Can Informational Nudges Shave Peak Demand?

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Proposal for
NBER Environmental and Energy Economics Policy Conference

Oct. 14, 2024

Abstract: Informational nudges to encourage energy conservation or load shifting have been tried in various contexts. This paper studies a program run by a small municipally owned electric utility to reduce demand on certain peak demand days. An email alert is sent out to residential customers who sign up for the alerts. Some recipients of those alerts forward the alerts on to other customers or community groups, making it difficult to determine how broadly the alerts are disseminated. The alerts encourage load shifting and energy saving during specific hours on the following day.

Using hourly load data for the utility, I estimate the reduction in electricity load caused by the alert emails. Using an instrumental variables approach, initial estimates suggest that load is reduced by roughly 1.5 MWs per hour when an alert is sent out. This works out to a reduction in load on the order of 3 to 4 percent. I calculate the cost savings to the municipal utility and discuss social and private benefits of the program.

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I am grateful for helpful insights and data assistance from Laura Scott at Concord Municipal Light Plant and Scott Bertrand at ISO-NE. All errors are my own.

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ISO-NE, the grid operator for New England charges load consumers an annual capacity charge based on each load's share of system load in the single highest peak demand hour for the system in a year. To reduce its charge, the Concord Municipal Light Plant (CMLP), the municipally owned utility in Concord Massachusetts, takes various actions to encourage customers to reduce their load when it believes ISO-NE load will hit an annual peak. Among other actions, it sends an alert out, typically one-day ahead, encouraging residential customers to reduce load during the hours when the utility predicts system load might peak. Those alerts are sent to anyone who signs up to receive the emails. The total number of email recipients is not known as some recipients forward them to other individuals or groups in the community.

This paper measures whether and how much these informational alerts lower the utility's load during those hours. Using hourly data in the summer months when alerts are sent, I carry out an econometric analysis of hourly load over the years 2009 to 2023.[1] Initial estimates suggest that the alerts may reduce load demand by as much as four percent. That estimate is subject to change as my analysis continues.

In addition to measuring the efficacy of the alert program, I make some estimates of the private and social costs of the program. If the program led to reductions in Concord's load in one peak hour while having no effect on total system load, then the program has no social benefits, but does shift some of the capacity charge from CMLP onto other load consumers. If, however, the alert program leads to aggregate reduced demand in ISO-NE, there would be social benefits in the form of reduced generation and, possibly, reduced greenhouse gas emissions.

A final question asks whether the program leads to a reduction in demand by CMLP customers during the alert hours. Local demand differs from load given the presence of 3 solar arrays in the community totaling 6.4 MW and an additional 4.5 MW of behind-the-meter solar capacity. Local demand equals CMLP load plus local solar production. If solar production in the community is systematically related to the occurrence of peak alerts, then estimates from load regressions will not provide an unbiased estimate of the effect of the alert program on demand. Because CMLP does not have smart meters installed, it does not measure the behind-the-meter solar production. I have data on production from the solar arrays in the community and I may be able to use this information, along with solar capacity information to estimate solar electricity production in Concord.

Background

The Concord Municipal Light Plant (CMLP) is a municipally owned electric utility (one of 41 in Massachusetts) in Concord, MA. Concord is a wealthy, suburban community with a population of over 18,000 and CMLP serves over 8,300 customers in Concord (and a handful of customers in adjacent communities). The utility's total load in 2022 was 175,229 MWh, nearly 45 percent of which was load of residential customers. Another 20 percent of load serves small commercial and industrial customers while 30 percent serves large commercial and industrial customers. Municipal load makes up the balance.

[1] Some of the analysis is restricted to the years 2017-2023 given data limitations on ISO-NE real time load.

Beginning in 2009, CMLP initiated an email alert program to encourage energy saving during hours of projected ISO-NE peak load. Reducing demand during potential system-wide peaks has two benefits. First, it reduces the utility's need to purchase expensive peak power. Second, ISO-NE charges load consumers an annual capacity charge for an entire year based on each load consumer's share of system peak load in that single peak hour. That charge is applied for a year-long capacity commitment period (CCP). For example, the annual capacity commitment period for June 1, 2024 through May 31, 2025 is based on a system peak occurring in calendar year 2023. In that year, the system peak load occurred in the hour between 5:00 and 6:00 pm on Sept. 7, 2023. CMLP's peak during that hour equaled 0.161 percent of the system-wide peak. CMLP's share of the forward capacity charge for the CCP ending May 31, 2025, therefore, is 0.161 percent of the total ISO-NE capacity charge.[2]

Alerts are sent out typically 4 to 6 times a year. Figure 1 illustrates a typical alert sent to members of the CMLP *Concordians Addressing the Peak* (CAP) google group. For my analysis below, I code this particular peak alert as occurring on Sept. 7, 2023 for the hours ending 5 pm, 6 pm, and 7 pm. Figure 2 shows that most peak alerts cover the hours between 3 and 6 pm.

Data

For my analysis, I have CMLP hourly load data for summer months (June through September) for the years 2008 – 2023.[3] I also have all of the peak alert messages sent out by CMLP starting in 2009. In order to estimate hourly solar electricity production in Concord, I have the capacity figures for the three central solar arrays in town as well as monthly behind the meter solar capacity. Finally, I have hourly solar production data for the three central arrays for the years 2015 through 2023. It may be possible to use this production data to estimate capacity factors conditional on weather and apply these factors to the behind-the-meter solar capacity to estimate total solar production. Figure 3 shows load for the hour with peak load in each month for CMLP for 2022. This is typical of other years in the data.

From NOAA, I have hourly weather data for Hanscom Air Field, located in Bedford, MA, just adjacent to Concord. From ISO-NE, I have one- through four-day ahead capacity peak forecasts (and hour of predicted peak) for 2008 through 2023 along with predicted high temperatures and dew points for Boston MA and Hartford, CT (as illustrated in Figure 1). It is these day-ahead forecasts that CMLP relies on for issuing a peak alert. From ISO-NE, I also have real-time hourly load data for the ISO-NE system for the years 2017 through 2023.[4]

Table 1 provides descriptive statistics for the dataset. CMLP load during midday hours (when a peak might occur) varies between 8.7 and 45 MW with a mean of 25.[5] As Figure 3 illustrates, peak loads can be above 30 and approaching 40 MW. Peak alerts are infrequent with less than 2 percent of hours during the midday (between 1 and 8 pm) covered by a peak alert. Concord is a small load in ISO-NE with its load accounting for less than 0.2 percent of total load in the region.

[2] Data on CMLP's CCP share from Laura Scott, CMLP employee in charge of the peak alert program, contained in an email dated June 24, 2024.

[3] CMLP is only now beginning to roll out the installation of smart meters. Thus, I am forced to use aggregate CMLP data for my analysis.

[4] I am in conversation with ISO-NE to see if they can provide system load data prior to 2017.

[5] The interquartile range is 21.1 to 28.2 MW. Low values typically occur in late September and indicates the importance of electricity for cooling in the summer months.

Preliminary Results

To assess the impact of CMLP's peak alert program, I run regressions of the following form:

$$(1) \qquad Load_{hdmy} = \beta \cdot Alert_{hdmy} + \gamma X_{hdmy} + \alpha_h + \alpha_d + \alpha_m + \alpha_y + \varepsilon_{hdmy}$$

where I can control for hour of day (h), day of week (d), month of year (m), and year (y). Potential regressors included in X are temperature and humidity (and other weather variables) and load in the rest of the ISO-NE region. Between the various fixed effects and Concord area weather conditions, I should control for much of the variation in electrical load in Concord. Including load in the rest of the ISO-NE region captures unexplained variation in load demand not captured by my fixed effects and weather variables.

A major concern with running OLS regressions is that peak alerts are endogenous. CMLP issues a peak alert when the expected load in ISO-NE for the next day is predicted to be high. A high demand day in ISO-NE is very likely associated with a high demand day in ISO-NE. We can expect, therefore, a positive correlation between load and the alert.

Results from simple OLS regressions of Equation (1) bear that out as shown in Table 2. If we simply split the data between hours with a peak alert and hours without, the mean hourly load is 11.25 MW higher during hours when an alert is called relative to a non-alert hour. Controlling for weather conditions and fixed effects lowers the mean difference from 11.25 MW to 4.35 MW. Even after controlling for load in the rest of ISO-NE, which should soak up a great deal of unexplained variation in CMLP load demand, there is still a positive and statistically significant correlation between a peak alert hour and CMLP load.

To address this problem, I take an instrumental variables (IV) approach. Valid instruments are correlated with the decision to issue a peak alert for a given hour but uncorrelated with the error term in the CMLP load regression. Discussions with CMLP staff indicate that a key factor in their decision to issue a peak alert is the day-ahead peak forecast issued by ISO-NE each day. As illustrated in Figure 1, ISO-NE provides peak forecasts (as well as Boston and Hartford weather data) going out six days. Day 1 of the forecast refers to the day when the peak alert is sent out, so the relevant one-day ahead forecast is the Day 2 forecast in Figure 1. I will use various combinations of ISO-NE forecasts as instruments. They are clearly correlated with the decision to issue a peak alert, but should not be correlated with actual load (after conditioning on other explanatory variables).

Table 3 provides initial IV results. Column 1 includes the one-day ahead peak forecast as an instrument. The coefficient on the peak alert in the second-stage regression is strongly negative and implausibly large. One problem with simply including the one-day ahead forecast is that it does not vary across hours in a day. Before addressing this issue, I consider whether adding additional day-ahead forecasts appreciably affects results. Including day 1 through day 4 forecasts does not affect results appreciably (column 2). Adding Boston forecasted weather conditions (column 3) brings the coefficient estimate on the Peak Alert down to -3.4 while maintaining strong statistical significance. The last two columns interact the one-day ahead peak load forecast with indicator variables for the hour of the day. It is reasonable to expect that CMLP is more likely to call an alert in an hour of the day when ISO-NE load is high and a peak is expected.[6] In column 4, I interact the peak forecast with the hour of the day but do

[6] As Figure 1 indicates, ISO-NE reports the hour in which a peak is forecast to occur. While I have not done this yet, I can use this information of expected peak hour in combination with the peak forecast to construct instruments.

not include Boston weather forecasts. The coefficient continues to be statistically significant and now equals -1.7. Including Boston weather forecast information lowers the estimated coefficient to -0.27 and it no longer is statistically significant.

While these are preliminary results, I can draw out some implications from them. A first question is whether these estimates are plausible. Consider the coefficient estimate of -1.7. The average July and August peak in 2022 was 38.7 MW. This suggests that the peak in the absence of the alert would have been 40.4 MW and that the alert reduced load by 4.2 percent. The estimate from column (5) in Table 3 suggests the peak alert reduced load by 0.7 percent. With further analysis, I hope to refine these estimates. I also will compare to estimates from comparable programs analyzed in the literature.

A second question to consider is the welfare implications of the program. To the extent that the program reduces CMLP load when an alert is issued, there are social benefits equal to the avoided costs of power generation and reduction in pollution damages from fossil fuel generation. Consider the alert shown in Figure 1 issued for September 7, 2023 from 4 to 7 pm. The locational marginal price (LMP) of electricity for the Northeastern Massachusetts load zone in those three hours was $66.95, $159.55, and $62.75 per MWh, respectively.[7] LMPs are comprised of an energy, congestion, and marginal loss component. Nearly all of the LMP is an energy cost for these hours. During these hours, the marginal generating source is primarily natural gas. I can calculate the social benefit of the peak alert hour for each hour of an alert as the sum of the avoided costs during that hour (as represented by the LMP) and the pollution damages. For the latter, I focus on the greenhouse gas damages using the US social cost of carbon (SCC).[8] On average, electricity produced from natural gas in the United States produces 0.44 metric tons of carbon dioxide emissions per megawatt-hour of electricity.[9] Using the 2021 US social cost of carbon for 2025 of $56 per metric ton, the full social marginal benefit of CMLP's peak alert would range from $87.41 to $184.21 per megawatt-hour of reduction in load for the three hours of the alert on Sept. 7, 2023.

These estimates of the social marginal benefit of the program assume no load shifting to non-peak hours. Even if all of the reduction represents load shifting, there is still a social benefit since the LMPs in non-peak hours are significantly lower than during peak hours. I can check for load shifting by estimating load in non-peak hours during peak alert days relative to non-peak alert days.

Assume for the moment that there is no load shifting and that the estimates above reflect true savings. With an average of 3 to 4 peak hours during a peak alert day, and roughly 5 peak days per year, this suggests annual savings (and social benefits) through reduced load on the order of $2,000 per year. While the benefits of the program are not large, the costs are very low, yielding a high benefit to cost ratio. This is a pattern frequently found in informational programs.

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[7] These are the final real-time LMPs as reported by ISO-NE at https://www.iso-ne.com/isoexpress/web/reports/pricing/-/tree/lmps-rt-hourly-final.

[8] The marginal generator can vary within an hour. ISO-NE data on fuel mix indicate that natural gas is the predominant marginal fuel. For the hour between 4 and 5 pm on Sept. 7, 2023, natural gas is the marginal fuel 92 percent of the time and hydro 8 percent of the time. For the SCC, I can take a weighted average across the fuel types within an hour during a peak alert. For the hour between 4 and 5 pm in this example, the SCC would be the social cost of carbon applied to emissions from natural gas generation times 0.92, assuming zero GHG emissions from the production of hydropower.

[9] Numbers taken from https://www.eia.gov/tools/faqs/faq.php?id=74&t=11.

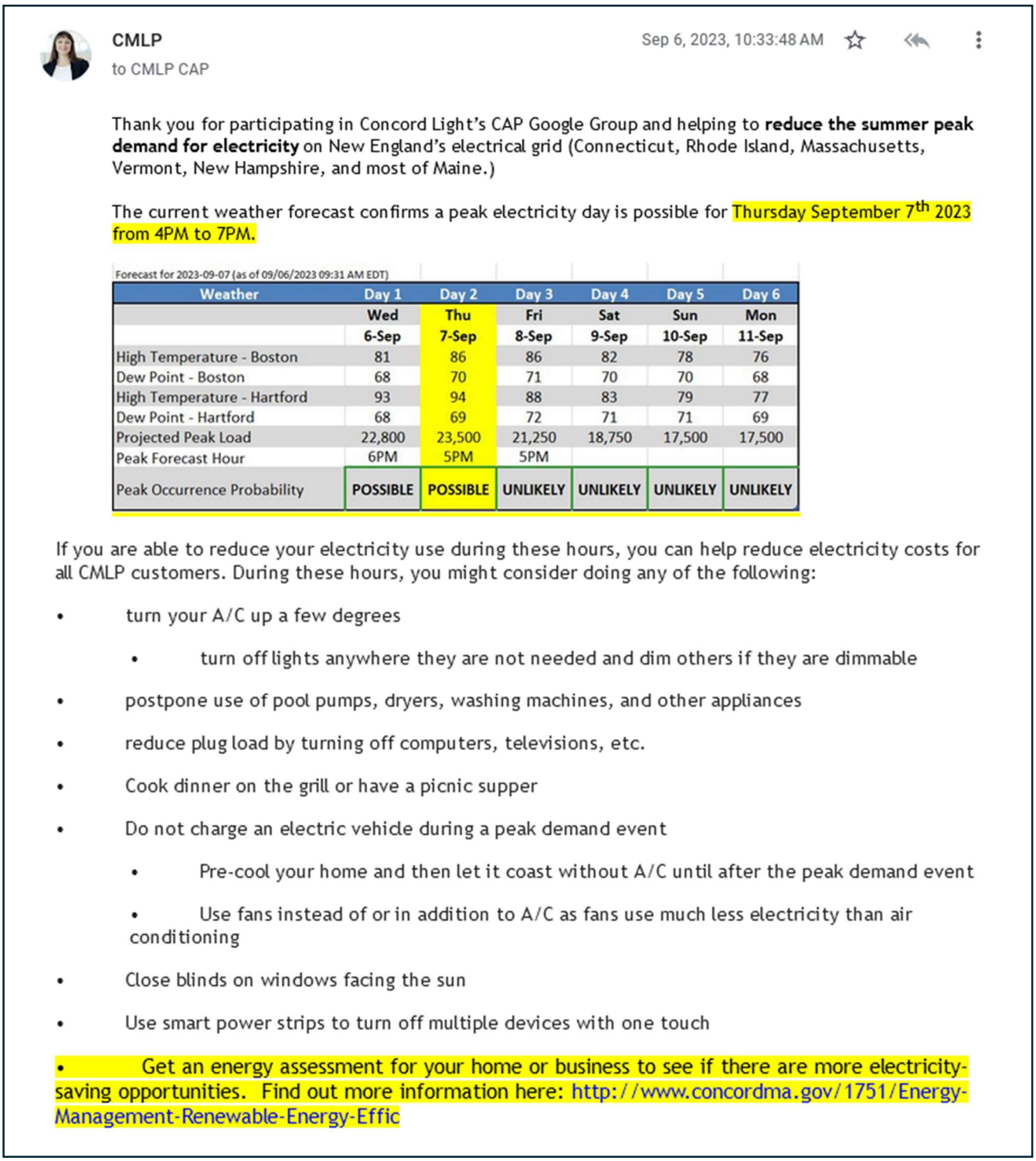
Lastly, I consider the private benefits to CMLP of this program. CMLP's peak alert initiative is unlikely to materially affect the system's overall capacity needs or the total capacity charge assessed on load for ISO-NE participants. If the peak alert program had reduced CMLP's peak as much as 1.67 MW in the ISO-NE peak hour, it would have reduced CMLP's share of the aggregate ISO-NE capacity charge from 0.161 percent to 0.154 percent for the capacity commitment period of 6/1/24 – 5/31/25. That would have translated into over $70,000 in savings to the local utility.[10] This is a private rather than a social benefit assuming CMLP's actions don't affect the system-wide capacity charge. It simply reflects a shifting of costs from CMLP to other system load users.

Conclusion

The Concord municipal peak alert program is an interesting example of an informational nudge program to reduce peak demand. It is but one of a large number of programs that have been carried out across the country. Despite the fact that there is limited information dispersion through the email group and no individual financial incentive to reduce or shift demand, the program appears to reduce load during peak hours when an alert is called. Annual social benefits are modest, but the costs of the program are trivial. Private benefits, however, are significant for this small, municipal utility as any reduction in its capacity share shifts aggregate ISO-NE capacity charges onto other utilities and load customers in the region. This, of course, suggests a unproductive competition where ISO-NE utilities implement similar programs to reduce peak demand during the hour that ISO-NE is predicted to hit its annual peak. A focus on reducing this singular hour of demand is unlikely to reduce overall peak demands and the need to have capacity available for high-demand summer hours. Such a competition would suggest that it would be fruitful for ISO-NE to consider alternative ways to allocate capacity charges across its customers that don't focus on a single peak hour of the year to allocate annual charges.

[10] I need to confirm this number with CMLP.

Figure 1. A Typical Peak Alert Message



CMLP Sep 6, 2023, 10:33:48 AM

to CMLP CAP

Thank you for participating in Concord Light's CAP Google Group and helping to **reduce the summer peak demand for electricity** on New England's electrical grid (Connecticut, Rhode Island, Massachusetts, Vermont, New Hampshire, and most of Maine.)

The current weather forecast confirms a peak electricity day is possible for Thursday September 7th 2023 from 4PM to 7PM.

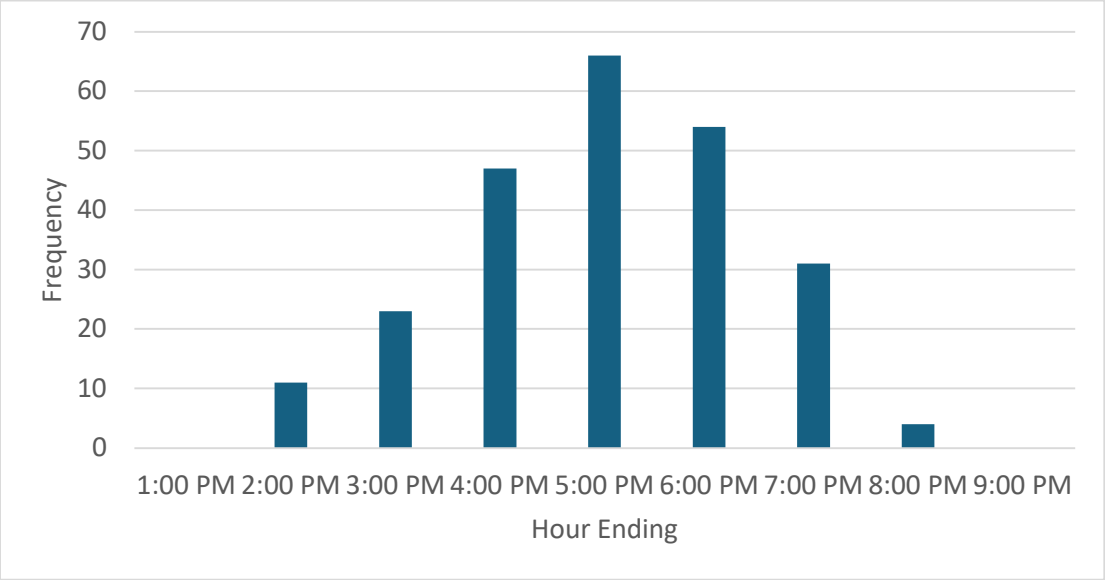
Forecast for 2023-09-07 (as of 09/06/2023 09:31 AM EDT)

Weather	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
	Wed	Thu	Fri	Sat	Sun	Mon
	6-Sep	7-Sep	8-Sep	9-Sep	10-Sep	11-Sep
High Temperature - Boston	81	86	86	82	78	76
Dew Point - Boston	68	70	71	70	70	68
High Temperature - Hartford	93	94	88	83	79	77
Dew Point - Hartford	68	69	72	71	71	69
Projected Peak Load	22,800	23,500	21,250	18,750	17,500	17,500
Peak Forecast Hour	6PM	5PM	5PM			
Peak Occurrence Probability	POSSIBLE	POSSIBLE	UNLIKELY	UNLIKELY	UNLIKELY	UNLIKELY

If you are able to reduce your electricity use during these hours, you can help reduce electricity costs for all CMLP customers. During these hours, you might consider doing any of the following:

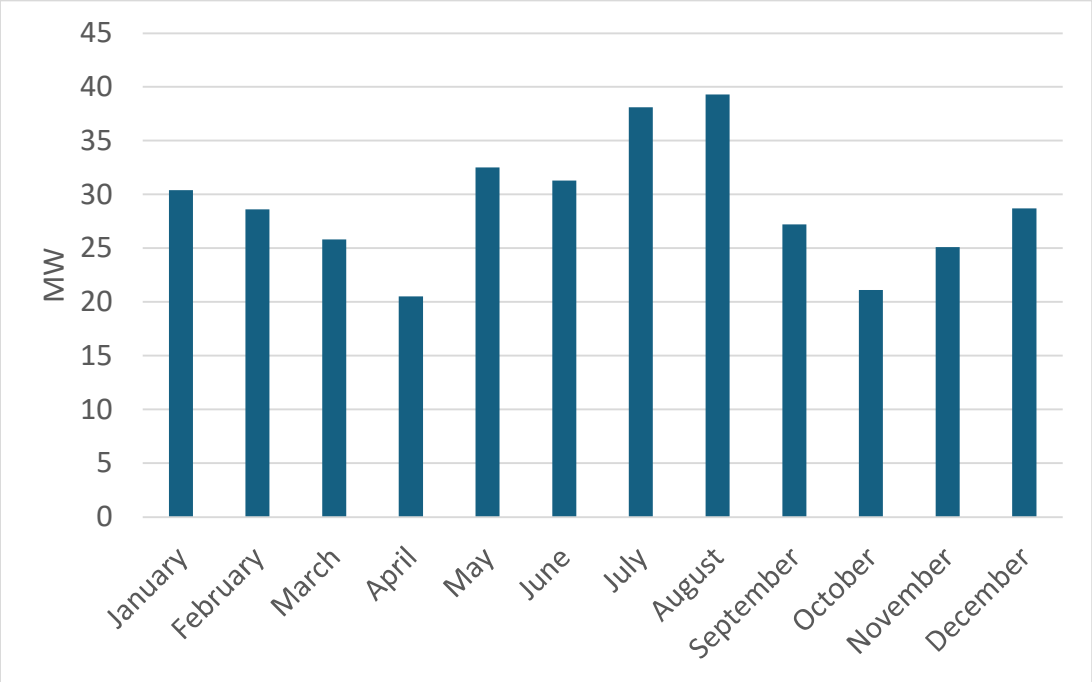
- turn your A/C up a few degrees
- turn off lights anywhere they are not needed and dim others if they are dimmable
- postpone use of pool pumps, dryers, washing machines, and other appliances
- reduce plug load by turning off computers, televisions, etc.
- Cook dinner on the grill or have a picnic supper
- Do not charge an electric vehicle during a peak demand event
- Pre-cool your home and then let it coast without A/C until after the peak demand event
- Use fans instead of or in addition to A/C as fans use much less electricity than air conditioning
- Close blinds on windows facing the sun
- Use smart power strips to turn off multiple devices with one touch
- Get an energy assessment for your home or business to see if there are more electricity-saving opportunities. Find out more information here: http://www.concordma.gov/1751/Energy-Management-Renewable-Energy-Effic

Figure 2. Frequency of Peak Alert Messages by Hour Ending



Source: CMLP Peak Alert Data on peak alerts for years 2009 – 2023
from the CAP Google Group

Figure 3. Peak Load in 2022



Source: CMLP load data.

Table 1. Descriptive Statistics

Variable	N	Mean	Std. Dev.	Min	Max
CMLP Real Time Load (MWh)	13657	25.0	5.5	8.7	45.0
Peak Alert Hour	13657	0.017	0.130	0	1
Dry Bulb Temperature	13632	74.2	9.2	42	101
Relative Humidity	13609	61.3	19.1	19	100
Visibility (miles)	13632	9.5	1.7	0.5	10
Hourly precipitation (inches)	13481	0.01	0.05	0	2.23
Dummy for 3 day heat wave >= 90	13321	0.06	0.24	0	1
ISO Load less CMLP Load (GWh)	9387	17.06	3.11	9.04	27.33

Sample limited June-September and to midday hours when peak alerts may be called

Table 2. OLS Regressions of CMLP Load

	(1)	(2)	(3)	(4)
VARIABLES	RTLoad	RTLoad	RTLoad	RTLoad
Peak	11.25***	6.006***	4.351***	0.817***
	(0.350)	(0.272)	(0.181)	(0.0899)
DryBulbTemp		0.225***	0.335***	0.00270
		(0.00424)	(0.00357)	(0.00245)
DewPointTemp		0.246***	0.185***	0.00756***
		(0.00445)	(0.00327)	(0.00198)
ISO Load				1.758***
				(0.00872)
Observations	13,657	13,609	13,609	9,348
R-squared	0.070	0.468	0.769	0.955
Fixed Effects	No	No	Yes	Yes
ISO Load	No	No	No	Yes

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Controls for hour of day, day of week, month, and year included. ISO Load excludes CMLP load.
Midday hours only in regressions

Table 3. Instrumental Variable Regressions of CMLP Load

VARIABLES	**CMLP Load**				
	(1)	(2)	(3)	(4)	(5)
Peak Alert	-13.42***	-10.88***	-3.416***	-1.667***	-0.270
	(1.755)	(1.561)	(0.818)	(0.398)	(0.432)
Observations	9,348	7,573	7,793	9,348	7,793
R-squared	0.836	0.874	0.942	0.952	0.952
Instruments:					
1 Day Ahead ISO Load Forecast	Yes	No	Yes	No	No
1-4 Day Ahead ISO Load Forecast	No	Yes	No	No	No
Boston Weather Forecast	No	No	Yes	No	No
1 Day Ahead ISO Load Forecast interacted with hour of day fixed effects	No	No	No	Yes	Yes
Boston Weather Forecast interacted with hour of day fixed effects	No	No	No	No	Yes

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Fixed effects and weather variables included in regression
Controls for hour of day, day of week, month, and year included. ISO Load excludes CMLP Load.
Midday hours only in regression