

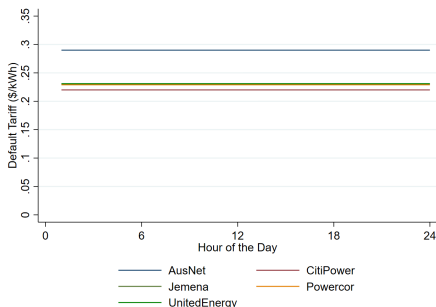
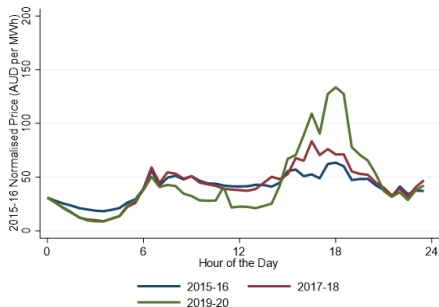
The Load Shifting Challenge: Incentivising within-day shifting of household electricity use

Anke Leroux
(w/ Gordon Leslie and Michael Ward)

Monash University

30 November 2022
AEMI Workshop on Energy Markets

Boom in solar PV's impact on wholesale electricity prices



Average VIC spot price by half-hour of day (Normalised by hour 0, 2016 -2016)

Default flat rate retail tariffs 2022/23 VIC (ESC, 2022)

- Deepens the disconnect between wholesale and retail prices

Curtailement of rooftop PV underway in South Australia

Posted by PAUL MCARDLE Sunday, November 13 2022 Topic: 2022-11 SA Islanded, Spring 2022 in the NEM

A short article just to note that curtailement of distributed PV in South Australia is underway on Sunday morning 13th November 2022 as a result of the islanding on Saturday afternoon. We'll come along later to explain more in a subsequent article.

The Sydney Morning Herald

Brits facing 'managed and controlled' power blackouts if energy supply falters



Rob Harris

October 7, 2022 – 7:51am

London: British homes and businesses could face rolling three-hour blackouts in the coming months if the country cannot import electricity from Europe and source enough gas to fuel gas-fired power plants.

National Grid, the company in charge of Britain's electricity and gas systems, warned on Thursday that millions of British households would need to cut back on energy consumption to avoid the worst-case scenarios.



Maintaining operational demand in South Australia on 14 March 2021

November 2021

Reviewable Operating Incident Report under the
National Electricity Rules

Economic challenges to maximising value from solar boom

- Many households are long accustomed to flat rate tariffs and are therefore not trained to be price responsive on short time horizons
- Elasticity of electricity use is dependent on past and planned actions - this is a dynamic problem
- There are unobserved costs to households from changing electricity use patterns

Can we incentivise households to better align their consumption with solar output?)

- 1 Are households more responsive to programs that encourage load shifting by
 - subsidising daytime use (solar sponge)
 - rewarding evening use reductions (peak shave)
- 2 Are households more responsive to routine or ad hoc incentives?
- 3 How sensitive are households to the magnitude of the incentives offered? Can non-monetary rewards generate comparable responses?

Design a field experiment with 6000+ Powerpal customers - about half have rooftop solar systems installed

Preview

- 1 Households' sensitivity to program design and incentive size:
 - Ex ante *solar households* are more preconditioned to alter consumption habits and we find they are more *responsive* to programs but *not sensitive* to incentive size
 - *Non-solar households* are *responsive* to solar sponge programs and *sensitive* to level of incentives offered for peak shave programs
- 2 Are households responsive to routine or ad hoc incentives?
 - *Little evidence of habit formation*
- 3 Encouraging signs for program design
 - Surplus from *lower procurement costs in some groups*
 - *Targeting* high peak / deep trough days can work

Literature

- 1** The solar-timing for an into vs away style program with real time feedback speaks directly to the literature on time-varying electricity pricing (Faruqi and Sergici 2010; Alcott 2011; Kessels et al. 2016, Wolak 2006, 2010, 2011, 2021; Burkhardt et al. 2019, 2020; Andersen et al. 2021) as well as DR trials by some Australian retailers

▶ TVP literature expanded

- 2** Ability to directly compare routine and ad hoc programs in a common setting to address questions on habit formation (Thompson and Spencer 1966; Becker and Murphy 1988; Alcott and Rogers 2014; Jesoe and Rapson 2014; Ito et al. 2018; Costa and Gerard 2021; Byrne et al. 2021)

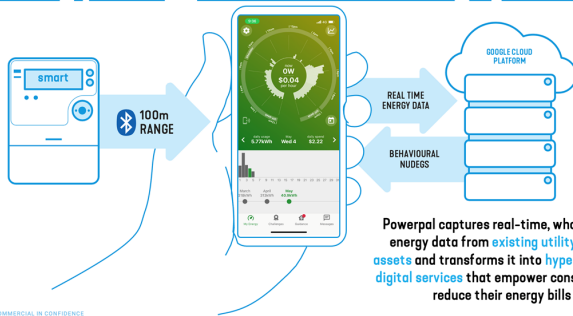
▶ Habit literature expanded

Outline

- 1 Motivation
- 2 Setting and experimental design**
- 3 Empirical model
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- 5 Discussion
- 6 Appended Slides

Partnership with Powerpal

powerpal: real-time energy engagement



- Free Powerpal device and app for Victorian customers with smart meters
- Fast-growing customer base (April 2022: 140,000 customers)

Experimental design: 3 dimensions

	Routine		Ad hoc		
Peak Shave	5c/kWh	Non-mon.	5c/kWh	10c/kWh	50c/kWh
Solar Sponge	5c/kWh		5c/kWh	10c/kWh	

- 1** Action: peak shave (XkWh for all consumption below personalised baseline between 5pm-8pm) vs solar sponge (Xc/kWh for all consumption between 12pm-3pm)
- 2** Frequency: every day vs ad hoc (with day-ahead notice)
- 3** Incentive type: 5c/kWh, 10c/kWh, 50c/kWh, non-monetary incentives (0-3 stars)

Participants

(# solar households, # non-solar households)

	Routine		Ad hoc		
Peak Shave	5c/kWh (486, 310)	Non-mon. (484, 306)	5c/kWh (486, 312)	10c/kWh (489, 0)	50c/kWh (490, 307)
Solar Sponge	5c/kWh (0, 308)		5c/kWh (0, 309)	10c/kWh (0, 303)	
Control			(809, 607)		

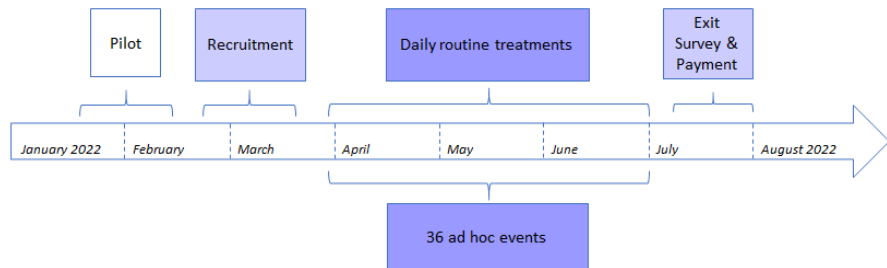
- 6005 participating households in total
- Of these, 3245 have a rooftop solar systems installed and 2760 do not

Ex ante solar/non-solar differences

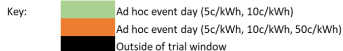
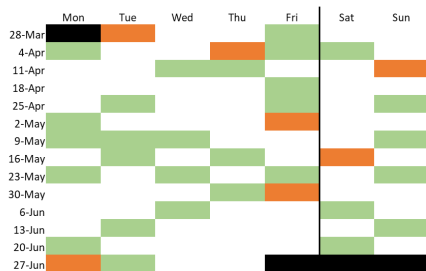
	Solar	Non-Solar	p-value
Powerpal Tenure	276.1	275.7	0.91
Major Retailer	0.35	0.36	0.35
Android OS	0.39	0.39	0.95
12-6am Energy Use (Wh)	2193	2142	0.32
Time-of-use Tariff	0.45	0.12	0.00
App Engagement	2.38	1.56	0.00

- Solar households are ex ante more engaged and more likely to be on a time-of-use tariff

Experimental Timeline



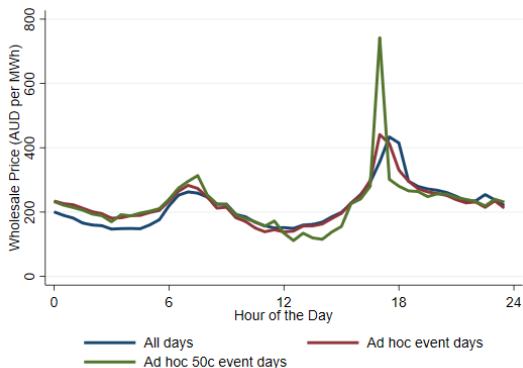
Ad Hoc Events



Selection usually one week ahead and informed by

- weather forecast (low cloud)
- approx. balance by day of week

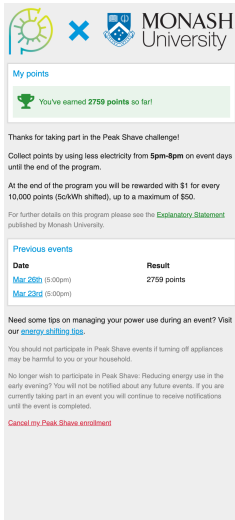
Trial period: wholesale prices




Average Vic spot price by half-hour of day during trial


- Exceptional value for load shifting
- More than \$200/MWh value can be created from load shifting on average
- Potential for significantly more value if targeting high-spread days

User Experience - peak shave, routine, 5c



 MONASH University

My points

 You've earned **2759 points** so far!

Thanks for taking part in the Peak Shave challenge!

Collect points by using less electricity from **5pm-8pm** on event days until the end of the program.

At the end of the program you will be rewarded with \$1 for every 10,000 points (5c/kWh shifted), up to a maximum of \$50.

For further details on this program please see the [Explanatory Statement](#) published by Monash University.

Previous events

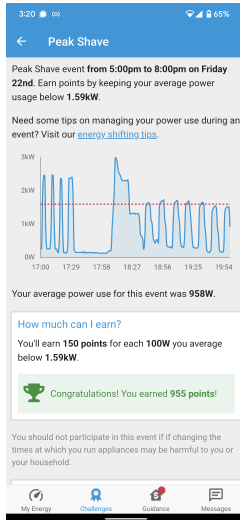
Date	Result
Mar 26th (5:00pm)	2759 points
Mar 23rd (5:00pm)	

Need some tips on managing your power use during an event? Visit our [energy shifting tips](#).

You should not participate in Peak Shave events if turning off appliances may be harmful to you or your household.

No longer wish to participate in Peak Shave: Reducing energy use in the early evening? You will not be notified about any future events. If you are currently taking part in an event you will continue to receive notifications until the event is completed.

[Cancel my Peak Shave enrolment](#)

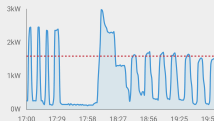


3:20 (09) 65%

← **Peak Shave**

Peak Shave event from **5:00pm to 8:00pm on Friday 22nd**. Earn points by keeping your average power usage below **1.59kW**.


Need some tips on managing your power use during an event? Visit our [energy shifting tips](#).



Your average power use for this event was **958W**.

How much can I earn?

You'll earn **150 points** for each **100W** you average below **1.59kW**.

 **Congratulations! You earned 955 points!**

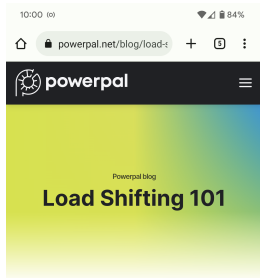
You should not participate in this event if changing the times at which you run appliances may be harmful to you or your household.

My Energy Challenges Guidance Messages

▶ Sponge

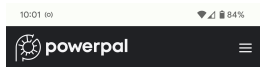
▶ Non-monetary

User Experience - load shaving tips



What is Load Shifting?

When talking about electricity consumption we often talk about **how much** we use or how we can be **more efficient** with the energy that we consume. Load shifting (or peak shaving)



Load Shifting Tips

Obviously, there are some things you can't schedule, like your fridge running or when you cook dinner. However, we've put together some simple tips to help you become a load-shifter.

1. Cooling or heating your house before you get home.

Use your device's inbuilt timer to heat or cool your house before you get home. Heating and cooling make up to **40% of your household energy**, bills so shifting this usage can pay huge dividends over time.

2. Use timers or delay functions to shift optional, non-time-sensitive use to the middle of the day.

For example:

- **Put a timer on your dishwasher** and let it run during the middle of the day.
- **Load up your washing machine** and use a timer to run it during the day. If you're using a dryer, use it during the weekend when you're home during the day.
- If you own a pool, time your **pool pump** to run during times of peak solar.
- Charge your **Electric Vehicle** in the



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Data

- Household \times hour electricity use (imported net consumption, censored at 0) for all trial participants
 - Panel of 6005 households and $(24 \text{ hour} \times 212 \text{ days}) = 5088$ time periods
- Data window covers approx. 4 months pre-trial plus the 3 months of the trial: 1 Dec 2021 - 30 June 2022
- Infer solar status from observing periods of zero consumption
- Additional data: app engagement, exit survey data and (not yet exploited) post trial consumption data

Base Model: DiD by hour of day

$$y_{i,t} = \mu_h + \nu_i + \eta_d + \sum_{h=0}^{23} \alpha_h H_{t,h} W_t + \sum_{h=0}^{23} \sum_g \beta_{g,h} H_{t,h} W_t G_{i,g} + \varepsilon_{i,t},$$

where $y_{i,t}$ is outcome variable for hh i in hour-of-sample t (Wh or \$), μ_h , ν_i , η_d are hour-of day, household and date-of sample fixed effects, $H_{t,h}$ is hour-of-day for hour-of-sample dummy, $W_t = 1$ if hour-of-sample is in trial window, $G_{i,g} = 1$ if hh i is allocated to experimental group g . Standard errors are clustered by household.

Model 2: augmented to test for habit formation

$$y_{i,t} = \mu_h + \nu_i + \eta_d + \sum_{h=0}^{23} \alpha_h H_{t,h} A_{g,t} W_t + \sum_{h=0}^{23} \alpha'_h H_{t,h} A'_{g,t} W_t \\ + \sum_{h=0}^{23} \sum_g \gamma_{g,h} H_{t,h} A_{g,t} W_t G_{i,g} + \sum_{h=0}^{23} \sum_g \gamma'_{g,h} H_{t,h} A'_{g,t} W_t G_{i,g} + \varepsilon_{i,t},$$

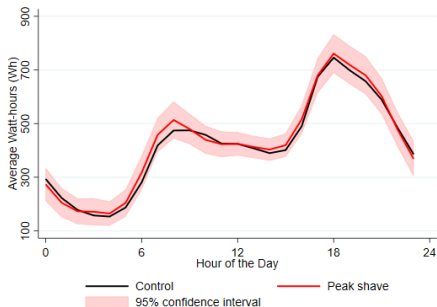
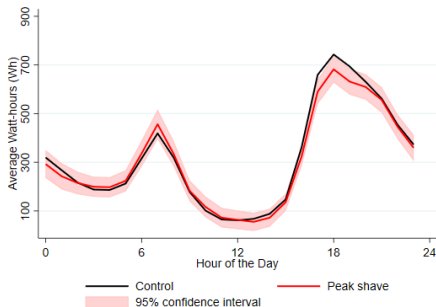
where $y_{i,t}$ is outcome variable for hh i in hour-of-sample t (Wh or \$), μ_h , ν_i , η_d are hour-of day, household and date-of sample fixed effects, $H_{t,h}$ is hour-of-day for hour-of-sample dummy, $W_t = 1$ if hour-of-sample is in trial window, $G_{i,g} = 1$ if hh i is allocated to experimental group g , $A_t = 1$ if hour-of-sample t is during an *event day* (5&10c/kWh ad hoc groups), $A'_t = 1$ is not during an event day. Standard errors are clustered by household.

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Solar/non-solar: same incentive, different responses (1)

► Randomisation

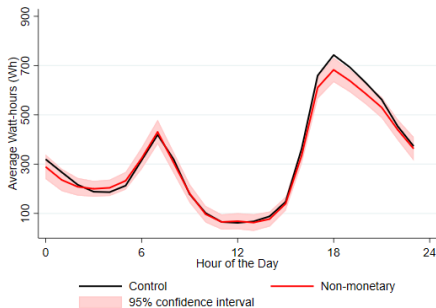


Solar: Routine peak shave 5c/kWh

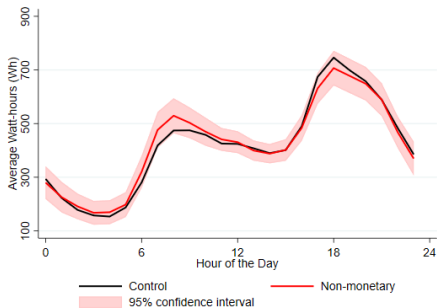
Non-solar: Routine peak shave 5c/kWh

- Routine peak shave incentive *decreases* average usage *per solar household* by 192Wh (9%) during the peak shave window (5pm-8pm)
- *No effect* for *non-solar households*

Solar/non-solar: same incentive, different responses (2)



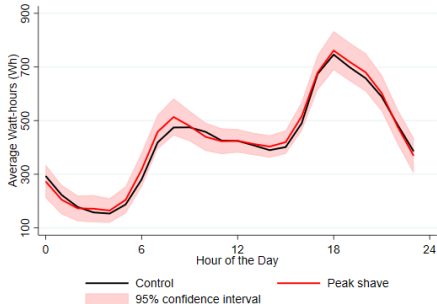
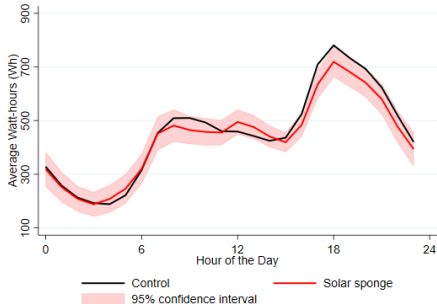
Solar: Routine non-monetary



Non-solar: Routine non-monetary

- Routine non-monetary peak shave incentive *decreases* average usage *per solar household* by 163Wh (8%) during the peak shave window (5pm-8pm)
- *No effect for non-solar households*

Non-solar: Responsive to solar sponge incentives



Non-solar: Routine *solar sponge* 5c/kWh

Non-solar: Routine *peak shave* 5c/kWh

■ Evidence that non-solar users load-shift in response to solar sponge incentives ▶ Wald test

- *Increased* use by 85Wh (6%) in the sponge window (12pm-3pm)
- *Decreased* use by 188Wh (8%) in the shave window (5pm-8pm)

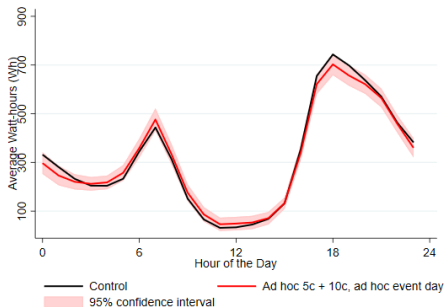
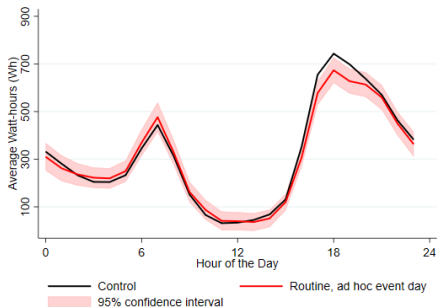
Solar and non-solar households: routine incentives summary

Both household types are *responsive to programs*, but non-solar users more sensitive to incentive design

- Everyday peak shave incentives elicit responses only from solar users who decrease peak usage by 9%
 - no detectable degree of price elasticity from the 0c/kWh-5c/kWh range suggests this customer segment is *motivated by being in a program*
- Non-solar users are responsive to solar sponge incentives by
 - increasing middle-of-the day consumption by 6% *and* decrease evening consumption by 8%
 - observed load shifting from high cost evening use to low cost middle of the day use encouraging for policy makers and retailers

Next: habit formation?

Solar users: similar responses on event days (routine vs ad hoc)

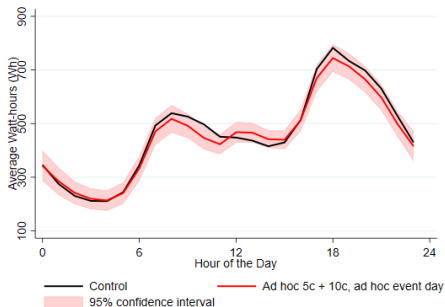
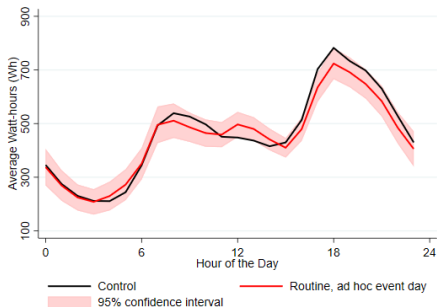


Solar: Event day, *routine* peak shave 5c/kWh

Solar: Event day, *ad hoc* peak shave 5 & 10c/kWh

- Can detect *peak shaving* by *routine* and *ad hoc* groups
- No statistically significant difference in the response across both groups on event days

Non-solar users: similar responses on event days (routine vs ad hoc)

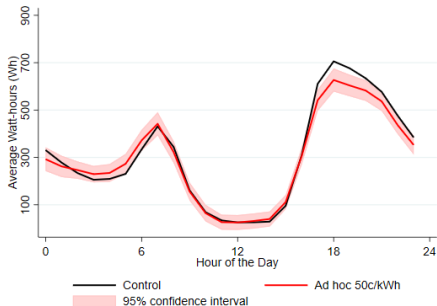


Non-solar: Event day, *routine* solar
sponge 5c/kWh

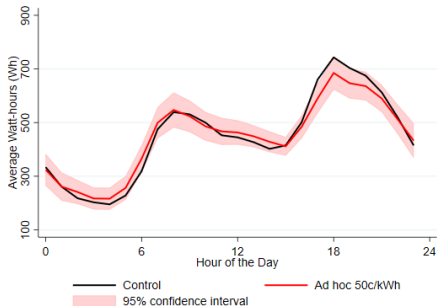
Non-solar: Event day, *ad hoc* solar
sponge (5 & 10c/kWh)

- Can statistically detect *load shifting* by *routine* and *ad hoc* groups
- No statistically significant difference in the response across both groups on event days

Less frequent targeting? 50c/kWh peak shave incentive)



Solar: Event day, ad hoc peak shave (50c/kWh)



Non-solar: Event day, ad hoc peak shave (50c/kWh)

Can statistically detect *peak shaving* by *solar and non-solar households*

- Solar group magnitudes are larger for 50c/kWh than for 5c/kWh incentives but not statistically different
- Shows non-solar group can respond to peak shave incentives if they are large enough

Ad hoc and routine incentives: summary

Responsiveness on event days similar across routine and ad hoc groups

- Demonstrates that both time-of-use and flexible demand programs can impact behaviour to serve their respective purposes (average cost to service versus demand flexibility)
- No evidence of price elasticity for solar users, non-solar users more sensitive to incentive type and level

Puzzle - two distinct user segments

Solar and *non-solar* users differ in their sensitivity to routine incentive type and ad hoc incentive level

- Routine peak shave incentives elicit responses only from solar users who decrease peak usage by 9%
- Non-solar users load shift by increasing middle-of-the day consumption by 6% and decreasing evening consumption by 8% in response to routine solar sponge incentives
- When user types respond to a program their responsiveness on event days is similar across routine and ad hoc groups
- Evidence of price elasticity only for non-solar users

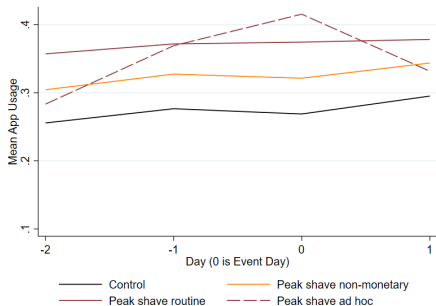
Can we explain these differences with differences in engagement?

Outline

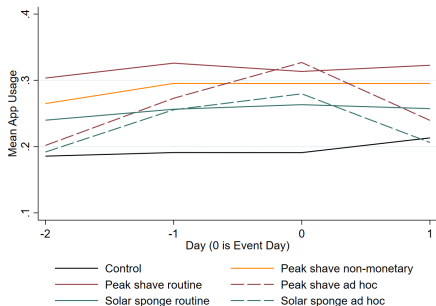
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Solar/non-solar: App engagement

Proportion of users opening the app on and around event days



Solar: App usage



Non-solar: App usage

- Increased engagement for solar and non-solar users across *all* programs
- Engagement spikes for ad hoc groups on event days, but similar average engagement ▶ 50c

Solar/non-solar: Insights from the exit survey

	Solar	Non-Solar	p-value
Completed survey	0.66	0.65	0.61
<i>Financial</i>			
Experiences energy bill distress	0.17	0.25	0.00
Financial motive to load shift	0.43	0.46	0.09
<i>Energy Cognizance</i>			
Education > HS	0.88	0.84	0.00
Searches retail market each year	0.52	0.46	0.00
Time-of-use tariff*	0.45	0.12	0.00
<i>Ability to load shift</i>			
Work from home >2 days	0.37	0.33	0.06
Children at home	0.58	0.53	0.01
Used load timers	0.46	0.36	0.00
Used heating/cooling to load shift	0.66	0.63	0.07

* From metadata

Engagement: summary

- Solar households seem more preconditioned while non-solar household seem more financially motivated to load shift
- *Similar engagement* with load shifting programs across solar and non-solar households
 - Marginal increase in app engagement comparable across solar and non-solar users as well as programs
- Exit survey results suggest that solar households may have a *greater ability* to respond given their greater propensity to
 - work from home
 - use load timers and heating/cooling appliances to load shift

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Procurement and program costs: summary

- Given the load shifting we observe there will exist *some* price series that makes these programs cost effective / welfare improving.
- We see surpluses generated from observed wholesale prices *during our trial period*:
 - Non-monetary incentive reduced wholesale procurement costs for solar customers by an average of \$17 (6.5%) over the trial; or \$12 (4.6%) when including the \$5 participation payment ▶ Procurement costs: solar
 - Routine 5c/kWh solar sponge incentive reduced wholesale procurement costs for non-solar customers by an average of \$29 (9.4%) over the trial; or \$22 (7.1%) when including the program costs ▶ Procurement costs: non-solar
- Given the current trend in solar uptake we expect price differentials to become more favourable in the future

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Discussion

- Changes in aggregate consumption profiles in response to every day *and* ad hoc incentives provide support for time-of-use style tariffs as well as programs that target demand flexibility
- Non-solar households more sensitive to incentive design
 - Non-solar households respond to solar sponge incentives but not to (most) peak shave incentives, despite similar engagement with program
 - greater reported work from home and load timer use by solar households suggests that non-solar may be less able to respond to some programs
 - solar households respond to peak shave incentives with little evidence of being price elastic
- Depending on future price distributions we can create value from tariffs that encourage load shifting
 - Scope for targeting: type of user, type and time of day

Next steps

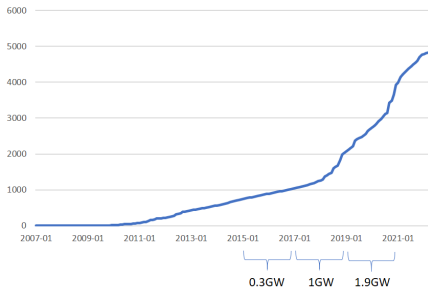
- Exploit post-trial usage data
- Drivers of the solar vs non-solar household differences in program response?
 - Run analysis excluding good solar days to address truncation problem
 - Temperature
- Investigate the heterogeneity of responses more generally (day of week, degree days, location characteristics, etc.)

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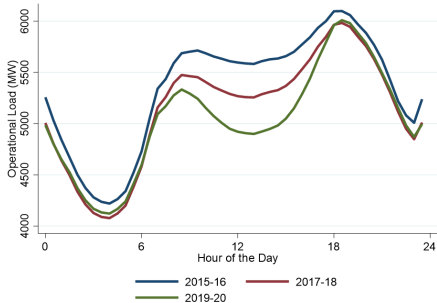
<https://sites.google.com/a/monash.edu/anke-leroux/>

Integrating solar

Rooftop solar capacity (MW), Victoria



Generation net of rooftop PV



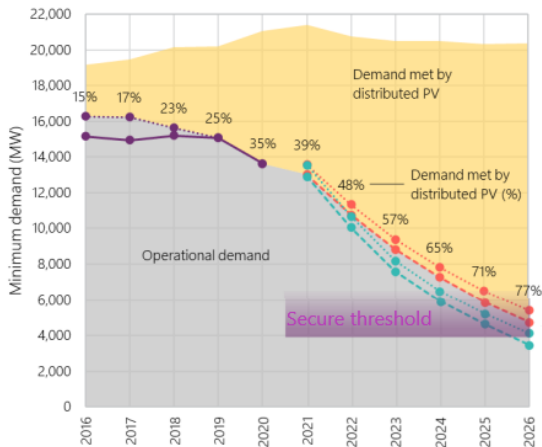
Operational load

- More rooftop solar - less generation needed from other sources

Solar value is growing

- Moving 1kWh from 6pm to midday in 2019-20 would create 11c on average
 - Context on magnitude: Load-weighted w'sale prices for 2019-20 were 9c/kWh
- Selectively moving load from 6pm to midday for highest value days in 2019/20:
 - 25% of days: 17c/kWh shifted
 - 5% of days: 34c/kWh shifted
 - 1% of days: 200c/kWh shifted
- Grid stability benefits from increasing middle of the day demand

AEMO projections of minimum demand



Projected minimum operational demand in the NEM
(Source: AEMO,ESOO2021)

Literature - Time-varying pricing



- Peak pricing and time of use pricing (Faruqi and Sergici 2010, Kessels et al. 2016, Wolak (2006, 2010, 2011, 2021) and non-monetary interventions (Burkhardt et al. 2019, Ito et al. 2018, Jessoe and Rapson 2014), DR trials by Australian retailers - *we test monetary and non-monetary incentives with solar and non-solar households in Australia*
- Mixed evidence on load shifting (Faruqi and Sergici 2010, Wolak 2006, Alcott 2011, Burkhardt et al. 2020) - *our experiment is specifically designed to encourage and test load shifting*
- Incentives to increase consumption versus incentives to reduce consumption (Andersen et al., 2021) - *participants in our trial receive real-time feedback on their consumption and rewards via an app*

◀ Overview


Literature - Habit formation and habituation

- Competing theoretical concepts on the effects of repeated interventions resulting in the desensitisation to the intervention (Thompson and Spencer 1966) or in habit formation (Becker and Murphy 1988)
- Evidence of repeated moral suasion interventions resulting in declining peak load electricity conservation over time (Ito et al. 2018) while repeated monetary incentives found to result in habit formation (Costa and Gerard 2021)
- Frequent real-time feedback on consumption shown to support habit formation in water (Byrne et al. 2021) and electricity conservation (Alcott and Rogers 2014) as well as greater response to monetary incentives (Jessoe and Rapson 2014) - *we compare directly the effects of receiving financial incentives every day versus on an ad hoc basis*

User Experience - solar sponge, ad hoc, 10c

  **MONASH University**

My points

 You've earned **1482 points** so far!

Thanks for taking part in the Solar Sponge challenge!

Collect points by using more electricity use from **12pm-3pm** on event days until the end of the program. We'll notify you 24 hours before your next event day.

At the end of the program you will be rewarded with \$1 for every 10,000 points (10c/kWh shifted), up to a maximum of \$50.

For further details on this program please see the [Explanatory Statement](#) published by Monash University.

Previous events

Date	Result
Mar 26th (12:00pm)	
Mar 23rd (12:00pm)	1482 points

Need some tips on managing your power use during an event? Visit our [energy shifting tips](#).


You should not participate in Solar Sponge events if turning off appliances may be harmful to you or your household.

No longer wish to participate in Solar Sponge: Increasing energy use in the middle of the day? You will not be notified about any future events. If you are currently taking part in an event you will continue to receive notifications until the event is completed.

[Cancel my Solar Sponge enrollment](#)

Solar Sponge event from 12:00pm to 3:00pm on Wednesday 23rd. Earn points by using more power.


Need some tips on managing your power use during an event? Visit our [energy shifting tips](#).



Your average power use for this event was **494W**.

How much can I earn?


You'll earn **300 points** for each **100W** you average.

 Congratulations! You earned **1482 points!**

You should not participate in this event if turning off appliances may be harmful to you or your household.


Solar Sponge: Increasing energy use in the middle of the day

See all your events, track your previous results, and manage your enrollment here:

 Solar Sponge

◀ Shave

User Experience - peak shave, routine, non-monetary



My star rating

★★★

You've earned 3★ so far. Keep it up!

Thanks for taking part in the Peak Shave challenge!

Collect stars by using less electricity from 5pm-8pm on event days until the end of the program.

Stars do not provide any additional functionality or rewards.

For further details on this program please see the [Explanatory Statement](#) published by Monash University.

Previous events	Date	Result
Mar 26th	(5:00pm)	★★★
Mar 23rd	(5:00pm)	★★★

Need some tips on managing your power use during an event? Visit our [energy shifting tips](#).


You should not participate in Peak Shave events if turning off appliances may be harmful to you or your household.

No longer wish to participate in Peak Shave? Reducing energy use in the early evening? You will not be notified about any future events. If you are currently taking part in an event you will continue to receive notifications until the event is completed.

[Cancel my Peak Shave enrollment](#)

Peak Shave event from 5:00pm to 8:00pm on Saturday 26th. Earn stars by keeping your average power usage below 2.2kW.

Need some tips on managing your power use during an event? Visit our [energy shifting tips](#).



Your average power use for this event was 361W.

How much can I earn?	Reward
Average less than 2.2kW	★
less than 1.1kW	★★
less than 550W	★★★

🏆 Congratulations! You earned ★★★!

You should not participate in this event if turning off appliances may be harmful to you or your household.

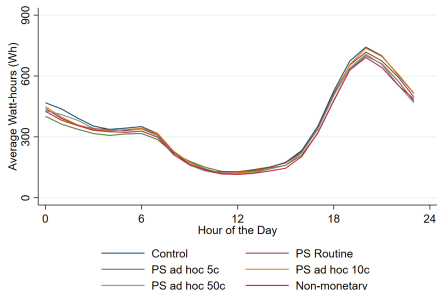
Peak Shave: Reducing energy use in the early evening

See all your events, track your previous results, and manage your enrollment here:

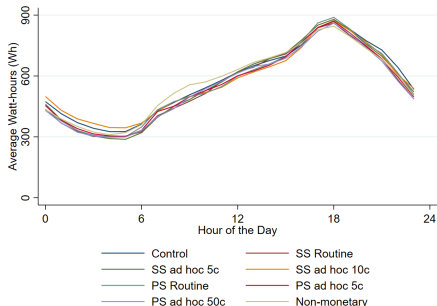
[🏆 Peak Shave](#)

◀ Shave

Randomisation



Solar: pre-trial usage



Non-solar: pre-trial usage

No significant differences in pre-trial electricity usage by hour of day between the treatment groups and the control groups. [◀ Results](#)

[▶ Model specification](#)

Randomisation test: equivalence of load profiles

$$y_{i,h} = \sum_{h=0}^{23} \left[\alpha_h^S H_h S_i + \alpha_h^{NS} H_h S_i (1 - S_i) \right] \\ + \sum_{h=0}^{23} \sum_g \left[\beta_{g,h}^S H_h S_i G_{i,g} + \beta_{g,h}^{NS} H_h (1 - S_i) G_{i,g} \right] + \varepsilon_{i,h},$$

where $y_{i,h}$ is average Wh for each hour of day h by household i , μ_h , is an hour-of-day fixed effect, $S_i = 1$ if the household has rooftop solar, $G_{i,g} = 1$ if hh i is allocated to experimental group g

The tests are

$$\beta_{g,0}^S = \beta_{g,1}^S = \dots = \beta_{g,23}^S = 0; \\ \beta_{g,0}^{NS} = \beta_{g,1}^{NS} = \dots = \beta_{g,23}^{NS} = 0$$

Treatment effects tests: non-solar households

Wald test p-values for tests relating to usage and load shifting: routine incentives

		Solar sponge	Peak Shave	Non-monetary
Aggregate	$\sum_{h=0}^{23} \beta_{g,h} = 0$	0.324	0.661	0.816
Daytime window	$\sum_{h=12}^{14} \beta_{g,h} = 0$	0.177	0.757	0.949
Evening window	$\sum_{h=17}^{19} \beta_{g,h} = 0$	0.019	0.688	0.256
Load shifting (event windows)	$\sum_{h=12}^{14} \beta_{g,h} = 0$ $\sum_{h=17}^{19} \beta_{g,h} = 0$	0.000	0.793	0.236
Load shifting (daytime immediate)	$\beta_{g,12} - \beta_{g,11} = 0$; $\beta_{g,15} - \beta_{g,14} = 0$	0.000	0.830	0.615
Load shifting (evening immediate)	$\beta_{g,17} - \beta_{g,16} = 0$; $\beta_{g,20} - \beta_{g,19} = 0$	0.048	0.444	0.101

Procurement and program costs: Solar households

	Procurement	Procurement and Program	
	(\$, daily average)	(\$, daily average)	(\$, 90-day program)
Control	\$2.91	\$2.91	\$261.90
Routine peak shave (5c/kWh)	\$2.83 (p=0.44)	\$2.92 (p=0.95)	\$262.80
Ad hoc peak shave (5 & 10c/kWh)	\$2.81 (p=0.27)	\$2.86 (p=0.58)	\$257.40
Ad hoc peak shave (50c/kWh)	\$2.72 (p=0.06)	\$2.80 (p=0.25)	\$252.00
Non-monetary	\$2.72 (p=0.05)	\$2.72 (p=0.05)	\$249.80 (\$244.80+\$5)

Note: p-values for Wald test for equivalence to control group listed in parentheses. Program cost for non-monetary group includes the \$5 lump sum participation payment. [◀ Summary](#)

Procurement and program costs: Non-solar households

	Procurement	Procurement and Program	
	(\$, daily average)	(\$, daily average)	(\$, 90-day program)
Control	\$3.51	\$3.51	\$315.90
Routine peak shave (5c/kWh)	\$3.49 ($p = 0.91$)	\$3.64 ($p = 0.50$)	\$327.60
Ad hoc peak shave (5 & 10c/kWh)	\$3.44 ($p = 0.71$)	\$3.50 ($p = 0.98$)	\$315.00
Ad hoc peak shave (50c/kWh)	\$3.40 ($p = 0.45$)	\$3.52 ($p = 0.94$)	\$316.80
Routine solar sponge (5c/kWh)	\$3.18 ($p = 0.01$)	\$3.27 ($p = 0.10$)	\$294.30
Ad hoc solar sponge (5 & 10c/kWh)	\$3.30 ($p = 0.12$)	\$3.35 ($p = 0.25$)	\$301.50
Non-monetary	\$3.46 ($p = 0.76$)	\$3.46 ($p = 0.76$)	\$316.40 (\$311.40+\$5)

Note: p-values for Wald test for equivalence to control group listed in parentheses. Program cost for non-monetary group includes the \$5 lump sum participation payment

[◀ Summary](#)