Online Appendix:

Moral Suasion and Economic Incentives: Field Experimental Evidence from Energy Demand

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Online Appendix A: Welfare Implications

When pursuing a variety of policy goals, policymakers can design policies to influence intrinsic and extrinsic motivations. Our empirical findings suggest that these two policy instruments are likely to have different policy implications, particularly when we consider persistence. In this section, we highlight such policy implications by analyzing the welfare gains from the two policies in the context of electricity markets.

Conceptual Framework

We introduce a simple conceptual framework for a model of electricity consumers to guide our welfare analysis. When consumers receive no treatment, each consumer uses electricity $\bar{x}$ at a given power price P, where $\bar{x}$ can be regarded as a "business as usual" (BAU) consumption level. When they receive moral suasion for conserving energy, they may voluntarily decrease their consumption from $\bar{x}$ to x. Voluntary conservation of electricity, g, is then expressed as the difference between $\bar{x}$ and x. The saved amount in economic terms, Pg, is added to the numeraire y, which totals $Y = y + Pg$. Alternatively, $Y = I - Px$ from the budget constraint of a consumer with income I.

We assume that utility is additively separable into three components. The first term, $u(x)$, denotes utility from consuming electricity, which is assumed to be increasing and concave ($u' > 0$ and $u'' < 0$). The second term, $v(I - Px)$, is utility from numeraire consumption, which is assumed to be increasing and weakly concave ($v' > 0$ and $v'' \leq 0$). Lastly, we consider utility from conservation of electricity, $\phi(g; \theta)$. This is also assumed to be increasing and weakly concave ($\phi_g = \frac{\partial \phi}{\partial g} > 0$ and $\phi_{gg} = \frac{\partial^2 \phi}{\partial g^2} \leq 0$). The utility term $\phi(g; \theta)$ may represent a warm glow component, which is a type of impure altruism, as discussed by Andreoni (1989). Let θ be a parameter that represents the frequency of interventions. We assume that utility and marginal utility of electricity conservation are decreasing in the frequency of interventions, that is, $\phi_\theta = \frac{\partial \phi}{\partial \theta} < 0$ and $\phi_{g\theta} = \frac{\partial^2 \phi}{\partial \theta \partial g} < 0$. The subscript notation denotes a partial derivative.

Andreoni (1989) and Kingma (1989) argue that there are several competing theoretical models of charitable contributions. In the case of pure altruism (pure public good), consumers may care about the total contributions to voluntary conservation. Moreover, consumers may take account of the utility cost (disutilily) of social pressure for not contributing or only contributing a small amount toward voluntary conservation, as illustrated by DellaVigna, List and Malmendier (2012). It is not our primary focus to compare these competing models, but note that we can extend our simple model to incorporate other potential mechanisms behind contributions to voluntary conservation.[1]

The BAU consumption level, $\bar{x}$, in the absence of treatment can be expressed by $\bar{x} = \arg\max\{u(x) + v(I - Px)\}$. Consumers in the economic incentive group have a price change and simply adjust their consumption such that $u' - Pv' = 0$ responding to the price changes. Consumers in the moral suasion group receive moral suasion without economic incentives. When they receive moral suasion, they maximize the following overall utility function:

$$\begin{aligned} &\max_{x,g}\ u(x) + v(I - Px) + \phi(g; \theta) \\ &\text{s.t. } g = \bar{x} - x. \end{aligned} \tag{1}$$

This problem can be rewritten as follows:

$$\max_{x}\ u(x) + v(I - Px) + \phi(\bar{x} - x; \theta). \tag{2}$$

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[1] For example, Kotchen (2006); Kotchen and Moore (2007) consider different participation mechanisms for environmental public goods and show how they relate to existing theory on either *pure* or *impure* public goods.

Let x^* denote the optimal solution for the maximization problem (2), namely, the optimal consumption level under moral suasion. Note that x^* satisfies $u' - Pv' - \phi_g = 0$.[2]

The effect of repeated interventions on voluntary conservation can be easily derived by differentiating the first order condition for the optimization problem (2).[3] Simple calculation yields

$$g_\theta^* = \bar{x}_\theta - x_\theta^* = -x_\theta^* = -\frac{\phi_{g\theta}}{u'' + P^2 v'' + \phi_{gg}} < 0. \tag{3}$$

The optimal consumption of electricity is increasing in θ, that is, $x_\theta^* > 0$, while the BAU consumption level $\bar{x}$ is not affected by θ, that is, $\bar{x}_\theta = 0$. Therefore, the model suggests that repeated interventions may decrease voluntary conservation of electricity, which is consistent with our empirical findings. In the next subsection, we use this conceptual framework to highlight the welfare implications of our empirical findings.

Welfare Gains from the Two Policies

We examine the welfare implications of two policy instruments that are intended to reduce energy usage during peak demand hours: 1) moral suasion and 2) economic incentives. Recall that the fundamental inefficiency in electricity markets is that consumers do not pay time-varying prices for electricity. Thus, they do not have an incentive to use less energy when the marginal cost becomes very high during peak

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[2] Alternatively, we may consider social pressure instead of warm glow. The utility maximization problem may be represented as $\max_x \ u(x) + v(I - Px) - \phi(x;\theta)$, where $\phi(x;\theta)$ can be interpreted as a utility cost of social pressure for not contributing to conservation. This argument is in line with those in DellaVigna, List and Malmendier (2012) and Gerard (2013). Note that x^* satisfies $u' - Pv' - \phi_x = 0$. Thus, if the functional form of $\phi(\,\cdot\,;\theta)$ is the same for both warm glow and social pressure, we obtain the same results in a marginal sense.

[3] Total differentiation of the first order condition for (2) gives $(u'' + P^2v'' + \phi_{gg})dx - (Pv'' + \phi_{gg}\bar{x}_I)dI - (v' - Pxv'' + \phi_{gg}\bar{x}_P)dP - \phi_{g\theta}d\theta = 0$. Thus, we have $x_\theta^* = \frac{\phi_{g\theta}}{u''+P^2v''+\phi_{gg}} > 0$ with $dI = dP = 0$.

demand hours. We begin with the assumption that the marginal cost of electricity for the critical peak hours is 65 cents/kWh, which was the peak wholesale price in the Japanese wholesale electricity market, the Japan Electric Power Exchange, during our experimental period. For a few reasons, this number is likely to be a lower bound for the social marginal cost of electricity in the critical peak hours in Japan during the period.[4] Therefore, we provide the same analysis for different assumptions on the marginal cost of electricity supply (85 and 105 cents/kWh) in Tables A.2 and A.3 in the Appendix. Different assumptions on the marginal cost do not change the qualitative results of our welfare analysis, although the welfare gains are larger when we consider a higher marginal cost of electricity supply.[5]

We consider two policies as well as a baseline case with no policy intervention. In the baseline case, consumers pay 25 cents/kWh for their electricity usage, the average residential electricity price in Japan in 2012. The first policy is our economic incentive treatment. We consider that consumers with this policy pay the price that

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[4] The Japanese electricity market was only partially deregulated during our experimental period. As a result, not all electricity was traded in the centralized Japanese wholesale market. Regulators knew that most of the marginal power plants supplying electricity for peak demand hours were owned by vertically integrated local monopoly power companies, whose electricity was usually not sold in the centralized wholesale market. During our experimental period, these power companies needed to run their old and inefficient power plants to meet unexpected supply shortages after the Fukushima Daiichi Nuclear Disaster. This is one of the reasons why our assumption of 65 cents/kWh is likely to be a lower bound for the marginal cost. In addition, regulators avoided system-wide blackouts by forcing manufacturing firms to stop operating during peak demand hours. If this cost is considered to be a marginal cost for peak hour electricity, the marginal cost can be much higher than the wholesale electricity price in this partially deregulated market. Finally, the wholesale price did not include environmental externalities from electricity generation, the cost of which is likely to underestimate the social marginal cost of electricity.

[5] Another reason why our welfare calculation is likely to provide a lower bound is that it does not consider long-run avoidable investment costs for generation capacity. According to Kansai Electric Power Company, their long-run avoidable cost for a 600 MW thermal plant is \$150,000/MW per year, assuming that the payment period is 10 years and the discount rate is 4%. The maximum total electricity load from residential customers in Japan is 46,800MW, which implies that our economic incentive policy would induce a reduction in the maximum load by 7,198 MW ($= 46,800 \cdot 0.1538$). Therefore, a back of envelop calculation of the long-run avoidable cost from the economic incentive policy is \$1,080 million ($= 7,198 \cdot 150,000$) per year, which is significantly larger than the welfare gains in Table A.1, which does not consider long-run avoidable investment costs for generation capacity.

equals the marginal cost, which is 65 cents/kWh. The second policy is our moral suasion treatment. Consumers with this policy pay the baseline price but receive moral suasion for energy conservation.

Consider a quasi-linear utility function for equation (2). To be consistent with the empirical estimation for electricity demand from our field experiment, we characterize the electricity demand by $\ln x = a + \beta D + \epsilon \ln p$, where D equals 1 if consumers receive the moral suasion treatment, p is the electricity price, and ϵ is the price elasticity. We obtain parameters a, β and ϵ from our field experiment.[6] The inverse demand is defined by $p(x) = [x/(\exp(a) \cdot \exp(\beta D))]^{1/\epsilon}$.

The baseline consumption is $\bar{x} = \exp(a) \cdot 25^{\epsilon}$. When consumers receive the economic incentive, the usage becomes $x_e = \exp(a) \cdot 65^{\epsilon}$. The efficiency gain is characterized by $\int_{x_e}^{\bar{x}} (c - p(x))dx$, the area between the marginal cost c and the inverse demand curve $p(x)$ in the range between x_e and $\bar{x}$. We begin by calculating this efficiency gain for the Japanese electricity market. For a typical summer peak hour, electricity consumption from residential customers is 46,800 MWh. An important assumption in this welfare calculation is that residential customers in Japan respond in the same manner to these two policies as the consumers in our experimental households. We consider two scenarios. In the first scenario, we provide the policy for a short run only, by having only 3 treatment days. In the second scenario, we offer the treatment repeatedly for a total of 15 treatment days. This comparison is consistent with our empirical analyses in the previous section, from which we obtain necessary parameters for our welfare calculation.

Column 1 of Table A.1 shows the efficiency gain from the economic incentive policy. With the short-run policy, the total efficiency gain for the three treatment

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[6] Recall that we estimated β (the effect of the moral suasion) and γ (the effect of economic incentives) in our field experiment. We use γ for the case with treatment price 65 cents/kWh to calculate the price elasticity $\epsilon = \gamma / \ln(65/25)$.

days is \$16.84 million. We then calculate the welfare gains for the repeated policy with 15 treatment days based on the estimated parameters from our experimental findings for the repeated interventions. Because the responses to the economic incentive treatments (γ) do not decay much, more treatment days provide further efficiency gains. With 15 treatment days, the efficiency gain is \$76.55 million. The difference between the short-run and repeated polices is \$59.71 million and statistically significant. These results suggest that 1) the economic incentive policy can provide substantial efficiency gains for the electricity market, and 2) repeated interventions can obtain further gains when there are many critical peak demand days, during which the marginal cost of electricity becomes very high.

When consumers receive moral suasion, the usage can be characterized by $x^* = \exp(a) \cdot \exp(\beta) \cdot 25^{\epsilon}$. The efficiency gain is $\int_{x^*}^{\bar{x}} (c - p(x))dx$, which we calculate in Column 2. With the short-run treatment, the efficiency gain is \$11.37 million, which is lower than the gain from the economic incentive treatment, but it still has a meaningful magnitude for the market. Because the moral suasion effect decays, the efficiency gain does not increase much with repeated interventions. We cannot reject the null that the efficiency gain from the moral suasion treatment is the same for the short-run policy and repeated policy.

When consumers receive moral suasion, there is one more channel through which the welfare can be changed. In our model in equation (2), consumers who receive moral suasion would change their usage from $\bar{x}$ to x^* because they feel warm glow or self-satisfaction from behaving prosocially. In this case, consumers obtain a surplus from their conservation $g = \bar{x} - x^*$. Note that consumers do not necessarily gain a surplus if we consider different models that could explain their motives. For example, consumers may reduce usage because they feel social pressure (DellaVigna, List and Malmendier, 2012) or obedience for authorities. In such cases, it is possible that consumers may lose a surplus when receiving moral suasion. Given our experimental setting, the primary motive for our consumers was more likely to be warm glow. However, we cannot completely exclude the possibility that our households may have lost a surplus or gained no surplus when receiving moral suasion. Therefore, we provide the welfare change from the efficiency gain and that from (potential) warm glow separately in the table and interpret the gain from warm glow with this caution. Recall that the inverse demand is $p(x) = [x/(\exp(a) \cdot \exp(\beta D))]^{1/\epsilon}$. The surplus from warm glow is, therefore, obtained by $\int_{x^*}^{\bar{x}} \left([x/\exp(a)]^{1/\epsilon} - [x/(\exp(a) \cdot \exp(\beta))]^{1/\epsilon}\right) dx$, in which parameters a, β, and ϵ are obtained from the field experiment.

We provide the sum of the efficiency gain and warm glow in the last column of Table A.1. The results suggest that if we take account of a positive gain from warm glow, the total welfare gains from the moral suasion policy can be close to the gains from the economic incentive policy in the short-run. However, this is not the case for the repeated intervention, in which the welfare gain is much larger for the economic incentive policy even if we incorporate potential gains from warm glow. Finally, these results suggest that while in theory welfare gains can arise from the warm glow effect in theory, the major welfare gains in our context arise from the efficiency gains—from letting consumers pay prices that reflect the actual marginal cost of electricity during the critical peak hours.

Online Appendix B: Additional Tables and Figures

Table A.1: Welfare Gains from the Two Policies (Assumption on Marginal Cost = 65 cents/kWh)

	Economic Incentive	Moral Suasion	
	Efficiency Gain ($M)	Efficiency Gain ($M)	Efficiency Gain + Warm Glow ($M)
Short-Run Treatments (3 days)	16.84	11.37	15.02
	(1.99)	(2.55)	(4.62)
Repeated Treatments (15 days)	76.55	24.40	27.32
	(9.04)	(9.92)	(12.38)

Notes: This table shows the estimated welfare gains per season from the two policies in our field experiment. We use 46,800 kWh as the peak hour residential electricity consumption in the Japanese electricity market for the baseline case, which does not refer to either of our policies. We use 65 cents/kWh as the marginal cost of electricity for these critical peak hours. In the Appendix, we provide the same analyses for different assumptions of the marginal cost of electricity.

Table A.2: Welfare Gains from the Two Policies (When Marginal Cost = 85 cents/kWh)

	Economic Incentive	Moral Suasion	
	Efficiency Gain ($M)	Efficiency Gain ($M)	Efficiency Gain + Warm Glow ($M)
Short-Run Treatments (3 days)	26.15	17.38	22.11
	(3.08)	(3.98)	(6.69)
Repeated Treatments (15 days)	118.88	36.91	40.65
	(14.03)	(15.13)	(18.29)

Notes: This table shows the estimated welfare gains per season from the two policies in our field experiment. We use 46,800 kWh as the peak hour residential electricity consumption in the Japanese electricity market for the baseline case, which does not refer to either of our policies. For this table, we use 85 cents/kWh as the marginal cost of electricity for these critical peak hours. In the Appendix, we provide the same analyses for different assumptions of the marginal cost of electricity.

Table A.3: Welfare Gains from the Two Policies (When Marginal Cost = 105 cents/kWh)

	Economic Incentive	Moral Suasion	
	Efficiency Gain ($M)	Efficiency Gain ($M)	Efficiency Gain + Warm Glow ($M)
Short-Run Treatments (3 days)	35.78	23.51	29.10
	(4.21)	(5.47)	(8.70)
Repeated Treatments (15 days)	162.65	49.50	53.89
	(19.18)	(20.41)	(24.12)

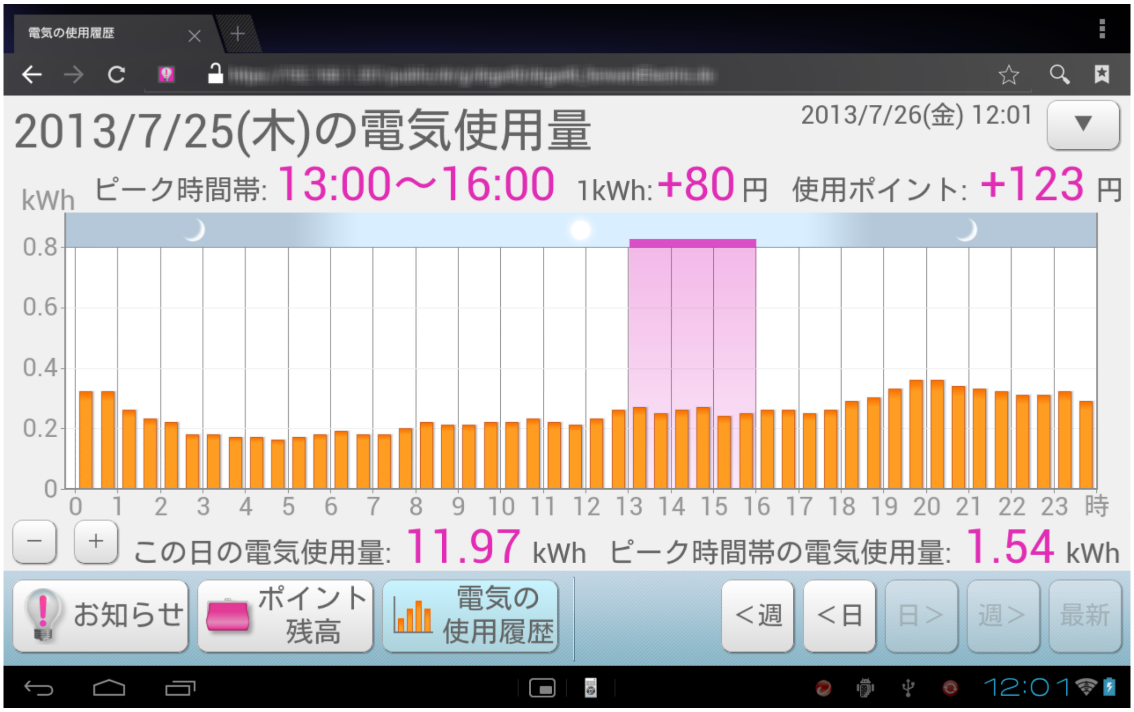
Notes: This table shows the estimated welfare gains per season from the two policies in our field experiment. We use 46,800 kWh as the peak hour residential electricity consumption in the Japanese electricity market for the baseline case, which does not refer to either of our policies. For this table, we use 105 cents/kWh as the marginal cost of electricity for these critical peak hours. In the Appendix, we provide the same analyses for different assumptions of the marginal cost of electricity.

Table A.4: Heterogeneity in the Treatment Effects

	Summer			Winter		
	(1)	(2)	(3)	(4)	(5)	(6)
Moral suasion	-0.044	-0.045	-0.045	-0.034	-0.034	-0.034
	(0.014)	(0.014)	(0.014)	(0.022)	(0.022)	(0.022)
Economic incentive	-0.168	-0.178	-0.178	-0.178	-0.177	-0.177
	(0.022)	(0.023)	(0.023)	(0.023)	(0.024)	(0.023)
Moral suasion × Income	-0.052		-0.054	-0.002		-0.003
	(0.029)		(0.030)	(0.040)		(0.040)
Economic incentive × Income	0.119		0.126	0.108		0.100
	(0.051)		(0.050)	(0.046)		(0.046)
Moral suasion × Usage		0.058	0.069		0.005	0.007
		(0.089)	(0.089)		(0.117)	(0.119)
Economic incentive × Usage		-0.516	-0.531		0.138	0.072
		(0.178)	(0.171)		(0.117)	(0.117)
Observations	105107	105107	105107	205357	205357	205357

Notes: Table A.4 shows the estimation results for regressions that include the interaction terms for household income and usage. Columns 1 and 4 include the interaction terms for household income, columns 2 and 5 include the interaction terms for pre-experiment usage levels, and columns 3 and 6 include both interaction terms. Although we found weak evidence for the moral suasion effect being larger for higher-income households, the estimates are not statistically significant. We found a consistent relationship between economic incentives and income—the economic incentive effect is lower for higher-income households compared to lower-income households. Note that our dependent variable is the log of electricity usage, and the treatment variables are dummy variables. Therefore, for example, the coefficient (0.126 log points) in column 2 implies that an increase in household income by $10,000 would be associated with a 0.0126 log-point increase for the coefficient for the economic incentive dummy variable (i.e., a 0.0126 log-point *decrease* in the treatment effect).

Figure A.1: Information Provided by an In-Home Display



2013/7/25(木)の電気使用量

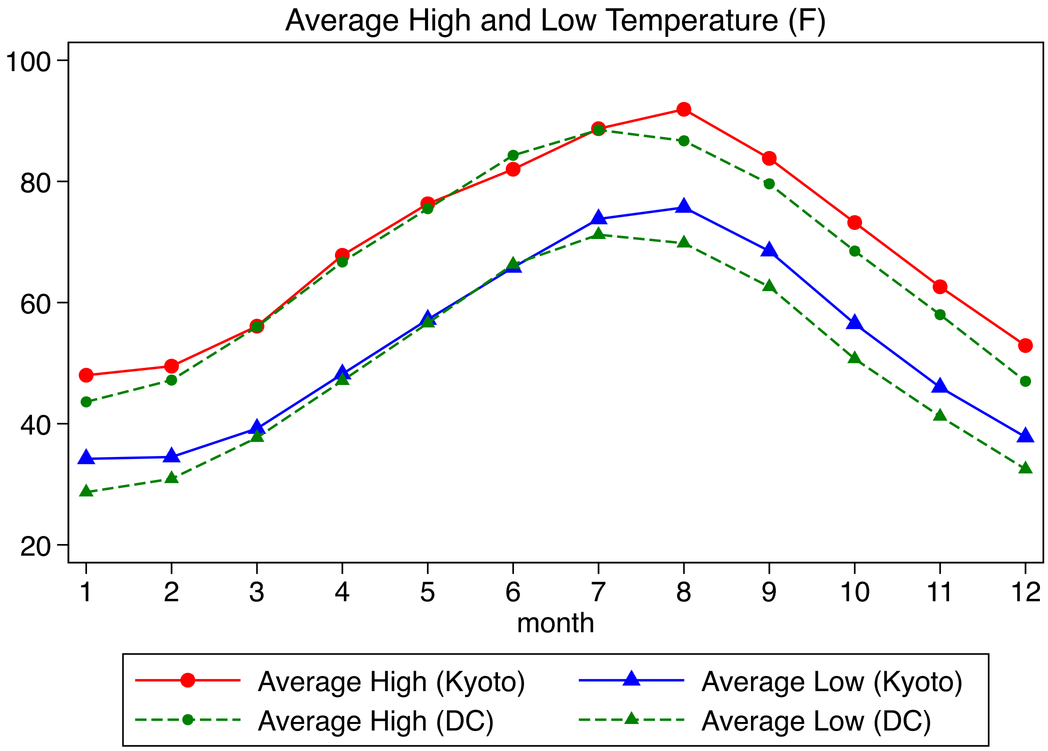
2013/7/26(金) 12:01

ピーク時間帯: 13:00～16:00 1kWh: +80 円 使用ポイント: +123 円

この日の電気使用量: 11.97 kWh ピーク時間帯の電気使用量: 1.54 kWh

Notes: This figure shows an example screenshot of the in-home displays that were installed for both the control and the treatment consumers in the experiment. On the top of the figure, it shows "Electricity usage for July 25, 2013. Peak hours: 13:00 to 16:00. The price increase is +80 yen per kWh." The figure in the middle shows usage in kWh for each 30-minute interval from hour 0 to hour 24 of the day. The shaded area shows the peak hours, which are from 13:00 to 16:00. On the bottom of the figure, it shows "The daily electricity usage is 11.97 kWh. Usage for the peak hours is 1.54 kWh."

Figure A.2: Average High and Low Temperatures in Kyoto, Japan and Washington DC, United States



Notes: This figure compares the average high and low temperatures (°F) in Kyoto, Japan and Washington DC, United States.

Online Appendix B: Materials from the Field Experiment

Invitation Letter (Translated in English)

The Keihanna Eco-City Next-Generation Energy/Community System Demonstration Project

Questionnaire for Assessing Interest in Participating in the Smart Power Usage Program

The Keihanna Eco-City Next-Generation Energy/Community System Demonstration Project Promotion Council created with the support of the Ministry of Economy, Trade and Industry, Keihanna Science City's Next-Generation Energy/Community System Demonstration Project consists of a variety of initiatives designed to create a leading low-carbon community in Japan. As part of this project, we have recently started a power usage demonstration program. As part of this program, we request several households to adopt an energy-saving but easily sustainable lifestyle. We have created this questionnaire to assess the interest of Keihanna Science City residents participating in the program. Please take some time to read and complete this questionnaire. Thank you for your cooperation.

Points to Note before Filling Out the Questionnaire

- Respondents who agree to participate in the program and receive an at-home program briefing will be rewarded with a 1,000-yen prepaid card.
- Read the program overview (on the other side of this sheet) before responding to the questionnaire (separate sheet).
- Place the completed questionnaire in the prepaid return envelope provided and mail it before February 13 (Mon).

■ Questionnaire participants

This questionnaire was distributed by Japan Post's Yu-Mail designated delivery area service after selecting survey areas from among the districts of Keihanna Science City (Kyotanabe, Kizugawa, and Seika).

■ Terms of privacy for personal information

Personal information obtained using this questionnaire will be rigorously managed by the questionnaire administrator, Mitsubishi Heavy Industries. It will be used only to implement the Smart Power Usage Program and for no other purposes. If information about your electric power agreement, facilities, or usage is required for the program, Mitsubishi Heavy Industries will request the information from the Kansai Electric Power Company, and the Kansai Electric Power Company will provide Mitsubishi Heavy Industries with the information requested about your electric power agreement, facilities, or usage.

The Keihanna Eco-City Next-Generation Energy/Community System Demonstration Project Promotion Council

Members: Kyoto Prefecture, City of Kyotanabe, City of Kizugawa, Town of Seika, Public Foundation of Kansai Research Institute, Kansai Electric Power Company, Mitsubishi Electric Corporation, Mitsubishi Heavy Industries, other private-sector companies

For inquiries about the questionnaire, contact the questionnaire administrator organization below.

Questionnaire administrator organization: Regional Futures Research Center

Staff members: Horibe, Yoshiura, Tabuchi

Tel. (toll-free): 0120-79-7711 (9:30~17:00, except weekends and holidays)

Please continue to the program overview on the other side.

Program Overview

Three aspects of smart power usage

- The program will use modern telecommunications technology to create smarter and more streamlined power use by equipping households to moderate their power usage volume and adopt energy-saving habits.

✓ Awareness of energy-saving timing
✓ Visibility of power wastage
✓ Advice from other households

Program Description

- Participating households will engage in some of the following activities.

– The activities will vary depending on households and will be set at random according to the needs of the survey.

–Participants will not incur any cost as a result of taking part in these activities.

Activity 1 Setting variable power charges

- We will provide simulated power charges that vary in time slots of rising power demand.
- You will work on moderating your power usage as much as possible in time slots of high power charges (about 2 or 3 hours during the day).

Activity 2 Providing information on power usage

- We will provide a system enabling participating households to check their power usage every hour.
- You will check your power usage in each time slot and devise ways to minimize wasteful power usage.

Activity 3 Providing energy-saving advice

- After analyzing your power usage, we will advise you on areas such as power-usage methods and replacing appliances (in 2013 summer).
- You will follow the above advice to reduce wasteful power use.

You will not be pressured into replacing appliances.

Program Period, Rewards

- We plan to conduct the program from July 2012 through the end of 2014.
- Participants will receive a small reward (in addition to the reward for completing this questionnaire).

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