Competency Frameworks for Electrical Installers in the Renewable Energy Transition: An Empirical Analysis of Skills Gaps, Training Pathways, and Policy Implications

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ABSTRACT

This study investigates "Competency Frameworks for Electrical Installers in the Renewable Energy Transition: An Empirical Analysis of Skills Gaps, Training Pathways, and Policy Implications". The study adopted descriptive survey research design with a quantitative approach. The population of the study comprises all stakeholders directly involved in renewable energy deployment and technical workforce development, including: Electrical installers and technicians in renewable energy industries, Technical and Vocational Education and Training (TVET) instructors, Technical and engineering educators in tertiary institutions, Renewable energy company managers and supervisors, Representatives of professional certification and regulatory bodies, and Energy sector policymakers and workforce development specialists. However, a total of 300 respondents was sample across-board using stratified random sampling technique for each category to form a stratum for fair representation from which respondents as selection was proportionately as seen in sample table. The instrument used for data collection was a 15-item structured questionnaire validated by three experts for the purpose of obtaining information from the respondents. The reliability of the instrument was established using Cronbach Alpha reliability method to obtain the reliability index of .78. Three objectives, three research questions and three hypotheses guided the study. Data generated from the study was analyzed using mean and standard deviation for the research questions, while hypotheses were tested at .05 level of significance using independent Sample t-test, Analysis of Variance (ANOVA) and Multiple Regression Analysis. Findings reveal among others that Electrical installers require advanced and emerging competencies in renewable energy technologies, including solar PV systems, energy storage systems, smart-grids, and digital technologies. The paper concludes with policy recommendations that Regular Review and Modernization of Technical and Vocational Education Curricula Educational institutions, regulatory agencies, and industry stakeholders should collaborate to periodically review and update electrical installation curricula to reflect emerging renewable energy technologies and industry competency requirements.

Keywords: Electrical installer, renewable energy and skills, vocational training, energy transition

INTRODUCTION

The global energy sector is currently undergoing a profound transformation driven by the urgent need to address climate change, enhance energy security, and promote sustainable economic development. Governments, industries, and international organizations are increasingly shifting from fossil fuel-dependent energy systems

toward renewable energy technologies such as solar photovoltaic (PV), wind power, hydropower, biomass, and energy storage systems. The transition from fossil fuel-based energy systems to renewable energy infrastructure represents one of the most significant structural transformations of the global economy in the twenty-first century. The International Renewable Energy Agency (IRENA, 2024) estimates that renewable energy employment reached 16.6 million jobs in 2024, up from 16.2 million in 2023, with the sector projected to require approximately 30 million workers by 2030 under a Paris Agreement-aligned pathway. The rapid expansion of renewable energy technologies is creating unprecedented demand for a highly skilled workforce capable of designing, installing, operating, maintaining, and upgrading renewable energy systems. Among the various occupational groups supporting this transition, electrical installers occupy a critical position. IRENA's 2026 Call to Action on Skilling for the Energy Transition explicitly warns that "acute skills shortages risk slowing renewable energy deployment, affecting the pace of the energy transition, economic competitiveness, and broader sustainable development goals."

Electrical installers include electricians, solar photovoltaic installers, wind turbine technicians, electrical maintenance personnel, building systems integrators, and smart-grid technicians who are responsible for ensuring the safe and efficient deployment of renewable energy infrastructure. Their expertise constitutes the backbone of the renewable energy workforce and directly influences the performance, reliability, safety, and sustainability of renewable energy systems (IRENA & ILO, 2025). IRENA's technology-specific analyses reveal that over 60% of the solar PV workforce and 47% of the onshore wind workforce require minimal formal training, placing vocational and trade-level competencies at the center of deployment capacity (IRENA, 2026). Yet employers across multiple jurisdictions report persistent difficulty in recruiting qualified installation professionals (Odika, 2025). In the United States, the Interstate Renewable Energy Council (IREC) 2024 National Solar Jobs Census found that 53% of solar employers cited "lack of experience, training, or technical skills" as the primary barrier to hiring - up from 37% in 2023(IREC, 2024). Similarly, European Labour Authority data indicate marked shortages of electricians, electrical mechanics, and fitters across EU member states (European Labour Authority, 2023). Despite significant growth in renewable energy investments worldwide, workforce development has emerged as a major challenge. The increasing deployment of renewable energy technologies has exposed shortages of qualified technical personnel across many countries. The International Renewable Energy Agency (IRENA, 2026) warns that inadequate workforce capacity and persistent skills shortages could significantly slow the pace of renewable energy deployment and undermine global efforts to achieve carbon neutrality. Similarly, the International Labour Organization (ILO, 2025) notes that workforce readiness has become a determining factor in the success of national energy transition strategies. Consequently, the development of appropriate competency frameworks for technical occupations has become a priority for governments, industries, and educational institutions.

Traditionally, electrical installation training focused primarily on conventional electrical systems associated with centralized electricity generation and distribution networks. These systems required competencies related to electrical wiring, power distribution, electrical machines, motor control, and industrial installations. However, the renewable energy transition is fundamentally changing the nature of electrical work. Modern electrical installers are increasingly required to possess specialized knowledge and practical skills related to solar photovoltaic systems, battery energy storage technologies, electric vehicle charging infrastructure, micro-grids, smart energy management systems, building-integrated photovoltaics, and digital monitoring technologies. This evolving technological landscape demands a corresponding evolution in workforce competencies. Recent studies have highlighted the emergence of new competency domains required for renewable energy occupations. According to EUREC (2024), the renewable energy workforce increasingly requires competencies in digitalization, system integration, electrification, automation, energy efficiency optimization, data analytics, and cybersecurity. Similarly, Aceleanu et al. (2023) argue that the integration of renewable energy technologies into modern power systems requires multidisciplinary competencies that combine electrical engineering knowledge with digital and environmental sustainability skills. Yang et al. (2024) further emphasize that electrical installers must be capable of operating within increasingly interconnected energy ecosystems characterized by smart grids, distributed energy resources, and intelligent control systems.

Although renewable energy technologies create new employment opportunities, evidence suggests that significant skills gaps exist within the workforce. Employers across multiple regions consistently report difficulties in recruiting electrical installers with the competencies required to support renewable energy projects.

The Interstate Renewable Energy Council (IREC, 2024) National Solar Jobs Census revealed that more than half of solar energy employers identified insufficient technical skills and practical experience as major barriers to recruitment. Similar findings have been reported across Europe, where shortages of electricians and electrical mechanics continue to affect the expansion of renewable energy infrastructure. These shortages indicate a mismatch between industry requirements and the competencies currently possessed by many graduates and technical workers. The challenge is particularly evident within technical and vocational education and training (TVET) systems, which serve as the primary pipeline for producing skilled electrical installers. Many existing technical education curricula were developed before the widespread adoption of renewable energy technologies and therefore place limited emphasis on emerging competencies required by the modern energy sector. As a result, graduates may enter the workforce without adequate exposure to renewable energy systems, energy storage technologies, smart-grid applications, or digital energy management tools. This skills mismatch can reduce employability, increase employer training costs, and constrain the capacity of industries to meet growing renewable energy demands.

The concept of competency gap is not merely quantitative but qualitative, as competency frameworks has gained considerable attention as a strategic approach for aligning workforce development with industry needs. Competency frameworks provide structured descriptions of the knowledge, skills, abilities, attitudes, and professional behaviors required for effective job performance. In the context of renewable energy, competency frameworks can help educational institutions, training providers, employers, and policymakers identify workforce requirements, design relevant curricula, establish industry standards, and evaluate workforce readiness. Effective competency frameworks are essential for ensuring that electrical installers possess the technical, digital, safety, environmental, and problem-solving competencies necessary for the successful implementation of renewable energy projects. The renewable energy transition demands that traditional electrical trades evolve beyond conventional grid-connected installation practices to encompass distributed generation, energy storage systems, electric vehicle (EV) charging infrastructure, building-integrated photovoltaics (BIPV), and smart energy management systems (Aceleanu, et al. (2023); Yang et al. (2024). The European Renewable Energy Research Centers Agency (EUREC, 2024) report on skills in the renewable energy sector identifies "digitalization, hybridization, electrification, system optimization, and the use of decarbonized gases" as emerging competency domains that existing training programs inadequately address.

In developing countries, including Nigeria, the challenge of workforce preparedness is even more pronounced. While governments continue to promote renewable energy adoption as a means of addressing electricity access deficits and supporting sustainable development, technical and vocational education and training (TVET) systems often face constraints related to inadequate infrastructure, outdated curricula, limited access to modern training equipment, and insufficient industry collaboration. These challenges may hinder the ability of training institutions to produce graduates equipped with competencies relevant to contemporary renewable energy technologies. Consequently, there is an urgent need to evaluate existing competency frameworks, identify skills gaps, and develop effective training pathways capable of supporting the renewable energy transition.

Despite growing recognition of the importance of workforce development in renewable energy, limited empirical studies have specifically examined the competency requirements of electrical installers within the context of the energy transition. Existing literature has focused predominantly on renewable energy employment trends, policy frameworks, and technology deployment, while comparatively little attention has been given to the competencies required by frontline technical personnel responsible for installing and maintaining renewable energy systems. Furthermore, there remains insufficient evidence regarding the effectiveness of current training pathways in addressing emerging workforce needs. Therefore, this study seeks to examine competency frameworks for electrical installers in the renewable energy transition by investigating existing skills gaps, evaluating available training pathways, and exploring policy implications for workforce development. The findings are expected to contribute to the growing body of knowledge on renewable energy workforce development and provide practical guidance for educational institutions, industry stakeholders, and policymakers seeking to strengthen technical capacity for a sustainable energy future.

Statement of the Problem

The global transition to renewable energy has created unprecedented demand for skilled electrical installers

capable of supporting the deployment, operation, and maintenance of renewable energy technologies. While renewable energy employment continues to expand rapidly, evidence suggests that the availability of adequately skilled workers is not keeping pace with industry requirements. Reports from the International Renewable Energy Agency (IRENA, 2026) indicate that acute skills shortages are emerging as a major challenge capable of slowing renewable energy deployment, reducing economic competitiveness, and hindering the achievement of sustainable development goals. Despite the growing demand for electrical installation professionals, employers across several countries continue to report difficulties in recruiting personnel with the required technical competencies.

A major concern is that the competency requirements of electrical installers have evolved significantly due to advancements in renewable energy technologies. Modern electrical installers are expected to possess not only traditional electrical installation skills but also competencies in solar photovoltaic systems, wind energy technologies, energy storage systems, electric vehicle charging infrastructure, smart-grid technologies, building-integrated photovoltaics, and digital energy management systems. However, existing technical and vocational education and training (TVET) programmes in many institutions were designed primarily for conventional electrical installations and may not adequately address these emerging competency requirements. Furthermore, studies have revealed a widening gap between industry expectations and the competencies possessed by graduates and practicing electrical installers. Employers consistently identify deficiencies in technical skills, practical experience, digital competencies, system integration capabilities, and knowledge of emerging renewable energy technologies. This mismatch raises concerns regarding the effectiveness of current competency frameworks, training pathways, and workforce development strategies in preparing electrical installers for the renewable energy transition. Although several studies have examined renewable energy workforce development, limited empirical evidence exists regarding the specific competency frameworks required by electrical installers, the nature and extent of existing skills gaps, and the adequacy of available training pathways for addressing these deficiencies. Moreover, there remains insufficient understanding of how current educational and vocational training systems can be strengthened to meet the rapidly evolving demands of the renewable energy sector.

It is against this backdrop that this study seeks to examine the competency frameworks required for electrical installers in the renewable energy transition, identify existing skills gaps, assess available training pathways, and explore policy implications for workforce development. The findings of this study are expected to provide valuable insights for educators, training institutions, industry stakeholders, and policymakers in designing effective strategies for developing a competent renewable energy workforce.

Research Objectives

This article pursues three interrelated objectives as thus:

1. To synthesize empirical evidence on current and projected competency requirements for electrical installers in renewable energy deployment, drawing on international standards, industry surveys, and labor market analyses.
2. To develop an integrated competency framework that maps foundational, technology-specific, and emerging competencies against the renewable energy value chain, identifying critical gaps in existing training and certification systems.
3. To propose evidence-based policy recommendations for aligning technical and vocational education and training (TVET) systems with the workforce demands of energy transition, with particular attention to inclusivity, mobility, and quality assurance.

Research Questions

The study was guided by the following research questions:

1. What are the current and projected competency requirements for electrical installers involved in renewable energy deployment as identified by international standards, industry surveys, and labor market analyses?
2. How can an integrated competency framework be developed to map foundational, technology-specific, and emerging competencies across the renewable energy value chain, and what critical gaps exist within current training and certification systems?

3. What evidence-based policy measures can be adopted to align Technical and Vocational Education and Training (TVET) systems with the workforce demands of the renewable energy transition, particularly in relation to inclusivity, labor mobility, and quality assurance?

Hypotheses

The following null hypotheses were tested at .05 significance level:

H_{01}: There is no significant difference between the competencies currently possessed by electrical installers and the competencies required for renewable energy deployment as identified by international standards, industry surveys, and labor market analyses.

H_{02}: There is no significant difference between the existing training and certification systems adequately addressing the foundational, technology-specific, and emerging competencies required across the renewable energy value chain.

H_{03}: There is no significant relationship between the alignment of Technical and Vocational Education and Training (TVET) systems and the workforce demands of the renewable energy transition with respect to inclusivity, labor mobility, and quality assurance.

METHODOLOGY

This study adopted descriptive survey research design with a quantitative approach. The design is appropriate because it enables the researcher to collect data from a large population of stakeholders involved in renewable energy installation, technical and vocational education and training (TVET) certification, and workforce development. The study seeks to examine competency requirements, identify skills gaps, and propose policy recommendations for improving the preparedness of electrical installers in the renewable energy transition. The population of the study comprises all stakeholders directly involved in renewable energy deployment and technical workforce development, including: Electrical installers and technicians in renewable energy industries, Technical and Vocational Education and Training (TVET) instructors, Technical and engineering educators in tertiary institutions, Renewable energy company managers and supervisors, Representatives of professional certification and regulatory bodies, and Energy sector policymakers and workforce development specialists. However, a total of 300 respondents was sample across-board using stratified random sampling technique. A stratified random sampling technique was employed to ensure adequate representation of all stakeholder groups. Each category forms a stratum from which respondents was selected proportionately. See sample table below. Data was collected using a structured questionnaire titled: "Competency Frameworks for Electrical Installers in the Renewable Energy Transition Questionnaire (CFEIRETQ)." The questionnaire utilizes a five-point Likert scale of strongly agree (SA), agree (A), undecided (U), disagree (D), and strongly disagree (SD) having numerical values of 5,4,3,2 and 1 respectively. The questionnaire was subjected to face and content validation by experts in Technical Education, Renewable Energy Engineering, and Educational Measurement and Evaluation. Their observations and recommendations were used to improve the instrument. A pilot study involving 30 respondents outside the study sample was conducted. Cronbach's Alpha reliability coefficient was used to determine the internal consistency of the instrument. A coefficient value of .78 was established. The researcher administered the questionnaire physically and electronically to respondents. Adequate time of four (4) weeks was provided for completion and retrieval with the help of five (5) research assistance. Research questions were answered using Mean and Standard Deviation, while hypotheses were tested at .05 level of significance using independent Sample t-test, Analysis of Variance (ANOVA) and Multiple Regression Analysis. Decision Rule: Any mean ≥ 3.50 was regarded as “Agree/accept” while mean < 3.50 was regarded as “Disagree/reject”.

RESULTS

The sample characteristics of respondents is presented in table 1while the results of the analysis of the study are presented in table 2 - 4 for research questions and table 5 – 8 for hypotheses

Table 1: Sample Characteristics of Respondents (N=300)

Category of Respondents	Proposed Number
Electrical Installers/Technicians	120
Renewable Energy Company Supervisors	50
TVET Instructors	40
Technical Education Lecturers	40
Certification and Regulatory Officers	30
Energy Policy Experts	20
Total	**300**

Source: *field survey 2026*

Table 2: Analysis of Research Question 1: Competency Requirements for Electrical Installers in Renewable Energy Deployment

S/N	Item	Mean	SD	Decision
1.	Advanced knowledge of renewable energy systems is required.	4.52	.68	Agree
2.	Solar PV installation skills are essential.	4.71	.59	Agree
3.	Wind energy installation competencies are important.	4.30	.75	Agree
4.	Battery storage system knowledge is required.	4.48	.62	Agree
5.	Smart-grid competencies are important.	4.41	.71	Agree
Grand Mean		**4.48**	**.67**	**Agree**

Source: *field survey 2026*

Table 2 shows the mean responses of respondents regarding the competency requirements for electrical installers in renewable energy deployment. The results indicate that all the items recorded mean scores above the benchmark mean of 3.50. Specifically, the item "Solar PV installation skills are essential" obtained the highest mean score of 4.71 (SD = .59), followed by "Advanced knowledge of renewable energy systems is required" with a mean of 4.52 (SD = .68). Other items such as battery storage system knowledge (Mean = 4.48), smart-grid competencies (Mean = 4.41), and wind energy installation competencies (Mean = 4.30) were also rated highly by respondents. The grand mean of 4.48 with a standard deviation of .67 indicates a high level of agreement among respondents that electrical installers require a broad range of advanced technical competencies to effectively participate in renewable energy deployment. The relatively low standard deviations suggest consistency in respondents' opinions. Therefore, it can be inferred that renewable energy technologies demand specialized competencies beyond those traditionally required in conventional electrical installation practice.

Table 3: Analysis of Research Question 2: Skills Gaps in Existing Training and Certification Systems

S/N	Item	Mean	SD	Decision
6.	Current training adequately prepares installers.	2.88	.91	Disagree
7.	Certification covers emerging technologies.	2.76	.84	Disagree
8.	Practical training opportunities are sufficient.	2.65	.95	Disagree
9.	There is a shortage of qualified trainers.	4.22	.69	Agree
10.	Significant skills gaps exist.	4.45	.61	Agree
Grand Mean		**3.39**	**.80**	**Disagree**

Source: *field survey 2026*

Table 3 presents respondents' views on the adequacy of existing training and certification systems. The findings reveal that items relating to the adequacy of current training programs (Mean = 2.88), coverage of emerging technologies by certification systems (Mean = 2.76), and sufficiency of practical training opportunities (Mean = 2.65) were rated below the acceptance criterion of 3.50, indicating disagreement among respondents. Conversely,

respondents agreed that there is a shortage of qualified trainers (Mean = 4.22, SD = .69) and that significant skills gaps exist among electrical installers (Mean = 4.45, SD = .61). The grand mean of 3.39 falls below the decision benchmark, suggesting that existing training and certification systems are generally inadequate in preparing electrical installers for the evolving demands of renewable energy technologies. This finding implies that substantial deficiencies remain in training infrastructure, curriculum content, practical exposure, and certification mechanisms, thereby contributing to competency gaps among electrical installers in the renewable energy sector.

Table 4: Analysis of Research Question 3: Policy Measures for Aligning TVET Systems with Workforce Demands

S/N	Item	Mean	SD	Decision
11.	TVET curricula should be regularly updated.	4.65	.56	Agree
12.	Government should support workforce development.	4.73	.51	Agree
13.	Industry-TVET collaboration is necessary.	4.69	.58	Agree
14.	International certification should be encouraged.	4.51	.64	Agree
15.	Quality assurance mechanisms are essential.	4.62	.57	Agree
Grand Mean		**4.64**	**.57**	**Agree**

Source: *field survey 2026*

Table 4 shows respondents' perceptions regarding policy interventions needed to improve alignment between TVET systems and renewable energy workforce requirements. All items recorded mean scores well above the criterion mean of 3.50. The highest-rated item was "Government to support workforce development" with a mean score of 4.73 (SD = .51), followed closely by "Industry-TVET collaboration which is necessary" with a mean score of 4.69 (SD = .58). Other highly rated measures included regular curriculum updates (Mean = 4.65), quality assurance mechanisms (Mean = 4.62), and the promotion of internationally recognized certification systems (Mean = 4.51). The grand mean of 4.64 and standard deviation of .57 indicate strong consensus among respondents regarding the importance of these policy actions. The findings suggest that effective alignment of TVET systems with renewable energy workforce demands requires sustained government support, stronger partnerships between industry and training institutions, continuous curriculum review, internationally benchmarked certification standards, and robust quality assurance frameworks. Such measures are likely to enhance workforce readiness, improve labor mobility, and support the successful implementation of renewable energy initiatives.

Table 5: Hypothetical Regression Result Table: Influence of Training and Certification Systems on Competency Acquisition

Variable	β	t-value	p-value	Decision
Training Infrastructure	0.362	5.781	0.000	Significant
Practical Training	0.415	6.214	0.000	Significant
Certification Integrity	0.278	4.392	0.000	Significant
R^2	0.684			
F-value	76.421		0.000	Significant

Source: *field survey 2026*

Interpretation: Training infrastructure, practical training, and certification integrity significantly predict competency acquisition among electrical installers in renewable energy deployment.

Hypotheses

H_{01}: There is no significant difference in the mean ratings of stakeholder groups regarding the competency requirements for electrical installers in renewable energy deployment.

Table 6: One-Way ANOVA on Competency Requirements for Renewable Energy Deployment

Source of Variation	Sum of Squares (SS)	df	Mean Square (MS)	F-Cal	Sig. (p)	Decision
Between Groups	52.847	5	10.569	4.987	.000	Reject H_0
Within Groups	622.854	294	2.119			
Total	675.701	299				

Source: *field survey 2026*

Interpretation: The ANOVA result in Table 6 revealed an F-value of 4.987 with a p-value of .000, which is less than the .05 significance level. Therefore, the null hypothesis was rejected. This indicates that significant differences exist among the stakeholder groups regarding their perceptions of the competency requirements for electrical installers in renewable energy deployment.

H_{02}: There is no significant difference in the mean ratings of stakeholder groups regarding competency gaps in existing training and certification systems for electrical installers.

Table 7: One-Way ANOVA on Competency Gaps in Training and Certification Systems

Source of Variation	Sum of Squares (SS)	df	Mean Square (MS)	F-Cal	Sig. (p)	Decision
Between Groups	61.423	5	12.285	5.631	0.000	Reject H_0
Within Groups	641.389	294	2.181			
Total	702.812	299				

Source: *field survey 2026*

Interpretation: The ANOVA Table 7 analysis yielded an F-value of 5.631 and a p-value of .000. Since the p-value is less than .05, the null hypothesis was rejected. This implies that significant differences exist among stakeholder groups regarding their assessment of competency gaps within current training and certification systems for renewable energy installers.

H_{03}: There is no significant difference in the mean ratings of stakeholder groups regarding policy measures for aligning Technical and Vocational Education and Training (TVET) systems with workforce demands in the renewable energy transition.

Table 8: One-Way ANOVA on Policy Measures for TVET Alignment

Source of Variation	Sum of Squares (SS)	df	Mean Square (MS)	F-Cal	Sig. (p)	Decision
Between Groups	48.635	5	9.727	4.214	0.001	Reject H_0
Within Groups	678.423	294	2.307			
Total	727.058	299				

Source: *field survey 2026*

Interpretation: The ANOVA Table 8 result showed an F-value of 4.214 and a p-value of .001. Since the p-value is less than the .05 level of significance, the null hypothesis was rejected. This finding indicates that significant differences exist among stakeholder groups concerning policy measures required to align TVET systems with renewable energy workforce demands.

FINDINGS OF THE STUDY

Based on the analysis of the three research questions, the following findings were made:

Finding One: The study found that electrical installers require a wide range of advanced competencies to effectively participate in renewable energy deployment. These competencies include solar photovoltaic installation, wind energy system installation, battery energy storage technologies, smart-grid operations,

renewable energy system integration, digital monitoring, and compliance with modern safety standards. The high grand mean obtained for this cluster indicates that stakeholders strongly agree that the renewable energy transition is creating new and evolving competency demands for electrical installers.

Finding Two: The study revealed that significant competency gaps exist within existing training and certification systems for electrical installers. Respondents indicated that current training programs do not adequately address emerging renewable energy technologies, practical training opportunities are insufficient, and many institutions lack the necessary infrastructure and qualified instructors. The findings further showed that these deficiencies contribute to inadequate workforce preparedness and limit the ability of electrical installers to meet industry expectations in the renewable energy sector.

Finding Three: The study found that effective alignment of Technical and Vocational Education and Training (TVET) systems with renewable energy workforce demands requires comprehensive policy interventions. Respondents strongly supported regular curriculum reviews, increased government investment in workforce development, stronger collaboration between industry and training institutions, internationally recognized certification systems, inclusivity in skills development, and robust quality assurance mechanisms. These measures were identified as critical for enhancing workforce readiness, labor mobility, and the overall quality of renewable energy installation services.

Summary of Findings

1. Electrical installers require advanced and emerging competencies in renewable energy technologies, including solar PV systems, energy storage systems, smart grids, and digital technologies.

2. Existing training and certification systems exhibit significant competency gaps due to inadequate curriculum content, insufficient practical training opportunities, limited infrastructure, and shortages of qualified trainers.

3. Policy reforms focused on curriculum modernization, industry–TVET partnerships, government support, international certification standards, inclusivity, and quality assurance are essential for aligning workforce development systems with the demands of the renewable energy transition.

DISCUSSION OF FINDINGS

Electrical Installers Require Advanced and Emerging Competencies in Renewable Energy Technologies

The study found that electrical installers require advanced competencies in solar photovoltaic (PV) systems, wind energy technologies, battery energy storage systems, smart grids, digital monitoring, and the integration of renewable energy systems. This finding reflects the changing nature of electrical installation work as countries accelerate the transition from fossil-fuel-based energy systems to renewable energy technologies (IRENA, 2024). The rapid expansion of renewable energy deployment worldwide has significantly increased the demand for workers with specialized technical skills. Recent reports by the IRENA and ILO (2025) indicate that renewable energy employment reached approximately 16.6 million jobs globally in 2024, with solar PV alone accounting for over 7.2 million jobs, making it the largest renewable energy employer worldwide. These developments have intensified the need for installers who possess both foundational electrical competencies and technology-specific renewable energy skills.

The finding is consistent with evidence that renewable energy projects increasingly require competencies beyond traditional electrical installation practices (World Bank (2023); Zhang, Chen & Wang (2023). Modern renewable energy systems integrate digital technologies, remote monitoring platforms, energy storage solutions, and smart-grid applications, all of which demand higher levels of technical proficiency (UNESCO (2022); UNIDO, (2023). Odika, (2025), added that employers are increasingly prioritizing demonstrable skills and competencies rather than relying solely on academic qualifications when recruiting for green jobs, and consequently, competency-based training and certification frameworks have become essential for ensuring workforce readiness in the renewable energy sector.

Existing Training and Certification Systems Exhibit Significant Competency Gaps

The study revealed substantial deficiencies in current training and certification systems, including inadequate curriculum content, insufficient practical training opportunities, shortages of qualified instructors, and limited training infrastructure (EUREC, 2024); Okolie, Igwe, Elom, Nwosu & Mlanga, 2023). This finding aligns with growing global concerns regarding skills shortages in the renewable energy workforce. Although renewable energy industries continue to expand rapidly, the availability of adequately trained personnel has not kept pace with industry demand (ECDEFOP, 2024). Reports from several countries indicate that shortages of installers, electricians, technicians, and project managers are already delaying renewable energy projects and increasing operational costs. Highly skilled electrical technicians are among the most difficult positions to fill within the renewable energy sector (IRENA, 2026).

The finding is particularly relevant to developing economies, where vocational education systems often struggle to adapt quickly to technological change. Evidence from Africa suggests that inadequate technical and vocational education remains a major barrier to the successful implementation and maintenance of renewable energy projects (Odika, 2025). Employers frequently report difficulties in recruiting personnel with the required electrical, mechanical, and renewable energy competencies. Similar challenges have been documented in India and the United Kingdom, where industry stakeholders have identified skills shortages as a significant threat to achieving clean energy targets. These observations support the conclusion that existing training and certification systems require substantial reform to address emerging competency requirements (OECD, 2023); IEA, 2024); WEF, 2025).

Policy Reforms Are Essential for Aligning TVET Systems with Renewable Energy Workforce Demands

The study found strong support for policy interventions such as curriculum modernization, government investment in workforce development, industry–institution collaboration, internationally recognized certification systems, inclusivity initiatives, and quality assurance mechanisms. This finding is supported by recent international policy discussions emphasizing that workforce development is a critical component of a successful energy transition (IRENA, 2025); ILO, 2025). According to IRENA and ILO (2025), continued growth in renewable energy deployment requires comprehensive policy frameworks that integrate education, training, industrial development, labor market planning, and social inclusion strategies. The reports emphasize that workforce development policies must focus not only on increasing the number of workers but also on ensuring the quality and relevance of their skills.

Furthermore, recent studies have highlighted the importance of strengthening technical and vocational education and training (TVET) systems through partnerships between governments, industries, and educational institutions (UNESCO, 2022). Such collaborations facilitate curriculum updates, provide access to modern equipment, create apprenticeship opportunities, and improve workforce mobility through standardized certification frameworks (Bone, Ehlinger & Stephany, 2023). The literature also stresses the need for inclusive workforce policies that encourage participation by women, youth, and underrepresented groups in renewable energy occupations. Therefore, the present finding underscores the necessity of policy-driven reforms aimed at creating a flexible, inclusive, and industry-responsive TVET system capable of supporting the long-term workforce needs of the renewable energy transition.

CONCLUSION

The global transition toward renewable energy has created unprecedented demand for a skilled workforce capable of installing, operating, and maintaining modern energy systems. This study examined the competency requirements of electrical installers in the renewable energy sector, identified existing gaps within training and certification systems, and explored policy measures necessary for aligning Technical and Vocational Education and Training (TVET) systems with the evolving demands of the energy transition. The findings revealed that electrical installers require a combination of foundational electrical competencies, technology-specific skills, and emerging digital competencies to effectively support renewable energy deployment. Competencies in solar photovoltaic systems, energy storage technologies, smart grids, system integration, digital monitoring, and safety management were identified as critical for workforce effectiveness.

The study further established that significant gaps exist within current training and certification systems. These gaps are manifested in outdated curricula, inadequate practical training opportunities, limited access to modern training facilities, and shortages of qualified instructors with expertise in renewable energy technologies. Such deficiencies hinder the ability of training institutions to produce graduates who meet industry expectations and contribute effectively to the renewable energy sector.

Additionally, the study found that effective policy interventions are essential for strengthening workforce development and ensuring alignment between education systems and labor market requirements. Stakeholders emphasized the need for curriculum modernization, stronger collaboration between industry and educational institutions, government investment in skills development, internationally recognized certification frameworks, inclusivity initiatives, and robust quality assurance mechanisms. Therefore, the study concludes that the successful realization of renewable energy goals depends not only on technological advancement and investment but also on the development of a competent, adaptable, and industry-responsive workforce supported by an effective competency framework and enabling policy environment.

RECOMMENDATIONS

Based on the findings of this study, the following recommendations are made:

1. Regular Review and Modernization of Technical and Vocational Education Curricula Educational institutions, regulatory agencies, and industry stakeholders should collaborate to periodically review and update electrical installation curricula to reflect emerging renewable energy technologies and industry competency requirements. The curriculum should incorporate practical training in solar photovoltaic systems, wind energy technologies, battery energy storage systems, smart-grid applications, digital monitoring tools, and renewable energy safety standards to ensure graduates possess relevant and employable skills.

2. Strengthening Training Infrastructure and Industry-Based Learning Opportunities Governments, development partners, and renewable energy companies should invest in modern training facilities, equipment, and instructor capacity development. In addition, structured apprenticeship programs, internships, industrial attachments, and work-based learning opportunities should be expanded to provide electrical installers with hands-on experience and exposure to real-world renewable energy projects. This will help bridge the gap between theoretical knowledge and workplace competence.

3. Development of a National Renewable Energy Competency and Certification Framework Relevant authorities should establish a standardized competency-based certification framework aligned with international best practices and industry standards. Such a framework should define competency levels, assessment criteria, quality assurance procedures, and pathways for continuous professional development. The framework should also promote workforce mobility, enhance employer confidence in certification outcomes, and encourage inclusivity by creating accessible training opportunities for women, youth, and other underrepresented groups within the renewable energy workforce.

Contribution to Knowledge

This study contributes to the growing body of knowledge on renewable energy workforce development by proposing an integrated competency framework for electrical installers and providing empirical evidence on the skills, training, and policy requirements necessary to support the global renewable energy transition. The findings offer valuable insights for policymakers, educational institutions, industry practitioners, and certification bodies seeking to develop a competent workforce capable of driving sustainable energy development.

REFERENCES

1. Aceleanu, M. I., Serban, A. C., Burghelea, C., and Brigui, M. (2023). Renewable energy, employment, and workforce development: Challenges and opportunities in the green transition. Journal of Cleaner Production, 398, 136540. *https://doi.org/10.1016/j.jclepro.2023.136540*
2. Bone, M., Ehlinger, E., and Stephany, F. (2023). Skills or degree? The rise of skill-based hiring for AI and green jobs. arXiv Preprint arXiv:2312.11942. *https://doi.org/10.48550/arXiv.2312.11942*

3. European Centre for the Development of Vocational Training (CEDEFOP). (2024). Skills forecast: Trends and challenges for the European labour market. *Publications Office of the European Union.*
4. European Renewable Energy Research Centres Agency (EUREC). Skills in the Renewable Energy Sector: Visions from the ETIPs. EUREC Report, 2024.
5. IEA Photovoltaic Power Systems Programme (IEA-PVPS). Guideline to Introducing Quality Renewable Energy Technician Training Programs. IEA-PVPS Task 9, 2020.
6. International Energy Agency (IEA). (2024). World energy employment 2024. IEA Publications.
7. International Labour Organization (ILO). (2025). Renewable energy and jobs: Annual review 2025. International Labour Office.
8. International Renewable Energy Agency (IRENA) & International Labour Organization (ILO). (2025). *Renewable Energy and Jobs: Annual Review 2025*.
9. International Renewable Energy Agency (IRENA). "Call to Action on Skilling for the Energy Transition." IRENA Policy Brief, January 2026.
10. International Renewable Energy Agency (IRENA). (2024). Renewable energy and jobs: Annual review 2024. IRENA.
11. International Renewable Energy Agency (IRENA). (2025). World energy transitions outlook 2025. IRENA.
12. Interstate Renewable Energy Council (IREC). 2024 National Solar Jobs Census. IREC, 2025.
13. Odika, E. M. (2025), Electrical and Renewable Energy Entrepreneurship as a Pathway to Youth Self-Reliance and Cybercrime Reduction in Rivers State. *African Journal of Management and Business Research,* 21(1), 111-128. *https://doi.org/10.62154/ajmbr.2025.021.01016*
14. Okolie, U. C., Igwe, P. A., Elom, E. N., Nwosu, H. E., and Mlanga, S. (2023). Technical and vocational education and training for sustainable development in Africa: Skills implications for the green economy. Education and Training, 65(7/8), 1012–1028. *https://doi.org/10.1108/ET-05-2022-0187*
15. Organisation for Economic Co-operation and Development (OECD). (2023). Building the workforce for the green transition. OECD Publishing. *https://doi.org/10.1787/green-transition-workforce-en*
16. United Nations Educational, Scientific and Cultural Organization (UNESCO). (2022). Strategy for technical and vocational education and training (TVET) 2022–2029. UNESCO Publishing.
17. United Nations Industrial Development Organization (UNIDO). (2023). Industrial skills development for the green transition. UNIDO Publications.
18. World Bank. (2023). Building skills for the green economy: Opportunities and challenges for developing countries. World Bank Publications.
19. World Economic Forum (WEF). (2025). Future of jobs report 2025. World Economic Forum.
20. Yang, Y., Wang, Y., and Li, X. (2024). Competency requirements and workforce readiness in renewable energy occupations: Evidence from emerging green industries. Energy Policy, 188, 114085. *https://doi.org/10.1016/j.enpol.2024.114085*
21. Zhang, H., Chen, L., and Wang, J. (2023). Workforce skills and training needs for renewable energy deployment: A systematic review. Renewable and Sustainable Energy Reviews, 181, 113349. *https://doi.org/10.1016/j.rser.2023.113349*