

Exploring Awareness, Knowledge, and Interest in Energy Equity Among Civil, Architectural & Construction Undergraduates

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ABSTRACT: Energy equity, which addresses disparities in access to affordable and reliable energy, is a critical challenge within the architecture, engineering, and construction (AEC) sectors. As future AEC professionals shape how infrastructure systems would function to support human activities, engineering educators in higher education increasingly recognize the need to equip students with the skills and mindsets to make informed decisions that balance social justice and economic trade-offs. However, there is limited understanding of the current status of energy equity education. This study investigates undergraduate students' awareness, knowledge, experiences, and interest in energy equity within the context of built environments. Using a structured survey, this research explores students' familiarity with energy equity, their perceptions of its social and environmental implications, and their interest in pursuing related education, research, or careers. A total of 67 undergraduate students from Purdue University and the University of Arizona participated in the survey. While most respondents expressed interest in equitable energy systems and recognized inequities in energy distribution and renewable energy access, they also reported significant gaps in their educational experiences. Specifically, students indicated limited knowledge of building- and human- related factors contributing to energy inequities. ANOVA analysis revealed significant differences in awareness, interest, and knowledge of energy equity across institutions and demographic groups. The findings provide insights for developing targeted educational initiatives and strategies to prepare future AEC professionals to address energy inequities in their practice. This study also highlights the importance of integrating energy equity as a foundational principle in education and professional development across built environment disciplines.

1. INTRODUCTION

The benefits of clean and efficient energy technologies have not reached all U.S. citizens. The affordability barriers to adopting clean and efficient energy technologies were not deeply taken into account by federal agencies' programs (Brown et al. 2020; Steinberger and Roberts 2010). Indeed, subsidies to support the adoption of electric vehicles (EVs) benefited top-income earners primarily (Caulfield et al. 2022) and low-income communities were often excluded from U.S. community solar projects (U.S. Department of Energy 2023). Accordingly, addressing such inequitable benefits from advanced energy technologies has become a key agenda in recent years (Jenkins et al. 2016). Increasingly, engineering educators in higher education

recognize that students need specialized training in how to make engineering decisions in a way that considers key social justice and economic trade-offs (Armanios et al. 2021).

Energy equity, defined below, recognize that access to affordable, efficient, clean energy is a fundamental right that should not be limited by one's socioeconomic status or geographic location (Hall et al. 2013). Energy equity initiatives from the U.S. federal agencies and professional organizations have broadened the awareness, interest, and responsibility of stakeholders (e.g., the Justice40 Initiative by the U.S. White House (2021)). In this movement, civil, architectural, and construction (CAC) engineers play a critical role in addressing energy inequity by designing energy-efficient buildings and infrastructure that meet the needs of underserved communities.

- Energy Equity: refers to equitable access to clean energy and energy efficient housing (U.S. Department of Energy 2023), and fair distributions of benefits and burdens (Park 2014).

This study aims to evaluate CACE students' awareness, knowledge, and interest in energy equity through a survey-base approach. Our research questions are the following.

- RQ 1. What is the current status of CACE students regarding their awareness, interest, and knowledge of energy equity?
- RQ 2. Do current CACE curricula incorporate sufficient educational interventions to effectively teach energy equity?
- RQ 3. Do CACE students at a minority-serving institution (MSI) differ from those at non-MSI in their awareness, interest, and knowledge of energy equity?

The objective of this study is to understand how students perceive energy equity, the extent of their knowledge on the subject, and their interest in integrating these concepts into their future careers. By examining these factors, this study contributes to the CACE education by identifying gaps in students' understanding of energy equity and highlighting the potential for incorporating the critical issues into CACE curricula to better prepare students for addressing energy disparities in their professional work. To date, very few studies investigated how social justice has been incorporated into CACE education, and this study aims to fill that gap by focusing on specifically energy equity.

CACE students need concrete tools and training to fulfill their roles as prospective decision-makers who can contribute to equitably sustainable energy infrastructure systems across all communities (Conlon 2008). Educating energy equity to CACE students ensures that 21st century CAC professionals contribute to infrastructure systems that not only meet environmental standards but also promote social sustainability and reduce economic burdens on underserved populations.

2. ENGINEER EDUCATION STANDARDS AND CODES

Current standards and codes within engineering education underscore the imperative for engineers to cultivate a professional commitment to public welfare and social justice as organized below.

- The Accreditation Board for Engineering and Technology (ABET) (2023): One of the expected student outcomes is 'an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.'
- American Society of Civil Engineers (ASCE) (2023): The code of ethics by ASCE states that engineers should, in all matters related to their profession, treat all persons fairly and encourage equitable participation without regard to gender or gender identity, race, national origin, ethnicity, religion, age, sexual orientation, disability, political affiliation, or family, marital, or economic status.
- National Academy of Engineering (NAE) (2023): The code of conduct by NAE mentions that NAE members shall not engage in discrimination, harassment, or bullying. These behaviors interfere with or sabotage engineering activities and careers, and create a hostile environment that reduces

the quality, integrity, and pace of the advancement of engineering and technology by marginalizing individuals or communities, and preventing the healthy exchange of ideas.

- National Society of Professional Engineers (NSPE) (2019): Engineers shall conduct themselves honorably, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.

These standards and codes should be incorporated into CACE education and guide students to develop a strong sense of responsibility toward society, fostering a commitment to creating solutions that benefit all, while rejecting discrimination and harmful behaviors.

3. SOCIAL JUSTICE IN CIVIL, ARCHITECTURAL, & CONSTRUCTION ENGINEERING EDUCATION

To date, very few studies have explored how to incorporate social justice into CACE education. Their key focus was on making systematic changes within departments to better meet above-mentioned engineer standards and codes. Specifically, Armanios et al. (2021) shared departmental-level efforts of interweaving diversity, equity, and inclusion principles and practices into their pedagogy and culture. Specifically, they integrated unjust issues into their courses, such as the introductory course, computational and data science course, and capstone course, and instituted a committee that strategically plans for a diverse, equitable, safe, and inclusive environment that supports the community within the department. These integration efforts, as results, stimulated higher-level thinking in students, outlined in Bloom's Taxonomy scale and fostered a more inclusive and equitable learning environment. Another effort, shared by Farrell et al. (2017), was again a departmental-level approach that increased diversity in civil and environmental engineering curricula by introducing topics like engineering and social justice and engineering ethics. Also, instructors framed student discussions around societal and cultural intersections of engineering. To sum up, there was little efforts in understanding CACE students' awareness, knowledge, and interest in social justice.

Our literature review highlighted the need for sustained and consistent efforts to integrated social justice into CACE education. Sanford et al. (2022) argued that civil engineers have historically been complicit in discriminatory actions carried out by the government, leading to inequities being embedded in the design and development of neighborhoods. Moreover, they critiqued the CACE education system for continuing to educate engineers in ways that are disconnected from the broader social context, thus perpetuating these inequities. As an example consequence, Keku et al. (2021) identified significant differences in career satisfaction expectations between underrepresented minority (URM) student groups and non-URM student groups, underscoring the need for more inclusive and contextually aware engineering education.

Accordingly, this research, which focuses on energy equity – a key facet of social justice in CACE – aims to uncover CACE students' levels of awareness, knowledge, and interest in the subject. The findings will inform discussions on how energy equity, along with other social justice components, can be more effectively embedded into CACE curricula to prepare students for addressing equity challenges in their future careers.

4. METHODOLOGY

To investigate the current status of CACE students' awareness, interest, and knowledge of energy equity, as well as the sufficiency of educational interventions in CACE curricula, a structured survey was conducted among students at Purdue University (PU) and the University of Arizona (UA). These institutions were selected to represent both a non-Minority Serving Institution (non-MSI) (PU) and a MSI (UA), allowing for a comparative analysis of students from different institutional backgrounds.

A total of 73 students participated in the survey, with 67 students completing more than 50% of the survey questions. Figure 1 illustrates the demographic breakdown of these 67 participants, showing distributions based on institution, field of study, age, gender, ethnicity, and academic standing. Respondents were from two institutions, PU and UA, with a slightly higher representation from PU (56.7%). The majority were studying Civil Engineering (56.7%), followed by Construction Engineering and Management (19.4%) and

Architectural Engineering (13.4%), while 10.4% identified with other fields. Regarding gender, 53.7% identified as male, 43.3% as female, and 3.0% as non-binary. In terms of ethnicity, 76.1% identified as Non-Hispanic, while 23.9% identified as Hispanic. The majority of respondents were upperclassmen, with 35.8% juniors and 31.3% seniors, while sophomores (26.9%) and freshmen (6.0%) made up the remainder.

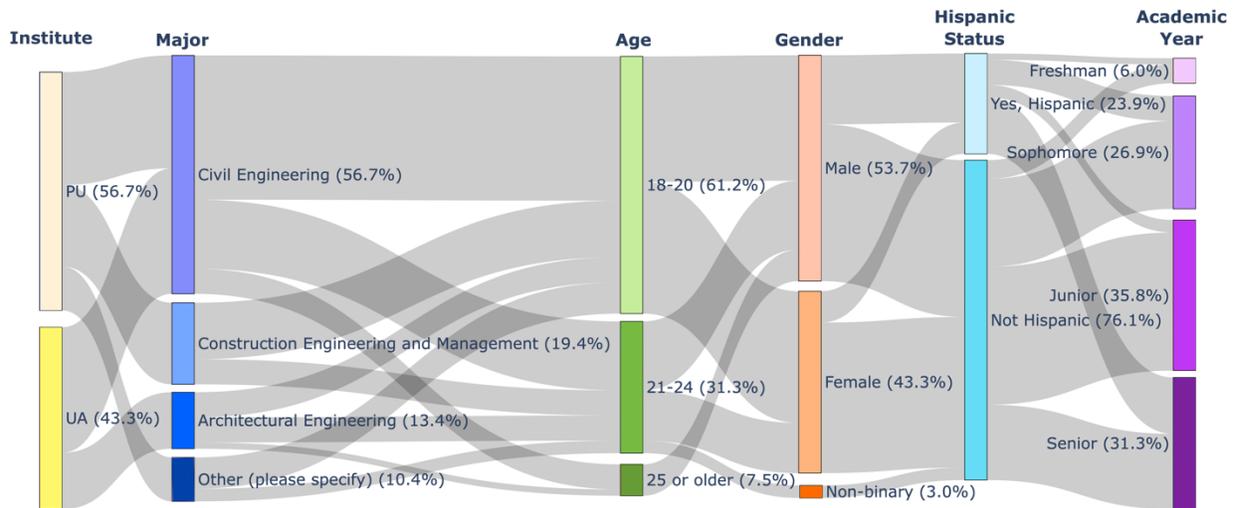


Figure 1: Survey Demographics

To address the research questions, a combination of descriptive and inferential statistical methods was employed. Descriptive statistics (e.g., mean) were used to analyze students' awareness, interest, and knowledge of energy equity. Responses regarding energy-related course offerings and curriculum flexibility were summarized to assess students' perceptions of educational interventions. One-way ANOVA was conducted to determine if there were significant differences in students' awareness, interest, and knowledge of energy equity between the MSI (UA) and non-MSI (PU) institutions. Two-way ANOVA was used to explore potential interactions between demographic factors (e.g., gender, ethnicity) and institutional type in shaping students' perceptions of energy equity. A 95% confidence interval was adopted in these inferential analyses. By employing these methods, this study aims to provide a comprehensive understanding of how energy equity is integrated into CACE education and whether institutional differences impact student learning outcomes.

5. RESULTS

5.1 Current Status of CACE Students' Awareness, Interest, and Knowledge of Energy Equity

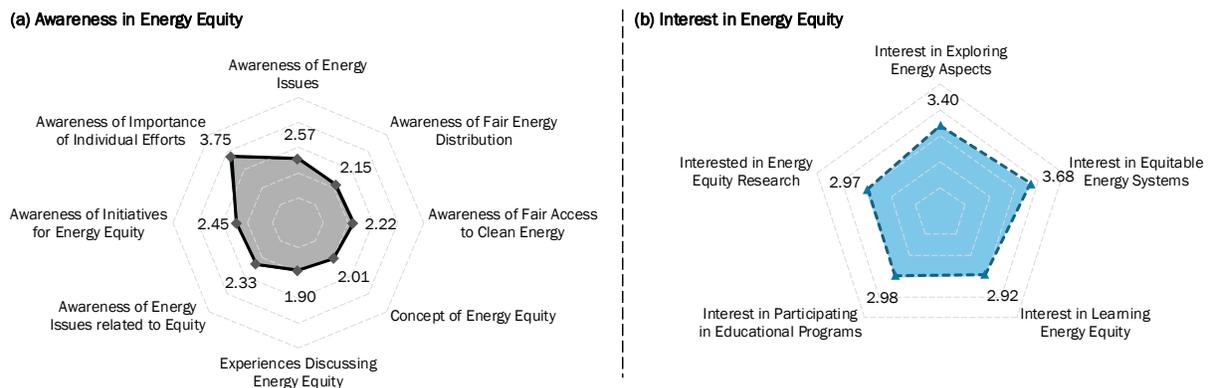


Figure 2: CACE students' Awareness (a) and Interest (b) in Energy Equity

The survey results revealed a contrast between CACE students' awareness of energy equity issues and their interest in exploring the topic further. As in Figure 2 (a), while general awareness of energy issues (2.57) was moderate, familiarity with specific aspects such as energy distribution (2.15), access to clean energy (2.22), and the concept of energy equity (2.01) were relatively low. Discussions about energy equity (1.90) were infrequent, indicating a lack of engagement with the subject. However, awareness of energy equity issues (2.33) and initiatives promoting it (2.45) suggested some recognition of ongoing efforts. Notably, the highest awareness score (3.75) pertained to the importance of individual efforts, implying that respondents saw their role in energy equity but might lack a comprehensive understanding of the broader systemic issues.

In contrast, interest in energy-equity-related topics, Figure 2 (b), was higher across most categories. CACE students showed strong enthusiasm for exploring energy aspects (3.40) and equitable energy systems (3.68), surpassing their awareness levels. However, interest in structured learning opportunities — such as educational programs (2.98) and research involvement (2.97) — remained moderate, suggesting that while students recognized the importance of energy equity, they might not have actively sought formal education on the subject. The gap between awareness and interest highlighted an opportunity for targeted educational initiatives that could have translated curiosity into deeper knowledge and engagement, particularly in fostering discussions and increasing familiarity with equity-related issues in the energy sector.

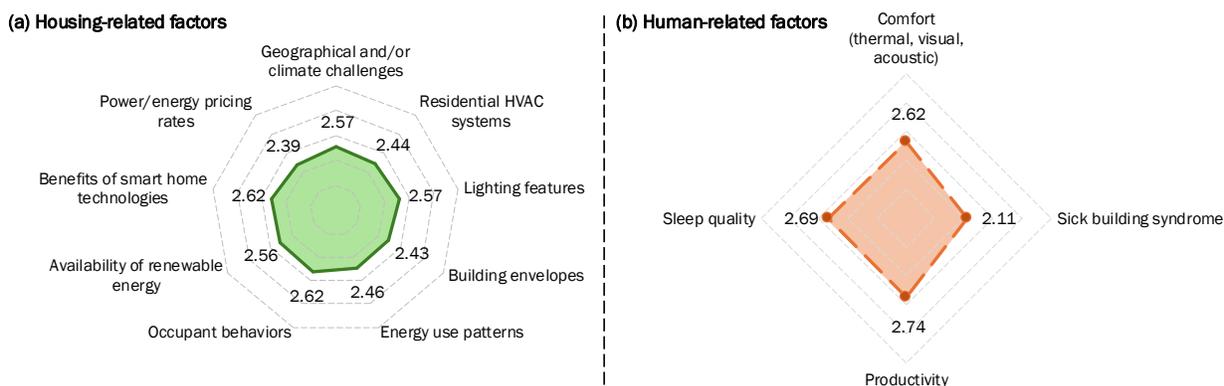


Figure 3. CACE students' self-evaluated knowledge levels about housing and human-related factors

Additionally, respondents' self-evaluated knowledge levels about factors associated with energy equity were relatively consistent across different categories but remained low overall (Figure 3). CACE students demonstrated a basic understanding of geographical and climate challenges (2.57), residential HVAC systems (2.44), lighting features (2.57), building envelopes (2.43), and energy use patterns (2.46). Their knowledge of occupant behaviors (2.62) and the availability of renewable energy (2.56) was slightly higher, aligning with their familiarity with smart home technology benefits (2.62). However, knowledge of power and energy pricing rates (2.39) was among the lowest, indicating limited familiarity with the economic aspects of energy use. Similarly, their understanding of human-related factors, including thermal, visual, and acoustic comfort (2.62), productivity impacts (2.74), and sleep quality (2.69), suggests room for improvement. In particular, awareness of health-related concerns, such as sick building syndrome, was notably low. These findings highlight the need for stronger educational efforts to enhance students' knowledge in both technical and human-related aspects of energy equity, ensuring a more comprehensive understanding of their roles in society.

5.2 Current Status of Academic Offerings in the CACE Field

As students progress through their studies in CACE programs, the question of whether their curricula sufficiently incorporate energy equity education remains a crucial concern. The data suggests that while some exposure to energy-related courses exists, it may not be enough to fully prepare students for the complexities of energy equity in their professional careers. Despite the variety of fields of study, the majority shared a common experience, which was limited engagement with energy-related coursework.

When asked about the number of energy-related courses they had taken, most students (76.1%) reported having completed only one or two courses (Figure 4). A much smaller percentage had taken three to four courses (14.9%), and an even smaller group had completed five or more. This suggests that while energy topics are present within CACE programs, they are not deeply embedded in the curriculum, often appearing as electives or supplementary courses rather than core requirements. Students' perceptions of the sufficiency of energy-related course offerings revealed a mixed perspective: Only 10.4% strongly believed that their institutions provide enough courses to address energy issues effectively. A larger portion (46.3%) leaned toward a more optimistic view, stating that course offerings are “probably” sufficient. However, a significant number of students remained uncertain or dissatisfied, showing 20.9% expressed ambivalence, while 19.4% said offerings were “probably not” enough, and 3% firmly believed that there were not nearly enough courses to address energy equity education adequately.

Beyond the availability of courses, students also reflected on the flexibility of their coursework. While 46.2% of respondents (10.4% strongly agree, 35.8% agree) felt that their programs allowed for enough flexibility to engage with energy topics, more than half expressed concerns. A notable 23.9% remained neutral, while 28.4% disagreed and 1.5% strongly disagreed, which indicates frustration with rigid course structures that may not accommodate interdisciplinary learning or electives related to energy equity.

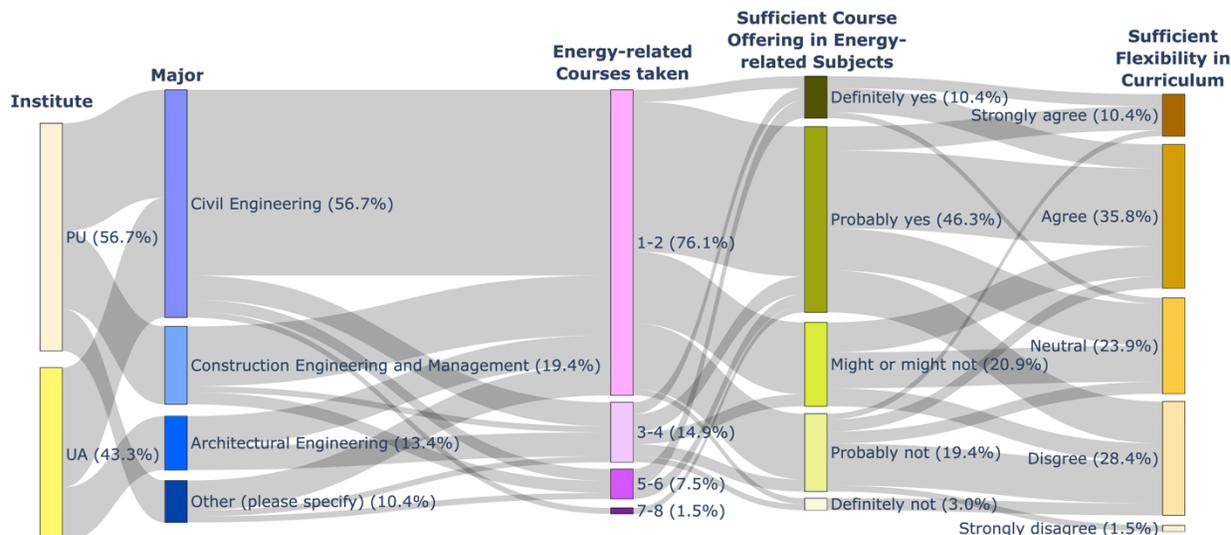


Figure 4: Current academic offerings reported by survey participants

In the survey results, we found that while some students found the existing offerings adequate, a substantial portion perceived gaps in course availability and flexibility. If CACE programs aim to prepare future engineers to tackle energy equity challenges, they may need to reconsider how these topics are embedded within required coursework. Expanding access to energy-related courses and increasing curricular flexibility could help ensure that all students, regardless of their field of study, receive the necessary education to address energy equity effectively in their careers.

5.3 Awareness, Interest, and Knowledge of Energy Equity between MSI and Non-MSI Students

Table 1 shows the results of one-way and two-way ANOVA. A one-way ANOVA was conducted to examine differences in students' awareness, interest, and knowledge of energy equity between PU and UA. In the awareness category, PU students reported a greater awareness of industry, government, and academic initiatives aimed at supporting disadvantaged communities compared to UA students ($p < 0.05$). In the interest category, UA students showed a higher level of interest in exploring energy aspects within their disciplines than PU students ($p < 0.1$). In the knowledge category, institutional differences were noted in students' knowledge of housing-related factors contributing to energy inequity. PU students demonstrated more knowledge of geographical or climate challenges affecting energy equity ($p < 0.1$), whereas UA students exhibited greater knowledge of the availability of renewable energy availability ($p < 0.1$).

To further investigate whether gender and Hispanic status influence the effect of institution type on students' awareness, interest, and knowledge of energy equity, a two-way ANOVA was conducted. In the gender-related analysis, two non-binary respondents were excluded due to an insufficient sample size to ensure the analysis's robustness.

The results indicate significant gender-based differences. In awareness, males more strongly agreed with the statements: "Energy is used fairly across all populations" ($p < 0.1$) and "Renewable energy resources are accessible to all populations" ($p < 0.05$). Regarding knowledge of housing-related factors that may contribute to energy inequity, males exhibited a greater understanding of "lighting features" ($p < 0.05$), "energy use patterns" ($p < 0.05$), "occupant behaviors" ($p < 0.1$), and "the availability of renewable energy" ($p < 0.1$). Additionally, male participants reported higher knowledge concerning the human-related factors that may be impacted by energy inequity: "sick building syndrome" ($p < 0.05$), "productivity" ($p < 0.05$), and "sleep quality" ($p < 0.05$).

The results also indicate that there were differences based on Hispanic identity. In terms of awareness, Hispanic students highlighted "the importance of individuals advocating for energy equity in their communities and workplaces" ($p < 0.05$). Additionally, they expressed significantly greater interest in "learning more about energy equity and its implications" ($p < 0.05$). When discussing their knowledge of housing-related factors that may contribute to energy inequity, Hispanic students demonstrated a stronger understanding of "lighting features" ($p < 0.1$), "building envelopes" ($p < 0.05$), "occupant behaviors" ($p < 0.1$), and "energy prices" ($p < 0.1$). They also showed enhanced knowledge regarding human-related factors that may impact energy inequity, particularly "sleep quality" ($p < 0.1$).

Table 1: One-way and Two-way ANOVA Results

Category	Response Variable		One-way ANOVA	Two-way ANOVA					
			Institute (I)	I & Gender (G)		I & Hispanic (H)			
			I	G	I & G	I	H	I & H	
Awareness	Energy issues in AEC								
	Fairness in energy								
	Access to renewable energy						M*		
	Concept of energy equity						M**		
	Discussions in energy equity								
	Energy issues and equity								
	Support for disadvantaged communities		P**			P**		P*	
Interest	Importance of individuals for energy equity							H**	
	Energy in your discipline		A*						
	Equitable energy systems								
	Learning about energy equity							H**	
	Willingness to energy equity-related programs								
Knowledge	Housing-related	Energy equity-related research							
		Geographical or climate challenges	P*			P*		P*	
		HVAC					P*		
		Lighting					M**	H*	
		Envelopes						H**	
		Energy use pattern					M**		
		Occupant behaviors					M*	H*	
		Availability of renewable energy	A*				M*	**	
	Human-related	Smart technologies							
		Energy price						H*	**
		Comfort							
		Sick building syndrome					M**		
		Productivity					M**		
		Sleep quality					M**		H*

P = Purdue University, A = University of Arizona, M = Male, H = Hispanic, ** = $p < 0.05$, * = $p < 0.1$

Additionally, two-way ANOVA results revealed two significant interaction effects (Figure 5). The first interaction effect suggests that gender differences in knowledge about renewable energy availability were influenced by the institution. Specifically, at PU, male and female students had comparable knowledge levels, whereas at UA, male students exhibited significantly higher knowledge than female students. The second interaction effect indicates that Hispanic students at PU reported significantly greater knowledge of energy prices compared to non-Hispanic students. However, at UA, this difference was not observed, as non-Hispanic students had knowledge levels similar to those of Hispanic students.

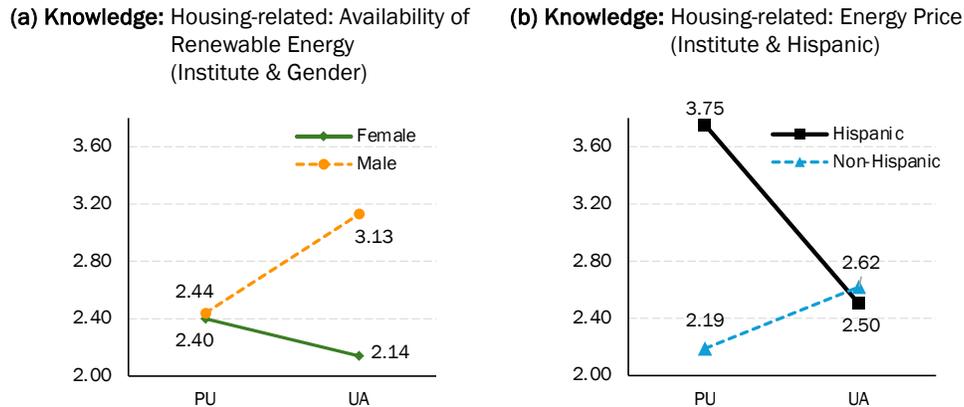


Figure 5: Interaction plot illustrating knowledge of housing-related factors in energy equity: availability of renewable energy (a); and energy price (b).

6. CONCLUSIONS

This study highlights the critical role of energy equity in the architecture, engineering, and construction (AEC) sectors and underscores the need for improved education on this topic. Findings from the survey of undergraduate students at PU and UA reveal a strong interest in energy equity but also significant gaps in knowledge and educational exposure. While students recognize inequities in energy distribution and renewable energy access, they report limited understanding of the specific building- and human-related factors contributing to these disparities. Furthermore, ANOVA analysis revealed significant differences in awareness, interest, and knowledge of energy equity across institutions and demographic groups. These findings suggest that students' exposure to energy equity concepts may be influenced by their academic environment and background, reinforcing the need for targeted educational interventions. To bridge these gaps, AEC programs should integrate energy equity more explicitly into curricula, incorporating case studies, interdisciplinary collaborations, and experiential learning opportunities. Educators must equip future professionals with the tools to address energy inequities in practice to ensure that sustainable and just energy solutions are fully taken into consideration in the built environment.

Future research should explore how different pedagogical approaches impact students' understanding of energy equity and assess the effectiveness of curriculum interventions. Additionally, expanding the study to a broader range of institutions and student populations could provide deeper insights into how demographic and educational factors shape awareness and engagement with energy equity. Lastly, a comparative analysis on CACE curricula would also be beneficial to assess their contributions to CACE students' awareness, perspective, and interest in energy equity.

By incorporating energy equity into CACE education, AEC disciplines can better prepare graduates to navigate the complex intersection of sustainability, social justice, and engineering decision-making, ultimately fostering more equitable and resilient built environments.

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