

# Energy-consumption monitoring system and integrative time-series analysis models - case study of green city demonstration project in Bogor, Indonesia –

†Seiya MAKI, Shuichi ASHINA, Minoru FUJII, Tsuyoshi FUJITA, Norio YABE, Kenji UCHIDA, Gito Ginting, Rizaldi Boer, Remi Chandran  
 † Center for Social and Environmental Systems Research e-mail:maki.seiya@nies.go.jp

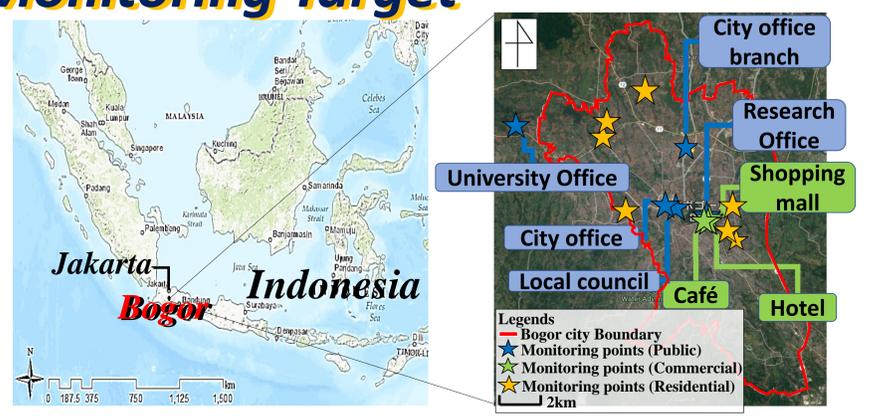
## 1. Introduction

Realize low-carbon society, there is apparent *need to transform the energy system with city & regional scale*. Particularly in developing countries, there is an *enormous potential to reduce energy in various sectors by ICT systems into energy management*.

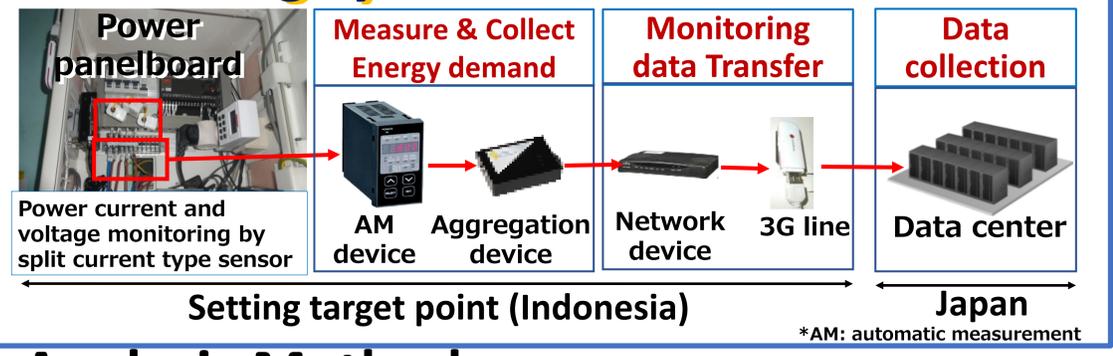
- ◆ Energy consumption **monitoring systems are introduced** at some of buildings in **Bogor, Indonesia**.
- ◆ **Energy demand prediction model** is developed by **Auto-regression eXogeneous (ARX model)**.
- ◆ **Describing** monitoring target by Hourly & Daily **Time-series Energy consumption pattern**.

## 2. Methodology

### Monitoring Target



### Monitoring Systems



Term	Building	Sensor number						Target Area information
		T	AC	L	Re	Rf	Sp	
2015 Mar.	Research Office	15	7	3	3	1	server : 1	243 m <sup>2</sup>
	Hotel	16	7	2	1	1	Room:4	413.8 m <sup>2</sup>
	Café	6	4	(1/3)	(2/3)	1		150 m <sup>2</sup>
2016 Dec.	University office	46	6	5	5		others : 30	N. D.
	Residence 1	4	1	1	1	1		68m <sup>2</sup>
	Residence 2	6		3	2	1		80m <sup>2</sup>
	Residence 3	4	1	1	1	1		87m <sup>2</sup>
2016 Feb.	Residence 4	12	1	5	4	1	Pool : 1	210 m <sup>2</sup>
	City office	12	4	2	6			377.8m <sup>2</sup>
	Local council	6	6					1021.6m <sup>2</sup>
2016 Dec.	City office brunch	9	5	2	1	1		587m <sup>2</sup>
	Shopping mall	10	2				others : 8	42000m <sup>2</sup> (4F)
2016 Dec.	Residence 5	3	1	1	1			99.4m <sup>2</sup>
	Residence 6	3		1	1	1		137.1m <sup>2</sup>
	Residence 7	4	1	1	1		2F : 1	156.4m <sup>2</sup>

T: total, AC: air conditioner, L:Lighting, Re: Receptacle, Rf: Refrigerator, Sp: Special

### Analysis Method

#### 1. Development Prediction model

Identify effective factors by **multi-regression analysis**

Develop **ARX model** using over 5% significance factors

External Factor: Electricity Consumption  $y_t$ , Temperature  $x_t^1$ , Office Hour  $x_t^2$ , Holiday  $x_t^3$

Prediction result:  $y_t = f(x_{t-1}^1, x_{t-2}^1, \dots, x_{t-1}^2, x_{t-2}^2, \dots, x_{t-1}^3, x_{t-2}^3, \dots)$

#### 2. Clustering by Time-series character

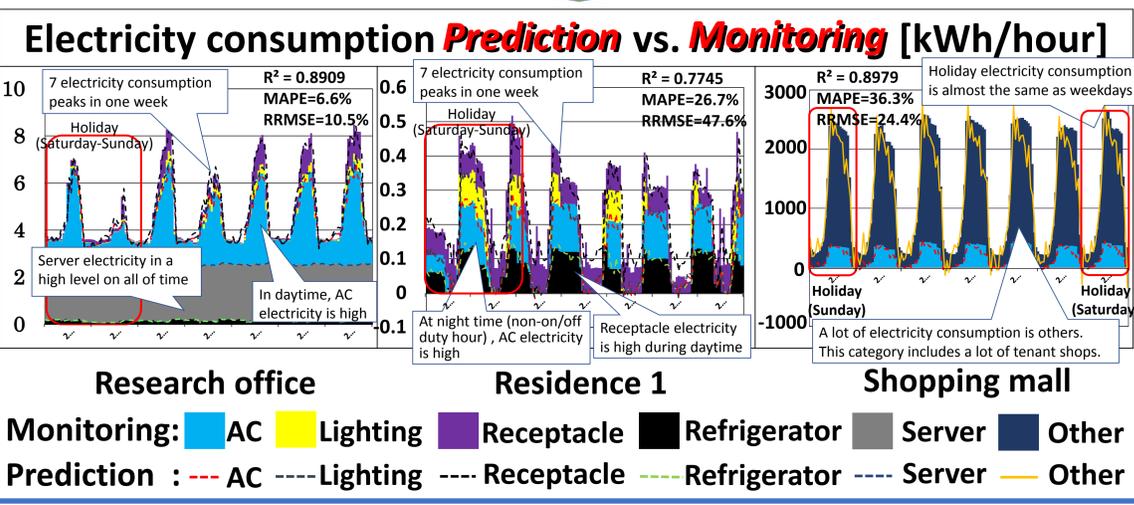
- Time-series cluster analysis on **Dynamic Time Warping (DTW)** and **furthest neighbor method**
- Clustering by **Hourly and Daily energy demand pattern**
- **Used prediction results** from 3/1 – 12/31, 2016

## 3. Result and Discussion

### Monitoring data Prediction

Result of **Multi-Regression Analysis**, e.g. Research office

	Intercept	Holiday	Office Hour	Ramadan	Temperature	Humidity	Wind speed	R <sup>2</sup>
Total	2.91 **	12.28 ***	21.31 ***	2.38 *	6.50 ***	1.02	1.83	0.57
AC	1.21	10.49 ***	21.36 ***	1.85	7.51 ***	1.97 *	2.19 *	0.56
Lighting	1.38	14.28 ***	15.68 ***	1.10	0.14	0.38	1.48	0.38
Receptacle	4.85 ***	12.67 ***	22.14 ***	3.00 **	7.13 ***	4.03 ***	0.09	0.55
Refrigerator	8.82 ***	1.94	6.77 ***	2.88 **	4.13 ***	2.87 **	2.45 *	0.11
Server	25.09 ***	0.16	2.30 *	3.18 **	1.11	6.60 ***	2.21 *	0.13



### Time-series Clustering

#### 1. Hourly character

Calculated rate of Hourly variability in one day from average number equal 1

- Cluster 1: Residential 5, Residential 1, Shopping 7, Shopping mall, Café.  $\times 1.5$  from Ave. in peak
- Cluster 2: Residential 3, Research Office, City office brunch.  $\times 1.2$  from Ave. in peak
- Cluster 3: Residential 4, Residential 2, Residential 6, Hotel. Almost no change
- Cluster 4: Local council, City office.  $\times 2$  from Ave. in peak

#### 2. Monthly character

Calculated rate of long-term variability in one month from average number equal 1

- Cluster 1: Residential 6, Research Office, Residential 2, Hotel, Residential 4, Residential 5, Residential 7, Residential 3. Increase in Ramadan
- Cluster 2: Shopping mall, Residential 1, Café. Increase in Ramadan
- Cluster 3: City office brunch, Local council, City office. Decrease in Ramadan
- Cluster 4: Local council, City office. Almost no change

✓ Cluster 1 & 2 are increased in Ramadan.  
 ✓ However, Cluster 3 & 4 are decreased or not change.

- Classified short or long term energy demand pattern
- Cluster 3 of hourly variability is included in cluster 1 of long-term
- Hourly & monthly patterns might have common characteristics

## 4. Conclusion & Next stage

- Installed innovative **energy demand monitoring system** and development of **prediction models by ARX**
- Categorize to **4 different hourly trend clusters** and **4 different long-term trend clusters** by Time-series clustering
- These models are able to be used **high accuracy prediction**, it is thought that we could **provide basic data for electricity management** such as ADR and supply side plan for realizing low carbon society
- Clustering results suggested that hourly and long-term variability **trend might be estimated from not monitoring**
- For the future, improving analysis for **Development of Innovative Prediction & Extended Regional analysis**