minnesota wastewater treatment plants presented in webinar about MN CARD white paper study &quot;A Cohort Approach to Wastewater Treatment Energy Efficiency;&quot; actual baseline may be bigger if large treatment plants are included.</td>
<td></td>
</tr>
</tbody>
</table>

#### Minnesota statewide base energy use input

<table>
<thead>
<tr>
<th>Point estimate</th>
<th>Low</th>
<th>High</th>
<th>Units</th>
<th>Source(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical consumption by Minnesota wastewater treatment plants</td>
<td>0.127</td>
<td>0.127</td>
<td>0.127</td>
<td>TWh</td>
</tr>
</tbody>
</table>

#### Technology-specific savings inputs

<table>
<thead>
<tr>
<th>Point estimate</th>
<th>Low</th>
<th>High</th>
<th>Units</th>
<th>Source(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated electrical savings from total treatment process</td>
<td>20%</td>
<td>10%</td>
<td>40%</td>
<td>percent</td>
</tr>
<tr>
<td>EPIC grantee estimates; ranges assigned by Evergreen Economics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Market and measure life inputs

<table>
<thead>
<tr>
<th>Point estimate</th>
<th>Low</th>
<th>High</th>
<th>Units</th>
<th>Source(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adoption rate</td>
<td>30%</td>
<td>20%</td>
<td>50%</td>
<td>percent</td>
</tr>
<tr>
<td>Evergreen Economics estimates based on EPIC project description and professional judgment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measure life</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>years</td>
</tr>
<tr>
<td>Typical major system life expectancy, corroborated for wastewater treatment plants by &quot;A comparative life cycle assessment of a wastewater treatment technology considering two inflow scales &quot; by Leonor Patricia Güereca Hernández et al.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0.2</td>
<td>0.1</td>
<td>0.5</td>
<td>TWh</td>
</tr>
<tr>
<td>Computation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Biofiltration as an Advanced Primary Treatment Method

<table>
<thead>
<tr>
<th>Source(s)</th>
<th>Units</th>
<th>Low</th>
<th>Point estimate</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated electrical usage by small and medium-sized Minnesota wastewater treatment plants presented in webinar about MN CARD white paper study &quot;A Cohort Approach to Wastewater Treatment Energy Efficiency;&quot; actual baseline may be bigger if large treatment plants are included</td>
<td>TWh</td>
<td>0.127</td>
<td>0.127</td>
<td>0.127</td>
</tr>
<tr>
<td>Provided by an EPIC grantee working on multiple wastewater treatment studies</td>
<td>percent</td>
<td>50%</td>
<td>40%</td>
<td>60%</td>
</tr>
<tr>
<td>EPIC grantee estimates; ranges assigned by Evergreen Economics</td>
<td>percent</td>
<td>55%</td>
<td>45%</td>
<td>65%</td>
</tr>
<tr>
<td>Evergreen Economics estimates based on EPIC project description and professional judgment</td>
<td>percent</td>
<td>50%</td>
<td>25%</td>
<td>75%</td>
</tr>
<tr>
<td>Typical major system life expectancy, corroborated for wastewater treatment plants by &quot;A comparative life cycle assessment of a wastewater treatment technology considering two inflow scales&quot; by Leonor Patricia Güereca Hernández et al.</td>
<td>years</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Computation</td>
<td>TWh</td>
<td>0.3</td>
<td>0.1</td>
<td>0.7</td>
</tr>
</tbody>
</table>

### Minnesota statewide base energy use input

- **Electrical consumption by Minnesota wastewater treatment plants**
  - **Point estimate**: 0.127 TWh
  - **Low**: 0.127 TWh
  - **High**: 0.127 TWh

### Technology-specific savings inputs

- **Share of treatment electricity in secondary aeration step**
  - **Low**: 50%
  - **Point estimate**: 60%
  - **High**: 60%

- **Estimated electrical savings in secondary aeration stage**
  - **Low**: 55%
  - **Point estimate**: 45%
  - **High**: 65%

### Market and measure life inputs

- **Adoption rate**
  - **Low**: 50%
  - **Point estimate**: 25%
  - **High**: 75%

- **Measure life**
  - **Low**: 20 years
  - **Point estimate**: 20 years
  - **High**: 20 years
## Biological Double Efficiency Process

<table>
<thead>
<tr>
<th>Point estimate</th>
<th>Low</th>
<th>High</th>
<th>Units</th>
<th>Source(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Minnesota statewide base energy use input</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrical consumption by Minnesota wastewater treatment plants</td>
<td>0.127</td>
<td>0.127</td>
<td>0.127</td>
<td>TWh</td>
</tr>
<tr>
<td><strong>Technology-specific saving inputs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Share of treatment electricity in secondary aeration step</td>
<td>50%</td>
<td>40%</td>
<td>60%</td>
<td>percent</td>
</tr>
<tr>
<td>Estimated electrical savings in secondary aeration stage</td>
<td>50%</td>
<td>25%</td>
<td>75%</td>
<td>percent</td>
</tr>
<tr>
<td><strong>Market and measure life inputs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adoption rate</td>
<td>40%</td>
<td>15%</td>
<td>65%</td>
<td>percent</td>
</tr>
<tr>
<td>Measure life</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>years</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>0.25</td>
<td>0.04</td>
<td>0.74</td>
<td>TWh</td>
</tr>
</tbody>
</table>
## Electric Plug Load Savings Potential of Commercial Foodservice Equipment

<table>
<thead>
<tr>
<th>Point estimate</th>
<th>Low</th>
<th>High</th>
<th>Units</th>
<th>Source(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Establishment-level savings</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daily savings per establishment</td>
<td>6.7</td>
<td>4.3</td>
<td>9.1</td>
<td>kWh</td>
</tr>
<tr>
<td>Annual days of operation</td>
<td>250</td>
<td>200</td>
<td>300</td>
<td>days</td>
</tr>
</tbody>
</table>

**Market and measure life inputs**

<table>
<thead>
<tr>
<th></th>
<th>Low</th>
<th>High</th>
<th>Units</th>
<th>Source(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of establishments in Minnesota</td>
<td>10,681</td>
<td>10,681</td>
<td>10,681</td>
<td>sites Evergreen Economics secondary research</td>
</tr>
<tr>
<td>Measure life</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>years Evergreen Economics estimates based on range of equipment types included in analysis</td>
</tr>
</tbody>
</table>

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td>0.09</td>
<td>0.05</td>
<td>0.15</td>
<td>TWh</td>
</tr>
</tbody>
</table>

## Customer-Centric Approach to Scaling Retrofits in Low-Income Multifamily Buildings

<table>
<thead>
<tr>
<th></th>
<th>Point estimate</th>
<th>Low</th>
<th>High</th>
<th>Units</th>
<th>Source(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Minnesota statewide base energy use input</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual electrical consumption in low-income multifamily bldgs.</td>
<td>1.7</td>
<td>1.7</td>
<td>1.7</td>
<td>TWh</td>
<td>Minnesota potential study baseline data* (sectors: small multifamily-low income, large multifamily-low income; end-uses: all)</td>
</tr>
</tbody>
</table>

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technology inputs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tech. applicability</td>
<td>50%</td>
<td>25%</td>
<td>75%</td>
<td>percent Evergreen Economics estimates based on EPIC project description, fit with sector and end-uses included in baseline value, and professional judgment</td>
</tr>
<tr>
<td>Energy use reduction</td>
<td>35%</td>
<td>30%</td>
<td>40%</td>
<td>percent EPIC grantee estimates; ranges assigned by Evergreen Economics</td>
</tr>
</tbody>
</table>

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Market and measure life inputs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adoption rate</td>
<td>30%</td>
<td>20%</td>
<td>50%</td>
<td>percent Evergreen Economics estimates based on EPIC project description and professional judgment</td>
</tr>
<tr>
<td>Measure life</td>
<td>10</td>
<td>5</td>
<td>20</td>
<td>years Evergreen Economics estimates based on range of equipment types included in analysis</td>
</tr>
</tbody>
</table>

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td>0.9</td>
<td>0.1</td>
<td>5.1</td>
<td>TWh</td>
</tr>
</tbody>
</table>

*Note: TWh = terawatt-hours.*
About This Fact Sheet Package

Evergreen Economics created a series of fact sheets for the Minnesota Department of Commerce to highlight energy-saving technologies being developed and tested using public R&D funding in California. This fact sheet package addresses three emerging commercial HVAC technologies that can reduce commercial building energy use through HVAC controls and efficiency.

For more information about these fact sheets, please contact Ingo Bensch, bensch@evergreenecon.com, or Mary Sue Lobenstein, marysue.lobenstein@state.mn.us.

Fact Sheet Topics

California’s Electric Program Investment Charge (EPIC) grant program has supported hundreds of studies to advance clean energy technologies. We examined several that our initial screening process identified as most promising for Minnesota and developed fact sheets for the applicable technologies. Status updates shown in the fact sheets are current as of summer 2019.

This Fact Sheet Package:

Commercial HVAC Technologies and Controls Fact Sheet Package
- Ultrasonic Anemometer
- Integrated Building Control Retrofit Package
- Optimized Hybrid Cooling Controls

Other Fact Sheet Packages:

New Wastewater Treatment Technologies
- Raw Wastewater Filtration Cloth Depth Filters
- Novel Staged Anaerobic Fluidized Bed Membrane Bioreactor
- Biofiltration as an Advanced Primary Treatment Method
- Biological Double-Efficiency Process (BDP)

Emerging Technologies in Food Services and Groceries
- Electric Plug Load Savings Potential of Commercial Foodservice Equipment

Program Adoption Insights from Consumer Studies
- Customer-Centric Approach to Scaling Retrofits in Low-Income Multifamily Buildings

Additional technologies being investigated can be found on the California Energy Commission’s Energy Innovation Showcase website (http://innovation.energy.ca.gov).
Ultrasonic Anemometer

The Center for the Built Environment at the University of California-Berkeley has developed a low-cost ultrasonic anemometer that can be used indoors and in HVAC ducts to measure airflow metrics. This technology is expected to be available for $20 to $100 and offer improved operational data communicated wirelessly to HVAC control systems and operators. Such data could allow for reduced airflow when ventilation requirements have been met, greater temperature setbacks while maintaining comfort, and identification of system anomalies or failures. The project team estimates potential savings of 10% to 15% of a building's HVAC usage and technology applicability in between 25% and 75% of commercial buildings.

**PROBLEM ADDRESSED:** Excess ventilation and operational constraints due to lack of distributed sensor feedback about airflow.

**STATUS**
The project team completed prototypes of an indoor and duct sensor and was testing them in 2018. A project report is expected in 2019.

**NEXT STEPS AND WHAT TO WATCH**
The next step is most likely development of these products for the marketplace. UC-Berkeley had included several industry partners in this effort, at least two of which are active in the HVAC industry (Price Industries and Vigilent).

**ENERGY SAVINGS POTENTIAL**

**Lifetime Energy Savings**
- Point estimate: 0.9 TWh
- Range: 0.3-2.8 TWh

**Assumptions and Inputs**
- Annual commercial HVAC consumption: 2.5 TWh
- Tech. applicability: 25%-75%
- HVAC energy use reduction: range: 10%-15%
- Adoption rate: 20%-50%
- Measure life: 20 years

**FOR MORE INFORMATION**

**EPIC grant project:** Very Low-cost MEMS-based Ultrasonic Anemometer for Use Indoors and in HVAC Ducts
- Summary at the California Energy Commission's [Energy Innovation Showcase website](http://innovation.energy.ca.gov). (Search for project by EPIC grant project name.)

**Contacts**
- California Energy Commission Agreement manager: Heather Bird, [heather.bird@energy.ca.gov](mailto:heather.bird@energy.ca.gov), (916) 327-3094
- UC-Berkeley contact: Edward Arens, [earens@berkeley.edu](mailto:earens@berkeley.edu), (510) 642-1158
Optimized Hybrid Cooling Controls

The Electric Power Research Institute is testing the use of an intelligent HVAC controller that processes signals from building sensors and system feedback to maximize system efficiency. This particular study is applying the controller to the optimization of variable refrigerant flow and indirect evaporative cooling for the optimal mix. The control system utilizes cloud-based optimization using weather, grid conditions, and occupancy (CO2) as inputs to optimally operate the hybrid system. (For Midwestern applications, such a controller would need to be configured to optimize hybrid cooling solutions for humid climates.)

**PROBLEM ADDRESSED:**
Lack of control technology to effectively integrate multiple cooling approaches optimized based on existing conditions.

**STATUS**
As of the end of 2018, baseline conditions were being measured at three project sites in California where this system will be tested. The study is scheduled to be completed in 2020.

**ENERGY SAVINGS POTENTIAL**

**Lifetime Energy Savings**
- Point estimate: 0.3 TWh
- Range: 0.1-0.9 TWh

**Note:** High uncertainty. A Midwest-specific analysis would be needed to determine savings potential for hybrid systems for humid climates.

**Assumptions and Inputs**
- Annual commercial cooling consumption: 1.2 TWh
- Tech. applicability: 20%-50%
- Cooling energy use reduction: 10%-15%
- Adoption rate: 20%-50%
- Measure life: 20 years

**FOR MORE INFORMATION**

**EPIC grant project:** Climate appropriate HVAC Systems for Commercial Buildings to Reduce Energy Use and Demand
- Summary at at the California Energy Commission’s [Energy Innovation Showcase website](http://innovation.energy.ca.gov). (Search for project by EPIC grant project name.)

**Contacts**
- Bradley Meister, [brad.meister@energy.ca.gov](mailto:brad.meister@energy.ca.gov), (916) 327-1722
- Project recipient contact: Ram Narayananmurthy, [rnarayanamurthy@epri.com](mailto:rnarayanamurthy@epri.com), (650) 855-2419
**Commercial HVAC Technologies and Controls**

**Integrated Building Control Retrofit Package**

The California Lighting Technology Center at the University of California-Davis is developing and testing a retrofit package for commercial buildings that integrates and optimizes control of lighting, fenestration, and space-conditioning systems under a single, unified platform. Initial estimates through computer simulations by the project team show energy savings potential of up to 37% percent of commercial building lighting and HVAC energy use. The control system allows for integration of existing end-use technologies and controls using added sensors and a master controller, and allows for optimization of comfort and energy use based on space occupancy and environmental conditions.

**PROBLEM ADDRESSED:**
Efficiency losses when HVAC, lighting, and fenestration controls do not coordinate.

**STATUS**
The UC-Davis research team has tested the system in a laboratory setting and had planned to install it in a UC-Davis building in 2019 for demonstration and performance monitoring and evaluation. Results on energy performance and occupant satisfaction should be available in 2020. Final report expected in 2020 or 2021.

**NEXT STEPS AND WHAT TO WATCH**
Key items to watch are the in-field performance of the controller at producing electrical savings and comfort during testing, as well as market response once the study is concluded. The algorithms and system details will be publicly available, but it remains to be seen which market actors will integrate the controller in their offerings or promote the technology to building decision-makers.

**ENERGY SAVINGS POTENTIAL**

**Lifetime Energy Savings**
- Point estimate: 2.2 TWh
- Range: 0.4-11.1 TWh

**Assumptions and Inputs**
- Annual commercial HVAC and lighting consumption: 3.7 TWh
- Tech. applicability: 25%-75%
- Energy use reduction: 10%-40%
- Adoption rate: 20%-50%
- Savings persistence: 20 years

**FOR MORE INFORMATION**

**EPIC grant project:** Pilot-Scale Evaluation of an Integrated Building Control Retrofit Package

**Contacts**
- California Energy Commission project manager: Felix Villanueva, felix.villanueva@energy.ca.gov, (916) 327-2206
- UC-Davis contact: Cori Jackson, cmjackson@ucdavis.edu, (530) 747-3812
Technology Fact Sheet
New Wastewater Treatment Technologies

Project funded by Minnesota’s Conservation Applied Research and Development Program

About This Fact Sheet Package

Evergreen Economics created a series of fact sheets for the Minnesota Department of Commerce to highlight energy-saving technologies being developed and tested using public R&D funding in California. This fact sheet package addresses four new wastewater treatment technologies that reduce electricity consumption, often by reducing the need for aeration in the secondary stage of treatment.

For more information about these fact sheets, please contact Ingo Bensch, bensch@evergreenecon.com, or Mary Sue Lobenstein, marysue.lobenstein@state.mn.us.

Fact Sheet Topics

California’s Electric Program Investment Charge (EPIC) grant program has supported hundreds of studies to advance clean energy technologies. We examined several that our initial screening process identified as most promising for Minnesota and developed fact sheets for the applicable technologies. Status updates shown in the fact sheets are current as of summer 2019.

This Fact Sheet Package:

New Wastewater Treatment Technologies
• Raw Wastewater Filtration Cloth Depth Filters
• Novel Staged Anaerobic Fluidized Bed Membrane Bioreactor
• Biofiltration as an Advanced Primary Treatment Method
• Biological Double-Efficiency Process (BDP)

Other Fact Sheet Packages:

Commercial HVAC Technologies and Controls
• Ultrasonic Anemometer
• Integrated Building Control Retrofit Package
• Optimized Hybrid Cooling Controls

Emerging Technologies in Food Services and Groceries
• Electric Plug Load Savings Potential of Commercial Foodservice Equipment

Program Adoption Insights from Consumer Studies
• Customer-Centric Approach to Scaling Retrofits in Low-Income Multifamily Buildings

Additional technologies being investigated can be found on the California Energy Commission’s Energy Innovation Showcase website (http://innovation.energy.ca.gov).
**New Wastewater Treatment Technologies**

**Raw Wastewater Filtration Cloth Depth Filters**

The Cloth Depth Filter (CDF) is an emerging water filtration technology that aims to reduce the energy input needed during the secondary biological wastewater treatment process through filtering out biosolids beforehand. The implementation of CDFs as a primary filtration step is projected to result in a higher rate of biosolid removal as well as the reduced need for aeration and activated sludge processing, two steps that when combined account for 40% to 60% of total wastewater treatment plant electricity consumption. The study demonstrated the application of CDFs at three California wastewater treatment plants: the Linda County Water District, the City of Manteca, and the Los Angeles County Sanitation District, as well as a pilot demonstration in the Rock River Water Reclamation District in Rockford, Illinois.

**PROBLEM ADDRESSED:**
The energy heavy aeration and activated sludge processing steps that account for 40% to 60% of wastewater treatment plant energy consumption.

**STATUS**
The project team has completed its demonstration of the CDF filters at three California wastewater treatment plants as of March 2019.

**ENERGY SAVINGS POTENTIAL**

**Cumulatively Persisting Energy Savings**

- Point estimate: .2 TWh
- Range: .06 -- .5 TWh

**Assumptions and Inputs**

- Annual total energy use for target wastewater treatment plants: 0.127 TWh/yr
- Secondary aeration accounts for 40%-60% of treatment cycle energy use
- Electrical savings in secondary aeration stage of 25%-45%
- Adoption rate: 25%-75%
- Measure life: 20 years

**NEXT STEPS AND WHAT TO WATCH**

A final report is currently in the works. The next step is the introduction of these products to the marketplace. Kennedy/Jenks Consultants is currently developing a website to introduce CDFs to the market as well as track the technology’s progress.

**FOR MORE INFORMATION**

**EPIC grant project:** Raw Wastewater Filtration to Increase Organic Removal Efficiency and Achieve Significant Electrical Savings

- Summary at the California Energy Commission’s Energy Innovation Showcase website (http://innovation.energy.ca.gov). (Search for project by EPIC grant project name.)

**Contacts**

- California Energy Commission project manager: Anish Gautam, Anish.Gautam@energy.ca.gov (916) 327-2382
- Kennedy/Jenks Consulting contact: Onder Caliskaner, ondercaliskaner@kennedyjenks.com
New Wastewater Treatment Technologies

Biofiltration as an Advanced Primary Treatment Method

Raw waste water filtration or biofiltration is an alternative wastewater treatment model that aims to save overall wastewater treatment plant energy consumption through replacing conventional primary wastewater clarifiers with wastewater filters to reduce downstream energy use. This project is quantifying the water savings and electrical energy reduction that can be achieved by biofiltration based on demonstration results at the Linda County Water District wastewater plant. This project will provide the cost and performance data to evaluate the benefits from sustained, full scale validation testing, including quantification of electrical energy savings, determination of water savings, organic solids removal efficiencies, operation and maintenance and design criteria, independent monitoring and verification and technology transfer. According to preliminary results from the pilot study at the Linda County Water District wastewater plant, biofiltration has the potential to decrease later stage aeration energy inputs by 45% to 60% while increasing gas production and treatment capacity.

Problem Addressed:
The energy intensive secondary aeration process in wastewater treatment.

Status
Project in progress. Pilot project ongoing at the Linda County Water District wastewater plant.

Next steps and what to watch
Final study report is scheduled to be released in March 2021.

Energy savings potential

Lifetime Energy Savings
- Point estimate: 0.3 TWh/yr
- Range: 0.1-0.7 TWh/yr

Assumptions and inputs
- Annual total energy use for target wastewater treatment plans: 0.127 TWh/yr
- Secondary aeration accounts for 40%-60% of treatment cycle energy use
- Electrical savings in secondary aeration stage of 25%-75%
- Adoption rate: 25%-75%
- Measure life: 20 years

For more information

EPIC grant project: Biofiltration as an Advanced Primary Treatment Method to Achieve Substantial Energy Savings
- Summary at the California Energy Commission's Energy Innovation Showcase website (http://innovation.energy.ca.gov). (Search for project by EPIC grant project name.)

Contacts
- California Energy Commission project manager: Kevin Mori, (916) 327-1475
- Kennedy/Jenks Consulting contact: Onder Caliskaner, ondercaliskaner@kennedyjenks.com
New Wastewater Treatment Technologies

Biological Double Efficiency Process (BDP)

The Biological Double Efficiency Process is an alternative to the separate anoxic and aerobic tanks conventionally used in secondary wastewater clarifiers. Combining state-of-the-art aeration technology, airlift circulation/dilution technology, and an integrated all-in-one bioreactor model, the BDP simultaneously achieves nitrification/denitrification and accomplishing the work of two separate anoxic and aerobic tanks. According to initial estimates from a study on BDP technology, the technology has the potential to reduce 50% of aeration required for secondary treatment as well as reduce necessary wastewater treatment plant (WWTP) capital by 30%, necessary land for WWTPs by 50%, and WWTP maintenance costs by 50%.

PROBLEM ADDRESSED:
The high capital costs, land footprint, and energy costs associated with conventional activated sludge processes.

STATUS
Project is ongoing. Final report in the works.

ENERGY SAVINGS POTENTIAL

Lifetime Energy Savings
- Point estimate: 0.25 TWh
- Savings range: 0.04-0.7 TWh

Assumptions and Inputs
- Annual total energy use for target wastewater treatment plants: .127 TWh
- Secondary aeration accounts for 40%-60% of treatment cycle energy use
- Electrical savings in secondary aeration stage of 25%-75%
- Adoption rate: 15%-65%
- Measure life: 20 years

FOR MORE INFORMATION

EPIC grant project: Biological Double-Efficiency Process as an Advanced Wastewater Treatment Method to Achieve Substantial Energy and Water Savings
- Summary at the California Energy Commission’s Energy Innovation Showcase website (http://innovation.energy.ca.gov). (Search for project by EPIC grant project name.)

Contacts
- California Energy Commission project manager: Michael Lozano, Michael.Lozano@energy.ca.gov, (916) 327-1425
- Recipient Project Manager: Ben Chi Wai Chow, Benchow@bdpenvironotech.com, (626) 215-5587
Novel Staged Anaerobic Fluidized Bed Membrane Bioreactor

The Novel Staged Anaerobic Fluidized Bed Membrane Bioreactor is an emerging technology that uses anaerobic bacteria to filter industrial wastewater. Anaerobic-based facilities require less space than aerobic-based ones and may produce 30% less solid waste. For the study, an anaerobic system was demonstrated at the Silicon Valley Clean Water (SVCW) treatment facility, replacing the aeration step in the filtration process. The system is projected to filter 30% more bio-solids than conventional systems while reducing energy consumption and environmental impact for the wastewater plant. The filtered higher quality water is also being demonstrated as a potential source of local water supply through the use of reuse treatment trains.

**Problem Addressed:**

Conventional wastewater systems are based on 100 year-old technology that is energy intensive (3% of electricity nationwide), produces bio-solids, and neglects the value of wastewater as a reliable water supply.

**Status**

Initial reports are currently being reviewed. The study is on track to being completed by March 1, 2021.

**Next Steps and What to Watch**

Publication of study's finding in a peer reviewed trade journal and, eventually, market availability through vendors such as Suez. The SVCW website (www.svcw.org) and the Codiga Resource Recovery Center website (https://cr2c.standford.edu) can both be used to follow the progress of this project.

**Energy Savings Potential**

**Lifetime Energy Savings**

- Point estimate: 0.2 TWh
- Range: 0.1-0.5 TWh

**Assumptions and Inputs**

- Annual total energy use for target wastewater treatment plants: 0.127 TWh/yr
- Electrical savings of total treatment energy use: 10-40%
- Adoption rate: 20%-50%
- Measure life: 20 years

**For More Information**

**EPIC grant project:** Maximizing Energy Efficiency and Reducing Bio-solids Waste from New Anaerobic Wastewater Treatment Technology

- Summary at the California Energy Commission's Energy Innovation Showcase website (http://innovation.energy.ca.gov). (Search for project by EPIC grant project name.)

**Contacts**

- David Weightman, (916) 327-1631
- Recipient Project Manager: Eric Hansen, Ehansen@svcw.org, (650) 832-6228
Technology Fact Sheet  
Program Adoption Insights from Consumer Studies  

Project funded by Minnesota's Conservation Applied Research and Development Program

About This Fact Sheet Package

Evergreen Economics created a series of fact sheets for the Minnesota Department of Commerce to highlight energy-saving technologies being developed and tested using public R&D funding in California. This fact sheet package summarizes a study that developed multifamily retrofits designed for high adoption rates.

For more information about these fact sheets, please contact Ingo Bensch, bensch@evergreenecon.com, or Mary Sue Lobenstein, marysue.lobenstein@state.mn.us.

Fact Sheet Topics

California's Electric Program Investment Charge (EPIC) grant program has supported hundreds of studies to advance clean energy technologies. We examined several that our initial screening process identified as most promising for Minnesota and developed fact sheets for the applicable technologies. Status updates shown in the fact sheets are current as of summer 2019.

This Fact Sheet Package:
Program Adoption Insights from Consumer Studies
• Customer-Centric Approach to Scaling Retrofits in Low-Income Multifamily Buildings

Other Fact Sheet Packages:
Commercial HVAC Technologies and Controls
• Ultrasonic Anemometer
• Integrated Building Control Retrofit Package
• Optimized Hybrid Cooling Controls

Raw Wastewater Treatment Technologies
• Raw Wastewater Filtration Cloth Depth Filters
• Novel Staged Anaerobic Fluidized Bed Membrane Bioreactor
• Biofiltration as an Advanced Primary Treatment Method
• Biological Double-Efficiency Process (BDP)

Emerging Technologies in Food Services and Groceries
• Electric Plug Load Savings Potential of Commercial Foodservice Equipment

Additional technologies being investigated can be found on the California Energy Commission's Energy Innovation Showcase website (http://innovation.energy.ca.gov).
Customer-Centric Approach to Scaling Retrofits in Low-Income Multifamily Buildings

The customer-centric approach to retrofit projects demonstrates an approach to scale residential retrofits specifically tailored towards low-income multifamily buildings. The approach is based on energy efficient retrofit packages developed for the project that are non-intrusive to occupants and have the potential of reducing energy use by 30% to 40%. The project also provides new data, analysis, and designs for cost-effective integrated demand side management retrofits such as advanced HVAC, smart thermostats, plug load controls, LED lighting, and heat pump water heaters for residential communities, all designed to minimize tenant disruptions. This study is intended to help California reach its goal of reducing energy use in existing buildings by 50% by 2030 through actionable approaches for affordable multifamily buildings.

PROBLEM ADDRESSED:
Low income and Multi-family are two of the most important retrofit targets, yet have been historically underserved.

STATUS
The research team has completed installation of efficiency measures and has begun a 12-month monitoring and commission period in Ontario, CA.

ENERGY SAVINGS POTENTIAL

Lifetime Energy Savings
- Point estimate: 0.9 TWh
- Savings range: 0.1-5.1 TWh

Assumptions and Inputs
- 2016 Minnesota Low Income Multi-family building electric load: 1,695,686 MWh
- Technology applicability: 25%-75% of buildings
- Energy savings when applied: 30%-40% of electric consumption
- Adoption rate: 20%-50%
- Measure life: 5-20 years

FOR MORE INFORMATION

EPIC grant project: Customer-Centric Approach to Scaling Integrated Demand Side Management (IDSM) Retrofits
- Summary at the California Energy Commission’s Energy Innovation Showcase website (http://innovation.energy.ca.gov). (Search for project by EPIC grant project name.)

Contacts
- California Energy Commission project manager: Felix Villanueva, felix.villanueva@energy.ca.gov, (916) 327-2206
- Recipient Project Manager: Andra Rogers, arogers@epri.com, (650) 855-2101
Technology Fact Sheet
Emerging Tech in Food Service and Grocery

Project funded by Minnesota’s Conservation Applied Research and Development Program

About This Fact Sheet Package
Evergreen Economics created a series of fact sheets for the Minnesota Department of Commerce to highlight energy-saving technologies being developed and tested using public R&D funding in California. This fact sheet package addresses a study that assessed the electric plug load savings potential of emerging plug-load reducing technologies for the commercial food service sector.

For more information about these fact sheets, please contact Ingo Bensch, bensch@evergreen econ.com, or Mary Sue Lobenstein, marysue.lobenstein@state.mn.us.

Fact Sheet Topics
California’s Electric Program Investment Charge (EPIC) grant program has supported hundreds of studies to advance clean energy technologies. We examined several that our initial screening process identified as most promising for Minnesota and developed fact sheets for the applicable technologies. Status updates shown in the fact sheets are current as of summer 2019.

This Fact Sheet Package:
Emerging Technologies in Food Services and Groceries
• Electric Plug Load Savings Potential of Commercial Foodservice Equipment

Other Fact Sheet Packages:
Commercial HVAC Technologies and Controls
• Ultrasonic Anemometer
• Integrated Building Control Retrofit Package
• Optimized Hybrid Cooling Controls

Raw Wastewater Treatment Technologies
• Raw Wastewater Filtration Cloth Depth Filters
• Novel Staged Anaerobic Fluidized Bed Membrane Bioreactor
• Biofiltration as an Advanced Primary Treatment Method
• Biological Double-Efficiency Process (BDP)

Program Adoption Insights from Consumer Studies
• Customer-Centric Approach to Scaling Retrofits in Low-Income Multifamily Buildings

Additional technologies being investigated can be found on the California Energy Commission’s Energy Innovation Showcase website (http://innovation.energy.ca.gov).
Electric Plug Load Savings Potential of Commercial Foodservice Equipment

The Electric Plug Load Savings Potential project is a market analysis of the quantity and types of unventilated commercial food preparation equipment in common use and the savings potential from alternatives. The study monitored 10 commercial food service facilities and 52 appliances over 19 appliance types and concluded that smart conveyor toasters, induction soup warmers, and modular insulated hot-food holding cabinets offered the greatest savings potential. Energy savings were found to justify early retirement programs.

PROBLEM ADDRESSED:
Commercial foodservice facilities are among the largest energy consumers within the commercial building sector and consume as much as five times more electricity per square foot than any other commercial building type.

STATUS

ENERGY SAVINGS POTENTIAL

Lifetime Energy Savings
Savings after baseline equipment was replaced by the updated appliance.

- Savings estimate: 0.09 TWh
- Savings range: 0.04-0.15 TWh

Assumptions and Inputs
The most prominent foodservice appliance savings potentials:

- Converyer Toasters: 1.8-2.2 kWh/day
- Soup Wells: 0.2-0.6 kWh/day
- Holding Cabinets: 2.3-6.3 kWh/day

Market and measure assumptions:

- Appliance lifespan: 5 years
- Days of operation a year: 200-300
- Food service sites in Minnesota in 2019: 10,681

NEXT STEPS AND WHAT TO WATCH
Utility CIP programs serving commercial foodservice facilities should consider the potential role of such technologies as smart conveyor toasters, induction soup warmers, and modular insulated hot food holding cabinets.

FOR MORE INFORMATION
EPIC grant project: Electric Plug Load Savings Potential of Commercial Foodservice Equipment

- Summary at the California Energy Commission's Energy Innovation Showcase website (http://innovation.energy.ca.gov). (Search for project by EPIC grant project name.)

Contacts
- California Energy Commission project manager: Bradley Meister, brad.meister@energy.ca.gov, (916) 327-1722
- Grant Recipient Project Manager: David Zabrowski, dzabrowski@fishnick.com, (925) 866-5614