Does disaggregated electricity feedback reduce domestic electricity consumption?
A systematic review of the literature

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Average energy reductions

We examine twelve studies on the efficacy of disaggregated electricity feedback. The weighted-average electricity reduction across these studies is 4.5%. There is a lot of uncertainty associated with the existing evidence and many subtleties and caveats. For full details, please see Kelly and Knottenbelt 2016.

Biases

4.5% is likely to be a positively-biased estimate of the savings achievable across the entire population because all twelve studies are likely to be prone to 'opt-in' bias. Hence none test the effect of disaggregated feedback on the general population. The average opt-in rate is 16%. Hence a crude estimate of the population-wide energy reductions with disaggregated data is 4.5% × 16% = 0.7%. Many of the studies are prone to multiple other sources of bias.

Disaggregated versus aggregate feedback

Disaggregation may not be *required* to achieve these energy reductions: *Aggregate* feedback alone drives 3% reductions (Davis et al. 2013); and the four studies which directly compared aggregate feedback against disaggregated feedback (McCalley & Midden 2002, Krishnamurti et al. 2013, Churchwell et al. 2014, Sokoloski 2015) found that aggregate feedback is *at least as effective* as disaggregated feedback, possibly because web apps are viewed less often than in-home-displays (in the short-term, at least) and because some users do not trust fine-grained disaggregation (although this may be an issue with the specific user interface studied).

Disaggregation has many uses beyond those discussed here. But, on the specific question of promoting energy reduction in the general population, there is no robust evidence that current forms of disaggregated energy feedback are more effective than aggregate energy feedback.

Energy enthusiasts

Disaggregated electricity feedback may help a motivated sub-group of the population ('energy enthusiasts') to save more energy but fine-grained disaggregation may not be necessary to achieve these energy savings. HEA achieved 6.1% reductions despite using coarse-granularity disaggregated feedback.

Effectiveness may increase in the future

The effectiveness of disaggregated feedback may increase if:

- The general population become more energy-conscious (e.g. if energy prices rise or concern about climate change deepens);
- Or if users' trust in fine-grained disaggregation increases;
- Or if innovative new approaches or alternative disaggregation strategies (e.g. disaggregating by behaviour rather than by appliance) out-perform existing feedback.

More field studies required!

- Need large, **opt-out**, randomised controlled trial.
- Compare agg. feedback on IHD vs. disag. feedback on IHD.
- Compare (agg. on IHD *with* disag. on website) vs. agg. on IHD.
- Compare fine-grained versus coarse-grained disag. feedback.

Study	Feedback presentation	Num. houses in disag. group	Num. houses in study	Num. disaggregation categories	Duration (months of disag)	Reduction in electricity use^U (%)	Reduction is for whole house?	Sample period of meter	Feedback delay	Timing: Historic or Concurrent?	Time frames for historic^T	Recommendations given?^{R}	Control group?	Controlled for Hawthorne?	Volunteer bias?^{V}	Controlled for weather?
"RECS" Dobson and Griffin 1992	dedicated computer	25	100	~ 8	2	12.9	✓	0.6 sec	0	H&C	HDM	✗	✓	✓	L[a]	✓
McCalley and Midden 2002	Virtual washing machine[b]	25	100	1	-	0.0	✗	-	0	H&C	-	G	✓	✓	L	-
Wood and Newborough 03; Mansouri and Newborough 99	LCD by cooker	10	44	1	≥ 2	12.2	✗	15 sec	0	C	-	✗[c]	✓	✓	L	✓
"ECOIS-I" Ueno et al. 2006b; Ueno et al. 2006c	Dedicated laptop	8	8[d]	16	2	9	✓	30 min	next day	H	D, 10D	P	✗	✗	H#	✓[e]
"ECOIS-II" Ueno et al. 2005; Ueno et al. 2006a; Ueno et al. 2006c	Dedicated laptop	10	19	16	3	18	✓	30 min	next day	H	D, 10D	P	✓	✓	H#	✓
"EnergyLife" trial 1 Jacucci et al. 2009; Spagnolli et al. 2011; Gamberini et al. 2011	iPhone	13	13	7	3	5	✓	?	1-2 min	H&C	D	P	✗#	✗#	H#	✗#
"EnergyLife" trial 2 Gamberini et al. 2012	iPhone	4	4	7	4	38	✗	?	1-2 min	H&C	D	P	✗	✗#	H#	✗#
Home Energy Analytics HEA 2012; HEA 2013; Brown 2014; HEA 2015	Web & email & home visits	1623	1623	5	≤ 44	6.1	✓	hourly	0	H	Y	P	✗	✗	L	✓
Bidgely Chakravarty and Gupta 2013; Gupta and Chakravarty 2014	Web, mobile, email	163	328	≥ 3?	-	6	✓	30 sec & 1 hr	0[f]	H&C[f]	DBY	P	✓	✗	H	✓
PG&E Pilot Churchwell et al. 2014; Bidgely 2015	Web, mobile, email	844	1685	≥ 3?	3	2.1	✓	30 sec	0[f]	H&C[f]	DBY	P	✓	✗	H	✓
Schwartz et al. 2015	Web, mob, TV	6	6	~ 10	18	7.8	✓	?	0?	H&C	?	?	✗	✗	H	✗
Sokoloski 2015	Web, mob, email	12	70	≥ 3?	0.75	3	✓	30 sec	0[f]	H&C[f]	DBY	P	✓	✗	L	✓

A dash '-' in a cell means 'not applicable (NA)' and '?' means 'not specified in paper'.

^{U} Absolute reductions minus reductions for the no-contact control (or the most similar group to a no-contact control available).

^{R} Recommendations can be 'P' for 'personalised' or 'G' for 'general' or '✗' for none given.

^{V} Volunteer bias can be 'H' for 'high' (subjects sought out the intervention) or 'L' for 'low' (subjects were approached by the experimenters but only a fraction agreed to participate).

^{T} H=hourly, D=daily, M=monthly, Y=yearly, B=current billing cycle.

\# Paper is silent on this question. Assume the worst.

[a] Dobson and Griffin 1992 do not state exactly how households were recruited. They write "*100 all-electric households were qualified from a random sample drawn from a population of approximately 8800 such houses*". I assume households were not *forced* to participate so they must have self-selected to some extent.

[b] A washing machine control was simulated on a computer. The reported energy reduction is *only* for the simulated washer. The no-feedback-no-goal condition and the feedback-no-goal conditions achieved the same reduction (11%), hence the difference in energy savings between those two conditions is 0%.

[c] One group received both real-time energy feedback for the cooker and a printed information pack of general recommendations but this group achieved lower energy savings (8.9%) than the group which only received energy feedback.

[d] ECOIS-I started with 9 houses but one house was excluded because it had solar PV installed.

[e] Ueno et al. 2006b report that the "*average ambient temperatures before and after installation were 6.4 and 6.8 °C, respectively. Generally, the power consumption of the whole household increases with the fall in ambient temperature in winter; hence, it is thought that the true effect was more than this 9% value.*"

[f] Aggregate data was displayed real-time. Disaggregated data was not real-time.

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