Load shifting: the market potential for carbon and energy savings

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Open or close your control panel

Screen
Maximize screen for better view.

Audio options
Select either the Computer audio or a Phone call.

• If you are using your telephone:
  • Select the “Phone call” button
  • Dial in and enter your access code
  • Enter your audio pin and press #

You will be joined into the webinar on mute.

Participation
Type in a question and hit “send” to ask a question.
Purpose to help Minnesota utilities achieve 1.5% energy savings goal by:

- Identifying new technologies or strategies to maximize energy savings;
- Improving effectiveness of energy conservation programs;
- Documenting CO$_2$ reductions from energy conservation programs.

Utility may reach its energy savings goal

- Directly through its Conservation Improvement Program (CIP)
- Indirectly through energy codes, appliance standards, behavior, and other market transformation programs

Minnesota Statutes §216B.241, Subd. 1e
CARD RFP Spending by Sector thru FY2019

RFP Summary
- 10 Funding Cycles
- 472 proposals
- 121 projects funded
- $27.4 million in research

CARD RFP Projects by Sectors thru FY2019
- Commercial (41), 38.3%
- Residential 1 - 4 unit (18), 17.5%
- Industrial (11), 10.0%
- Multifamily 5+ unit (5), 5.0%
- Agricultural (6), 5.0%
- Multi-sector (26), 24.2%
Thank you to our research partners!
Agenda

- Study Goals and Approach
- Results
  - Price Optimization
  - Emissions Optimization
- Recommendations
- Questions
Study goals and approach
To quantify the energy, energy cost, and emissions impacts of measures that shift load with or without saving energy
Minnesota context for this research

Energy efficiency saturation

Changing generation mix

Overlap between EE and load shifting
Study approach

SELECT
measures that represent a variety of load shifting effects

COLLECT
avoided costs and emissions data for current and future years

APPLY
load shifting methodology

SCALE
measures to achieve consistent savings
Measure Selection

- Event-based load shift
- Regularly-occurring shift
- Energy efficiency
<table>
<thead>
<tr>
<th><strong>Event-based load shift</strong></th>
<th><strong>Regularly-occurring shift</strong></th>
<th><strong>Energy efficiency</strong></th>
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<tbody>
<tr>
<td>Smart thermostats + demand response control (R)</td>
<td></td>
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<td>Air source heat pumps + demand response control (R)</td>
<td></td>
<td></td>
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<tr>
<td>Envelope measures + ASHP (R)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Networked lighting controls + demand response control (C)</td>
<td></td>
<td></td>
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<tr>
<td>Strategic Energy Management (I)</td>
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<td>Critical peak pricing (R)</td>
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**BUILDING TYPES**
- R = Residential
- C = Commercial
- I = Industrial
### Event-based load shift
- Smart thermostats + demand response control (R)
- Air source heat pumps + demand response control (R)
- Envelope measures + ASHP (R)
- Networked lighting controls + demand response control (C)
- Strategic Energy Management (I)
- Critical peak pricing (R)

### Regularly-occurring shift
- Phase change materials for space conditioning (C)
- Phase change materials for refrigeration (C)
- Active ice thermal storage (C)
- Electric water heater controls (R)
- Electric vehicles with charging controls (R)
- Refrigeration load control (C)

### Energy efficiency

### BUILDING TYPES
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<td>Plug load controls (C)</td>
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**BUILDING TYPES**
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<table>
<thead>
<tr>
<th>Measure</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Phase change materials for space conditioning</td>
<td>Phase change materials (PCM) are ‘melted’ and ‘frozen’ at temperatures near the setpoint to shift load in conditioned places</td>
</tr>
<tr>
<td>Phase change materials for refrigeration</td>
<td>In refrigerated areas, PCM is frozen during non-peak hours and melted to cool goods during peak hours.</td>
</tr>
<tr>
<td>Active ice thermal storage</td>
<td>Cool thermal storage attached to a chilled water system; chillers make ice or chilled water at off-peak times for use during peak-times</td>
</tr>
<tr>
<td>Electric vehicles with charging controls</td>
<td>A managed controlled charging program that sets charging time between 9 pm and 5 am</td>
</tr>
<tr>
<td>Strategic energy management with demand focus</td>
<td>Programming common efficiency measures’ controls, based on worker shifts to shift load</td>
</tr>
<tr>
<td>Refrigeration load control</td>
<td>Refrigeration system operators use the setpoints in refrigerated spaces to shift the time at which compressors run, without impacting food quality.</td>
</tr>
</tbody>
</table>
## Event-based Measure Definitions

<table>
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<tr>
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<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smart thermostats with demand response</td>
<td>Smart thermostat with demand response functionality, to run air conditioning less when loads are peaking, or utility prices are high.</td>
</tr>
<tr>
<td>Air source heat pumps with demand response control</td>
<td>ASHP with controls that allow utilities to remotely adjust heating or cooling load. Includes pre-cooling or pre-heating prior to the event and a recovery period after the event.</td>
</tr>
<tr>
<td>Envelope measures combined with ASHP</td>
<td>Deep envelope retrofits combined with the ASHP measure to show the impact of having a well-insulated home</td>
</tr>
<tr>
<td>Electric water heater controls</td>
<td>Use of more efficient heat pump water heater and pre-heat during off peak times to shift usage</td>
</tr>
<tr>
<td>Networked lighting controls with demand response</td>
<td>A lighting retrofit with controls that are digitally networked for additional lighting energy savings during peak times</td>
</tr>
<tr>
<td>Critical peak pricing to drive behavior change</td>
<td>Advanced notice of higher prices for certain hours of days when demand is expected to be high</td>
</tr>
</tbody>
</table>
## Energy Efficiency Measure Definitions

<table>
<thead>
<tr>
<th>Measure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plug load controls</strong></td>
<td>Commercial plug load controls turn off computing equipment and peripherals, saving energy.</td>
</tr>
<tr>
<td><strong>Lighting efficiency and controls</strong></td>
<td>A typical LED retrofit along with daylighting, task tuning, and occupancy controls.</td>
</tr>
</tbody>
</table>
For load shape development, we relied on

**EMPIRICAL DATA**
from technology field tests and secondary sources and research

**SECONDARY DATA**
that combined Minnesota-specific assumptions with energy modeling
Scaled each measure to achieve 500 kW peak savings state-wide

Controls for the variability in per-unit demand
## Load Shape Optimization

<table>
<thead>
<tr>
<th>Regularly-occurring shift</th>
<th>Event-based shift</th>
<th>Energy efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OPTION 1</strong></td>
<td><strong>OPTION 1</strong></td>
<td>Shed energy all day</td>
</tr>
<tr>
<td>Avoid energy use during the <strong>middle of the day</strong></td>
<td>Shed energy during <em>high price hours</em> of top 20 days in a year</td>
<td></td>
</tr>
<tr>
<td><strong>OPTION 2</strong></td>
<td><strong>OPTION 2</strong></td>
<td></td>
</tr>
<tr>
<td>Avoid energy use <strong>during day or night</strong></td>
<td>Shed energy during <em>high emissions hours</em> of top 20 days in a year</td>
<td></td>
</tr>
</tbody>
</table>
Regularly-occurring Shift Example

Phase Change Materials — Refrigeration

Day Shift

Night Shift
Event-based Example

Air Source Heat Pump + Demand Response

![Graph showing electricity use over hours with baseline and measure lines.](image-url)
Cost and Emissions Data Sources

**Independent Service Operator**
- Current MISO Market and fuel mix/marginal plant data
- Future data unavailable

**Statewide**
- Current and forecasted emissions (EPA hourly emissions and known future retirements)

**Utility specific**
- Current data and future costs and emissions: Integrated Resource Planning data
Price Optimization Results
Goal for Optimizing for Energy Cost

HIGH COST → LOW COST

FOURTEEN MEASURES

Modeled three time periods (2018, 2026, 2034)
Percent cost savings vs. annual energy savings

- Demand Response
- Energy Efficiency
- Energy Efficiency + Demand Response
- Shift
Percent cost savings vs. annual energy savings

- Networked Lighting
- EV Charging
- Smart Tstats
- PCM - Refrigeration
- PCM - General
- CPP
- Industrial SEM
- Thermal Storage
- ASHP
- HPWH
- Lighting efficiency
- Plug loads

- Demand Response
- Energy Efficiency
- Energy Efficiency + Demand Response
- Shift

Percent Cost Savings vs. Annual Energy Savings Chart

- Electricity Savings (MWh)
- Percent Cost Savings

Percent cost savings range from -50% to 80%, with annual energy savings ranging from -500 MWh to 2500 MWh.
Percent cost savings vs. annual energy savings

- Networked Lighting
- EV Charging
- Smart Tstats
- CPP
- PCM - General
- Refrigeration Load Control
- Industrial SEM
- Thermal Storage
- Deep Envelope Retrofits + ASHP
- Lighting efficiency
- HPWH
- ASHP
- Plug loads

Electricity Savings (MWh)

- Demand Response
- Energy Efficiency
- Energy Efficiency + Demand Response
- Shift
Regularly-occurring Measures

Regularly-occurring shifts: Percent cost savings over baseline

<table>
<thead>
<tr>
<th>Category</th>
<th>Percent Cost Savings over Baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric Vehicle Charging</td>
<td>0 MWh</td>
</tr>
<tr>
<td>Phase Change Materials - Refrigeration</td>
<td>862 MWh</td>
</tr>
<tr>
<td>Phase Change Materials - General</td>
<td>496 MWh</td>
</tr>
<tr>
<td>Industrial SEM</td>
<td>-74 MWh</td>
</tr>
<tr>
<td>Refrigeration Load Control</td>
<td>-108 MWh</td>
</tr>
<tr>
<td>Thermal Storage</td>
<td>-102 MWh</td>
</tr>
</tbody>
</table>

Annual energy savings
Regularly-occurring Measures

Regularly-occurring shifts: Percent cost savings over baseline

- Electric Vehicle Charging
- Phase Change Materials - Refrigeration
- Phase Change Materials - General
- Industrial SEM
- Refrigeration Load Control
- Thermal Storage

0 MWh
862 MWh
496 MWh
-74 MWh
-108 MWh
-102 MWh
Event-based shifts: Percent cost savings over baseline

- **Air Source Heat Pump**: 1529 MWh
- **Heat Pump Water Heater**: 1721 MWh
- **Networked Lighting**: 1311 MWh
- **Critical Peak Pricing**: 76 MWh

The graph shows the percent cost savings over baseline for various measures, with categories including Efficiency, Efficiency + DR, and DR only.
Other Findings

Future

- Mostly stable percent cost savings across time
- Regularly-occurring shifts experience declines in cost savings
  (Due to lower prices in middle of day from renewable integration)

Carbon emissions

- Most measures save emissions when compared to the baseline
- Exception: those measures with an energy penalty
Key Takeaways

- **Energy efficiency** dominates both cost and emission savings opportunities
- Measures that increase energy use can *save energy costs through shifting*
- The timing of shifts may need to *change in the future to* respond to changes in price profiles
- **Capacity costs can have a significant impact** on cost savings for pure demand response and shifting measures
Emissions Optimization Results
Goal for Optimizing for Carbon Emissions

HIGH EMISSIONS ➔ LOW EMISSIONS

- air source heat pumps
- electric vehicles
- phase change materials for refrigeration

THREE MEASURES

MODELED THREE TIME PERIODS

MODELED THREE TERRITORIES
Annual emission factors across time and footprint

- MISO Marginal
- Statewide
- MISO Average
- Statewide
- Xcel Energy

Annual Emission Factors

Annual Average CO₂ Emissions (tons/MWh)

Year

2015 2020 2025 2030 2035
Air Source Heat Pumps

Air source heat pumps: Percent emissions savings over baseline

<table>
<thead>
<tr>
<th>Year</th>
<th>Average Emissions</th>
<th>Marginal Emissions</th>
<th>Statewide Emissions</th>
<th>Energy Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018 MISO</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2026</td>
<td></td>
<td></td>
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<tr>
<td>2034</td>
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CO2 Savings Over Baseline

- Air Source Heat Pump
- Air Source Heat Pump with DR

Current Years

Future Years
Electric vehicles: Percent emissions savings over baseline

<table>
<thead>
<tr>
<th>Year</th>
<th>Type</th>
<th>Emission Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018 MISO Average Emissions</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>2019 Xcel Energy Emissions</td>
<td>15%</td>
<td></td>
</tr>
<tr>
<td>2026 Statewide Emissions</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>2034 Xcel Energy Emissions</td>
<td>20%</td>
<td></td>
</tr>
</tbody>
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Electric Vehicle Daytime Charging

Electric Vehicle Nighttime Charging
Electric vehicles: Percent emissions savings over baseline

Current Years

Future Years

2018 MISO Average Emissions
2018 MISO Marginal Emissions
2018 Statewide Emissions
2019 Xcel Energy Emissions
2026 Statewide Emissions
2026 Xcel Energy Emissions
2034 Statewide Emissions
2034 Xcel Energy Emissions

Electric Vehicle Daytime Charging
Electric Vehicle Nighttime Charging
Electric vehicles: Percent emissions savings over baseline

- **2018 MISO Average Emissions**
- **2018 MISO Marginal Emissions**
- **2018 Statewide Emissions**
- **2019 Xcel Energy Emissions**
- **2026 Statewide Emissions**
- **2026 Xcel Energy Emissions**
- **2034 Statewide Emissions**
- **2034 Xcel Energy Emissions**

- **Electric Vehicle Daytime Charging**
- **Electric Vehicle Nighttime Charging**

**Current Years**

**Future Years**

- CO₂ Savings over Baseline
- 25%
- 20%
- 15%
- 10%
- 5%
- 0%
- -5%
- -10%

- **2018 MISO**
- **2018 MISO**
- **2018**
- **2019 Xcel**
- **2026**
- **2026 Xcel**
- **2034**
- **2034 Xcel**

- **Average Emissions**
- **Marginal Emissions**
- **Statewide Emissions**
- **Energy Emissions**
- **Statewide Emissions**
- **Energy Emissions**
- **Statewide Emissions**
- **Energy Emissions**

- **Electric Vehicle Daytime Charging**
- **Electric Vehicle Nighttime Charging**
Key Takeaways for Carbon Emission Optimization

Key Takeaways

• Absolute carbon savings can as much as double depending on which grid region is used to analyze emissions.

• For measures with energy efficiency benefits, optimization based on prices versus average emissions does not lead to significant changes in average emissions savings in the current Minnesota grid.
Recommendations
Program Recommendations, part 1

1. Continue to pursue **load shifting measures that can save energy** in CIP portfolios.

2. Bundle **cost-effective load shifting measures** with other measures in CIP portfolios.

3. Consider **future rate designs** that incentivize customers to shift energy when system is near capacity.
Program Recommendations, part 2

4. Apply a **utility-specific grid region** to calculate emissions benefits where available.

5. Further investigate measures **that shift load to nighttime hours** absent any energy savings benefits.

6. Explore **additional measures** that may offer similar load shifting benefits.
Future Research Recommendations

1. For future demand side management potential studies, **expand consideration of measure benefits to include cost savings and carbon benefits** associated with load shifting.

2. Perform additional **field research on load shifting measures** to generate a more robust database of empirical load shapes.

3. Conduct additional research to **improve marginal emissions, energy costs, and capacity cost forecasts**.
Thank you for your time!
Questions?

Load shifting: market potential for carbon and energy savings

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Send us your questions using Q&A box
CARD Project Resources

For Reports use CARD Search Quick Link
For Webinars use CARD Webinars & Videos Quick Link
For Other research documents use CARD Fact Sheets, Guidelines & Tools Quick Link

Webinar Recording & Final Report available in couple months

R&D Web Page (https://mn.gov/commerce/industries/energy/utilities/cip/applied-research-development/)
Upcoming CARD Webinars:

• December 4 *(New Date)* – Reconsidering MN Cooling Loads (Center for Energy and Environment)
• December 10 *(Tentative)* – C&I Refrigeration Market Assessment (Center for Energy and Environment)
• December 16 – Codes and Standards Roadmap (2050 Partners)

**Commerce Division of Energy Resources e-mail list sign-up**

If you have questions or feedback on the CARD program contact:

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How Did We Do?

Location:

https://app.keysurvey.com/f/41513460/f6c7/