A Social experiment for controlling electricity demand by visualization - A case of Nushima Island

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Introduction

Background

- Distributed autonomous energy systems have received remarkable attention.
  - as a measure for climate change and natural hazards mitigation
- Especially for remote islands, such systems are expected to be a powerful solution for disaster preparedness.
- In the system, power demand management system will play a significant role.

Objective

- This study puts its focus on developing an effective methodology of controlling electricity demand suited for regional conditions.
  - Conducting a social experiment of visualizing real-time electricity consumptions in Nushima Island, one of remote islands in Japan
  - Estimating an effect of visualization to reduce power demand by panel data analysis

Where is Nushima Island?

Special zone
"Awaji Environmental Future Island"

About Nushima Island

Area	$2.71km^2$ A little larger than Tokyo Disney Resort
Population	514 persons
Number of households	231 households
Main industries	Fishery Famous for “hamo” – A kind of eels – Popular food in summer in Kyoto  
Features	■ Electricity and water are supplied from Awaji Island through submarine cables. ■ There are no high school or police stations.

Project design

Outline of the social experiment

Place	Nushima Island
Period	3 years (2012-2014)
Number of participants	51 households
Objective	Developing an effective methodology of managing electricity demand

- Several projects are implemented in Nushima Island as a part of the vision for Awaji Environment Future Island.
  - Example: Photovoltaic and DC power system
  - This experiment of visualization is one of them.

- In 2012, smart meters were installed in 51 houses.
- In May 2013, tablet PCs are distributed to the participants and the electricity consumptions has been presented through them.
- In this study, power consumptions measured by the smart meters during this summer are analyzed.

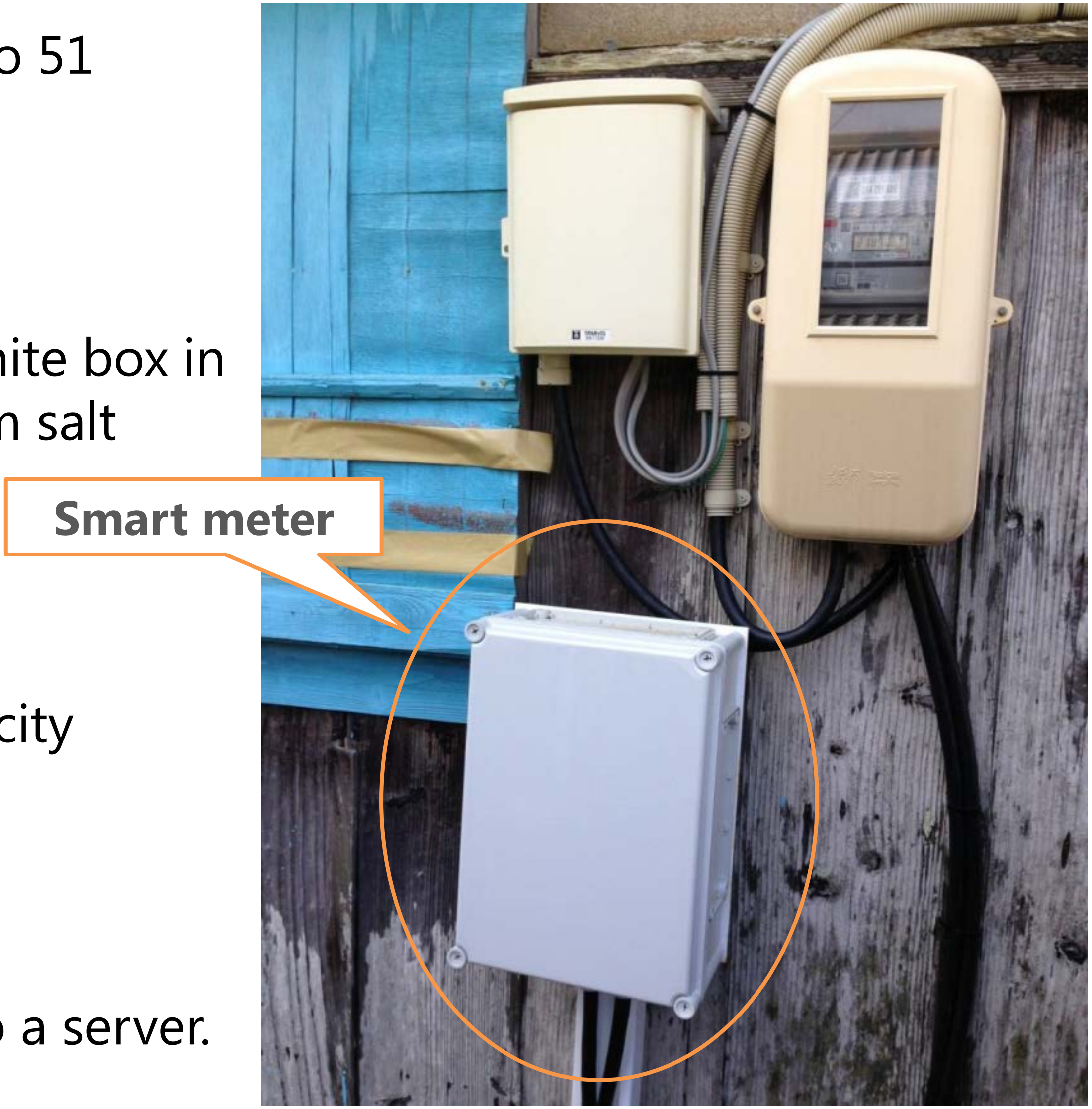
Smart meter

- Smart meters were installed to 51 houses in 2012.

- Equipment is covered by a white box in order to prevent damage from salt breeze.

- Smart meters measure electricity consumptions continually.

- Consumption data are sent to a server.



Visualization

- Tablet PCs are distributed to the participants in May 2013.
- Each family can view their real-time electricity consumptions through a tablet PC.

Only in pattern 2 and 3

- Contents of visualization are rotated monthly from pattern 1 to pattern 3.

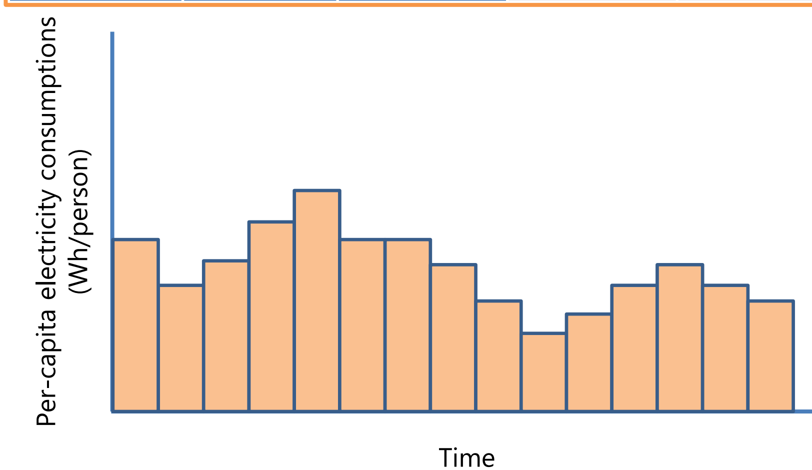
Only in pattern 3

Electricity consumptions in your house

Now (W/person)	Today (Wh/person)	Yesterday (Wh/person)	This month (Wh/person)
450	3,000	7,500	27,000

Per-capita electricity consumptions

	Now (W/person)	Today (Wh/person)	Yesterday (Wh/person)	This month (Wh/person)
Your house	150	1,000	2,500	9,000
Average of all houses			3,625	10,756



Least Electricity consumption ranking

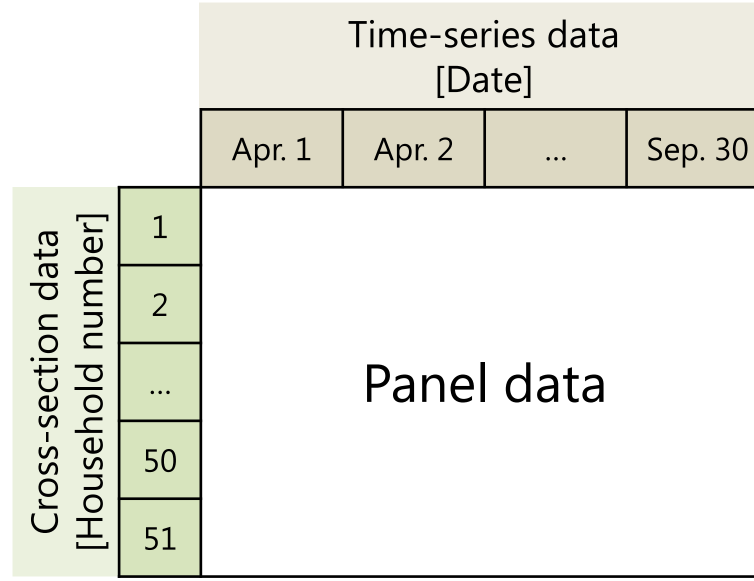
Your rank: 14th (yesterday)

Methodology

Panel data analysis

Analyzing factors that may have an influence on electricity consumptions by panel data analysis

- Formulating an estimating equation that explain electricity consumptions
- Estimating coefficients α by using panel data
- Sample: 51 households × 183 days (Apr. 1 – Sep. 30)



(Per-capita electricity consumptions)

= (Constant) + α_1 × (Temperature) + α_2 × (Wind speed)

+ α_3 × (Number of refrigerators)

+ α_4 × (Number of commercial freezers)

+ α_5 × (Frequency of viewing consumptions by a tablet PC [Pattern1])

+ α_6 × (Frequency of viewing consumptions by a tablet PC [Pattern2])

+ α_7 × (Frequency of viewing consumptions by a tablet PC [Pattern3])

+ α_8 × (Dummy variables for households where all energy is supplied with electricity)

+ α_9 × (Dummy variables for timber frame houses)

+ α_{10} × (Dummy variables for summer vacation)

Data collection

Variables	References	Remarks
Per-capita electricity consumption	Smart meters	Household size by questionnaire
Daily mean temperature	Japan Meteorological Agency	
Daily mean wind speed	Japan Meteorological Agency	
Number of refrigerators	Questionnaire	
Number of commercial freezers	Questionnaire	
Frequency of viewing consumptions by a tablet PC	Tablet PC access log	
Dummy variables for households where all energy is supplied with electricity	Kansai Electric Power Co., Inc.	Yes: "1" No: "0"
Dummy variables for timber frame houses	Questionnaire	Yes: "1" No: "0"
Dummy variables for summer vacation	-	Aug. 8 – Aug. 18: "1" The rest: "0"

Results

			Estimation Results	
Constant			1,565	***
Coefficient α	Daily mean temperature		31.21	***
	Daily mean wind speed		31.45	
	Number of refrigerators		2,249	***
	Number of commercial freezers		3,298	***
	Frequency of viewing consumptions by a tablet PC	Pattern 1	-31.23	***
		Pattern 2	-18.30	***
		Pattern 3	77.82	***
	Dummy variable for households where all energy is supplied with electricity		215.4	***
	Dummy variable for timber frame houses		-752.4	***
	Dummy variable for summer vacation		2,347	***
Adjusted R-squared			0.9656	
Durbin-Watson stat			1.392	
Model			Cross-section SUR	

*** indicates statistical significance at the 1% level.

The larger the value is, the larger an impact on power demand is.

■ Positive value
→ Electricity consumptions increase.

■ Negative value
→ Electricity consumptions decrease.

*** indicates statistical significance at the 1% level.

Adjusted R-squared is an indicator for the estimating equation.
The closer to 1, the better.

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- The estimating equation explains electricity consumptions by 97%.
- Factors other than wind speed are considered statistical significant at the 1% level.
- As a tablet PC is viewed every time, per-capita electricity consumptions
  - decrease by 31 Wh/day (Pattern 1)
  - decrease by 18 Wh/day (Pattern 2)
  - increase by 78 Wh/day (Pattern 3)
- A family who checks their consumptions 5 times a day saves electricity by 2.6% compared with a family who does not.

Visualization has some effect to reduce power demand, but it is insufficient.

Conclusions

- We are conducting a social experiment of visualizing real-time electricity consumptions in Nushima Island, one of remote islands in Japan.
- Factors that may have an impact on electricity consumptions were analyzed by panel data analysis.
- Although visualization has some effect to reduce power demand, a more influential instrument is needed.
- In this experimental project, dynamic pricing will be designed and introduced in 2014 based on the present study. Economic incentive with visualization is assumed to be more effective to manage electricity demand.
- These kinds of consumption behavioral change had better be taken into account when projecting future energy demand in smart-energy communities.


Thank you for your kind attention.