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Evaluation of Performance of the Developed Solar-Powered Portable Multi-Gas Detector Device

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Abstract

Aim: This study aims to evaluate a solar-powered portable multi-gas detector device developed to enhance environmental monitoring and ensure safety in industrial and field settings. The evaluation focused on functionality, accuracy, detection range, cost, reliability, consistency, and compliance with safety standards. The device integrates sensors that detect carbon monoxide (CO), methane (CH_4), and hydrogen sulfide (H_2S) and is powered by solar energy to promote sustainability and portability.

Methodology: A descriptive-evaluative research design with a quantitative approach was employed. Seventeen experts with academic or technical backgrounds in Electronics, Engineering, or Industrial Technology assessed the prototype using a structured evaluation tool. The instrument, based on a 5-point Likert scale, measured six performance parameters. Due to the small sample size, the median was used to describe the device's overall performance.

Results: The developed gas detector received consistently high ratings across all parameters, demonstrating strong functionality, high accuracy, wide detection range, cost efficiency, reliability, and compliance with safety standards. These results indicate that the device performs effectively and meets the essential requirements for safety and environmental monitoring applications.

Conclusion: The developed device addresses the limitations of conventional gas detectors by combining renewable energy, multi-gas detection, and real-time monitoring in a compact, stand-alone design. Its solar-powered system ensures continuous, sustainable, and cost-effective operation, making it ideal for remote or off-grid areas. Furthermore, its eco-friendly build minimizes electronic waste and carbon emissions, while the real-time alert system enhances safety in high-risk environments.

Keywords: *solar-powered device, multi-gas detector, environmental monitoring, portable sensor, safety technology*

INTRODUCTION

As industrialization and urbanization continue to accelerate, the use of various gases in manufacturing, energy, and domestic applications has increased dramatically. However, gas leakage or excessive concentrations can cause life-threatening accidents and severe property damage. Industrial environments are especially vulnerable due to the presence of hazardous gases such as carbon monoxide (CO), methane (CH_4), hydrogen sulfide (H_2S), and volatile organic compounds (VOCs) (Rashid et al., 2024). The growing prevalence of toxic gas exposure in industrial, environmental, and occupational settings underscores the urgent need for reliable, portable, and energy-efficient gas detection systems.

Globally, occupational safety remains a pressing concern. The International Labour Organization (ILO, 2019) estimates that 2.78 million workers die annually from work-related accidents and diseases, with gas inhalation being one of the primary causes. This alarming statistic emphasizes the necessity of real-time gas monitoring systems that can safeguard workers and prevent industrial disasters. The challenge is particularly acute in sectors such as mining, oil and gas extraction, construction, and waste management, where exposure to toxic gases is frequent and potentially fatal.

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Compounding this problem is the lack of access to stable electricity in many hazardous or remote work environments. According to the World Bank (2021), approximately 733 million people worldwide still live without electricity, especially in rural and industrial areas of developing nations. Conventional gas detectors—often dependent on grid power or disposable batteries—are therefore impractical in these contexts. A solar-powered portable detector presents an innovative solution by ensuring uninterrupted operation through renewable energy, making it suitable for deployment in isolated, disaster-prone, or resource-limited areas.

Environmental sustainability adds another dimension to the significance of multi-gas detection systems. Methane, for instance, is a greenhouse gas with a global warming potential 84 times greater than that of carbon dioxide over a 20-year period. The United Nations Environment Programme (UNEP, 2022) highlights methane reduction as one of the most effective strategies to mitigate climate change. By enabling early detection of leaks, a portable multi-gas detector directly contributes to climate mitigation, disaster prevention, and environmental protection.

In compliance with occupational health and safety regulations, agencies such as the U.S. Occupational Safety and Health Administration (OSHA) require continuous monitoring of hazardous gases in confined spaces, as stated in OSHA Standard 1910.146(c)(5). A portable, solar-powered multi-gas detector thus aligns with global safety standards, promoting proactive risk management and reducing occupational hazards while ensuring regulatory compliance.

Despite the availability of commercial gas detectors, current technologies exhibit notable limitations. Many existing models are bulky, limited to detecting a single gas, and constrained by short battery life and high energy consumption. Bhattacharya and Paul (2020) identified a technological gap in the development of compact, energy-efficient, and multi-functional gas-sensing devices. This gap underscores the necessity for innovative detectors that combine high performance, portability, and sustainable operation.

In the Philippine context, the problem is equally significant. Bagares et al. (2023) reported that carbon monoxide (CO) poisoning remains a critical health risk, leading to dizziness, headaches, and even death. Fire incidents, often exacerbated by undetected gas leaks, account for over 75% of fire-related emergencies in residential areas in Manila (Varsitarian.net, 2021). Furthermore, in Eastern and Central Visayas, communities relying on biomass, kerosene, or charcoal for daily use are exposed to hazardous gases within poorly ventilated spaces. Reports from the Department of Health–Eastern Visayas Center for Health Development (DOH–EVCHD) and the Environmental Management Bureau (EMB) affirm that air pollution continues to pose serious health and environmental challenges in the region.

These global and local realities establish the necessity for a reliable and sustainable gas detection system, especially one adaptable to Philippine conditions. The present study addresses this gap by evaluating a solar-powered portable multi-gas detector device designed to provide continuous, cost-effective, and environmentally friendly monitoring in both industrial and domestic settings such as homes, school laboratories, and boarding houses.

Recent advancements in gas-sensing technologies further justify this development. Catalytic bead sensors, commonly used for detecting combustible gases, exhibit high sensitivity but suffer from poisoning and energy inefficiency (NevadaNano, 2023; MSA Safety, 2024). Nondispersive infrared (NDIR) sensors, while accurate and long-lasting, are affected by humidity and temperature fluctuations (Industrial Scientific, 2023; Pluto Detectors, 2024). Electrochemical sensors, on the other hand, offer high selectivity and sensitivity at low concentrations, particularly with the integration of nanomaterials and advanced electrode architectures (Bhattacharya & Paul, 2020; Cvetković et al., 2024; Pătru et al., 2025).

By integrating these sensor technologies into a solar-powered platform, the developed device ensures sustainable operation, real-time monitoring, and multi-gas detection capabilities. This integration not only bridges the technological gap in existing detectors but also represents a novel contribution to the fields of occupational safety, environmental monitoring, and renewable energy utilization. The innovation lies in combining energy autonomy, portability, and multi-sensor capability—a synthesis that enhances safety and environmental sustainability while addressing the distinct needs of resource-limited communities in the Philippines and beyond.

Theoretical Framework

The development and evaluation of the solar-powered portable multi-gas detector device are grounded in three interrelated theoretical foundations: the Technology Acceptance Model (TAM) (Davis, 1989), Systems Theory(Bertalanffy, 1968), and the Diffusion of Innovations Theory (Rogers, 2003). Each theory provides a distinct yet complementary perspective on the design, implementation, and social relevance of the developed technology.

The Technology Acceptance Model (TAM) explains how perceived usefulness and perceived ease of use influence the acceptance of technological innovations. In this study, TAM guides the assessment of the device's usability and potential adoption by industry practitioners, students, and local communities. The solar-powered detector's

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portability, reliability, and ease of operation directly affect users' willingness to utilize it in various field applications, reflecting TAM's emphasis on behavioral intention toward technology acceptance.

Systems Theory (Bertalanffy, 1968) views the developed detector as an interconnected system composed of subsystems—solar power generation, gas sensing, signal processing, and alert mechanisms—working cohesively to achieve the overarching goal of safety monitoring. The integration of renewable energy, electronics, and data systems exemplifies the interdependence of components necessary for system stability and sustainability. This theoretical lens ensures that the device is not seen as an isolated instrument but as part of a broader socio-technical ecosystem involving users, energy systems, and environmental safety networks.

Finally, Diffusion of Innovations Theory (Rogers, 2003) elucidates how new technologies are communicated and adopted within a social system. It frames how the developed multi-gas detector can be introduced, accepted, and scaled among industrial, educational, and community users. The innovation's relative advantage—renewable power, portability, and multi-gas detection—positions it for wider dissemination and long-term adoption, particularly in developing regions where safety technology accessibility remains limited.

By integrating these three frameworks, the study ensures that both the technical and social dimensions of innovation are addressed. TAM emphasizes user acceptance, Systems Theory underscores structural interdependence, and Diffusion of Innovations highlights the pathways for large-scale adoption. Together, they establish a solid theoretical foundation for developing and evaluating a sustainable, efficient, and socially relevant gas detection device.

Statement of the Problem

Environmental monitoring and industrial safety often rely on gas detection devices to identify hazardous gases such as carbon monoxide (CO), methane (CH_4), and hydrogen sulfide (H_2S). However, conventional gas detectors are typically limited by their dependency on electrical power sources, single-gas detection capability, and lack of portability, which hinder their application in remote or off-grid areas. These limitations pose safety risks for workers and communities exposed to potential gas leaks or contamination. Moreover, the increasing demand for sustainable and cost-effective safety technologies underscores the need for innovative, energy-efficient solutions. To address these gaps, this study developed a solar-powered portable multi-gas detector device designed to integrate renewable energy technology with multi-gas detection capability. The study specifically evaluates the device's performance in terms of functionality, accuracy, detection range, cost, reliability and consistency, and compliance with safety standards to determine its suitability for environmental and industrial safety monitoring.

Research Objectives

General Objective:

To evaluate the performance of the developed solar-powered portable multi-gas detector device designed for environmental and industrial safety applications.

Specific Objectives:

1. To assess the functionality of the developed solar-powered portable multi-gas detector device.
2. To determine the accuracy of the device in detecting multiple hazardous gases such as CO, CH_4, and H_2S.
3. To examine the detection range of the device in varied environmental settings.
4. To evaluate the cost-effectiveness of the developed device compared to conventional gas detectors.
5. To determine the reliability and consistency of the device during operation.
6. To assess the level of compliance of the developed device with safety and environmental standards.
7. To provide recommendations for improvement and future applications based on the evaluation findings.

Research Questions

1. What is the performance of the developed solar-powered portable multi-gas detector device in terms of:
   1.1 Functionality;
   1.2 Accuracy;
   1.3 Detection range;
   1.4 Cost;
   1.5 Reliability and consistency; and
   1.6 Compliance with safety standards?
2. What recommendations can be formulated based on the findings of the evaluation of the developed device?

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METHODS

Research Design

The study employed a descriptive-evaluative research design rather than an experimental or quasi-experimental approach, as the primary purpose was to assess the performance, functionality, and acceptability of the developed solar-powered portable multi-gas detector device, rather than to establish cause-and-effect relationships. The descriptive-evaluative design is most suitable when the focus is on documenting, analyzing, and interpreting the characteristics, quality, and efficiency of a developed product or innovation in its actual context of use.

Unlike experimental and quasi-experimental designs, which manipulate variables and require control and treatment groups, the current study does not aim to compare the device against alternative interventions under controlled conditions. Instead, it sought to determine whether the developed device meets specific performance criteria, such as functionality, accuracy, detection range, cost, reliability, consistency, and compliance with safety standards. The evaluative component provides systematic judgment about the merits and effectiveness of the device based on predetermined standards and expert or user assessments.

Population and Sampling

The developed solar-powered portable multi-gas detector device was evaluated by 17 purposefully chosen experts from two universities in Eastern Visayas. The experts were selected based on their academic or technical backgrounds in Electronics, Engineering, Industrial Technology, or related disciplines, and their willingness to participate in the study. Purposive sampling ensured that only individuals with adequate technical competence and familiarity with instrumentation systems could provide credible evaluations. Purposeful expert selection has been emphasized in prior research as crucial for ensuring validity in evaluative and descriptive inquiries (Carvajal et al., 2025; Bontuyan, 2025).

Instrument

The indicators included in the evaluation instrument were carefully developed based on established international standards and guidelines. Usability-related items were informed by the ISO 9241-11 standard, which outlines ergonomic principles for human-system interaction (International Organization for Standardization [ISO], 2018). Indicators related to gas detection accuracy, reliability, and range were guided by technical standards such as IEC 60079-29-1 (International Electrotechnical Commission [IEC], 2015) and recommendations from the National Institute for Occupational Safety and Health (NIOSH, 2020). In addition, best practices and performance benchmarks from reputable sources, including the Occupational Safety and Health Administration (OSHA, 2012) and ESPM SENSE (2023), were consulted to ensure the instrument's relevance, technical accuracy, and alignment with industry expectations.

To ensure the validity and reliability of the instrument, a panel of three experts was selected based on their professional expertise in electronics and industrial technology. These experts reviewed the instrument for clarity, relevance, appropriateness of statements, and alignment with the objectives of the study. Pilot testing was then conducted to establish the reliability of the instrument, yielding a Cronbach's alpha coefficient of 0.82, which indicates internal consistency. This rigorous validation process aligns with research advocacy for sustained quality assurance and methodological transparency in empirical research.

Data Collection

A formal request letter was sent to the selected institutions and individuals, informing them about the purpose of the study and requesting their participation in the evaluation process. Data collection began immediately after the approval of the two universities involved in the study in July–August 2025.

Before distributing the evaluation instruments, an orientation session was conducted with each participant. During this session, the purpose and scope of the study were clearly explained; the functionality of the solar-powered multi-gas detector device was demonstrated; instructions for evaluating the device using the structured tool were provided; and participants were allowed to ask questions or clarify aspects of the device's features. This ensured that all respondents had firsthand exposure to the device before completing the evaluation form.

After the orientation, participants independently accomplished the structured evaluation tool, which contained Likert-scale items under each of the six evaluation parameters. The completed instruments were collected personally, checked for completeness and consistency, and encoded for analysis. Following standard research practices,

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clarity in communication, accurate documentation, and ethical conduct were maintained throughout the data-gathering process (Carvajal et al., 2024; Sanchez et al., 2024).

Treatment of Data

The data gathered from expert evaluations were analyzed using descriptive statistics, specifically the median (Md) and interquartile range (IQR), which are appropriate for ordinal data and small sample sizes. These measures were used to describe the evaluation parameters of the solar-powered portable multi-gas detector device in terms of functionality, accuracy, detection range, cost, reliability and consistency, and compliance with safety standards. The use of nonparametric descriptive tools was deemed suitable to ensure accurate interpretation without distortion caused by sample limitations. Statistical accuracy and responsible data handling are consistent with methodological principles promoted in the conduct of research.

Ethical Considerations

The study was submitted to the Ethics Review Committee of the university, and strictly adhered to ethical standards in conducting research involving human participants. All respondents were informed that participation was voluntary, and written informed consent was obtained. Participants were assured of confidentiality, and all data were used exclusively for academic purposes. Ethical transparency, informed participation, and data confidentiality are hallmarks of studies emphasizing researcher accountability and participant respect.

RESULTS and DISCUSSION

This section presents an evaluation of experts on the solar-powered, portable multi-gas detector device, assessing its functionality, accuracy, detection range, cost, reliability, consistency, and compliance with safety standards.

Performance of the Solar-Powered Portable Multi-Gas Detector Device

Tables 1-6 present the evaluation of the solar-powered portable multi-gas detector device by experts in terms of functionality, accuracy, detection range, cost, reliability, consistency, and compliance with safety standards.

Functionality. Table 1 presents the evaluation of the solar-powered, portable multi-gas detector device by experts, including its functionality. It was found that the Solar-Powered Portable Multi-Gas Detector Device was rated "highly functional" across all evaluated statements, with a consistent rating (Md=5,IQR=0) for each performance indicator.

Table 1. Evaluation of the Functionality Performance of the Solar-Powered Portable Multi-Gas Detector Device

	Statements	Median Score	Interpretation
1	The device is easy to operate and use.	5	Highly Functional
2	The device provides real-time gas monitoring effectively.	5	Highly Functional
3	The device is user-friendly and requires minimal technical knowledge.	5	Highly Functional
4	The solar-powered feature works efficiently and ensures continuous operation.	5	Highly Functional
5	The overall design of the user interface makes it easy to use in home, boarding house, and school shop laboratory settings.	5	Highly Functional
	Overall Median	**5**	Highly Functional
	IQR	**0**	No variability

Legend:
5 – Highly Functional
4 – Functional
3 – Moderately Functional
2 – Less Functional
1 – Not Functional

The evaluation results highlight the device's strong usability and efficiency. It achieved the highest ratings (Md = 5, IQR = 0) for ease of use, real-time gas monitoring, and user-friendliness, confirming its intuitive operation

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and suitability even for non-technical users. These findings align with studies emphasizing the importance of usability and minimal learning curves in technology acceptance, particularly in educational and community settings (Lopez et al., 2025; Ardito et al., 2006). Moreover, the solar-powered feature was rated highly functional, demonstrating its effectiveness in ensuring sustainability and reliability, especially in off-grid areas (Sharma et al., 2015).

Lastly, the statement regarding the device's suitability for various environments—homes, boarding houses, and school laboratories—also received a median score of 5. This suggests that the device is versatile and adaptable for different real-world applications. As stated by Albar and Jetter (2009), the contextual adaptability of technology increases its value and utility, especially in multi-use scenarios.

The results showed a strong consensus among the users regarding the device's functionality and user-centered design features. This indicates that the device meets user expectations in terms of functionality, ease of use, and sustainability—key factors that contribute to the successful deployment of safety monitoring technologies.

Accuracy. Table 2 shows the evaluation of the accuracy of the solar-powered portable multi-gas detector device by the experts.

The findings show that the Solar-Powered Portable Multi-Gas Detector Device received a consistent rating (Md=5, IQR=0) (Highly Accurate) across all accuracy-related performance indicators. This indicates a high level of user satisfaction regarding the device's reliability, precision, and responsiveness.

Table 2. Evaluation of the Accuracy Performance of the Solar-Powered Portable Multi-Gas Detector Device

	Statements	Median Score	Interpretation
1.	The device accurately detects gases such as Carbon Monoxide (CO), Methane (CH4), Hydrogen sulfide (N2S) and Volatile organic compounds (VOCs).	5	Highly Accurate
2.	The readings provided by the device are consistent and precise.	5	Highly Accurate
3.	The device gives timely warnings when hazardous gases are present.	5	Highly Accurate
4.	The readings from the device closely match those from standard laboratory equipment.	5	Highly Accurate
5.	The device performs well in different locations (home, boarding house, school, shop, laboratory)	5	Highly Accurate
	Overall Median	**5**	Highly Accurate
	IQR	**0**	No Variability

5 – Highly Accurate
4 – Accurate
3 – Moderately Accurate
2 – Less Accurate
1 – Not accurate

The consistently high ratings of the experts imply that the device is not only functional but also a scientifically accurate and practical tool for daily safety monitoring.

Detection Range. Table 3 contains the evaluation of the detection range of the solar-powered portable multi-gas detector device by the experts.

The results illustrate that the Solar-Powered Portable Multi-Gas Detector Device achieved a consistent rating (Md = 5, IQR = 0) (Highly Detectable) across all statements related to detection range. These results demonstrate strong user confidence in the device's ability to detect harmful gases across a range of concentrations and environments.

The statement, the detector can detect gases at varying concentrations effectively, being rated as "Highly detectable," highlights the device's sensitivity across a wide concentration range. This is critical in early detection and prevention of gas-related incidents.

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Table 3. Performance of the Solar-Powered Portable Multi-Gas Detector Device Along with Detection Range

	Statements	Median Score	Interpretation
1	The detector can detect gases at varying concentrations effectively.	5	Highly Detectable
2	The device covers a sufficient area for monitoring gases.	5	Highly Detectable
3	The detection range is appropriate for home, school, and industrial settings.	5	Highly Detectable
4	The device alert system activates promptly when gas levels reach dangerous thresholds.	5	Highly Detectable
5	The detection range of the device meets operational requirements for typical usage environments.	5	Highly Detectable
	Overall Median	**5**	Highly Detectable
	IQR	**0**	No Variability

5 – Highly Detectable
4 – Detectable
3 – Moderately Detectable
2 – Less Detectable
1 – Not Detectable

Moreover, the experts also agreed that the device covers a sufficient area for gas monitoring, confirming its suitability for both small and moderately large spaces. This indicates that the detection range is appropriate for home, school, and industrial settings, which indicates the device's versatility, which also aligns with literature stating that adaptable gas sensors are more valuable in diverse usage environments due to their broader application potential and the device's alert system which activates promptly at hazardous gas thresholds received a top rating, indicating strong real-time response.

This confirms, as noted by Dai et al. (2019), that prompt alerts are crucial in minimizing exposure risks and enabling quick evacuation or corrective action. Furthermore, experts agree that the detection range meets operational requirements, indicating that the device performs in line with safety standards for residential, academic, and small industrial applications. Meeting standard detection range requirements is crucial for ensuring regulatory compliance and reliability in critical settings.

The findings imply that the device's detection range is reliable and sufficient for typical monitoring scenarios. This makes it a viable safety tool in homes, school laboratories, and small-scale industrial spaces. Its sensitivity, broad coverage, and quick alert features support proactive gas management, helping to prevent accidents and health risks.

Cost. Table 4 contains the evaluation of the cost of the solar-powered portable multi-gas detector device by the experts.

The result shows a consistent median score of 5 (Highly Affordable) across all cost-related statements, indicating that users find the Solar-Powered Portable Multi-Gas Detector Device to be highly cost-effective in terms of purchase price, operation, and maintenance.

The first item, "The device is affordable compared to other gas detectors on the market," reflects its competitive pricing. Cost is a critical factor in technology adoption, especially in low-resource communities. According to Rogers (2003), affordability significantly influences the rate of diffusion of innovations, especially in safety and health technologies.

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Table 4. Performance of the Solar-Powered Portable Multi-Gas Detector Device in terms of Cost

	Statements	Median Score	Interpretation
1	The device is affordable compared to other gas detectors on the market.	5	Highly Affordable
2	The solar-powered feature reduces operational costs effectively.	5	Highly Affordable
3	Maintenance and repair costs are reasonable.	5	Highly Affordable
4	The cost of the device is justified by its durability, accuracy, and detection range.	5	Highly Affordable
5	Operating costs (e.g., charging, maintenance) are minimal over time.	5	Highly Affordable
	Overall Median	**5**	Highly Affordable
	IQR	**0**	No Variability

5 – Highly Affordable
4 – Affordable
3 – Moderately affordable
2 – Less affordable
1 – Not affordable

The device received top ratings for cost-related features, confirming its economic efficiency and sustainability. Users valued the solar-powered design for its ability to reduce long-term expenses, minimal maintenance, and operating costs, as well as its justified pricing based on durability, accuracy, and range. These findings align with studies that highlight the importance of cost efficiency and perceived value in promoting user satisfaction and continued adoption (Armaroli & Balzani, 2015; Kotler & Keller, 2016).

These imply that the device is financially accessible and economically sustainable over time, making it an ideal safety solution for households, schools, and small-scale facilities. Its low operating cost and self-sustaining power source encourage adoption in underserved or off-grid areas.

Reliability and Consistency. Table 5 contains the evaluation of the reliability and consistency of the solar-powered portable multi-gas detector device by the experts.

The results present uniform "Highly reliable and consistent " ratings (Md=5, IQR=0) across all reliability and consistency indicators, indicating strong user satisfaction with the device's stability and dependable performance in various conditions.

Table 5. Evaluation of the Reliability and Consistency Performance of the Solar-Powered Portable Multi-Gas Detector Device

	Statements	Median Score	Interpretation
1	The device functions consistently without frequent malfunctions.	5	Highly Reliable and consistent
2	The battery and solar power system are reliable for continuous operation.	5	Highly Reliable and consistent
3	The device performs well under different environmental conditions.	5	Highly Reliable and consistent
4	The device provides a reliable and efficient solution for monitoring hazardous gas levels in everyday settings.	5	Highly Reliable and consistent
5	The device effectively alerts users in different environmental settings (home, boarding houses, school labs).	5	Highly Reliable and consistent
	Overall Median	**5**	Highly Reliable and consistent
	IQR	**0**	No Variability

5 – Highly Reliable and consistent
4 – Reliable and consistent

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3 – Moderately Reliable and Consistent
2 – Less reliable and consistent
1 – Not reliable and consistent

The device was highly rated for reliability, consistently performing without malfunctions, providing dependable solar-battery operation, and demonstrating resilience in various environments.

Compliance with Safety Standards. Table 6 contains the evaluation of the Compliance with safety standards of the solar-powered portable multi-gas detector device by the experts.

Table 6. Evaluation of the Compliance with Safety Standards of the Solar-Powered Portable Multi-Gas Detector Device

	Statements	Median Score	Interpretation
1	The device meets recognized safety standards for gas detection.	5	Highly compliant
2	The warning and alarm system is effective in preventing hazards.	5	Highly compliant
3	The materials and design of the device are compliant with industry safety regulations.	5	Highly compliant
4	Built-in safety features function as intended.	5	Highly compliant
5	It performs reliably in hazardous or safety-critical environments.	5	Highly compliant
	Overall Median	**5**	Highly compliant
	IQR	**0**	No Variability

5 – Highly compliant
4 – Compliant
3 – Moderately compliant
2 – Less compliant
1 – Not compliant

The expert showed a consistent rating (Md=5, IQR=0) (Highly compliant) across all items related to compliance with safety standards, indicating that the Solar-Powered Portable Multi-Gas Detector Device adheres to industry expectations for safety, reliability, and regulatory compliance.

The item "The device meets recognized safety standards for gas detection," being rated highly compliant, highlights the device's adherence to established guidelines, such as those from OSHA (Occupational Safety and Health Administration) or ISO standards. Devices that comply with such standards are generally trusted to deliver accurate and safe performance in hazardous environments (OECD, 2012).

The statement "The warning and alarm system is effective in preventing hazards" also received the highest rating. This emphasizes the importance of early detection and immediate alert features. Real-time alarm systems are essential for mitigating risks and ensuring swift evacuation or corrective actions in environments with gas exposure threats.

Respondents also affirmed that "The materials and design of the device are compliant with industry safety regulations." Material compliance—such as using fire-resistant, corrosion-resistant, or durable components—is vital in producing safety-critical tools. The high rating for "Built-in safety features function as intended" suggests that the device incorporates effective protective mechanisms such as automatic shut-off, sensor calibration, and alert escalation. These features enhance the integrity of the monitoring system (Lin et al., 2014) and reduce the margin for human error.

Lastly, the device's reliable performance in hazardous or safety-critical environments confirms its practical applicability in real-world conditions, particularly where gas leaks may pose severe risks. The consistently high ratings on safety compliance indicators by experts imply that the device can be deployed confidently in sensitive environments, such as school laboratories, boarding houses, and residential areas. Its adherence to safety standards ensures not only functional reliability but also legal and institutional acceptability.

The developed solar-powered multi-gas detector demonstrated strong and consistent performance across all parameters (IQR=0), with experts in full agreement on its functionality, accuracy, detection range, cost, reliability,

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consistency, and compliance with safety standards. These findings align with recent studies emphasizing the value of accuracy and renewable energy integration in gas detection technologies (Bhattacharya & Paul, 2020; Cvetković et al., 2024; MSA Safety, 2024). A limitation, however, is the small number of evaluators and controlled testing, which may not fully reflect real-world conditions.

Conclusions

This study concludes that the developed gas detector device proved to be highly functional, user-friendly, and accessible even to non-technical users, making it suitable for diverse settings.

The developed device was found to overcome the limitations of conventional detectors by integrating renewable energy, multi-gas detection, and real-time monitoring in a portable and stand-alone design. Powered by solar energy, it ensures continuous, cost-effective, and sustainable operation, making it suitable for remote and off-grid areas. Its ability to simultaneously detect hazardous gases such as carbon monoxide, methane, and hydrogen sulfide enhances safety, reduces the need for multiple devices, and streamlines monitoring processes. Moreover, its eco-friendly design minimizes electronic waste and carbon emissions, while its immediate alert system strengthens protection in high-risk environments.

Recommendations

The device is recommended for use in homes, school laboratories, dormitories, and boarding houses, especially in rural or off-grid areas due to its solar-powered feature. The practical use of the solar-powered multi-gas detector, Local Government Units (LGUs) may consider partnerships with academic institutions and safety agencies training-workshops or devoce subsidies to the community. A cost-benefit analysis also justifies the investment, as the device reduces long-term expenses on batteries, minimizes risks associated with gas-related incidents, and advances sustainability goals. Furthermore, targeted training for safety officers, first responders, and disaster risk reduction units is recommended to ensure proper operation, calibration, and maintenance, thereby maximizing the device's effectiveness in safeguarding communities. Future research may focus on adding features such as wireless alerts and data logging, as well as evaluating the long-term performance of the system across various environments.

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