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An Exploration of Using Solar Photovoltaic Cells as a Sustainable Solution in Higher Education

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ABSTRACT

The purpose of this convergent parallel mixed-methods instrumental case study was to examine the feasibility of Solar Photovoltaics (PV) as an economic and environmental sustainability tool for higher education while, at the same time, gauging essential university stakeholder knowledge, opinions and beliefs regarding sustainable development, sustainable universities, and support for sustainable initiatives on campus. The findings from this study at a Midwestern university indicated that the solar power system generated electricity at a lower cost than the local electric utility was charging and a varied understanding of sustainable development by participants. Implications for provide insight into establishing stakeholder support and a cost/benefit model for sustainable development for institutions of higher learning.
Keywords: sustainable development, sustainable university, higher education, solar PV, renewable energy

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Higher Education Institutions (HEIs) face lower revenue from reduced enrollment and incurred costs for online teaching and pandemic protocols, which have placed new financial burdens on them (Eide, 2018). All these factors threaten the sustainability of higher education (Carlson & Gardner, 2021; Collins et al., 2021; Whitford, 2021). Furthermore, changes in enrollment caused by the pandemic could significantly impact institutions of higher learning, primarily private, four-year universities and colleges that receive very little public funding (Carlson & Gardner, 2021). For example, Collins et al. (2021) reported that enrollment, a critical factor in HEI revenue, declined (-10.5%) at private US colleges and universities from fall 2019 to fall 2020. However, public institutions, both two- and four-year, are not exempt from financial deficits with significant losses in revenue reported at many IHEs as state and local budgets experienced shortfalls (Collins et al., 2021).

Carlson and Gardner (2021) posited institutions of higher learning faced problems on multiple fronts even before the onset of the coronavirus pandemic in 2020. Maintaining that higher education had not fully recovered from the 2008-2009 recession, the authors also contended that further problems were related to changing demographics, increasing tuition rates, and a shift in the value proposition for higher education (Carlson & Gardner, 2021). The recession compounded a deepening demographic shift which changed the number of potential students planning on attending college in many regions of the U.S. Colleges and universities have engaged in intense competition to attract from this shrinking pool of candidates. State support for public colleges has increased to some extent, but not reached pre-recession levels, leaving the burden of cost of attendance on students and their families. HEIs had already been trimming expenses where possible before the pandemic started. Some colleges and universities had to resort to staff reductions which typically affected the lower-income positions (Carlson & Gardner, 2021). An estimated 10 percent of college staff have been lost since the pandemic's beginning (Carlson & Gardner, 2021).

Staisloff (2020) suggested that higher education institutions must become more sustainable as soon as possible. The author has labeled the pandemic as a dislodging event that will force colleges and universities to re-evaluate their current cost structures. Staisloff surmised that "endowments will be decimated, enrollments will decline, and both public and private funds will be hard to acquire" due to the impacts of the coronavirus pandemic on higher education (Staisloff, 2020, p. 1).

A focus on sustainability and implementing sustainable initiatives on the campuses of higher education institutions (HEI) may provide some relief for universities and colleges facing some of these challenges. The United Nations Brundtland Commission, in 1987, defined sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs (Hooey et al., 2017). Sustainability requires decisions that balance how we use the environment, social equity, and the ongoing need for economic growth. The environmental aspect of sustainability means using resources wisely and respecting the environment (Hooey et al., 2017).

The Stockholm Declaration of 1972 included the first direct reference to "sustainability in higher education" (Mohammadalizadehkorde & Weaver, 2018, p. 2). Amaral et al. (2015) presented the idea of a "sustainable university" as one that leads by example in minimizing the negative impacts of its resource use on the environment, the economy, and society (Amaral et al., 2015, p. 157). Among the higher operational costs of a university are its utilities, especially electric power (National Grid, 2003). In addition, university infrastructures usually are large systems of several energy-consuming buildings and facilities (Amaral et al., 2015). According to Hanus et al. (2019), educational institutions represent 11% of electricity consumed by buildings in the US and 4% of the total US carbon emissions.

Renewable energy resources can provide cost-savings and reduced greenhouse gases (GHG) along with intangible benefits such as achieving Environmental, Social & Governance (ESG) goals and the development of a "sustainable university" (Amaral et al., 2015, p. 157). Solar photovoltaic (PV) energy applications are the dominant form of renewable energy used at HEIs (Filho et al., 2018). And an increase in the use of rooftop solar PV on college campuses could reduce the costs related to the health, environmental, and climate change damage caused by fossil fuel consumption. Several studies (Filho et al., 2018; Hahn, 2017; Hanus et al., 2019; Herrmann, 2008; Jo et al., 2017) have evaluated the cost/benefits of installing solar PV infrastructure at campuses. Other studies (Dahle & Neumayer, 2001; Djordjevic & Cotton, 2011; Mascarenhas et al., 2020; Murray, 2018; Speer et al., 2020; Wright & Horst, 2013) have attempted to gauge support for sustainability and renewable energy initiatives in areas such as waste management, energy management and water consumption as well as, the use of solar energy on campus.

This convergent parallel mixed-methods approach instrumental case study explored the attitudes and opinions of a university's stakeholders regarding sustainability and renewable energy use while providing a feasibility study for the benefit of solar PV infrastructure at a specified campus building, combining both prior approaches in a mixed-methods case study. Specifically, this study also explored the financial and environmental sustainability benefits of installing a solar PV power system at a university campus building. For institutions of higher learning that contemplate utilizing solar PV, this work potentially provides a method of establishing stakeholder support (qualitative) and a cost/benefit model for the system itself (quantitative) in consideration of institutional sustainability initiatives.

Context and Setting

The host institution of this convergent parallel mixed methods instrumental case study was a private, Midwestern liberal arts university in the United States. The institution is situated within a large urban area and has an enrollment of fewer than 4,000 students. Faculty and staff represent an additional 800 members of the proposed research population. The state where the institution is situated is a significant producer of fossil fuels. This case study situates a selected campus facility which was a three-story, 21,000 ft. sq. administrative building containing standard office spaces, a small auditorium, and a few computer labs. This campus building was selected because of: (1) roof position relative to the daily movement of the sun in which a south-facing roof is preferable; (2) age of the building in which older buildings are less efficient and could benefit from solar power generation; and (3) a separate electric utility meter to establish power consumption for this facility alone because some university building share a common meter.

METHODS

Prior research into sustainability in higher education (SHE) has sought to either establish beliefs, opinions, and support for SHE with university stakeholders or to study the feasibility and effectiveness of using solar PV as an aid in SHE (Dahle &

Neumayer, 2001; Djordjevic & Cotton, 2011; Filho et al., 2018; Hahn, 2017; Hanus et al., 2019; Herrmann, 2008; Jo et al., 2017; Mascarenhas et al., 2020; Murray, 2018; Speer et al., 2020; Wright & Horst, 2013). This study utilized a non-experimental, convergent parallel mixed method instrumental case design with a concurrent approach which allowed for simultaneous data collection and interpretation of two or more data sources (Edmonds & Kennedy, 2017). This research design is described as a "mixed research method with an emphasis on quantitative data to research both the qualitative and quantitative aspects" of the proposed sustainability initiative (Johnson & Christensen, 2019, p. 32). Mixed methods research has emerged in response to the perceived limitations of both qualitative and quantitative designs and itself is more complex since it combines elements of both and can offer more insight into the phenomenon being studied (Caruth, 2013). The philosophical tenets of pragmatism both allow and guide mixed-methods researchers to utilize a variety of approaches to address research questions that cannot be answered using a single methodology (Doyle et al., 2009).

The mixed-methods approach employed here is an instrumental case study with a positivist epistemological approach (Crowe et al., 2011). This case study can be categorized as "instrumental" because the objective is to observe a particular issue (the sustainability solution) and gain a better understanding of the level of support and practical feasibility (Crowe et al., 2011, p. 2). The researcher undertook a positivist epistemological approach, tested defined phenomena, and drew conclusions from the findings related to the theory of SHE (Crowe et al., 2011).

Quantitative data was gathered via a cost/benefit analysis of the sustainability initiative to assess its feasibility for a specific campus building. An established solar PV installation company designed the solar PV system and calculated the cost per kWh to be generated using a National Renewable Energy Laboratory (NREL) approved model (Aurora Solar, 2022). Qualitative data was gathered using a researcher-designed structured interview guide for individual face-to-face interviews with key university stakeholders representing the administration, faculty, staff, and students. Some interviewees are the ultimate decision-makers for any capital expenditure or long-term contractual commitments. This study was guided by the following research questions:

1) What is the feasibility of implementing a specific sustainable initiative for a designated building at a private, Midwestern university?
2) What are the stakeholders' perceptions of a specific sustainable initiative for a designated building at a private, Midwestern university?

Positionality

The primary researcher is a White, middle-class male in his 60s with an extensive background in the energy industry in the USA. While conducting this study, the researcher was employed by the subject institution as a faculty member and administrative department chairman responsible for the evolution of its energy business curriculum to include more varied forms of energy. Despite many years of experience in the oil and gas industry, the primary researcher has always supported the efficient use of energy and has been interested in and taught about alternative and renewable energy. He also has experience installing small-scale solar PV modules and is the owner of a residential solar PV system which has shown to be cost-effective relative to the cost of power provided by the same local electric utility that serves the subject university. The second author is a mixed-heritage Latino male and supported the research design and has previously worked with student unions as a student affairs professional. The researchers hold assumptions about the feasibility study to indicate a financial benefit to the test institution which were bracketed during the data analysis process.

Participants

Seven stakeholders representing the administration, board of trustees, faculty, staff, and students were recruited as participants using a purposive sampling procedure. This sampling approach is described as "judgmental" since the researcher specified the characteristics of the population of interest (Johnson & Christensen, 2019, p. 254). Inclusion criteria included that participants had to be full-time employees or university students identified as either key decision-makers or as those elected to represent the entirety of the faculty, staff, or students. Each was assigned a pseudonym to protect confidentiality based on their positionality at the host institution of the study.

Table 1: Participant Demographics

Participant Role	Race	Gender	Age Group	Education
University President (UP)	White	Male	50-55	J.D.
University Provost (PR)	White	Male	50-55	Ph.D.
University CFO (CFO)	White	Male	50-55	M.B.A.
University Trustee (UT)	White	Male	45-50	B.S.
Faculty Senate President (FS)	Asian	Male	50-55	Ph.D.
Staff Council Chairman (SC)	White	Male	40-45	M.B.A.
Student Association President (SA)	Asian	Male	20-25	B.A.

Data Analysis

Qualitative coding included thematic analysis, which was conducted using several phases (Nowell et al., 2017). First, a list of *a priori* codes was created, and then iterative coding of the transcripts resulted in the development of new inductive codes and changes. Next, through a comprehensive review of the data, *a priori codes* were added as a deeper conceptualization as the data became apparent. Finally, inductive and deductive coding were applied to capture the experiences of individuals who were not correctly reflected in *a priori* codes (Johnson & Christenson, 2019).

Thematic analysis was done using higher-level descriptive codes, and individual transcript codes were categorized into themes based on the link between the coded material and its higher level. To convey the depth of meaning in each theme, the researcher combined a wide range of codes, resulting in the formation of subthemes (Johnson & Christenson 2019). The preliminary results of the thematic analysis yielded three topics. The researcher then examined the coded data inside each theme to ensure its consistency. Finally, an iterative approach resulted in code recoding and rearrangement to represent better the facts and themes' essential meanings (Nowell et al., 2017).

For the quantitative analysis, a feasibility study was undertaken for the proposed sustainable solution. An established solar PV installation company designed the solar PV system for a designated campus building. The cost per kWh to be generated by the system was calculated using a National Renewable Energy Laboratory (NREL) approved model, Aurora Solar® (Aurora Solar, 2022).

FINDINGS

Qualitative Findings

Data analysis revealed three distinct themes. Participants generally felt that campus sustainability initiatives were a priority but questioned the feasibility of projects depending on the scale (complexity) and cost. Definitions of sustainable development varied among the respondents, with most associating SD with the responsible use of natural resources. When discussing the concept of a sustainable university, there was an even greater disparity among the descriptions given with some personnel viewing the ties with the local community as important while others pointed to the use of alternative or renewable energy as a necessary component. As to support for any sustainability project or initiative, the overriding determinant was the economic viability of the proposed undertaking.

A Need for Consensus on the Meaning of Sustainable Development

All participants were familiar with the term sustainable development but varied in their exact definitions. Some interviewees mentioned consideration of the environment or green construction while others emphasized the viable longevity of any undertaking. But there was no one universal understanding that developed. Considering the earth's resources emerged as a sub-theme of sustainable development, with only two respondents using the terms *environment* or *ESG*. The University President (UP) viewed SD as “development that can be… maintained over decades, if not centuries, that, does not deplete future resources” while the Provost (PR) believed that SD should be looked at “in the context of a kind of limited set of natural resources in which we live on this planet, and that we should think about sustainability even as we think about economic growth”.

Beyond the environmental and earth resources concerns, a few respondents addressed the use of sustainable methods for any future campus buildings and structures. While consideration was given to retrofitting existing facilities, these participants placed an emphasis on SD going forward. The representative of the university staff council (SC) saw sustainable development as “new construction, new developments being built in sustainable manners…so green buildings if you want to think of it that way". The Trustee (UT) interviewed saw SD as "the combination of a thoughtful process around new building or refurbishment".

Given the current economic struggles facing higher education, other participants highlighted financial sustainability. SC addressed total cost of ownership of any development, "And how do you make the life of that development be sustainable both financially and physically?" While UT saw that SD "takes into account, obviously, the costs in the overall financial viability of a project".

The conclusion derived from the responses was the need for more sustainable development education at this particular institution. A lack of agreement on exactly what constitutes sustainable development can thwart discussions surrounding both the subject and any SD initiatives this university may consider.

University as Role Model/Thought Leader

Participants felt that universities had a role to play in sustainable development and an obligation to do so. A frequent sentiment that emerged was supporting the local community in achieving sustainability through research and by being thought leaders. By utilizing a university's facilities and engaging faculty, staff, and students, HEIs can create "living labs" for sustainable development that incorporate its various stakeholders including, the greater community within which it resides. Participants provided examples of how they view this function of a university. PR stated, "We should think about our development as an institution in terms not only of environmental sustainability but community sustainability." while SC posited "I think the universities have a unique position to be think tank leaders in these types of initiatives."

None of the participants mentioned the establishment of a sustainable development curricula or educating students on sustainability principles. However, respondents did indicate that universities should conduct research and pursue sustainability-related topics. The UP gave specifics on how the institution could lead by "R&D into renewable energy or other sustainable technologies and then second as thought leaders."

When asked to address sustainable efforts by universities, several of the respondents specifically mentioned renewable energy or a reduction in the use of fossil fuels. Specifically, some interviewees specifically referenced solar power as part of their view of what constitutes a sustainable university. Further emphasis was on business continuity or the university as an ongoing concern. Other participants mentioned financial sustainability, while just one included monitoring water usage as part of a university's sustainable efforts, while some mentioned the concept of universities as leaders in sustainable initiatives. The Chief Financial Officer (CFO) reacted immediately to the perceived cost of becoming and maintaining a sustainable university. "Sounds expensive." While the Student Association President (SA) indicated support for university sustainability efforts. "The sustainable university is one that is proactive in its approach to switching to sustainable energy and sustainable projects and initiatives."

Others addressed some of the more traditional thinking on SD which surrounds a reduction in fossil fuel consumption, recycling, and the use of renewable energy.

The SC specifically mentioned some key areas to be considered, “How do we recycle more? How do we use less fossil fuels? How do we capture and reuse stormwater?” And, the UT, while specifically mentioning solar power, addressed the need to justify such projects based upon a return, “Are we doing the return on investments that would lead toward integration of new solar projects or different ways to heat?”

While numerous, the participants’ thoughts on what constitutes a sustainable university actually reflect an all-encompassing definition. To be sustainable, a university must maintain financial viability while considering sustainable initiatives such as the use of sustainable energy resources. And to be truly recognized as a sustainable university, the greater community needs to be incorporated into the institution’s efforts.

Cost and Politics as Barriers

One of the most common barriers to sustainability in higher education is a lack of agreement on the meaning of the term itself. As previously illustrated by participants in the first theme, definitions of sustainability in higher education continue to differ. The cost of implementing sustainable initiatives was an overriding concern of most respondents. Here again, sustainability was viewed as related to energy-efficient or "green" buildings. Increased costs are associated with retrofitting existing buildings to meet specific efficiency standards and constructing new facilities using best practices in energy usage. In addition, some interviewees addressed the issue of *Return on Investment* (ROI) as necessary to justify new efforts toward sustainability. The CFO specifically mentioned that support for a sustainable initiative would be “depending on what the ROI is, the return on investment”. Following that concern, the UP asserted that “There’s always a cost associated with sustainability”. And, while not emphatically associating sustainability with cost, the SC observed “sustainability has always equated to cost, not revenue, not profit, but expense”. The PR addressed the on-going financial issues facing HEIs today, “We also have economic constraints in terms of retrofitting existing buildings, building new buildings to more expensive standards.”

Participants expressed their opinions about spending capital to install alternative or renewable energy infrastructure on campus, even if there was no positive return on this investment. The shared concern regarding expenditures was an underlying theme while there was no recognition of any non-financial benefit that could be derived from having such a sustainable energy source on campus. Most answers were direct and to-the-point with the UP simply responding with “No, I probably wouldn’t.” and the SC replying, “No would be the answer.” A more definitive answer was given by the PR who recognized the fiduciary responsibility a university has in managing its funds, “We have to be good stewards of the students' tuition dollars and endowment funds, and that means probably not experimenting with technologies.” Somewhat aligned with the costs to install alternative and renewable energy infrastructure on campus was the perspective that college enrollments are expected to decline in the coming years and adding expenses would not be fiscally prudent. The CFO pointed to this trend, “You know, in six years, they're projecting it to be the lowest number of students entering college.”

One study participant who represented the study body (SA) believed that students would support an alternative/renewable energy project even if there were a loss stating, “I'm almost positive that a lot of students on campus would be OK with taking some kind of loss to pursue more, you know, a more sustainable university.”

Solar PV systems can provide reduced energy costs and lower carbon footprints, represent new education and research opportunities, and improve the academic institution's reputation. Solar PV systems are a visible sign of an HEI's commitment to sustainability and are popular with students. In addition, they can aid in recruiting students seeking to study alternative/renewable energy as they represent a "working lab" on campus. Furthermore, the institution is sending a message to the larger community about its commitment to sustainability.

Participants mentioned political issues as a potential barrier to supporting sustainable projects because a university's location has a bearing on the political climate in wherein it must operate. “You know there are people who are skeptical of sustainable energy.” “I think it’s just finding the right fit.” As a result, there could be a situation whereby philanthropists supporting the institution may not share the university's views on sustainability. This environment is especially true in states where the production of fossil fuels represents a large portion of the economy. Therefore, installing alternative and renewable energy sources on those campuses could be seen as a threat to the industries providing substantial financial support to the HEIs. The UP expressed concern that the image of alternative and renewable energy can be a political issue which could influence stakeholder support for any proposed sustainable energy initiative. “You know there are people who are skeptical of sustainable energy on the political front.”

For this particular institution, any alternative or renewable project proposed would have to stand on its own financially speaking, especially given that the participants are critical decision-makers for the university. Should the benefits outweigh the costs, the institutions current financial condition along with opportunities for capital deployment has to be considered. Further thought must be given to the political climate regarding the use of alternative & renewable energy along with the feasibility study which follows will aid in determining the financial viability of a specific sustainable solution.

Quantitative Results

The following section describes the results of the feasibility study or cost/benefit analysis of a specific sustainable solution utilizing a solar PV installation on a selected campus building. University personnel from facilities management as well as, an outside energy efficiency contractor, were involved in the choice of sites. Past electric consumption was provided, and a target power production level was set. Compiled data was analyzed in a proprietary model which designed a complete solar system along with associated costs, internal rate of return, payback period, etc.

Solar PV Infrastructure in Higher Education

There are many examples of higher education institutions pursuing solar energy infrastructure to enhance their environmental and financial sustainability. Jo et al. (2017) studied installations at several universities, including the University of Colorado at Colorado Springs, Smith College (MA), and Agnes Scott College (GA), to determine both how the systems were designed and how they were financed. The goal was to decide on the best methods necessary to propose similar installations on the campus of Illinois State University, Normal, Illinois.

Having determined suitable sites for multiple solar PV installations, the Illinois State researchers used an energy performance modeling system known as "SAM," or System Advisory Model, developed by the National Renewable Energy Laboratory (NREL). The model includes data such as weather from the National Solar Radiation Data Base (NSRDB) and information on the solar module and inverter performance data. Once the key inputs are submitted, the model can estimate the potential solar energy production on an annualized basis using the proposed system size. From there, the researchers calculated the cost of electricity per kWh generated by the solar PV design and compared that to the local electric utility's charge per kWh, which was adjusted by 2% per annum for inflation. Ultimately, it was determined that the university should not buy the system outright because, as a public institution, Illinois State cannot take advantage of the tax credits available since it pays no taxes (Jo et al., 2017).

Solar PV modeling tools have significantly improved in just the time since the Jo et al. (2017) study. They now incorporate the base NREL model but can also calculate the installation cost and the cost per kWh of generated electricity. Some tools even have GPS capabilities whereby the proposed solar solution can be shown on a map of the project site's rooftop. This function eliminates the need for a preliminary site visit before an estimate is produced (Aurora Solar, 2022).

Proposed Solar PV System Design

The model chosen for the feasibility study of this proposed solar PV solution was the Aurora Solar® design system. The company uses LiDAR technology, which stands for "light detection and ranging," to determine solar and shade exposure. Their computer-aided design or CAD system can simulate the essential components required on the roof of the proposed site using GPS maps. In addition, the company's proprietary AI software can generate a 3D version of the system design with just a location address and the corresponding electric utility bills (Aurora Solar, 2022).

The campus facility chosen for this study is a 3-story, 21,000 ft. sq. academic building. The selection was based upon certain factors such as: (1) Roof position relative to the daily movement of the sun (a south-facing roof is preferable); (2) Age of the building (older buildings are less efficient and could benefit from solar power generation); and (3) A separate electric utility meter (some university buildings share a common one, and determining split consumption would be hard).

The average power consumption for this facility in 2022 was approximately 10,200 kWh per month. The targeted electricity production of the solar PV system for this building was 80% of current consumption, annualized. However, 100% power production is not possible with a solar PV system due to the limitations of sunlight. Furthermore, achieving total solar power usage coverage would be difficult even with battery backup, which was not planned. Therefore, the cost vs. benefits of installing this solar PV system was determined by comparing the cost of power per kWh generated by the installation vs. the current and projected cost of utility-provided power.

The Aurora Solar model's proposed design for this building would be a 63 kW (DC) system utilizing (140) solar panels with (36) power inverters spread across the south-facing roof. The initial installed cost would be approximately $185,850. In addition, the subject institution can avail itself of the 30% federal investment tax credit for solar energy, which was part of the Inflation Reduction Act passed in August 2022 (*Homeowner's Guide to the Federal Tax Credit for Solar Photovoltaics*, n.d.). Applying the credit reduces the initial outlay for the project to $130,095.

Thus, the resulting system would generate electric power at a rate of $0.052/kWh vs. the current utility rate of $0.072/kWh being charged. Beyond that, additional cost savings can be achieved by eliminating utility fuel surcharges. Regulated electric utilities can charge a fee for the fuel they use to generate power. The university's electricity provider has a combination of natural gas-fired power plants and wind farms. The resulting present fuel charge is $0.05/kWh. When added to the $0.072/kWh, the actual present-day per kWh cost of electricity from the local provider equates to $0.122, +$0.07/kWh higher than the solar-powered generation. For this specific application, the calculated payout period was 11.6 years, after which 100% savings would be recognized.

In addition, power prices do not remain constant, while the cost of electricity generated by solar PV systems does. Jo et al. (2017) used a 2% escalator to forecast the possible increases in the price of utility-provided power. But, according to the US Federal Reserve Bank, actual inflation over the past (10) years has averaged 2.5% and has risen to 3.7% over just the past (5) years (*Consumer Price Index, 1913- | Federal Reserve Bank of Minneapolis*, n.d.). Using either of these measures as an escalator for power prices indicates that they will increase. Furthermore, the price of fuel, such as natural gas, varies widely and could rise over time. Finally, no ongoing fees or improvements are necessary after the initial cost of the solar equipment.

This sustainable initiative, as modeled, represents cost savings to the university on its face. However, the multiple ancillary benefits mentioned earlier in this study add more value to this investment. The issue for decision-makers is deploying the initial capital while recouping savings over time. Again, the key stakeholders in the survey expressed concerns about new financial expenditures and may be reluctant to make the investment despite both tangible and intangible gains.

DISCUSSION

This study undertook an examination of the feasibility of the implementation of a sustainable energy initiative at a Midwestern university while ascertaining key stakeholder understanding of sustainable development and a sustainable university as well as, gauging support for the proposed sustainable initiative. There are three key findings that were contextualized with this research. First, the quantitative economic modeling illustrated the potential savings for this institution that could result from the installation of a solar PV system on a specific campus building. Secondly, the analysis of the qualitative data indicated varied understanding of sustainable development and a sustainable university, Participants defined SD using terms associated with environmental conservation, financial stability, and green infrastructure. And a sustainable university was perceived as one that remains viable for decades to come, utilizes renewable energy, considers sustainability in future buildings, and includes the greater community in its sustainable efforts.

The first research question evaluated the cost/benefit of implementing a sustainable initiative at a private, Midwestern university. The modeled estimated cost per kWh of electricity to be generated by the proposed solar PV system was less than the current cost per kWh charged by the university's local electric utility. The power price and generation fuel escalator used indicated increased future savings as well. The second research question assessed the perceptions of key stakeholders regarding a specific sustainable initiative. While the definitions of sustainable development and a sustainable university varied among Participants, sustainable initiatives were viewed in the most basic economic terms, benefits must exceed costs.

Sustainability in higher education (SHE) has become more important in just the past few years. As universities seek to lower operating costs while improving their environmental footprint, sustainable energy resources have become an area of increased interest. Prior qualitative studies have focused on the belief systems held by university stakeholders regarding sustainable development and the concept of a sustainable university.

In 2010, Wright found that university presidents overwhelmingly associated sustainable development with protecting the environment (Wright, 2010). In a subsequent study of a wider group of university stakeholders in 2013, Wright & Horst found that 100% of interviewees associated sustainable development with environmental issues (Wright & Horst, 2013). The researchers also found that almost half of their respondents associated sustainability with the use of resources as well.

The findings gathered from this research study illustrated that little has changed in the perception of what constitutes sustainable development. For example, one interviewee's definition of sustainable development was along the lines of the meaning of sustainability as presented by the United Nations Brundtland Commission in 1987, which stated it as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (Hooey et al., 2017, pp. 280-281).

As to the concept of a sustainable university, Djordjevic and Cotton (2011) found that one of the most common barriers to sustainability in higher education was a lack of agreement on the meaning of the term itself. Reviewing the answers to this same question posed in this study, differences in the definition remain. Helmer (2017) saw one of higher education's missions as contributing to society, and sustainable development requires a link between higher education and the community. Purcell et al. (2019) contended that universities could do more to achieve sustainable development goals (SDG). They suggest HEIs can be "engines of societal transformation" because they significantly educate the larger community and deliver innovation (Purcell et al., 2019, p. 1343).

Participants echoed some of the same sentiments about assisting the local community in sustainable development and pursuing research in the field. Interestingly, however, not one person interviewed voiced the idea of sustainability as part of the curriculum. Hooey et al. (2017) advocated for creating integrated academic sustainability programs. Purcell et al. (2019) contended that universities could do more to achieve sustainable development goals (SDG). They suggested that HEIs can be "engines of societal transformation" because they significantly educate the larger community and deliver innovation (Purcell et al., 2019, p. 1343). And Filho et al. (2018) posited that HEIs can initiate sustainability concepts and put them into practice across different areas such as curricula, research, facilities & campus operations, and community outreach. Finally, Wright and Horst (2013) interviewees contended that educating students about sustainability would raise awareness while preparing future leaders to take on these issues.

Purcell et al. (2019) suggested that by utilizing a university's facilities and engaging faculty, staff, and students, HEIs can create "living labs" for sustainable development that incorporate the various stakeholders (Purcell et al., 2019, p. 1345). And many colleges and universities have responded by creating or initiating environmental research, integrating sustainability in curriculum and operations, and building green facilities (Mossman, 2018).

In explaining their views on what constitutes a sustainable university, none of the participants in this study emphasized the need to pursue green methods with new campus construction or modify existing structures to become more energy efficient. This concept was stated by 15 of 17 participants in the Wright (2010) study. However, in the follow-up 2013 study, none of the 32 interviewed mentioned green initiatives or the use of alternative/renewable energy as part of a sustainable university, aligning with the results presented herein (Wright & Horst, 2013).

As expressed by the stakeholder interviews, the barriers to implementing sustainable initiatives focused mainly on the costs, and those concerns are supported by previous studies. Chui (2020) emphasized financial sustainability as the underpinning for a sustainable campus. Mossman (2018), while asserting that higher education institutions should be at the center of research and education in sustainable initiatives, admitted that economic reasons may stand in the way. Filho et al. (2018) saw that the "most significant barrier was budget restrictions in part due to a lack of knowledge about how green initiatives can minimize costs, followed by institutional reluctance to change the barriers" (Filho et al., 2018, p. 1). Furthermore, those researchers found a desire for a quick return on capital expended as preferable to a long-term investment such as sustainable energy initiatives (Filho et al., 2018). In the Wright and Horst (2013) study, "the greatest perceived barrier…was the financial costs associated with new initiatives" (Wright & Horst, 2013, p. 220).

Previous quantitative studies have delved into the feasibility of alternative and renewable energy infrastructure additions to college campuses. In most cases, more complex evaluation tools and financial models were utilized (Jo et al., 2017).

However, the evolution of technology in analyzing the costs/benefits of solar PV systems now allows for a reduced timeframe in which to design and estimate project costs and comparative savings. One such model has been presented here, and its use resulted in a finding that the proposed renewable energy project would be cost-effective.

Limitations

There are several limitations to this study. First, the qualitative survey was conducted using a minimal sample size of seven key stakeholders who were only asked six questions. As a result, that may limit the transferability of the findings. However, this should not diminish the importance of the opinions expressed by the participants, as those were found to be relevant based on prior literature on the topics.

The feasibility study in the quantitative analysis was accurate for this university's specific building, which may not be valid for its other facilities. Additionally, the cost of electricity provided by a university's local utility will vary with location. The study institute is in a state with about the 10th-lowest commercial electricity rates in the country.

Implications for Practice

As higher education institutions (HEI) grapple with declining enrollments and the inflationary impacts on operations, there is a need to explore ways to achieve financial sustainability through cost-savings efforts. HEIs are also expected to be leaders in areas such as protecting the environment, sustainable development, and using sustainable resources, including energy. Solar PV infrastructure may provide an avenue to reduce a university's overall utility expenses while, at the same time, utilizing a sustainable energy resource. Additionally, the institution will lower its carbon footprint and provide working labs for the faculty and students.

The solar design model used in this study validated the benefits that renewable energy can provide on campuses of institutions of higher education. The tool utilized in this research can be applied to any setting and at any university. In addition, its simplistic process creates quick results from which to evaluate the cost/benefit of adding this form of renewable energy. Establishing the thoughts, opinions, and level of support for sustainable development in higher education is essential before proceeding with proposals for new expenditures involving sustainable energy sources. This study illustrated the diverse levels of understanding that can be present among key university stakeholders and decision-makers. A lack of knowledge regarding sustainable development, a sustainable university and sustainable energy sources could hamper efforts by HEIs to enhance their financial and environmental sustainability.

Despite the sample size, the qualitative approach used here provided additional context into this subject for this particular institution. That, in turn, allowed for conjecture as to whether or not crucial decision-makers would approve a proven-to-be feasible renewable energy project.

As evidenced by study findings, higher education institutions need to incorporate more sustainability learning into their curricula, mission, and day-to-day operations. For many of the interviewees, there was a lack of a consistent and detailed definition of sustainable development and a sustainable university, and no thoughts were expressed regarding sustainability education.

CONCLUSION

This mixed-methods case study approach combined elements of prior studies, namely, qualitative studies on sustainable development and sustainable universities, coupled with feasibility studies evaluating the cost/benefit of renewable energy projects on HEI campuses. The findings illustrate that solar PV systems can be readily assessed with current modeling software and can prove cost-effective depending on the university's electric utility charges. However, for proposed renewable energy projects that are not self-sustainable from a profit standpoint, key stakeholders need to evaluate the intangible benefits associated with green energy endeavors before arriving at a final decision as to whether or to approve these projects.

Based upon the results of this study alone, knowledge regarding sustainability and sustainable initiatives needs to be more prevalent at colleges and universities if financial and environmental sustainability is to be achieved. For institutions of higher learning that contemplate utilizing solar PV, this work will provide a method of establishing stakeholder support (qualitative) and a cost/benefit model for the system itself (quantitative).

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