

Final Project 1

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Project Template

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To

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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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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 (WBRENSE).

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.

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