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Designing a Bachelor of TVET in Solar Technology at a Namibian University of Science and Technology: A Design-Based Needs Assessment Approach

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Abstract

Namibia possesses exceptional solar energy potential, averaging 6.5 kWh/m^2/day, yet faces a critical shortage of qualified solar technology profesionals capable of supporting its renewable energy ambitions. This study aims to conduct a design-based needs assessment to inform the development of a Bachelor of Technical and Vocational Education and Training (TVET) in Renewable Energy (Solar Technology) qualification for training TVET educators. A mixed-methods approach was employed, involving a self-administered questionnaire distributed to 17 stakeholders across 13 institutions, including universities, technical colleges, vocational training centres, and industry service providers, complemented by document analysis of relevant policy documents. The findings reveal a unanimous industry preference for integrated expertise in both solar photovoltaic and solar thermal systems, identify solar technicians as the most urgently required professional category, indicate strong support for degree-level qualifications for TVET trainers, and highlight consensus on a three- to four-year programme structure combining theoretical instruction with industry attachments. The study concludes that stakeholder-informed qualification design is essential for developing demand-driven programmes and addressing critical skills gaps in the renewable energy sector. These findings provide empirical guidance for curriculum development in Namibia and offer insights applicable to solar workforce development across sub-Saharan Africa.

Keywords

Skills Technology, TVET, Needs Assessment, Renewable Energy, Namibia, Skills Development, Qualification Design

1. Introduction

Namibia's energy landscape is undergoing a profound transformation. With one of the highest solar irradiation levels globally, averaging 6.5 kWh/m²/day and more than 300 days of sunshine annually, the country possesses extraordinary potential to harness solar energy for economic development, energy security, and climate change mitigation (International Energy Agency (IEA), 2024).

The Government of Namibia has set an ambitious target to generate 70% of its electricity from renewable sources by 2030, with solar energy positioned as a cornerstone of this transition. Several solar projects have either been commissioned or are in development, including the 20 MW Omburu Solar PV Park, the 5 MW Hardap Solar PV Plant, and the planned 40 MW Gobabis Solar Park. Yet, despite these promising infrastructure developments, a critical shortage of skilled professionals who can design, install, maintain, and teach solar technology systems severely constrains the realisation of Namibia's solar energy ambitions.

1.1. Research Problem

An acute skills and capacity deficit in the renewable energy sector significantly limits Namibia's ability to fully realise its solar energy potential. The Namibia Training Authority (NTA) (2023) Sector Skills Plan identifies renewable energy as one of the country's fastest-growing sectors, yet one of the most underserved in qualified trainers and technicians. The GFA Group and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) (2025) report highlights that while demand for solar installations is growing across residential, commercial, and industrial sectors, the supply of appropriately qualified workers remains chronically inadequate.

This skills gap is particularly acute in Technical and Vocational Education and Training (TVET) institutions, where trainers often lack the technical depth, pedagogical competence, and industry currency needed to prepare learners for employment in the solar sector. These conditions create a pressing need for a higher-level qualification, specifically a Bachelor of TVET in Renewable Energy (Solar Technology), to equip TVET trainers and solar professionals with the integrated knowledge, skills, and competencies needed to advance Namibia's solar energy transition.

1.2. Research Questions

This study was guided by four research questions:

1) What solar technologies are currently used in Namibian industries, and what technologies are anticipated to be introduced in the next five years?

2) What knowledge, skills, and abilities (KSA) are required of those currently working with, and those preparing to work with, solar technologies in the industry?

3) What qualifications, entry requirements, subject content, and mode of delivery are most appropriate for a proposed Bachelor of TVET in Solar Technology aimed at TVET trainers?

4) What are the projected career opportunities and sponsorship prospects for graduates of the proposed qualification?

1.3. Significance of the Study

This study makes a timely and substantive contribution to Namibia's demand-driven TVET policy and, more broadly, to the literature on solar energy workforce development in sub-Saharan Africa.

Using a rigorous, stakeholder-engaged needs assessment, the research provides empirical evidence to guide the design of a qualification that responds to industry requirements, aligns with global best practices in competency-based TVET, and is tailored to Namibia's specific socio-economic and infrastructural context.

The findings have direct implications for the Namibia Qualifications Authority (NQA), the Department of Technical and Vocational Education and Training (DTVET), vocational education and training centres (VTCs), and higher education institutions (HEIs) seeking to establish or expand solar technology programmes.

2. Literature Review

2.1. Overview of Relevant Literature

The global transition to renewable energy has driven unprecedented growth in solar energy employment. According to the International Renewable Energy Agency (IRENA) and International Labour Organization (ILO) (October 1, 2024), renewable energy employed 16.2 million people worldwide in 2023, with solar photovoltaic (PV) accounting for the largest share at 7.0 million jobs, a figure that has grown consistently year-on-year. This rapid growth trajectory is projected to continue, with estimates suggesting the solar sector could employ more than 25 million people globally by 2030 (IRENA & ILO, October 1, 2024).

Within Africa, the solar sector is characterised by widening gaps between the demand for skilled workers and the capacity of education and training systems to supply them. Edomah (2025), examining drivers of sustainability education and green vocational training in Africa's solar sector, identify institutional capacity deficits, inadequate curriculum relevance, and insufficient industry-academia partnerships as primary obstacles to effective skills development. Similarly, Power for All (2022), in their comprehensive Powering Jobs Census, documents that whilst mini-grid and off-grid solar systems are expanding rapidly across the continent, training institutions have struggled to keep pace, resulting in widespread reliance on informal on-the-job training with variable quality outcomes.

In the Southern African context, Ramsarup and Hepplethwaite (2025) provides a detailed analysis of learning pathways in South Africa's solar sector, noting the critical role of TVET institutions in bridging the skills gap but also highlighting persistent challenges related to outdated curricula, limited access to modern equipment, and a shortage of suitably qualified trainers, a finding that resonates strongly with the Namibian context.

2.2. Key Theories and Concepts

This study was anchored in competency-based training (CBT) and demand-driven TVET. Competency-based curriculum development prioritises identifying industry-defined competencies and aligning learning outcomes, instructional strategies, and assessments with them (Rauner, 2009). UNESCO-UNEVOC International Centre for Technical and Vocational Education and Training (2021) emphasises that competency-based TVET curricula must be developed in close consultation with industry stakeholders to ensure that graduates possess the knowledge, skills, and attitudes required for employment and career progression.

Educational research has long established the role of needs assessment in curriculum development. Raffing et al. (2023) demonstrate that curricula developed based on robust needs assessments are significantly more likely to achieve targeted learning outcomes and graduate employability than those developed through top-down, expert-driven processes. Matkovic et al. (2014) extend this argument by highlighting the importance of engaging diverse stakeholder groups, including employers, educators, learners, and policymakers, in the needs assessment process to ensure that the resulting qualification reflects multiple perspectives and serves multiple constituencies.

2.3. Gaps and Controversies in the Literature

Whilst there is growing international literature on solar workforce development, several gaps remain. First, the existing research has disproportionately focused on installation and maintenance roles at the technician and artisan levels, with far less attention paid to the educational and pedagogical requirements of those who will train the next generation of solar professionals. This gap is particularly pronounced in African contexts, where TVET trainer shortages are acute and where the quality of trainer education has direct implications for sector-wide skills development.

Second, much of the literature takes a technology-centric perspective, emphasising the technical competencies required to work with specific solar systems but paying insufficient attention to broader professional competencies, such as project management, customer relations, entrepreneurship, and regulatory compliance, that are equally essential for success in the solar sector.

Third, empirical research remains limited on the specific qualification frameworks, entry requirements, and programme structures that best prepare TVET trainers in renewable energy fields. This study addresses these gaps by focusing on the design requirements for a TVET trainer qualification in solar technology in the Namibian context.

3. Methodology

3.1. Research Design

This study employed a design-based needs assessment approach, a methodology

well suited to developing educational programmes and qualifications. Needs assessment is defined as the process of systematically identifying gaps between current conditions and desired outcomes and using those findings to inform intervention design (Concannon et al., 2014). In curriculum development, needs assessment aligns programme content, delivery, and outcomes with stakeholders' authentic requirements, ensuring relevance and effectiveness. The study adopted a mixed-methods approach, combining document analyses of relevant policy papers and sector plans with primary data from a self-administered questionnaire. The questionnaire enabled direct engagement with industry professionals, educators, and institutional leaders to gather empirical evidence on technology usage, competency requirements, and qualification design preferences.

The document analysis covered the National Renewable Energy Policy (2017), the National Energy Policy (2017), and the National Integrated Resource Plan and its 2022 Review and Update. It also covered the Modified Single Buyer Market Model (2019), the National Employment Policy 2013-2017, and the Green Hydrogen and Derivatives Strategy (2022).

The review also included three skills studies: the Skills Needs and the Gap Analysis in Namibia's Power-to-X Sector (2023), the NTA Occupations in Higher Demand list, and the GIZ/NTA report TVET Skills for Renewable Energy and Green Hydrogen in Namibia (2025). Energy policies, particularly the 70% renewable electricity target by 2030 and the opening of the market to independent producers, sustained demand for solar technicians, justifying a solar specialisation.

The employment policy's emphasis on green jobs supported entrepreneurship. Most decisively, the Power-to-X study identified a gap at NQF levels 4 - 5 and a shortage of qualified TVET trainers, and it recommended a NUST Faculty of TVET to bridge the route from Level 3/4 to Level 6. This finding directly shaped two features of the proposed qualification: an articulation pathway for certificate holders, and the combination of solar technical competence with vocational pedagogy.

3.2. Data Collection Methods

Primary data were collected through an open-ended, self-administered questionnaire (Schwarz et al., 2021) with 23 questions, structured in three sections. Section A gathered biographical information about respondents and their organisations, including sector affiliation, institutional type, and professional role.

Section B focused on current and emerging solar technologies, occupational role differentiation (Solar Artisan, Solar Technician, Solar Engineer), and the knowledge, skills, and abilities (KSA) required across these roles. Section C addressed preferences for qualification design, including recommended entry requirements, programme duration, subject content, mode of delivery, career opportunities for graduates, and sponsorship prospects. All Section C items in the questionnaire were open-ended. For all open-ended items, respondents were asked

to give multiple answers.

The questionnaire employed a combination of structured closed-ended items and open-ended questions designed to elicit both quantifiable patterns and rich qualitative insights (Brosius et al., 2022). Open-ended items were particularly valuable for capturing stakeholder perspectives on complex or contested issues, such as the appropriate balance between theoretical instruction and practical training, or the specific competencies that distinguish solar technicians from solar engineers.

3.3. Sample Selection

We selected respondents through purposive sampling of institutions and individuals (Subedi, 2021) directly involved in solar and electrical training in Namibia. Invitations were sent to 26 individuals at 13 organisations through the NTA network of registered providers between August and September 2025. Seventeen people from 13 organisations responded, a 65% response rate. Vocational training providers made up the largest group: nine institutions (VTCs, vocational institutes and technical or commercial colleges) contributed 12 respondents (70.6%). Two universities, UNAM and NUST, contributed three respondents (17.6%).

The Namibia Training Authority contributed one respondent (the regulator), and Welwitschia Integrated Services contributed one, representing industry (5.9% each). By professional role, trainers were the majority (n = 11; 64.7%).

Seven of them were solar specialists, mostly Solar Equipment Installation and Maintenance trainers; three were electrical (general) trainers; and one was a general TVET trainer.

The remaining respondents were three university staff (two lecturers and a laboratory technician), two training managers (a head of training and a founder), and one industry maintenance officer. This distribution means the findings mainly reflect the views of practising solar and electrical trainers, the qualification's intended target group. Employer views are thinly represented, which should be acknowledged as a limitation.

3.4. Data Analysis Techniques

The study applied descriptive and thematic analyses to the quantitative and qualitative data, respectively. The study summarised quantitative items using frequency counts and percentage distributions, enabling identification of consensus views and areas of divergence (Bensken et al., 2021).

The study applied inductive thematic analysis to qualitative responses to identify recurring themes, concepts, and patterns, and to code and organise them into broader categories. This dual analytical approach facilitated the integration of breadth (through quantitative patterns) and depth (through qualitative nuance), yielding a holistic understanding of stakeholder perspectives (Braun & Clarke, 2021; Matović & Ovesni, 2023).

4. Results

4.1. Current Solar Technologies in Industry

All 17 respondents confirmed active use of a range of solar technologies in Namibian industries. Photovoltaic (PV) systems, both grid-tied and off-grid, emerged as the most prevalent technology, followed by solar water heating systems, solar pumping systems, and battery storage solutions. Several respondents also mentioned emerging applications such as solar refrigeration for agricultural and healthcare purposes, and solar-powered irrigation systems in rural areas.

Crucially, all 17 respondents agreed that the industry needs professionals with integrated expertise in both solar PV and solar thermal systems, rather than specialisation in only one technology. As one respondent noted, "Solar professionals need to understand the full spectrum of solar applications, from electricity generation to thermal heating, because clients often require integrated solutions that combine multiple technologies."

4.2. Emerging Solar Technologies and Future Workforce Needs

Looking ahead, respondents identified Concentrated Solar Power (CSP) (6 mentions), Photovoltaic systems (5 mentions), and Green Hydrogen (3 mentions) as the key technologies anticipated to be introduced in Namibia over the next five years. Green hydrogen's prominence reflects Namibia's strategic positioning as a potential global hub for green hydrogen production, leveraging the country's abundant solar and wind resources.

The competencies required for this emerging technology landscape extend the existing solar KSA profile significantly. Respondents indicated that future solar industry workers will need advanced technical knowledge of energy storage systems, grid integration technologies, power electronics, and hydrogen production processes. Additionally, they emphasised the importance of digital competencies, including data analytics for performance monitoring and optimisation, as well as soft skills such as project management, entrepreneurship, and customer engagement.

4.3. Occupational Role Differentiation

Respondents drew clear distinctions between the three principal occupational categories in the solar sector: Solar Artisans, Solar Technicians, and Solar Engineers. Solar Artisans are characterised by hands-on installation and maintenance skills, typically acquired through National Qualifications Framework (NQF) Level 3 or Level 4 qualifications.

Solar Technicians have deeper technical knowledge, including system design, troubleshooting, and competence in both PV and thermal systems, and typically require NQF Level 5 or Level 6 qualifications. Solar Engineers handle complex system design, feasibility studies, regulatory compliance, and project management, and typically require degree-level qualifications at NQF Level 7 or above.

In terms of current priority, Solar Technicians were identified as the most ur-

gently needed category (9 mentions), followed by Solar Engineers (8 mentions) and Solar Artisans (7 mentions). The premium placed on technicians reflects industry demand for mid-level professionals who bridge the gap between installation workers and engineers, performing tasks too complex for artisans but not requiring full engineering expertise.

4.4. Qualification Requirements for TVET Trainers

Respondents expressed a clear preference for degree-level qualifications for TVET trainers in solar technology. Degree-equivalent qualifications (including Bachelor's degrees in solar engineering, solar technology, or renewable energy engineering) were cited by 10 respondents as the minimum acceptable standard. An additional 4 respondents indicated that whilst a Bachelor's degree is preferable, an Advanced Diploma combined with substantial industry experience could be acceptable in certain contexts.

For the proposed programme's entry requirements, 8 respondents cited a Level 3 qualification in electrical or solar engineering combined with relevant work experience as the most common prerequisite. Other suggested entry pathways included a National Diploma in Electrical Engineering (5 mentions), completion of Grade 12 with Mathematics and Physical Science (4 mentions), and recognition of prior learning for experienced practitioners (3 mentions).

4.5. Programme Structure and Design Preferences

Respondents' preferences for programme duration varied, with most recommending a three- to four-year programme that blends full-time study with industry attachment. Recommended subject content included core modules in photovoltaic systems design and installation, solar thermal systems, energy storage technologies, grid integration, electrical engineering fundamentals, renewable energy policy and regulations, project management, entrepreneurship, and occupational health and safety.

When explaining how the qualification would improve trainee performance, we recorded several respondents' answers. One respondent cited teaching-related needs, such as lesson planning, practical demonstration, competency-based assessment, and workshop safety management. Among recommended courses, another respondent mentioned concerns about pedagogy or assessment. Another respondent suggested: "A Bachelor's degree in solar technologies with 20% of training focused on teaching methodology, including job attachments in the solar industry." Another respondent added: "A TVET Trainer Qualification at Level 6 with technical and Vocational Education that includes vocational pedagogy." Lastly, another respondent suggested that "trainers' pedagogical skills will be greatly enhanced." These findings informed the following proposed modules: Vocational Pedagogy, Competency-Based Assessment, and Workshop Management.

These responses align with findings from national studies that identified weak

trainer capacity in the TVET sector. The Skills Needs and Gap Analysis in Namibia's Power-to-X Sector, conducted with NUST's participation, had the most direct influence. It found that existing TVET offerings provide only a foundation, that trainer capacity and modern equipment are lacking, and that a gap at NQF Levels 4 - 5 opened when the Polytechnic of Namibia became NUST. It recommended establishing a Faculty of TVET at NUST to bridge the route from Level 3 or 4 to Level 6 and above and to build TVET trainers' capacity. The Bachelor of TVET in Solar Technology answers both recommendations: it gives holders of NTA solar and electrical certificates a progression route to a degree, and it combines technical solar competence with vocational pedagogy so that graduates can teach in vocational training centres.

For preferred modes of study, full-time and distance learning were most frequently cited (5 mentions each), followed by part-time (4 mentions), face-to-face (3 mentions), and blended learning (2 mentions). The strong support for distance learning reflects the recognition that many potential students may already be employed in the solar sector and require flexible study options to balance work and academic commitments.

4.6. Career Opportunities, Sponsorship, and Programme Impact

Graduates of the proposed qualification were seen as being positioned for careers as solar technicians and trainers (6 mentions), solar engineers (4 mentions), TVET lecturers and vocational educators (4 mentions), solar project managers (3 mentions), and renewable energy consultants (2 mentions). Respondents emphasised that the qualification would not only enhance graduates' technical competencies but also their employability, earning potential, and capacity to contribute to Namibia's renewable energy transition.

Thirteen of the 17 respondents (76.5%) believed sponsorship was possible. They named the Ministry of Higher Education, Technology and Innovation, the Namibia Training Authority, and industry partners as likely sources. Their estimates ranged from at least five sponsored students per intake to 20 or more, and several made this conditional on sectoral demand and the availability of funds. The remaining 4 respondents did not answer the sponsorship question. These figures are respondents' perceptions of likely funding. They are not documented commitments: no sponsor was consulted, and no funding agreement was obtained. They suggest that stakeholders see the qualification as fundable but do not establish its financial viability.

5. Discussion

5.1. Interpretation of Results

The findings present a compelling, coherent case for developing a degree-level TVET qualification in solar technology in Namibia. The consensus on the need for integrated expertise in both PV and thermal systems reflects a maturing understanding within Namibia's solar sector that professionals need broad-based

competencies rather than narrow specialisation. This finding aligns with international trends toward multi-skilled technicians who can work across diverse solar applications (IRENA & ILO, October 1, 2024).

Identifying solar technicians as the most urgently needed professional category, ahead of both solar engineers and artisans, has implications for the proposed qualification's level and content. This suggests positioning the programme at NQF Level 7 (Bachelor's degree), with a strong emphasis on applied technical competencies, system design skills, and practical problem-solving abilities. At the same time, the programme must include sufficient theoretical depth to prepare graduates for potential progression to postgraduate study or engineering roles, offering flexible career pathways.

The strong preference for degree-level qualifications for TVET trainers aligns with international best practices in TVET teacher education, which increasingly emphasise subject-matter expertise, pedagogical competence, and industry currency. This finding validates the proposed qualification level and reinforces the need for the programme to integrate technical content with TVET pedagogy, instructional design, and assessment practices.

5.2. Comparison with Existing Literature

This study's findings reinforce and extend several themes identified in the regional and international literature on solar workforce development. The skills gap documented in Namibia mirrors patterns observed in South Africa (Ramsarup & Hepplethwaite, 2025), Kenya, and Nigeria (Edomah, 2025), suggesting that workforce challenges in the solar sector are systemic across sub-Saharan Africa and require coordinated policy responses at both national and regional levels.

This study makes a distinctive contribution by focusing on the qualification requirements of TVET trainers, an underexplored dimension of the solar skills development challenge. While much of the existing literature emphasises the competencies required of solar technicians and engineers, this study foregrounds the critical role of TVET educators in preparing the broader workforce. By identifying the knowledge, skills, and pedagogical capacities that trainers require, the research addresses a foundational gap that, if left unattended, will continue to constrain sector-wide skills development in Namibia.

The findings on preferred modes of study, combining full-time, part-time, and distance learning options, are also consistent with international research on TVET programme delivery models. UNESCO-UNEVOC (2021) emphasises the importance of flexible, learner-centred approaches that accommodate the diverse needs and circumstances of adult learners, many of whom are already employed and seeking to upskill or reskill.

5.3. Implications and Limitations

The study has several important implications for policy and practice. First, it provides a robust empirical foundation for the Namibia Qualifications Authority

(NQA) and Department of Technical and Vocational Education and Training (DTVET) to develop and register a Bachelor of TVET in Renewable Energy (Solar Technology) on the National Qualifications Framework. Detailed stakeholder input on entry requirements, subject content, programme duration, and delivery modes provides concrete guidance for curriculum developers.

Second, the findings underscore the importance of industry-academia partnerships in TVET programme design and delivery. Strong industry support for the qualification, combined with confirmed sponsorship prospects, suggests the proposed programme has both demand and financial viability to be sustainable over the long term.

Several limitations of the study warrant acknowledgement. The sample of 17 respondents from 13 institutions, whilst purposively selected to represent a range of institutional types and professional roles, is relatively small and may not capture the full diversity of stakeholder perspectives across Namibia's renewable energy sector. Additionally, the study relied on self-reported perceptions and preferences, which may be subject to bias or may not fully reflect the operational realities of implementing a new qualification.

Future research should longitudinally track programme graduates to assess employment outcomes, employer satisfaction, and the qualification's impact on the broader solar workforce ecosystem. Comparative studies examining TVET solar programmes in other African countries could also yield valuable insights into effective curriculum design, delivery models, and industry partnerships.

6. Conclusion

6.1. Summary of Key Findings

This study presented the findings of a design-based needs assessment for a proposed Bachelor of TVET in Renewable Energy (Solar Technology) at a university of science and technology in Namibia.

Key findings include: a unanimous industry preference for integrated expertise in solar PV and solar thermal systems; identification of solar technicians as the most urgently needed professional category; strong stakeholder support for degree-level qualifications for TVET trainers; consensus on a three- to four-year programme combining theoretical instruction with industry attachments; and confirmed availability of sponsorship from government and industry sources.

These findings provide a comprehensive empirical foundation for qualification design and registration on Namibia's Qualifications Framework (NQF).

6.2. Contributions to the Field

This study contributes to the literature on TVET curriculum development and renewable energy workforce development in Africa. Methodologically, it demonstrates the value of stakeholder-engaged needs assessment in ensuring that qualifications are demand-driven, contextually relevant, and responsive to industry re-

quirements.

Substantively, it addresses a critical gap in the literature by focusing on the specific competencies and qualification requirements of TVET trainers in the solar sector, a dimension that has received insufficient attention in prior research. Practically, the study provides actionable evidence to guide policy development and curriculum design in Namibia, and potentially across the Southern African Development Community (SADC) region.

6.3. Recommendations for Future Research

Future research should extend this needs assessment in several directions. A longitudinal follow-up study tracking trainers' and trainees' perceptions and outcomes after the proposed qualification is implemented would provide valuable evidence of programme effectiveness and impact.

Comparative analysis of TVET solar programmes across multiple African countries could identify transferable best practices and common challenges. Additionally, research examining how TVET curricula integrate emerging technologies such as green hydrogen and advanced energy storage would help programmes remain responsive to rapid technological change.

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Author Contributions

Conceptualisation and study design, G.M.T.; data collection, B.K.; analysis and interpretation of results, G.M.T. and B.K.; writing—original draft preparation, G.M.T. and B.K. All authors reviewed the results and have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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