When does it work?

The Effect of a Smart Meter Mobile Application on Korean Residential Electricity Consumption

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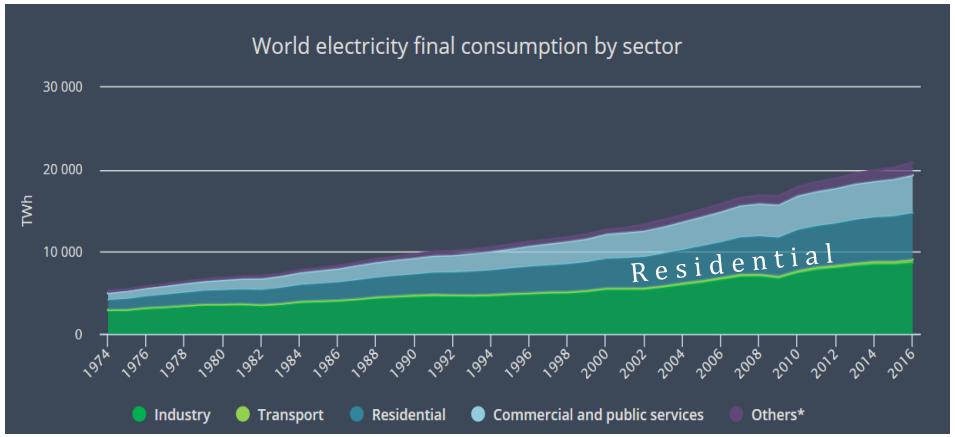
Motivation

Residential Sector Electricity Consumption

- **27%** of world total final electricity consumption in 2016 was from residential sector (IEA, 2018)

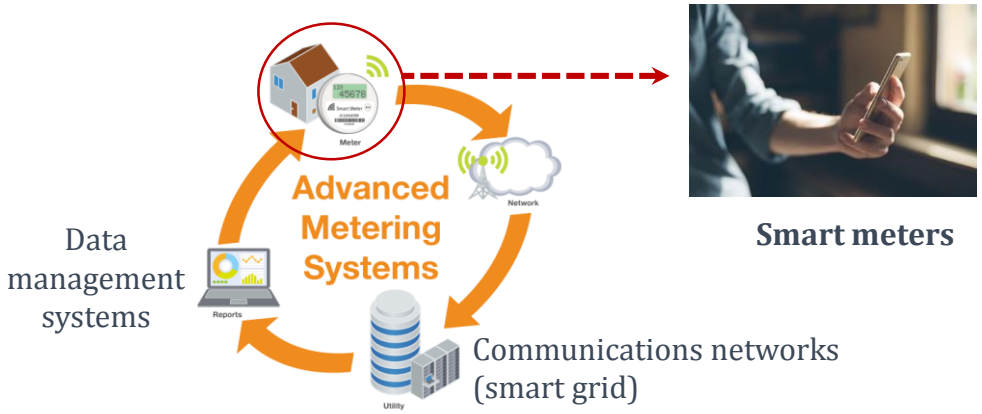


Source : IEA electricity statistics

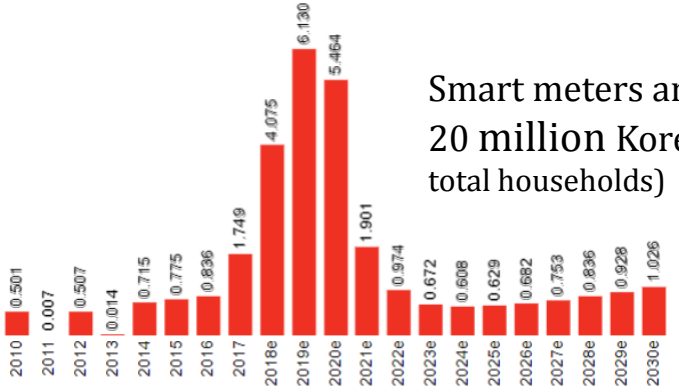
In South Korea…

- The electricity consumption of the residential sector doubled since 2000
- Total electricity consumption increased in 2018: the highest growth has been driven by the residential sector (6.3% rise)

New Technology as a Solution?



South Korean's Smart meter coverage



BNEF projection of smart meter dissemination in Korea

Smart meters are projected to be installed in over 20 million Korean homes by 2020 (over 80 % of the total households)

78.5 millions homes owns (2017)

99.5 million homes (by 2020)

Motivation

Smart meter feedback can lead to energy savings

- Smart meter can fill the **'information vacuum'** → Increases the **visibility** of energy → Trigger energy saving behavior (Fisher, 2008)
- A smart metering program from Austria and Germany showed **an average of about 3.7% electricity consumption reduction** (Schleich et al., 2011)
- **42 empirical studies on s**mart meter feedback - an average of **7% energy reduction** (Kalin et al., 2015)
- **Tailored messages, personalized information, and interactive tools would lead to higher user engagement** which can result in energy usage reduction (Bager & Mundaca, 2017 & Schultz, 2015)

➢ **Is the reduction effect sustain in the long-term?**
➢ **Experiment vs. natural setting**

The saving effect is not persistent

- Device may **lose its novelty and the initial enthusiasm** fades away into the background of daily life (Buchanan et al., 2011)
- **Knowledge** (energy consumption) **alone does not motivate the users** to reduce their consumption (Hargreaves, 2010)
- A year after the smart meter intervention experiment with the same participants
  - ✓ **The savings achieved during the study did not maintain after a year** (Wemyss et al. 2019)

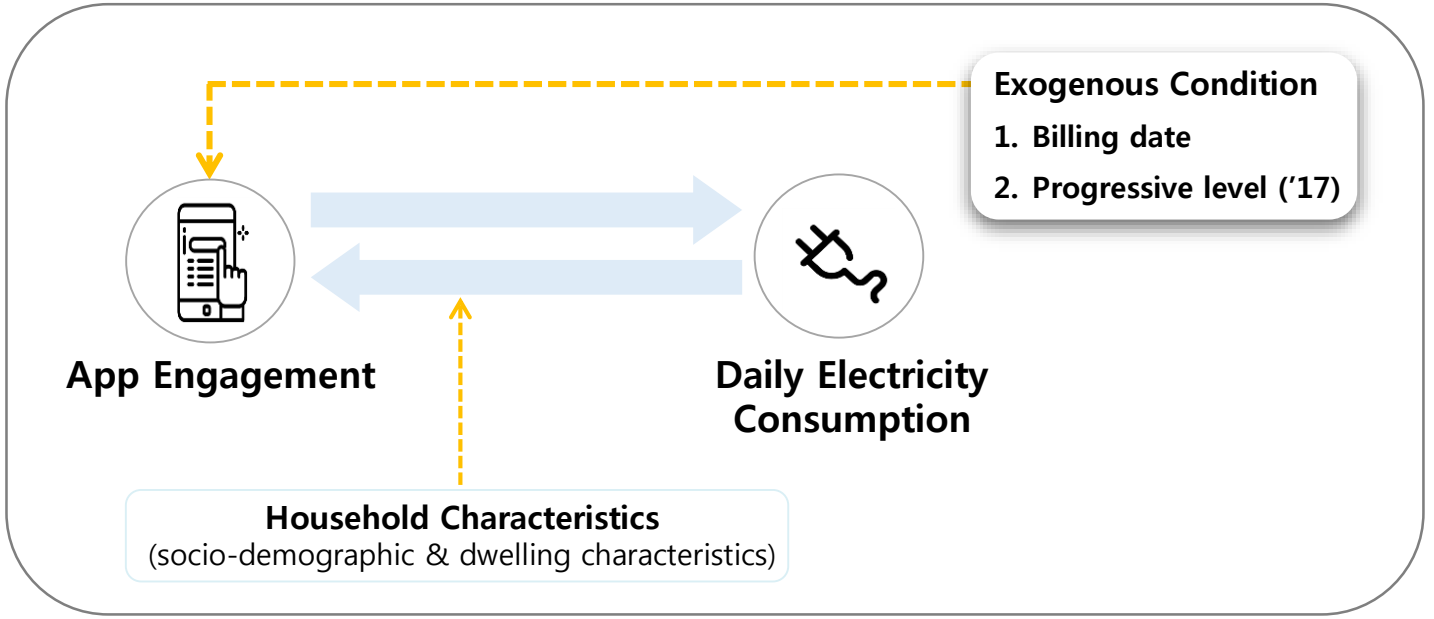
➢ **Can we conclude that smart meter is not effective in energy saving?**

When does increased knowledge lead to behavioral change?

H1: When the smart meter app is monitored on any given day of the month, the electricity consumption decreases on the following days

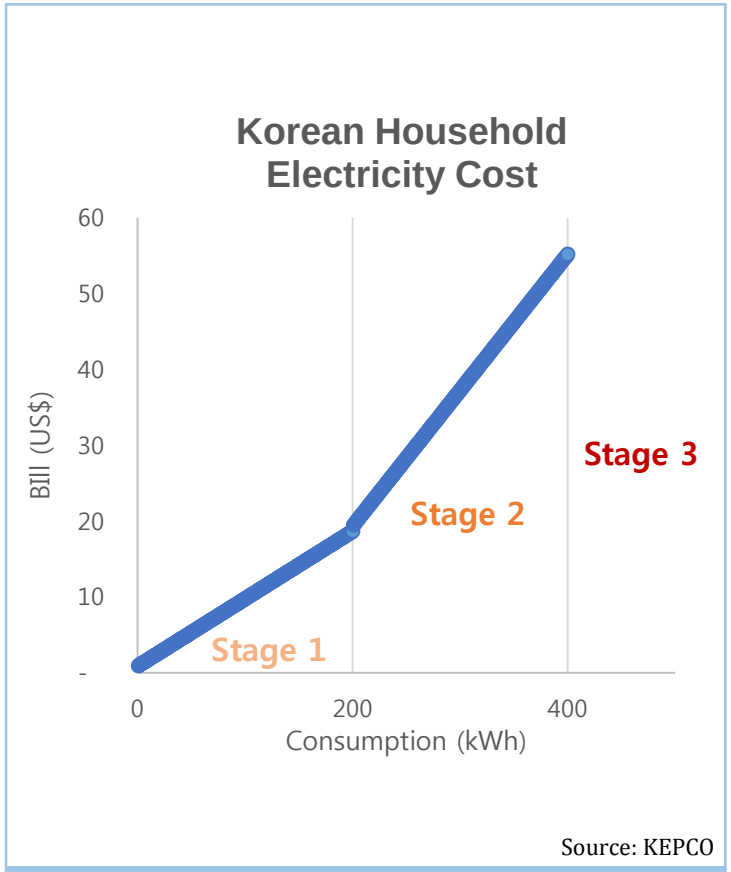
H2: When the electricity consumption is increased or decreased by a consumer, he/she monitors the smart meter app on the following days

H3: When the smart meter app is monitored before or after entering the next progressive tariff stage, the electricity consumption decreases

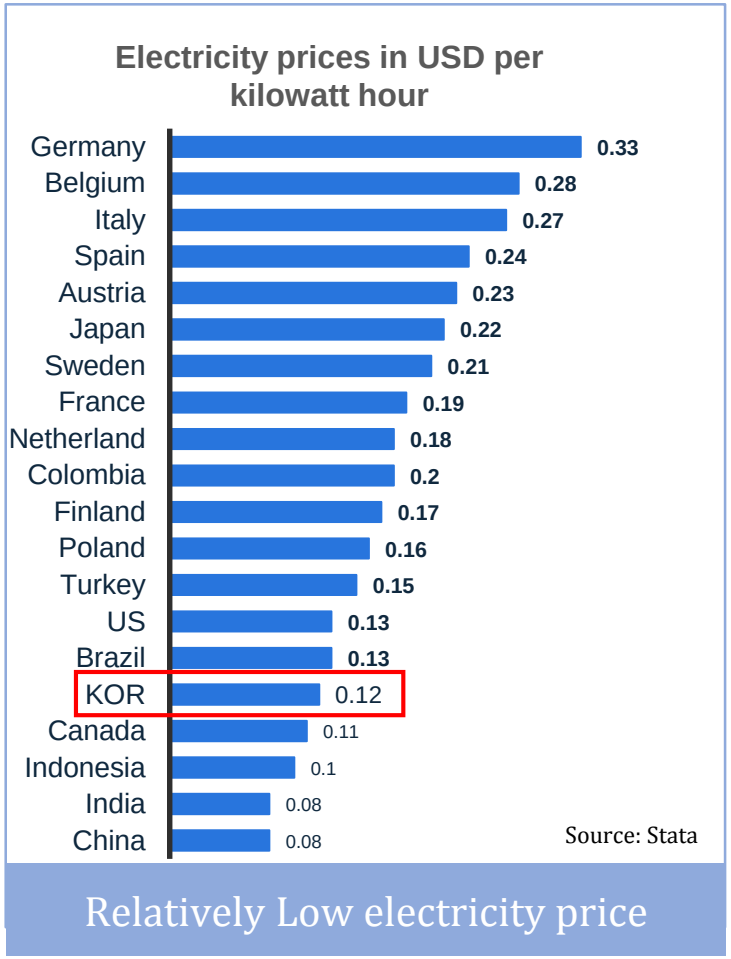


The research was conducted in South Korea which has a unique electricity market

One Electricity Retailer



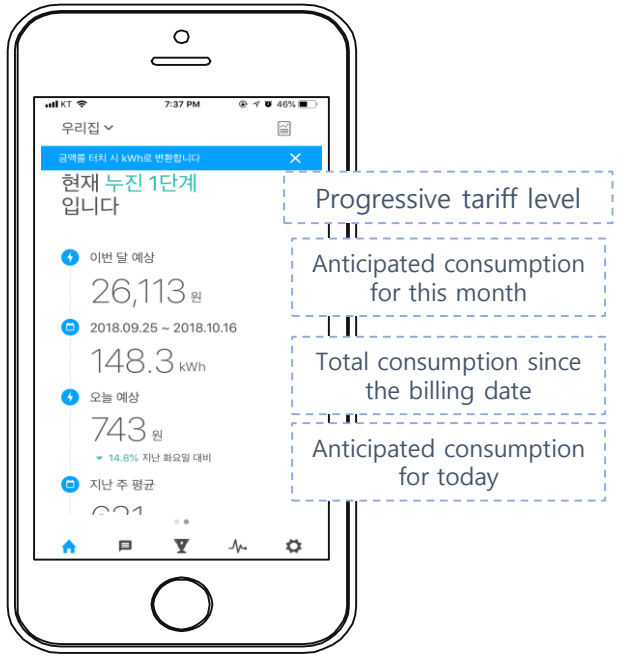
Progressive electricity tariff system



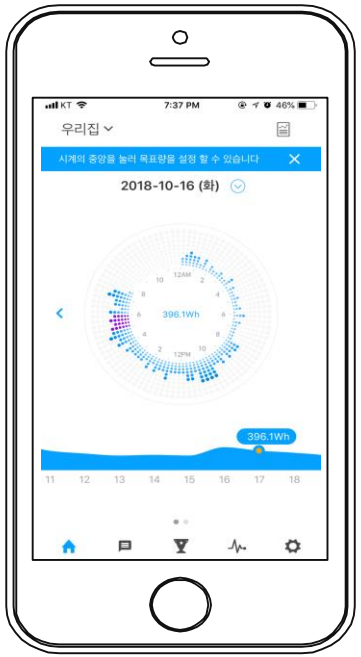
Relatively Low electricity price

Smart meter device - EnerTalk

- Released in 2015 (1st Smart meter service provider in Korea)
- It is based on IoT technology measuring the electricity consumption of a household with the real-time information provided through the EnerTalk mobile application
- Improving In-home display's (IHD) shortcomings



<Bill Manager>



<Energy Clock>

<Energy Mission>

**Majority of the users have used the EnerTalk more than 6 months (74%), thus we presumed that the users are aware of the information when they open the app*

Panel electricity consumption observation data

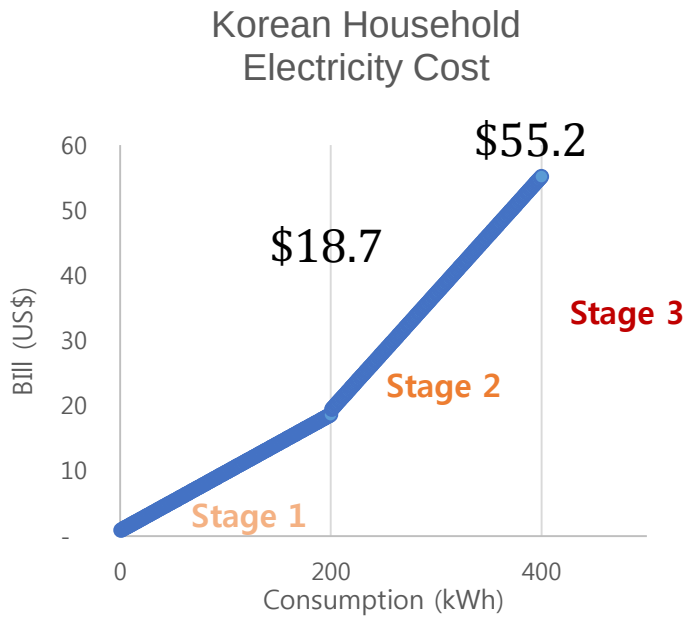
- Observation period : 2017 9/1~11/30 (October)
- Daily consumption per household
- (Monthly) The total consumption for October month was aggregated based on individuals' billing date

Panel EnerTalk log-in data

- Observation period : 2017 9/1~11/30
- Binary data reveals the app check (binary variable)
  - User's last app log-in time

Table 1. Summary statistics

Number of Observations	284 (households)			
Variables	Mean / %	Std. dev.	Min	Max.
Average daily electricity consumption in October (kWh)	7.95	3.13	0.37	26.89
Average total electricity consumption in October (kWh)	238.08 ($26)	90.69	7.34	767.2
The proportion of each progressive level (%)				
Level 1: 0 - 200 kWh	32.40%			
Level 2: 201 - 400 kWh	**63.70%**			
Level 3: over 401 kWh	3.90%			
EnerTalk mobile app usage frequency in October (times)	3.68	5.58	0	30



Who are the EnerTalk Panels?

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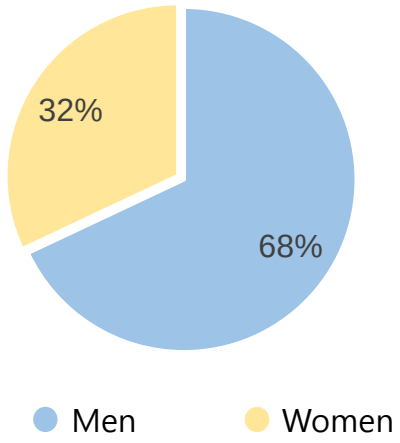
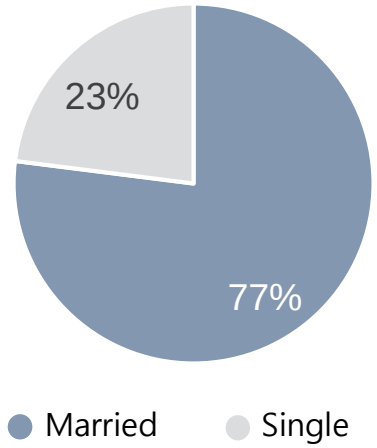
Gender

(n=284)



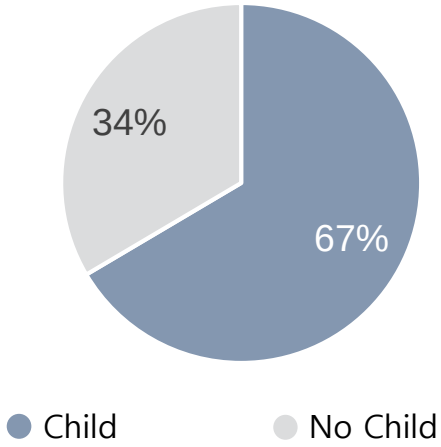
Marital Status

(n=284)



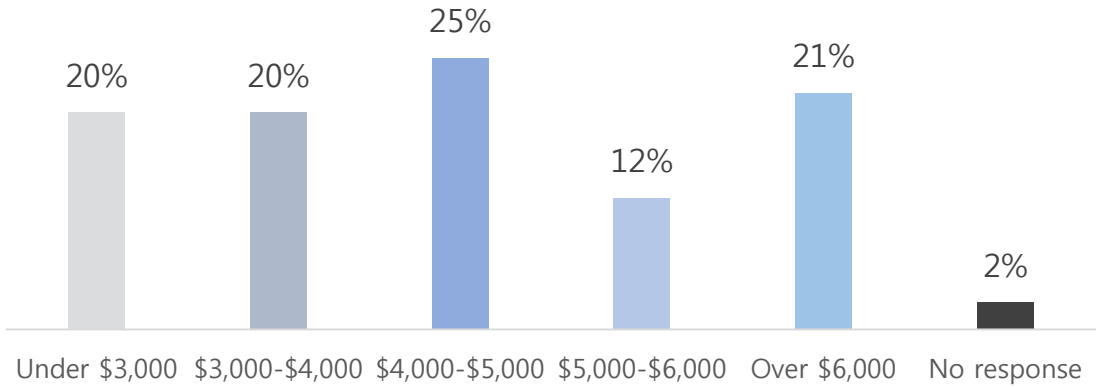
Child/ No child

(n=284)



Income Distribution

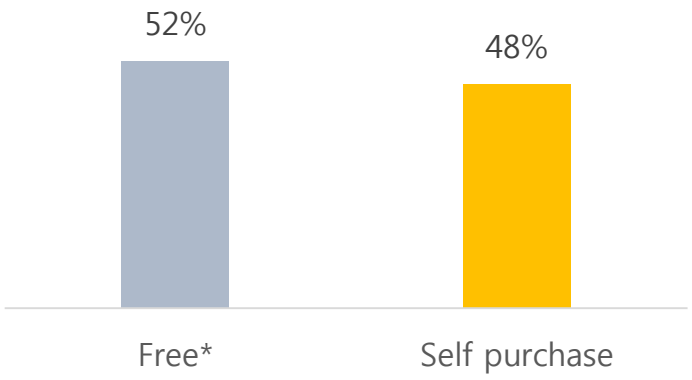
(n=284)



Who are the EnerTalk Panels?

EnerTalk Purchase Type

(n=284)



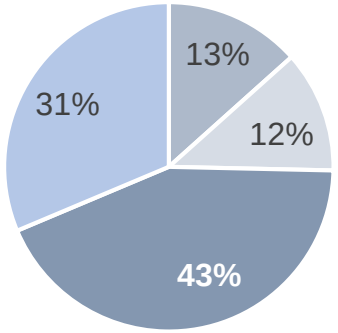
*some 'Smart apartments' have already installed the smart meters

EnerTalk Usage Period

(n=284)

Long-term users (Over 6 months)

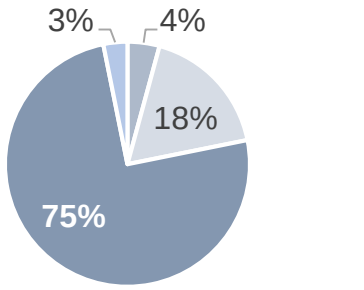
74%



1 - 3 months 3 - 6months 6 - 12months Over 1 year

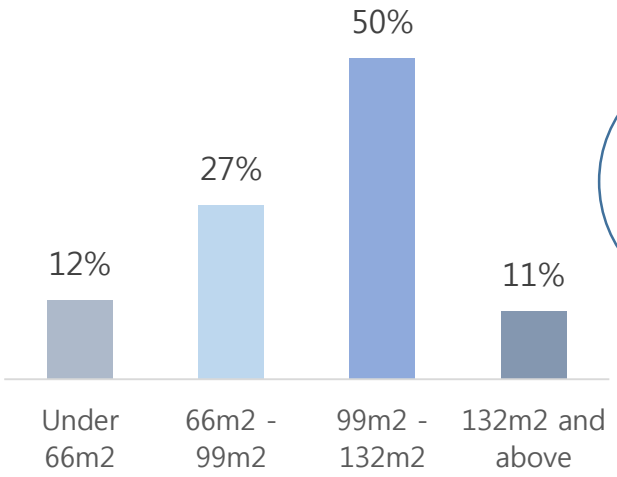
Housing Type & Area

(n=284)



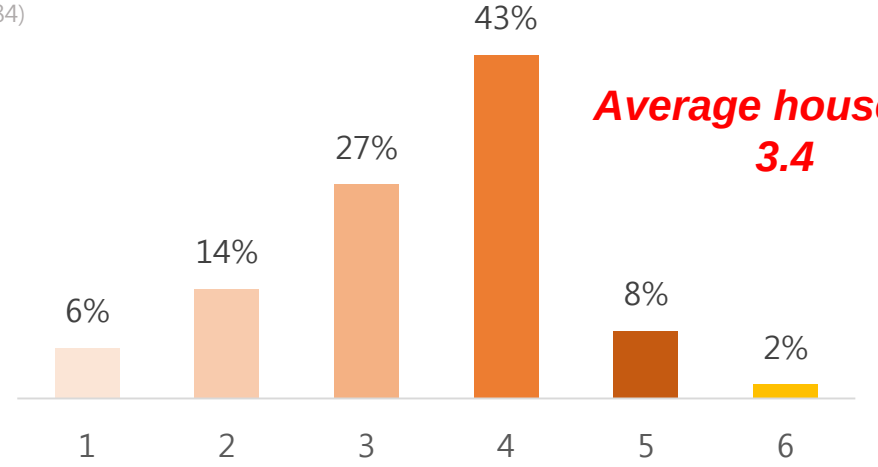
Detached house Town house

Apartment Studio



Number of Household

(n=284)



Average household 3.4

(1) Panel vector autoregression (PVAR)

Why PVAR? How?

- It can capture the endogeneity in the panel data, and reveal the relationship between endogenous variables meaning capturing **Interdependency with heterogeneity**
- The dynamic interactions between electricity consumption and real-time feedback or EnerTalk monitoring behavior will be examined

$$Y_{it} = \begin{pmatrix} AppCheck_{it} \\ Usage_{it} \end{pmatrix} = \sum_{s=1}^{P} \Phi_s \begin{pmatrix} AppCheck_{it-s} \\ Usage_{it-s} \end{pmatrix} + \begin{pmatrix} \delta_{1t} \\ \delta_{2t} \end{pmatrix} + \begin{pmatrix} f_{1i} \\ f_{2i} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1it} \\ \varepsilon_{2it} \end{pmatrix}$$

- $Y_{it} = (AppCheck_{it}, Usage_{it})$ **:** two-element column vector for an individual household $_i$ at time $_t$
- $_i$: Household individual
- $_t$: Day
- *AppCheck* : EnerTalk mobile application engagement on the day (binary)
- *Usage* : Daily electricity consumption of each panel in kWh

(1) Panel vector autoregression (PVAR)

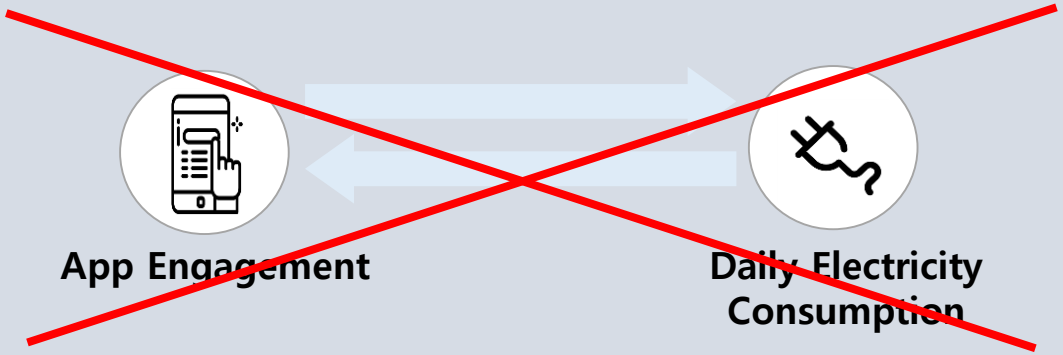
Lag Selection

Lag	J pvalue	MBIC	MAIC	MQIC
1	0.011	-106.358	-0.381	-37.325
2	0.136	-86.111	-6.629	-34.336
3	0.124	56.325	-3.337	-21.809
4	0.397	-30.424	-3.930	-13.166

Two of three criteria suggest that Lag 1 is the appropriate length of the lag

	Dependent variable	
Independent variable	$DailyUse_{i,t}$	$AppCheck_{i,t}$
$DailyUse_{i,t-1}$	0.301 (0.216)	0.059 (0.32)
$AppCheck_{i,t-1}$	0.002 (0.013)	-0.011 (0.028)
Observations	7872	
Households	284	

Note:
*** Significant at p < 0.01; ** Significant at p < 0.05; * Significant at p < 0.1



(2) Difference in differences

Decreased amount in the 2nd stage for those who checked EnerTalk during specific period in comparison to the 1st stage consumption (H3)

$$ln(E_{it}) = \alpha_i + \beta * Progressive2_{it} + (\gamma * AppCheckatT_i) * (Progressive2_{it}) + d_t + \varepsilon_{it}$$

Interpretation

- E_{it} : Daily electricity consumption in kWh measured by the smart meter of individual household
- α_i : Individual fixed effect (no need for other control variables)
- $Progressive2$: Dates after an individual entered 2nd Progressive tariff stage, >200kwh (binary)
- $AppCheckatT$: Those who checked EnerTalk at least once during 180~220kwh
  - Daily average consumption for those who entered the 2nd stage : **9.16 kwh**
  - 1~3 days before or after entering the 2nd stage of progressive tariff
  - **72 panels out of 192 checked**
- d_t : time fixed effect

Result – DID

Statistically not significant for the total sample (n=192) for those who consumed over 200 kwh in October

Variables	Total
AppCheckatT * Progressive2	-0.010
	(0.011)
Progressive2	-0.001
	(0.009)
Observations	5913
Households	192
Those who checked EnerTalk 180~220kwh range	72 (38%)
R-Squared	0.049

- **"What if we consider the demographic characteristics of the panels?"**

Result – DID

Different results depending on the subgroups

Variables	Housing area ($<99m^2$)	Housing area ($\geq 99m^2$)	Household size 1~3	Household size > 3	Child or children	No child	Average Monthly income (< 4 K USD)	Average Monthly income (≥ 4 K USD)	Self-efficacy score top 25%
AppCheckatT * Progressive2	**-0.068*** (0.022)**	0.014 (0.014)	**-0.044** (0.019)**	0.014 (0.014)	0.008 (0.013)	**-0.084*** (0.025)**	-0.024 (0.018)	0.007 (0.016)	0.0187 (0.019)
Progressive2	0.048** (0.02)	-0.017 (0.010)	0.046*** (0.017)	-0.027** (0.011)	-0.009 (0.010)	0.035* (0.019)	0.022 (0.015)	-0.004 (0.011)	-0.005 (0.013)
Observations	1632	4281	2032	3881	4465	1448	2182	3546	2590
Households	53	139	66	126	145	47	71	115	84
R-Squared	0.083	0.052	0.059	0.074	0.08	0.08	0.055	0.077	0.049

Result – DID

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R-Squared	0.083	0.052	0.059	0.074	0.08	0.08	0.055	0.077	0.049

- **-6.8%** housing area 99m²
- **-4.4%** family with less than 3 people
- **-8.4%** user without a child

1. Findings & Implications:

- Long-term smart meter users do not sensitively react to the day-to-day feedback
  - ✓ Financial reward from saving can be too little to motivate
- Energy consumption feedback from EnerTalk was effective depending on the demographical subgroups
  - ✓ Tailored messages sent out near the next tariff stage can possibly delay entering into the next tariff stage by reducing its consumption
- Electricity consumption information alone is difficult to have a high app engagement (low app check frequency)
  - ✓ Contents on saving electricity tips, increase gamification features, etc.

- The research improved the understanding of smart meter users in a natural setting and discovered how people use the smart meter in their daily life
- The shortcoming of IHDs were significantly improved

2. Future study

- Extending the data collection duration and specifically including summer or winter months
- Including samples representing the entire population
- Electricity data of the smart meter users before installing the device
- Conducting the analysis where the electricity tariff is higher than Korea or with dynamic pricing scheme (Germany, USA, etc.)
- Conducting an intervention study concentrating on progressive stage

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Question and Comments?

Thank you

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