

A PROPOSED MODEL FOR USING THE ENERGY- SAVING FEATURES OF HOUSEHOLD APPLIANCES

László Berényi^{1*}

¹ Institute of Management Science, Faculty of Economics, University of Miskolc, Hungary,

<https://orcid.org/0000-0003-0596-9315>
<https://doi.org/10.47833/2025.2.ECO.019>

Keywords:

energy saving
household
sustainability
Technology Acceptance Model
PLS-SEM

Article history:

Received 30 March 2025
Revised 28 April 2025
Accepted 1 June 2025

Abstract

Access to affordable and clear energy is listed as Goal 7 of the SDGs. The increased global energy consumption is critical, despite efforts to increase the efficiency of devices. Personal approach to energy saving is key to achieving sustainability. The study focuses on a selected topic within this area. Using the energy-saving features of household appliances is a small but fundamental milestone on the path to change. Understanding the personal motivation behind using or rejecting such features is a valuable contribution to developing both the tools and the behaviors. The study presents a proposed model for measuring the influencing factors of the topic designed for PLS-SEM modeling. A pilot test was conducted using a sample of 198 respondents. The applicability of the technology acceptance approach was confirmed, including the need to add environmentalism to the model. A key conclusion of the analysis is that including use behavior is questionable, as such models are primarily designed to assess intentions.

1 Introduction

The growth in energy consumption has led to global environmental and social problems [1]. Individual energy use and energy-saving practices initially have an impact only on reducing household-level energy costs, but the widespread application of these practices leaves a visible trace. The corporate impact on personal energy-saving attitudes [2] [3] is obviously beneficial for the organization, but the new behavior also contributes to sustainability on both personal and global levels.

Goal 7 of the Sustainable Development Goals (SDGs) [4] is about access to affordable and clean energy. There are both technical and social challenges in the field. Above all, without the outstanding efforts of engineers to improve the energy efficiency of the machines and to exploit renewable energy sources, there is nothing to discuss. Energy saving is an obvious endeavor to achieve a sustainable world. Beyond the technical issues, the acceptance and use of the new technologies require managerial, educational, and other actions as well. Any feature is useless even if it is built in if people do not use it. Individuals should be encouraged to use it. Cost savings, true conviction, commitment, copying a pattern, habit, and forced behavior can both support and hinder the fulfillment of the expectations. Beneficial strategies and actions require exploring the influencing factors. A contribution to the mission is to understand the motivations for using the energy-saving features of household appliances, to explore the main characteristics, and the opinion patterns. Comprehensive investigations in the field ask for a suitable framework model.

The aim of the study is to check the structure of a preliminary model concept designed for PLS-SEM analysis. A sample of 198 Hungarian higher education students was available for the pilot

* Corresponding author.
E-mail address: laszlo.berenyi@uni-miskolc.hu

testing in SmartPLS software. The purpose of the analysis was limited to checking the loadings of the proposed items in the external model.

2 Literature review

In recent decades, numerous framework models have been developed to describe the factors that influence certain behaviors. Isaias and Issa [5] give a comprehensive overview of such models and their applications for information systems; however, the scope of most models is much broader, including environmentally conscious or purchasing behaviors. With the expansion of statistical analysis capabilities, especially the widespread adoption of structural equation modelling software solutions, the validation of derived and extended instruments has become relatively simple, enabling the model to be adjusted for new technologies or functions as well. Theories such as the Theory of Planned Behavior [6], the Theory of Reasoned Action [7], and Technology Acceptance Models [8] offer flexible basepoints. Ultimately, while the development of the Unified Theory of Acceptance and Use of Technology [9], [10] has implemented combinations of former models and incorporated various explanatory factors.

Liu et al. [11] confirmed the applicability of the Theory of Planned Behavior and the impact of attitudes on intentions and behavior. However, they could not present a significant impact of norms or grouping factors by education or income. In relation to energy savings, studies were usually conducted with the models above with new extensions. Attitudes to environmental consciousness were designed by the authors to give special emphasis to sustainability aspects. Ru et al. [12] introduced environmental concern, referring to the extent to which one is conscious of environmental issues and supportive of addressing them [13], into their model to investigate energy-saving behavior in the workplace. They found that it had a significant impact on intentions. Qalati et al. [14] used the Theory of Planned Behavior model to explore household energy saving intentions and found significant impacts of attitudes, norms, and moral responsibility on intention and actual behavior. According to home energy management systems, Washizu et al [15] found a high willingness to pay for such systems. Park et al [16] performed a detailed analysis based on the Technology Acceptance model of the influencing factors of using such systems. Usefulness of the system was confirmed by economic benefit, social contribution, environmental responsibility, and innovativeness. Both usefulness and ease of use have a significant impact on the intention to use. They emphasized the responsibility of the government in strong communication about the benefits of the system, including the cost savings, since improved commitment of the users is the key to acceptance.

3 Framework model and initial measuring elements

The proposed model (Figure 1) used the main constructs of the technology acceptance model as perceived usefulness, perceived ease of use, intention to use, and actual use.

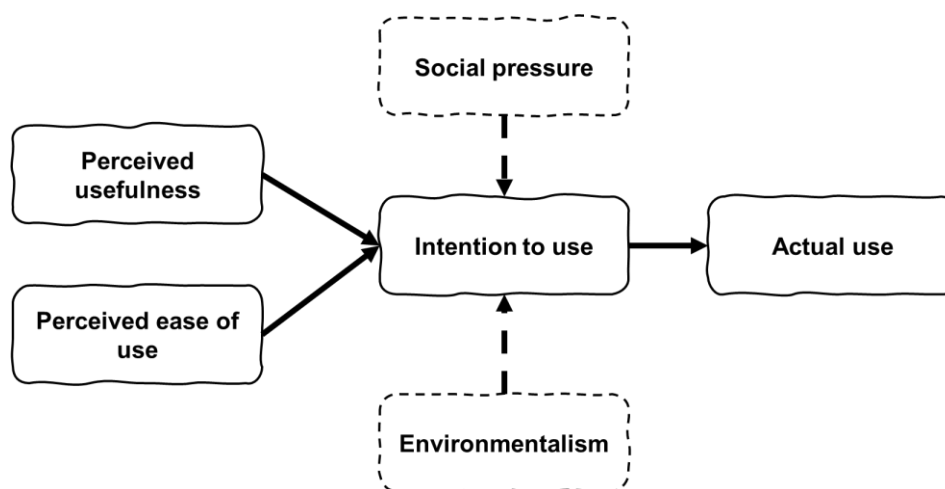


Figure 1. Proposed framework model

Two additional constructs were created to summarize the influencing factors with an impact on the intention to use:

- Social pressure: the impact of family, friends, and colleagues, as well as the force of government and corporations.
- Environmentalism: attitudes and approaches to sustainability, climate change, and energy savings.

The initial items of the measurement model consisted of 28 statements (Table 1).

Table 1. Construct and items of the framework model

Construct	Code	Item
Social pressure (SP)	SP1*	Government truly supports energy savings.
	SP2*	High energy prices force energy savings.
	SP3*	Producers are partners in energy-saving.
	SP4	People who are important to me make efforts to save energy.
	SP5	My family, friends and colleagues influence me to save more energy.
	SP6*	I want to decide for myself how I use my tools, not rely on the opinions of others.
Environmentalism (ENV)	ENV1	I am worried about climate change.
	ENV2	I feel I can do something for sustainability.
	ENV3	I feel morally obligated to save energy.
	ENV4*	I turn off lights and home appliances when not in use.
	ENV5	I am interested in environmental and sustainability issues.
Perceived usefulness (PU)	PU1	Energy-saving features of the devices help to reduce costs for me and my family.
	PU2	Energy-saving features of the devices help to prevent global environmental problems.
	PU3	Energy-saving features of the devices are worth a little discomfort.
	PU4	Energy-saving features of the devices contribute to the well-being of the society.
	PU5*	Energy-saving features of the devices help to increase the lifetime of the devices.
Perceived ease of use (PEU)	PEU1	Energy-saving features of the devices are easy to use.
	PEU2	Energy-saving options of the devices are not overcomplicated.
	PEU3	It will not take much time and effort to learn how to use energy-saving settings.
	PEU4	I have the knowledge, ability, and resources to use energy-saving options.
Intention to use (INT)	INT1	I intend to make efforts to save energy at home.
	INT2	I measure or estimate my energy costs.
	INT3	I prefer buying products with energy-saving features.

	INT4	I usually buy energy-efficient household appliances.
Actual use (USE)	USE1	I use energy-saving functions on many devices.
	USE2	I encourage others to use energy-saving functions.
	USE3	I always look for the energy-saving mode in the device settings.
	USE4	I am satisfied with using the energy-saving features of the devices.

The codes marked with * were excluded from the final model.

4 Results

The respondents of the pilot sample were asked to mark their agreement with the statements using a 7-point scale. SmartPLS 4 software [17] supported model building and testing. Analysis procedure and acceptance threshold values followed the instructions of Hair et al. [18]. The results confirmed the usability of the framework model concept and clearly pointed out the need for improvement.

Some items were suggested to be deleted from the measurement model since the factor loadings were under the threshold value of 0.704, and keeping them did not support model fit indices. The analysis confirmed the constructs of perceived ease of use, intention to use, and use from the TAM model. Among perceived usefulness, the PU5 item was deleted. According to the additional constructs, 'Environmentalism' seems to be applicable; just one proposed item (ENV4) should have been excluded. At the same time, 'Social Pressure' must be reconsidered. The influence of other people who are important for the respondents (SP4) and the impact of the close environment (SP5) have remained in the model. Excluded questions could not establish any new constructs to improve model fit. The final model is presented in Figure 2, including the outer loading and the path coefficients.

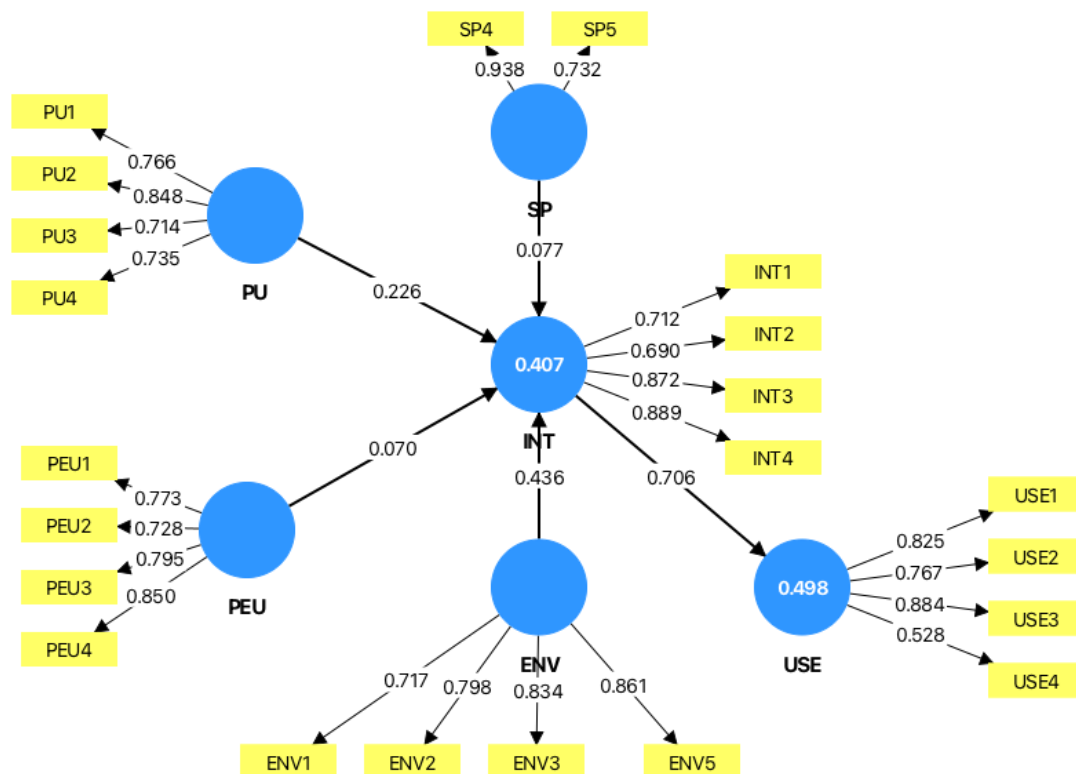


Figure 2. SmartPLS model with factor loadings and path coefficients (SmartPLS output)

Construct reliability and validity indicators confirm the model, except for the Cronbach Alpha value for social pressure (Table 2). Collinearity is acceptable, VIF values are lower than 3, the minimum value is 1.255 (SP4), and the maximum is 2.762 (INT4). Discriminant validity is also acceptable; the heterotrait-monotrait ratio is near the threshold value of 0.9 in the case of 'Intention to use' and 'Actual use' constructs.

Table 2. Construct reliability and validity indicators for the final model

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Threshold value	min. 0.700	min. 0.700	min. 0.700	min. 0.500
SP	0.622	0.818	0.827	0.708
ENV	0.820	0.846	0.879	0.647
PU	0.769	0.777	0.851	0.589
PEU	0.826	0.963	0.867	0.621
INT	0.804	0.828	0.872	0.633
USE	0.755	0.802	0.844	0.582

The sample size and composition do not allow a comprehensive conclusion. The pilot study aimed to improve the model and highlight the need for further changes, but additionally, model fit and path coefficients are checked. Model fit is poor but close to acceptance based on a 0.088 SRMR value (threshold value is < 0.080). Other indicators: $d_ULS = 1,964$, $d_G = 0,602$, Chi-square = 674.199, NFI = 0.680 (< 0.090). For 'Actual use' is moderate ($R^2 = 49.8\%$), as is the variance explained for intention to use ($R^2 = 40.7\%$). Increasing sample size may improve the indicator values, but even these results can contribute to model building.

5 Conclusions

The complexity of social and environmental problems requires the harmonization of engineering efforts and shaping attitudes. Due to the high variety of products, services, as well as individual needs and opinions, there is no ultimate way to describe the influencing factors. At the same time, carefully selected framework models enable targeted investigations and a contribution to a common knowledge base about the area. Energy-saving features cover just a slice of the topic, but the general appearance of it in household appliances validates the relevance of the analysis. The study shows that technology acceptance models are applicable to measure the influencing factors of using energy-saving features. Understanding personal motivations can contribute to technological development actions, and the model can serve as a sample for other targeted examinations. Although such models have a limited scope, they play a remarkable role in uncovering behavioral patterns.

The results pointed out that social pressure in that form cannot be added to the model; personal influencing factors, economic, and legal factors require a new approach for the measurement model. Future work aims to explore additional factors and establish latent variable constructs of them.

Checking the path coefficients values relative to each other, it is suggested that environmentalism has the highest impact on intention to use energy-saving features. Perceived usefulness has a lower impact, while the impact of perceived ease of use is very low, alike to the social pressure. The role of perceived ease of use may be an indicator of the successful technical development of the producers, i.e., it is not a barrier to use.

The implication of the study is that focusing on improving environmentally conscious behavior in general and one's own judgment has more impact on energy savings than forcing and proving just one highlighted issue.

A methodological implication is suggested by the statistical results, especially the close R^2 values of 'Intention to use' and 'Actual Use' constructs, which show the high similarity between them. It is advisable to assess actual use through objective measurements instead of self-reporting, but

the feasibility of data collection is questionable. Future work requires enhanced data collection from various respondent groups to validate the constructs and their relationships.

Acknowledgment

The study was conducted as part of the OTKA T139225 project entitled “Management readiness level towards Strategic Technology Management Excellence”.

References

- [1] X. Xu, B. Xiao, and C. Z. Li, “Analysis of critical factors and their interactions influencing individual’s energy conservation behavior in the workplace: A case study in China,” *Journal of Cleaner Production*, vol. 286, p. 124955, Mar. 2021, doi: 10.1016/j.jclepro.2020.124955.
- [2] B. Wang, X. Wang, D. Guo, B. Zhang, and Z. Wang, “Analysis of factors influencing residents’ habitual energy-saving behaviour based on NAM and TPB models: Egoism or altruism?,” *Energy Policy*, vol. 116, pp. 68–77, May 2018, doi: 10.1016/j.enpol.2018.01.055.
- [3] Z. He, T. Hong, and S. K. Chou, “A framework for estimating the energy-saving potential of occupant behaviour improvement,” *Applied Energy*, vol. 287, p. 116591, Apr. 2021, doi: 10.1016/j.apenergy.2021.116591.
- [4] *Transforming Our World: The 2030 Agenda for Sustainable Development*. United Nations, 2015.
- [5] P. Isaías and T. Issa, *High Level Models and Methodologies for Information Systems*. New York, NY: Springer New York, 2015. doi: 10.1007/978-1-4614-9254-2.
- [6] I. Ajzen, “The theory of planned behavior,” *Organizational Behavior and Human Decision Processes*, vol. 50, no. 2, pp. 179–211, Dec. 1991, doi: 10.1016/0749-5978(91)90020-t.
- [7] I. Ajzen, “Martin Fishbein’s Legacy: The Reasoned Action Approach,” *The ANNALS of the American Academy of Political and Social Science*, vol. 640, no. 1, pp. 11–27, Mar. 2012, doi: 10.1177/0002716211423363.
- [8] F. D. Davis, “Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology,” *MIS Quarterly*, vol. 13, no. 3, p. 319, Sep. 1989, doi: 10.2307/249008.
- [9] Venkatesh, Morris, Davis, and Davis, “User Acceptance of Information Technology: Toward a Unified View,” *MIS Quarterly*, vol. 27, no. 3, p. 425, 2003, doi: 10.2307/30036540.
- [10] Venkatesh, Thong, and Xu, “Consumer Acceptance and Use of Information Technology: Extending the Unified Theory of Acceptance and Use of Technology,” *MIS Quarterly*, vol. 36, no. 1, p. 157, 2012, doi: 10.2307/41410412.
- [11] X. Liu, Q. Wang, H.-H. Wei, H.-L. Chi, Y. Ma, and I. Y. Jian, “Psychological and Demographic Factors Affecting Household Energy-Saving Intentions: A TPB-Based Study in Northwest China,” *Sustainability*, vol. 12, no. 3, p. 836, Jan. 2020, doi: 10.3390/su12030836.
- [12] X. Ru, M. Chen, S. Wang, and Z. Chen, “Does environmental concern fail to predict energy-saving behavior? A study on the office energy-saving behavior of employees of Chinese Internet companies,” *Environ Dev Sustain*, vol. 24, no. 11, pp. 12691–12711, Nov. 2022, doi: 10.1007/s10668-021-01960-6.
- [13] R. E. Dunlap and R. E. Jones, “Environmental concern: Conceptual and measurement issues,” in *Handbook of environmental sociology*, Westport: Greenwood Press, 2002, pp. 482–524.
- [14] S. A. Qalati, N. A. Qureshi, D. Ostic, and M. A. B. A. Sulaiman, “An extension of the theory of planned behavior to understand factors influencing Pakistani households’ energy-saving intentions and behavior: a mediated–moderated model,” *Energy Efficiency*, vol. 15, no. 6, Aug. 2022, doi: 10.1007/s12053-022-10050-z.
- [15] A. Washizu, S. Nakano, H. Ishii, and Y. Hayashi, “Willingness to Pay for Home Energy Management Systems: A Survey in New York and Tokyo,” *Sustainability*, vol. 11, no. 17, p. 4790, Sep. 2019, doi: 10.3390/su11174790.
- [16] E.-S. Park, B. Hwang, K. Ko, and D. Kim, “Consumer Acceptance Analysis of the Home Energy Management System,” *Sustainability*, vol. 9, no. 12, p. 2351, Dec. 2017, doi: 10.3390/su9122351.
- [17] C. M. Ringle and J.-M. Becker, *SmartPLS 4*. (2024). SmartPLS, Bönningstedt. [Online]. Available: <https://www.smartpls.com>

- [18] J. F. Hair, G. T. M. Hult, C. M. Ringle, and M. Sarstedt, *A primer on partial least squares structural equation modeling (PLS-SEM)*, Third edition. Los Angeles: SAGE, 2022.
- [19] S. Duer, L. Pokoradi, D. Bernatowicz, and R. Duer, "Classification of elements in the diagnostic model of a technical object for building an expert knowledge base," *Journal of Mechanical and Energy Engineering*, vol. Vol. 1, No 1, pp. 71–78, 2017.
- [20] K. Tehlan, S. Chakraverty, P. Chakraborty, and S. Khapra, "A genetic algorithm-based approach for making pairs and assigning exercises in a programming course," *Comput Appl Eng Educ*, vol. 28, no. 6, pp. 1708–1721, Nov. 2020, doi: 10.1002/cae.22349.
- [21] M. A. Angulo and O. Aktunc, "Using GitHub as a teaching tool for programming courses," in *2018 Gulf Southwest Section Conference*, 2019.
- [22] M. Babič, I. Karabegović, S. I. Martinčič, and G. Varga, "New Method of Sequences Spiral Hybrid Using Machine Learning Systems and Its Application to Engineering," in *New Technologies, Development and Application*, Springer, Cham, 2019, pp. 227–237. doi: 10.1007/978-3-319-90893-9_28.