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# AWARENESS AND PERCEPTIONS OF ENERGY-AWARE VIRTUAL MACHINE CONSOLIDATION IN CLOUD DATA CENTRES

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**Abstract -** *Cloud data centres consume electricity to operate physical servers and supporting infrastructure. Virtual Machine (VM) consolidation can improve server utilisation by placing workloads on fewer suitable physical servers, potentially allowing idle servers to enter low-power states. However, consolidation must also consider VM migration overhead, application performance, and Service Level Agreement (SLA) compliance. This paper analyses 60 questionnaire responses collected through Google Forms to examine cloud-computing familiarity, awareness of data-centre electricity consumption, understanding of VM consolidation, perceived importance of energy efficiency, and support for energy-aware resource management. The results show that 49 respondents (81.7%) consider energy efficiency very or extremely important. Additionally, 26 respondents (43.3%) have heard of VM consolidation but do not fully understand the concept, while 42 respondents (70.0%) support or strongly support energy-aware consolidation. Reduced electricity consumption and reduced environmental impact are among the most frequently selected perceived benefits. The findings describe respondents' awareness and perceptions rather than actual technical performance. Hypothesis tests showed that cloud-computing familiarity was significantly associated with awareness of VM consolidation (Spearman $\rho = 0.56$, $p < 0.001$) and that the perceived importance of energy efficiency was associated with overall opinion ($\rho = 0.35$, $p = 0.006$). Awareness of data-centre electricity consumption was not associated with support for energy-aware consolidation once responses were grouped (Fisher's exact $p = 0.50$). Since the study does not measure server energy consumption, VM migrations, or SLA violations, simulation-based evaluation is required to assess the technical effectiveness of energy-aware VM consolidation.*

**Key Words: Cloud computing, virtual machine consolidation, energy efficiency, green computing, questionnaire analysis, cloud data centres.**

## 1. INTRODUCTION

Cloud computing delivers computing, storage and software resources on demand. As cloud services scale, data centres operate large numbers of physical servers, increasing electricity use and operating costs, so energy efficiency is an important consideration in sustainable cloud infrastructure.

Virtual Machine (VM) consolidation places workloads from multiple physical hosts onto fewer suitable hosts; the vacated hosts may then be switched off or placed into low-power states. Nevertheless, overly aggressive consolidation can increase resource contention, migration traffic and Service Level Agreement (SLA) violations. An energy-aware policy must balance power reduction with application performance and system stability.

This paper focuses on questionnaire-based descriptions of cloud-computing familiarity, awareness of data-centre electricity consumption, VM-consolidation awareness, perceptions of energy efficiency and support for energy-aware resource management. The questionnaire complements technical research; it does not directly measure server energy consumption or prove algorithm performance.

## 2. LITERATURE REVIEW

Beloglazov, Abawajy and Buyya developed energy-aware resource-allocation heuristics for cloud data centres, including power-conscious VM placement and VM-selection policies [1], providing a basis for reducing active-host energy while preserving quality-of-service constraints. Srikantaiah, Kansal and Zhao investigated the relationship between consolidation, energy consumption and performance [2]; their work shows that packing workloads more tightly does not necessarily minimise energy per unit of work, because contention can reduce performance, which supports a balanced rather than energy-only policy.

Verma, Ahuja and Neogi proposed pMapper, an application-placement architecture that accounts for power and migration costs along with performance [3]. Farahnakian and colleagues explored prediction-based VM consolidation, illustrating how workload forecasts can inform host overload and underload decisions [4]. CloudSim provides a simulation environment for studying cloud resource provisioning and consolidation algorithms under controlled configurations [5] and is a suitable tool for future technical validation.

Questionnaire responses can describe perceptions, but cannot replace controlled energy, migration and SLA measurements.

## 3. RESEARCH GAP

Existing research on VM consolidation primarily examines technical indicators such as energy consumption,

server utilisation, migration overhead and SLA violations. However, technical evaluations do not necessarily explain how familiar students and other technology users are with VM consolidation or how they perceive its role in improving energy efficiency. Understanding these perceptions provides additional information about awareness of sustainable cloud-computing practices.

This study addresses this complementary area by analysing questionnaire responses on cloud-computing familiarity, awareness of data-centre electricity consumption, understanding of VM consolidation, and support for energy-aware resource management. It does not propose experimentally validated algorithmic improvements; it provides a descriptive analysis supported by tests of association between selected responses. Future research can examine other stakeholder groups and evaluate technical performance through controlled simulation.

## 4. PROBLEM STATEMENT

Cloud data centre servers consume electricity even when their resources are not fully utilised. VM consolidation can improve utilisation by moving workloads onto fewer suitable servers, but excessive consolidation may increase resource contention, migration overhead, and the risk of SLA violations. Energy-aware VM consolidation therefore requires a balance between reducing energy consumption and maintaining acceptable application performance and service quality. In addition to technical evaluation, it is useful to understand how people perceive energy efficiency and how familiar they are with VM consolidation.

The present study analyses 60 questionnaire responses collected through Google Forms, combining descriptive statistics with tests of association between selected responses. It does not directly measure the energy savings or performance of a consolidation algorithm.

## 5. RESEARCH OBJECTIVES, QUESTIONS AND HYPOTHESES

### Research Objectives

- To describe respondents' familiarity with cloud computing and awareness of data-centre electricity consumption.
- To examine respondents' awareness and understanding of VM consolidation.
- To analyse the perceived importance of energy efficiency and opinions about the potential energy-saving benefits of VM consolidation.
- To identify the operational factors and perceived benefits associated with energy-aware VM consolidation.
- To describe respondents' levels of support for energy-aware resource management in cloud data centres.

### Research Questions

- What is the level of cloud-computing familiarity among the respondents?
- How aware are respondents of data-centre electricity consumption and VM consolidation?
- Which operational factors and perceived benefits are selected most frequently?
- What proportion of respondents supports energy-aware VM consolidation?
- What are the respondents' overall opinions about energy-efficient resource management?

### 5.1 Survey Hypotheses

The following hypotheses investigate possible relationships between questionnaire responses and are tested in Section 7.10. In each pair, H0 states that there is no statistically significant association and H1 states that there is one.

- **Pair 1:** H01/H11 – cloud-computing familiarity (Q2) and awareness of VM consolidation (Q5).
- **Pair 2:** H02/H12 – awareness that data centres consume electricity (Q3) and support for energy-aware VM consolidation (Q10).
- **Pair 3:** H03/H13 – perceived importance of energy efficiency (Q4) and overall opinion of energy-efficient resource management (Q12).

### 5.2 Technical Hypotheses for Future Simulation

The following hypotheses are intended for future simulation-based evaluation and are not tested using the questionnaire dataset. Under equivalent workload and system conditions, compared with a selected baseline policy:

- **Pair 4 (energy consumption):** H04 – energy-aware VM consolidation does not significantly reduce measured energy consumption; H14 – it significantly reduces measured energy consumption.
- **Pair 5 (SLA compliance and migration overhead):** H05 – it does not improve the combined outcome of SLA compliance and VM migration overhead; H15 – it improves that combined outcome.

These can be evaluated in future work using CloudSim or CloudSim Plus by comparing a clearly defined energy-aware policy with a baseline.

## 6. RESEARCH METHODOLOGY

### 6.1 Research Design and Questionnaire

This study uses a questionnaire-based descriptive research design. The questionnaire contains 12 questions covering respondent background, cloud-computing familiarity, awareness of data-centre electricity

consumption, VM-consolidation awareness, perceived energy-saving potential, operational considerations, concern about unnecessary energy consumption, support for energy-aware consolidation, perceived benefits, and overall opinion. Questions Q8 and Q11 allow multiple selections. The analysis focuses on response counts and percentages, supplemented by tests of association between selected questions.

### 6.2 Dataset and Data Handling

The study analyses 60 questionnaire responses collected through Google Forms. Respondent names and email addresses are excluded from the aggregated analysis to protect privacy. The findings should be interpreted in the context of the respondents included and should not automatically be generalised to the entire cloud-computing community.

### 6.3 Data Processing and Analysis

For single-choice questions, Percentage = (Number of responses in a category / Total number of respondents) × 100, with a total of 60 respondents. For multiple-selection questions, the number of selections for each option is reported with its percentage of the 60 respondents, so percentages may exceed 100% when added together. Percentages are rounded to one decimal place. The three survey hypotheses were tested at a significance level of 0.05. Because many response categories had small counts (several expected cell counts below 5), Monte Carlo exact tests, Fisher's exact test, and Spearman's rank correlation were used instead of the standard chi-square test.

### 6.4 Scope of Measurement

The dataset contains categorical responses about awareness, familiarity, opinions and perceived benefits. It does not contain direct measurements of server power consumption, energy usage in kilowatt-hours, VM migration counts, active-host utilisation, SLA violations, or application response times. Consequently, the study cannot establish the actual energy savings or technical performance of an energy-aware VM-consolidation algorithm; this should be done in a simulation environment such as CloudSim or CloudSim Plus.

### 6.5 Research Ethics and Privacy

Participation was voluntary, and the purpose of the study was explained to participants before they responded. No sensitive personal information was collected. Names and email addresses were not used in the analysis and do not appear in any table or chart. All results are reported in aggregated form, so no individual respondent can be identified, and the data was used only for this academic study.

## 7. DATA ANALYSIS

This section presents a descriptive analysis of the 60 questionnaire responses. Single-choice responses are summarised using counts and percentages; for multiple-selection questions, each option is reported as a proportion of the 60 respondents. The findings describe the available dataset and do not establish causal relationships or experimentally measured energy savings.

### 7.1 Respondent Profile and Cloud-Computing Familiarity

The largest background category is MCA/Postgraduate CS students (31; 51.7%), followed by undergraduate CS/IT students (10; 16.7%), other respondents (10; 16.7%), other postgraduate students (6; 10.0%) and IT/Software professionals (3; 5.0%) (Fig -1). For familiarity with cloud computing, 22 respondents (36.7%) were very familiar, 22 (36.7%) somewhat familiar, 8 (13.3%) had heard of it but knew very little, and 8 (13.3%) were not familiar (Fig -2).

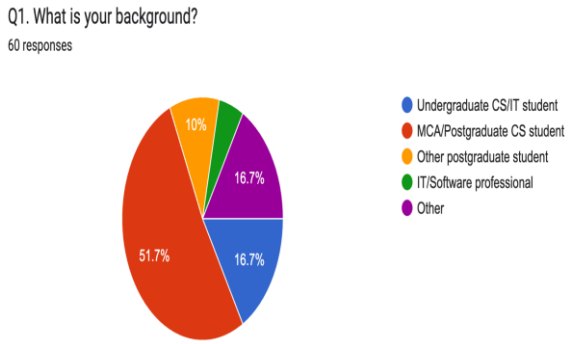



**Fig -1**: Respondent background (Q1).

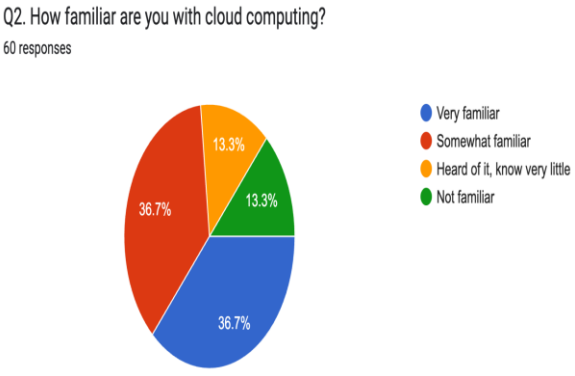



**Fig -2**: Familiarity with cloud computing (Q2).

### 7.2 Awareness of Data-Centre Electricity Use

A total of 47 respondents (78.3%) were aware that data centres consume electricity, 8 (13.3%) were not sure, and 5 (8.3%) were not aware (Fig -3).

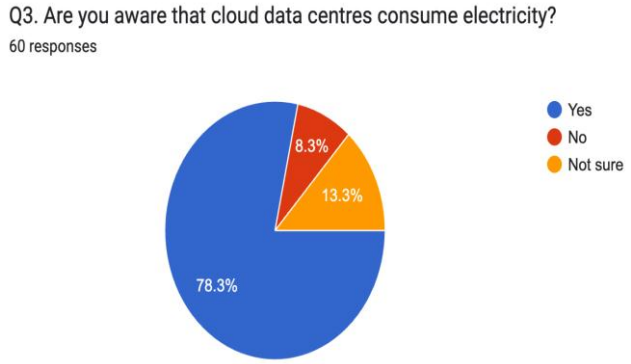



**Fig -3**: Awareness of data-centre electricity consumption (Q3).

### 7.3 Importance of Energy Efficiency

Energy efficiency was rated very important by 32 respondents (53.3%), extremely important by 17 (28.3%), moderately important by 8 (13.3%), slightly important by 2 (3.3%) and not important by 1 (1.7%) (Fig -4).

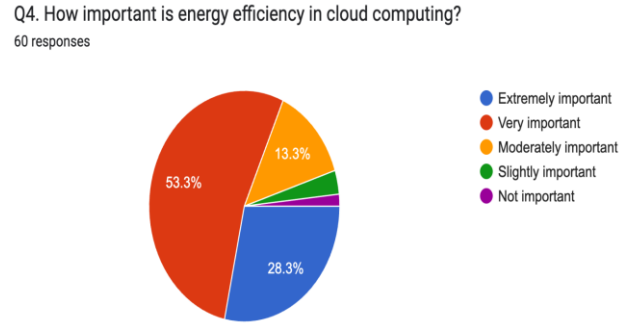



**Fig -4**: Importance of energy efficiency in cloud computing (Q4).

### 7.4 Awareness of VM Consolidation

Twenty-six respondents (43.3%) had heard of VM consolidation but did not fully understand it, 20 (33.3%) understood the concept, and 14 (23.3%) were not aware of it (Fig -5).

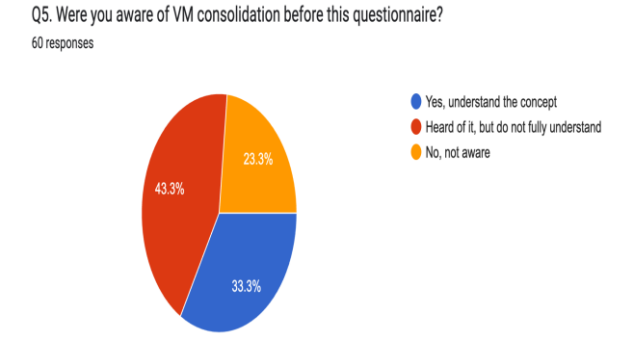



**Fig -5**: Awareness of VM consolidation (Q5).

### 7.5 Clarity and Perceived Energy-Reduction Potential

After a brief explanation, the concept was neutral for 24 respondents (40.0%), very clear for 15 (25.0%), somewhat clear for 14 (23.3%), not very clear for 4 (6.7%) and not clear at all for 3 (5.0%) (Fig -6). Thirty-seven respondents (61.7%) believed VM consolidation can reduce energy consumption, 19 (31.7%) were not sure, and 4 (6.7%) said no (Fig -7).

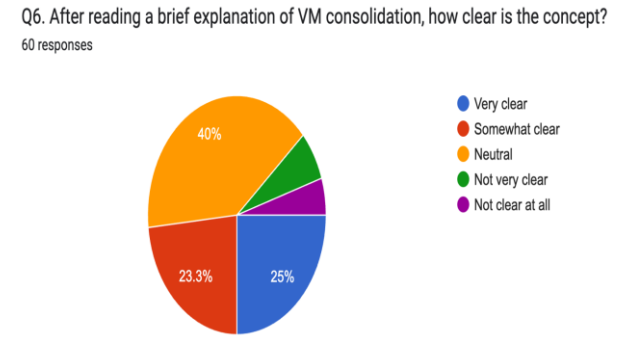



**Fig -6**: Clarity of VM consolidation after explanation (Q6).

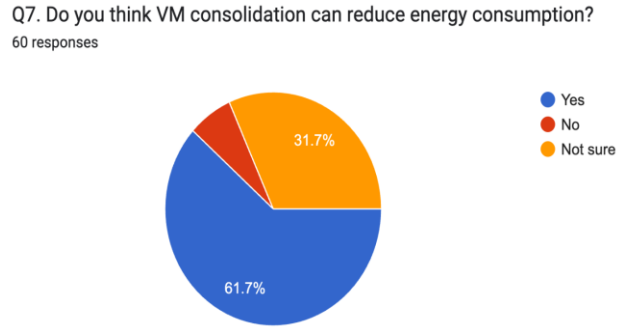



**Fig -7**: Belief that VM consolidation can reduce energy consumption (Q7).

### 7.6 Factors to Consider During VM Consolidation

The option "All of the above" was selected by 28 respondents (46.7%), followed by energy consumption (25; 41.7%), CPU/memory utilisation (18; 30.0%), VM migration overhead (17; 28.3%), SLA compliance (8; 13.3%) and application performance (6; 10.0%) (Fig -8). "All of the above" is reported as a separate category and is not redistributed among individual factors. Because multiple selections were allowed, the percentages are proportions of respondents selecting each option, and they describe perceptions rather than the relative technical importance of each factor in an actual data centre.

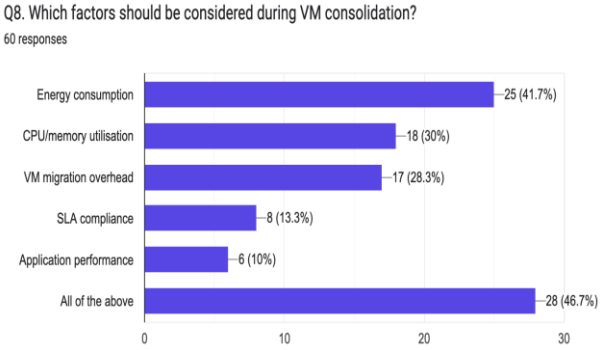



**Fig -8**: Factors to consider during VM consolidation (Q8, multiple choice).

### 7.7 Concern and Support for Energy-Aware Consolidation

Regarding unnecessary energy consumption, 24 respondents (40.0%) were very concerned, 16 (26.7%) moderately, 13 (21.7%) extremely, 4 (6.7%) slightly and 3 (5.0%) not concerned (Fig -9). Support for energy-aware consolidation was strong: 22 respondents (36.7%) strongly supported and 20 (33.3%) supported it, 15 (25.0%) were neutral, 2 (3.3%) opposed and 1 (1.7%) strongly opposed (Fig -10).

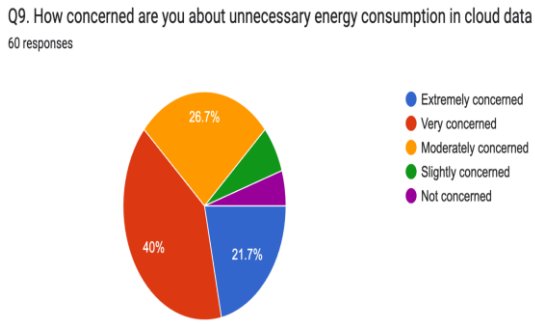



**Fig -9**: Concern about unnecessary energy consumption (Q9).

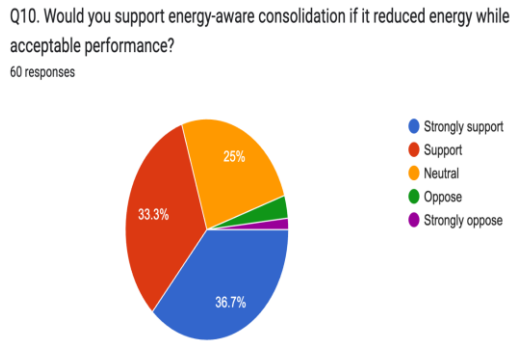



**Fig -10**: Support for energy-aware consolidation (Q10).

### 7.8 Perceived Benefits

The most frequently selected benefits were reduced electricity consumption (33; 55.0%), reduced environmental impact (30; 50.0%), lower operating costs (29; 48.3%), better server utilisation (22; 36.7%) and better resource allocation (13; 21.7%); 7 respondents (11.7%) were unsure (Fig -11).

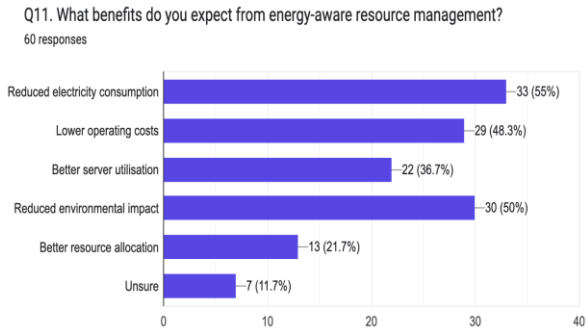



**Fig -11**: Expected benefits of energy-aware resource management (Q11, multiple choice).

### 7.9 Overall Opinion

The overall opinion of energy-efficient resource management was positive for 27 respondents (45.0%), very positive for 23 (38.3%), neutral for 9 (15.0%) and very negative for 1 (1.7%) (Fig -12).

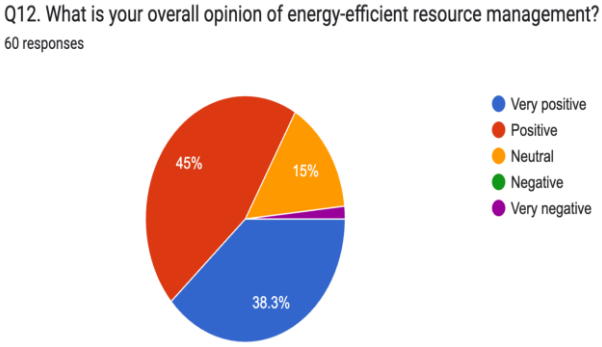



**Fig -12**: Overall opinion of energy-efficient resource management (Q12).

### 7.10 Hypothesis Testing

Statistical tests (Monte Carlo exact tests, Fisher's exact test and Spearman's rank correlation, $\alpha = 0.05$) were applied to the three survey hypotheses.

*Hypothesis 1 (Q2 and Q5).* A significant association was found between cloud-computing familiarity and awareness of VM consolidation (exact test $p < 0.001$; Spearman $\rho = 0.56$, $p < 0.001$). More familiar respondents were more likely to understand VM consolidation, so H01 is rejected: 19 of 44 respondents who were very or somewhat familiar

with cloud computing understood VM consolidation, compared with 1 of 16 with little or no familiarity.

*Hypothesis 2 (Q3 and Q10).* The full response table showed a statistically significant association (exact test p = 0.012), but this was driven by respondents who answered "Not sure" about data-centre electricity use, who accounted for all three oppose or strongly oppose responses. When responses were grouped as supports versus neutral/oppose, no significant difference was found between aware respondents (72.3% support) and unaware or unsure respondents (61.5% support) (Fisher's exact p = 0.50), and there was no monotonic correlation (Spearman ρ = 0.05, p = 0.70). The data therefore do not show that awareness of data-centre electricity use increases support for energy-aware consolidation.

*Hypothesis 3 (Q4 and Q12).* A significant positive association was found between the perceived importance of energy efficiency and overall opinion (Spearman ρ = 0.35, p = 0.006). Respondents who rated energy efficiency as more important tended to hold more positive opinions, so H03 is rejected. Because nearly all respondents rated energy efficiency as important, this association should be interpreted cautiously.

## 8. RESEARCH FINDINGS

- **Familiarity:** 44 respondents (73.3%) were very or somewhat familiar with cloud computing.
- **Electricity consumption:** 47 respondents (78.3%) were aware that data centres consume electricity.
- **Importance of energy efficiency:** 49 respondents (81.7%) considered it very or extremely important.
- **VM consolidation awareness:** 26 respondents (43.3%) had heard of it but did not fully understand it; 20 (33.3%) understood it.
- **Energy-saving potential:** 37 respondents (61.7%) believed VM consolidation could reduce energy consumption; 19 (31.7%) were unsure.
- **Support:** 42 respondents (70.0%) supported or strongly supported energy-aware consolidation.
- **Perceived benefits:** reduced electricity consumption (33; 55.0%), reduced environmental impact (30; 50.0%) and lower operating costs (29; 48.3%).
- **Overall opinion:** 50 respondents (83.3%) were positive or very positive about energy-efficient resource management.
- **Hypothesis 1:** familiarity was significantly associated with awareness of VM consolidation (ρ = 0.56, p < 0.001).
- **Hypothesis 2:** awareness of data-centre electricity use was not associated with support (72.3% vs 61.5%; Fisher's exact p = 0.50).
- **Hypothesis 3:** perceived importance of energy efficiency was positively associated with overall opinion (ρ = 0.35, p = 0.006).

Overall, the results indicate favourable perceptions of energy efficiency and energy-aware VM consolidation among the respondents. The associations are limited to the available sample and do not establish causal relationships or prove actual reductions in energy consumption.

## 9. RECOMMENDATIONS

- **Improve awareness:** educational initiatives should explain VM consolidation, its role in improving server utilisation and its contribution to energy efficiency, using practical examples.
- **Balance energy efficiency and service quality:** policies should consider energy consumption, CPU and memory utilisation, migration overhead, application performance and SLA compliance together; reducing the number of active servers should not be the only measure of success.
- **Confirm statistical findings with a larger sample:** the associations should be re-tested, particularly between awareness of data-centre electricity use and support, because several response categories had very few respondents.
- **Evaluate technical performance:** a simulation study should compare a clearly defined energy-aware policy with a baseline, measuring energy consumption, server utilisation, VM migrations and SLA-related outcomes under equivalent workloads.
- **Expand the respondent sample:** include cloud-computing students, IT professionals, cloud administrators and other stakeholders.

## 10. CONCLUSION

This study analysed 60 questionnaire responses on awareness and perceptions of energy-aware VM consolidation in cloud data centres. The findings show that 81.7% of respondents considered energy efficiency very or extremely important, while 70.0% supported or strongly supported energy-aware consolidation. At the same time, 43.3% had heard of VM consolidation but did not fully understand it, indicating a potential need for greater awareness and education.

Hypothesis tests showed that cloud-computing familiarity was associated with awareness of VM consolidation and that perceived importance of energy efficiency was associated with a more positive overall opinion, whereas awareness of data-centre electricity use was not associated with the level of support. However, the study is limited to questionnaire data and does not measure actual energy consumption, migration overhead, or SLA compliance, so the findings should not be interpreted as proof of the technical effectiveness of any consolidation algorithm. Further research should confirm these associations with a larger sample and evaluate technical performance through controlled simulation.

## 11. LIMITATIONS

- **Limited sample size:** 60 responses may not represent the wider cloud-computing community.
- **Sample composition:** the largest group is MCA or postgraduate computer-science students, so findings may not reflect cloud professionals or data-centre administrators.
- **Self-reported responses:** the study relies on reported awareness, familiarity and opinions rather than direct assessments of technical knowledge.
- **Limited statistical analysis:** only three associations were tested in a small sample with several sparse categories; results are preliminary.
- **No technical measurements:** no server energy consumption, VM migration overhead, utilisation or SLA data.
- **Limited generalisability and no causal conclusions:** the findings describe the analysed sample, and the survey cannot establish that awareness of cloud computing causes greater support for energy-efficient resource management.

## 12. FUTURE SCOPE OF RESEARCH

- **Statistical confirmation:** repeat the association tests with a larger sample, comparing respondent groups and using methods suited to ordered response categories.
- **Broader participation and improved questionnaire design:** collect responses from more diverse stakeholders, with clearly defined categories that distinguish awareness, conceptual understanding and practical experience.
- **Cloud simulation:** implement or select an energy-aware VM-consolidation policy using CloudSim or CloudSim Plus and compare it against a defined baseline.
- **Energy and performance evaluation:** measure simulated energy consumption, active-host utilisation, VM migration frequency and SLA-related outcomes under equivalent workloads, and compare policies under varied workload patterns.
- **Stakeholder-specific analysis:** investigate whether students, IT professionals and cloud administrators differ in awareness and perceptions, provided sample sizes support such comparisons.

Combining statistical survey analysis with controlled simulation could provide a more comprehensive understanding of energy-aware VM consolidation, covering both stakeholder perceptions and technical performance.

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