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The UQ CHARGE-EV Project

FINAL REPORT

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The UQ CHARGE-EV Project

Overview

The UQ CHARGE-EV Project studied the driving and charging behaviour of electric vehicle owners in Australia, and their attitudes and responses to incentives to shift the time of their charging. It leverages the successful UQ Teslascope project launched in 2021. Non-Tesla owners were also recruited for a baseline survey to compare attitudes and beliefs across vehicle make. The *UQ CHARGE-EV Project Baseline Report* concluded that there were some differences between the characteristics of Tesla and Non-Tesla owners but overall attitudes towards shifting the time of charging were similar.

To collect driving and charging data, UQ partnered with the analytics platform Teslascope. Teslascope collects data from consenting Tesla owners and this data is shared with the research team at UQ. Survey data for the project was collected online.

Recruitment of participants for UQ Teslascope project began in November 2021. Recruitment of participants for the UQ CHARGE-EV Project began in November 2022. Incentives to shift charging away from peak periods and to the middle of the day were provided to randomly selected vehicle owners between September and December 2023. Owners without rooftop solar received both rewards, owners with rooftop solar received the peak reduction reward only.

Monetary rewards led to statistically significant shifts in charging behaviour. We estimate that electric vehicle owners without rooftop solar reduced their charging 4pm-8pm by 20-26% and increased their charging 10am-3pm by between 22 and 25%. Owners with rooftop solar reduced their peak charging by 8-25%.

The UQ Teslascope project was funded by Advance Queensland and iMOVE Cooperative Research Australia. The UQ CHARGE-EV Project is funded by Energy Consumer's Australia's Grants Program.

The UQ research team appreciates the participants who made this unique and important research possible.

Background

Transition of energy systems to renewable sources and electrification of transportation are key components of most net-zero emission pathways. Electric vehicles could function as “batteries on wheels’’ to help stabilise the grid and store energy from times of peak renewable production to times of peak consumption, or they could put increasing pressure on the grid if they are predominantly charged at times of peak demand.

In electricity networks with a high proportion of electricity generated by solar, peak renewable production will often occur during the middle of the day. In this project, we assess whether and by how much current electric vehicle owners will shift when they charge their vehicles in response to price incentives.

We randomly assigned half of the 388 eligible vehicle owners recruited for the UQ CHARGE-EV project to the “treatment” group to receive optional monetary rewards to shift their charging. Vehicle owners not assigned to the treatment group received no charging rewards during this period and function as a comparison group for the treatment group – this is to ensure that the effects of the rewards can be distinguished from other changes in charging over time that are not due to rewards (e.g. changes in driving and charging due to seasonality).

The incentives offered were payments for differences in charging compared to a baseline determined using data from the period before rewards were offered. The rewards period started on Monday September 11 and ended on Friday December 8. During this period, all owners in the treatment group earned 20 cents for every kWh they decreased this charge below their baseline between 4pm-8pm Monday to Friday (peak rewards). In addition, electric vehicle owners without rooftop solar in the treatment group earned 20 cents for every kWh they increased their charge above their baseline between 10am-3pm Monday to Friday (sun soak rewards). Because most owners of rooftop solar panels already face strong monetary incentives to charge when the sun is shining, only non-solar owners were eligible for monetary payments to increase their charge during the middle of the day. Both solar and non-solar owners in the treatment group were eligible to receive rewards for reducing charge during the peak period.

Results

Consumption over a 24 hour period

The following figures show the pattern of average electricity use by **non-solar owners** over a 24-hour period before (left) and after (right) treatment for both the control group and the treatment group. Both figures show that non-solar owners are more likely to charge around midday and during the evening-night period. We see a noticeable shift after the treatment with the participants in the treatment group shifting their consumption away from peak hour period.

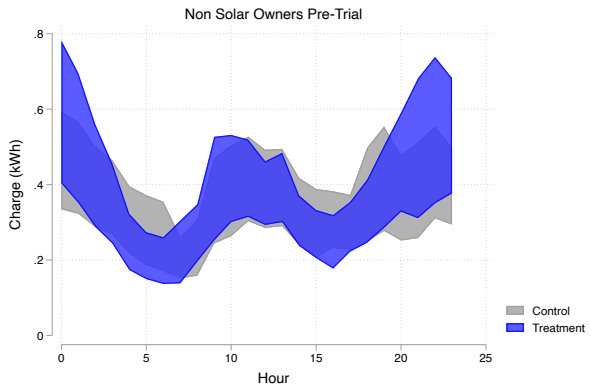


Figure.1a Electricity use by non-solar EV owners before treatment

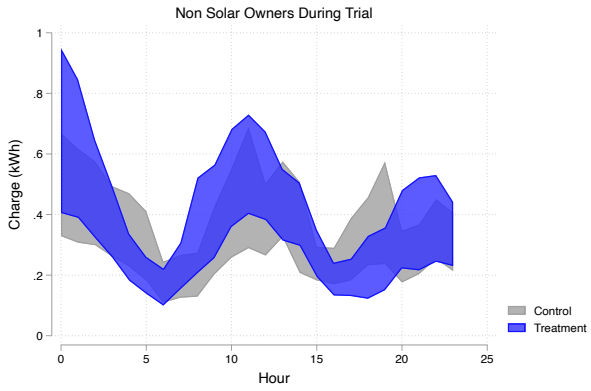


Figure.1b Electricity use by non-solar EV owners after treatment

Insight

As seen in Figure.1a, before the rewards trial began, non-solar owners in treatment and control groups had similar charging profiles. After the rewards period began, treatment owners appear to have shifted their charging towards the middle of the day and away from the peak period, as shown in Figure.1b.

The following figures show the pattern of average electricity use by **solar owners** over a 24-hour period before (left) and after (right) treatment for both the control group and the treatment group. Both figures show that solar owners were already less likely to charge during peak hours before the treatment. The treatment seems to increase this pattern for the treatment group.

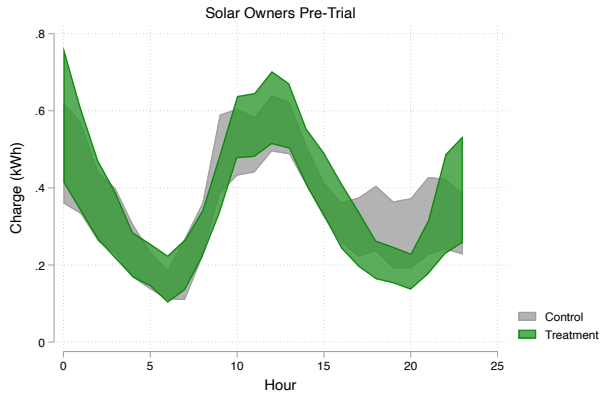


Figure.2a Electricity use by solar EV owners before treatment

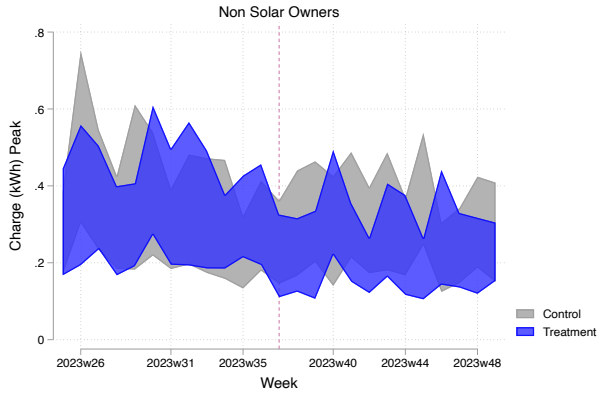
Figure.2b Electricity use by solar EV owners after treatment

Insight

Before the rewards trial began, solar owners in the treatment group had slightly lower charge during peak hours (difference is not statistically significant), as seen in Figure.2a. After the rewards period began, treatment owners had lower charge during more of the peak hours and may have shifted away from the peak period, as seen in Figure.2b.

Consumption over the duration of the study

The following figures show the average electricity use by **non-solar owners** over the duration of the study for the peak hours, 4pm-8pm Monday to Friday, (left) and the sun soak hours, 10am-3pm Monday to Friday, (right) for both the control group and the treatment group. Both figures show that non-solar owners were already less likely to charge during peak hours before the treatment. The treatment seems to have an effect over both time windows.



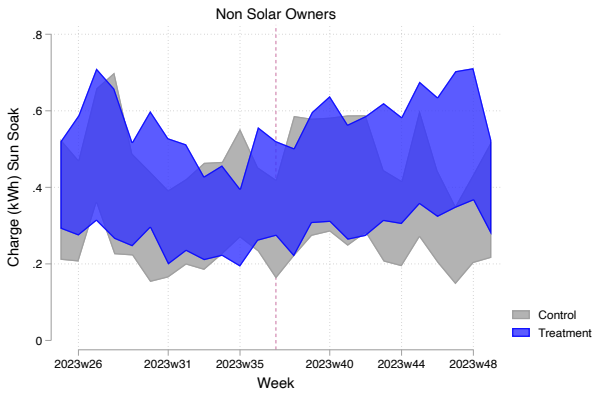


Figure.3a Weekday evening peak hours electricity use by non-solar EV owners before treatment

Figure.3b Weekday sun soak hours electricity use by non-solar EV owners after treatment

Insights

Before the rewards trial began, non-solar owners in treatment and control groups had similar hourly peak (4pm-8pm Monday to Friday) and sun soak (10am-3pm Monday to Friday) charge.

As seen in Figure.3a, after the rewards period began, the average hourly charge during 4pm-8pm Monday to Friday declines for both treatment and control groups however the decline is much larger for the treatment group – the rewards caused owners to shift charging away from the peak period.

As seen in Figure.3b, after the rewards period began, the average hourly charge during 10am-3pm Monday to Friday stays the same for the control group but increases for the treatment group – the rewards caused owners to shift charging towards the sun soak period.

The following figure shows the average electricity use by **solar owners** over the duration of the study for the peak hours, 4pm-8pm Monday to Friday, for both the control group and the treatment group. Both figures show that solar owners were already less likely to charge during peak hours before the treatment. The treatment seems to have an effect with a decrease of peak charging for the treated group.

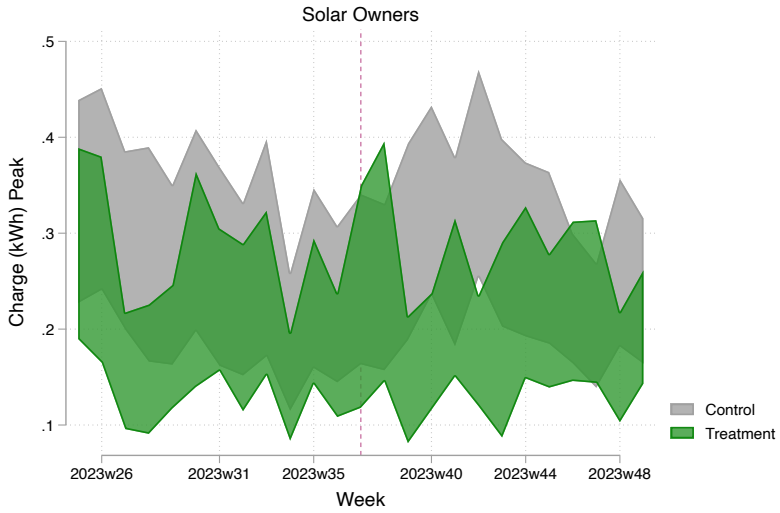


Figure.4 Average electricity use by solar EV owners over the project duration

Insights

Figure 4 shows that before the rewards trial began, solar owners in treatment group had slightly lower average charge during 4pm-8pm Monday to Friday.

After the rewards period began, the average hourly charge during 4pm-8pm Monday to Friday decreases for the treatment group compared to the control group. The rewards caused solar owners to reduce peak charging. This effect appears smaller than the peak effect for non-solar owners.

Hourly charge by period and group

Hourly Charge (kWh) by Period and Group

	Control	Treatment
Non Solar Pre-Trial		
Charge (kWh) Peak	0.352	0.344
	(0.378)	(0.315)
Charge (kWh) Sun Soak	0.368	0.363
	(0.378	(0.325)
Non Solar Trial		
Charge (kWh) Peak	0.305	0.242
	(0.317)	(0.286)
Charge (kWh) Sun Soak	0.387	0.453
	(0.476)	(0.483)
Non Solar Owners	70	70
Solar Pre-Trial		
Charge (kWh) Peak	0.298	0.238
	(0.357)	(0.265)
Charge (kWh) Sun Soak	0.496	0.534
	(0.303)	(0.401)
Solar Trial		
Charge (kWh) Peak	0.274	0.207
	(0.324)	(0.220)
Charge (kWh) Sun Soak	0.540	0.533
	(0.381)	(0.428)
Solar Owners	125	123

Notes: Table reports mean and standard deviation in parentheses of hourly charge (kWh) for peak (4pm-8pm) and sun soak (10am-3pm) for treatment and control groups in both pre-trial and trial periods. Sample includes all pre-trial data. In the trial period, non-solar owners in treatment received rewards to reduce peak charge (4pm-8pm) and increase sun soak charge (10am-3pm). In the trial period, solar owners in treatment received rewards to reduce peak charge.

Table.1 Average hourly charge by period and group for the participants in the control and treatment groups, before and during the treatment

Insights

As outlined in Table 1, before the rewards trial began, there was 0.008 kWh difference in peak charge between non-solar control and treatment and 0.005 kWh difference in sun soak charge. During the rewards trial there was 0.063 difference in peak charge and -0.066 difference in sun soak.

Before the rewards trial there was -0.06 difference in peak charge between solar control and treatment. During the rewards trial there was -0.067 difference.

Treatment effects

Table 2 below shows the estimated treatment effects, using regression analysis, for the three types of situations: non-solar participants for peak and sun soak hours and solar participants for peak hours. The treatment has a significant effect in each situation over the different models estimated (different columns).

Treatment Effects

	(1)	(2)	(3)
	Hourly Charge (kWh)		
Non Solar × Peak	-0.0971***	-0.0891**	-0.0724**
	(0.0262)	(0.0273)	(0.0290)
Solar × Peak	-0.0615**	-0.0463**	-0.0214
	(0.0205)	(0.0202)	(0.0209)
Non Solar × Sun Soak	0.0923*	0.0757*	0.0808*
	(0.0501)	(0.0456)	(0.0451)
Observations	2743872	1856592	1226184

Notes: Table reports results of regressions where the dependent variable is hourly charge in kWh. The sample includes treatment and control owners. The estimates reported are the effect of rewards for each treatment group. Non-solar owners received rewards to reduce peak charge (4pm-8pm) and increase sun soak charge (10am-3pm). Solar owners received rewards to reduce peak charge. All models control for the charging profile of owners with owner by hour of day fixed effects and allow for trends in average charging to differ between solar and non solar owners with solar by date fixed effects. Column 1 includes all pre-trial data. Column 2 restricts the pre-trial data to 2023 only. Column 3 restricts the data to the baseline period where all owners are observed. Standard errors in parentheses are clustered by owner. * ($p < 0.1$), ** ($p < 0.05$), *** ($p < 0.001$)

Table.2 Estimated treatment effects

Insights

Regression analysis, as reported in Table 2, shows that the rewards led to statistically significant and robust changes in charging behaviour:

- Rewards decreased hourly peak charging for non-solar owners by between 0.07 and 0.1 kWh.
- Rewards decreased hourly peak charging for solar owners by between 0.02 and 0.06 kWh.
- Rewards increases sun soak charging by between 0.076 and 0.09 kWh.

Treatment effects on subgroups of participants

Tables 3a and 3b below decompose the effect of the treatment over different subgroups of participants for non-solar and solar owners respectively.

Sub-Group Treatment Effects Non Solar Owners

	(1)	(2)	(3)	(4)
	Hourly Charge (kWh)			
Younger × Peak	-0.105**			
	(0.0326)			
Older × Peak	-0.0864**			
	(0.0387)			
Younger × Sun Soak	0.0747			
	(0.0710)			
Older × Sun Soak	0.116*			
	(0.0604)			
Variable Rate × Peak		-0.0749		
		(0.0464)		
Flat Rate × Peak		-0.108***		
		(0.0301)		
Variable Rate × Sun Soak		-0.00910		
		(0.0879)		
Flat Rate × Sun Soak		0.144**		
		(0.0560)		
New Owner × Peak			-0.102**	
			(0.0431)	
Experienced Owner × Peak			-0.0925***	
			(0.0263)	
New Owner × Sun Soak			0.0142	
			(0.0715)	
Experienced Owner × Sun Soak			0.170**	
			(0.0640)	
Income $<$ \$130,000 × Peak				-0.102*
				(0.0533)
Income $\geq$ \$130,000 × Peak				-0.0879**
				(0.0271)
Income $<$ \$130,000 × Sun Soak				-0.0521
				(0.0776)
Income $\geq$ \$130,000 × Sun Soak				0.165**
				(0.0639)
Observations	923592	923592	923592	855528

Notes: Table reports results of regressions where the dependent variable is hourly charge in kWh. The sample includes non-solar treatment and control owners. The estimates reported are the effect of rewards for each group. Non-solar treatment owners received rewards to reduce peak charge (4pm-8pm) and increase sun soak charge (10am-3pm). All models control for the charging profile of owners with owner by hour of day fixed effects and allow for trends in average charging to differ between solar and non solar owners with solar by date fixed effects. Younger/Older are owners below/above 45. Flat/Variable Rate are owners who have flat/time varying electricity rates. New/Experienced owners have had an electric vehicle for one year or less/more. Standard errors in parentheses are clustered by owner. * ($p < 0.1$), ** ($p < 0.05$), *** ($p < 0.001$)

Table.3a Effect of treatment over different subgroups of non-solar EV owners

Sub-Group Treatment Effects Solar Owners

	(1)	(2)	(3)	(4)
	Hourly Charge (kWh)			
Younger × Peak	-0.0359			
	(0.0300)			
Older × Peak	-0.0811**			
	(0.0262)			
Variable Rate × Peak		-0.0831**		
		(0.0274)		
Flat Rate × Peak		-0.0301		
		(0.0274)		
New Owner × Peak			-0.0443	
			(0.0316)	
Experienced Owner × Peak			-0.0719**	
			(0.0256)	
Income $< \$130,000$ × Peak				-0.0738*
				(0.0390)
Income $\geq \$130,000$ × Peak				-0.0391
				(0.0240)
Observations	1820280	1820280	1820280	1633920

Notes: Table reports results of regressions where the dependent variable is hourly charge in kWh. The sample includes solar treatment and control owners. The estimates reported are the effect of rewards for each group. Solar treatment owners received rewards to reduce peak charge (4pm-8pm). All models control for the charging profile of owners with owner by hour of day fixed effects and allow for trends in average charging to differ between solar and non solar owners with solar by date fixed effects. Younger/Older are owners below/above 45. Flat/Variable Rate are owners who have flat/time varying electricity rates. New/Experienced owners have had an electric vehicle for one year or less/more. Standard errors in parentheses are clustered by owner. * ($p < 0.1$), ** ($p < 0.05$), *** ($p < 0.001$)

Table.3b Effect of treatment over different subgroups of solar EV owners

Insights

As outlined in Table.3a, rewards have a different effect for different sub-groups of non-solar owners. Many of these differences are not statistically significant. However, more experienced owners and higher income owners respond more to sun soak incentives.

As outlined in Table.3b, the effect of treatment rewards on owners with solar panels is constant. No statistically significant differences in the effects of rewards were found.

Acknowledgments

On behalf of the research team, we would like to express our heartfelt appreciation to all the individuals and organisations who have contributed to the successful completion of this research to date.

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