Changes to Victorian Intraday Electricity Demand Following COVID-19 Restrictions

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1 Context and Findings

Daily lives of Victorians have been disrupted by geographic and activity restrictions due to the COVID pandemic. These disturbances may have affected how Victorians consume electricity. First, the total electricity consumed might have dropped due to workplace and industrial closures. Second, the distribution of electricity usage throughout each day may have shifted because of changes to individuals' schedules. We find statistically significant evidence to support the latter. Specifically, we observe that transition into Stage 3 restrictions in late March diminished morning peak energy consumption, whilst evening peak energy consumption was unchanged (the marginal effect of transitioning from Stage 3 to Stage 4 restrictions in August was statistically insignificant). Although we detect changes to intraday seasonality upon the introduction of movement restrictions, we do not find that total energy consumption, as measured by the average half-hourly energy demand, differed in August and April 2020 compared to the same months in previous years.[1]

2 Data

We use electricity demand data provided by the Australian Energy Market Operator and temperature data from the Australian Government Bureau of Meteorology (BOM)[2]. The electricity demand data is measured over half-hour intervals for all days in the sample. We focus on the period from 1st January 2015 to 21st September 2020. These dates are selected such that our sample has sufficient data to account for yearly seasonality (as depicted in Figure 1) without extending into earlier periods that are subject to different political environments or technological realities.

3 Methods and Interpretation

3.1 Usage Behaviour and Timing

We find that:

- **Morning peak electricity demand decreases after Stage 3 restrictions were enacted, though no significant effect is detected when Stage 3 restrictions are increased to Stage 4.**
- **Evening peak electricity demand is unchanged.**
- **The timing of the peaks is unchanged.**

Unchanged evening demand is expected: the evening peak corresponds to consumers using artificial lighting, heating, and household appliances around dinner; factors that are unlikely to change timing based on movement restrictions. On the contrary, the morning peak corresponds to individuals using artificial lighting and household appliances upon waking up. Consequently, this peak flattens if there is a wider distribution of times when people wake up (due to changed

*`https://github.com/nspyrison/melb_datathon2020/blob/master/_paper/supplementary_material.pdf`

[1] Additional details relating to Stage 3 and Stage 4 restrictions in Victoria can be found in the accompanying supplementary materials.

[2] See supplementary materials for details on sourcing this data.

work schedules or avoiding a commute), or if some proportion of the population wakes up after sunrise and no longer needs to use artificial lighting. Figure 2 illustrates that morning peaks in 2019 were flatter on weekdays than weekends, an effect driven by similar forces to the flattening of peaks during COVID movement restrictions.

To reach these conclusions, we formally test for changes to the levels of the peaks before and after Stage 3 and Stage 4 restrictions in Victoria by estimating a regression model that controls for seasonal cycles, day-of-week effects, and the effects of temperature on demand. The model[3] is

$$y_t = \sum_{k=1}^{K} \Big(c_k + \mathbb{1}(\mathrm{S3}_t) d_{1k} + \mathbb{1}(\mathrm{S4}_t) d_{2k}\Big) x_{kt} + f_{seas}(t) + \varepsilon_t, \tag{1}$$

where x_{kt} is a set of $K = 9$ variables including a constant, six dummy variables controlling for days of the week, as well as two temperature-related variables. The temperature variables are heating degree days (HDD_t) and cooling degree days (CDD_t) as defined by the Australian Government BOM using a BASE temperature of 18°C. The x_{kt} variables are permitted to have one set of coefficients before Stage 3 restrictions (c_k), a second set of coefficients to accommodate the effect of Stage 3 restrictions (c_k+d_{1k}), and a third set of coefficients to accommodate the effect of Stage 4 restrictions ($c_k + d_{1k} + d_{2k}$). The indicator variable $\mathbb{1}(\mathrm{S3}_t)$ takes the value 1 after Stage 3 began and 0 otherwise, and $\mathbb{1}(\mathrm{S4}_t)$ takes the value 1 after Stage 4 began and 0 otherwise. Finally, we assume that long-run seasonal fluctuations do not change, meaning that the variables which control for long-run seasonality ($f_{seas}(t)$) are the same throughout the sample. From the model defined in (1), we can check for a statistically significant effect of Stage 3 and Stage 4 restrictions by conducting a hypothesis test for the significance of the d_{1k} and d_{2k} variables, respectively. In testing for a change in the level of the morning peak, we let y_t be the series shown by "Morning peak" in Figure 3. Likewise, testing for a change in evening peak demand is performed by using the series shown by "Evening peak" in Figure 3 as y_t. Our findings suggest that morning peaks are statistically significantly lower from 1st April 2020 than they were before, at the 5% level of significance, whereas there is no statistically significant change in evening peaks. Figure 3 illustrates these observations graphically by showing that the difference in peak sizes (driven by the changes to the morning peak) behaves differently during lockdown restrictions compared to previous years.

3.2 Mean Half-Hourly Energy Consumption

We find that mean half-hourly energy consumption in April and August (where Stage 3 and Stage 4 restrictions were in place, respectively) is not significantly different from previous years.

To assess the impact of Stage 3 and Stage 4 restrictions on total energy consumption, we compare electricity demand in April 2020 and August 2020 with the same months from 2015 - 2019 respectively. Mean half-hourly electricity demand for each month is total electricity demand for the month, divided by the number of half-hour windows in the month (i.e. the total number of observations reported in the data for that month).

To determine whether or not the 2020 values are statistical anomalies when compared to previous years, we test to see whether 2020 constitutes an outlier. We define an outlier as an observation that is more than three scaled median absolute deviations (MAD) from the median[4] [5] [6]. Using this definition, we find that neither 2020 April nor 2020 August mean half-hourly energy consumption is materially different from previous years. Such an observation can be explained by the fact that energy consumption has shifted: although many workplaces are closed, people consequently consume electricity from their homes at times when they usually would not. Although 2020 represents lower energy consumption than in recent years, this difference is not statistically significant under our definition (potentially due to ongoing changes in consumer behaviour or improvements in energy efficiency technology). This finding is in line with a quarterly report by the Australian Energy Market Operator (Australian Energy Market Operator, 2020).

[3]See supplementary materials for a description of peak identification, the regression model, variables used, and further discussion of estimation outputs.

[4]We elect to subtract the median rather than a trend: using least squares, we have already assessed whether or not an influential trend exists both on aggregated data and on data which has not been aggregated into a mean, and we have not detected an influential trend in any instance.

[5]We also show our results are robust by defining outliers as being three standard deviations from the mean; the April 2020 mean deviation is 0.90 times the standard deviation, whilst the August 2020 mean deviation is 1.63 times the standard deviation.

[6]The scaled median absolute deviation of a vector A is defined as $MAD = c \times median(|A - median(A)|)$, where $c = -\frac{1}{\sqrt{2}} \times erfcinv(1.5))$ and $erfcinv$ is the inverse complementary error function.

4 Figures

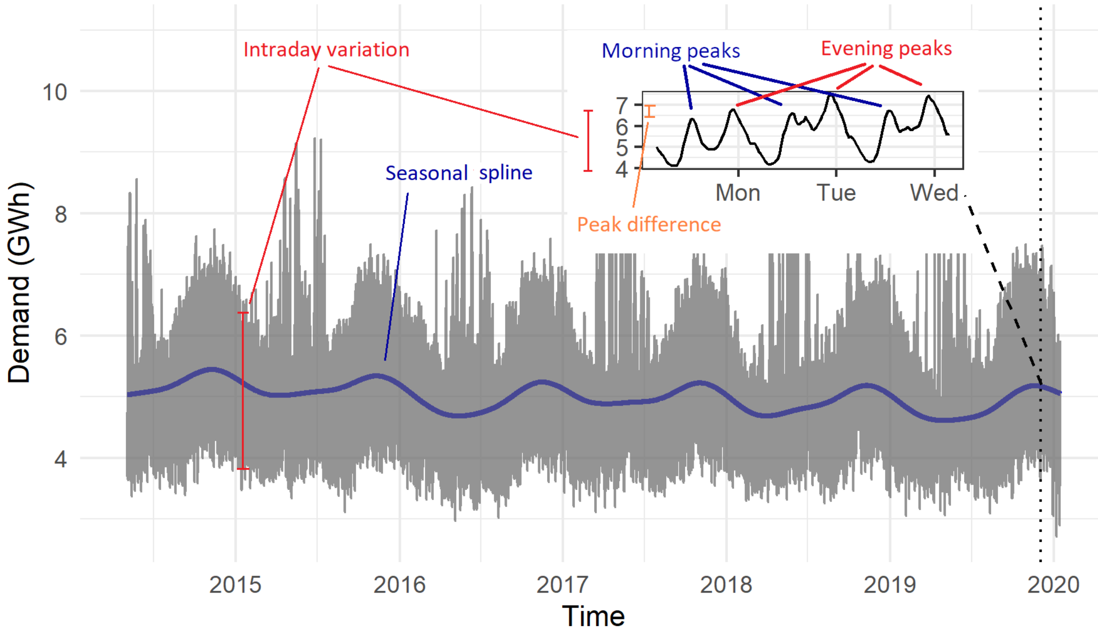

Figure 1: Half-hourly electricity demand for Victoria, Australia, 2015-2020. Annotations highlight some of the key features, trends, and long-term seasonality.

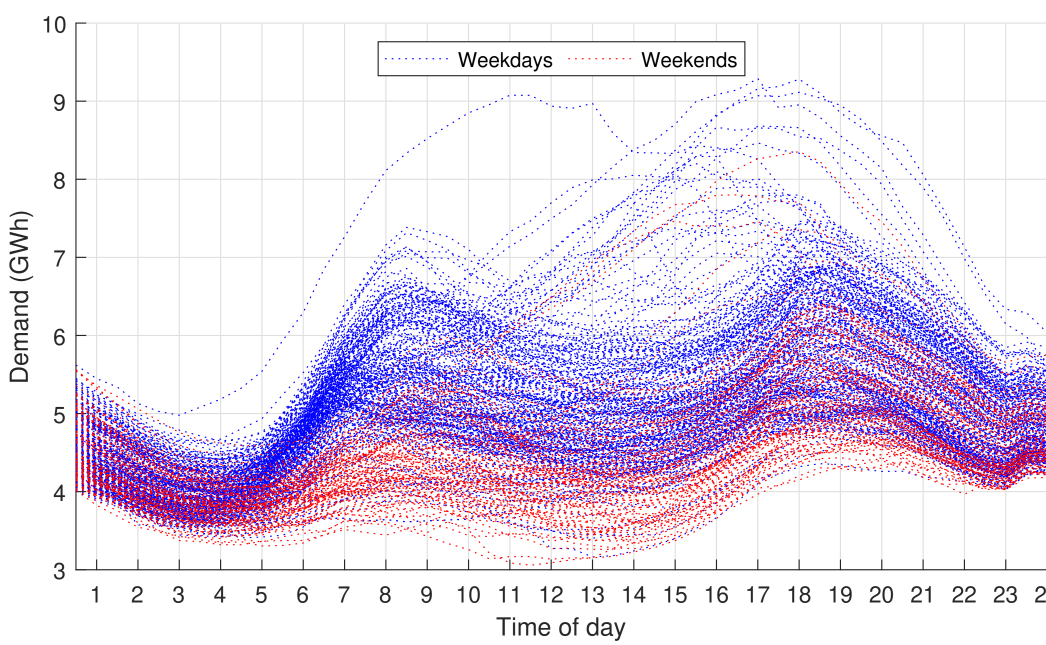

Figure 2: Daily intraday curves for 2019.

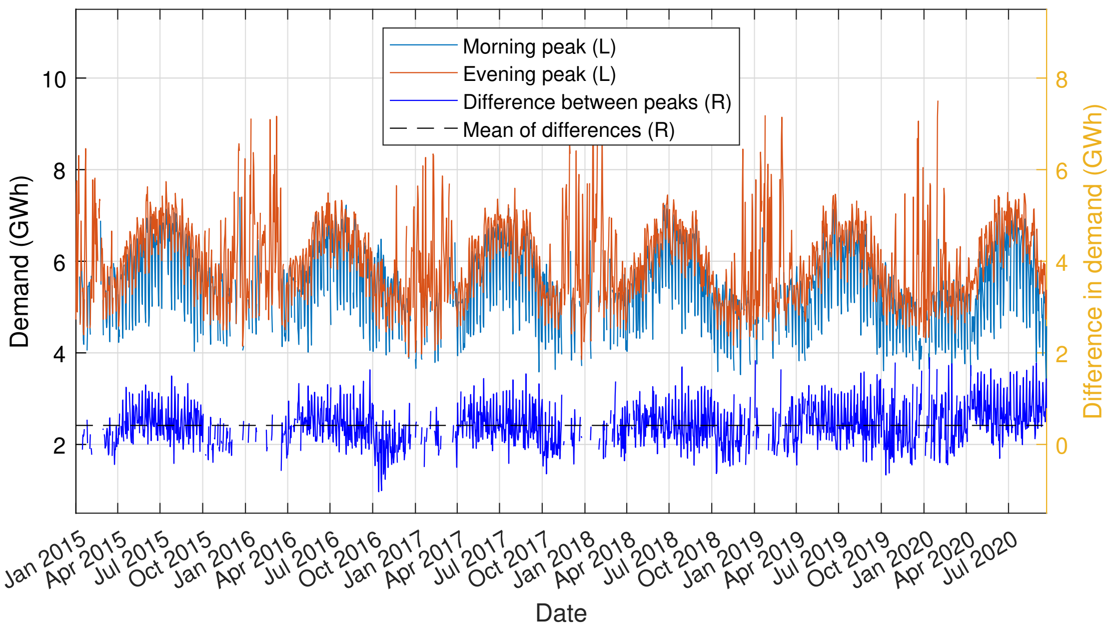

Figure 3: Levels of the morning and evening peaks (left y-axis), as well as the difference in levels on days with two peaks (right y-axis).

References

Australian Energy Market Operator (2020). Quarterly Energy Dynamics Q2 2020. Version 1: 22 July 2020.