Education, Gender and the Energy Management role to the Energy Transition

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Abstract

The International Energy Agency notes that energy efficiency, behavioral changes, and demand management—core components of effective Energy Management Strategies—could achieve nearly 25% of the emissions reductions needed for a net-zero transition. To harness this potential and ensure a just transition, the [anonymized] project focuses on empowering female students and teachers in public schools. Through targeted workshops and educational experiences, the project builds capacity for energy efficiency and conscious consumption in school and home environments, promoting social justice by ensuring women's equal participation. Initial results are promising: activities like an energy efficiency experiment, a collaborative card game, and presentations for 8th and 9th graders have significantly raised student awareness. This inquiry-based learning approach has catalyzed student-led research projects on lighting efficiency, which were presented at regional scientific fairs, confirming the project's success in engaging students and facilitating lasting learning.

Keywords: Energy Transition; Energy Management; Gender Equity; Education; SDG; Efficiency.

1. Introduction

The energy transition, so necessary for a net zero future, brings numerous challenges in its trajectory. There have been global advances in the use of renewable energies, and these advances have been reflected in the Brazilian energy matrix, but even so, we see that this matrix remains 51% non-renewable. This value is lower than that observed in the rest of the world, mainly due to the highly renewable quality of the electrical matrix in Brazil (EPE, 2024), but it is still necessary to evolve, especially in other areas of the energy transition, such as energy storage, energy management and efficiency.

According to a report by the International Energy Agency (IEA, 2023), a quarter of the emissions reduction needed to achieve the net zero scenario comes from the use of solar photovoltaic and wind energy. With similar importance, 24% of emissions reduction can be achieved through energy efficiency and behavioral changes and avoided demand. Thus, energy efficiency and behavioral changes are important elements of an integrated energy strategy aimed at improving an institution's energy performance.

In this sense, energy management is a comprehensive process that, through behavioral changes and the establishment of an energy conservation culture, aims to optimize energy consumption, reduce costs, and minimize environmental impacts. This approach recognizes that sustainable efficiency gains are fundamentally driven by shifts in behavior and values and are core principles in the project [anonymized].

In addition, education plays an essential role in understanding and seeking solutions to the environmental challenges caused by human activities, serving as a strategic tool to foster the energy transition and sustainable development (UNESCO, 1997; Tilbury et al., 2002). When promoted from early ages, this learning process supports the development of more critical and aware individuals by encouraging reflections on the values and ways of life of contemporary society. Thus, introducing the topic of energy management in Elementary Education helps prepare a new generation better equipped to face the climate crisis and lead the energy transition.

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(MCTI) and National Council for Scientific and Technological Development (CNPq), aiming to expand female participation in STEM fields by promoting four thematic workshops: renewable energies, energy management, scientific methodology, and gender equity, all aligned with the Sustainable Development Goals - SDGs (UN, 2015) and the Brazilian National Common Curricular Base - BNCC (BRASIL, 2018).

The project operates across six public schools in Rio Grande do Sul (RS) and Santa Catarina (SC), directly benefiting 105 elementary students and 21 teachers over a three-year period. It represents a collaborative effort between three Brazilian federal universities [anonymized] and professional networks including Rede MESol (Brazilian Network of Women in Solar Energy), Mulheres do Biogás (Women in Biogas), and CREA-RS (Regional Council of Engineering and Agronomy of Rio Grande do Sul). Experts from these partner organizations design and facilitate the workshops and mentorship programs, fostering meaningful connections between public schools, universities, and the energy sector while emphasizing social justice, equity, diversity, and sustainability.

In 2025, the participating schools were located in the municipalities of Osório (RS), Tramandaí (RS), Santa Maria (RS), Passo Fundo (RS), and Florianópolis (SC). In Florianópolis, School A is a state school offering both primary and secondary education, serving 919 students. In Tramandaí, School B is a state high school with approximately 950 students, while School C, a State Institute of Education, offers a variety of programs, including Youth and Adult Education (EJA), and technical courses in accounting and teacher training, also with around 950 students. School D, located in Osório, is a state school that provides primary, secondary, and technical education in electrotechnics, and is notable for having a dedicated class for deaf students, with a total of 983 students.

In the municipalities of Santa Maria (School E) and Passo Fundo (School F), the participating schools are public municipal institutions, serving 434 and 346 students respectively. These schools, with diverse profiles, enable the engagement of students from a wide range of economic, social, and cultural backgrounds, reinforcing the importance of promoting equity.

The Energy Management workshop, which is the focus of this paper, seeks to raise awareness and empower students towards energy efficiency practices and conscious energy consumption in school and domestic environments.

2. Methodology - Workshop Development

Each thematic workshop, delivered over a four week module includes (1) recommended readings on the topic, a (2) teaching process involving hands-on activities, experiments and gamification, (3) a technical visit and, finally, the (4) preparation of materials to disseminate knowledge.

2.1 Recommended readings on the topic

The first module applied the flipped classroom methodology (Strelan et al., 2020) to foster active learning. Prior to the formal instruction, students engaged with the subject matter through guided readings in the Workshop Guide. This preparatory work was extended in the classroom through a research activity where students used scholarly databases (e.g., Google Scholar, SciELO, CAPES) to explore and define core concepts. They investigated questions including: the meaning and context of "management"; the definition and production of "energy"; and the principles of "energy management" and "energy efficiency."

2.2 Teaching process involving hands-on activities, experiments and gamification

The teaching process was designed around traditional PowerPoint slides, covering key topics such as energy transformations, end-use consumption patterns, management and efficiency strategies, the relationship between consumption and emissions, and practical approaches for reducing energy use. The presentation content was developed using established references, including the ISO 50001 Energy Management standard (ABNT, 2018), a study on residential energy consumption patterns in southern Brazil (Teixeira and Lambert, 2021), and documents from government agencies (EPE, 2024). To reinforce the theoretical concepts, the workshop module also incorporated hands-on experiments demonstrating the conversion of chemical energy

to kinetic energy and electrical energy to radiant energy.

Energy transformation principles are demonstrated through an accessible educational experiment concept presented in Fig.1 using lemons as an energy source to power an LED. The experiment illustrates the conversion of chemical energy into electrical energy—with lemons serving as electrolytes—followed by the transformation of electricity into light. Though not novel, this experiment remains educationally valuable due to its simplicity and practicality in conveying fundamental energy transformation concepts. The setup allows for versatility through substitution of different energy sources (like batteries) and light technologies (LED versus incandescent bulbs), enabling exploration of efficiency concepts. Current, voltage, and luminosity measurements further enrich the learning experience by quantifying the energy transformations observed.

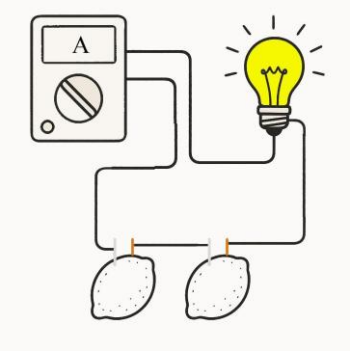

Figure.1:- Energy Transformation Experiment Schematic

Gamification enhances content engagement through a collaborative card game developed specifically for the Energy Management Module. This adaptation of mystery-solving investigative storytelling cards features visuals paired with cryptic sentences depicting real-life energy use scenarios. Participants engage in investigative inquiry by posing questions answerable only with "yes," "no," or "not relevant to the case" (Fig. 2). Each narrative explores energy efficiency themes including outdated equipment usage, improperly sized systems, overheating due to inadequate battery configurations, and energy-wasting behavioral patterns. The activity effectively cultivates critical thinking and inquiry-based learning around energy topics through an engaging, accessible format.

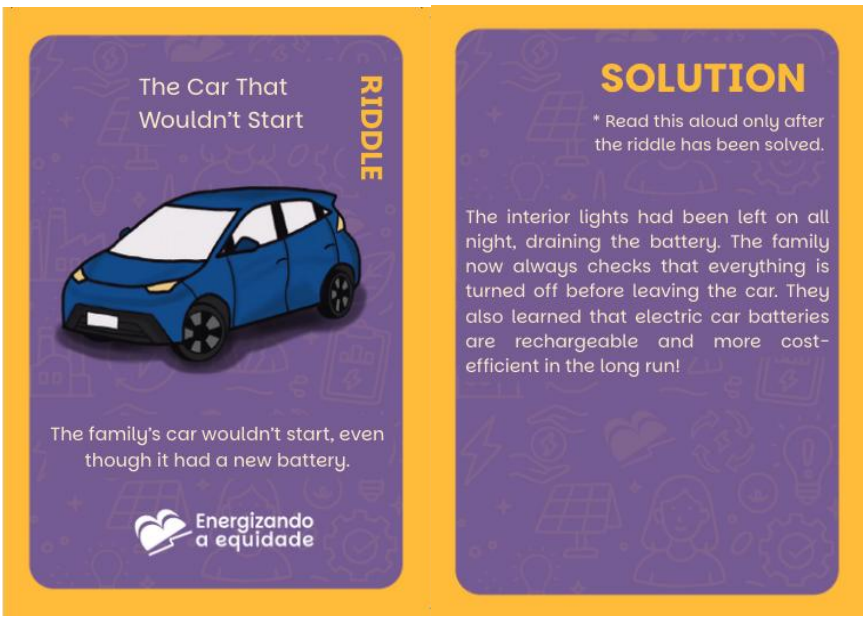

Figure. 2: Gamified card-based activity fostering inquiry on real-life energy efficiency issues through collaborative investigation.

2.3 Technical visit

A technical visit was included in the methodology to provide an in-depth, hands-on experience related to Energy Management. The main objective was to visit an energy-efficient building where students could see the concepts learned in practice. Beyond the technical aspects, leaving the school environment offered valuable opportunities for group bonding and exposure to new settings and professionals.

2.4 Preparation of materials to disseminate knowledge

During this module, the methodology proposed that the students prepare materials to promote energy management and efficiency among their peers, teachers, and the school administration. The concept is to encourage students to take a lead role and to draw the promotion not only on the knowledge acquired throughout the module but also on real data, such as the school's energy consumption and potential performance improvements. Additionally, students should also read the energy meter and analyze variations in energy use, identifying increases or decreases in consumption.

Furthermore, the methodology includes the possibility that the students evolve the module's experience to a research project related to the content that could be presented in Junior Scientific Fairs.

3. Results and Discussions

The workshops were held in the six schools participating in the project, following the structure of the four modules.

3.1. Recommended readings on the topic

The development of the Energy Management workshop included moments of reflection and student protagonism, guided by their teachers. The activities began with a diagnostic questionnaire on the meaning of "management" and "energy efficiency." Collective discussions enabled a deeper understanding of these concepts and the elaboration of mind maps that synthesized the acquired knowledge.

To consolidate the knowledge gained from the readings, the students created a mind map, shown in Fig. 3. At the center, they wrote the words *management* and *efficiency*, connecting them to the concept of *energy efficiency*. Around these central ideas, they included topics such as optimizing the use of electrical appliances, making better use of natural light, and understanding how reduced energy consumption contributes to lowering emissions of gases harmful to the climate and human health. In addition, observations were carried out in both school and domestic environments, involving simple measurements and consumption analyses, thereby fostering critical thinking about energy use habits.

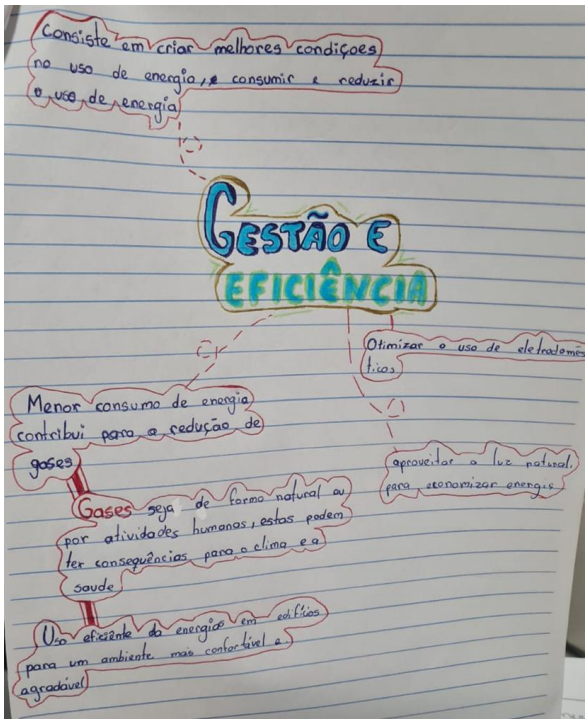

Figure 3: Mind Map produced by students.

3.2 Teaching process involving hands-on activities, experiments and gamification

The instructors, who were members of the project team, began the presentation (Fig.4) by asking questions similar to those proposed in the Workshop Guide from the first module. They explained the energy transformations behind the experiment the students were about to perform, followed by discussions on household electricity use, the energy meter, the concept of the electricity bill, and practical strategies to reduce energy costs.

During the workshop activities, the students calculated the amount of electrical energy consumed during their showers, considering the use of an electric showerhead, a common household appliance in Brazil. By estimating the average shower duration and the power rating of the equipment, they were able to quantify the energy used in a single bath and extrapolate it to monthly consumption. The results surprised many of them, as they realized how prolonged showers significantly increase household electricity usage and costs. This practical exercise not only connected theoretical learning to real-life situations but also served as an important moment of awareness, encouraging the students to adopt more responsible energy habits within their own homes.

Figure 4: Instructor at school Simão Hess.

After the presentation, the students were invited to assemble the experiment using the provided instructions and materials. They were excited when the LED light turned on and they were able to measure both voltage and current (Fig. 5). During the hands-on experiment, students explored the transformation of energy using lemons as an accessible source to power an LED. The activity demonstrated the conversion of chemical energy into electrical energy, with the lemon acting as an electrolyte, and subsequently into radiant energy. This simple yet effective experiment stimulated great curiosity among the students, who became deeply engaged in understanding how energy changes form and flows through different systems. By measuring current and voltage, they were able to visualize abstract theoretical concepts in a tangible way, reinforcing their comprehension of energy transformation and efficiency principles.

Figure 5: Instructor and students after experiment assembling.

3.3 Technical visit

After conducting research, no energy-efficient building was found near the schools where students could visit and experience the activity proposed in the methodology. Unfortunately, the Efficient House in Florianópolis, Santa Catarina, a partnership between the Federal University of Santa Catarina (UFSC), ELETROSUL, and ELETROBRÁS, created as a demonstration center for energy efficiency, was closed due to a lack of maintenance.

A visit to a science museum was considered; however, there are few such institutions near the schools, and

even fewer that feature exhibits related to energy efficiency. A visit to the local electricity supplier was also explored, but no company was found that could appropriately host students of this age group.

Ultimately, a visit (Fig. 6) was arranged to a wind energy management company, where students had the opportunity to meet professionals from the wind energy sector, allowing for at least partial fulfillment of the intended experiential learning goal. The great aspect of the visit was the presenter, a woman engineer, who inspired the students to pursue their goals through the presentation of her own personal experience.

Figure 6: Technical visit to Wobben Windpower

One of the main challenges encountered during the implementation of the technical visit stage was the scarcity of public or institutional spaces offering practical demonstrations of energy efficiency accessible to schools. Reference centers such as the *Casa Eficiente* at UFSC, created in partnership with Eletrosul and Eletrobrás, are currently deactivated, revealing a gap in the maintenance and updating of these learning environments.

Furthermore, few utility companies or science museums have facilities adapted to host elementary school groups, which limits students' exposure to real technologies and solutions for energy management. This difficulty highlights the need for public policies that promote the creation and reactivation of interactive energy education spaces capable of bridging theory and practice while inspiring interest and career aspirations in the fields of science, technology, and engineering.

3.4 Preparation of materials to disseminate knowledge

Most of the schools were unable to achieve the goal of promoting behavioral or consumption changes within the educational environment, due to several factors such as limited access to electricity bills or the inability to read the energy meter. However, two students decided to conduct a research project focused on promoting efficient energy use for lighting. They presented their results in September 2025 at the Rio Grande do Sul North Coast Scientific Fair (MOSCLING) (Fig. 7). The research included measurements of electrical and luminous data, along with efficiency comparisons (Fig. 8).

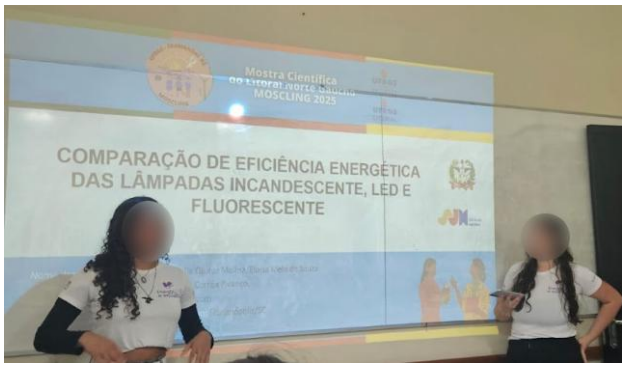

Figure 7: Presentation at the Rio Grande do Sul North Coast Scientific Fair (MOSCLING).

Figure 8: Students conducting measurements of electrical and luminous data to compare lighting efficiency as part of their research project presented at the 2025 MOSCLING Scientific Fair

The preliminary results of the project demonstrate that the combination of hands-on workshops, gamification,

and technical visits constitutes an effective pedagogical strategy for introducing concepts of energy efficiency and consumption management among elementary school students. The energy transformation experiment, although simple, proved to be a valuable didactic resource to bridge abstract concepts with students' everyday realities, enabling them to establish connections between school content and energy-saving practices at home.

The gamification activity and its playful nature showed strong potential for engagement, fostering critical and collaborative reflection on energy consumption habits. This finding aligns with recent research indicating that participatory methodologies are fundamental for stimulating interest and consolidating learning in STEM fields, which have traditionally been marked by gender inequality.

The integration of the workshop content with the National Common Curricular Base (BNCC) broadens the scope of the proposal, ensuring stronger alignment with the official curriculum and facilitating its replication in other public schools.

The results also suggest that the gender-focused approach adopted is central to the project's success. By ensuring female protagonism in the workshops, the project not only addresses the representational gap in the energy sector but also promotes social justice and contributes to the Sustainable Development Goals (SDGs), particularly SDG 4 (quality education), SDG 5 (gender equality), SDG 7 (affordable and clean energy), and SDG 10 (reduced inequalities).

Finally, it is worth highlighting that the articulation between universities, public schools, and professional networks strengthens knowledge transfer and creates a support network for female students. This collaborative model underscores that the energy transition depends not only on technological advances but also on educational processes that foster behavioral, cultural, and social change.

4. Conclusions

Ensuring social justice in the energy transition requires the active inclusion and equitable participation of women at all stages of the process, from education and research to leadership and decision-making (Sumarsono et al., 2023). Diversity in the energy sector not only drives innovation and sustainability but also aligns with the United Nations Sustainable Development Goals (SDGs), particularly SDG 4 (quality education), SDG 5 (gender equality), SDG 7 (affordable and clean energy), and SDG 10 (reduced inequalities) (UN, 2015).

Within this context, the implementation of energy management workshops in public schools has proven to be an effective educational strategy for promoting awareness, technical understanding, and behavioral change regarding energy efficiency. Through hands-on experiments, reflective discussions, and gamified learning, the students, especially girls, developed an applied understanding of energy transformation, efficiency, and consumption patterns. The lemon-powered LED experiment, for instance, served as an accessible and engaging tool to visualize abstract energy concepts, sparking curiosity about how energy is produced, transformed, and utilized.

Beyond the technical dimension, the pedagogical framework emphasized collaboration, critical thinking, and social engagement, culminating in campaigns for more conscious energy use within the school community. The challenges faced in organizing technical visits, particularly the scarcity of accessible spaces for practical demonstrations of energy efficiency, further underscore the need for public policies that encourage the creation and maintenance of interactive learning environments connecting theory and practice.

By combining scientific knowledge, participatory methodologies, and a gender-transformative approach, the project not only fosters technical competence but also empowers girls and women as key actors in advancing a just and inclusive energy transition.

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