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Evaluation of lifestyle factors including people's values affecting electricity consumption in homes

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Abstract. A critical view holds that people's values are integral to lifestyle choices. This study investigated the effects of these values, energy-attitudes, and cognition on home electricity consumption through a case study on an all-electric apartment with HEMS in Yokohama. The conceptual framework assumed that "socially oriented values are related to factors that form energy-attitudes leading to a higher level of behavioral intentions and actual behaviors (and vice versa)" according to Schwartz's basic human value theory and several other sociopsychological models. Results suggest the importance of fostering self-transcendent values in linking people's behavioral intentions to actual actions. This study was one of the first to include people's values when considering energy-saving lifestyles in Japan. The fact that people's values have a certain level of influence on energy consumption has implications on future policy. This sheds light on the need for further research in this area, and thus in realizing energy-saving lifestyles.

1. Introduction

The dissemination of energy-saving lifestyles is a policy agenda under Japanese strategic energy plans^[1]. Here, increased importance has been placed on the household sector in terms of tackling global warming. Under the Paris Agreement, Japan has pledged to reduce its 2013 greenhouse gas emission measurements a full 26% by 2030. Of that 26%, a major portion (21.9%) is comprised of energy-related carbon dioxide emissions, which in turn requires a 40% reduction for the household sector^[2].

It is not easy to promote energy-saving lifestyles, however. This is especially true for the household sector. For one, regulating the individual household is not considered practical. Two, social norms do not tend to work properly in the private home sphere without the presence of others^[3]. This has historically led to the adoption of energy-saving promotion policies that largely focus on technological development, including advanced and more efficient household appliances^[4]. A number of non-technological (mainly economic) mechanisms have also been implemented, such as dynamic pricing and monetary incentives for saving energy^[4].

Under such policies and mechanisms, however, energy consumers are considered as and remain passive players. They are regarded as only being responsive to external forces and incentives when buying energy-efficient products or attempting to save energy for economic reasons. In addition, most previous studies on energy and lifestyles conducted in Japan have solely focused on the "ways of



living” as defined by the amount of time devoted to the individual daily routine and the use of electric devices^[5] in associated activities. In other words, prior studies have failed to capture underlying people’s values, which are considered integral to lifestyle choices. To understand what an energy-saving lifestyle entails, this study analyzed the relationship between people’s values, other determinant factors behind energy-saving behaviors, and actual electricity consumption. This is especially pertinent in view of a paradigm shift entailing personal lifestyle and value changes in post-Fukushima Japan.

2. Research Method

2.1. Conceptual framework

This study’s conceptual framework considered people’s internal values as integral to lifestyle choices. This assumption was based on the historical development of lifestyle concepts^{[6][7]} as well as the general definition of lifestyle (i.e., ways of living) used in energy research in Japan^[5]. This is expressed in the following equation (1) used to evaluate lifestyles that promote energy-saving:

$$Ce = f(Y, Np, T, Ned, \dots, EC, V) \quad (1)$$

Here, Ce represents energy consumption, Y represents household income, Np refers to the number of family members, T refers to time spent on daily routines and other purposes, Ned is the number of electric devices used in these daily routines, EC is energy consciousness, V represents values, and “...” implies that other variables may also affect energy consumption, including age, sex, and building features.

In considering values, this study also adopted Schwartz’s basic human value theory^{[8][9]} as an analytical foundation. Schwartz’s basic human value theory posits that people’s values serve as guiding life principles that influence people when considering their behaviors. For energy consciousness, Stern’s Value-Belief-Norm theory^[10] is used to explain environmental behaviors and necessary policy support in a worldwide context, while Hirose’s dual-process model for eco-friendly behavior^[3] is one of the most widely used models for explaining environmental behaviors in Japan. These were also referenced when building this study’s hypotheses, as follows: 1) Socially oriented values (i.e., “self-transcendence” and “conservation”) which put priorities on one’s surroundings including nature than oneself, function to conserve energy through one’s beliefs, energy-attitudes, and higher behavioral intentions. 2) Personally oriented values (i.e., “openness to change” and “self-enhancement”) form behavioral intentions without the corresponding development of energy-attitudes and thus result in more energy consumption. 3) Higher energy consciousness generally functions to reduce energy consumption, although “belief” and “behavioral evaluation” have differing patterns of influence. Other potentially influencing factors in the equation (1) (e.g., household income, number of family members, time, and electrical devices used) were also considered likely to increase energy consumption based on the findings of prior studies^[5].

2.2. Targeted case study

An all-electric apartment complex containing 177 housing units (built in October 2012) in Yokohama, Japan was the setting for this case study. The apartment was constructed with reinforced concrete and contained seven aboveground stories (no basement). Each unit consisted of two to four bedrooms with one bathroom, occupying floor areas between 55.08m² - 89.06m². A home energy-management system (HEMS) was also installed as standard equipment at the time of construction. The HEMS monitors nine points (i.e., a heat-pump water heater, three air-conditioning units (living-dining, kitchen, and two bedrooms), an electric floor heating system, a kitchen outlet, a washing machine, a bathroom heater/dryer, and an IH cooking stove) in addition to total household electricity consumption. Electricity consumption data are sent to a server every 30 minutes for storage. Residents can access these monitoring data on tablet PCs, which were distributed to them when taking residency. The

apartments were also equipped with a number of default energy-saving devices (e.g., LED bulbs for living rooms, energy-efficient air conditioners, and water-saving toilets).

A survey conducted by the apartment developer indicated the following resident demographic features when occupants moved into the units. There was a 4:6 ratio of small (one or two persons) to large (three persons or more) families. Heads of families were generally young (more than 80% were in their 30s and 40s). Other family members were also young: families with children under five years of age accounted for the greatest portion at 30%. For annual household income, 60% were in the higher income bracket (8 million yen or more) despite their young ages. In addition, 80% of all households reportedly contained an “eco-conscious” family member. However, less than 5% of all respondents regarded “having HEMS” as a key factor in deciding to purchase their apartment unit.

2.3. Electricity consumption data

Electricity consumption data collected by HEMS between April 2014 to March 2015 were obtained for analysis. Here, two-week periods where the effects of missing data and school holidays were minimal were chosen for analysis for each season based on past climatic conditions according to data from the Japan Meteorological Agency. Average electricity consumption per day for each household was calculated for weekdays and weekends, respectively. The final sample number was 147 of 177 households after a data cleansing process. Households showing irregular patterns of electricity consumption were eliminated because residents were assumed away from the home during the aforementioned two-week period. Electricity consumption outside each unit (i.e., in apartment corridors and staircases) was not included in this analysis. For electricity data according to monitoring points, “other” was calculated and used in the analysis by subtracting the total electricity consumed by nine monitoring points (mentioned in 2.2) from total household consumption.

Table 1 summarizes the main features of electricity consumption for this study's target. Generally, total household consumption is the largest in winter for both weekdays and weekends (almost double that of summer, which is the smallest electricity consumption season). Less electricity is used in summer because the demand for hot-water is included in electricity consumption for these apartments. Though not included in Table 1, the standard deviation was 8kWh/day for winter, showing the largest dispersion in electricity consumption per household (again, almost double of that of other seasons). For the electricity consumption trends according to the monitoring points, "other" accounted for the largest proportion (around 30 - 40% of the total). This is because there were relatively few monitoring points in these apartments. Thus, all lighting and outlet usage outside the kitchen was included in "other." Electricity usage for air-conditioning and water heating increased greatly during winter and summer, while kitchen and bathroom heater/dryer usage showed relatively small seasonal fluctuations. Moreover, large families consumed more electricity than small families throughout the year. If looked at in detail, Table 1 numbers imply that daily electricity consumption among small families barely differed between those containing one and two people. For large families, however, three-person families consumed more electricity than four-person families. Notably, total household electricity consumption varied widely, even for families with the same number of persons.

Table 1. Seasonal electricity consumption according to HEMS points and family size.

Period of analysis ^a					Average elec. consumption for all households ^b							Family size ^b	
Season	Dates ^a	Climatical condition			Household total		HEMS points ^c (weekdays)					Household total	
		Ave. daily temp.	Min/Max of daily maximum temp.	Min/Max of daily lowest temp.	week-end	week-days	A/C & heating	Hot water	Bath/ dryer	Kitchen total	Other	small (n=67)	large (n=79)
Spring	April 7th - 20th, 2014	13.8°C	23.4°C/14.2°C	13.2°C/4.6°C	14.91	13.80	0.41	4.08	0.92	2.00	6.50	12.23	14.39
Summer	July 1st - 14th, 2013	26.9°C	34.7°C/25.5°C	26.6°C/20.0°C	13.71	11.46	2.22	1.62	0.68	2.35	4.58	10.71	13.19
Fall	Nov 10th - 23rd, 2014	13.0°C	21.7°C/10.7°C	13.2°C/6.8°C	17.53	16.79	0.30	3.55	0.95	2.09	9.90	11.99	13.40
Winter	Feb 5th - 18th, 2014	4.5°C	19.1°C/4.7°C	7.0°C/-0.5°C	26.01	22.84	3.25	6.07	1.13	1.95	10.44	21.11	23.48

^a These periods were decided based on available data, school holidays, and climatic conditions. For spring and fall, temperatures closer to the previous 10-year chosen. For summer and winter, more stringent conditions were chosen compared to the previous 10-year average.

^b Units for electricity consumption are in kWh/day. Averages were calculated according to 10-day periods for weekdays and four-day periods for weekends in summer and fall. For winter, nine and five-day periods were used, respectively.

^c "A/C & heating" = air-conditioning lines and floor heater combined (only A/C lines for summer). However, any use of other oil or electric heaters was not "kitchen total" = kitchen outlet and IH cooking stove combined.

2.4. Analysis procedures

Physiological structures determining people's energy-saving behaviors were first examined using the results of a questionnaire conducted in August 2015. The survey asked 22 questions about people's values and 30 questions about energy-cognition, as well as behavioral intentions and the level of action taken for 16 items related to specific energy-saving behaviors (Table 2). Other questions asked for respondent opinions on the future energy-mix in Japan, their supported political party, and social actions taken (including those on energy). Two-sets of paper-based questionnaires were distributed to each household by posting a message asking all adults over 20-years of age to respond. If extra sets were needed, respondents were asked to obtain them from the apartment management office. The questionnaire survey was conducted from August 17 - 30, 2015. A total of 161 responses were obtained from 91 households (i.e., an effective household response rate of 52%).

Responses were first analyzed through a factor analysis in consideration of people's values, energy cognition, and behavioral indicators (i.e., behavioral intentions and level of energy-saving action taken). This information was then tested through a covariance structure analysis based on a hypothetical model (explained later in 3.1) to explore the relationships between people's values, energy cognition, and behavioral indicators using SPSS Amos 25. Analyses were then conducted on whether and how these relationships changed when applied to the household electricity consumption data accumulated by HEMS (the dependent variables). A total of 42 "lifestyle factors" in seven categories were considered to reflect and/or determine how people's lifestyles were defined according to the HEMS data (section 2.3), 2015 questionnaire results, and the survey conducted by the developer when residents took occupancy in 2012. Table 3 summarizes these lifestyle factors. Each is indicated according to the number of samples, average figures, standard deviations, and analysis items. Indicators categorized under "HEMS scales" (e.g., the total time of air-conditioning use, "Hours: AC-heating," and "day/night ratio" of electricity use) were considered to represent the "ways of living" factors conventionally used in Japanese "lifestyle" studies. A series of one-way analyses of variance were conducted for each factor among the three groups coded as "high," "middle," and "low" depending on their electricity consumption. People's values, energy cognition, and behavioral indicator factors were coded according to the direction of influence predicted in the earlier hypothesis. Factors showing statistical significance among the three coded groups were then taken for a further correlation analysis to evaluate interrelations among the factors affecting electricity consumption.

Table 2. Survey questions.

Values	Items	1) partner/family 2) security/peace 3) health 4) cleanliness 5) money/income 6) education 7) work 8) environmental quality 9) freedom 10) comfort 11) privacy 12) leisure 13) social relationship 14) material beauty 15) social justice 16) aesthetic beauty 17) identity 18) challenge/stimulation 19) social status/recognition 20) nature/biodiversity 21) change 22) spirituality/religion
	Scales	Rating by total of 9 scales on the importance each item as priorities in one's life: 0 being 'not important at all' to 7 (most important) and -1 being 'against my values'
Energy-cognition	Items	I. Risk perception: 1) electricity deficiency 2) oil depletion 3) global environmental issues 4) local environmental issues; II. Threat cognition: 5) major outage 6) nuclear accident 7) another accident; III. Social responsibility: 8) global environmental issues 9) major outage 10) risk reduction by energy-saving; IV. Societal efficacy: 11) meeting the global warming target 12) preventing sudden outage 13) solving oil depletion issue; V. Cost-benefit cognition: 14) knows energy-saving method 15) buys energy-saving products 16) knows own utility bills 17) conscious about savings of the bills; VI. Attitude: 18) energy-saving is rewarding 19) energy-saving interferes with convenience 20) energy-saving deteriorates comfort 21) energy-saving deteriorates quality of life 22) energy-saving limits freedom 23) energy-saving is a personal choice VII. Personal norm: feels expectation to save energy from 24) own family 25) people/friends surrounding me 26) the government VIII. Morality: 27) sense of guilt towards victims of Great East Japan Earthquake 28) energy-saving is social obligation 29) energy-saving is obligation for the victims 30) I should promote energy-saving to others
	Scales	Rating on the scale from 1 'do not agree at all' to 7 'agree completely'
Behavior	Items	1) air-condition (AC) setting @ 28 Celsius degrees 2) use sun shade 3) use LED lighting 4) reduced lighting 5) reduced TV brightness 6) turning off TV 7) use of a fridge curtain 8) reduce refrigeration temperature 9) refrain from use of keep-warm function 10) use of waste heat 11) reduced use of dishwasher 12) reduced use of drying function 13) reduce stand-by power use 14) bathing consecutively 15) cool/warm share at living room 16) reduce hot-water use
	Scales	Behavioral intention: rating of 'whether want to take these actions' on 7-pt. scale 1 being 'not at all' to 7 being 'very much so' Actual action: rating of the degree of conduct on 4-pt scale 1 'none' 2 'sometimes' 3 'always' and 4 'not applicable'

Here, sample numbers were reduced to 70 out of 161 responses from 91 households as determined by questionnaire responses from August 2015. Of these, 45 samples in which more than two responses were returned and individuals with lower levels of action were analyzed.

Table 3. Lifestyle factors used to analyze electricity consumption data.

Lifestyle factors (variables)		Spring			Summer			Fall			Winter		
		n	Ave.	S.D.	n	Ave.	S.D.	n	Ave.	S.D.	n	Ave.	S.D.
HEMS scales	Weekday/weekend ratio	145	0.90	0.16	145	0.88	0.18	147	0.96	0.16	146	0.85	0.14
	Day/night ratio	146	0.50	0.17	145	0.67	0.22	147	0.54	0.17	146	0.51	0.18
	AC use in non-LDK rooms				145	0.18	0.18				133	0.17	0.23
	Total AC-heating ^a	146	0.75	1.46				147	0.71	1.19			
	Type of heating	104	0.78	0.36				113	0.65	0.45	140	0.76	0.33
	Cooking ratio	146	0.26	0.14	145	0.20	0.12	147	0.27	0.14	146	0.31	0.16
	Hours: AC-heating ^a				145	9.40	9.63				146	11.57	13.29
	Hours - bath dryer ^a	146	1.61	2.87	145	0.47	1.50	147	1.58	2.35	146	1.02	2.58
a : Units: kWh/day for total AC/heating; hour/day for #hours AC & bath/dryer													
Bldg. Character		n	Ave. ^b	S.D.	Scales for comparison ^c (sample number used for analysis)								
	Floor level	147	1.97	0.53	1st fl. (23) , middle fls. (106), top fl.(18)								
	Floor plan	147	1.93	0.43	2LDK (19), 3LDK (118), 4 LDK (9)								
	Direction of balcony	147	1.23	0.42	South (113) , East (34)								
Household characteristics	Direction within site	147	2.38	1.09	SE (41) ,SW (38) , NE (38) , NW (29)								
	# of family members	147	2.61	1.06	Small (1 - 2persons , 60), Many (3persons or more, 85)								
	Age - head of family	142	1.65	0.79	20s (76) ,40s (37) , over 50s (28)								
	Wife - working or not	129	0.57	0.50	No (56) , Yes (73)								
	Baby/elderly member	144	0.35	0.48	Yes (92) , No (51)								
	Have a pet	145	0.88	0.32	No (127) , Yes (17)								
	Annual income (JPY)	145	3.12	0.83	<4mi (8), ~ 8mi(17), ~ 12mi yen (68), >12mi (51)								
	Eco-conscious member	145	0.77	0.43	Yes (34) , No (110)								
	Sex	70	1.43	0.50	Male (40) , Female (30)								
	Rolling blackout	69	1.61	0.49	Yes (27) , No (42)								
b: Figures indicate average of scale codes, except the actual ave. is used for number of family members.													
c: Each variable is coded with a smaller number from left to right.													
People's values		n	Ave.	S.D.	Items included ^d								
	Conservation	70	0.08	1.12	Security, Calmness, Env. Quality., Health								
	Stimulation	70	0.00	0.81	Challenge, Stimulation Change								
	Self-enhancement	70	-0.05	0.86	Social status&recognition, Work, Social relations								
	Self-transcendence	70	-0.10	0.94	Aesthetic beauty, Material beauty, Nature/biodiversity								
Energy-cognition	Self-direction	70	0.09	0.85	Freedom, Identity, Social justice								
	Attitude	70	-0.02	0.97	Comfort, Convenience, QoL, Freedome								
	Societal efficacy	70	-0.066	0.97	Global warming, Sudden outage, Oil depletion								
	Sense of guilt	70	-0.051	0.98	Sense of guilt, Obligation towards victims								
	Social responsibility	70	0.04	0.90	Global env. problems, Sudden outage								
	Personal norm	70	0.0099	0.91	Pressure from surroundings, Pressure from family								
	Cost-benefit cognition	70	-0.106	0.88	Energy-saving method, Utility bills, Cost-saving, Rewarding								
Behavioral Intention	Risk perception	70	0.01	0.81	Oil depletion, Elec. Difficiency, Global env. problems								
	Intention total pts.	70	-0.02	0.97	Factor scores of all 16 behaviors								
	Custom change	70	-0.066	0.97	TV off, Keep warm, Wasteheat, Drying, Standby, Hotwater								
	Setting change	70	-0.051	0.98	AC@28°C, TV brightness, Fridge curtain, Fridge temp., Lighting								
Action	Family behavior/space	70	0.04	0.90	Bathing in-sequence, Spend time at LDK								
	Action total pts.	70	0.0099	0.91	No action = 1pt. Sometimes = 2pts. Always = 3pts.								
	# of "always" actions	70	-0.106	0.87	# of actions "always" conducting								
	Custom change	70	-0.066	0.97	TV off, Keep warm, Wasteheat, Drying, Standby power, Hotwater								
	Setting change	70	-0.051	0.98	TV brightness, Fridge curtain, Fridge temp., Lighting								
Action	Family behavior/space	70	0.04	0.90	Bathing in-sequence, Spend time at LDK								
	d: Each item corresponds to a question asked in the questionnaire.												

3. Results and Discussion

3.1. Psychological determinants for electricity-saving behavior

To explore the psychological path determining the electricity-saving behavior among the people, a special focus was placed on people's values in testing the psychological model to explore the psychological path determining electricity-saving behaviors among residents. Figure 1 graphically expresses the hypotheses explained in section 2.1 as tested through a covariance structure analysis. Factors analyses were conducted prior to this for each questionnaire category (i.e., people's values, energy cognition, and behavioral intentions).

For questions relating to people's values, two of the 22 question items (i.e., partner/family and spirituality/religion) showing ceiling and floor effects were omitted from the factor analysis. A total of five factors were obtained from the 15 items asked in the questionnaire based on a series of generalized least-square method factor analyses with promax rotations. These five factors (i.e., "conservation," "stimulation," "self-enhancement," "self-transcendence," and "self-direction" according to Schwartz's basic human value theory) explained 64.5% of the variance. The same approach was applied for energy cognition, for which seven factors (i.e., "attitude," "self-efficacy," "moral norms," "social responsibility," "personal norms," "risk perception," and "cost-benefit evaluation") were identified. These explained 64% of the variance. Of these, it should be noted that only items related to victims of and those affected by the Great East Earthquake remained as factor components for "moral norms," thus implying a related sense of guilt (a new psychological factor) that arose separately from more general morality.

Figure 2 shows the results of testing the hypothetical model. Each oval in the Figure represents a factor identified in the factor analysis mentioned above. Although some indicators require improvement, social (i.e., self-transcendent) values lead to behavioral intentions to save energy through energy-attitude. Energy-attitude also prescribes actions through behavioral intentions. These two items supports hypothesis 1. Moral norms followed risk perception (opposing hypothesis 2), but formed behavioral intentions without forming energy-attitude (partially supporting hypothesis 2).

Better goodness-of-fit indicators were obtained when using behavioral intention as the dependent variable ($\chi^2=95.927(p<.196)$; RMSEA=0.031; GFI=0.919; CFI=0.985) as compared to the test results for the model using the level of actions shown in Figure 2. This was assumed to be the result of a gap between behavioral intentions and the level of action taken^[3], which is generally acknowledged in this research field. Though not included in detail in this paper, the results of a logistic regression analysis revealed that personal cost-benefit evaluations (a construct of environmental consciousness) and factors related to demographic attributes (i.e., sex and household income) were also likely to influence the factors leading to different levels of behavioral intentions and actions.

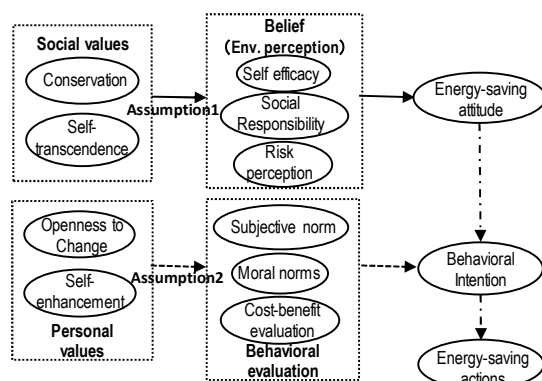


Figure 1. Sociopsychological hypothetical model used in this study.

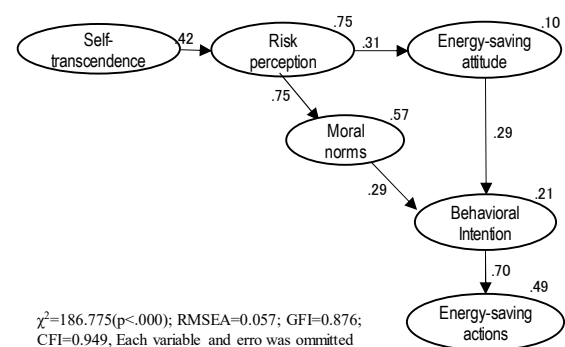


Figure 2. Hypothetical model test results.

3.2. Analysis using electricity consumption

Table 4 shows the results of a series of one-way analyses of variance including factors calculated from electricity consumption data collected by HEMS. Results for summer, spring, and fall were limited to the “kWh trend” whether or not they supported the hypothesis and according to statistical significance among the three analyzed groups (high, middle, and low). Results indicated that the “ways of living” indicators represented by HEMS scales generally had the strongest influence on electricity consumption, followed by household demographic factors. This supports the previous studies mentioned earlier. All HEMS scales were especially statistically significant at 1% or 5% standards for winter. This was also generally true for other seasons, although the statistical standards differed

Table 4. One-way analyses of variance results (electricity consumption as the dependent variable).

Lifestyle factors (variables)				Winter							Summer			Spring		Fall	
				Average kWh/day			kWh	ANOVA			Tukey			kWh	ANOVA	kWh	ANOVA
HEMS scales		Low	Middle	High	trend ^a	Df	F	p	L-M	M-H	L-H	trend ^a	p	trend ^a	p	trend ^a	p
	Weekday/weekend ratio	19.26	23.63	22.78	Δ	2, 143	4.637	0.011**	***	*		○	0.001***	○	0.020**	○	0.026**
	Day/night ratio	16.93	23.71	25.06	○	2, 143	19.525	0.000***	***	***	***	○	0.000***	○	0.001***	○	0.003***
	AC use in non-LDK rooms	20.32	21.01	24.62	○	2, 130	4.714	0.011**	***	**		Δ	0.496				
	Total AC/heating					2, 143	57.501	0.000***	***	***	***			○	0.000***	○	0.000***
	Type of heating	19.60	23.37	26.12	○	2, 137	7.634	0.001***	**	***				○	0.088*	○	0.114
	Cooking ratio	18.83	23.83	22.93	Δ	2, 143	6.174	0.003***	***	**		○	0.002***	○	0.068*	Δ	0.003***
	Hours: AC used	16.44	23.20	26.05	○	2, 143	27.213	0.000***	***	*	***	○	0.000***				
Hours: bath dryer	19.14	22.02	24.62	○	2, 143	6.495	0.002***		***		○	0.000***	○	0.000***	○	0.000***	
Bldg. characteristics		1st fl.	middle	top fl.		Df	F	p					p		p		p
	Floor level	24.01	20.94	24.75	Δ	2, 143	2.972	0.054*	※			Δ	1.265	Δ	0.061*	○	0.454
		2LDK	3LDK	4LDK													
	Floor plan	22.96	21.53	24.32	Δ	2, 143	0.748	0.475				×	0.804	×	0.475	×	0.534
		S	E														
	Direction of balcony	21.74	22.39		○	1, 144	0.178	0.674				○	0.203	○	0.674	○	0.377
		SE	SW	NE	NW												
	Direction within site	21.81	20.58	22.69	22.67	○	3, 142	0.596	0.618			○	0.477	×	0.618	○	0.439
Household characteristics		Small	Many			Df	F	p									
	# of family members	19.69	23.50		○	1, 143	9.021	0.003***				○	0.029**	○	0.006***	○	0.002***
		20s/30s	40s	>50s													
	Age -head of family	21.21	23.44	22.03	Δ	2, 138	1.059	0.349				Δ	0.789	Δ	0.249	Δ	0.363
		No	Yes														
	Wife - working or not	24.13	21.45		○	1, 127	4.020	0.047**				○	0.014**	○	0.013**	○	0.462
		No	Yes														
	Baby/elderly member	20.69	24.27		○	1, 141	7.399	0.007***				○	0.037**	○	0.024**	○	0.002***
People's values		Yes	No														
	Have a pet	26.99	21.35		○	1, 142	8.471	0.004***				○	0.014**	○	0.001***	○	0.058*
		<4mi	~8mi	~12mi	>12mi												
	Annual income (mil. JPY)	18.81	21.85	22.38	22.08	○	3, 140	0.513	0.674			○	0.101	○	0.269	○	0.057*
		No	Yes														
	Eco-conscious member	25.22	21.02		○	1, 142	8.089	0.005***				○	0.489	×	0.192	○	0.231
		Male	Female														
	Sex	20.90	20.88		○	1, 68	0.000	0.990				○	2.634	○	0.445	○	0.393
Energy-cognition		Yes	No														
	Rolling blackouts	20.06	21.64		○	1, 67	0.732	0.395				○	1.253	○	0.532	○	0.658
		High	Middle	Low		Df	F	p	H-M	M-L	L-H	p	p	p	p	p	p
	Self-transcendent	19.16	20.83	22.41	○	2, 67	1.030	0.363				○	0.079*	○	0.230	○	0.184
	Conservation	18.73	20.62	23.34	○	2, 67	2.300	0.108				○	0.066*	○	0.133	○	0.067*
		Low	Middle	High		Df	F	p	H-M	M-L	L-H	p	p	p	p	p	p
	Stimulation	18.80	21.37	22.71	○	2, 67	1.933	0.153				Δ	0.656	○	0.378	○	0.361
	Self-enhancement	18.19	22.86	21.82	Δ	2, 67	2.799	0.068*	*			○	0.685	○	0.425	○	0.293
Intention		High	Middle	Low		Df	F	p	H-M	M-L	L-H	p	p	p	p	p	p
	Attitude	20.92	20.56	21.95	Δ	2, 67	0.479	0.622				Δ	0.096*	Δ	0.916	Δ	0.092*
	Societal efficacy	19.50	20.90	22.30	○	2, 67	2.260	0.112				○	0.244	○	0.591	○	0.942
	Social responsibility	21.30	20.50	21.10	Δ	2, 67	0.230	0.795				×	0.149	×	0.357	×	0.368
	Risk perceptin	21.80	18.10	22.50	Δ	2, 67	0.757	0.061*	※			Δ	0.958	Δ	0.065*	Δ	0.876
	Sense of guilt	20.10	20.60	22.20	○	2, 67	1.774	0.178				○	0.467	○	0.216	Δ	0.256
	Personal norm	20.40	22.20	20.10	Δ	2, 67	1.464	0.239				Δ	0.859	○	0.942	○	0.940
	Cost-benefit cognition	21.50	18.50	22.60	Δ	2, 67	4.781	0.239				Δ	0.646	Δ	0.027**	Δ	0.383
Action		High	Middle	Low		Df	F	p	H-M	M-L	L-H	p	p	p	p	p	p
	Intention total points	18.02	21.87	22.13	○	2, 67	2.148	0.125				○	0.022**	○	0.008***	○	0.017**
	Custom change	17.96	22.78	21.72	Δ	2, 67	2.542	0.086*	*			Δ	0.011**	Δ	0.030**	○	0.084*
	Setting change	20.34	20.22	22.06	Δ	2, 67	0.440	0.646				○	0.237	○	0.164	○	0.240
	Family behavior/space	22.45	19.48	19.98	×	2, 67	1.092	0.341				×	0.353	Δ	0.934	×	0.719
	# of "always" actions	17.45	23.99	20.81	Δ	2, 67	4.754	0.012**	***			Δ	0.011**	Δ	0.002***	Δ	0.022**
	Action total points	18.95	21.10	22.12	○	2, 67	1.062	0.352				○	0.247	○	0.286	○	0.243
	Custom change	17.88	22.72	21.80	Δ	2, 67	2.841	0.065*	*			Δ	0.004***	Δ	0.013**	Δ	0.055*
Family behavior/space	Setting change	20.36	19.07	23.18	Δ	2, 67	1.712	0.188				Δ	0.247	○	0.460	○	0.351
	Family behavior/space	20.26	19.70	22.59	Δ	2, 67	0.984	0.379				×	0.486	○	0.509	Δ	0.357

a: For "kWh trend" ○= support the hypothesis, Δ=partly support the hypothesis, ×= do not support the hypothesis; *** p<0.01, ** p<0.05, * p<0.1; ※=not significant as result of Tukey.

slightly. The “kWh trends” generally supported the hypothesis stating that higher ratios (i.e., greater electricity consumption or time use) indicated higher average electricity consumption.

Of the four building characteristics, “floor level” was the only item that showed marginal significance (at 10% standards) in winter and spring. Different trends were also noted. For instance, households on the top floor showed the largest electricity consumption in winter, while households on the ground floor consumed more electricity in spring. A total of three household demographic characteristics (i.e., number of family members, living with baby and/or older members of the family, and having a pet) were identified as factors influencing electricity consumption during all seasons. The employment status of the household wife also influenced electricity consumption in all seasons except for fall. In addition, the kWh trends for other items without statistical significance generally supported this study’s hypotheses and trends found by previous studies.

For the scales developed based on the self-reported questionnaire responses, general trends in electricity consumption and people’s values supported this study’s hypothesis (i.e., electricity consumption in households among people with higher social values scores were smaller than those for people with lower social value scores (and vice versa for personal values)). “Conservation” values were also identified as potential influencers during summer and fall. However, this influence was considered weak (i.e., of marginal significance compared to the scales mentioned above). For energy cognition, however, the hypothesis stating that higher energy cognition was related to lower energy consumption was not supported for “middle” and “high” scoring groups for many items. Furthermore, the total points for all 16 behavioral intentions revealed statistically significant influences either at 1% or 5% in all seasons except winter. Lower-scale behavioral intentions for “custom change” were also noted to have certain influences with marginal significance. Higher action levels were related to lower electricity consumption compared to households with middle-action levels in all seasons, while the opposite trend was observed between households with low and middle-level actions. Thus, the relationships between self-declared behavioral indicators and electricity consumption are not necessarily proportional. This is especially evident for behavioral indicators involving the actions of family members.

3.3. Correlations between lifestyle factors

Correlation analyses were conducted to further evaluate the relationships between the lifestyle factors found to influence electricity consumption within households of statistical significance in the above section and the pathways by which they influenced electricity consumption/saving behavior. Table 5 summarizes the results of these analysis, including the lifestyle factors determined from the

Table 5. Results of the correlation analysis for winter.

	Total kWh	Hours: AC-heating	# family member	Day/Night ratio	Self-enhancement	Intention (custom)
Degree of correlation rank	1	2	3	4	5	
Day/Night ratio	0.290*	0.523**	0.011	1.000	-0.013	0.064
AC use in non-LDK	0.222	0.400**	-0.062	0.130	-0.025	0.092
HEMS Type of heating	0.215	0.014	0.018	0.065	-0.046	0.016
Cooking ratio	0.060	0.182	0.082	0.295*	-0.065	-0.067
Hours: AC-heating	0.493**	1.000	0.134	0.523**	0.164	0.126
Hours: bath-dryer	0.226	0.041	-0.015	-0.091	0.121	0.046
Bldg. Floor level	0.125	0.047	-0.094	0.030	-0.082	0.093
# of family members	0.300*	0.134	1.000	0.011	0.107	0.160
House Wife - working or not	-0.058	-0.223	0.194	-0.412**	0.017	-0.002
charac- Baby/elderly member	0.156	0.224	0.364**	0.108	-0.138	-0.050
ter Have a pet	0.177	0.090	0.078	0.097	0.207	-0.006
Eco-conscious member	-0.144	-0.174	0.060	-0.021	-0.275*	-0.175
People's Conservation	0.147	0.251*	0.072	0.143	0.137	0.220
values Self-enhancement	0.246*	0.164	0.107	-0.013	1.000	-0.130
Energy Cost-benefit cognition	0.009	-0.067	-0.021	-0.206	0.074	0.130
cognition Risk perception	-0.038	0.000	-0.028	0.080	0.076	0.020
Behavior Actions (custom change)	0.224	0.103	0.222	0.147	0.038	0.508**
Intention (custom)	0.241*	0.126	0.160	0.064	-0.130	1.000

Spearman's rank correlation coefficients **p<0.01, *p<0.05

Table 6. Lifestyle factors affecting electricity consumption by season.

		Winter	Summer	Spring	Fall
HEMS scales, bldg. & house character only (n=147)	1	Hours: AC-heating	Hours: AC-heating	Total AC/heating	Total AC/heating
	2	Day/night ratio	Hours: bath dryer	Hours: bath dryer	Hours: bath dryer
	3	# of family member	Cooking ratio	Day/night ratio	Baby/elderly member
	4	Have a pet	Day/night ratio	Have a pet	# of family member
	5	Baby/elderly member	Have a pet	Baby/elderly member	Day/night ratio
Including people's values, energy cognitions, behaviors (n=70)	1	Hours: AC-heating	Hours: AC-heating	Total AC/heating	Hours: bath dryer
	2	# of family member	Hours: bath dryer	Day/night ratio	Conservation
	3	Day/night ratio	Day/night ratio	Hours: bath dryer	Intention (total pts.)
	4	Self-enhancement	Wife-working or no	Intention (total pts.)	# of family member
	5	Intention (custom)	Cooking ratio	# of family member	n/a

questionnaire (n=70) for winter. The results indicated strong correlations between electricity consumption (winter, weekday) and the time used for air-conditioning and heating, day/night ratio, and number of family members in order of their degree of correlation ranking, followed by self-enhancement values on the fourth line and behavioral intentions for custom changes on the fifth. A closer look at the correlations between the factors ranked first to fifth reveals features such as “household with baby/senior members,” “non-working wife,” “with a pet,” and “larger number of family members.”

Table 6 summarizes the factors with strong influences on electricity consumption for each season. Results also indicate that the use of air-conditioning/heating was the strongest influencer in other seasons. Further analyses using the HEMS branch data indicated that the “ways of living” factors were linked to different patterns depending on resident life-stages. For instance, “age of the family member” was linked to air-conditioning usage in non-LDK rooms for senior residents, but was linked to the use of air-conditioning and floor heating in the LDK for houses with babies.

3.4. Discussion: Lifestyle factors affecting electricity consumption

From the above, the lifestyle factors affecting electricity consumption (C_e) in equation (1) (see section 2.1) can be expressed in following equation (2):

$$C_e = f(Tac, Tbd, Afm, Ww, V, Ie) \quad (2)$$

Here, Tac stands for hours of air-conditioning/heating use, Tbd represents hours of bathroom dryer/heater, Afm is age of the family member (e.g., senior members or babies), Ww represents whether the wife of the house was employed or stayed at home during the daytime, V is for values, and Ie is for energy-saving behavioral intention.

As shown above, different values affected electricity consumption based on the season. However, Ie was influenced by self-transcendent values (as previously shown in Figure 2). This emphasizes the importance of these factors. For example, electricity consumption in winter is expressed through the following equation (3):

$$C_e = f(Tac, Tbd, Afm, Ww, Vse, \underline{Vst}, Sex, EC, -Y) \quad (3)$$

Here, the underlined variables were substituted for Ie (behavioral intention) in equation (2), where Vst stands for self-transcendent values, Sex represents female, EC is energy cognition (specifically, cost-benefit evaluation, attitude, and personal norms), and Y is household income. Two types of “ V ” variables (Vse as “self-enhancement” and Vst as “self-transcendence”) represented opposite values in Schwartz's value theory. This implies that personal energy-saving or more consuming behaviors were determined by the balance between the strength of self-enhancement values (a direct determinant for winter as shown in Table 6) and self-transcendence values (included as a determinant for energy-

saving behavioral intentions). Furthermore, there is a policy implication for the role of values (especially those related to self-transcendence) in linking behavioral intentions to actions.

4. Concluding remarks

This study examined the relationship between people's values, other determinant factors behind energy-saving behaviors, and electricity consumption by analyzing self-declared responses obtained from a questionnaire and electricity data collected by HEMS. Results generally indicated the following. First, the influence of "way of living" factors was found to be stronger than that of people's values. This reassures the validity of these factors as conventionally used in energy research in Japan. Electricity data monitored by and obtained from HEMS were useful for extracting the factors representing the "way of living" indicators widely studied in prior research.

Second, although they were found to be weaker than the conventional "way of living" factors, this study's results also highlight the potential role of people's values in realizing energy-saving lifestyles. This study's hypotheses were generally supported in terms of the effects of people's values and energy cognition on electricity consumption. For example, people's values affected through different patterns according to resident life-stage when studied in greater detail by dividing items into categories based on their strength of influence (e.g., number of family members).

Further research is needed to derive a more general conclusion among a wider sample in a greater scope of work to include energy usage outside homes (e.g., in transportation and indirect energy consumed by actions such as eating out) as well as by looking at the dynamics of behavior and influences among family members.

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