

Incentivising households to reduce electricity consumption

A meta-analysis of the experimental evidence

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AIEE, Rome



Context

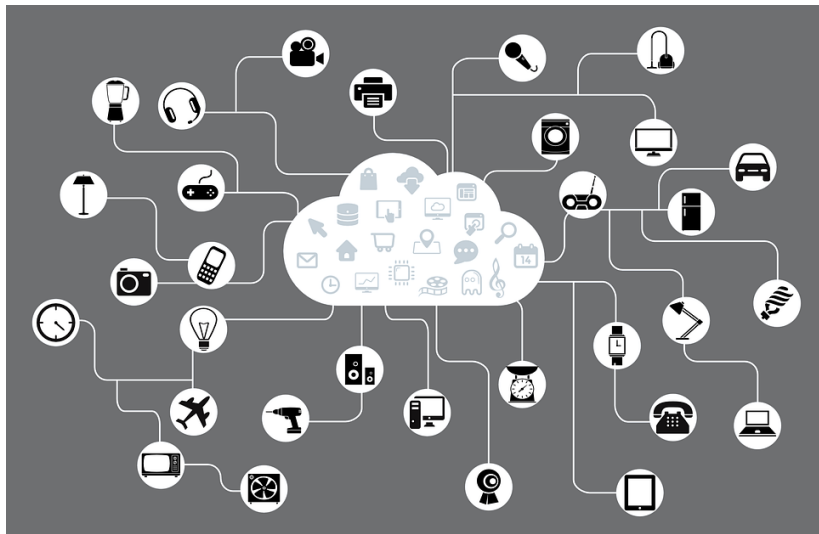


20% reduction in CO₂ emissions (1990 levels)

20% increase in renewable energy share

20% improvement in energy efficiency

Context



Objectives

Exploring the effect of different incentive mechanisms on residential electricity consumption.

Analysing which incentives are the most effective at reducing residential electricity consumption.

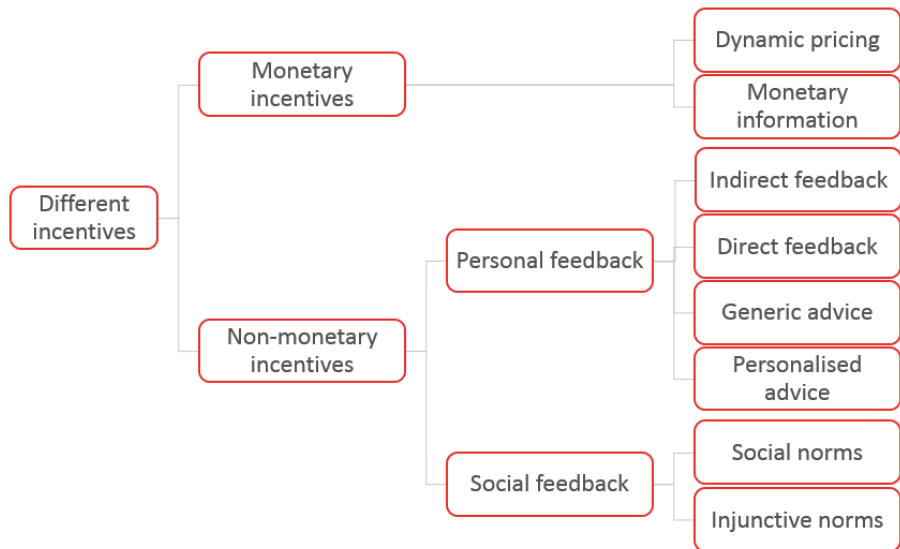
Definition

A meta-analysis is a **quantitative method** of systematically analysing the results of **empirical studies** which explore a **common objective**.

The idea is to calculate the **mean effect** across studies in order to obtain a more **precise estimate** of the **true effect** being studied.

(Stanley and Jarrell 1989; Nelson and Kennedy 2009).

Incentive mechanisms



Previous meta analyses

Authors	Objective	Timeframe	Effect size
Darby (2006)	Direct and indirect feedback	1979-2006	Direct: -15% to -5% Indirect: -10% to 0%
Ehrhardt-Martinez et al. (2010)	Different feedback treatments	1974-2010	-12% to -4%
Faruqui et al. (2010)	IHD feedback	1989-2010	-13% to -3%
Delmas et al. (2013)	All treatment types	1975-2010	-55% to +18% ATE : -7.4%
McKerracher and Torriti (2013)	IHD feedback	1979-2011	-5% to -3% ATE: -6.4%

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Previous meta analyses

Ehrhardt-Martinez et al. (2010)

Energy Crisis Era	1970s - 1995	-10.3%
Climate Change Era	1995 - 2005	-8.2%

McKerracher and Torriti (2013)

Pre Smart Grid Era	1979 - 2004	-11.06%
Smart Grid Era	2005 - present	-4.46%

Previous meta analyses

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"[...] studies that compare feedback-related savings across all four decades may result in inflated expectations regarding potential energy savings today." (Ehrhardt-Martinez et al. 2010)

Study selection criteria

- Date range: "Smart Grid Era": 2005 - 2016 (McKerracher and Torriti 2013).
- Databases consulted: Web of Science, ScienceDirect, Ebsco, EconPapers, SpringerLink, NBER, SSRN.
- Study type: Peer-reviewed articles, working papers, utility or government reports written in English.
- Quantitative studies, i.e.: field experiments, pilot studies.

Study selection criteria

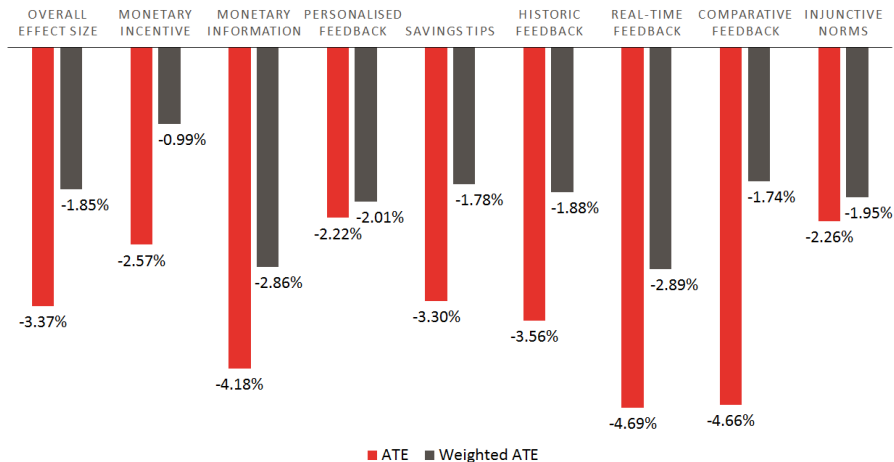
Type of consumption	electricity consumption, electricity demand, electricity usage
Level of consumption	residential, household, consumer
Type of study	pilot, trial, experiment, field
Type of incentive	smart meter, advanced meter, feedback, nudge, norm, dynamic pricing

Geographical distribution of observations

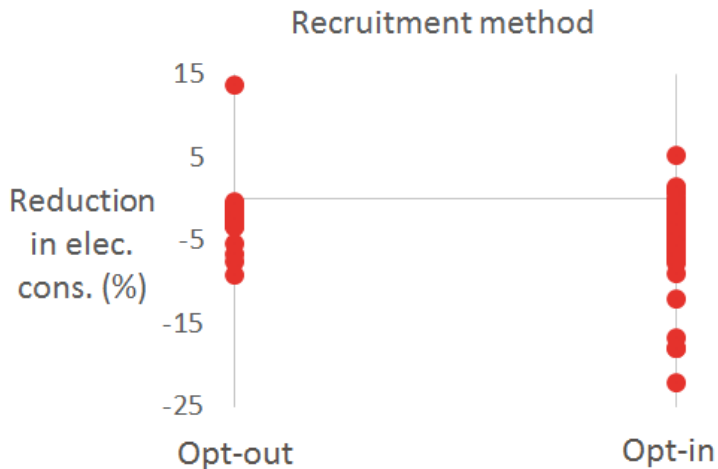
39 studies - 105 observations



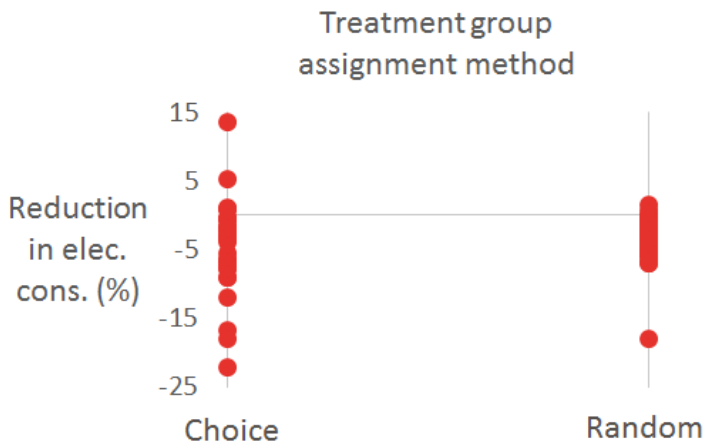
Average treatment effects



Effect size distribution by study characteristic



Effect size distribution by study characteristic



Econometric analysis results

Savings tips

Generic savings tips do not help to reduce electricity consumption.

Indirect and direct feedback

Significant negative effect on electricity consumption.

Social and injunctive norms

Significant negative effect on electricity consumption.

Control group

Studies without a control group tend to overestimate the extent of possible electricity reduction.

Duration

The longer studies continue, the smaller the effects on electricity consumption.

Peer reviewed

Peer reviewed studies tend to understate the electricity reduction effects of incentives.

Key findings

- On average, an incentive can be expected to reduce residential electricity consumption by **1.85%** or **3.37%**. This is much lower than predicted by previous meta-analyses (6.4% and 7.4%).
- Direct feedback and monetary information have the greatest average treatment effect of **nearly 3%** (accounting for sample size).
- Social norms achieve electricity consumption savings regardless of injunctive norms.
- When households choose to participate in studies, larger percentages of electricity savings are observed.
 - **A national deployment of an incentive mechanism may lead to smaller effects on consumption than predicted by the literature.**

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Hypotheses

- H1 Economic incentives (monetary information, dynamic pricing) have a negative effect on electricity demand
- H2 Information (historic, personalised, and comparative) has a negative effect on electricity demand
- H3 Comparative feedback in the absence of injunctive norms has no significant effect on electricity demand
- H4 Studies with an opt-in recruitment method show a larger negative effect of an incentive on electricity demand
- H5 Peer reviewed studies show a smaller effect of an incentive on electricity demand

Model

$$\tilde{\beta}_i = \alpha_0 + \alpha_1 x_{i1} + \dots + \alpha_K x_{iK} + e_i$$

- where (x_{i1}, \dots, x_{iK}) is a vector of study characteristics, and $(\alpha_1, \dots, \alpha_K)$ are unknown parameters
- The model is estimated by weighted least squares (WLS) using the inverse standard error as weights to correct for heteroscedasticity (Nelson and Kennedy 2009).
- As standard errors are not always reported in the primary studies, the model will be weighted by the inverse square root of the sample size. As such, studies with a larger sample size are given more weight.

WLS regression

	(1) Full model	(2) Monetary	(3) Personal feedback	(4) Social feedback	(5) Study design
Monetary incentive	1.318 (1.571)	2.790 (1.462)			
Monetary information	2.492 (1.414)	0.662 (1.384)			
Personalised advice	-0.746 (2.425)		0.562 (2.021)		
Saving tips	4.069* (1.967)		4.385* (2.104)		
Individual feedback	-3.919* (1.675)		-3.115* (1.358)		
Real-time feedback	-2.138 (1.584)		-0.651 (1.415)		
Social norms	-4.518* (2.174)			-4.316 (2.387)	
Injunctive norms	-3.238 (3.281)			-5.000* (1.998)	

WLS regression

	(1)	(2)	(3)	(4)	(5)
	Full model	Monetary	Personal feedback	Social feedback	Study design
Control group	11.161*** (2.840)	7.278* (3.307)	10.790** (3.259)	8.483* (3.414)	7.642* (3.489)
Weather controls	-0.671 (1.985)	-0.095 (1.436)	0.804 (1.449)	0.856 (1.385)	0.671 (1.311)
Demographic controls	2.455 (2.776)	1.295 (2.631)	1.314 (2.857)	2.524 (3.118)	1.104 (2.962)
Random assignment	-2.783 (2.457)	-1.704 (2.216)	-2.727 (2.446)	-1.642 (2.777)	-1.490 (2.419)
Opt-in recruitment	-3.262 (2.840)	-1.604 (1.554)	0.546 (1.710)	-3.795 (2.179)	-0.466 (1.336)
Duration	0.325** (0.111)	0.198 (0.102)	0.265* (0.119)	0.205 (0.105)	0.170 (0.103)
Peer reviewed	5.801** (1.883)	4.638** (1.698)	4.208* (1.840)	4.831** (1.635)	3.503* (1.549)
Constant	-17.496** (5.348)	-15.394*** (4.160)	-19.722** (5.760)	-14.319** (4.352)	-14.936** (4.201)
Observations	105	105	105	105	105

Standard errors in parentheses. Standard errors are clustered by primary study.

Inverse square roots of sample size are used as analytical weights.

A negative coefficient reads as a reduction in energy consumption.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

FGLS regression

	(1) Full model	(2) Monetary	(3) Personal feedback	(4) Social feedback	(5) Study design
Monetary incentive	0.800 (0.869)	2.402*** (0.497)			
Monetary information	2.041* (0.824)	-1.033 (0.591)			
Personalised advice	-0.242 (1.035)		0.172 (0.829)		
Saving tips	2.918*** (0.701)		2.499*** (0.644)		
Individual feedback	-1.852* (0.773)		-1.321* (0.628)		
Real-time feedback	-2.661*** (0.773)		-2.114** (0.689)		
Social norms	-4.866*** (1.059)			-2.891** (0.951)	
Injunctive norms	-0.943 (1.652)			-2.186 (1.301)	

FGLS regression

	(1)	(2)	(3)	(4)	(5)
	Full model	Monetary	Personal feedback	Social feedback	Study design
Control group	9.941*** (1.198)	5.007*** (1.084)	7.112*** (1.471)	7.218*** (0.879)	6.493*** (0.934)
Weather controls	-0.199 (0.702)	-0.032 (0.667)	0.576 (0.613)	0.289 (0.762)	0.270 (0.566)
Demographic controls	-0.277 (1.204)	1.299* (0.532)	0.634 (0.907)	2.053* (0.956)	1.363 (0.801)
Random assignment	-1.895* (0.952)	-1.285* (0.517)	-1.691* (0.685)	-0.515 (0.734)	-0.864 (0.526)
Opt-in recruitment	-0.784 (1.443)	-0.487 (0.627)	0.605 (0.659)	-1.041 (1.107)	-0.087 (0.513)
Duration	0.199*** (0.045)	0.130*** (0.034)	0.168*** (0.040)	0.109** (0.034)	0.088** (0.030)
Peer reviewed	3.171*** (0.891)	2.907*** (0.606)	1.838** (0.705)	2.893*** (0.601)	1.833*** (0.538)
Constant	-14.511*** (2.193)	-11.604*** (1.613)	-13.363*** (2.377)	-13.341*** (1.745)	-12.201*** (1.428)
Observations	105	105	105	105	105

Standard errors in parentheses. Panel data methods group observation by primary study.

Inverse square root of sample size is used as analytical weights.

A negative coefficient reads as a reduction in energy consumption.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Verification of hypotheses

- H1: Partially Monetary information reduces electricity consumption, monetary incentives increase it.
- H2: Mostly Generic savings tips do not reduce, individual and real-time information decrease electricity consumption.
- H3: Rejected Comparative feedback reduces electricity consumption both with and without injunctive norms.
- H4: Verified Greater levels of reduction in energy consumption are achieved on an opt-in basis.
- H5: Verified Peer reviewed studies show a smaller reduction in electricity consumption.