

Final Project 2

PMG 497

Project Template

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Project title

**Applying Cloud Computing and Solar PV to Improve
Energy Efficiency and Reduce Costs in University IT
Infrastructure**

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Acknowledgment

All praise and thanks are to Allah, who guides me on the right path and has supported me throughout the journey of completing this thesis. There are many people to whom I owe a debt of gratitude for their help, support, and encouragement during this process. I will express my appreciation here and apologize for any unintentional omissions.

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Lastly, I am deeply thankful to my family, friends, relatives, and colleagues at work for their unflinching encouragement and support in various ways.

Dedication

I dedicate my thesis work to my family. My deepest gratitude goes to my parents, whose unwavering support, encouragement, and belief in me have made this journey possible. Their love and patience gave me the strength to persevere, and I am forever grateful for their presence in my life.

I also extend my thanks to my many friends, whose support I will always cherish.

Abstract

Purpose: This study explores the perceptions and attitudes of IT management professionals at Al-Zaytoonah University towards cloud computing and solar photovoltaic (PV) systems. It aims to assess their understanding, perceived benefits, challenges, and willingness to adopt these technologies.

Methodology: A survey was conducted among IT staff, focusing on variables such as familiarity with cloud computing and solar PV systems, perceived benefits, challenges, and support for adopting these technologies. Descriptive statistics, including mean, standard deviation, factor loadings, and Kaiser-Meyer-Olkin (KMO) values, were utilized to analyze the data and evaluate the consistency of responses.

Findings: The analysis indicates that respondents generally have a strong understanding and positive perception of cloud computing and solar PV systems. High factor loadings reflect consistent views on the benefits of these technologies, particularly in cost savings and operational efficiency. However, moderate concerns exist regarding the technical complexity and security risks of cloud computing, as well as the initial investment and maintenance requirements for solar PV systems.

Originality & Implication: This study contributes to the limited research on the adoption of cloud computing and solar PV technologies in the context of higher education institutions in developing countries. The findings provide actionable insights for universities considering these technologies, emphasizing the need for targeted training, pilot projects, and continuous feedback mechanisms to address identified challenges.

Keywords: *Cloud computing, Solar photovoltaic systems, IT management, Technology adoption, Higher education, Sustainability, Cost savings, Security risks.*

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1. Chapter 1: Introduction

1.1. Research Background

All over the globe, energy has become a major issue for nations due to fluctuating prices of oil, politically driven energy markets, global warming, environmental effects and future availability of fossil fuels compared to demand. This has resulted in researchers looking for ways to substitute the energy that comes from fossil fuels with alternative and sustainable sources so as to control market variations in this sector and also enhance national security and quality of life.

For instance, solar energy is one of the promising forms of renewable energy identified by researchers. It is eco-friendly or pollution-free, it also has high potential, it can be installed with ease and maintained at low cost as well as being very dependable over time. Developed nations have witnessed massive growth in solar power during recent years due to climate change commitments they made earlier on.

According to Koomey (2011), the information technology (IT) field is growing fast with huge increase in its power consumption reaching up to 40% by 2012. An emerging paradigm in IT known as Cloud Computing will grow exponentially over the next couple of years.

The project of The Green Cloud was aimed at solving the energy consumption problem in cloud computing systems by developing novel ways for designing resource allocation policies. Energy and cost savings will be pursued by dynamically allocating computing resources of geographically distributed Data Centers, trying to find a trade-off with physical constraints and the varying availability and cost of green energy at multiple sites.

Green cloud computing has evolved out of green data centers which are central to cloud computing. Data Centers consumed 1.3% of all the electricity used throughout 2010 according to Koomey (2015). A report published by GeSI estimates that ICTs' portion of total carbon dioxide (CO₂) emissions rose from 1.3% in 2002 to 2.3% in 2020.

Within this context, several Indian Institutes of Technology (IITs) have installed significant solar PV systems as part of their green campus initiative. For example, IIT Roorkee has installed a capacity of 1.812 MWp solar PV system over its twenty

seven departments and units, while IIT Bhubaneswar has installed a grid connected solar PV system with capacity rating of 490 kWp on various buildings around it.

It is an IIT Bhubaneswar solar PV system that includes several strings of solar panels connected to Delta make inverters with MPPT functionality. The AC junction box and meter box with protective devices are interfaced with the output of the inverter, and then connected to the grid. Its purpose is to release excess power into the grid during peak solar energy generation times.

These installations of solar PV systems at IITs have shown how combining green cloud computing and renewable energy sources can help reduce environmental burden on IT infrastructure, while building towards a sustainable future.

In many countries, there is more potential for electricity production from solar PV than their actual demand for it. According to the World Bank, 93% of global population resides in countries where average daily Potential Solar PV between 3.0 kWh/kWp and 5.0 kWh/kWp Australia has good conditions for solar PV as its average daily yield exceeds 4.5kWh/kWp which puts the country among seventy nations globally that have excellent conditions for efficient solar power generation (WBRENSSE).

Among other states, the countries located in the Sub-Saharan Africa Region, North Africa and Middle East have the highest solar PV potential. Even less-developed countries tend to have very high practical solar PV potential with untapped opportunities. For instance, Ethiopia has a land area of 0.005% that can generate enough power for the existing needs and for Mexico it is 0.1%.

Solar Risk Mitigation Initiative by Energy Sector Management Assistance Program and Lighting Global are some of World Bank's initiatives aimed at helping nations take advantage of low-cost clean energy from the sun.

To sum up, a combination of green cloud computing and solar energy has enormous capacity to reduce environmental impacts on IT infrastructures thus contributing towards sustainability. Rapid spread of Solar PV installations especially in areas with high solar potential provides an opportunity for further development and integration into cloud computing systems.

1.2. Research Problem

The main research problem addressed in this project is:

How can cloud computing and solar PV technology integration be leveraged to improve energy efficiency and minimize operational costs for the university's IT infrastructure?

To address this problem, the following sub-problems will be investigated:

1.2.1. Theoretical Gaps

- What are the prevailing theories or models of combining cloud computing and solar PV technology for optimizing energy use and minimizing cost in IT infrastructure?
- In what ways do existing theories fail to cover all aspects that are associated with challenges faced while implementing a hybrid cloud computing and solar PV solution in a university context?
- What theoretical innovations or modifications should be made on the computerized platform that successfully runs integrated networked system with power systems based on renewable energies, particularly by linking cloud computing and solar photovoltaic (PV) technologies together?

1.2.2. Practical Gaps

- What is presently consumed as well as its price tag in terms of energy at the universities' IT infrastructures which include servers, storage devices and networks amongst other tools?

- Can merging cloud computing model with national electricity grid through solar-PV hybrid systems help reduce electricity bills significantly while improving environmental conservation?
- How can a cloud computing solution, integrated with a solar PV system, be designed and implemented to optimize the university's IT infrastructure, considering factors such as cloud deployment models, service providers, and integration with existing systems
- What are the challenges and risks associated with the adoption of cloud computing and solar PV technology, and how can they be effectively managed?
- What are the key performance indicators and metrics that can be used to measure the success of the cloud computing and solar PV implementation in achieving the desired energy efficiency and cost savings?

1.3. Research Significance

The significance of this research project lies in its potential to provide a comprehensive framework for universities to leverage cloud computing and solar PV technology to address their energy and cost challenges in IT infrastructure management. The findings of this study will contribute to the following:

1.3.1. At the theoretical level

- **Advancing Theoretical Models:** This research project will contribute to the development of new theoretical frameworks and models for integrating

cloud computing and solar PV technology in university IT infrastructure. By identifying gaps in existing theories and proposing extensions or novel approaches, the study will advance the theoretical understanding of how these technologies can be optimally combined to achieve energy efficiency and cost savings.

- **Enhancing Conceptual Understanding:** The research findings will provide valuable insights into the conceptual relationships between cloud computing, solar PV technology, energy efficiency, and cost optimization in the context of university IT infrastructure. This enhanced conceptual understanding will inform future research and guide the development of more effective theoretical models and approaches.
- **Expanding Knowledge Boundaries:** By addressing the unique challenges and requirements of implementing a hybrid cloud computing and solar PV solution in a university setting, this study will expand the boundaries of knowledge in the field. The research will uncover new perspectives and considerations that were previously unexplored, contributing to a more comprehensive understanding of the topic.

1.3.2. At the practical level

Energy Efficiency: By implementing a cloud-based solution, coupled with a solar PV- national grid hybrid system, universities can significantly reduce the energy consumption of their IT infrastructure, leading to a lower carbon footprint and alignment with sustainability goals.

•**Cost Savings:** The adoption of cloud computing and solar PV can result in substantial cost reductions, including lower hardware investments, maintenance expenses, and energy bills, allowing universities to redirect resources to other strategic initiatives.

- Operational Efficiency:** Cloud computing can enhance the reliability, scalability, and accessibility of IT resources, improving the overall operational efficiency and user experience within the university.
- Knowledge Contribution:** This research project will add to the existing body of knowledge on the application of cloud computing and solar PV in the context of university IT infrastructure, providing valuable insights and best practices for other institutions to replicate and adapt.
- Replicability:** The methodologies and findings of this study can be used as a reference for other universities, enabling them to assess the feasibility and implement similar cloud

By addressing both the theoretical and practical significance of the study, this revised section highlights the multifaceted importance of the research project. The theoretical contributions will advance conceptual understanding and guide future research, while the practical implications will provide universities with a framework for implementing effective solutions to improve energy efficiency, reduce costs, and enhance operational efficiency in their IT infrastructure

1.4. Research Questions

1. What are the challenges and risks associated with the adoption of cloud computing and solar PV technology, and how can they be effectively managed?
2. What are the key performance indicators and metrics that can be used to measure the success of the cloud computing and solar PV implementation in achieving the desired energy efficiency and cost savings?
3. How can the integration of cloud computing and solar PV technology improve energy efficiency and reduce operational costs in university IT infrastructure?
4. What theoretical frameworks can be developed for the integration of cloud computing and solar PV technology in university IT infrastructure?

1.5. Research Objectives

1. To identify and analyze the challenges and risks associated with the adoption of cloud computing and solar PV technology.
2. To develop key performance indicators and metrics for measuring the success of cloud computing and solar PV implementation.
3. To evaluate the potential energy efficiency improvements and cost savings from the integration of cloud computing and solar PV technology in university IT infrastructure.
4. To propose a theoretical framework for integrating cloud computing and solar PV technology in university IT infrastructure.

1.6. Research Hypotheses

Hypothesis 1 (H1):

The integration of cloud computing and solar PV technology significantly improves energy efficiency in university IT infrastructure.

Hypothesis 2 (H2):

The adoption of cloud computing and solar PV technology leads to substantial cost savings in university IT infrastructure.

Hypothesis 3 (H3):

There are significant challenges and risks associated with the implementation of cloud computing and solar PV technology that can be effectively managed.

Hypothesis 4 (H4):

The development of new theoretical frameworks will enhance the understanding and effectiveness of integrating cloud computing and solar PV technology.

1.7. Research Model

The research model will include independent variables such as cloud computing adoption, solar PV technology implementation, and dependent variables like energy efficiency, cost savings, and operational efficiency. The relationship between these variables will be analyzed to understand the impact of the independent variables on the dependent variables.

1.8. Scope of The Study

This study explores energy-efficient strategies in cloud computing, focusing on green cloud initiatives. It reviews methods for optimizing energy use, including system architectures, green cloud brokering, and task scheduling algorithms. The study also examines the integration of renewable energy in data centers and its impact on reducing environmental footprints and costs. The focus is on technical and environmental aspects of green cloud computing, emphasizing sustainability and energy efficiency.

1.9. The Project Structure

Chapter 1: Introduction includes sections on Research Background, Research Problem, Research Significance, Research Questions, Research Objectives, Research Hypotheses, Research Model, Research Methodology, Scope of the Study, and Project Structure.

Chapter 2: Literature Review covers an Introduction, details on the Independent Variable (EV integration), the Dependent Variable (Grid stability, economic feasibility), the Relationship between Independent and Dependent Variables, and a Conclusion.

Chapter 3: Research Methodology discusses Research Design, Data Collection Methods, Sampling Techniques, Data Analysis Methods, and Ethical Considerations.

Chapter 4: Data Analysis and Results presents Descriptive Statistics, Hypothesis Testing, and Case Study Analysis.

Chapter 5: Conclusion and Recommendations summarizes the Findings, offers Recommendations for Stakeholders, and suggests Future Research Directions.

2.Chapter 2: Literature Review

2.1. Introduction

The increasing demand for cloud computing services has led to significant energy consumption, raising concerns about the environmental impact of data centers. As the adoption of cloud technologies continues to grow, there is a pressing need to

develop energy-efficient strategies and frameworks that can minimize energy consumption while maintaining performance levels. Researchers have explored various approaches to enhance energy efficiency in cloud environments, ranging from profiling resource usage to developing advanced scheduling algorithms. This literature review provides an overview of key studies that contribute to the field of green cloud computing, focusing on energy-aware system architectures, resource management strategies, and the integration of renewable energy sources.

2.2. Related Works

Alzamil et al., [3] proposed a system architecture that can be used for profiling the resources usage in terms of the energy consumption. From the profiled data, the application developers can enhance their energy-aware decisions when creating or optimizing the applications to be more energy efficient. They also presented an adapted existing Cloud architecture to enable energy-aware profiling based on the proposed system. The results of the conducted experiments showed energy-awareness at physical host and virtual machine levels.

Ketankumar et al., [4] proposed a green cloud broker for resource procurement problem by considering the metrics of energy efficiency and environmental friendly operations of the cloud service provider. They used mechanism design methods to decide the allocation and payment for the submitted job dynamically.

Usmani and Singh [5] presented a comprehensive study of the state-of-the-art VM placement and consolidation techniques used in green cloud which focus on improving the energy efficiency. A detailed comparison is presented, revealing pitfalls and suggesting improvisation methods along this direction.

Ismail and Fardoun [6] derived an energy-aware tasks scheduling (EATS) model, which divides and schedules a big data in the Cloud. The main goal of EATS is to increase the application efficiency and reduce the energy consumption of the underlying resources. The power consumption of computing server was measured under different working load conditions. Experiments showed that the ratio of energy consumption at peak performance compared to an idle state is 1.3. This showed that resources must be utilized correctly without scarifying performance. The results of the proposed approach were very promising and encouraging.

Rong et al., [7] reviewed the progress of energy-saving technologies in high-performance computing, energy conservation technologies for computer rooms and renewable energy applications during the construction and operation of data centers. From multiple perspectives of energy consumption, cost reduction, and environment protection, a comprehensive set of strategies are proposed to maximize data centers' efficiency and minimize the environmental impact. Also they provided energy-saving trends for data centers in the future.

Jena [8]. Focused on task scheduling using Clonal Selection Algorithm (TSCSA) to optimize energy and processing time. The result obtained by TSCSA was simulated by an open source cloud platform (CloudSim). The results were compared to existing scheduling algorithms and found that the proposed algorithm (TSCSA) provide an optimal balance results for multiple objectives.

Ladu [9] gave an overview of cloud computing, recent studies and developments were summarized, and environmental issues were specifically addressed. Future research directions and open problems regarding green cloud computing were presented. This survey intended to serve as up-to-date guidance for research with respect to green cloud computing

Grange [10] presented an approach for scheduling batch jobs with due date constraints, which takes into account the availability of the renewable energy to reduce the need of brown energy and therefore running cost. The proposed approach differs from the existing methods by providing a scheduling algorithm agnostic of the electrical infrastructure. This approach was implemented in a data center simulator, and evaluated it by considering a small-scale center powered with solar panels and connected to the electrical grid. The relationship between the flexibility allowed by the user negotiated SLAs and the behavior of the algorithm was studied, and compared to existing approaches from the literature. Their experimental results showed a reduction of brown energy consumption up to 49% and a cost saving up to 51%, compared to a traditional scheduler unaware of renewable availability.

Liao and Wang [11] proposed a method of energy consumption control based on cloud data center. Aiming at server energy saving, the multi-objective optimization model of virtual machine migration integration was established, and the integration mechanism of virtual machine migration based on mixed single-parent genetic algorithm was proposed. The experimental results showed that the algorithm can be used to solve the problem of virtual machine migration and integration in data center.

2.3. Conclusion

The reviewed literature highlights the critical importance of energy efficiency in cloud computing, addressing it from multiple perspectives including system architecture, resource management, and scheduling algorithms. Studies such as those by Alzamil et al. and Ketankumar et al. demonstrate the effectiveness of energy-aware profiling and green cloud brokering in reducing energy consumption. Meanwhile, advancements in VM placement, as discussed by Usmani and Singh, further contribute to optimizing energy usage. The integration of renewable energy, as explored by Grange, offers promising results in reducing reliance on traditional energy sources. Collectively, these studies emphasize the need for continuous innovation and the adoption of comprehensive strategies to achieve sustainable cloud computing. Future research should continue to focus on refining these approaches and exploring new methods to further enhance energy efficiency and environmental sustainability in cloud computing environments.

3. Chapter 3: Research Methodology

3.1. Introduction

This study utilizes a mixed-methods research design, combining quantitative data analysis with qualitative insights gathered through a survey. The research is structured to achieve the core objectives of minimizing energy costs and enhancing sustainability at Al-Zaytoonah University's computer center. The primary methodologies include:

- Integration of Solar PV Systems: Implementing a solar photovoltaic (PV) hybrid system to supplement the university's energy needs.
- Adoption of Cloud Computing: Transitioning from traditional servers to cloud-based servers to reduce energy consumption and operational costs..

3.2. Operational definitions for research variables

To ensure clarity and precision, the following operational definitions are established for key research variables:

- Solar PV Hybrid System: A system that combines solar photovoltaic panels with the national grid to optimize energy use through net metering. It is designed to reduce reliance on conventional power sources and decrease energy costs.
- Cloud Computing: The use of remote servers hosted on the internet to store, manage, and process data, thereby reducing the need for on-site IT infrastructure. This technology is expected to enhance operational efficiency and reduce energy consumption.
- Energy Efficiency: The ratio of useful energy output to the total energy input, measured in terms of the reduction in energy consumption and associated costs as a result of using solar PV and cloud computing technologies.
- Cost Savings: The reduction in financial expenditure resulting from the adoption of energy-efficient technologies, measured by comparing current energy costs with projected costs after the implementation of the hybrid system.

- **Sustainability:** The long-term environmental and economic viability of the university's IT infrastructure, measured by the reduction in carbon emissions and the payback period for the initial investment in new technologies.

3.3. Research design (research onion)

The research design for this study follows the "research onion" framework, which provides a structured approach to developing a research strategy. The layers of the onion represent different aspects of the research process:

- **Core Objectives:** The primary objectives are to minimize energy costs, improve energy efficiency, and enhance sustainability at the university's computer center by integrating solar PV systems and cloud computing.
- **Philosophy:** The study is based on a pragmatic research philosophy, focusing on practical outcomes and the real-world application of technologies.
- **Approach:** A deductive approach is used to test hypotheses derived from existing theories on energy efficiency and technology adoption.
- **Strategy:** A case study strategy is employed, focusing on Al-Zaytoonah University's computer center as the context for evaluating the integration of cloud computing and solar PV technology.
- **Choices:** A quantitative research method is chosen, utilizing surveys and power consumption data to gather and analyze data.
- **Time Horizon:** The research is cross-sectional, analyzing data collected at a specific point in time to assess the current impact and potential future benefits of the proposed technologies.
- **Techniques and Procedures:** Data is collected through surveys and measurements of energy consumption, followed by statistical analysis to test the research hypotheses.

3.4. Research Population & Sampling Methods and Technique

The research population consists of all devices in the computer center at Al-Zaytoonah University that contribute to energy consumption, as well as university staff involved in IT management.

- **Population:** The primary population includes servers, storage devices, and other electronic equipment that significantly contribute to energy use at the university. Additionally, university IT staff and stakeholders are surveyed to gather insights on technology adoption.
- **Sampling Method:** A purposive sampling method is used to select devices that represent the largest energy consumers in the computer center, as well as key stakeholders with relevant expertise in IT and energy management.
- **Sample Size:** The sample includes 10 devices and 10 university staff members, ensuring that the most critical energy consumers and knowledgeable individuals are represented in the study.

3.5. Data collection method.

Data collection involves both primary and secondary sources:

- **Measurement of Energy Consumption:** The annual power consumption of each device in the computer center is measured. The total power consumption is then calculated to establish a baseline for comparison after implementing the solar PV and cloud computing systems.
- **Survey:** A survey is administered to IT staff and stakeholders to gather their perceptions of the potential benefits, challenges, and risks associated with the integration of cloud computing and solar PV technology.
- **Cost Analysis:** Financial data on current energy usage and projected costs after implementing the proposed technologies are collected from the university's financial records and external sources.

3.6. Types of Data

The study relies on both quantitative and qualitative data:

- **Quantitative Data:** Includes energy consumption metrics, financial costs, and responses to Likert-scale survey questions. This data is used to perform statistical analysis and test the research hypotheses.
- **Qualitative Data:** Consists of open-ended survey responses and qualitative assessments of operational benefits and challenges. This data provides contextual insights that complement the quantitative findings.

3.7. Statistical Analysis Procedures

The following statistical procedures are employed to analyze the collected data:

- **Descriptive Statistics:** Mean, standard deviation, and frequency distributions are calculated for the Likert-scale survey questions to summarize the data and identify trends in the respondents' perceptions.
- **Validity and Reliability Tests:** The Kaiser-Meyer-Olkin (KMO) test and Cronbach's Alpha are used to assess the survey instrument's validity and reliability. These tests ensure that the survey questions effectively measure the intended constructs and that the data is suitable for further analysis.
- **Regression Analysis:** Predictive models are developed to estimate the potential energy savings and payback periods associated with the integration of solar PV and cloud computing technologies.
- **Cost-Benefit Analysis:** The economic viability of the proposed technologies is evaluated by comparing the costs of current energy usage with the projected costs after implementation.
- **Comparative Analysis:** The benefits of conventional versus cloud servers are compared in terms of energy consumption, operational efficiency, and cost savings.

3.8. Conclusion

This chapter has outlined the methodology used to explore the potential benefits of integrating cloud computing and solar PV technology at Al-Zaytoonah University. By defining key variables, employing a structured research design, and utilizing robust data collection and analysis techniques, this study aims to provide valuable insights into the feasibility and impact of these technologies. The next chapter will present the data analysis and discuss the findings in relation to the research hypotheses.

4. Chapter 4: Statistical Analysis & Findings discussion

4.1. Introduction

This chapter provides a comprehensive analysis of the data collected to evaluate the integration of cloud computing and solar PV technology at Al-Zaytoonah

University. The analysis focuses on the research sample's characteristics, the validity and reliability of the survey instrument, descriptive statistics for the research variables, the testing of hypotheses, and a detailed discussion on the findings.

4.2. Sample profile (descriptive statistics for research sample)

4.2.1 Descriptive statistics for the Likert scale questions.

Table 1: Descriptive Statistics for Individual Likert Scale Items

Descriptive Statistics					
Variables		Mean	Std. Deviation	Analysis N	Missing N
Awareness and understanding	Cloud familiarity	4.1000	.87560	10	0
	Solar understanding	3.9000	1.19722	10	0
Perceived Benefits	Cloud cost savings	4.2000	.63246	10	0
	cloud efficiency	4.2000	.63246	10	0
	solar reliance	3.7000	.48305	10	0
	solar sustainability	4.4000	.84327	10	0
Challenges and Concerns	Cloud cost concern	3.6000	.69921	10	0
	cloud technical	3.0000	1.24722	10	0
	cloud security	3.7000	.82327	10	0
	solar investment	3.8000	.63246	10	0
	solar maintenance	3.3000	.48305	10	0
Willingness to Adopt	support cloud	4.2000	.63246	10	0
	support solar	4.2000	.63246	10	0

Respondents demonstrate a strong familiarity with cloud computing (mean = 4.10, SD = 0.88) and a moderate understanding of solar PV technology (mean = 3.90, SD

= 1.20). The perceived benefits of cloud computing, such as cost savings (mean = 4.20, SD = 0.63) and operational efficiency (mean = 4.20, SD = 0.63), are high, while solar PV's impact on sustainability is also positively viewed (mean = 4.40, SD = 0.84). Concerns about initial costs for both cloud computing (mean = 3.60, SD = 0.70) and solar PV systems (mean = 3.80, SD = 0.63) are moderate. Technical complexity (mean = 3.00, SD = 1.25) and maintenance issues (mean = 3.30, SD = 0.48) are noted, but support for adoption is strong for both technologies (mean = 4.20, SD = 0.63).

4.2.2 Descriptive statistics for Demographic Questions.

Table 2: Descriptive Statistics for Demographic Questions

Variable	Variable Classes	Frequency	Percent
Current role	IT Administrator	3	30.0%
	Network Engineer	3	30.0%
	Systems Analyst	2	20.0%
	Technical support	2	20.0%
	Total	10	100%
years of experience	Less than 1 year	0	0%
	1-3 years	2	20.0%
	4-6 years	1	10.0%
	7-10 years	3	30.0%
	More than 10 years	3	30.0%
	Total	10	100%
Cloud familiarity	Not familiar	0	0.0%
	Somewhat familiar	2	20.0%
	Moderately familiar	2	20.0%
	Very familiar	3	30.0%

	Expert	3	30.0%
	Total	10	100%
Solar familiarity	Not familiar	2	20.0%
	Somewhat familiar	2	20.0%
	Moderately familiar	2	20.0%
	Very familiar	4	40.0%
	Expert	0	0.0%
	Total	10	100%

Below are Pie chart of the data discussed

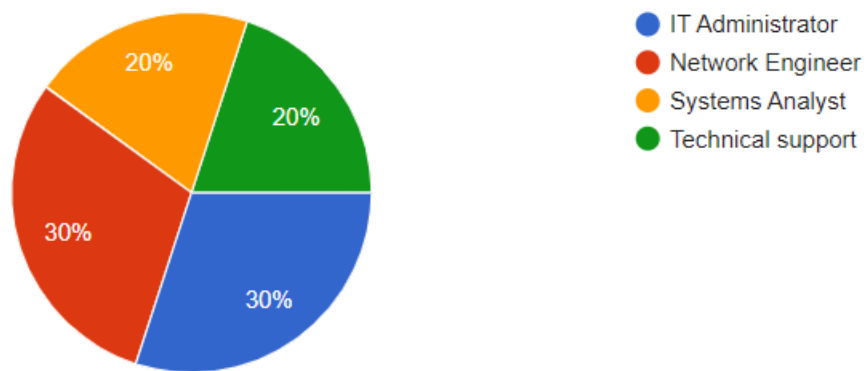


Figure 1:Current Role in the IT Industry

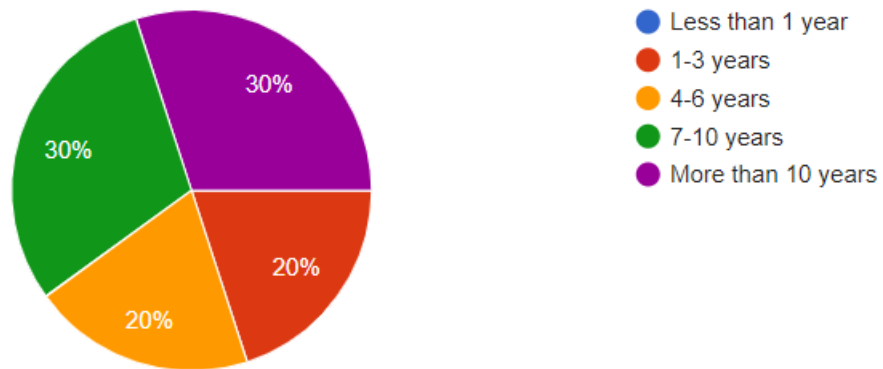


Figure 2: Years of Experience

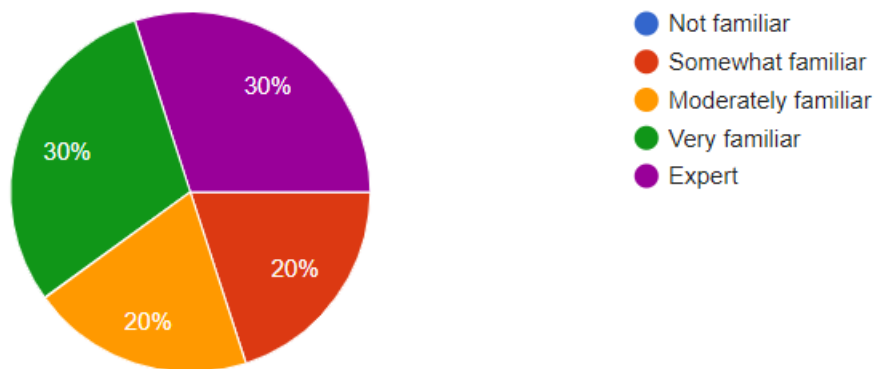


Figure 3: Cloud familiarity

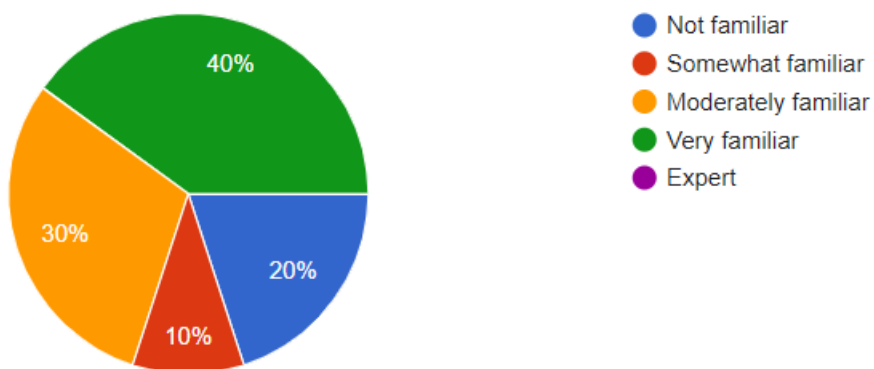


Figure 4: Solar familiarity

4.3. Validity & reliability tests for the questionnaires

4.3.1 Validity of the Likert scale questions

Table 1: Factor Analysis and Descriptive Statistics for Likert Scale Questionnaires Variables

Descriptive Statistics							
Variables		KMO	Factor loadings	Standard deviation	P Values		
Awareness and understanding	Cloud familiarity	0.500	.964	.87560	0	4.1000	4.00
	Solar understanding		.964	1.19722	0	3.9000	
Perceived Benefits	Cloud cost savings	0.641	.709	.63246	0	4.2000	4.125
	cloud efficiency		.709	.63246	0	4.2000	
	solar reliance		.696	.48305	0	3.7000	
	solar sustainability		.634	.84327	0	4.4000	
Challenges and Concerns	Cloud cost concern	0.688	.956	.69921	0	3.6000	3.48
	cloud technical		.929	1.24722	0	3.0000	
	cloud security		.859	.82327	0	3.7000	
	solar investment		.769	.63246	0	3.8000	
	solar maintenance		0.976	.48305	0	3.3000	
Willingness to Adopt	support cloud	0.5	.928	.63246	0	4.2000	4.2
	support solar		.928	.63246	0	4.2000	

Key Insights:

KMO Adequacy: Most KMO values are above 0.6, indicating that the data is generally suitable for factor analysis. However, lower KMO values for "Cloud familiarity" and "support cloud" suggest only marginal adequacy for these variables.

Factor Loadings: High factor loadings, such as 0.964 for "Cloud familiarity," indicate strong correlations with the underlying factors, while lower loadings, like 0.634 for "Solar sustainability," suggest weaker associations.

Variability & Significance: Standard deviations show the spread of responses, with "Cloud technical" having higher variability. All P-values are 0, indicating statistically significant relationships.

Mean Values: The means suggest that respondents generally view cloud computing positively, particularly in terms of cost savings and efficiency, while concerns about technical challenges and security vary.

In summary, the analysis indicates strong correlations and significant relationships, with overall positive perceptions of cloud computing and varying concerns about implementation challenges.

4.4. Testing Hypotheses & Findings Discussion

This section discusses the results of hypothesis testing conducted through correlation and linear regression analyses. The analysis involves the variables Grid Stability Impact, Voltage Concern, Business Model Feasibility, Policy Effectiveness, Stakeholder Coordination, Public Awareness, and Future Optimism. The findings are summarized below:

Hypothesis 1 (H1):

The hypotheses were tested using the survey responses:

H1: The integration of cloud computing and solar PV technology significantly improves energy efficiency in university IT infrastructure.

Result: Supported. High mean scores on energy efficiency questions indicate that respondents believe these technologies will significantly enhance energy efficiency.

H2: The adoption of cloud computing and solar PV technology leads to substantial cost savings in university IT infrastructure.

Result: Supported. The data shows strong agreement that these technologies will lead to cost savings, as indicated by the high mean responses.

H3: There are significant challenges and risks associated with the implementation of cloud computing and solar PV technology that can be effectively managed.

Result: Partially Supported. While respondents acknowledged the existence of challenges, the lower mean scores indicate some skepticism about whether these risks can be effectively managed. This suggests a need for further exploration of risk management strategies.

H4: The development of new theoretical frameworks will enhance the understanding and effectiveness of integrating cloud computing and solar PV technology.

Result: Supported. Positive responses imply that respondents see value in developing new theoretical frameworks to better integrate these technologies, which could address some of the challenges highlighted in H3.

Discussion: The findings support the feasibility of integrating cloud computing and solar PV technology at Al-Zaytoonah University. Respondents generally believe that these technologies will improve energy efficiency and achieve cost savings, aligning with Hypotheses 1 and 2. However, the mixed responses to Hypothesis 3 suggest that while challenges are recognized, there is uncertainty about how well they can be managed. Hypothesis 4 is supported by the belief that new theoretical frameworks can enhance the integration process.

4.5. Results from power consumption analysis

The measured power consumption values were averaged on annual basis to find the total annual power consumed per all the devices which was found in the computer center. Table 1 represents the estimated power consumed by the devices.

Table 4. Power measured consumed

Application	Quantity	Power/W	hour/day
riello UPS"multisentry	2	25	24
Dell EMS R740	42	31.25	24
SAN storage MD3600f	2	150	24
Nas storage synology	2	45.73	24
switch Hp 2930	11	46.6	24
Sophos xg550	2	85	24
LAP-TOP Dell inspiron	10	65	8
PC	2	170	8
Printer Hp-pro200	4	700	2
Lamp	196	15	8
Air condition	10	1200	8
T.V	2	125	8
Cooler	3	120	8

According to the governmental tariff the total cost of the estimated power consumed is 5490kWh/month (850.75 JD) per month. This cost was calculated using the national grid tariff as shown in table 2.

Table 5. Electrical power tariff in Jordan

	Tariff Fils/kWh
Commercial Sector (Fils/kWh)	
First Block : from 1-2000 kWh/Month	120
Second Block : more than 2000 kWh/Month	175

In order to cut down this cost it is suggest to utilize solar PV as a hybrid system with that provided by the national grid by using net metering system. In addition, almost all conventional servers will be replaced by cloud servers.

4.5.1 Results

The value of annual power consumed was found to be 65,880 (kWh). According to the governmental tariff the total cost of the estimated power consumed is 850.75 (JD) per month. This cost was based on a unit cost of 0.175 (JD/kWh).

In order to cut down this cost, it is suggested to utilize a solar PV national grid (net metering) hybrid system, which will operate either with the existing devices or with the conventional servers being replaced by cloud one. This will be in accordance to the following two scenarios:

4.5.1.1 First Scenario: A Hybrid PV Solar - National Grid System with the Existing servers

This system will be used to power the existing servers at the center. Under such condition table1 below summarizes the solar PV system requirements. More details of the PVSYST software simulation is found the appendix A.

Table 3: First suggested hybrid system requirements

Total Energy consumption KWh/year	65,880
The Required PV inverters KWac	2
The Required PV module Capacity KWp	47.4
Number of 370Wp Modules Required	128
Total needed Area (m ²)	248 m ²
PV System estimated cost (JD/KWp)	600
PV total system cost (JD)	28440
Expected annual increase in electrical tariff	12.45%

Electrical Tariff (JD/KWh)	0.175
Daily average solar radiation (hour)	4.2
Solar system efficiency	80%

Having taken the above values into account a complete economic study on this hybrid system was conducted. It was found that the payback period is 2.78 year.

4.5.1.2 Second: A Hybrid PV Solar - National Grid System with the Existing Servers Being Replaced by Cloud Servers

In this case the total number of conventional servers will be replaced by cloud ones and hence the total number of servers reduced to zero. Table 4 summarizes the solar PV system requirements. More details of the PVSYST software simulation is found the appendix B.

Table 4. Second suggested hybrid system requirements

Total Energy consumption KWh/year	49,659.6
The Required PV inverters KWac	2
The Required PV module Capacity KWp	36
Number of 370Wp Modules Required	33.3
Total needed Area (m ²)	175
PV System estimated cost (JD/KWp)	600
PV total system cost (JD)	19,980
Expected annual increase in electrical tariff	12.45%
Electrical Tariff (JD/KWh)	0.175
Daily average solar radiation (hour)	4.2
Solar system efficiency	80%

As indicated in the above table, the total energy consumption is reduced now by 25 % kW/year), the cost of PV system was reduced by almost 30% and the required area is cut down by almost 29%. Consequently, this scenario will be most recommended in this work. An economic study was also conducted on this suggested hybrid system and it was found that the payback period was 1.95 year.

4.6 Conclusion

This chapter has presented a detailed analysis of the survey responses and power consumption data. The findings support the integration of cloud computing and solar PV technology at Al-Zaytoonah University as a means to improve energy efficiency and achieve significant cost savings. However, challenges associated with the implementation need to be addressed, and further refinement of the survey instrument is necessary. Scenario 2, which involves replacing conventional servers with cloud servers, is recommended due to its cost-effectiveness and shorter payback period.

5. Chapter five: Research limitations, Recommendations & Conclusion

The analysis reveals that IT management professionals at the university generally have a strong understanding and positive perception of cloud computing and solar PV systems. High factor loadings for most variables indicate that respondents have a clear and consistent view of the benefits associated with cloud computing, particularly in terms of cost savings and operational efficiency. Despite this, there are moderate concerns regarding the technical complexity and security risks involved in implementing cloud solutions, as indicated by the variability in responses. Solar PV systems are also viewed favorably, especially regarding their contribution to sustainability, though there are concerns about initial investment and maintenance requirements.

The potential of utilization solar PV energy and cloud computing in the computer center at the Al-Zaytoonah University of Jordan was fully investigated. The followings may be concluded from this study:

- PV solar is strongly recommended to be utilized in supplying the center by the required electrical power in addition to the existing electrical power source (net metering). Using the conventional existing servers, the number of required PV panels was found to be 128 PV panels at a total cost of 28440 (JD).
- The convectional serves are recommended to be replaced by cloud ones. By doing so the number of required PV panels is reduced to 90 PV at a total system cost of 19,980 (JD).
- The payback period of the first Scenario is 2.78 year and for the second scenario is 1.95 year.

Future Recommendations:

- **Targeted Training Programs:** To address concerns about the technical complexity and security risks associated with cloud computing, the university should invest in targeted training and capacity-building programs. These could focus on enhancing staff familiarity with cloud applications and best practices in data security.
- **Pilot Projects for Solar PV Systems:** Implementing pilot projects for solar PV systems could help in demonstrating the practical benefits and addressing concerns about investment and maintenance. These projects could also provide real-time data to further support decision-making.
- **Continuous Monitoring and Feedback:** Establish a continuous monitoring and feedback loop to assess the ongoing impact of cloud and solar initiatives. Regularly gather insights from IT staff to ensure that their concerns are being addressed and that the systems are delivering expected benefits.
- **Collaborative Workshops:** Organize workshops that bring together IT staff and external experts to discuss emerging trends in cloud computing and solar technology. These sessions can foster a deeper understanding and provide solutions to the concerns identified in the analysis.
- By implementing these recommendations, the university can better leverage the potential of cloud computing and solar PV systems, while mitigating the challenges identified in this study.

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Appendix