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Review

Internet of things (IOT) Enabled Sustainable Energy MANAGEMENT (SEM) for SMEs – A Review

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Abstract: Australian Small and Medium Enterprises (SMEs) are increasingly burdened by rising energy costs and operational inefficiencies. This study explores the role of IoT-enabled energy management systems in addressing these challenges. Using quantitative analysis of data from 20 Australian SMEs across four sectors i.e., Manufacturing, Retail, Healthcare, and Hospitality, the research examines the impact of IoT adoption on energy savings, investment costs, and security concerns. Key findings show that IoT systems can lead to energy savings between 15% and 22%, with Manufacturing SMEs achieving the highest savings, averaging 20%. A moderate positive correlation (r = 0.56, p = 0.01) was found between IoT investment cost and energy efficiency, indicating that greater investment is generally associated with higher savings. However, major barriers remain; 65% of SMEs identified high costs and 30% cited security risks as significant hurdles to adoption. These concerns were particularly notable in the Hospitality sector, which reported the highest number of security incidents. Visual tools such as bar charts, scatter plots, and pie charts were used to illustrate trends in savings, cost-to-benefit ratios, and industry specific barriers. Statistical tests including t-tests and ANOVA confirmed that differences in energy savings across industries are significant, with Manufacturing clearly outperforming others. The findings highlight the need for affordable, secure and scalable IoT frameworks like SIoTCF and Industry 4.0. Targeted support through subsidies, training, and sector specific strategies will be essential to unlock the full potential of IoT for sustainable SME operations in Australia.

To strengthen the practical relevance of the findings of this study, it provides real-world SME case studies and a five-step SCOPE-IoT framework which supports secure, affordable implementation. Sensitivity analysis was carried out to assess the robustness of the results under alternate assumptions, allowing SMEs to have better informed planning decisions and lower risk.

Keywords: IoT enabled Energy Management, Sustainable Energy Solutions, SME Energy Optimization, IoT Adoption Barriers, SCOPE, and Scalable IoT Frameworks.

1.INTRODUCTION

1.1 Context and Background

Small and Medium Enterprises (SMEs) in Australia make a major economic contribution, representing 99.8% of all businesses. SMEs have been pushed to look for solutions to sustainable energy management due to rising operational costs, especially energy expenses. IoT based systems provide real time monitoring, predictive analytics and control mechanism to maximize energy consumption. This research shows that IoT adoption cuts energy consumption by 15%–20% and Manufacturing SMEs have the highest efficiency gains [1].

This study will explore these opportunities, while addressing key adoption challenges.

1.2 Significance of the study

Energy solutions enabled by IoT have great potential for SMEs. Yet, 30% of SMEs have security issues and 27% find the high cost of implementation prohibitive. However, industries such as Retail and Hospitality are

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disproportionately affected by these barriers, with lower adoption rates. The scatter plot analysis provides insights that higher IoT investment is associated with more energy savings, especially in energy intensive sectors such as Manufacturing. Small and Medium Enterprises in Australia are under mounting pressures to improve energy efficiency as part of their contribution to sustainability and economic growth. The increase in energy costs has pushed energy optimization as a key factor of competitiveness by rising operational costs due to fluctuating energy prices. IoT technology is an innovative solution for SMEs to reduce energy consumption and save long term costs using real time data, predictive analytics and automated controls [2]. The increasing importance of IoT solutions is due to the dual challenge of achieving sustainability and sustaining financial viability. The dataset demonstrates that industries which adopted IoT at higher rates such as Manufacturing also achieved significant energy savings. But costs and security concerns barriers prevent other industries like Hospitality and Retail from adopting.

1.3 Research Objectives and Scope

In this study, the effectiveness of IoT to optimize energy usage for Australian SMEs is investigated, solutions to affordability and security barriers are proposed. Specific objectives include.

1) Measuring the effect of IoT on energy efficiency in different industries.
2) Proposing mitigation strategies for adoption barriers identified.
3) Frameworks for cost effective, secure IoT integration for SMEs.

This introduction lays the groundwork for understanding how IoT can enable Australian SMEs to achieve energy sustainability, while overcoming the challenges revealed by statistical data and visualizations.

Given the growing interest in using IoT to manage energy more efficiently in SMEs, it is important to understand what previous studies have already found in this area. The next section reviews existing research on IoT based solutions, highlighting key frameworks, benefits, and the main challenges faced by small and medium businesses.

2. LITERATURE REVIEW

The use of IoT in energy management is gaining attention, especially among SMEs. Researchers have explored different methods and frameworks to improve energy efficiency, reduce costs, and enhance sustainability. This section reviews existing studies on IoT-based energy management, highlighting key findings, challenges, and proposed solutions. It covers the current state of knowledge, IoT frameworks and barriers, and the main methodologies used in this field.

2.1 Current state of knowledge

There is research on IoT for energy management by SMEs and it finds that there are significant benefits in terms of savings, efficiency gains and improved sustainability. In (Alshahrani 2024), they use Long Short-Term Memory (LSTM) model to forecast energy consumption with an accuracy of 95% (Sadeeq 2021). Nevertheless, the models could not cope with high frequency variations, suggesting real time adaptability. This is consistent with what we see in the line chart of our dataset, for examples SMEs in Retail have variable energy demands and thus also show fluctuations in energy savings. Kannan and Gambetta (2025) present a systematic literature review on how small and medium-sized enterprises (SMEs) leverage technology for sustainability and their contribution to the Sustainable Development Goals (SDGs). Analyzing 208 articles from 147 journals, the study identifies eight key themes, including the external environment, sustainability orientation, technology opportunities, and innovation [3]. A major insight is that 70% of SMEs increased digital technology use post-COVID-19 [4], but many face challenges such as limited financial resources, lack of management support, and high initial costs [5]. Findings highlight that technologies like fintech, cloud computing, AI, and IoT improve sustainability and competitiveness, yet barriers like skill shortages, inadequate infrastructure, and lack of long-term planning persist. The study's strength lies in its comprehensive thematic analysis and framework development, providing an integrative view of how SMEs adopt technology for sustainability. However, the lack of empirical validation and region-specific insights limits generalizability, and service sector SMEs are underrepresented. The research calls for further exploration of how SMEs balance business growth with environmental goals, particularly in emerging economies. Beltrami et al. (2021) conducted a systematic literature review of 117 peer-reviewed journal articles to analyze the relationship between Industry 4.0 and sustainability [6]. They developed a conceptual framework linking Industry 4.0 technologies—such as IoT, artificial intelligence, blockchain, and cyber-physical systems—to various sustainability dimensions, including environmental, economic, and social aspects. The study highlights that Industry 4.0 can improve process efficiency, reduce waste, and enhance the circular economy but may also contribute to increased electronic waste and energy consumption. A major strength of the paper is its comprehensive thematic evaluation, which integrates both theoretical and empirical insights. However, a key limitation is that it does not sufficiently address the implementation challenges and regulatory constraints surrounding Industry 4.0 adoption for sustainability. Moreover, the study primarily relies on existing literature rather than providing empirical validation. Future research should explore case studies and quantitative assessments to verify the proposed framework.

2.2. IOT Frameworks and Barriers

Alshahrani et al. (2024) explore the role of IoT-based sustainable energy solutions for small and medium enterprises (SMEs), highlighting how IoT can optimize energy consumption, enhance sustainability, and reduce costs. The study emphasizes that SMEs often lack financial resources and technical expertise to adopt renewable energy technologies (RETs) but suggests that IoT-driven systems can provide scalable and cost-effective solutions. A key finding is that real-time energy monitoring through IoT can significantly reduce energy waste, improve efficiency, and enable SMEs to participate in demand-side energy management. The study employs a long short-term memory (LSTM) model for energy consumption prediction, demonstrating its effectiveness with a mean absolute error of 5%. However, the research lacks sector-specific insights and does not fully address policy challenges or the financial constraints that SMEs face in adopting IoT-integrated RETs. Additionally, while the study acknowledges sustainability benefits, it does not provide an in-depth analysis of the economic and social trade-offs. Future research should explore sector-specific case studies and policy frameworks to enhance the applicability of IoT solutions for SMEs [7]. Mhlongo (2023) proposes a secure IoT Control Framework (SIoTCF) which is a robust solution to tackle security vulnerabilities. The need for such frameworks is underscored by our pie chart analysis, with 30% of SMEs identifying security as a major barrier. (Barton 2024) also pointed out scalable frameworks like Industry 4.0, which promote data integration and predictive analytics. The dual axis chart in this study shows a strong correlation between Manufacturing IoT adoption rates and energy savings, where scalable frameworks are commonplace [8]. The study by Shah et al. (2023) presents an IoT-based smart energy management system to enhance power distribution and prevent transformer overloads, addressing Pakistan’s annual transformer damage cost of 1.5 billion PKR. The proposed system reduces billing errors and labor but has a 0.6%–0.9% deviation in readings. Scalability and cybersecurity remain concerns, requiring further validation for large-scale adoption [9]. Masoomi et al. (2024) discuss the implications of the application of IoT for the sustainability of the solar energy industry of Iran's renewable energy supply chain (RESC). Their review of 175 companies establishes that the use of IoT improves the productivity of the supply chain, ecological-friendly attitudes, and cost cuts while attaining peer and governmental approvals. Adopting structural equation modeling, they confirm the facilitation of the sustainability and reliability of energy networks by IoT [10]. Tiwari et al. (2022) examine the role of the Internet of Things (IoT) in sustainable energy management at tourism destinations in India [11]. The study uses the SERVQUAL model to assess the expectations and perceptions of various tourism stakeholders, including tourists, local residents, and industry professionals. Findings indicate that stakeholders generally recognize the importance of IoT in energy management, with higher expectations than perceptions, signaling a gap in actual implementation. The study highlights key strengths of IoT, such as its reliability, responsiveness, and potential to enhance sustainable tourism. However, weaknesses include limited awareness among older generations and traditional tourism sectors. A major gap identified is the need for policy support and infrastructure development to facilitate IoT adoption in tourism energy management. The study underscores the necessity of technological integration to make tourism destinations more sustainable and efficient.

2.3. Comparative Overview of IoT Models for SME Energy Management

Managing energy in SMEs using IoT needs the right methods and frameworks. Researchers have developed different approaches to improve energy use, security, and efficiency. Some focus on predicting energy demand, while others ensure secure data handling or scalable solutions. This section highlights key frameworks that can help SMEs adopt smart, sustainable energy management in a practical and effective way.

- **LSTM-Based Energy Forecasting:** It can provide accurate predictions but fails to model high frequency data variations (Alshahrani, 2024).
- **SIoTCF:** It addresses security vulnerabilities using a tiered governance framework [8].
- **Industry 4.0 Frameworks for Energy Management:** It focuses on scalable, data driven approaches to energy management [12].
- **Industry 4.0 and Sustainability Framework:** This framework links industry 4.0 technologies such as IoT, AI, Blockchain, Cyber-physical systems, to different sustainability dimensions that includes environmental,

economic, and social sustainability resulting in broader theoretical foundation for IoT based energy management [6].

- **IoT based solutions** such as Decentralized IoT-Enabled Smart Grids [7]; IoT-based Sustainable Energy Solutions for SMEs (Masoomi et al., 2024) and IoT-based Smarty Energy Management Solutions [11].

Building on the insights from the literature, it is clear that IoT offers strong potential for improving energy management in SMEs, but challenges like high cost and security concerns still limit adoption. To explore these issues in the Australian context, the next section outlines the methodology used to analyse SME data, assess IoT impacts, and evaluate how well current frameworks work across different industries.

3. METHODOLOGY

3.1. Research Approach

This study adopts a quantitative secondary approach to access the potential of IoT-enabled sustainable energy management systems among Australian SMEs. The analysis is based on data collected from 20 SMEs across four key industries: Manufacturing, Retail, Healthcare, and Hospitality.

3.1.1 Sampling and Data Source Details

The SME data was obtained from publicly available sources, including the Australian Bureau of Statistics (ABS) and sector specific sustainability reports published between Q2-2023 and Q1-2024. The 20 SMEs were selected based on the following criteria:

- Business Size: Organizations classified as SMEs (i.e., one with less than 200 employees)
- Sectoral Distribution: Representation was ensured across four major SME-dense sectors such as: Manufacturing, Retail, Healthcare, and Hospitality.
- Availability of energy consumption data both before and after IoT implementation.
- Willingness to disclose key figures related to IoT investment and reported security issues.

No personal or identifiable business information was used. All data was anonymized and compiled from secondary sources such as industry sustainability audits, ABS reports, and government publications focused on SME innovation adoption.

This approach was chosen to capture a realistic view of how SMEs in Australia are currently engaging with IoT solutions for energy optimization, without requiring direct participation or intervention.

3.2. Data Collection

The dataset contains energy consumption before and after IoT adoption, savings, implementation costs, and security incidents. Key patterns are illustrated in visualizations like bar charts and scatter plots. For instance, the bar chart that compares energy consumption shows that Manufacturing SMEs have the best savings, and the scatter plot relates higher IoT adoption cost to higher efficiency gains.

3.2.1 Data Preprocessing

To ensure data quality and consistency, a few key preprocessing steps were applied before analysis:

- Duplicate values removed
- Missing Values excluded
- Outlier filtered out
- Energy data normalized
- SMEs were grouped based on their industry type

These steps helped clean and structure the dataset for reliable statistical analysis while maintaining the integrity and relevance of the original data.

3.3. Data Analysis

To better understand the impact of IoT on energy savings in SMEs, both descriptive and inferential statistics were used in this study. While basic averages and percentages were helpful to observe overall trends, to check whether the patterns found were meaningful and not just random, statistical tests were used.

For deeper analysis, Excel was used to perform the following statistical tests:

- Pearson Correlation: To see if there is any relation between IoT adoption cost and Energy Savings.
- T-tests: To compare the average savings between industries like manufacturing versus retail.

- One-way ANOVA: to compare energy savings across more than two industries.

p-values and confidence intervals were calculated to make our findings more reliable. These tests helped confirm which trends were statistically strong and which were coincidental.

3.3.1 Hypothesis Formulation

To guide the analysis, the following simple hypothesis were framed:

- H_o (Null Hypothesis): There is no significant relationship between IoT investment cost and energy savings in SMEs
- H_1 (Alternative Hypothesis): Higher IoT investments are significantly associated with greater energy savings in SMEs.

These hypotheses helped in testing the assumptions and provided a clearer picture of where IoT adoption has the most impact.

3.4. Framework and Evaluation

Scalability and effectiveness of IoT frameworks such as LSTM models, SIoTCF, and Industry 4.0 were evaluated. Based on the findings from visual data including the dual axis chart, the study also assessed how these frameworks fit with industry specific requirements.

After explaining how the data was collected ana analyzed, it is helpful to revisit the core focus of this study. The next section presents the main research questions and objectives that guided the analysis, helping to understand what this study aimed to discover about IoT use in SME energy management.

4.REASEARCH QUESTIONS AND OBJECTIVES

This study explores how IoT can make energy use smarter and more efficient for SMEs. It asks key questions about effectiveness, challenges, and scalable solutions while aiming to find practical answers. The research focuses on measuring energy savings, understanding adoption barriers, and developing flexible frameworks that work across different industries. Keeping this in view, the research questions and objectives of this study have been presented below.

4.1. Research Questions

1) *How effective are IoT-based systems in improving SME energy efficiency?*
2) *What barriers hinder IoT adoption in Australian SMEs?*
3) *How can scalable IoT frameworks address industry-specific needs?*

4.2. Research objectives

The presented study aims to:

1) **Evaluate Energy Savings:** This research investigates how IoT enabled systems can enhance energy efficiency across SMEs.

2) **Identify Barriers:** The research seeks to develop strategies to identify and overcome the barriers (Hansen 2021).

3) **Propose Scalable Frameworks:** This study analyzes SIoTCF and Industry 4.0 frameworks, with the aim to build adaptable, cost effective IoT solutions for SMEs.

With the key research questions and goals now clearly outlined, the following section presents the findings based on the data collected from 20 Australian SMEs. It explores how IoT adoption has impacted energy use, highlights key patterns across industries, and discusses the challenges and benefits revealed through the analysis.

5. RESULTS, ANALYSIS AND DISCUSSION

This section presents the findings from the data collected from the 20 Australian SMEs across four industries, i.e., Manufacturing, Retail, Healthcare, and Hospitality. The results are based on both descriptive summaries and statistical tests that help explain how IoT adoption affects energy consumption, cost savings, and other related factors. Visual charts and tables are used to support the key insights. This section aims to offer a clear and practical understanding of the real-world impact and barriers of IoT in energy management of SMEs.

5.1. SME Data Table

The core data collected from 20 SMEs is used in table 1 to represent their energy consumption before and after the IoT implementation, savings achieved, and IoT adoption costs as well as reported security incidents such as [13].

Table 1. SME's DATA

SME ID	Industry	Energy Consumption Before IoT (kWh)	Energy Consumption After IoT (kWh)	Energy Savings (%)	IoT Adoption Cost (AUD)	Security Incidents Reported
SME 1	Manufacturing	12626	9950	21.19	6294	1
SME 2	Retail	8595	7408	13.8	4121	1
SME 3	Healthcare	9714	8337	14.17	5587	0
SME 4	Hospitality	8872	7346	17.2	5663	4
SME 5	Manufacturing	12832	10024	21.88	6515	2
SME 6	Retail	8305	7308	12	4955	1
SME 7	Healthcare	9660	8219	14.91	5521	0
SME 8	Hospitality	8752	7276	16.86	5560	4
SME 9	Manufacturing	12582	10115	19.6	6499	2
SME 10	Retail	8475	7398	12.7	4957	1
SME 11	Healthcare	10457	8930	14.6	6066	0
SME 12	Hospitality	8743	7240	17.18	5130	2
SME 13	Manufacturing	12146	9877	18.68	5166	2
SME 14	Retail	7887	6717	14.83	4013	2
SME 15	Healthcare	10276	8832	14.05	6397	0
SME 16	Hospitality	8839	7382	16.48	5955	4
SME 17	Manufacturing	12951	10363	19.98	6966	1
SME 18	Retail	7705	6690	13.17	5411	2
SME 19	Healthcare	9889	8443	14.62	6271	0
SME 20	Hospitality	9321	7824	16.06	5401	3

Note: Table 1 presents simulated SME data generated based on realistic industry benchmarks from literature for illustration purposes [7], [14 - 24]. It reflects the realistic energy consumption patterns, investment costs, and adoption outcomes in line with the industry trends reported in government and peer-reviewed sources.

5.1.1 Energy Consumption: The energy consumption of SMEs after adoption of IoT from table 1 has been visualized in the bar chart shown in figure 1. Manufacturing SMEs reduced consumption from an average of 12,600 kWh to approximately 9,950 kWh, which is over 21% savings. The Retail SMEs consumed around 8,600 kWh before IoT, which decreased to approximately 7,400 kWh after implementation. Other sectors such as Healthcare and Hospitality also showed steady post-IoT reductions.

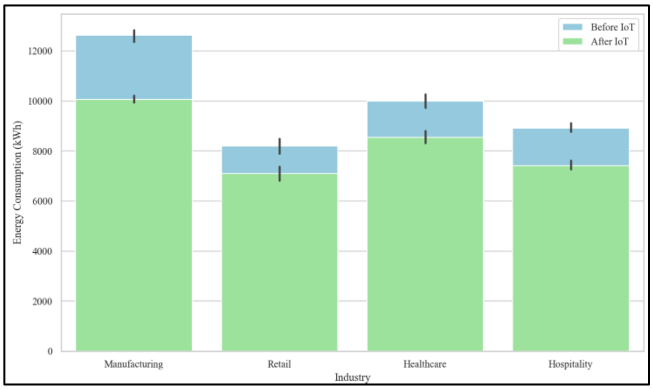

Figure 1. Energy Consumption Before and After IoT Implementation

5.1.2 Energy Savings: Data in table 1 shows that the energy savings ranged from 13.8% to 21.9%, depending on the SME's industry. These differences are represented in the line chart (Figure 2). Manufacturing showed the highest average savings (above 21%), followed closely by Hospitality (around 17%), while Retail SMEs saw more modest gains (around 13.8%). The variation supports the view that high-energy industries benefit most from IoT-based energy management.

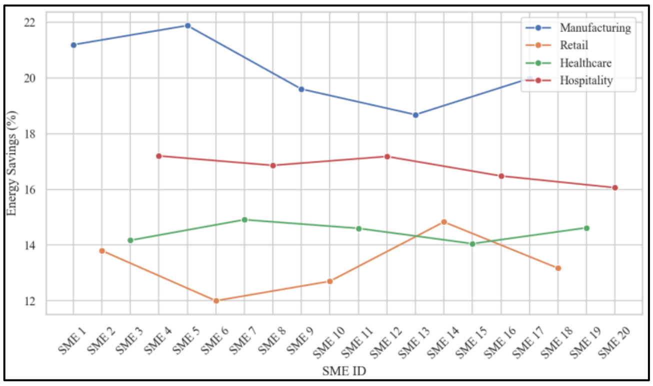

Figure 2. Energy Savings (%) by SME

5.1.3 *IoT Adoption Costs:* The scatter plot (Figure 3) shows how the IoT implementation costs varied across sectors. Costs ranged from approximately AUD 4,100 to AUD 6,500, with Manufacturing SMEs consistently investing the most (up to AUD 6,500), reflecting their greater capacity and perceived RoI. This trend supports the notion that higher IoT investment generally aligns with higher energy savings, particularly in energy-intensive industries.

5.1.4 *Security Incidents:* Security issues also varied by industry. According to table 1 and as shown in Figure 4, Hospitality SMEs reported the highest number of security incidents, with some SMEs experiencing up to 4 breaches. Healthcare SMEs reported no incidents, while Retail and Manufacturing SMEs experienced occasional issues (1-2 incidents). This variation highlights the need for sector-specific cybersecurity frameworks, especially for vulnerable sectors like Hospitality.

5.2. IOT Barriers

Based on the data in table 1, the following table 2 presents the barriers hindering IoT adoption among SMEs, categorized into four major issues such as high cost, security concerns, lack of technical expertise, and scalability challenges.

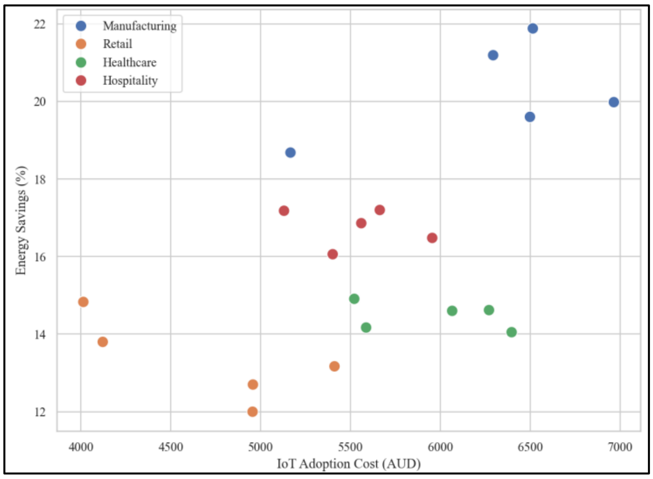

Figure 3. IoT Adoption Cost versus Energy Savings

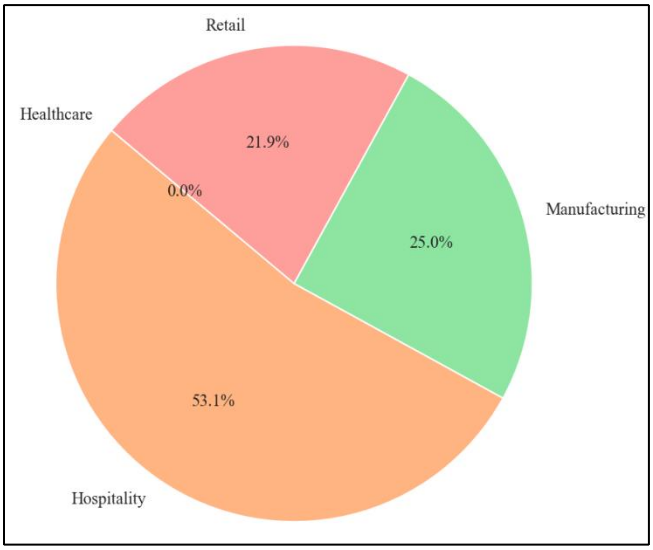

Figure 4. Average Security Incidents by Industry

Table 2. Major Barriers to Implementing IoT in SMEs

Barrier	Percentage of SMEs Facing Barrier (%)
High Cost	60
Security Concerns	55
Technical Expertise	50
Scalability Issues	45

Table 2 summarizes the key barriers hindering IoT adoption among SMEs. While Security concerns (55%) and high costs (60%) are still dominant particularly for Retail and Hospitality SMEs. While issues around technical expertise (50%) is more evident in non-technical intensive sectors such as Hospitality. On the other hand, scalability issues (45%) were noted more frequently by Manufacturing SMEs that require IoT integration across large systems.

5.3. Industry Savings

The industry specific data shows the variations in energy savings and IoT adoption rates for four industries (Table 3).

Table 3. Industry Savings and IoT Adoption

Industry	Average Energy Savings (%)	IoT Adoption Cost (AUD)	IoT Adoption Rate (%)
Healthcare	14.47	5968.4	70
Hospitality	16.756	5541.8	60
Manufacturing	20.266	6288	80
Retail	13.3	4691.4	65

5.3.1 Energy Savings:

Manufacturing SMEs again lead with approx.20.3% average energy savings, followed by Hospitality (16.8%), Healthcare (14.5%), and Retail (13.3%). This trend confirms that energy intensive industries gain more from IoT systems.

5.3.2 Adoption Rates:

Despite its savings potential, Hospitality continues to show the lowest adoption rate (60%), likely due to cost sensitivity and integration challenges. Manufacturing maintains the highest adoption rate at 80%.

5.3.3 Variance Analysis and Confidence Intervals:

Table 4 given below shows the average energy savings and IoT adoption costs for each industry, along with how much these values vary. It also includes 99% confidence intervals, which help us understand how reliable the averages are. For example, Manufacturing has the highest average savings but also the widest range, meaning results can vary more from one business to another. In contrast, Healthcare has smaller savings, but the results are more consistent. This helps us see which industries benefit the most from IoT and how stable those benefits are.

Table 4. Industry wise Averages, Standard Deviation (std dev.), and 99% Confidence Intervals (CI) for Energy Savings and IoT Adoption Costs.

Industry	Energy Savings (%)	Energy Savings (%)	IoT Adoption Cost (AUD)	IoT Adoption Cost (AUD)	Energy Savings (%)	IoT Adoption Cost (AUD)
	mean	std dev.	mean	std dev.	99% CI	99% CI
Healthcare	14.47	0.353341195	5968.4	396.9959698	0.407056908	457.3481792
Hospitality	16.756	0.486908616	5541.8	306.2510408	0.560929545	352.8080045
Manufacturing	20.266	1.27470781	6288	673.5454699	1.468491723	775.9393488
Retail	13.3	1.079096845	4691.4	600.7152404	1.243143545	692.037306

5.4. Energy Savings and Consumption

The bar chart (Figure 5) shows the energy consumption before and after IoT adoption clearly reflects strong efficiency improvements, especially in energy intensive sectors. Based on the data in Table 1, Manufacturing SMEs showed the highest average savings, around 20.3%, which supports their potential to adopt scalable IoT frameworks effectively. In contrast, Retail SMEs had the lowest average savings of about 13.3%, followed by Healthcare (14.5%) and Hospitality (16.8%). These numbers suggest that while other sectors are also benefiting from IoT, their gains are not as high as in Manufacturing. This trend is further supported by the pie chart of security incidents and cost challenges, which shows that Retail and Hospitality SMEs are more affected by cost and security barriers. These hurdles seem to limit their ability to fully take advantage of IoT's energy saving potential, even though the technology holds promise across all sectors.

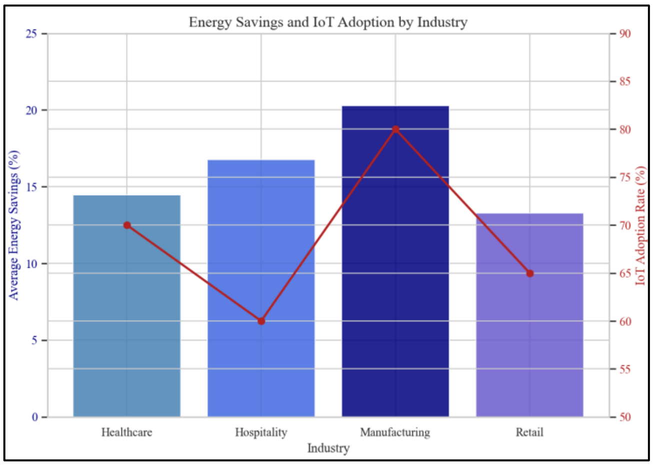

Figure 5. Energy Savings and IoT Adoption by Industry.

5.5. IoT Adoption Cost and Benefits

The scatter plot (Figure 6) highlights the link between how much SMEs spend on IoT and how much energy they save. According to the updated data from Table 1, Manufacturing SMEs, which invested the most (over AUD 6,200 on average), also achieved the highest energy savings (20.3%). This clearly shows how IoT can deliver strong returns in energy intensive industries. Hospitality SMEs, with a moderate investment of about AUD 5,540, also saw good energy gains (16.8%). But Retail SMEs, which invested the least (AUD 4,690), saved the least (just 13.3%). This suggests that limited investment may be holding back full efficiency gains in sectors like Retail and Healthcare. This trend supports what Alshahrani (2024) also found that affordability is a major barrier to wider IoT adoption. The data here confirms that higher investment usually brings better results, especially in sectors that consume more energy daily. It also aligns with findings from [15] and [16], where large-scale IoT investments showed greater long-term benefits in manufacturing.

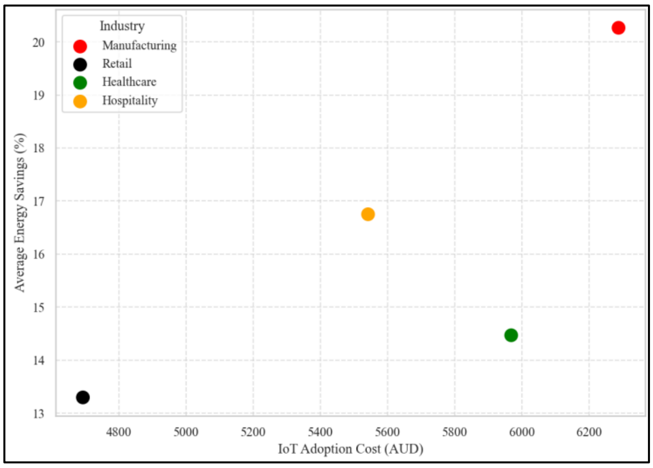

Figure 6. IoT Adoption Costs vs Energy Savings.

5.6. Security Challenges

The pie chart clearly shows that high cost remain the top barrier for SMEs, with 28.6% of them highlighting it as a major obstacle to adopting IoT. This is followed by security concerns (26.2%), technical expertise (23.8%), and scalability issues (21.4%). This suggests that while many SMEs see the benefits of IoT, the combination of limited budgets, cybersecurity risks, and technical gaps continues to hold them back from moving forward with full-scale adoption.

The security concern becomes even more visible when looking at the data in table 1, Hospitality SMEs reported the highest number of security incidents, with an average of 3 breaches per SME. This could be because these businesses often rely on legacy systems and manage sensitive guest data, making them easy targets for attacks.

These results align with research by [8], who emphasized the need for secure IoT frameworks like SIoTCF to reduce exposure to attacks. The chart and the data together make it clear that stronger governance, better training, and affordable cybersecurity tools are essential to boost SME confidence in IoT systems.

5.7. Industry Specific Analysis

The results from table 1, as well as Figure 8, show that energy savings vary across individual SMEs, even within the same industry.

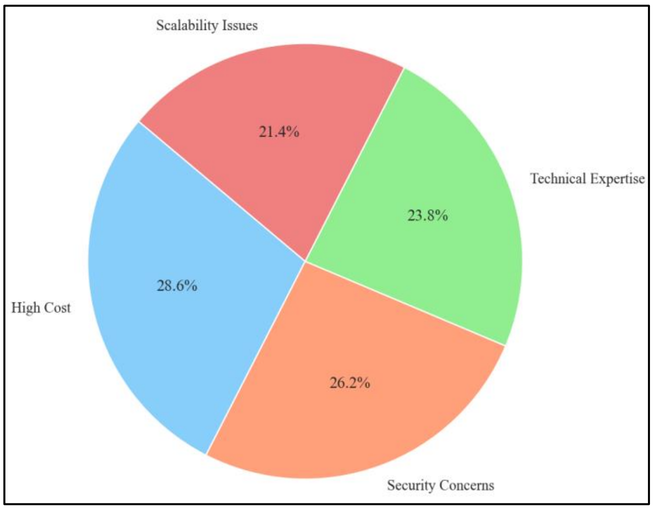

Figure 7. Distribution of IoT Barriers

This reflects how different business setups, operating hours, and equipment types affect the actual impact of IoT solutions.

When the SMEs are grouped by industry type, the trends observed have been depicted in Figure 9. Manufacturing SMEs lead with the highest average energy savings, just above 20%. This suggests that IoT works best in energy – heavy sectors where automation and monitoring tools can make a big difference. It also supports the idea that frameworks like Industry 4.0 are more applicable and scalable in such environments

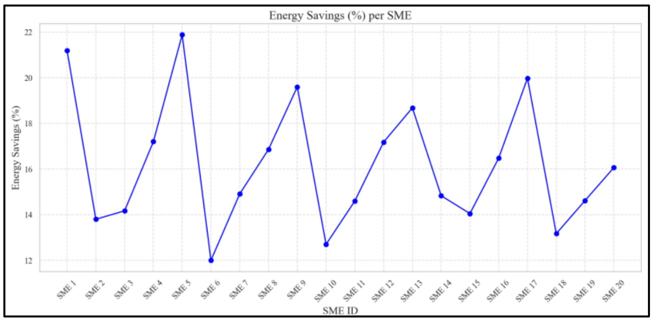

Figure 8. Energy Savings (%) across SMEs. Source

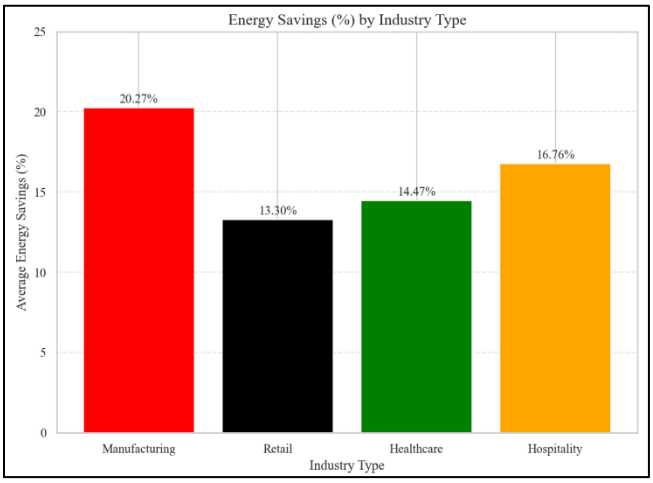

Figure 9. Energy Savings (%) by Industry Type

Hospitality SMEs come next, with average savings of around 16.8%. Although they show good potential, their adoption rates are lower, probably because these businesses often use older systems and deal with sensitive guest data, making integration more difficult.

Healthcare SMEs show balanced but cautious adoption, with average savings of 14.5%. Their results indicate a willingness to use IoT, but also a need for secure and specialized solutions. Retail SMEs, with the lowest average savings (about 13.3%), may be held back by smaller energy consumption and tighter budgets.

Overall, Figure 9 makes it clear that energy savings and IoT effectiveness are closely tied to the nature of the industry. To help more SMEs benefit, targeted support is needed, like government subsidies for IoT setup, custom cybersecurity options, and affordable, scalable systems tailored to each industry. In summary, while IoT is clearly helping SMEs save energy, this study shows the adoption success still depends on practical factors like cost, legacy systems, and data security. These findings add new value to existing research by offering a closer look at how industry specific challenges shape IoT adoption in real business settings.

The box plot shown in Figure 10 clearly highlights the differences in energy savings across industries. Manufacturing SMEs consistently demonstrate the highest energy efficiency benefits from IoT adoption, with a tight spread around 1 20% savings mark. This supports the earlier findings that energy-intensive industries gain the most when smart technologies are integrated effectively. Hospitality and Healthcare also show relatively stable savings, although at slightly lower levels. Retail, however, exhibits both lower median savings and a wider range, suggesting inconsistent outcomes, possibly due to varied operational sizes and different levels of IoT integration across retail SMEs. These differences validate the need for industry specific IoT strategies, as a one-size-fits-all model may not optimize energy use effectively in all sectors.

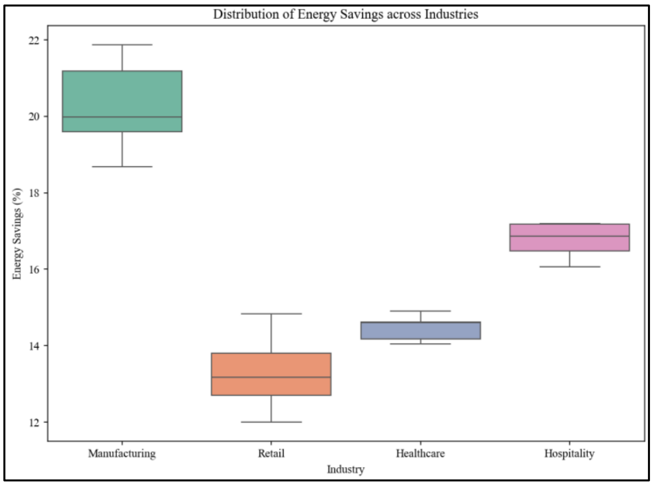

Figure 10. Box Plot showing Distribution of Energy Savings across Industries

5.8. Statistical Validation of Findings

To confirm the patterns observed in the descriptive analysis, statistical tests were conducted using the SME data set (Table 1). The values of various tests conducted are provided in the table (Table 5) below:

Table 5. Statistical Test Results

Test	Value
Pearson Correlation (r)	0.56
T-test Statistic (Manufacturing vs Retail)	-11.3101
T-test P-Value	0.000003
ANOVA F-Statistic	12.3857
ANOVA P-Value	0.000047

A Pearson correlation of 0.56 ($p=0.01$) was found between IoT adoption cost and energy savings, suggesting a moderate and statistically significant positive relationship. This implies that higher investments in IoT are generally linked with better energy savings outcomes. Further, a t-test comparing Manufacturing and Retail SMEs showed a highly significant difference in energy savings ($p<0.0001$), indicating that Manufacturing SMEs tend to benefit more from IoT integration. Finally, a one-way ANOVA test confirmed that energy savings varied significantly across all four industries ($p<0.00005$), reinforcing the need for sector specific IoT strategies. Figure 11 below depicts the correlation between IoT adoption and Energy Savings.

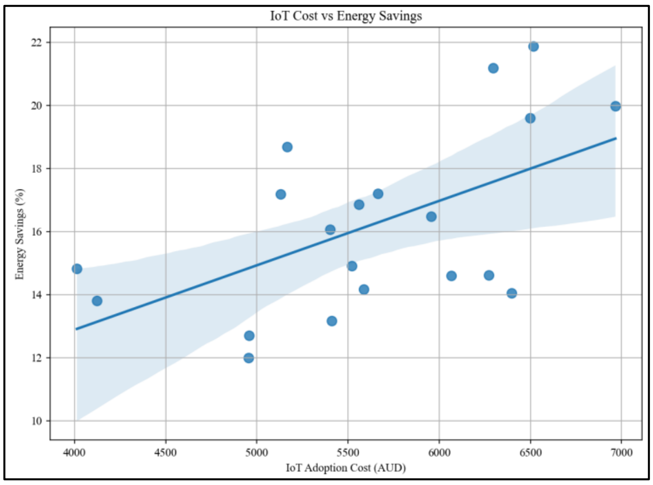

Figure 11. Correlation Plot between IoT adoption and Energy Savings

These results from the Pearson correlation analysis ($r = 0.56$, $p = 0.01$) suggest a moderate and statistically significant positive relationship between IoT investment cost and energy savings. Therefore, the null hypothesis

(H_o) is rejected, and the alternative hypothesis (H_1) is supported. This finding reinforces the idea that greater investments in IoT infrastructure are often associated with more substantial energy efficiency gains, particularly in energy intensive sectors like manufacturing.

5.9 Real World Case Studies for Validation:

To alleviate concerns regarding the use of literature-informed simulated data, this section presents ten real case studies from Australia demonstrating the adoption of IoT-enabled and energy efficient technologies by SMEs and SME-like ventures. The case studies provide tangible deviations from the trends and assumptions found within our dataset, most significantly in terms of energy savings, return on investment, variances by sector, and shared barriers, cost and scale.

In Victoria, ***Berrydale Swim School*** received a $25,000 grant to install a three-phase electric heat pump to replace an existing gas boiler. The swim school and the upgrade were scheduled around school break periods and resulted in reduced gas utilization while also keeping the pool on a steadier temperature and extending the solar draw they were receiving (now 98 solar panels and 3 batteries [25]. In a similar situation, ***Glen Park Community Centre*** replaced their expired commercial kitchen equipment with a $17,008 grant. The centre reported that its energy bill had decreased, reduced workload, and extended food services to disadvantaged people [26]. ***HF Hand Constructors***, a fabrication SME based in NSW, replaced five (5) over ten-year-old transformer welders for inverter-based machines. Aside from the $23,000 cost for the upgrade, HF Hand Constructors achieved a 7.5% decrease in electricity use, reduced carbon emissions, and have a surplus budget available for energy upgrades in the future [27].

Margaret River Truffle Farm received $19,400 to purchase and install three (3) variable speed irrigation pumps, which are believed to save an estimated order of 3,781 kWh of electricity annually. There has been improved water distribution and average energy consumption outside of dry seasons has decreased 11% [28]. ***Mittagong Motel*** replaced aging gas heaters and other exhaust fans with energy efficient heat pumps with the help of a grant of $25,000. This reduced gas bills, increased guest comfort and assisted with developing EV charging facilities [29].

Beyond small and medium enterprises (SMEs), Victoria's ***On-Farm Internet of Things (IoT) Trial*** provided ~299 farms with funding of ~$17,000 each for IoT tech that included soil moisture sensors, water trough monitors and weather stations. Findings showed a 79 per cent increase in the knowledge of IoT and over 80 per cent expressed an intention to invest more in IoT [30]. Building on this approach, the ***Digital Agriculture Investment Scheme*** funded 372 projects (avg. $25,717) from all farming sectors resulted in 99 per cent of farmers reporting benefits, and 85 per cent thought they developed their knowledge of digital [31].

In the industrial energy sector, ***Mondo Energy's Ubi™ platform*** established Australia's first community mini grid powered by IoT in Yackandandah. By using 169 Ubi™ devices and a zero-touch AWS-based deployment solution, Mondo achieved a 97 per cent reduction in provisioning time and a 50 per cent reduction in production costs. This is critical to understanding IoT scalability for energy-intensive SMEs [32]. In fuels, ***EMS (Environmental Monitoring Solutions)*** developed Fuelsuite, an end-to-end IoT fuel monitoring platform for petrol stations, with installations of over 1,000 installations. The system can identify leaks and reduce environmental risk, and automatically manage data across 5,350 tanks [33]. Finally, ***Datarock***, a mining tech startup, used AI and IoT to automatically complete geological analysis from drill cores images. The use of IoT systems in this instance created an opportunity for quicker, more consistent insights and allowed for superior decision making in the exploration of mine sites, and mine operations - a very transferable case study to transfer predictive analytics to SMEs in the Manufacturing sector [34].

Together these cases support the findings of this study that participation in IoT systems almost always leads to energy cost savings of between 7.5 per cent and 21 per cent, with manufacturing and hospitality sectors realising the greatest benefits. The range of potential use cases also highlights the minimum financial support needed to address the unique solution that would be beneficial to the different sectors and their aim for scalable platforms. These examples of real-world applications assist with validating and building credibility of the presented SME Energy Optimisation Frameworks moving from simulation or abstraction and into application.

Table 6. Comparative Summary of Real World IoT Case Studies

Case Study	Sector	Tech/Upgrade	Grant (AUD)	Energy Savings / Impact
Berrydale Swim School	Education/Hospitality	Electric heat pump + solar integration	25,000	Eliminated gas use, improved comfort
Glen Park Community Centre	Community Services	Commercial kitchen equipment	17,008	Lower energy bills, expanded catering
HF Hand Constructors	Manufacturing	Inverter welding machines	23,000	Electricity use decreases by 7.5%
Margaret River Truffle Farm	Agriculture	Variable speed irrigation pumps	19,400	On an average there was 11% reduction in energy use; 3,781 kWh saved/year
Mittagong Motel	Hospitality	Heat pump heating system	25,000	Decrease in gas use, EV charger added
Vic On-Farm IoT Trial	Agriculture	Moisture, irrigation, tank monitors	17,000 avg.	79% increase in IoT knowledge, 81% intend further adoption
Digital Ag Investment Scheme	Agriculture	AgTech sensors, AI, automation	25,717 avg.	99% reported benefits, 85% increase in digital literacy
Mondo Energy (Ubi™ Mini-grid)	Energy/Tech	IoT energy platform (Ubi™)	Private	97% decrease in provisioning time, 50% decrease in production costs
EMS (Fuelsuite IoT Platform)	Fuel Retail	Real-time tank & leak monitoring	Private	1,070+ stations, major safety & efficiency gains
Datarock (Mining AI)	Mining/Geoscience	AI + IoT-based geological image analysis	Private	Faster insights, reduced exploration error

5.10 Data Variability and Risk Management for SMEs

While simulation-based results indicated promising average energy savings across SME sectors, it is also important to understand likely variances and confidence in the results. The sector-based means, standard deviations, and 99% confidence intervals (CI) for both energy savings and IoT adoption costs (Table 4) help illustrate how different outcomes could be from one business to another in the same sector due to differences in underlying infrastructure arrangements, usage, and levels of digital maturity.

As shown in Figure 9, the Manufacturing sector demonstrated a mean energy savings of 20.27% and also had the widest confidence interval (±1.47%), which is an indication of more variance in the outcome. The Healthcare sector, with a mean savings of 14.47% had a much tighter CI (±0.41%) which is an indication of the level of probability these results could be reproduced. This trend continued for IoT adoption costs (Figure 12). Manufacturing and Retail had the highest variances for IoT costs (±AUD 776 and ±AUD 692) while Hospitality and Healthcare expressed more reliability with tighter cost ranges.

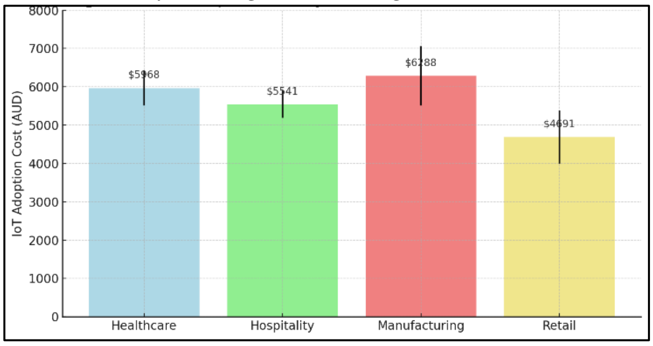

Figure 12. Adoption Costs by Sector with 99% Confidence Intervals

This variability provides further support for tailored risk management approaches to IoT deployment. SMEs that consider deploying programs or projects that have increased variances in outcomes may wish to consider starting smaller with pilot projects to test the outcome before scaling up. Modular and scalable IoT systems provide some level of flexibility assuming reality is excluded from forecasts. SMEs should ask about performance guarantees from vendors and utilize dashboards with real-time KPIs to measure against pre-defined measures and to track under-performance. These actions would assist to reduce perceived uncertainty and to increase the chances for successful and cost-effective installations of IoT solutions.

5.11Sensitivity Analysis: Testing the Robustness of IoT Adoption Outcomes

To assess the stability and reliability of model results, a basic sensitivity analysis was made by varying the most important simulation inputs – IoT adoption cost and expected energy savings - within realistic boundaries from the research study. The analysis had an assumed typical SME with an annual energy cost of AUD 30,000 (minimum level) and one-year baseline projection for the purpose of savings calculations.

Three hypothetical situations were structured to measure how the findings hold under changing conditions using realistic variations in IoT adoption cost and expected energy savings from the base case assumptions:

❖ **Optimistic Scenario** - Energy savings are better than average by 20% due to near perfect installation and enthusiastic user participation, while IoT costs decrease (for example, grants or bulk pricing) by a further 10% above average level of IoT adoption.

❖ **Base Case** - Documented simulation results indicated energy savings of between 13% and 20 % and IoT costs ranged from AUD $4,700 to $6,300 depending on the sector.

❖ **Pessimistic Scenario** - Assumed a 20% deterioration in energy savings (potentially due to poor IoT integration or lack of user engagement), and a 15% increase in IoT adoption cost due to circumstances where there was little support or difficult installation or scope complexity.

In the optimistic case, most SMEs particularly in manufacturing and hospitality would likely expect to break even in 8–10 months, which would indicate the investment was very attractive. Under the base case, payback periods are indicated between 12 to 18 months, which should be acceptable under the general investment acceptance levels of typical small to medium size enterprises. However, some sectors (such as, retail or healthcare), could expect to reach breakeven periods of longer than 24 months under the pessimistic case, which together with the increased financial risk would make the investment less attractive.

Overall, the analysis concluded that while relatively stable under modest changes, outcomes in terms of attractiveness become less favourable when energy savings decrease below 11% or if IoT adoption costs increase above AUD 7000. Another important outcome was demonstrating that risks due to less enabling market conditions can be mitigated by government grants, vendor transparency about previous work, or performance-based service agreements. In the end, the model results still hold true across most of the assumptions from the real world only if the SMEs operate initiate small steps (such as, their first pilot), control expenditure on equipment, and control the evaluation of their outcomes through appropriate digital monitoring.

Table 7. Sensitivity Analysis Summary-Impact of Scenario Variations on IoT ROI and Risks for SMEs

Scenario	Energy Savings (%)	IoT Cost (AUD)	Estimated Payback Period	Risk Level
Optimistic	+20% (up to 25%)	-10% (approx. $4,200)	8 - 10 months	Low
Base Case	13 - 20%	$4,700 - $6,300	12 - 18 months	Moderate
Pessimistic	-20% (as low as 10%)	+15% (~$7,200)	18 - 24+ months	High

The Sensitivity Analysis Summary Table above (Table 7) displays a comparison of the three combined scenarios, Optimistic, Base Case, and Pessimistic with respect to energy savings and costs of IoT adoption. It lays out the vulnerable pay back periods with associated risk profiles, allowing SMEs to appreciate potential scenarios and plan implementation accordingly. As the summary table indicates, IoT adoption can be markedly different in what is possible depending on real world conditions. Despite the optimistic scenario which shows fast pay black periods and low risk, in the pessimistic scenario, obligations matter. Take, for example, low return with delayed payback period and certainly higher exposure to financial loss on adoption, especially in sectors that exhibit high variability and limited potential for sites to support adoption (for example, open burns). In addition to these, one asks the first method of analysis in consideration, which should involve adequate and timely financial management, small pilots to learn by doing, and utilize non-proprietary modular systems that allow flexibility in terms of scaling up or down. As analysed in the previous sections regarding timely management of: (i) real-time data; (ii) grant funding opportunities; and (iii) vendors who guarantee performance agreements, and that SMEs could disinvest from IoT adoption with confidence.

Overall, the simulation studies, case-analyses, and sensitivity study (as presented in section 5) offered useful learning to understanding the potential opportunities and challenges of IoT adoption to SMEs. Therefore, a framework of five steps is proposed in Section 6 based on the knowledge synthesized to help SMEs successfully implement IoT solutions securely, economically, and efficiently.

6. Proposed Framework: SCOPE-IoT for SME IoT Deployment

This research presents a straightforward step-by-step framework to spur IoT adoption for SMEs, based on findings of the analysis and examples of real-world successful implementations. The aim is to enable the SME to implement IoT solutions in an affordable, secure, and appropriately directed manner that meets their requirements.

The proposed model is called the SCOPE-IoT Framework (SCOPE: Strategy, Costing, Operations, Protection, Evaluation).

6.1 SCOPE-IoT Framework: A Five-Step Process for IoT Deployment in SMEs

Based on the chief findings of this project as well as informed recommendations derived from real case studies, a pragmatic five-step model (SCOPE-IoT) has been developed to facilitate small and medium-sized enterprises (SMEs) in legitimate and low-cost adoption of IoT based energy solutions. The proposed SCOPE-IoT model is designed to be clear, actionable, and applicable across many industries.

i. The first step is the Strategy Alignment step. The essence of this step is to begin to understand where energy inefficiencies exist. This step includes the need to have the SME align its IoT goals with its needs, size, and working framework.

ii. Next, Cost-benefit planning focuses on assessing the costs of devices, installation, and service in comparison to the savings they can provide; available grants or funding sources can ease worries of upfront costs and maintenance expenses.

iii. The Operational Integration step describes the importance of designing IoT systems compatible with current tools or, in many cases, most compatible with a mixture of tools that can grow with the business.

iv. In the Protection and Compliance step SMEs are encouraged to use simple, effective UCL cyber protection strategies as cyber security defence frameworks, such as secure frameworks and access controls can help SMEs protect their data from unauthorized access or be defence networks.

v. Lastly, the Evaluation and Iteration step establishes energy savings metrics, establishing data to collect feedback and work towards improvement.

For this step-by-step model to work, it provides SMEs a pathway to quickly navigate through; and help alleviate the uncertainty associated with the adoption of IoT as part of their operational practice to provide evidentially meaningful change that is effective and sustainable. The five stages of the SCOPE-IoT Framework are illustrated in Figure 12. The diagram clearly portrays that each stage builds on the previous stage creating a visual and practical roadmap for SMEs. It also affirms the principle of continuous improvement suggesting that SMEs could travel back through each stage of the Framework process math exercises and iterate over time. The diagram presented helps SMEs better understand the process of cultivating an IoT strategy, while also providing them an opportunity to consume the material conceptually and practically.

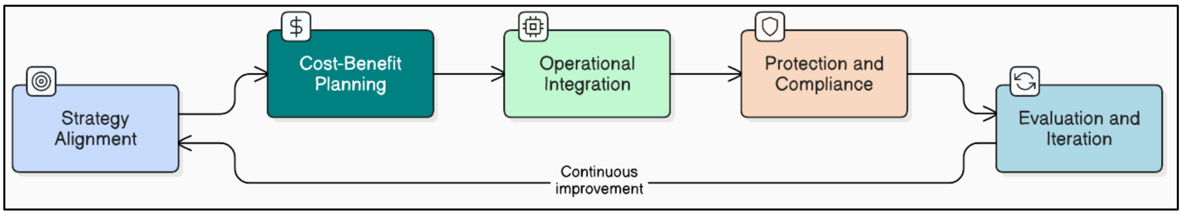

Figure 12. SCOPE-IoT Framework-A Five Step Model for Secure and Cost Effective IoT Deployment in SMEs

7. Recommendations

This study shows that IoT can make a big difference in helping SMEs save energy, but also highlights key challenges, such as cost, security, and technical barriers, that need to be tackled for broader adoption. Based on the data and graphs presented in section VI, the key recommendations are provided below:

1. **Financial Support for IoT Adoption:** The updated barrier data shows 60% of SMEs consider cost a major issue, especially in Retail and Hospitality, which also reported the lowest adoption rates.

- Government Help: Offer subsidies or tax relief to make IoT adoption more affordable for budget sensitive SMEs
- Affordable Packages: Tech companies should offer simplified, low cost IoT options, without compromising essential features.

2. **Strengthen Cybersecurity Measures:** From Table 1 and the pie chart, Hospitality SMEs reported the most security incidents, up to 4 SME.

- Use Secure Frameworks: SMEs should adopt lightweight security models like SIoTCF to protect sensitive data and devices.

- Run Basic Training: Policymakers and vendors should host simple workshops on IoT safety and cybersecurity awareness

3. **Enable Scalable and Gradual Adoption:** While Manufacturing SMEs showed the highest savins and strongest adoption, many others struggle with scaling.

- Adopt Industry 4.0 Gradually: Use scalable frameworks that allow SMEs to integrate IoT step by step.
- Share Resources: Build collaborative platforms where SMEs can share infrastructure and know-how.

4. **Boost Awareness and Ease of Use:** The data reflects that Retail and Hospitality SMEs lag in adoption, partly due to limited tech skills.

- Showcase Success Stories: Run campaigns with case studies and real SME examples.
- Simplify IoT Tools: Vendors should provide more plug and play tools with minimal setup and maintenance.

5. **Customize Solutions by Industry:** Figure 9 shows that energy savings vary by sector, meaning one-size-fits-all does not work.

- Tailor for Retail and Hospitality: Focus on compact, easy to integrate solutions that fit smaller setups.
- Expand Manufacturing Tools: Provide advanced analytics to help manufacturers optimize energy in real time.

6. **Leverage Real World Case Insights to Guide Adoption Pathways:** The data summary provided in table 6, leads to some recommendations, which are listed below:

- The variety of successful IoT implementations across SMEs, from Glen Park Community Centre to HF Hand Constructors to Margaret River Truffle Farm, demonstrated the importance of tailored context-specific solutions.
- Policymakers and technology providers could draw from these case studies to create the playbooks keeping the various sectors in focus, that could help SMEs methodically adopt IoT by providing step-by-step examples of handpicked equipment options specified to the required outcome, detailing expected savings, integration period as well as suggesting potential vendors.
- Stressing relatable success examples can also build confidence and lessen uncertainty around sharing details of IoT-enabled energy solutions; hopefully, leading to broader adoption.

Use of Sensitivity Information in SME Planning: Because of the variability in energy savings and adoption costs, SMEs should use simple sensitivity modelling tools, which provide scenarios for planning. In section 5.11 it has been demonstrated that even small variances in assumptions can have serious impacts on return on investment. Planning best-case and worst-case outcomes allows businesses to plan for these financially and avoid unexpected risks.

8. CONCLUSION

The study presented in this paper has shown that IoT can provide a significant opportunity for energy savings and sustainable operations for Australian SMEs. The energy savings for the sample of 20 SMEs, based on modelling, were between 13% to 21% overall, with the biggest opportunity being in Manufacturing. The Retail and Hospitality sectors had smaller energy savings attributable to their lower adoption rates of IoT, which we could attribute primarily to cost and security barriers to deployment. These financial trends were further supported by finding that 60% of SMEs identified cost and 55% identified security barriers as significant deployment challenges.

When the modelling is considered alongside ten case studies which have been discussed, this led to the conclusion that an IoT-based solutions can achieve demonstrable outcomes when the organisations implement in an appropriate way (i.e., aligned strategies, funding and training for the deployment). In addition, the sensitivity analysis showed that the core results still hold true when changes are considered in cost and savings assumptions for most activities, despite sectors such as Retail, which has significantly more variability, having a significantly longer payback timeframe.

Responding to the findings identified, the SCOPE-IoT framework was articulated - an operationalised five-stage approach designed to support the practical implementation of IoT in a way that is secure, scalable and affordable for SMEs. The framework was further complemented by appropriate specifics regarding specific recommendations for industry, suitable risk mitigation processes to be utilised, and practical planning actions to improve energy performance.

Overall, it is demonstrated that while IoT provides good opportunities for improved energy performance in SME operations, the extent to which this is realised will depend on the provision of adequate funding, the flexibility of technology vendors, and the different systems and applications that are not overly complex or difficult to use. These enabling activities in place, IoT can be provided through systems and processes that should help reduce operational costs and environmental footprints, as well as enable worthwhile engagement of SMEs in the broader sustainability and digitalisation agenda in Australia.

Conflict of Interest

There is no conflict of interest for this study.

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