2012 IEPEC
Presentation (Rome)

Analysis of effect of heat energy savings incentives program

June 12, 2012

Sangsoo Ahn

KEMCO

Background of Program

- Heat Energy Savings Incentive Program 한국지역난방공사 KOREA DISTRICT HEATING CORP.
  - KDHC (Korea District Heat Corporation) implemented the savings incentive program for their households customer in 2011
  - Household which had saved heat energy of winter season (3 months, Dec-Jan-Feb) more than 5% from the heat energy of previous year got organic rice as a incentive
  - Around 1% of total households which were supplied heat energy from KDHC participated in the program
  - The energy efficiency subsidy program has been implemented as a part of the investment program of energy suppliers for demand side management by Rational Energy Utilization Act

Purpose of the study

- To estimate energy savings of incentive program considering outdoor temperature effect on heat energy consumption of district heat energy customers
  - If outdoor temperature has an effect on heat energy consumption, baseline would be adjusted according to the relation of outdoor temperature and heat energy consumption
  - Generally speaking, outdoor temperature has strong influence on heat energy consumption. Many studies has been done regarding the effect of outdoor temperature on heat energy consumption
    - J. Paik at el (2010) proposed a regression analysis model to estimate heat demand by outdoor temperature, wind velocity and previous day's demand.

Data Revision

- Outliers exclusion by 0 energy consumption
  - A total of 339 household observations with zero (energy consumption in either 2010 or 2011)

Description	No. of Participating Households	2010 Energy Consumption = 0	2010 Energy Consumption > 0	
			2011 Energy Consumption = 0	2011 Energy Consumption > 0
Gyeonggi	671	142	58	6,136
Gyeongnam	6,336	43	17	1,169
Daegu	908	27	12	992
Seoul	1,031	21	5	645
Chungbuk	1,229	10	4	894
Total	10,175	243	96	9,836
		339		

Data Revision (cont)

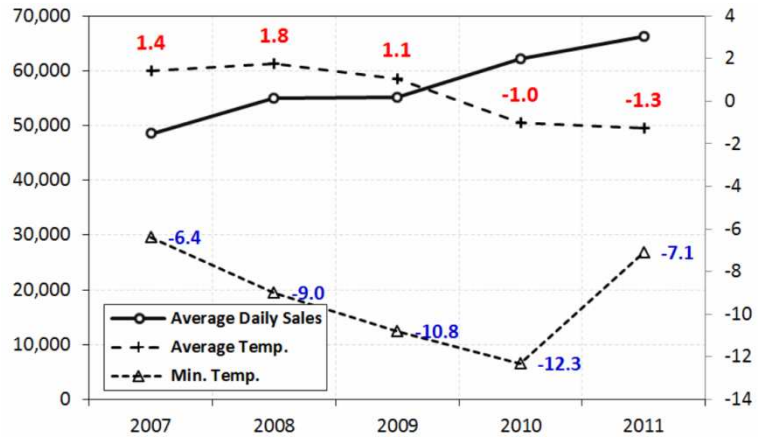
- Outliers exclusion by distribution
  - Outliers excluded according to the characteristics of distribution as a classical method
  - Data that exceeded four times the standard deviation were excluded
    - Minimum Guideline = Average – 4 x Standard Deviation
      = 0.3115 – 4 x 5.953 = -23.5005
    - Maximum Guideline = Average + 4 x Standard Deviation
      = 0.3115 + 4 x 5.953 = 24.1235

No. of Household	Average	Standard Deviatio	Min. Value	Max. Value	Average ± 4 × (Standard	
					Min.	Max.
9,836	0.312	5.953	-0.997	279	-23.501	24.124

Regression model development

- The heat energy sold for household consumption in the winter
  - It has been increasing each year by 4.6% per year
  - Average daily sales quantity were used to analyze the temperature effectiveness
- Relation between energy consumption and temperatures
  - Minimum temperature seemed to be unrelated to daily consumption

Year (Winter)	Energy Sales	No. of Days	Average Daily Sales	Variation Rate	Average Temp	Minimum Temp
2007 (2006.12 - 2007.2)	4,368,600	90	48,540	-8.30%	1.4	-6.4
2008 (2007.12 - 2008.2)	5,004,440	91	54,994	13.30%	1.8	-9
2009 (2008.12 - 2009.2)	4,962,473	90	55,139	0.30%	1.1	-10.8
2010 (2009.12 - 2010.2)	5,591,841	90	62,132	12.70%	-1	-12.3
2011 (2010.12 - 2011.2)	5,960,875	90	66,232	6.60%	-1.3	-7.1



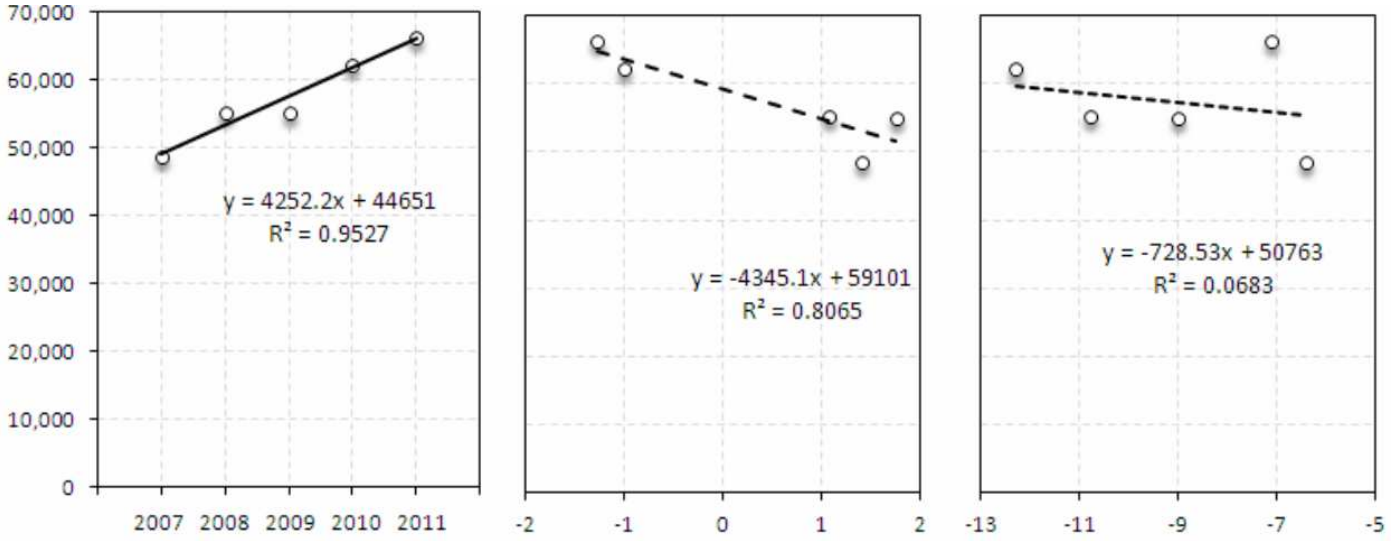
Regression model development (cont)

- 3 models to estimate energy consumption which is needed to adjust the baseline

Model A: $y_t = \alpha + \beta_a \cdot t \quad (t : 1, 2, \ldots)$

Model B: $y_t = \alpha + \beta_b \cdot Atemp_t \quad (Atemp : \text{Average Temperature})$

Model C: $y_t = \alpha + \beta_c \cdot Ltemp_t \quad (Ltemp : \text{Lowest Temperature})$



Model A Model B Model C

Regression model development (cont)

- Model evaluation results

Model	*F*-statistic	*P*-value	R^2	Adjusted R^2	*RMSE*	*BIC*
Model A	60.38	0.004	95.30%	93.70%	1,730.50	75.23
Model B	12.5	0.039	80.70%	74.20%	3,498.80	82.27
Model C	0.22	0.671	6.80%	-24.20%	7,677.50	90.13

Statistic	Evaluation Method	Model Evaluation Results		
		Model A	Model B	Model C
F-statistic and *P*-value	P-value less than 0.05	◎	○	X
R-square	Explanation power increases as it approaches 100%	◎	○	X
Adjusted *R*-square	Explanation power increases as it approaches 100%	◎	○	X
RMSE (Root of the mean square error)	Better if smaller (Distribution of Error)	◎	△	△
BIC (Bayesian Information Criterion)	Better if smaller (Suitability of the Model)	◎	△	△

◎: Very Good, ○: Good, △: Normal, X: Bad

Savings calculation

- Savings are defined as the quantity obtained by deducting the energy consumption in 2011 from that in 2010

$$E_{Savings} = \left\{ \sum_{i=1}^{n_h} EC_{hi,2010} \right\} - \left\{ \sum_{i=1}^{n_h} EC_{hi,2011} \right\}$$
$$= n_h \cdot EC_{Avg.Diff.}$$
$$= n_h \cdot \left\{ \overline{EC_{h,2010}} - \overline{EC_{h,2011}} \right\}$$

$E_{Savings}$: Energy Savings

EC : Energy Consumptions

$EC_{Avg.Diff.}$: Difference of Average Energy Consumptions

$$\overline{EC_{h,year}} = \left(\sum_{i}^{n_h} EC_{hi,year} / \sum_{i}^{n_h} N_{hi,year} \right)$$

h is a subscript that represents the energy consumption section
i is a subscript that represents the individual households in group h
nh stands for the total number of households in group h

Calculated energy savings

Sub-group of energy consumption (Mcal)	No. of Households(a)	Average Energy Consumption (*Gcal*/household)			Savings Rate (d / b)
		2010 (b)	2011 (c)	Difference (d = b - c)	
Less than 400	5,717	0.14	0.14	0.002	1.43%
400-700	606	0.51	0.46	0.046	9.02%
700-1,000	210	0.84	0.99	-0.155	-18.45%
1,000-1,500	273	1.26	1.53	-0.267	-21.19%
1,500-2,000	307	1.76	2.03	-0.272	-15.45%
2,000-2,500	388	2.26	2.32	-0.059	-2.61%
2,500-3,000	402	2.75	2.71	0.04	1.45%
3,000-3,500	381	3.25	3.14	0.106	3.26%
3,500-4,000	349	3.75	3.42	0.328	8.75%
4,000-4,500	279	4.24	3.75	0.487	11.49%
4,500-5,000	220	4.74	4.08	0.66	13.92%
5,000-6,000	328	5.48	4.87	0.608	11.09%
6,000-7,000	181	6.44	5.57	0.866	13.45%
7,000-8,000	85	7.43	6.06	1.366	18.38%
8,000-9,000	41	8.5	7.06	1.439	16.93%
9,000-10,000	25	9.52	6.92	2.596	27.27%
More than 10,000	19	15.96	12.87	3.09	19.36%
Total	9,811	1.37	1.27	0.095	6.93%

Calculated energy savings (cont)

Sub-group of energy consumption (Mcal)	No. of House-holds	Average	Standard Deviation	Standard Difference	*95% CI*		Degree of Freedom	Statistic	*P*-value	
					Min.	Max.				
Less than 400	5,717	0	0.22	0	-0.01	0	5,716	-0.57	0.28	①
400-700	606	-0.05	0.46	0.02	-0.08	-0.01	605	-2.48	0.01**	
700-1,000	210	0.16	0.95	0.07	0.03	0.28	209	2.37	0.01**	
1,000-1,500	273	0.27	1.11	0.07	0.13	0.4	272	3.97	< 0.001**	
1,500-2,000	307	0.27	1.2	0.07	0.14	0.41	306	3.97	< 0.001**	
2,000-2,500	388	0.06	0.97	0.05	-0.04	0.16	387	1.21	0.11	②
2,500-3,000	402	-0.04	0.95	0.05	-0.13	0.05	401	-0.85	0.2	③
3,000-3,500	381	-0.11	1.14	0.06	-0.22	0.01	380	-1.81	0.04**	
3,500-4,000	349	-0.33	1.11	0.06	-0.44	-0.21	348	-5.54	< 0.001**	
4,000-4,500	279	-0.49	1.16	0.07	-0.62	-0.35	278	-6.99	< 0.001**	
4,500-5,000	220	-0.66	1.5	0.1	-0.86	-0.46	219	-6.53	< 0.001**	
5,000-6,000	328	-0.61	1.52	0.08	-0.77	-0.44	327	-7.26	< 0.001**	
6,000-7,000	181	-0.87	1.75	0.13	-1.12	-0.61	180	-6.65	< 0.001**	
7,000-8,000	85	-1.37	2.01	0.22	-1.8	-0.93	84	-6.25	< 0.001**	
8,000-9,000	41	-1.44	1.89	0.3	-2.04	-0.84	40	-4.87	< 0.001**	
9,000-10,000	25	-2.6	2.56	0.51	-3.65	-1.54	24	-5.06	< 0.001**	
over 10,000	19	-3.09	7.14	1.64	-6.53	0.35	18	-1.89	0.04**	

Total energy savings = 932.3 Gcal – (9.5 Gcal + 16.2 Gcal) + 23 Gcal = **929.6 Gcal (6.94%)**

① ② ③

Conclusion

- The calculation of the net energy consumption savings needs to be calculated relative to a baseline
- Though heat energy consumption is closely related to the temperature, annual temperature fluctuations are minor and are statistically insignificant as an explanatory variable
- Calculated energy savings were statistically analyzed, the effects of the campaign according to the results was assessed
- Studies on effects of important factors on heat energy consumption such as outdoor temperature, type of housing, composition of families, heating method are needed in future