Conference: Interdisciplinary Congress of Renewable Energies, Industrial Maintenance, Mechatronics and Information Technology

BOOKLET

RENIECYT
Registro Nacional de Instituciones y Empresas Científicas y Tecnológicas
1702902 CONACYT

RENIECYT - LATINDEX - Research Gate - DULCINEA - CLASE - Sudoc - HISPANA - SHERPA UNIVERSIA - E-Revistas - Google Scholar
DOI - REDIB - Mendeley - DIALNET - ROAD - ORCID

Title: Design of a virtual photovoltaic microgrid, applying real-time energy monitoring, and behavior change theories for energy saving

Authors: RENTERÍA-MACEDO, Francisco Daniel, GARCÍA-GUERRERO, Santiago Martín, HARO-FALCÓN, Nicolás y CORONADO-MENDOZA, Alberto.

Editorial label ECORFAN: 607-8695
BCIERMMI Control Number: 2019-137
BCIERMMI Classification (2019): 241019-137

Pages: 13
RNA: 03-2010-032610115700-14

ECORFAN-México, S.C.
143 – 50 Itzopan Street
La Florida, Ecatepec Municipality
Mexico State, 55120 Zipcode
Phone: +52 1 55 6159 2296
Skype: ecorfan-mexico.s.c.
E-mail: contacto@ecorfan.org
Facebook: ECORFAN-México S. C.
Twitter: @EcorfanC

www.ecorfan.org

Holdings
Mexico Colombia Guatemala
Bolivia Cameroon Democratic
Spain El Salvador Republic
Ecuador Taiwan of Congo
Peru Paraguay Nicaragua

Introduction

Energy consumption in buildings + social science

- A low-carbon energy future requires a transition in both **technologies** and **human behavior** (Sovacool, 2014).

Real-time monitoring + behavior change

- **Real-time monitoring** affects the **attitudes and behavior** of **buildings' users** (Timm & Deal, 2016; Buchanan, Russo & Anderson, 2014; He, Greenberg & Huang, 2010).

Virtual microgrids as conceptual tools

- Virtual power plants (VPPs) are **a flexible representation** of distributed energy generation resources (Saboori, Mohammadi & Taghe, 2011).

The situation of the Tonala Campus - University of Guadalajara

- **Real-time energy monitoring** of: the consumption of 5 buildings on campus and the generation of a 499 kWp solar power plant.
- Institutional goal of r**educing the energy consumption** of every building by **20%** (Energy management team).
- **University's Comprehensive Plan for Energy Transition (PUITE-UDG).**

Methodology:

Interdisciplinary integration

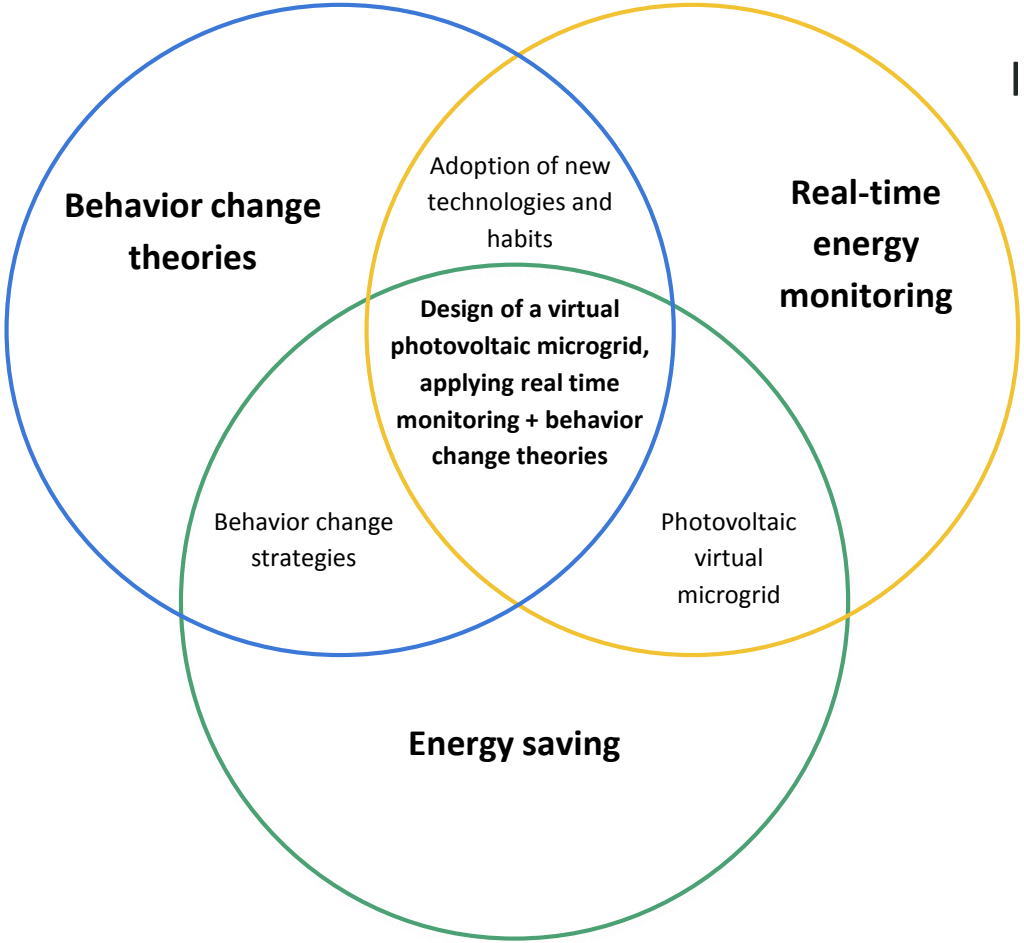
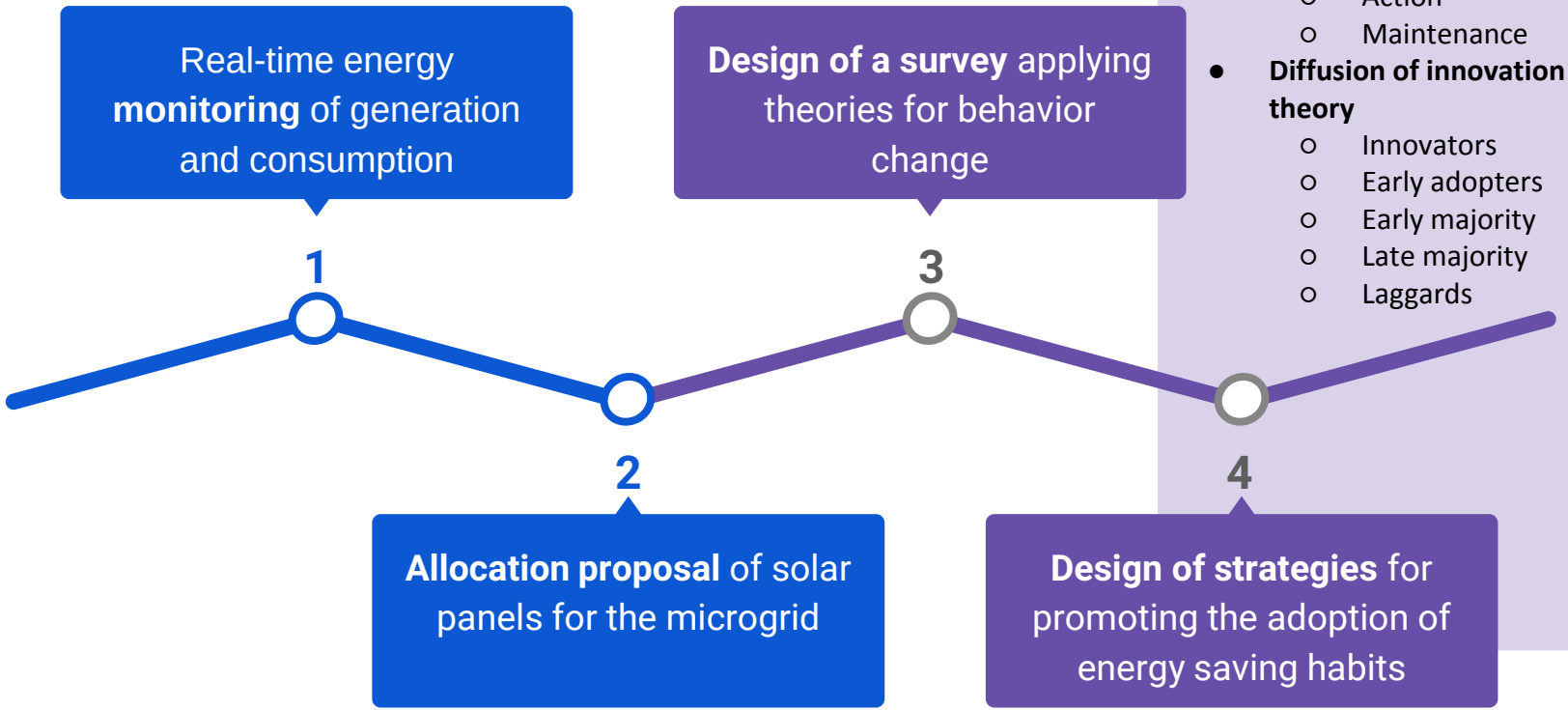


Figure 1. Integration of the design **dimensions** of a virtual micro-network that unites real-time monitoring and theories for behavior change.

Source: Authors' design assumptions.

Methodology

- **The transtheoretical (stages of change) model**
  - Precontemplation
  - Contemplation
  - Determination
  - Action
  - Maintenance
- **Diffusion of innovation theory**
  - Innovators
  - Early adopters
  - Early majority
  - Late majority
  - Laggards



Results: Power generation

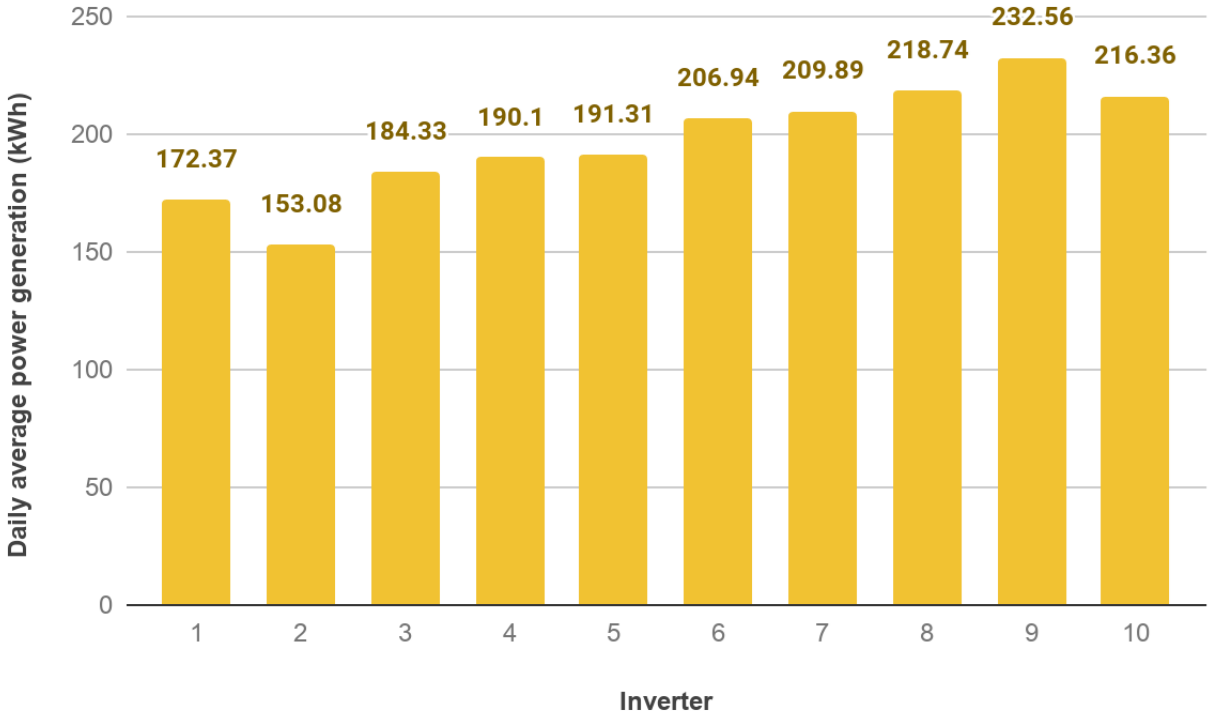


Figure 2. Average daily power generation per inverter

Source: Authors' results.

- Solar power plant on campus with 1560 solar panels.
- Energy output: 499 kWp.

Results: Power consumption

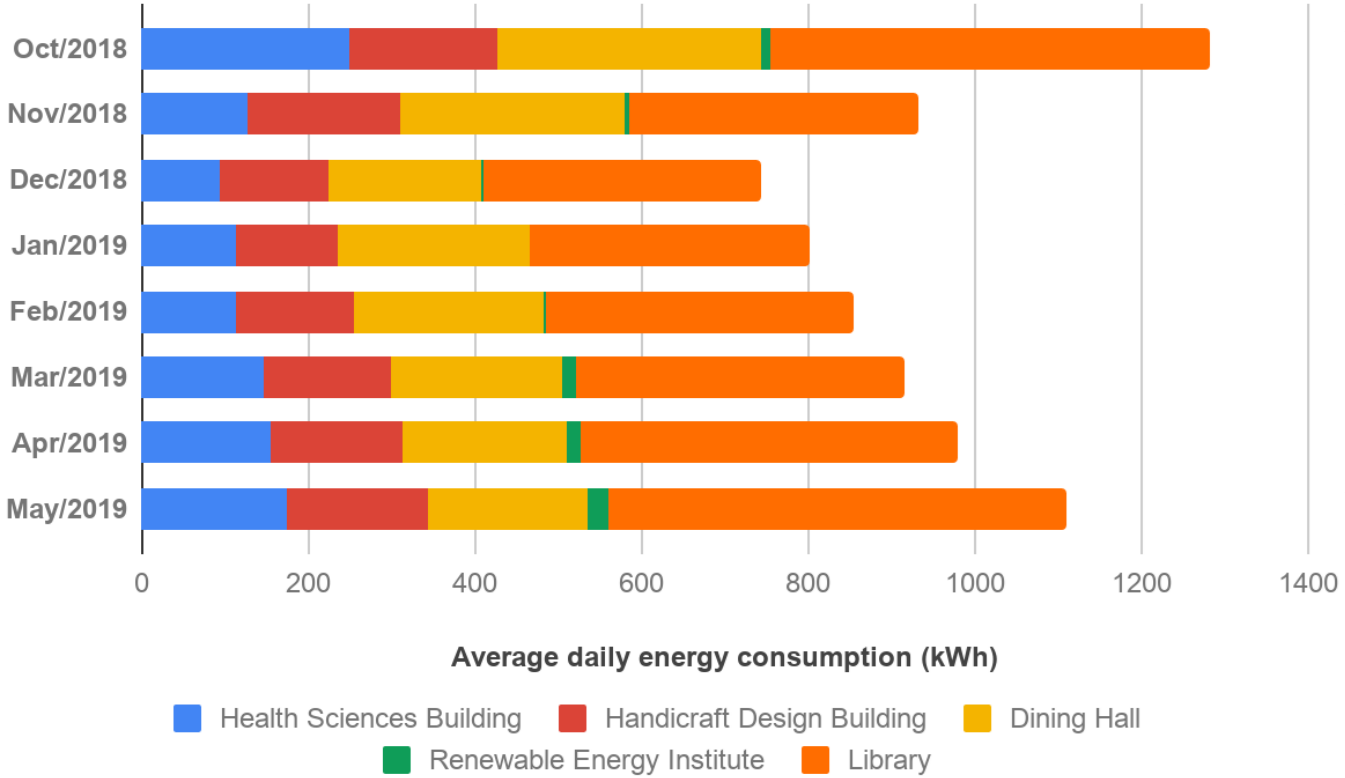


Figure 3. Average daily energy consumption per month

Source: Authors' results.

- The library is the highest consumer.
- The Renewable Energy Institute is being partially monitored.
- Energy consumption fluctuations may be related to seasonal temperature and activity fluctuations.

Results: Allocation of solar panels for the VPPs

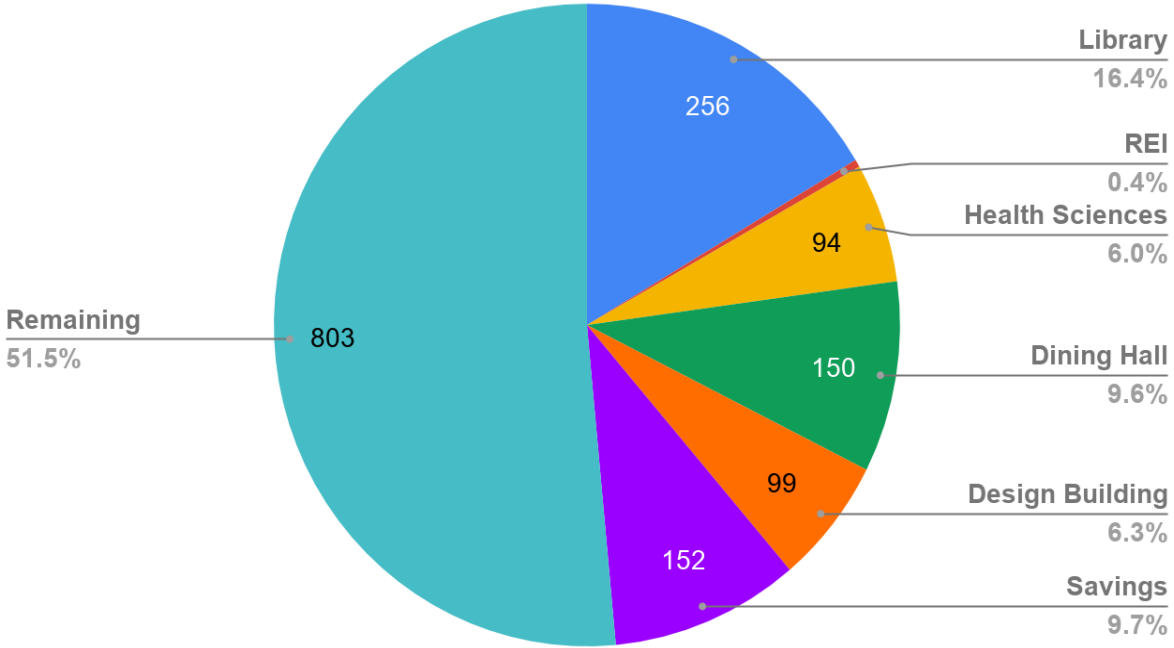
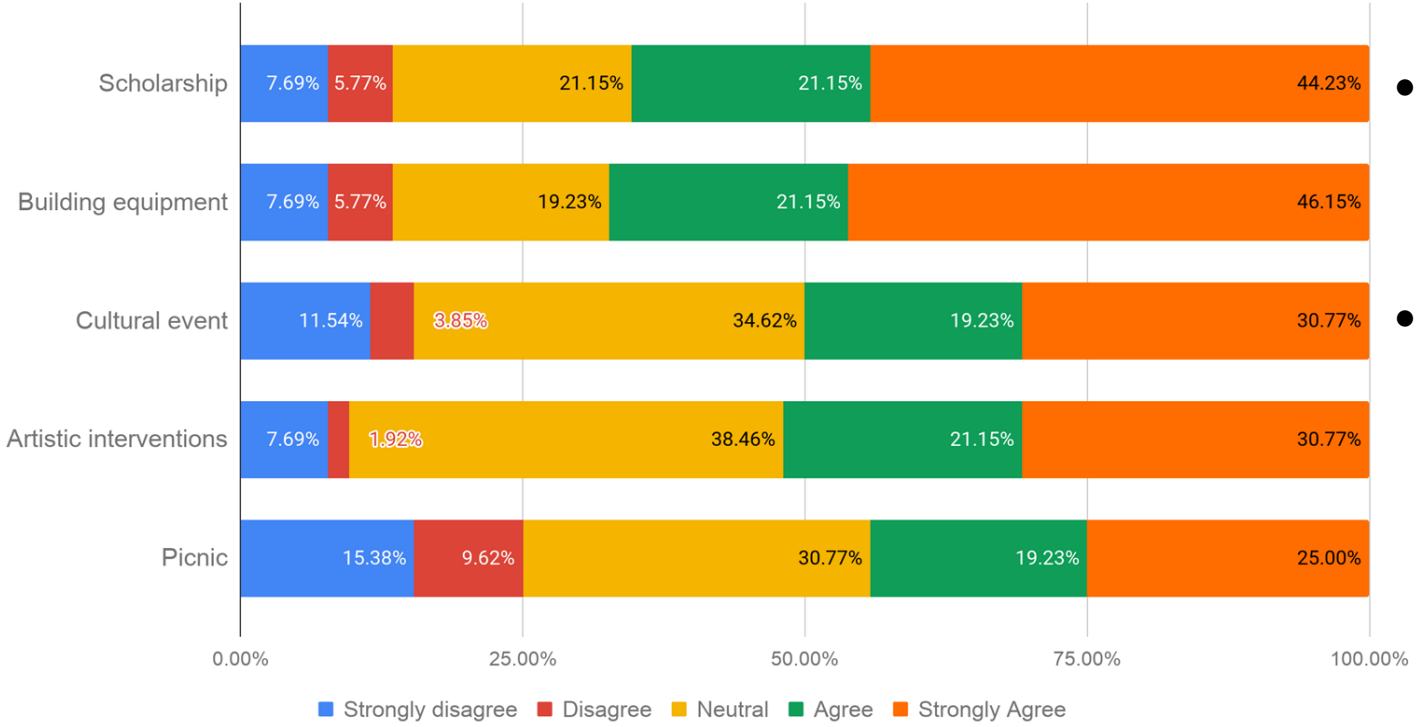


Figure 4. Proposed allocation of panels per building

Source: Authors' results.

- 20% reduction of energy consumption per building (institutional policy).
- 605 assigned panels for the 5 monitored buildings.
- Energy savings equivalent to 152 panels by reducing energy consumption by 20%.
- 955 panels are available to be allocated to other buildings (Savings + remaining).

Results: Survey - Incentives



- High acceptance of the proposed incentives.
- Scholarships (65.4%) and building equipment (67.4%), where the highest ranked incentives.

Figure 5. Perception of energy-saving incentives

Source: Authors' results.

Results: Survey - Corrective strategies

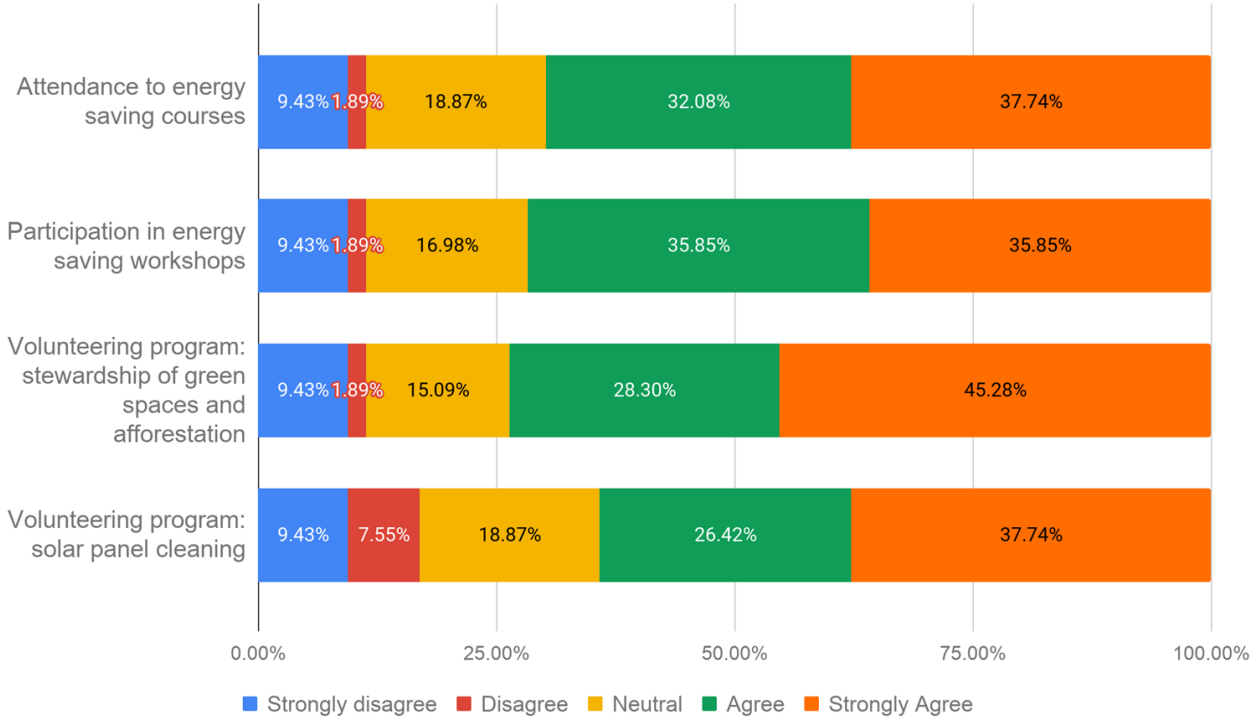


Figure 6. Perception of energy-saving corrective strategies

Source: Authors' results.

- High acceptance of all corrective strategies.
- One volunteering program, stewardship of green spaces and afforestation (73.6%), was the highest ranked corrective strategy, while the other program, solar panels cleaning, was the least supported (64.1%).

Results: Survey - Awareness, attitudes and self-efficacy

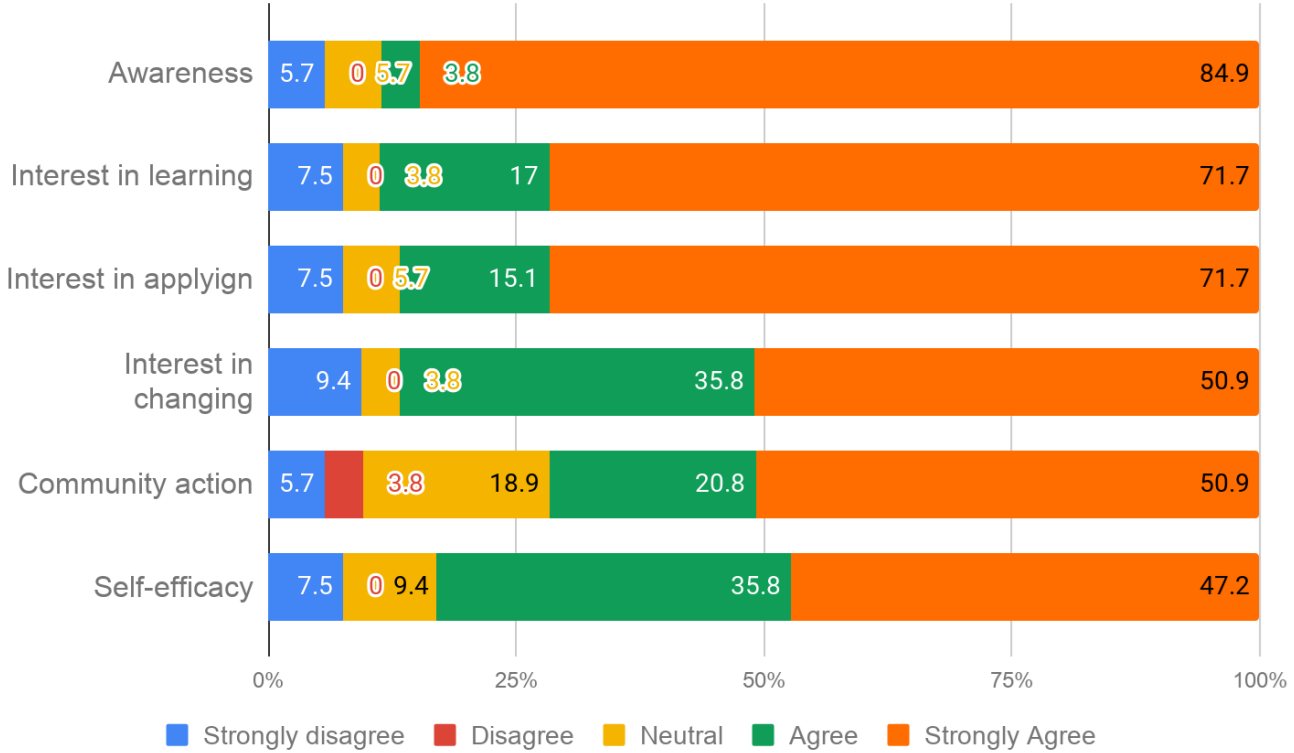


Figure 7. Levels of awareness, energy-saving attitudes and self efficacy

Source: Authors' results.

- High level of energy-saving awareness and attitudes.
- Strategies are needed for prompting interest in changing, community action and self-efficacy.

Results: Design of strategies considering behavior change theories

Table 1. Strategies considering the transtheoretical model

Stage of change	Strategy
Precontemplation	Publish and spread **pros and cons of unsustainable behavior**, appealing to social norms.
Contemplation	Publish and spread **sustainable lifestyle successful stories**.
Determination	**Connect with mentors** in action and maintenance stages.
Action	**Public recognition.**
Maintenance	Invitation to **join** a group of **mentors**.

Note: All through bulletin boards, social networks and a website.

Source: Authors' design assumptions and Nutbeam, Harris and Wise (2010).

Table 2. Strategies considering the diffusion of innovation theory

Category	Strategy
Innovators (2-3%)	**Early training** and integration of a team of energy-saving **mentors and managers.**
Early adopters (10-15%)	Public **recognition**.
Early majority (30-35%)	**Connect with mentors** in action and maintenance stages.
Late majority (30-35%)	Publish **sustainable lifestyle successful stories.**
Laggards (10-20%)	Appeal to social norms, **corrective strategies.**

Results: Acceptance of real-time monitoring display methods

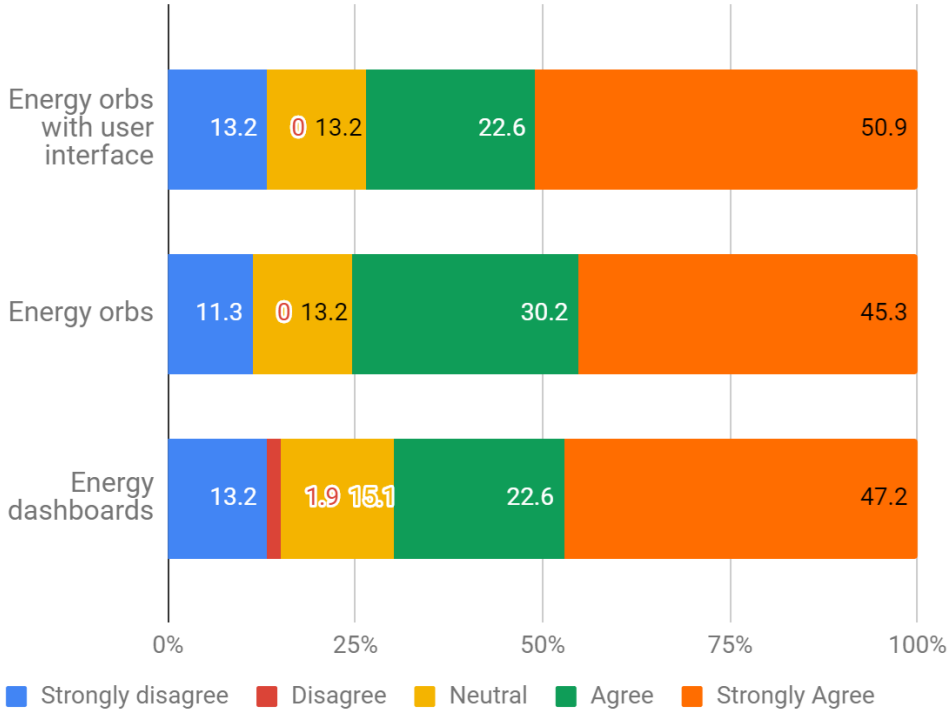


Figure 8. Acceptance of real-time monitoring display methods

Source: Authors' results.

Conclusions

- The incorporation of the diffusion of innovation theory and the transtheoretical model is **a new framework in the field of energy-saving for university buildings, which answers the call for integrating social science into energy studies.**
- This work had some **limitations**, for future work on this research line, it could be useful to propose **a variable target percentage** for the total energy consumption of each building, as well as a **panel relocation proposal**, using a database with **higher temporal resolution of energy generation and consumption**.
- The nature of this research is **multidisciplinary**, therefore, future stages of this project will **need to integrate different disciplines** to a higher extent.
- This project will serve as the **foundation** for the implementation of a **pilot Energy Market at the Tonalá Campus.**

References

Buchanan, K., Russo, R., & Anderson, B. (2014). Feeding back about eco-feedback: How do consumers use and respond to energy monitors?. *Energy Policy*, *73*, 138-146.

He, H. A., Greenberg, S., & Huang, E. M. (2010). One size does not fit all: applying the transtheoretical model to energy feedback technology design. In Proceedings of the SIGCHI conference on human factors in computing systems (927-936). ACM.

Nutbeam, D., Harris, E., & Wise, W. (2010). Theory in a nutshell: a practical guide to health promotion theories. Sídney, Australia: McGraw-Hill.

Saboori, H., Mohammadi, M., & Taghe, R. (2011). Virtual power plant (VPP), definition, concept, components and types. In 2011 Asia-Pacific Power and Energy Engineering Conference (pp. 1-4). IEEE.

Sovacool, B. K. (2014). Diversity: Energy studies need social science. *Nature*, *511*(7511), 529.

Timm, S. N., & Deal, B. M. (2016). Effective or ephemeral? The role of energy information dashboards in changing occupant energy behaviors. *Energy Research & Social Science*, *19*, 11-20.

ECORFAN ®