

Consumer's Expected Reaction and Preferred Service toward Deployment of AMI in Taiwan

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Abstract

Advanced Metering Infrastructure (AMI) is being used to raise the users' awareness of power consumption and to collect their real-time usage data. This enabling technology solution coupled with the time-of-use (TOU) pricing scheme can level off electricity load and the reduction of CO₂ emission can therefore be achieved. Although AMI has been deployed in limited scale in Taiwan, mass installation is still in discussion before its benefit can be sufficiently recognized. In consideration of future nation-wide installation, this research aims to understand consumer's interest in AMI and their willingness to change behavior in reaction to TOU pricing. A questionnaire survey was conducted. In the absence of historical data, the finding of the survey and our analysis hope to contribute to policy-making by identifying differences in demand for smart meter among a diverse of consumer groups. It is found that the consumers have low motivation to change their power consumption behavior under the scheme of profit neutral pricing, as average power rate is relatively low in Taiwan compared with neighboring nations. Additionally, consumers with higher income demonstrate higher interest in adopting AMI and the consumers' most demanded services related to AMI are fire emergency and home security alert.

1. Introduction

According to IEA, the energy efficiency improvement from user side is the key factor among all strategies. AMI can help balance power supply and demand, in addition to improving the energy efficiency.

The first AMI pilot has been deployed in Taiwan, at the same time the mass installation is still in discussion before the benefit of AMI can be sufficiently recognized. In consideration of future nation-wide installation, this research aims to understand consumer's interests in AMI and willingness to change behavior in reaction to AMI TOU pricing.

1.1 Policy context

The national AMI deployment plan was approved by the Executive Yuan in June of 2010. It becomes the guideline for AMI deployment and will be followed by the implementation of smart grid. The AMI installation was started from 23,000 high-voltage customers (accounting for 58% of total power consumption) and is scheduled to be completed in 2012. As to low voltage customers, a pilot systems were tested on 308 customers in 2010, serving as a reference for expanding to cover 10,000 customers in 2012. Functions such as remote meter reading, equipment management, power outage detection, meter box tampering detection (anti-theft) are included in Taiwan's AMI system.

1.2 Purpose of the investigation

Limited installation of AMI has been in place in Taiwan. However, full-scale deployment and the strategy of installation are yet to be decided. Understanding consumers' interest and attitude is conducive to drive the campaign for a nation-wide deployment. However, in the absence of historical

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data, we conducted a interview survey and tried to catch a general picture of consumers' acceptance and reaction to the ambitious plan. Data collected from the survey will also be used in the cost and benefit analysis before large scale installation. Location priorities and functions to be added to the meters, and the derived services to users as well, depend on the thorough analysis of consumers' lifestyle and behaviors.

2. Power load and tariff in Taiwan

Unlike the US and most Western European countries, households use electricity first and foremost for home heating, followed by heating of water¹⁾, while the highest level of power consumption comes in the hot summer afternoons in Taiwan when most of the air-conditioners are in operation. There is a 4GW difference between peak and average load during the peak hours.

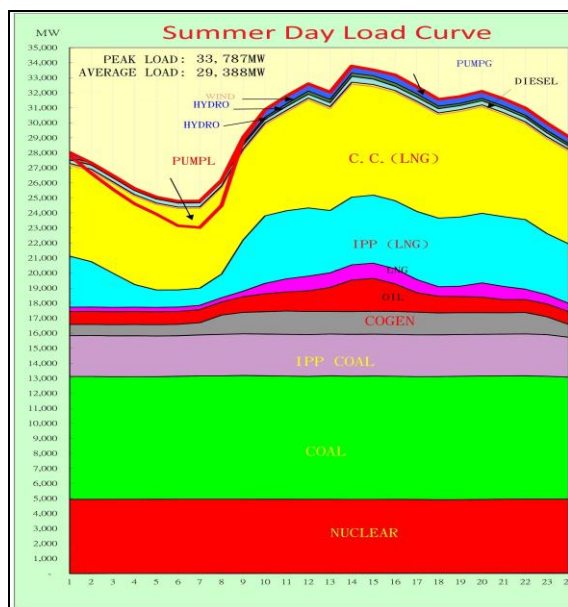


Figure 1 Load Curve in a Summer Day (sampled on August 18th, 2011)

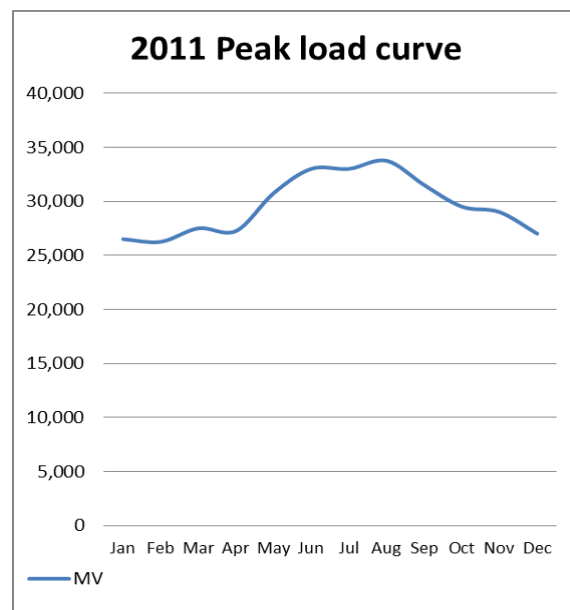


Figure 2 Load Curve in a Year (2011)

The power market is regulated in Taiwan. Taipower is the state-run integrated monopoly which offers TOU program to residential consumers. The scheme is complicated and, as a result, only less than 5% of its residential consumers opt to adopt TOU.

Taiwan's power rate level is relatively low as compared with its neighboring nations. Debates for a hike of utility rate continue. The issue is rather politically sensitive.

3. Method

The survey was conducted through face-to-face interviews. Interviewers were trained to explain the function of smart meter and the TOU rate to interviewees.

3.1 Investigation area, object and period

The interviewees, selected from three northern cities and one southern city, are over 20 years old with knowledge of their household electricity expenditure. The three northern cities are Taipei City, New Taipei City, and Hsinchu City while Kaohsiung is the southern city having been chosen. Taipei City is selected because it is the national capital and a commercial hub as well. The neighboring New

Taipei City has long been a satellite to Taipei City with its strong industrial base. Hsinchu City, on the other hand, has the world-renowned Hsinchu Science Park. We are also interested in the linkage between the climate condition, life styles and consumer’s attitude. So we put in the southern industrial city Kaohsiung.

Although Taiwan has typical island climate – hot and humid, the weather conditions are recognizably different across the island. The number of days with temperature exceeding 30°C is higher in the south. For example, Kaohsiung has 165.7days a year while Taipei has 134 days. But Taipei’s absolute temperature during the summer time is higher than Kaohsiung because of its basin terrain. In terms of humidity, Kaohsiung is relatively humid than Taipei in summer.

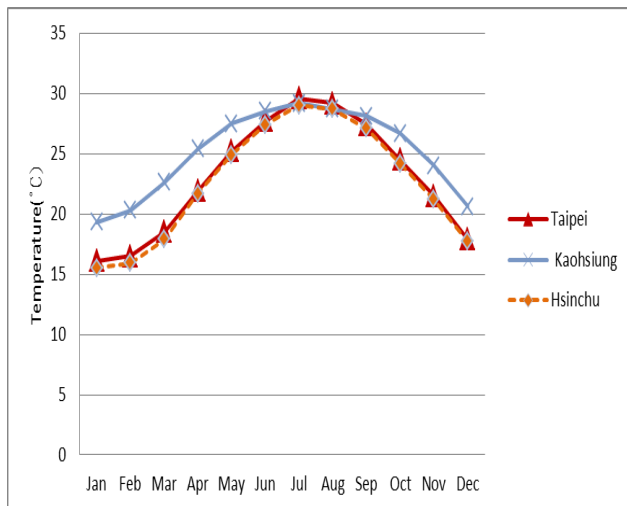


Figure 3 Average Temperature in a year

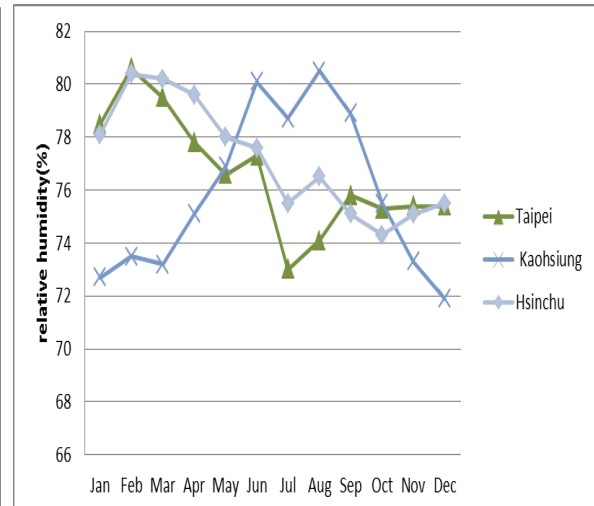


Figure 4 Average relative humidity in a Year

3.2 Content of investigation

The investigation content includes four parts, as shown in Table 1

Table 1 The content of the investigation

Category	Question
Background of the household	<ul style="list-style-type: none"> ● Locations ● Residential type ● Daytime and evening use of home appliances in summer ● Numbers of working household members, members at school, retirees, and members at home during daytime (10AM-4PM) ● TOU adopter? ● Electricity consumption in summer of 2010 ● The home appliances usage status in day and evening ● Household monthly income
Household’s interest in smart meter or IHD	<ul style="list-style-type: none"> ● The households’ interests in getting information of TOU rate and real-time power usage provided by the smart meter ● Information of average power usage in the vicinity and high volume users ● Willingness to support slightly higher rate to raise the energy efficiency, save energy, and reduce carbon emission through the adoption of smart meter ● Type of power rate to be chosen after smart meter installation ● Households’ willingness to change power consumption behavior when they have a display to show the power usage and power fee information

Expectation of response to TOU	<p>When the peak time rate is a double, quadruple, hextuple and octuple of the off-peak time rate, households' willingness to:</p> <ul style="list-style-type: none"> ● Reduce their air conditioner use ● Shift their laundry time to off-peak time (early morning or holidays) ● Temporarily stop using drying machine ● Change the cooking way from electric pot or microwave to gas stove ● Reduce TV usage time from six hours to one hour ● Reduce computer usage time from six hours to one hour ● Temporarily stop using dehumidifier ● Temporarily stop using electric boiler for 10 minutes ● Unplug all unused electrical appliances
Interest in additional services from the use of smart meter	<ul style="list-style-type: none"> ● Getting information of TOU rate and real-time power usage provided by the smart meter ● For better service and shorter possible blackout ● Air conditioner control and thermostat which enable automatic temperature adjustment during the peak rate hours, effectively reducing electricity bill ● Additional hardware installation on the smart meter which enables the fire emergency alert ● Home security service ● Services of immediate power and gas cutoff from the smart meter in case of fire emergencies ● The tendency to switch from network provider to power company that offer integrated services such as cable internet, mobile service, and internet TV

3.3 TOU rate setting

TOU pricing, the price of electricity varies depending on when it is used. Working with smart meter, TOU may stimulate consumers to vary their usage in response to such prices and manage their energy costs by shifting usage to a lower cost period or reducing their consumption. There are three reactions which consumer will take when they face TOU pricing: The first reaction is to reduce the peak time consumption only - no transfer; second, to transfer from peak time consumption to off-peak time; third, to implement on-site generation. The first reaction will achieve conservation, whereas shifting consumption from peak to off-peak can smoothen the load curve and lower the operating reserve²⁾. And the reaction of residential segment to dynamic pricing is obvious and estimated the pricing scheme can reduce 5-10% power consumption³⁾. As to the rate of peak time, increase the fee differentials close to the peak time can smoothen the peak curve⁴⁾, and when the fee difference between peak and off-peak reach 500%, the smoothen effect would appear⁵⁾.

Thus, based on Taiwan's summer day load curve, we set the summer peak time periods at 10AM-4PM and 7PM-10PM; the rest 15 hours are off-peak time. Trying to approximate Taipower's existing fix rate of 2.3 New Taiwan Dollar (NTD) per kWh and for the convenience of calculation, we set the fix rate at NTD 2.5 per kWh in our survey. We adopt the "Profit Neutrality" principle to set the different peak/off-peak multiple fees. In other words, compared to the fix rate of NTD 2.5 per kWh, power company's profit under the fix rate regime should equal to the TOU system.

The strategy of the TOU scheme in this survey is to enlarge the multiple between peak and off-peak time rate under the profit neutral principle. The TOU rate sheet shown as Table 2.

Table 2 TOU rate sheet

Rate	Fix rate	² x	4x	6x	8x
Off -peak rate	NTD 2.5 / kWh	NTD 1.8 / kWh	NTD 1.2 / kWh	NTD 0.9 / kWh	NTD 0.7 / kWh
Peak time rate	NTD2.5/ kWh	NTD 3.6 / kWh	NTD 4.7 / kWh	NTD 5.2 / kWh	NTD 5.5 / kWh
The difference	NTD 0 / kWh	NTD 1.8 / kWh	NTD 3.5 / kWh	NTD 4.4 / kWh	NTD 4.8 / kWh

4. Findings and discussion

4.1 Survey sample demographics

Our survey finds that, 86.1% of the households have someone at home during the daytime. With the high percentage, it serves our purpose of understanding the behavior of household during the daytime. Most of the cases answering no one at home during the daytime occur in Taipei City. Of the types of residence, townhouses take the lion share (54.3%), followed by villas (16.7%), apartments with stairs (14.2%), and normal houses (4.7%).

About 4.7% households adopt TOU scheme in our survey, almost identical to the 5% in actual situation in Taiwan. It is noteworthy that 41.6% of the interviewees have no idea of whether has been adopted in their households. It may represent the interviewees are not aware of the difference between the TOU rate and the fix rate, or they are not concerned about it.

Table 3 Survey sample demographics

Item	%
Respondents	
Whether someone is at home during the day (10AM-4PM)	
Someone is at home during the day	86.1%
No one is at home during the day	13.9%
Number of people per household	
2 and fewer	13.0%
3	18.6%
4	31.5%
5	23.5%
6 and more	13.5%
Number of working members per household	
None	8.3%
1	28.9%
2	35.0%
3	16.9%
4	11.0%
Number or retirees per household	
0	58.2%
1	26.2%
2 and more	15.7%
Adopt TOU or not	
Yes	4.7%
No	53.8%
Unclear	41.6%
Household income level (in NTD)	

² “2x” means the peak time rate is double of off-peak time’s

50 k and less	28.6%
50-100k	33.3%
100-200k	18.6%
200k and more	6.9%
Refuse to answer	12.7%
Location	
Taipei City	21.3%
New Taipei City	24%
Hsinchu City	3.4%
Kaohsiung City	51.4%
Types of residence	
Townhouse	54.3%
Villa	16.6%
Apartment with stairs	14.2%
Apartment with Elevator	10.3%
Normal house	4.7%
Sample size: 408 households	

Limited by the sample size of our survey, we opt to base the following cross analysis merely on location and income.

4.2 Households' interests on getting information from smart meter or IHD

We found that 77.3% of the reviewees show their interest in the smart meter. They were also asked their willingness to pay slightly higher rate in order to increase the overall energy efficiency, save energy, reduce carbon emission by installing smart meters in the households. Although more than half questioned are not willing to pay more, to our surprise, 41.8% of the households are.

Approximately 62% of the households are interested in the information of average power usage of the community as well as high volume users in the vicinity. Forty-five percent of the households would choose TOU rate scheme after the installation of smart meter and 41.3% prefer the fix rate. 81.7% of households agree to change power consumption behavior if a display of power usage and power fee information available.

A cross analysis of the households' background and interests issue reveals that a significant difference exist among different income level groups. So does among location groups. Households in Taipei City demonstrate higher interest in obtaining various information from smart meter or IHD. As to know getting information of average power usage in the vicinity and high volume users, people in Taipei City or with higher income shows higher interests. In addition, these two groups are willing to pay more for having smart meters.

Table 3 Cross Analysis of households' background and interests in smart meter or IHD (%)

Background item Category	Response	Location				Monthly income (NTD/Household)				
		Taipei	New Taipei	Hsin-chu	Kao-shiung	50k and less	50-100k	100-200k	200k and more	Refuse to answer
(*)Interests in getting information of TOU rate and real-time power usage provided by the smart meter	Yes	81.6	66.3	92.8	79.5	No significant difference				
	No	18.39	33.7	7.14	20.5					
(*a ³)Interests in getting information of average power usage in the vicinity and high volume users	Yes	72.4	41.8	64.3	66.2	53.0	65.4	53.9	96.4	63.5
	No	27.6	58.2	35.7	31.0	46.2	32.4	44.7	3.6	34.6
	Unclear / no opinion	0.0	0.0	0.0	2.9	0.9	2.2	1.3	0.0	1.9
(*a)Willingness to support slightly higher rate through the adoption of smart meter	Yes	77.0	32.7	64.3	30.0	29.9	39.0	40.8	96.4	48.1
	No	21.8	64.3	35.7	69.0	68.4	60.3	56.6	3.6	50.0
	Unclear / no opinion	1.1	3.1	0.0	1.0	1.7	0.7	2.6	0.0	1.9
(*a)Which types of power rate will household choose after smart meter installation	Fix rate	57.5	49.0	0.0	33.8	46.2	31.6	42.1	39.3	55.8
	TOU	28.7	37.8	64.3	54.3	39.3	52.9	42.1	57.1	36.5
	RTP	12.6	10.2	28.6	11.0	13.7	12.5	14.5	3.6	5.8
	Unclear / no opinion	1.1	3.1	7.1	1.0	0.9	2.9	1.3	0.0	1.9
(*a)Willingness to change behavior when they have a IHD to show information	Yes	89.7	66.3	100.0	84.3	76.9	83.1	80.3	96.4	82.7
	No	10.3	32.7	0.0	14.3	22.2	15.4	19.7	3.6	15.4
	Unclear / no opinion	0.0	1.0	0.0	1.4	0.9	1.5	0.0	0.0	1.9

4.3 Household's self-expected response to TOU fee

One of the main purposes of the survey is to understand households' react under different tariff. The TOU scheme in the survey varies with the rate of peak and off-peak time, and the price of peak time can be several times of off-peak. Since this survey does not implement smart meter and TOU rate, the result we get from interview survey is household's self-expected reaction to TOU.

The percentage of the household's self-expected response to TOU is shown below:

³ “*”: P-value<0.05, ”a”: the proportion of expectations between groups less than 5 is more than 25%

Table 4 Household's self-expected response to TOU

Types of Electric Appliances	Categories	Saving of the appliance (NTD)	Percentage of having willing to change behavior under TOU				
			2x	4x	6x	8x	No Change
Air conditioner	Willingness to turn one air conditioner off	596	12.0%	10.9%	8.8%	29.7%	38.5%
	Willingness to set lowest temperature from 26 to 28 degree Celsius	71	10.4%	5.7%	14.1%	23%	46.9%
	Willingness to set temperature of the air conditioner to 30 degree Celsius and add the use of electric fan	107	4.2%	7.8%	8.3%	8.3%	71.4%
	Willingness to use electric fans only	562	9.9%	3.7%	7.8%	22.4%	56.8%
	Willingness to use air conditioner with "energy-efficiency" logo	120	5.2%	8.3%	7.3%	17.2%	62.0%
Laundry machine	Willingness to change their laundry time to off-peak time	8	5.8%	1.9%	1.9%	13.0%	77.4%
Electric pot	Willingness to cook using electric pot in the morning and gas stove in the afternoon	29	4.9%	2.3%	2.7%	5.3%	84.9%
Microwave	Willingness to replace microwave with gas stove for 10 minutes	20	3.7%	11.1%	4.9%	7.4%	72.8%
TV	Willingness to reduce TV time from six hours to one hour	95	8.2%	5.6%	11.8%	5.3%	69.1%
Computer	Willingness to reduce computer time from six hours to one hour	186	12.0%	6.8%	4.7%	10.0%	66.5%
Thermos	Willingness to boil water using gas stove instead of thermos	144	10.3%	4.0%	5.4%	4.0%	76.3%
Dish dryer	Willingness to temporarily stop using dish dryer	19	8.1%	5.4%	8.1%	8.1%	70.3%
Dehumidifier	Willingness to temporarily stop using dehumidifier	180	6.9%	17.2%	6.9%	24.1%	44.8%
Electric boiler	Willingness to temporarily stop using electric boiler for 10 minutes when taking shower	158	1.5%	3.1%	7.7%	18.6%	69.2%
Standby appliance	Willingness to unplug all standby electrical appliances	29	13.9%	3.7%	1.7%	20.2%	60.5%

In our interviews, we refrained ourselves from showing the energy consumption data of particular appliances. Instead, we converted them into dollar expenditures. Consumers may have a clearer picture of utility bill they can save as a result of behavior change.

During the peak-time, the rate is a multiple of the off-time charge. The majority of people are unwilling to change their consumption behavior regardless of multiples. Nevertheless, among the home appliances that most people tend to change usage is air conditioner, as it can save electricity bill to the greatest extent.

4.4 Extended Service of AMI

The utility companies are anxious to know business models emerge when the traditional meters are replaced by smart meters. In this survey, we suggest some services related to AMI, such as immediate TOU rate and power usage information. We find the fire emergency alert⁴ (57.5%) is the most wanted service, followed by the households' security service (32.8%).

Air conditioner is the most energy-consuming appliance in residential segment. However, only half of the interviewees have interest in air conditioner control and thermostat service. We find significant difference exist among locations about the interest of having this service. A large percentage (78.2%) people in Taipei express their interest in this service, while in Kaohsiung the figure drop to 46.2%.

An anatomy into the data collected the background survey shows that Taipei City has the highest percentage of households (80.6%) having at least one air conditioner in operation during the daytime. This result does not include the households without anyone at home. And in New Taipei City and Kaohsiung City, we observe that households are used to have their air conditioners idle during the day but turn the machine on in the evening when the household's members are home.

Table 5 Percentage of households have air conditioner in operation during day time and evening

	Day	Evening
Taipei City	80.6%	92%
New Taipei City	31.6%	69.6%
Hsinchu	62.5%	76.9%
Kaohsiung	60.5%	89.5%

5. Conclusions

We learn from the survey that:

- a) Most households are unwilling to change their energy consumption behavior regardless of the multiples of TOU rate. It is noteworthy that 41.6% of the interviewees have no idea of whether TOU is in use in their households. It may represent the households are not aware of the difference between the TOU rate and the fix rate, or they are not concerned with a new pricing mechanism. Consumer's lackluster response to TOU may also be a consequence of Taiwan's low utility rate as compared with its neighboring nations.
- b) The two most demanded extended services related to AMI are fire emergency alert and households' home security.
- c) Households in different locations and with different level of income reveal their preference. Households in Taipei City demonstrate higher interest in obtaining various information from smart meter or IHD. They and the households with higher income are more interested in getting the information of average power usage in their neighborhood and high volume users' power usage. In addition, these two groups are willing to pay more for having smart meters.

6. Recommendation

There are some limitations of understand households' reaction by interview. The responses of interviewees represent their self- expected reaction only. We also encounter some difficulty in the process of interview. The more personal questions we ask such as interviewee's income and educational background, the more resistance we encounter. For raising the valid sample size, we have to reduce some sensitive items. Thus, we don't have enough variables or reason to explain some

⁴ Every household can choose two favorite services.

observation obtained in this survey.

We precede this survey before the mass installation of smart meter, in the future, we look forward to having a demonstration to run smart meter with TOU program and discover households' behavioral reaction.

Acknowledgement

The Bureau of Energy, Ministry of Economic Affairs

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