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# The perverse impact of calling for energy conservation

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ABSTRACT

In periods of high energy demand, utilities frequently issue "emergency" appeals for conservation over peak hours to reduce brownout risk. We estimate the impact of such appeals using high-frequency data on actual and forecasted electricity generation, pollutant emission measures, and real-time prices. Our results suggest a perverse impact; while there is no significant reduction in grid stress over superpeak hours, such calls lead to increased off-peak generation, $CO_2$ emissions, and price volatility. We postulate that consumer attempts at load shifting lead to this result.



## 1. Introduction

Policymakers and public utilities frequently rely upon targeted messages as a means to encourage energy conservation amongst residential and commercial customers. While varied in content, such appeals generally reflect one of two primary concerns. "General" appeals for conservation seek to impact long-term consumer behavior and emerge largely from concerns with environmental quality, the desire to delay investments in new generation or transmission capacity, or regulatory pressures to promote energy efficiency.[1] The second type of conservation call focuses on short-run behavioral adjustments during specific hours on a given day. These "emergency" calls are issued by individual utilities or independent system operators (ISOs) during times of heavy energy usage. Such calls aim to promote reductions in energy consumption during periods where the expected demand for power approaches maximum grid capacity. During such periods, even small reductions in energy use would have a significant impact on reliability and the threat of wide-scale brownouts.

While the effects of the first type of call are well documented (see, e.g., Costa and Kahn (2013), Ayres et al. (2013), Dolan and Metcalfe (2011), Reiss and White (2008) or Allcott (2011)), there is surprisingly little work exploring the effect

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[1] Examples of such appeals include a recent advertising campaign by the AD Council and U.S. Department of Energy urging individuals to save money by saving energy (http://www.adcouncil.org/News-Events/Press-Releases/U.S.-Department-of-Energy-and-Ad-Council-Launch-Consumer-Education-Campaign-Save-Money-By-Saving-Energy2) and OPOWER's Home Energy Report letters – normative messages designed to promote household level energy efficiency. Similar appeals have been used to promote water conservation. See, e.g., Ferraro and Price (2013); Ferraro et al. (2011).

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of emergency calls.[2] This study attempts to fill this gap in the literature. We estimate the effect of emergency calls for conservation on hour-by-hour patterns of energy generation in the Washington D.C.–Baltimore metropolitan area from the late spring of 2000 through the end of summer in 2010. As our data include information on pollutant emissions, we are also able to calculate the effect of emergency calls on $CO_2$ emissions in the broader generation footprint serving this area.

Our identification strategy exploits the fact that the ability of public utilities in the D.C.–Baltimore area to reach consumers depends crucially on the decisions of local media to broadcast emergency calls. The two public utilities in our sample, Baltimore Gas and Electric (BGE) and Potomac Electricity Power Company (PEPCO), disseminate conservation calls via a press release shared with local media outlets in advance of an anticipated peak event day. As column space and reporter time are largely fixed in the short-run, not all press releases are rebroadcast by local media outlets.[3] The media thus introduce a degree of randomness in whether consumers observe the utility's call for conservation. Accordingly, we use media coverage as an instrument and compare patterns of use across days where a press release is rebroadcast with those where a release goes unreported. Although we do not observe all media stories, we use the number of media stories we do observe as a proxy for the intensity of overall media coverage.

The critical assumption in our empirical strategy is that the decisions of media outlets to publish calls for energy conservation are independent of expected usage or generation. If media publication decisions are driven by a factor unobserved to us, but relevant for energy use, our results are biased. Controls for two potential confounders – air quality alerts and previous heat-related news stories – do not substantially change our estimates. We also evaluate the validity of the identifying assumption using market measures of day-ahead demand and price. Conditional on the publication of a press release, future media coverage is not discernably correlated with day-ahead load or day-ahead prices.[4]

Empirical results indicate that media coverage of an emergency call is associated with distortions in the temporal profile of generation. We find a statistically significant increase in generation over the late morning and early afternoon hours on media days. Between the hours of 9 a.m. and 3 p.m., our estimates suggest that hourly generation increases between 5.8 and 16.9 megawatts, on average, at each generating boiler in our sample. For perspective, the increased production over these hours represents approximately 2.6–7.7 percent of available capacity at these boilers.[5] Conversely, we find no discernible reduction in generation and grid stress over so-called "superpeak" (evening) hours. In total, we estimate that per boiler production increases by 58.1–76.5 megawatts, or approximately 1 percent of available generating capacity, over the course of a full media day. Valuing the increase in generation using prevailing prices on days with a press release but no media coverage, we calculate the cost of a media event to be in the neighborhood of $1.0 million. The lack of generation reduction at superpeak implies no commensurate benefit from brownout risk reduction.

This documented higher load on media days should intuitively translate into increases in $CO_2$ emissions, but the impact depends on the carbon content of the marginal fuel source (Zivin et al., 2014). We estimate net increases in $CO_2$ emissions on media days of between 35 and 63 tons per boiler. Using current EPA estimates of the social cost of carbon, this translates into a $147,000–$161,000 increase in unpriced externalities per media event. Although our primary results are based on generation data, we show that electricity demand (load) over the course of the day follows the pattern of generation, including on days with highest grid congestion when excess supply cannot be exported nor shortages imported. In the morning hours, load values peak along with generation before tapering off in the afternoon hours. The load estimates indicate significant usage reductions only in the late evening, mirroring the generation results. Additionally, estimated impacts of media coverage on "exports" (the difference in generation and load) from our region are insignificant for 23 of 24 hours.

Data on hourly real-time prices for energy traded on the wholesale market (operated by the Pennsylvania-New Jersey-Maryland interconnection (PJM), a regional transmission operator (RTO)), indicate significant price spikes in the morning hours coincident with generation spikes. We hypothesize that the morning usage peak spurs utilities to ramp up power across the grid, turning on last-resort sources of power such as low-efficiency coal, gas, and oil-based generators.[6] Estimated impacts by fuel source corroborate this view.

Taken jointly, our results provide a cautionary tale – emergency conservation calls appear to have perverse effects. Although we have no data on consumer behavior, we conjecture that consumers may respond to emergency calls by attempting to "store" cooling in advance of possible brownout conditions or otherwise front-load energy consumption into non-peak hours.[7] Similar usage shifts are documented in Lang and Okwelum (2014) in advance of direct load

[2] A notable exception is Ito et al. (2013) who study the impact of social pressure on the success of emergency conservation appeals in an experimental setting.

[3] See Eisensee and Strömberg (2007) for a similar identification strategy.

[4] The determinants of the gap between day-ahead and real-time prices are not well understood. Borenstein et al. (2008) finds that market power played a large role in the real-time (RT) to day-ahead (DA) price gap during the California energy crisis. Mansur (2008) uses a different methodology to suggest that start up and shut down costs of power plants could be more important than market power. He further finds that our study region is a particularly efficient market. Whatever the source, interpreting the gap between day ahead and real time prices should be done with caution. While the changes in the level of the RT-DA gap are consistent with our hypothesis, we do not take a stand on the source of the average RT-DA price gap. We discuss this issue further in Section 2.

[5] The average boiler in our sample has the capacity to produce 220 megawatts of electricity per hour.

[6] Natural gas prices were at current market lows only in the last two years of our sample period.

[7] In the absence of high frequency data on household electricity consumption, which does not exist over this time period, we cannot confirm that the observed generation changes are driven by this specific consumer behavior. Other plausible explanations consistent with this data are difficult to imagine;

control interventions and in Herter et al. (2007) and Herter and Wayland (2010) in advance of critical-peak pricing events. In our case, these shifts bring high-cost generation online early in the day, and these plants continue to fire throughout the day, causing significant shifts in real-time prices and increased pollution levels. We observe no commensurate reduction in grid stress over peak hours, and hypothesize that consumers simply fail to reduce peak-hour demand following the morning spikes. We believe our results speak to the ability of non-price interventions to promote behavioral change in energy usage.[8] Whereas prior work focused on the long-run behavioral impacts of such interventions, ours is the first to focus on demand management and response to day-of emergency conservation requests. Moreover, ours is the first to examine the environmental impacts as measured by $CO_2$ emissions.

The evidence that consumers increase energy consumption after being exposed to conservation calls, yet no reduction in generation is observed over critical superpeak hours, is consistent with an emergent body of work in environmental economics exploring the unintended consequences of various policy actions.[9] Whereas previous work focuses on leakages that arise through the spatial reallocation of actions, our paper highlights that a similar phenomena can arise as agents shift actions temporally.

## 2. Identification strategy

To estimate whether "emergency" appeals for conservation have a measurable impact on consumer behavior, we exploit random variation in consumers' exposure to utility press releases calling for same-day conservation. PEPCO and BGE issue press releases calling for energy conservation whenever their model of day-ahead load suggests peak usage above some critical threshold.[10] As utilities lack the ability to quickly disseminate such calls to their customer base, they must rely upon media coverage to spread the call to the target population. Importantly, however, media outlets do not always pick up the press release and publish the associated conservation calls. This may happen for a number of reasons, and we do not attempt to model editorial decisions. We refer readers to Eisensee and Strömberg (2007) for evidence that higher priority news crowds out media coverage of international natural disasters. If editors (and producers) treat emergency press releases in a similar fashion, then variation in media reporting of emergency calls is a function of other news events likely orthogonal to electricity demand.[11] We return to the exogeneity of media days later in the paper.

We exploit this variation in editorial decision-making to identify the impact of media-issued calls for conservation on subsequent energy generation. We assume that days with utility-issued press releases and no media coverage reflect the counterfactual pattern of generation and measure the impact of media as the difference in production relative to this baseline. To net out other confounding sources of variation across these days, we include a full complement of controls for time-of-day, day-of-week, and month-of-year, in addition to weather and energy market conditions. Our identification strategy thus relies upon the assumption that the decision of a media outlet to publish a utility's call for conservation is orthogonal to expected energy generation after conditioning on other factors that could influence production. We note that we have at our disposal the variables used by PJM to predict day-ahead load, i.e., all variables the systems operator views as determinant of energy usage.[12]

This empirical strategy allows us to abstract from two important confounding factors. First, we need not assume that press releases themselves are random. Indeed, we can employ a predictive model including observed weather and electricity market data to identify press release days with reasonable certainty. Rather, we rely on the assumption that the media's decision to publish a press release is uncorrelated with expected consumer demand, conditional on the press release being issued and a vector of observable control variables. In effect, the press release activity creates a perfect "match": days when the treatment (media coverage) did not happen but had high probability of doing so. We provide evidence in support of this claim below. Second, the empirical strategy allows us to abstract from other demand-control methods utilized by the utilities, including load shaving programs which incentivize participating customers to reduce usage on high-demand days.[13]

they require a specific pattern of load shifting across the hours of the day and that the shifts are unanticipated by the energy trading market. The day-of timing of the conservation calls is consistent with the inability of the market to anticipate such shocks in day-ahead markets. We consider other candidate explanations in a series of robustness checks.

[8] See, e.g., Luyben (1982), Schultz et al. (2007), Goldstein et al. (2008), Costa and Kahn (2013), Allcott (2011), Ayres et al. (2013), Harding and Hsiaw (2012), Jessoe and Rapson (2014), Reiss and White (2008), Lang and Okwelum (2014).

[9] See, e.g., Fowlie (2009), Davis and Kahn (2010), Goulder and Stavins (2011), Goulder et al. (2012).

[10] In issuing a release, PEPCO and BGE rely on day-ahead models of peak load which forecast next-day usage as a function of current and lagged weather, day-ahead weather predictions, and controls for prevailing economic and energy market conditions. The threshold above which utilities publish a press release is context-specific and therefore regression discontinuity approaches cannot be used to assess the impact of these calls for conservation.

[11] Data in Eisensee and Strömberg (2007) include 5212 natural disasters over 34 years and eighteen Olympic Games of several days' duration. They show that media reports of international natural disasters are significantly less frequent during the Olympic Games and use the Games as an instrument for overall coverage. Our data contain 28 press releases with 8 media coverage days, a far smaller sample with which to infer editorial decision making processes. Still, as an example, the Crandall Canyon Mine collapse on August 6, 2007 occurred two days prior to a press release on August 8 which was not picked up by media. Similarly, an August 4, 2005 press release went unreported the day after fourteen marines died in the worst IED attack in Iraq to date. Again, with a sample this small, we do not attempt to fully explain the editorial decision and must rely on other evidence to support exogeneity of media coverage.

[12] We control for some socio-economic variables such as GDP and population using fixed effects.

[13] Utilities in the region employ a number of load shaving programs, to directly control consumers' energy usage during times of high demand, primarily by cycling HVAC systems remotely. These programs are marketed to consumers under a variety of names including "PeakRewards" and "Energy Wise

**Table 1**
Media and press release distribution.
*Source:* See text.

| Date | Wash. Post | Daily Rec. Baltimore | Capital Annapolis | Wash Times | AP | WBAL TV.com | NPR | Baltimore Bus. Jour. | Washington Bus. Jour. | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| 8/8/2001 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 8/10/2001 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 |
| 7/30/2002 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 |
| 8/1/2006 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 3 |
| 8/2/2006 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 |
| 8/3/2006 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 6/9/2008 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| 6/24/2010 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 2 |
| 7/6/2010 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 7/7/2010 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 |
| Total | 5 | 2 | 2 | 1 | 1 | 4 | 1 | 1 | 1 | |

*Note:* Media stories by date and media outlet. On each date there was a press release from a local utility calling for conservation.

We include controls for peak shaving implementation but also note that in order for peak shaving to bias our estimates, it must be correlated with the intensity of media activity and not just with press release distribution itself. In addition, if peak shaving activity *is* positively correlated with media activity, and if peak shaving successfully reduces usage, it will bias our results towards finding a reduction in generation on press release days with media coverage. We find no such reductions in the empirical results.

The critical remaining assumption is that the media's decision to publish a press release is uncorrelated with expected generation, conditional on a battery of weather and energy market controls and fixed effects for time-of-day, day-of-week, and month-of-year. In support of this claim, we provide three pieces of evidence. Later in the paper, we evaluate additional scenarios whereby media coverage may be a proxy for some other factor correlated with energy usage and find little evidence in favor of these scenarios.

First, consider Table 1 which contains the dates and outlets of media conservation calls on press release days. As noted in the table, conditional on at least one outlet reporting a conservation call, there is substantial variation in which outlets report any given release. For example, while the Washington Post covers 5 of the 28 press releases in our data, the Associated Press (AP) only wrote a story following one of these releases. Similarly, while the local NBC broadcast affiliate (WBAL) provided coverage for four of the 28 releases, the local ABC affiliate reported none (and is therefore not listed in Table 1). The variation with which any given outlet picks up a press release is consistent with our assumption that the decision of any outlet to publish a release is orthogonal to expected energy generation patterns. If not, one would expect to observe systematic patterns of coverage both within and across outlets.

Second, for selection to bias our results it must be the case that, conditional on the set of controls listed above, media coverage of a release is correlated with expected consumer use. This would be the case if media outlets reported a utility's call to consumers only on those days where the counterfactual subsequent pattern of energy consumption is systematically different from that expected on days where releases are not picked up.[14] But we find such an argument unlikely given the data in Fig. 1 which presents the hour-by-hour difference in real-time (RT) and day-ahead (DA) prices across days where press releases are and are not picked up by a media outlet.[15] The figure plots these differences (averaged across PEPCO and BGE zones) on press release days, bifurcated by days with and without media coverage. As indicated in the figure, the absolute values of the plotted differences are systematically greater on days with media coverage than on those without coverage, particularly after 8 a.m. Between that hour and the end of the day, price gaps are substantially larger on media days with the hour ending at 12 noon as the sole exception. These price gaps on media days closely mirror generation and real-time price distortions we identify later in the paper.

Borenstein et al. (2008) find that market power played a large role in the RT-DA price gap during the California energy crisis, a result which leads us to interpret the price gaps in Fig. 1 with caution. Although the exercise of market power has been estimated to be far lower than that in Borenstein et al. (2008) in general and in the region covered by our paper in particular (Mansur, 2008), the possible existence of market power implies that day-ahead prices do not necessarily reflect aggregate expectations over future prices.[16] In addition to potential market power, the RT-DA price gap could be a function of start up and shut down costs of power plants. Whatever the source, and provided market power is not imparted differently and

Rewards" and provide consumers with monthly bill credits in exchange for providing the utilities with the option of reducing their electricity consumption a limited number of times during the summer. The utilities shared with us the dates these programs were implemented, and we included two types of controls for these events. Emergency peak shaving events occur when the utility requires all participants to have their HVAC cycle off. Economic events occur when the utilities give consumers the possibility of opting out of the cycling event.

[14] For example, utilities may lobby for press coverage on some days but not others and, if so, our identifying assumption would be violated.

[15] Hour labels in all figures and tables are hour-ending so that hour 8, for example, is the hour between 7:01 a.m. and 8:00 a.m.

[16] Mansur (2008) uses a different methodology which explicitly accounts for cost convexities and startup/shutdown costs. This methodology generates estimated market inefficiencies far below those in Borenstein et al. (2008). Mansur also finds BGE to be one of the least inefficient utilities in the PJM region.

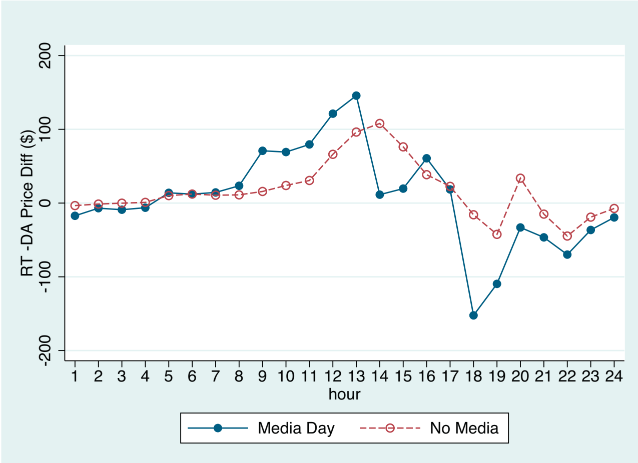


**Fig. 1.** RT-DA price differences. *Note:* Differences in the (unconditional) real-time and day-ahead prices on press release days for which the media does ("Media Day") and does not ("No Media") publish the utility's press release.

startup/shutdown costs not dissimilar on days preceding media events relative to days where press releases go unreported, the changes in the level of the RT-DA gap are consistent with our identification assumptions and subsequent estimated outcomes.

The mechanism by which market power would be exercised differently in the day-ahead market on media versus non-media days is difficult to imagine. Day-ahead markets clear well in advance of press release issuance and media decisions, rendering implausible any sort of back-channel effect whereby energy traders are tipped off to future media events. On the other hand, there may be some unobserved factor that dictates the behavior of monopsonistic market participants, media coverage of utility press releases, *and* subsequent energy usage. Although we cannot definitely rule out the existence of such an unobserved factor, all empirical specifications contain a rich set of controls and are robust to the inclusion of both air quality measures and the overall public discussion of heat and humidity as proxied by media stories on the same. They are also robust to day-ahead grid constraint expectations.[17] The RT-DA price gap may provide support for our identification assumption, but because the price gap may not be dictated purely through efficient market outcomes, we provide a variety of other evidence to justify our empirical approach.

The significance of the RT-DA price differences documented in Fig. 1 are evaluated in the first column of Table 2, which estimates the effect of media coverage on the difference between day-ahead and real-time prices, controlling for day-of-week, month-of-year, hour, weather and energy market variables.[18] The results indicate positive and significant differences early in the day, again in hours 10 through 13, and negative and significant differences in hours 16, 17, 19 and 20.

Third, as additional evidence that media and non-media press release days have similar *ex ante* usage expectations, we institute a "placebo test" on day-ahead load projections at the PJM market level.[19] If media coverage is a result of expectations about energy usage on high-demand days, those expectations would appear in day-ahead load projections. We estimate the "impact" of media coverage on these day-ahead load projections and find significant negative effects on *ex ante* expectations for hours 8 and 9 along with higher expected usage in hour 22 (Table 2, Column 2). Because these effects are (a) not systematic and (b) the opposite sign of what we find for media days in day-of generation regressions to follow, we conclude that the day-ahead market fails to predict the load differences on media and non-media press release days documented below.

Finally, we note that if selection in media coverage is the driving force behind our results, this implies either (a) the editors of the Washington Post have additional information that allows them to predict day-ahead use above and beyond that available to traders on the wholesale electricity market or (b) that these editors act on other information that is correlated with the usage patterns we document but not incorporated into day-ahead markets.[20] We view the first option as extremely unlikely given the sophistication of the day-ahead energy trading market. And although we cannot completely rule out the possibility that editors are acting on information correlated with subsequent usage, our results are robust to controlling for air quality and air quality alerts and to controlling for other heat-related media stories – two quantities which might influence editorial decisions.

[17] Results available upon request. We also note that the changing pattern of electricity consumption driven by media calls for conservation could affect existing market power or start-up/shut-down inefficiencies in the energy market causing changes in the RT-DA price gap.
[18] See Section 4.1 for a detailed list of control variables and estimating equation.
[19] Unfortunately, day-ahead load forecasts are not available at the utility level.
[20] This assumes prices in the BGE market are not driven by monopsonistic behavior.

**Table 2**
Estimates of $\gamma_m$ in Eq. (1) for RT-DA price differences and day-ahead load.
*Source:* Authors' calculations from data described in text.

| Hour | RT-DA price | DA load |
|---|---|---|
| 1 | 22.7* | 5900.5* |
| 2 | 15.8 | 5297.3* |
| 3 | 17.1 | 4927.0* |
| 4 | 23.7** | 2399.8 |
| 5 | 12.9 | 1688.2 |
| 6 | 4.6 | 683.4 |
| 7 | 8.8 | 678.5 |
| 8 | 12.7 | −2634.2** |
| 9 | 14.4 | −2118.2* |
| 10 | 24.3* | −1072.5 |
| 11 | 39.2*** | −1292.9 |
| 12 | 25.1* | −784.0 |
| 13 | 24.2* | 666.3 |
| 14 | −3.8 | −1894.2 |
| 15 | −9.1 | 359.6 |
| 16 | −38.4* | −230.3 |
| 17 | −43.5** | 420.7 |
| 18 | −25.0 | 1839.0 |
| 19 | −38.9* | 1699.4 |
| 20 | −28.5** | 3846.4 |
| 21 | −14.2 | 4005.5 |
| 22 | 11.9 | 4536.3* |
| 23 | −14.3 | 2889.0 |
| 24 | −22.9 | 1287.9 |

*Note:* Estimates for $\gamma_m$ in Eq. (1) with $REALTIMEPRICE_{ith} - DAYAHEADPRICE_{ith}$ (Column 1) and day-ahead load (Column 2) as the dependent variables. Hour labels are hour-ending so that hour 1 reflects 12:01 a.m.–1:00 a.m. * Indicates coefficient significance at the 10% level, ** at the 5% level and *** at the 1% level.

## 3. Data

To estimate the impact of appeals for conservation during periods of high electricity demand on grid reliability, we compile data from a variety of sources. We focus on the Washington DC–Baltimore area media market and obtain the dates of press releases encouraging energy conservation by searching the press release archives for the two utilities that service this area: BGE and PEPCO. Both utilities purchase electricity on the PJM wholesale market. We limit our search to announcements made between May 2000 and August 2010. From these archives, we are able to identify 28 days for which at least one of the utilities issued a press release calling for conservation.[21]

We next combine this data with information drawn from media search engines – Factiva, Lexis-Nexis, and Proquest – to identify stories in media outlets (print, web, radio, TV) in the DC – Baltimore area mentioning keywords related to electricity conservation and the local utilities.[22] The results of these searches were next filtered by hand to gather only those containing direct calls for conservation. Using this procedure, we identify 10 days on which such stories appear.[23] We do not view Table 1 as an exhaustive list of press release coverage. It is quite likely that outlets make reference to conservation requests in ways that our internet search results cannot capture, e.g., as part of weather reports that are not part of online indices. If so, this introduces noise in our treatment variable and attenuation bias in our estimates.

The Environmental Protection Agency maintains hourly data of the power generation and pollution emissions of every fossil fuel burning generator capable of producing at least 25 megawatts (MW) of power. From the EPA data, we obtain information on the hourly production and emissions for 65 boilers at 16 different power plants located throughout the state of Maryland. We augment the hourly production data to include a rich set of plant level characteristics including primary fuel source and a measure of productivity (generation as a fraction of nameplate capacity). We include all power plants in

[21] Press releases in the archives are dated for the day that conservation is requested. Conversations with media relations at PEPCO and BGE suggest that there are no informal back-channels through which press releases are circulated to media members in advance of the official announcement by the utility itself.

[22] The keywords used in this search included PJM, PEPCO, BGE, energy, demand, peak, power, reduce, cut back, save, use, utilize, electricity, and root words conserve-, prudent-, and wise-.

[23] There are 21 days with media stories calling for conservation, but 11 of those are days when there is no press release calling for conservation. Those days have been excluded from this analysis. The pattern of usage on those days is similar, but magnitudes are substantially reduced. This may reflect either consumers' ability to discern days where official press releases have been issued or, more likely, the fact that these "rogue" media stories do not reflect widespread media coverage across multiple outlets.

**Table 3**
Summary statistics.
*Source:* See text.

| | Full sample | $PR = 1$ | $MEDIA = 1$ |
|---|---|---|---|
| Press release days | 0.024 | | |
| Media days | 0.017 | 0.35 | |
| Multiple media days | 0.012 | 0.25 | |
| DA price BGE | 53.59 | 115.44 | 151.16 |
| | (41.03) | (110.38) | (124.23) |
| DA price PEPCO | 54.32 | 119.03 | 157.78 |
| | (42.21) | (115.62) | (135.19) |
| Max DA load %max | 0.74 | 0.97 | 0.98 |
| | (0.13) | (0.03) | (0.02) |
| Temp | 73.08 | 85.20 | 87.12 |
| | (10.34) | (7.74) | (7.76) |
| Dewpt. | 60.53 | 70.01 | 69.52 |
| | (9.65) | (3.33) | (3.46) |
| High temp | 82.80 | 95.94 | 98.02 |
| | (8.44) | (3.83) | (3.91) |
| High temp ($t-1$) | 82.14 | 94.01 | 96.84 |
| | (8.78) | (3.75) | (3.26) |
| High temp ($t-2$) | 82.01 | 91.27 | 95.03 |
| | (8.84) | (4.55) | (2.28) |
| *N* | 1,534,655 | 33,320 | 11,678 |

*Note:* The level of observation is a power generating boiler by hour. Sample means and standard deviations (in parentheses) are reported for 65 electricity generating boilers at 16 power plants in Maryland. The full sample consists of 1230 days between May and August of 2000–2010. There are 28 press release days and 10 media days in the sample. 7 of the 10 media days consisted of multiple media events ($MULTIM_t = 1$).

Maryland for which the EPA reports data to increase the probability of capturing the marginal generators which may be located outside the immediate DC-Baltimore geographic region.[24]

Before proceeding we should note that the boilers in our sample account for nearly 82.7 percent of the generating capacity in the state of Maryland.[25] Moreover, we do observe expansions at existing plants that lead to changes over time in the fraction of the state's total generation that is included in our final data set. Importantly, however, the omitted power plants all rely upon fuel sources that tend to have very low marginal costs and thus serve base load. As such, we would not expect production at the omitted plants to respond to short-term fluctuations in the electricity market.

We next augment the plant level data with information on weather and the wholesale electricity market in which BGE and PEPCO participate. The end goal of conservation calls is to reduce stress, and our focus on generation data allows us to both assess their effectiveness in doing so and to measure environmental impacts. At the same time, these calls rely on changes in consumer behavior to achieve their goal, and we incorporate demand-side usage data to evaluate their effectiveness on that dimension. Hourly load data are available from the PJM website and are measured at the zonal level for BGE and PEPCO. In addition to hourly load, the PJM site provides (i) hourly prices for both the day-ahead and real-time electricity markets and (ii) hourly day-ahead (predicted) and real-time load data for the entire PJM footprint.[26] Weather data are constructed using the National Oceanic and Atmospheric Administration's (NOAA) online data repository for a weather station at Baltimore-Washington International Airport. The intervals at which the monitors at BWI record weather conditions vary over time. We convert this data to an hourly time series by averaging over all observations within a given hour.

The merged data are a panel of approximately 1.6 million hour-boiler pairs for the years 2000 through 2010. As press releases and media calls only occur between the months of May and August, we restrict attention to these months for purposes of the empirical analysis. Missing data for some boiler-hours bring the estimation sample to 1.4 million hour-boiler pairs. Table 3 summarizes energy market and weather conditions across all summer days, days with a press release and no media coverage, and days where a press release is accompanied by media coverage.

As expected, press releases and media coverage are more likely to occur on hot, humid days when both load and price are higher. Press releases are also more likely to be picked up on days where lagged temperature is relatively high suggesting that newspapers may be responding to sustained heat waves as opposed to single day spikes in electricity demand. We therefore test the robustness of our results to controlling for days of consecutive press releases and for preceding media

[24] Because zone boundaries do not appear to be publicly available, we rely on the political region and err on the side of being overly-inclusive. The inclusion of generators that do not respond to changes in DC–Baltimore energy demand will also serve to bias our estimates towards finding no result.

[25] We do not observe hourly generation at eleven small facilities that fall below the 25 MW cutoff. However, these plants account for less than 0.5 percent of the state's overall generation. We also eliminate from our dataset any power plant that it is not active during the summer months (May–September) of our sample period. This eliminates a number of steam plants that burn fossil fuel to provide energy for heating needs. Potentially more problematic, we do not observe hourly production for a hydroelectric power plant and a nuclear generator with combined capacity of 2150 MW – or 16 percent of the state's overall capacity. Fortunately, these facilities likely serve base load and are not marginal electricity generators.

[26] Unfortunately, day-ahead load measures are not available at the level of the individual utility – PEPCO or BGE.

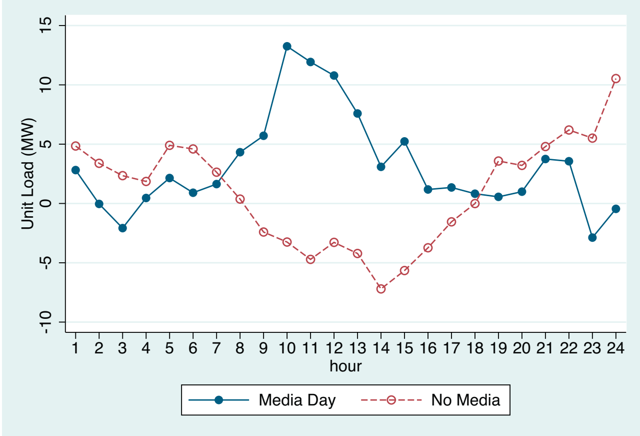


**Fig. 2.** Generation residuals. *Note:* Average hourly residuals from a regression including boiler, day of week, hour, and month-by-year fixed effects, weather, and energy market conditions across all days in the sample. The "Media Day"/"No Media" lines represent average residuals for days where the press release was/was not associated with one or more media stories calling for conservation. The residuals can be interpreted as the idiosyncratic error in hourly boiler-level generation after controlling for weather, energy market conditions, and fixed effects.

stories related to heat. However, there is no difference in load levels (defined as percentage of yearly max) in the day ahead market on days when press releases are picked up by the media and those when they are not. Moreover, while price levels in the day-ahead market are higher on days with media coverage, the resulting difference is not statistically significant at any meaningful level.

## 4. Empirical results

We employ a difference-in-difference estimator to measure the impact of media coverage on energy production and $CO_2$ emissions. We define an indicator variable for a utility's conservation call through a press release on day $t$, $PR_t$, and another for media coverage of such an event, $MEDIA_t$. The estimating equation for outcome $Y$ at boiler $i$ at hour $h$ on day $t$ ($Y_{ith}$) is:

$$Y_{ith} = \alpha_h \vec{hour} + \gamma_p PR_t * \vec{hour} + \gamma_m PR_t * MEDIA_t * \vec{hour} + \beta X_{th} + \eta_i + \lambda + \delta + \epsilon_{it}. \tag{1}$$

The $\vec{hour}$ vector contains an indicator for each of twenty-four hours and the vector $X_{th}$ contains weather data and data from the wholesale electricity market for hour $h$ on day $t$ as listed in the bottom two panels of Table 3. Importantly, the set of controls for weather and wholesale energy market conditions used in the analysis are based on the process used by PJM to predict maximum load.[27] The specification also includes boiler fixed effects ($\eta_i$) along with day-of-week ($\lambda$) and month-by-year ($\delta$) fixed effects designed to capture underlying macroeconomic conditions that may influence aggregate energy consumption. We also include indicators for demand-control (cycling) hours. Standard errors are clustered at the boiler level.

The set of fixed effects included in our specification ensures that identification of the impact of a press release (the vector $\gamma_p$) comes from differences in outcomes at a given boiler on a particular day across the different weeks of the month. For example, PEPCO published a press release calling for conservation on Monday, July 29, 2002. The generation impact of that press release is estimated by comparing hour-by-hour generation at each boiler in the state on that Monday compared to the other four Mondays that month – controlling for weather and day-ahead conditions on the wholesale electricity market. The vector of interest $\gamma_m$ measures the impact of media messaging on conservation and is identified as the hour-by-hour difference in the impact of a press release on days with and without media coverage.

### 4.1. Media coverage and electricity generation

We begin by examining the impact of conservation calls on electricity generation ($Gen_{ith}$). As a first look, consider Fig. 2 which presents the hour-by-hour residuals that arise from estimating Eq. (1) *excluding* the various media and press release indicators.[28] Within the figure, we bifurcate the resulting residuals on press release days by the value of $MEDIA_t$. The figure

[27] PJM's forecasting approach is described in their *Load Forecasting and Analysis Manual*. Following the PJM approach, we include controls for weather (temperature, dew point, high temperature and tomorrow's temperature) and wholesale energy market conditions (hour-specific day ahead load, maximum day ahead load, next day's day ahead load and today's day ahead load as a percentage of the pervious year's day ahead load). Moreover, we interact temperature with dew point, temperature with time of day, and time of day with tomorrow's day ahead load. PJM also incorporates atmospheric pressure, relative humidity and wind speed in their models. Our results are robust to the inclusion of those variables (see the Online Appendix), but they are missing for a significant percentage of the observations in our sample and are excluded from the baseline.

[28] The estimating equation is $Gen_{ith} = \alpha_h \vec{hour} + \beta X_{th} + \eta_i + \lambda + \delta + \epsilon_{ith}$.

**Table 4**
Estimates of $\gamma_m$ for generation, $CO_2$ emissions, and prices in Eq. (1).
*Source:* Authors' calculations from data described in text.

| Hour | (1) $Gen_{ith}$ | (2) $CO2_{ith}$ | (3) $P_{thBGE}$ | (4) $P_{thPEP}$ |
|---|---|---|---|---|
| 1 | −1.9 | −3.9 | −5.9 | −2.7 |
| 2 | −3.3 | −4.7 | −4.4 | 0.2 |
| 3 | −4.3 | −4.6 | −11.8 | −8.5 |
| 4 | −1.2 | −2.0 | −11.9** | −10 |
| 5 | −2.6 | −3.4 | 0.4 | 2.9 |
| 6 | −3.5 | −3.9 | −2.2 | 2.0 |
| 7 | −0.8 | −1.8 | 6.4 | 10.6 |
| 8 | 4.2 | 2.3 | 16.6** | 11.0 |
| 9 | 8.4*** | 5.8** | 65.9*** | 60.4*** |
| 10 | 16.8*** | 11.3*** | 64.4*** | 54.3*** |
| 11 | 16.9*** | 9.8*** | 80.6* | 74.2 |
| 12 | 14.3*** | 9.7*** | 74.9 | 62.5 |
| 13 | 12.0*** | 8.9*** | 97.4 | 69.3 |
| 14 | 10.5*** | 8.3** | −14.6 | −19.7 |
| 15 | 11.1** | 10.0*** | 104.1 | 100.9 |
| 16 | 5.1 | 6.0* | 114.8 | 99.1 |
| 17 | 3.0 | 4.9 | 95.5 | 87.8 |
| 18 | 1.0 | 3.1 | −56.4 | −62.0** |
| 19 | −2.9 | −0.8 | −12.1 | −12.4 |
| 20 | −2.1 | −0.5 | −23.7 | −8.3 |
| 21 | −0.9 | −0.3 | 3.5 | 12.3 |
| 22 | −2.5 | −2.3 | 1.7 | 8.1 |
| 23 | −8.3* | −7.3* | −11.3* | −4.1 |
| 24 | −10.9** | −9.3** | −7.9 | −4.1 |
| Total | 58.1 | 35.3 | – | – |
| Peak (8–23) | 86.6 | 68.9 | – | – |
| Super-peak (15–22) | 11.8 | 20.1 | – | – |
| *N* | 1,534,655 | 1,534,655 | 30,631 | 30,631 |
| Zonal or boiler level? | Boiler | Boiler | Zonal | Zonal |

*Note:* Estimates for $\gamma_m$ in Eq. (1) with $Gen_{ith}$, $CO2_{ith}$ or $P_{th}$ as dependent variables. Generation and $CO_2$ regressions are estimated on a boiler-hour panel. Price regressions are estimated as a time series using zonal real time price for BGE or PEPCO as the dependent variable. Hour labels are hour-ending so that hour 1 reflects 12:01 a.m.–1:00 a.m. * indicates coefficient significance at the 10% level, ** at the 5% level and *** at the 1% level.

thus depicts the underlying differences in the unexplained variation in hour-by-hour energy production across media and non-media days, conditional on a press release having been issued.

Fig. 2 shows a remarkable difference in the pattern of energy use over the course of the day across media and non-media days. Although there is a similar pattern of usage over the early hours of the day, usage patterns differ substantially after 7 a.m. – a time when many consumers likely observe the media story for the first time. On days where press releases go unreported, usage falls off over the late morning hours before beginning an upward climb at around 5 p.m. Conversely, media coverage of a press release is associated with no tapering of usage in the late morning. Instead, media days present a usage pattern with higher usage at every hour between 8 a.m. and 6 p.m. and somewhat lower usage after 6 p.m. until 11 p.m. when larger deficits are apparent.

To evaluate the statistical significance of these differences, we estimate Eq. (1) using the full sample of summer boiler-hour pairs. The parameters of interest are contained in the vector $\gamma_m$ which provides the hour-by-hour impact of media coverage on resulting energy generation. Column 1 of Table 4 contains estimates of $\gamma_m$ along with the estimated impact aggregated over (i) the entire day, (ii) peak hours only, and (iii) superpeak hours only.[29]

Estimates indicate no significant impact of media coverage on generation over the early morning hours (hour ending between 1 a.m. and 8 a.m.). Although point estimates suggest that generation for each of these hours on media days is lower than that observed on days with unreported press releases, none of these differences are significant at meaningful levels. Such a null result is expected given that most consumers are unlikely to have been exposed to media messages during the overnight hours.

Starting with the hour ending at 9 a.m. and running through 3 p.m., our point estimates suggest that hourly production increases by 8.4–16.9 MW over that observed on days where press releases are not picked up by the media. With the exception of the 3 p.m. hour, each of these differences is statistically significant at the $p < 0.01$ level. The estimated impact

[29] Peak hours are formally defined by PJM as hours 8–23 for trading in the wholesale market. Superpeak is not defined formally, but is often cited as hours 15–22. Adjusting the range of superpeak hours to other reasonable definitions – e.g., the 15–19 hour range frequently mentioned in PJM press releases – has no substantive impact on our conclusions.

on production over these hours is equivalent to approximately 3.8–7.7 percent of the available generating capacity for the boilers in our sample.

The observed increase in morning load would be consistent with the utility's goals for brownout risk reduction if accompanied by subsequent reductions in generation during the superpeak hours. Yet, we observe no such impact over these hours on media days. Between the hours ending at 4 p.m. and 10 p.m., there is no discernible difference in hourly production across media and non-media event days. Only during the 11 p.m. and 12 p.m. hours does generation fall at a statistically significant level.

Aggregated over all superpeak hours, our results suggest a net increase in generation of 11.8 MW per boiler. If we extend this horizon to consider the impact of media calls on peak generation, our estimates suggest that production rises by nearly 86.6 MW per boiler. These data are thus at odds with a pattern of successful load shifting. Higher generation over the morning hours does not seem to "buy" significant changes in generation during the crucial high demand hours. In fact, we observe no significant reductions in use on media days until the very end of the day during the hours ending at 11 p.m. and midnight. Aggregated over twenty-four hours, our estimates suggest a 58.1 MW increase in production per boiler on media days.

Although we do not observe consumer-level data, we hypothesize that consumers respond to calls for conservation by shifting usage earlier in the day but then fail to compensate for this shift with reductions over peak hours. Consumers may attempt to store cooling or otherwise shift elective activities to off-peak morning hours, similar to behavior documented by Lang and Okwelum (2014) in the case of explicit demand management. In the afternoon, when the electric grid is most at-risk for brownout conditions, consumers take some actions to increase thermostats or otherwise limit use (as indicated by negative point estimates in Table 4), but their actions are too weak to significantly impact overall grid stress.

Estimates bifurcated by single-day and consecutive conservation calls (located in Table 8) indicate that consumers are more successful at reducing load over peak hours for stand-alone conservation calls or calls that come on the first day in a series, but that some "burnout" may obtain after consecutive calls.[30] On these stand-alone days, evening reductions in generation are apparent, although not statistically significant. Calls coming on consecutive days, on the other hand, are characterized by even stronger increases in morning and mid-day generation and positive point estimates for generation over super-peak hours. See Section 6 for further discussion of these results. We also observe stronger responses in the morning hours on days with higher temperature and humidity. (Results not shown, available upon request.)

Alternative explanations for the results highlighted in Table 4 would require factors that are correlated with both media publication of a conservation call and energy generation. We examine two possibilities in Section 6. First, we control explicitly for the presence of air quality alerts in addition to underlying air quality index measures to ensure that the results are not simply masking a correlation between media reports of conservation calls and air quality alerts which might have encouraged more home energy usage as people stay indoors on days with such alerts. Second, we control explicitly for media stories related to excessive heat in the days prior to the observed press release days. In doing so, we ensure that the results are not driven by correlation between previous media stories on excessive heat and current reports of conservation calls. In neither case do the additional controls affect the coefficients presented in Column 1 of Table 4. We also include a variety of lagged weather variables in our baseline specification in robustness checks in Section 6 and observe no remarkable change in the estimates.

### *4.2. Media coverage and changes in carbon emissions*

Intuitively, the additional electricity generation observed on days when press releases are picked up by the media may have environmental impacts. To ensure compliance with the Acid Rain Program, the US EPA requires all boilers with capacity in excess of 25 MW that use fuels with a sulfur content above a critical threshold to install monitors that continuously measure $SO_2$, $NO_x$, and $CO_2$ emissions. The EPA maintains detailed data on pollution emissions at the hourly level for all such boilers, and we use this data to identify the environmental impacts of media calls as reflected in changing emission levels.

Under the 1990 Clean Air Act Amendments, $SO_2$ and $NO_x$ emissions are subject to cap-and-trade regulation. As such, there are no economic costs associated with changes in emissions of these pollutants at any given boiler.[31] $CO_2$ emissions, in contrast, are currently unregulated in our study region. Increased (decreased) emissions at any given source come at a real economic cost – changes in an unpriced externality. We therefore focus our analysis on the impact of media calls on subsequent carbon dioxide emissions. To do so, we replace $Gen_{ith}$ with a boiler level measure of carbon dioxide emissions per hour (in tons) as the dependent variable in Eq. (1) – $CO_{2_{ith}}$.

Column 2 of Table 4 details the impact of media calls on hour-by-hour $CO_2$ emissions, and the estimates mirror those for electricity generation. Although emissions in the overnight and early morning hours (midnight through 7 a.m.) are lower on media days, the observed differences are not statistically significant. Starting with the hour ending at 9 a.m. and running through the 3 p.m. hour, carbon emissions are estimated to be 5.8–11.3 tons per hour greater on media days – differences that are statistically significant at the $p < 0.05$ level. Between the hours ending at 5 p.m. and 10 p.m., there is little discernible difference in hourly carbon emissions across media and non-media event days, echoing the generation results in the first column.

[30] We thank an anonymous referee for suggesting this analysis.
[31] We examine the impact of media conservation calls on $SO_2$ and $NO_x$ in the Online Appendix.

**Table 5**
Estimates of $\gamma_m$ for generation by fuel source.
*Source:* See main text.

| Hour | Baseline (1) | Coal (2) | Gas (3) | Oil (4) |
|---|---|---|---|---|
| 1 | −1.9 | −20.4* | 5.3 | 4.1 |
| 2 | −3.3 | −20.9* | 5.6 | 1.1 |
| 3 | −4.3 | −12.8 | 2.2 | −4.5 |
| 4 | −1.2 | −5.3 | 3.8 | −3.0 |
| 5 | −2.6 | −13.7 | 4.7 | −1.7 |
| 6 | −3.5 | −18.1 | 6.3 | −2.1 |
| 7 | −0.8 | −15.1 | 6.7 | 1.9 |
| 8 | 4.2 | −2.6 | 10.2** | 4.2 |
| 9 | 8.4*** | −3.0 | 16.6*** | 10.2*** |
| 10 | 16.8*** | 1.6 | 24.8*** | 22.4** |
| 11 | 16.9*** | −0.9 | 26.8*** | 23.4*** |
| 12 | 14.3*** | 7.5 | 22.2*** | 14.0** |
| 13 | 12.0*** | 5.8 | 18.4*** | 13.0** |
| 14 | 10.5*** | −0.5 | 15.7*** | 16.4*** |
| 15 | 11.1** | 1.6 | 14.4*** | 17.9** |
| 16 | 5.1 | 1.8 | 7.5 | 9.1 |
| 17 | 3.0 | −4.8 | 7.0 | 9.6 |
| 18 | 1.0 | −3.0 | 6.1 | 3.4 |
| 19 | −2.9 | −12.4 | 4.9 | 0.02 |
| 20 | −2.1 | −21.1* | 9.4** | 4.5 |
| 21 | −0.9 | −19.4 | 12.0** | 4.4 |
| 22 | −2.5 | −21.2 | 10.9** | 2.1 |
| 23 | −8.3* | −25.8* | 6.0* | −5.9 |
| 24 | −10.9** | −30.3** | 6.0*** | −9.6* |
| *N* | 1,534,655 | 459,465 | 447,742 | 627,448 |
| Regional or boiler level? | Boiler | Boiler | Boiler | Boiler |

*Note:* Estimates for $\gamma_m$ in Eq. (1) with $Gen_{ith}$ as the dependent variable. Hour labels are hour-ending so that hour 1 reflects 12:01 a.m.–1:00 a.m. * indicates coefficient significance at the 10% level, ** at the 5% level and *** at the 1% level.

Aggregated over all twenty-four hours, our estimates suggest an approximate 35 ton increase in carbon dioxide emissions on media days. Using current estimates from the EPA on the social cost of carbon, this translates into an approximate $89,500–$160,700 increase in un-priced externalities per media event. To put this figure in perspective, the average passenger car in the United States emits approximately 5.1 metric tons of $CO_2$ per year. Hence, the estimated external costs of a media call for conservation is equivalent to the damages we would expect if there were an increase of 164,200 cars on the road per event day.

In considering the external validity of these results, we should note that the emissions impact in other parts of the country will depend on the carbon content of the marginal fuel source – a figure that varies both across regions and over the course of a day. For example, using data on marginal emissions rates for different regions of the U.S. in Zivin et al. (2014) to construct an hour-by-hour index of carbon intensity, the impact of a similar distortion in the Midwest would lead to a more than doubling of $CO_2$ emissions and the resulting un-priced externality. In contrast, if we were to focus on utilities in Texas and the ERCOT interconnection, the estimated impact on carbon emissions would be reduced by nearly 30 percent.

### 4.3. Generation by fuel type

To better understand the mechanism of generation changes within the PEPCO and BGE generation footprint, we estimate Eq. (1) separately by fuel source (Table 5). In general, coal-fired power plants have substantial start up and shut down costs, in part because they must ramp up and down slowly as the coal burning process cannot be switched on or off instantaneously. For this reason, the most efficient coal-fired plants typically serve base load, while low efficiency (high cost) boilers are used only as a last resort. Natural gas and oil fueled plants are more costly to operate due to higher fuel costs, but they can be turned on and off very quickly to respond to unexpected changes in demand.[32] These units are sometimes called peaking plants. Accordingly, if media coverage of utility press releases produces unanticipated shifts in energy demand, we expect to see strong impacts on gas and oil and limited or delayed impacts on coal plants.

Table 5 contains the results of estimating Eq. (1) separately for coal, natural gas, and oil-powered plants. For reference, our baseline generation results from Table 4 are repeated in the first column. Columns 2–4 contain the estimated impact on each fuel source, and the estimated impacts line up with these predictions. Natural gas plants respond to the increased generation on media days by firing at a significantly higher level than days with press releases that are not picked up, as do

[32] See, e.g., Bogorad and Huang (2005). The vast majority of our sample comes before the recent drop in natural gas prices due to new extraction technologies.

oil fired plants. Overall generation (Column 1) shows significant increases between hours 9 and 15, and early in this window the increases are met mostly by changes in generation at gas and oil plants (hours 8 through 15 in Columns 3 and 4). By hour 12, small impacts on coal-fired plants are apparent although those increases are statistically insignificant.

Because the marginal production comes primarily from natural gas and oil generating plants, we expect to see little impact on pollutants emitted at lower levels from these sources – namely $SO_2$ which is produced in only small quantities in natural gas generation. $NO_x$, on the other hand, is produced by all fuel sources. Indeed, estimates for $\gamma_m$ in Eq. (1) where $NO_x$ and $SO_2$ emissions are the dependent variables (not shown) confirm these predictions.[33]

### 4.4. Price effects

In addition to carbon emissions, temporal distortions in energy use following media calls for conservation are also reflected in real-time prices. We estimate Eq. (1) above with the zonal hourly price data for the PEPCO and BGE zones and report the results in Columns 3 and 4 of Table 4.[34] The morning usage spike is reflected in price peaks, beginning at hour 8 and continuing through hour 10. Price increases are apparent throughout the morning hours, although they become statistically insignificant. Later in the afternoon, as generation begins to abate, prices fall and, again, this may be the result of unexpected changes in usage. The estimated price effect becomes negative in both zones in hour 18 as additional generation brought online to meet the earlier than expected increase in consumption in the morning hours reduces prices after the peak.

## 5. Evaluating the role of electricity imports and exports

Energy supply and demand are necessarily equivalent at any given hour, and the role of the RTO is to facilitate efficient trades across the region. The estimates of media impacts on generation in Table 4 are reflective of consumer demand shifts only if "exports" from the PEPCO and BGE generation footprint are limited. We use the term exports loosely here as the boilers in our generation sample include those inside the PEPCO and BGE geographic zones and those on the periphery so that, even in the absence of transmission outside of the generation footprint, we would always measure positive "net exports" as the difference between Maryland-wide generation and usage in the PEPCO and BGE zones.

The PEPCO/BGE footprint falls in the eastern corridor from New York through mid-Virginia, designated by the Department of Energy as the "Mid-Atlantic Critical Congestion Area", reflecting its high levels of transmission congestion. In addition, PEPCO and BGE zones, specifically, are the two most highly congested areas in the PJM region, which overall experiences significant constraints on west-to-east generation transmission.[35] Indeed, the generation congestion credits and load congestion payments paid to BGE and PEPCO-area generators and users were, by far, the highest amongst eighteen PJM zones in 2008, representing severe limitations on import and export.[36]

Given these congestion statistics, it is unlikely that inter-regional transmission biases our results, which are identified off of generation differences on the highest usage days. All the same, we address the exports issue in two ways. First, we estimate our main results for regional demand (load) and inter-regional exports. Second, we repeat the analysis in Table 4 for hours in our sample with the highest levels of measured congestion in the region, hours when imports and exports would have been most unlikely.

Real-time load is available, by hour, for the PEPCO and BGE zones. We sum the load data over the two zones into a regional load measure to facilitate comparisons with regional generation and exports results. The estimating equation becomes

$$Load_{th} = \alpha_h \vec{hour} + \gamma_p PR_t * \vec{hour} + \gamma_m PR_t * MEDIA_t * \vec{hour} + \beta X_{th} + \lambda + \delta + \epsilon_{th} \quad (2)$$

where $t$ indicates day and $h$ indicates hour. Standard errors are clustered by day. We also aggregate generation across all power plants in the footprint by hour ($Gen_{th}$), and estimate the impact of media coverage on this aggregate generation measure as well as "Net Exports" ($NX_{th}$), measured as the difference between generation and usage in each hour.

The results are contained in Table 6. Estimates in Columns 1–3 reflect the relationship between media coverage and generation, load, and net exports, respectively. We expect results for these variables (measured at the regional level) to be less precisely estimated than those for generation (measured at the boiler level), but the results remain economically and statistically significant over the late morning hours. Point estimates for both generation and load regressions show a run-up in usage across the morning hours which then abate only at the very end of the day. A significant reduction in usage is apparent in the late evening hours in Column 2, but over the "superpeak" hours, the total reduction amounts to a miniscule 0.7% and the same reduction is not apparent in highly congested hours (see Table 7). Net exports follow a similar pattern as generation, but the values are statistically significant only at the 2 p.m. hour. Atypical differences between usage and generation on media days are, then, unlikely contributors to the results documented in Table 4.

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33 See detailed results in the Online Appendix.

34 We cluster errors within days rather than at the boiler level for this specification.

35 See U.S. Department of Energy study "National Electric Transmission Congestion Study", December 2009.

36 U.S. Department of Energy study "National Electric Transmission Congestion Study", December 2009, p. 48.

**Table 6**
Estimates of $\gamma_m$ for generation, load and exports in Eq. (2).
*Source:* Authors' calculations from data described in text.

| Hour | (1) $Gen_{th}$ | (2) $Load_{th}$ | (3) $NX_{th}$ |
|---|---|---|---|
| 1 | −111.0 | −311.4 | 200.3 |
| 2 | −171.1 | −308.2 | 137 |
| 3 | −215.3 | −313.6 | 98.3 |
| 4 | −62.6 | −205.4 | 142.8 |
| 5 | −154.7 | −87.7 | −67.0 |
| 6 | −216.5 | −53.5 | −163.0 |
| 7 | −90.5 | 4.8 | −95.3 |
| 8 | 182.1 | 189.5* | −7.4 |
| 9 | 375.2 | 284.5** | 90.7 |
| 10 | 762.4*** | 505.3*** | 257.2 |
| 11 | 789.9*** | 535.4*** | 254.5 |
| 12 | 675.5** | 410.6* | 264.8 |
| 13 | 560.2 | 281.2 | 278.9 |
| 14 | 480.0 | 134.6 | 345.4* |
| 15 | 497.1* | 249.1 | 248.0 |
| 16 | 182.9 | 37.7 | 145.3 |
| 17 | 78.9 | −32.1 | 111.0 |
| 18 | −25.1 | −103.2 | 78.1 |
| 19 | −201.9 | −171.8 | −30.2 |
| 20 | −200.3 | −202.9 | 2.6 |
| 21 | −123.1 | −213.3 | 90.2 |
| 22 | −196.3 | −226.2* | 29.9 |
| 23 | −462.7** | −226.3 | −236.4 |
| 24 | −607.0*** | −48.4 | −558.7 |
| Total | 1746.1 | 128.7 | 1617.0 |
| Peak (8–23) | 248.0 | 3374.8 | 1922.6 |
| Super-peak (15–22) | 12.2 | −662.7 | 674.9 |
| *N* | 30,631 | 30,631 | 30,631 |
| Regional or boiler level? | Regional | Regional | Regional |

*Note:* Estimates for $\gamma_m$ in Eq. (2) with $Gen_{th}$, $Load_{th}$, and $NX_{th}$ as dependent variables. All specifications estimated on a time series of regionally aggregated data across PEPCO and BGE zones. Hour labels are hour-ending so that hour 1 reflects 12:01 a.m.–1:00 a.m. * indicates coefficient significance at the 10% level, ** at the 5% level and *** at the 1% level.

As an additional test of the power of interregional exports to drive our results, we limit the sample to high congestion days when intra-region transmission would have been most difficult. Congestion is measured as the difference between the price in PEPCO/BGE zones and the APS zone which serves western Maryland, West Virginia, and eastern Ohio. The price wedge is indicative of limitations on the ability to move electricity where the demand is highest. We restrict estimation to hours above the 50th percentile of congestion.[37] We then repeat all analysis for these high-congestion days. Results for both generation and carbon emissions (Eq. (1)) are contained in Columns 1–2 of Table 7. The estimated increases in both generation and carbon emissions are greater under this restriction, and there are no major changes in our conclusions regarding generation spikes in the morning and reductions only in the late evening hours. Similarly, Columns 3–5 of Table 7 indicate that the congestion restriction increases the estimated impacts of conservation calls on regional generation ($Gen_{th}$) and demand ($Load_{th}$), while the impact on exports ($NX_{th}$) is negligible. Indeed, in contrast to the small reductions over superpeak indicated in Table 6, the congestion hour restriction results in no reductions in load over the same hours.

The relationship between media coverage and generation patterns measured in Table 4 is, then, robust to controls for the possible transport across regional lines and appears to result from shifts in consumer usage in the local PEPCO and BGE service areas.

## 6. Robustness checks and alternate explanations

The results above suggest media-driven appeals for conservation lead to increases in energy generation and carbon emissions in the PEPCO and BGE footprint. Below we implement a number of robustness checks related to the exogeneity of media days, as well as evaluations of other possible explanations for the results.

[37] There are no observations with congestion and media stories or press releases in hour 1. The results are unchanged using different pricing points and price difference thresholds to define congestions, see the Online Appendix for details. Hourly congestion prices are published by PJM at the zonal level beginning on June 1st, 2007. A univariate regression of the PEPCO-APS price spread on the real time congestion price in PEPCO has an $R^2 = 0.92$ from the date that congestion data is published through the end of our sample period. We take this as evidence that our proxy for congestion serves the intended purpose.

**Table 7**
Estimates of $\gamma_m$ in Eqs. (1) and (2) for congestion hours only.
*Source:* Authors' calculations from data described in text.

| Hour | (1) $Gen_{ith}$ | (2) $CO_{2_{ith}}$ | (3) $Gen_{th}$ | (4) $Load_{th}$ | (5) $NX_{th}$ |
|---|---|---|---|---|---|
| 1 | – | – | – | – | – |
| 2 | −3.7 | −4.7 | −160.0 | −164.4 | −4.4 |
| 3 | −2.5 | −4.4 | −134.0 | −104.2 | 29.8 |
| 4 | −2.6 | −3.7 | −103.0 | −119.8 | −16.8 |
| 5 | −7.4 | −6.5 | 2.0 | −355.5 | −357.5 |
| 6 | −8.0 | −6.3 | 24.6 | −394.7 | −419.3 |
| 7 | −1.9 | −2.3 | 46.5 | −104.7 | −151.1 |
| 8 | 7.2 | 5.1 | 145.0 | 342.1 | 197.1 |
| 9 | 9.9** | 7.6** | 375.5** | 476.1 | 100.6 |
| 10 | 15.7*** | 10.7** | 575.8*** | 709.8*** | 134.1 |
| 11 | 16.9*** | 10.7*** | 665.4*** | 786.7*** | 121.3 |
| 12 | 17.2*** | 11.2** | 614.3*** | 834.2*** | 219.9 |
| 13 | 20.1*** | 14.3*** | 713.2*** | 936.0*** | 222.8 |
| 14 | 17.7*** | 13.6*** | 433.5*** | 804.6*** | 371.1** |
| 15 | 16.6*** | 14.2*** | 415.7*** | 739.2*** | 323.5* |
| 16 | 7.7* | 7.9* | 156.2 | 318.1* | 161.9 |
| 17 | 5.4 | 7.5* | 101.1 | 186.9 | 85.8 |
| 18 | 4.6 | 6.0 | 75.2 | 156.9 | 81.7 |
| 19 | 3.7 | 6.1 | 59.4 | 101.3 | 41.9 |
| 20 | 4.5 | 5.8 | 21.5 | 112.8 | 91.3 |
| 21 | 1.7 | 3.1 | −118.2 | 2.2 | 120.4 |
| 22 | 0.07 | 1.3 | −246.0* | −49.2 | 196.7 |
| 23 | −7.5 | −4.2 | −322.2** | −346.7 | −24.4 |
| 24 | −13.9* | −12.4* | −224.1 | −687.9** | −463.7 |
| Total | 101.5 | 80.6 | 3117.4 | 4179.8 | 1062.7 |
| Peak (8–23) | 127.6 | 108.5 | 3441.3 | 5423.1 | 1982.0 |
| Super-peak (15–22) | 44.3 | 51.9 | 464.9 | 1568.2 | 1103.2 |
| *N* | 808,875 | 808,875 | 16,145 | 16,145 | 16,145 |
| Regional or boiler level? | Boiler | Boiler | Regional | Regional | Regional |

*Note:* Columns 1 and 2 contain estimates for $\gamma_m$ in Eq. (1) with $Gen_{ith}$ and $CO_{2_{ith}}$ as dependent variables. Both regressions are estimated on a boiler-hour panel. Columns 3–5 contain estimates for $\gamma_m$ in Eq. (2) with $Gen_{th}$, $Load_{th}$ and $NX_{th}$ as dependent variables. All are estimated on a time-series of regional-level data. Congestion hours are defined as price difference between PEPCO and APS (in West Virginia and western Pennsylvania) above the 50*th* percentile. There are no observations with congestion and media stories or press releases in hour 1. There are large number of hours at the median. Hour labels are hour-ending so that hour 1 reflects 12:01 a.m.–1:00 a.m. * indicates coefficient significance at the 10% level, ** at the 5% level and *** at the 1% level.

As a first robustness check, we explore whether the intensity of media coverage influences the temporal pattern of energy demand. Specifically, we explore if the estimated media effect is greater on days where calls for conservation are picked up by multiple media outlets. Intuitively, if the observed pattern of usage is driven by a response to media coverage, larger distortions should be observed on days where multiple outlets publish conservation calls as it would increase exposure to the underlying message.

To test this hypothesis, we generate a new indicator variable $MULTIM_t$ which equals one on days where more than one media outlet relayed a conservation call. We then re-estimate Eq (1), substituting this new indicator variable for our original indicator of media coverage, $MEDIA_t$. Note that in doing so, we include in our set of control days those occasions where only a single media outlet publishes a call for conservation. To the extent that coverage by a single media outlet is sufficient to distort energy use, the coefficients of interest (vector $\gamma_m$) thus provide a lower bound on the effect of increased media coverage on hour-by-hour energy use.

Estimated values for $\gamma_m$ when $MULTIM_t$ is the independent variable are included in the second column of Table 8 and underscore the assertion that the observed patterns of usage are driven by a response to media coverage. (The table's first column is the replicated baseline from Table 4.) Point estimates are larger across the late morning hours using the multimedia proxy compared to the baseline results.[38]

An alternate explanation for the observed patterns of energy use is that media call days are correlated with other factors that affect energy usage. We cannot rule out this possibility completely as, given the DA-RT price gap results, this factor is also either presumably unobserved by day-ahead energy markets or cannot be arbitraged away. Still, we examine two confounders with a high likelihood of driving media decisions. First, local air quality and air quality alerts increase the number of individuals who work from home or decide to stay indoors during normal work hours.[39] Because such behavior has little

[38] The same qualitative pattern of differences arises if we look at the effect of multiple versus any media coverage on other metrics of interest – real time prices and $CO_2$ emissions. Results available upon request.
[39] See Zivin and Neidell (2009) for evidence of behavioral responses to air quality alerts.

**Table 8**
Robustness checks.
*Source:* Authors' calculations from data described in text.

| Hour | Baseline (1) | *MULTIM*$_t$ (2) | Include air quality alerts (3) | Include heat stories (4) | Lag weather (5) | Media only days (6) | Consecutive *MEDIA* (7) | Single day *MEDIA* (8) |
|---|---|---|---|---|---|---|---|---|
| 1 | −1.9 | −4.4 | −2.3 | −2.6 | −2.9 | 3.3 | −20.3** | 5.0 |
| 2 | −3.3 | −6.6 | −3.7 | −4.0 | −4.2 | 1.6 | −19.7** | 2.9 |
| 3 | −4.3 | −11.7* | −4.6 | −4.9 | −5.2 | 2.5 | −16.3* | 1.2 |
| 4 | −1.2 | −7.6 | −1.6 | −1.9 | −2.1 | 2.3 | −12.7 | 3.2 |
| 5 | −2.6 | −10.0** | −3.0 | −3.3 | −3.5 | 1.0 | −12.8 | 1.4 |
| 6 | −3.5 | −10.5* | −3.9 | −3.9 | −4.1 | −2.2 | −12.7 | 0.2 |
| 7 | −0.8 | −8.3 | −1.2 | −2.1 | −2.3 | −1.9 | −5.9 | 1.4 |
| 8 | 4.2 | −2.4 | 3.8 | 3.0 | 2.9 | −0.7 | 7.7 | 3.4 |
| 9 | 8.4*** | 4.6 | 7.9** | 6.2** | 6.0* | 0.5 | 12.7** | 7.2** |
| 10 | 16.8*** | 16.9*** | 16.4*** | 15.0*** | 15.0*** | 4.6 | 21.1*** | 15.5*** |
| 11 | 16.9*** | 17.4*** | 16.5*** | 14.0*** | 13.9*** | 8.1** | 30.7*** | 12.3*** |
| 12 | 14.3*** | 16.8*** | 13.9*** | 11.4*** | 11.3*** | 8.9** | 35.0*** | 7.1*** |
| 13 | 12.0*** | 14.9*** | 11.6*** | 9.1*** | 9.1*** | 6.3 | 35.7*** | 3.7 |
| 14 | 10.5*** | 14.0*** | 10.1** | 7.3** | 7.2** | 2.1 | 30.6*** | 3.5 |
| 15 | 11.1** | 15.1*** | 10.6** | 6.6* | 6.5 | 1.7 | 25.3*** | 6.2* |
| 16 | 5.1 | 9.0** | 4.7 | 2.0 | 1.9 | −3.7 | 18.4** | 0.6 |
| 17 | 3.0 | 6.7* | 2.7 | 0.07 | −0.04 | −2.8 | 13.1* | −0.2 |
| 18 | 1.0 | 3.6 | 0.5 | −1.6 | −1.7 | 0.9 | 11.6 | −2.5 |
| 19 | −2.9 | 0.7 | −3.3 | −6.3 | −6.3 | 4.8 | 8.3 | −5.4* |
| 20 | −2.1 | 1.7 | −2.5 | −4.6 | −4.7 | 2.8 | 7.3 | −5.2 |
| 21 | −0.9 | 1.5 | −1.3 | −2.9 | −3.1 | 2.2 | 7.5 | −3.7 |
| 22 | −2.5 | −0.7 | −2.9 | −4.1 | −4.2 | −4.7 | 4.0 | −4.6 |
| 23 | −8.3* | −8.2* | −8.7* | −9.6** | −9.8** | −6.8* | −7.5 | −8.3* |
| 24 | −10.9** | −13.2** | −11.3** | −12.3** | −12.5** | −3.4 | −18.5** | −7.8* |
| *N* | 1,534,655 | 1,534,655 | 1,533,527 | 1,493,322 | 1,516,686 | 1,546,304 | 1,525,897 | 1,531,365 |

*Note:* See notes to Table 4 and specification descriptions in Section 6.

to no impact on energy usage in the workplace (where usage is impervious to the attendance of workers), in this case we would expect to see increased energy consumption system-wide over prime working hours. Although the estimated change in system load is valid under this alternative explanation, the mechanism is decidedly different if media coverage is simply correlated with air quality alerts. To assess the validity of such an alternative, we augment our baseline regression model to include an indicator for days where air quality entered the highest levels (Code Orange or Code Red) for the Baltimore-DC region as well as the underlying value of the air quality index.[40] We observe a total of 298 such days in our data. Estimated values for $\gamma_m$ – the hour-by-hour impact of media coverage – under this alternate specification are included in Column 3 of Table 8. The estimated impact of conservation calls is virtually unchanged given these additional controls.

A second possible confounder is the presence of other media stories in the days prior to ones calling for conservation. If media are more likely to cover conservation calls on days following other media stories related to heat conditions, the estimates in question may be a response to prior media stories rather than conservation calls *per se*. We run a media search similar to the one described above for conservation calls with key words related to heat.[41] We then control for the presence of these media stories in day $t$, day $t-1$ and day $t-2$.[42] Controlling for media stories about heat reduces the magnitude of the increase in generation over the peak somewhat relative to the baseline as indicated in Column 4 of Table 8, but the qualitative conclusions are essentially unchanged.

Our next robustness check is designed to control for more complex weather effects based on PJM's internal projection tools. To do so, we augment our baseline specification to include indicator variables for nighttime (hours ending 1 a.m. to 6 a.m.), morning (hours ending 6 a.m. to noon), afternoon (hours ending noon to 6 p.m.) and evening (hours ending 6 p.m. to midnight) hours that are interacted with measures for cooling degree hours, wind speed, and weighted lagged cooling degree hours.[43] PJM suggests these variables are most useful in predicting *peak* daily loads, but we adapt them to our hourly specification as a robustness check to control for complex weather interactions that could be missed by the baseline weather specification. Estimates for this model are presented in Column 5 of Table 8 and are similar to those identified in our primary specification.[44]

Additional evidence that media coverage drives our results comes from a number of days in the sample where media issue a call for conservation that is not representative of an underlying press release. There are 11 such "rogue" days in our sample. On these dates, media outlets noted that high temperatures were forecast and urged energy conservation, but without a nudge from the local utility. If consumers do not distinguish between emergency calls "sponsored" by local utilities and un-sponsored calls, the impact of these media calls on consumer behavior should be similar to our baseline estimates. On the other hand, these calls may not be indicative of broader media coverage, as we have argued for our baseline results, and the impacts on consumer behavior should be correspondingly smaller. Column 6 of Table 8 contains the estimates for media call days with no corresponding press release.[45] These point estimates are muted relative to the baseline results, but the patterns of usage are similar with higher usage over the mid-day hours and no significant reduction over afternoon and evening hours.

Finally, to assess the power of repeated media calls for conservation, we compare the effect of media coverage across days where there were no prior media days (single day events or first events in a series of events) and those where media releases occur on consecutive days.[46] Intuitively, one can envision temporal patterns of use in the midst of a prolonged heat wave that differ substantially from those realized during isolated events caused by unanticipated/temporary weather shocks. Consumers may initially take care with their response to conservation calls but "burnout", i.e., lose interest or motivation, as time goes on.

The results of estimating Eq. (1) for single-day and consecutive media days are presented in Columns 7 and 8 of Table 8. For the consecutive media day results, we drop single-day media days from the sample, and vice versa, so that identification is identical to the baseline results. For single day and consecutive day events alike, electricity generation between mid-morning and mid-afternoon follows a temporal pattern similar to that noted in the baseline results in Column 1. Stronger

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[40] Amongst the set of media articles included in our sample, there are a few that include parallel notification of "Code Orange" or "Code Red" air quality alerts for the region and calls for caution in outdoor activities and exercise. Such alerts are targeted at children, the elderly, and those suffering from heart disease or asthma and other lung diseases. However, two of the calls target the broader population and include appeals for individuals to "limit driving" or to otherwise avoid public places – including the workplace.

[41] We check the same sources for keywords "heat wave", "high temperatures", "swelter-", "record-breaking temperatures", "soaring temperatures", and "excessive heat", exclusive of news stories also calling for conservation.

[42] The results are similar when controlling for these stories in $t-3$ and $t-4$ as well.

[43] "Cooling degree hours" is defined as the difference between the observed hourly temperature and 72 degrees. Lagged cooling hours is defined as $0.75 * \text{temp}_{h-24} + 0.25 * \text{temp}_{h-48}$.

[44] A similar pattern of generation emerges if we restrict our sample to the set of days where the daily high temperature exceeds 29.5 °C – the lowest high temperature on a press release day. Results from this model are included in the Online Appendix.

[45] Including both *MEDIA* and *MEDIA* * *PR* as regressors in Eq. (1) does not allow for clean identification of either if the impact on consumer behavior is the same in both cases. Instead, we augment Eq. (1) with an additional term which contains a coefficient on $MEDIA-NOPR_t$, a value equal to one when there is a media conservation call with no corresponding press release. With that control, $\gamma_m$ represents the impact of a press release interacted with media days and the coefficient on $MEDIA-NOPR$ represents the impact of a media day with no associated release. The full equation is $Y_{ith} = \alpha_h \vec{hour} + \gamma_p PR_t * \vec{hour} + \gamma_m MEDIA-PR_t * \vec{hour} + \gamma_c MEDIA-NOPR_t * \vec{hour} + \beta X_{th} + \eta_i + \lambda + \delta + \epsilon_{it}$, and $\gamma_c$ is reported in Column 6.

[46] We observe one two-day and one three-day event, indicating 7 media days with no media call immediately preceding and 3 media calls which are preceded by media calls for the same.

load impacts obtain on days with consecutive press releases (Column 6), particularly regarding increased usage in the early morning and evening, perhaps reflecting burnout. All the same, single-day media events exhibit the temporal usage pattern evident in our baseline regressions.

## 7. Conclusion

There is a growing body of literature exploring the effects of targeted messages and similar non-price interventions on household-level energy use. Taken in its totality, this body of work underscores the promise of behavioral "nudges" as a means to promote household changes in energy efficiency. Our study extends this literature by providing the first attempt to measure consumer response to day-of emergency conservation requests. Our results suggest a perverse effect. When utility calls for conservation are relayed by the media, we observe significantly higher generation during the early hours of the day and no compensating reduction over "superpeak" hours as compared to conservation calls without media coverage. This leads to an increase in daily production, but no apparent reduction in grid stress.

Our methods also represent an advent in measuring the supply-side impact of demand management policies in general. The benefit of this approach is that it allows us to not only estimate the impact of conservation messaging on grid stress, but also to capture the pecuniary and non-pecuniary effects operating through other channels – prices and $CO_2$ emissions. In this case, we find that the perverse impacts of conservation messaging on energy consumption spill over into significantly more volatile prices and higher emissions levels.

Our results provide a word of caution for utilities pursuing real-time demand management. Attempts to alter consumer behavior through public pleas may backfire, particularly if utility generation strategies fail to respond to consumer use. In our sample, conservation calls were associated with remarkably increased emissions over the course of the highest use days. Future work should seek to better understand the household- and commercial-level decisions leading to these impacts, as well as explore whether optimal generation strategies over peak periods might serve to mitigate the perverse impacts highlighted within.

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## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jebo.2014.11.008.

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