SHINE

Solar Hands-on training and International Network of Exchange

Greening TVET for the solar industry in Africa

Insight paper

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1. About SHINE

SHINE is a Capacity Building project funded by the EU Commission that seeks to drive the green transition and enhance energy Access in Africa. A European African consortium, involving VET providers and stakeholders from education, industry, and policy makers, is collaboratively redesigning a market-oriented VET program focused on solar panel technology.

Starting in January 2024 and for 36 months, the SHINE project gathers 10 organizations from Europe and Africa actives in the field of TVET and education and experts in the solar energy industry. It is constituted by VET providers and their networks (CIFP Usurbil LHII - ZubiGune Foundation in Spain, AKMI in Greece, Jobitech in Nigeria, Suame Technical Institute in Ghana, and Kiryandongo TI & Huys Link VTC in Uganda), Universities, research and business development centers (Start-up SMEs Centre, SSC, in Ghana, Pan-Atlantic University in Lagos, Nigeria and Universiteit Leiden with their Dutch-African knowledge platform of researchers, INCLUDE). All of them led by Mundus, an Spanish organization with a wide experience in the African continent and presence in more than 25 countries through capacity building initiatives.

The main objective is to deliver an innovative capacity building program in Solar Training in Africa and the specific objectives include:

1. To strengthen the evidence-base around green skills in the solar industry in Africa
2. To develop a hybrid capacity building program for VET teachers
3. To redesign and pilot Solar Panel technology program
4. To promote the employability and self- employment of learners
5. To encourage long- lasting international partnerships

To achieve this ambitious goal, the working methodology is divided into three distinct phases:

- The first phase is focused on research, during which study visits, interviews, and meetings with key stakeholders in TVET, employment, and the energy sector (schools, universities, government bodies, and the private sector) are conducted to map out the current state of solar energy and training, identifying the main challenges and opportunities.

- Once the context is understood, capacity-building pathways are designed to upskill trainers in VET centres in Nigeria, Ghana, and Uganda, with specific training provided in centres of excellence in Europe.

- Finally, based on the groundwork, the training for educators, and collaboration with key stakeholders, the curriculum is co-created and redesigned to align with market needs.

Below is one of the key outcomes of the project's first phase, where the solar energy landscape and the sector's needs in terms of skills, strategies, and policies were thoroughly analyzed.

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1. Introduction

The world stands on the brink of a green economic transformation, ready to unlock the vast potential of renewable energy to power its economies and societies.

With its abundant sunlight and significant untapped resources, Africa is perfectly positioned to leverage solar energy as a catalyst for the continent's development and environmental sustainability.

This is crucial, as traditional energy systems struggle to meet the growing energy demand. Still more than half of the continent does not have access to electricity and even when there is access it is not reliable or affordable for everyone.

The greening of economies through a process of low carbon transition (LCT) is also seen as a pivotal strategy in creating green jobs. ILO estimates that by 2030, 24 million new jobs will be created globally if the right policies to promote a greener economy are put in place.[1] For Africa, leveraging this potential will be critical to create employment for its ever-growing youth workforce, which is estimated to become the largest in the world by 2040. So far, Africa has been struggling with creating sufficient employment, especially jobs that can be labelled as decent. In this regard, the call for a *just* energy transition that provides pathways for scaling up clean energy supply and creating decent employment opportunities for youth, while at the same time improving access to affordable and reliable electricity and ensuring that no-one is left behind, is growing[2] increasingly louder.

One key barrier holding Africa back in realising its potential however, is the skills mismatch that exists between the needs of the private sector in a changing labour market, and the educational background and skill-set of its youth. Technical and Vocational Education and Training (TVET) is in this respect crucial, not only in equipping youth with the right skills for the labour market today, but also in preparing youth for the future of work. However, TVET institutes in Africa still face many barriers and systems for identifying, integrating and implementing new green competencies in TVET in Africa remain underdeveloped. Greening TVET, an approach that aims to support green skills development and facilitate sustainable policies and institutionalise sustainable practices and education, is seen as a key strategy to enable Africa to not only respond to the global call for a low-carbon transition, but to drive and thrive in the green economy.

Despite its prominence, still little is known about how greening TVET in Africa works in practice and what the roles and responsibilities are for different stakeholders in the ecosystem. This paper seeks to bridge this gap by combining insights from the literature with emerging findings from case study research conducted in Ghana, Nigeria, and Uganda, particularly within the solar energy sector. By contextualizing these findings, the paper offers a comprehensive analysis of the barriers and opportunities for greening TVET in Africa, identifying skills needs, best practices and providing recommendations and pathways for change.

Grounded in a transnational and multi-stakeholder partnership, the research underscores the value of connecting local experiences with global perspectives through South-South and South-North exchanges, fostering mutual learning and shared progress in the greening TVET journey. Ultimately, the paper emphasizes the importance of multi-stakeholder collaboration, decent employment and inclusive, youth-centered approaches to create an enabling environment for young people to contribute to a just, low-carbon transition in Africa.

1 *ILO (2018) World Social Outlook.*

2 *Lijfering, S. Kazimierczuk, A., Abagun, O. (2024).*

2. Insights from research: Green skills and the need for greening TVET

Accelerating the green transformation while expanding access to the opportunities it opens up, requires the development of skills, knowledge and competences that can drive innovation, support sustainable practices, and adapt to new technologies.

It is in this context that the concept of greening TVET is gaining traction in both policy and programming circles and is increasingly seen as a central part of a just transition process. However, there is still a lack of conceptual clarity of what greening TVET actually entails and which "green skills" are meant to be developed. This section outlines the main definitions and approaches of greening TVET and green skills and applies these to the solar industry in Africa. As such, this chapter provides the theoretical foundation for the rest of the paper which explores how greening TVET in Africa works in practice.

Green skills

The greening of the economy brings with it changes in the demand for certain skills in the labour market. Understanding these changes has important implications for policy aiming to support a conducive business environment. Such skills enable the adoption and use of resource-efficient, sustainable processes and technologies by the private sector and individual consumers. These skills, also labelled 'green skills', are broadly understood as "The knowledge, abilities, values and attitudes needed to live in, develop and support a sustainable and resource efficient society", and encompass a variety of different skill-sets.[3]

There are many different understandings of what constitutes a green skill. The green skills index[4] identifies four types of skills that can be marked as green: 1). Engineering and technical skills. These are hard skills encompassing competences involved in the design, construction and assessment of technology, usually mastered by engineers and technicians. 2) Science skills. These competences are essential to innovation activities and are in especially high demand at each stage of value chains and in the utility sector. 3). Operation management skills. This refers to the know-how related to the change in organizational structure required to support green activities. 4) Monitoring skills. This refers to the skills required to assess the observance of technical criteria and legal standards.

However, it is increasingly acknowledged that green competences go beyond just technical skills and also encompass transversal skills which include soft skills or life skills that can be applied across a wide range of jobs and support green transitions through other avenues than technical application.[5] Examples include strategic thinking, project management, decision-making, leadership, and effective communication. In addition, entrepreneurship skills are deemed increasingly important as most new labour market entrants in the green economy end up self-employed. Finally, digital skills and basic digital literacy are recognised as essential in navigating the technological advancements that come from the green and technological transformation.[6]

Skills forecasting

To determine the skills that are needed both in the current labour market but also in the future of work, it becomes increasingly important to conduct labour market and skills analyses. Skills

3 *Cedefop; OECD (2015)*
4 *Arthur, C. (2022)*
5 *Lijfering, S. & Lacey, N. (2023)*
6 *Howard, C. (2023)*

forecasting can in this regard play a crucial role in facilitating and shaping change and transitions, as they provide evidence-based insight into labour market trends and a range of other societal developments and their implications.[7] The private sector can use forecasts to anticipate future skills shortages which can inform the development of training programmes and policies to promote skills development and utilisation. This is particularly important for TVET institutions as they provide the pipeline of workers for these industries and need to equip and prepare youth for the future of work.

However, labour force data is weak in most African countries and systems for identifying, integrating and implementing new green competencies in TVET in Africa are limited.[8] In terms of identification, only 20% of African TVET stakeholders surveyed in 2020 said that their country regularly conducts national skills forecasts and that these forecasts pay explicit attention to the new skills required in a green economy.[9] Regarding integration, a 2017 analysis of the existing qualifications for sustainable development occupations in South Africa found that green skills occupations are poorly defined in the national system of occupations and that the bulk of environmentally-related qualifications are registered at tertiary or postgraduate education levels, reflecting a specialist entry-point and limited pathways into environmental jobs for individuals with lower-level or non-traditional qualifications.[10] Finally, in terms of implementation, a 2015 study examining the status of green skills and technologies on offer in TVET institutions in Africa found that the majority of TVET courses do not integrate green technologies in their training and that practical training through project work was missing. It also noted low skill levels among instructors linked to low levels of funding and support, including insufficient staff training on renewable energy skills and green technologies.[11]

However, while foresighting and industry-led TVET approaches are useful to support demand-driven curricula, the dependence on employer-specific competencies means there is little engagement with the realities of the predominantly informal nature of African labour markets and self-employment, which is where the majority of workers end up. In addition, an external skills audit might not pick up the more nuanced skill needs in a changing labour market and may not align with the structure of the TVET system and other non-formal and informal training offers. As such, there is a growing need for more contextually driven approaches that take the reality of African economies and VET systems as the starting point.[12] This entails engaging with different stakeholders in the ecosystem to look more systematically at the elements of the system that are needed to support both the demand for skills and the development and utilization of skills in a holistic manner. McGrath describes this as skills ecosystem thinking, which recognises that future skills are influenced by a variety of interconnected factors and stakeholders. These can range from industry demands and political conditions to financial resources and cultural norms.[13]

Greening TVET

In line with these calls, the concept of Greening TVET emerges which aims to transform TVET education to the overall concept of sustainability. However, despite its prominence, there is still no consensus on what greening TVET actually refers to and which approach should be taken. Building on the framework presented by the UNESCO-UNEVOC International Centre for Technical and

7 *Cedefop (2021)*
8 *Cramer, J. Sender, A. Oqubay (2020)*
9 *Regt, W. de, & Gianchandani, P. (2020)*
10 *Ramsarup. P. (2017)*
11 *Jahonga, W. M., Ngore, P. R. Muramba, V. W. (2015)*
12 *Allais, S. (2023)*
13 *McGrath, S. (2022)*

Vocational Education and Training[14] and the work of Majumdar,[15] three perspectives on greening TVET can be discerned. Firstly, on an institutional level, which sees greening TVET as an approach to align the educational institution with sustainability practices. Adding a sustainability mindset to operational practices, strategic decision-making, curricula development and creating a green culture is seen as critical in preparing students for the future of work in the green economy. The second approach focuses on the learners, providing them with the right knowledge, skills and attitudes to make them active members of green economies and enable them to pursue lifelong and decent work. The third perspective views greening TVET as a cross-cutting theme that is influenced by externalities like policies and plays a role in reinforcing, or reorienting certain beliefs and values within society.

Despite different entry points, what most current conceptualisations of greening TVET recognise is that the process of "greening" goes far beyond simply altering what is taught in school. Greening reaches into all aspects of the institution's operations and the ecosystem around it. Adapting definitions from existing literature,[16] we define greening TVET as follows:

> "Greening TVET is an approach that aims to facilitate sustainable policies and institutionalize sustainable practices and education in schools, communities and workplaces to equip individuals with the green skills and knowledge necessary to actively participate in sustainable practices and enabling them to pursue decent work and contribute to the green economy."

In conclusion, to effectively green TVET, it is crucial to adopt both a holistic and a context-specific approach. Rather than relying solely on established qualification frameworks and immediate skill requirements, TVET should address the diverse and multifaceted realities of Africa. This includes considering informal economies, political dynamics, and socio-cultural factors to better meet the needs of learners and adapt to evolving industries. This will be particularly important for the solar sector, as the industry is still emerging and changing, which requires a responsive and future-oriented vision. It also requires an inclusive and gender-responsive approach that recognises the different experiences and perspectives of learners and addresses inequalities on multiple dimensions, including barriers for learners with disabilities and female students in male-dominated fields and facilitating meaningful engagement of youth in decision-making processes.

In addition to institutional changes, greening TVET should involve shaping the enabling environment through policy adaptation and promoting sustainable practices within industries and communities.

Recognizing and addressing both internal challenges, like resource limitations and teacher shortages, and external factors, such as policy frameworks and industry demands, will help TVET align more closely with learner and labour market needs. In this regard, a multi-stakeholder approach is instrumental, whereby key players in the TVET and solar ecosystem come together to identify emerging skill needs, determine relevant training requirements and establish supportive structures and favourable policies. This collaborative and contextual approach is essential for empowering young people to lead the transition towards a sustainable future.

14 *UNESCO-UNEVOC International Centre for TVET (2017)*

15 *Majumdar, S. (2010)*

16 *See the various definitions in the UNESCO UNEVOC Glossary: here*

3. Insights from practice: greening TVET in Ghana, Uganda and Nigeria

In order to facilitate a more contextual understanding, this section presents the main insights from case study research into opportunities and barriers for greening TVET for the solar industry in Ghana, Uganda and Nigeria. These main insights and lessons learned are synthesised from the full case studies which can be found on the website of the SHINE project.[17]

Methodology

The findings presented below are grounded in both (academic and grey) literature and empirical data collected during study visits taking place between April and July 2024. The study visit team consisted of African and European experts from TVET institutions, solar energy and TVET organisations, and research institutions. A participatory research approach was used by collaboratively shaping the research questions and engaging key actors in the TVET and solar energy sectors in the three countries. During a final workshop, findings were validated and synthesized, establishing the groundwork for the national greening TVET roadmaps outlined below.

In total a number of 45 semi-structured interviews were conducted with diverse participants, including government representatives, policy makers, companies, researchers, renewable energy associations, sector skills bodies, entrepreneurs and civil society organisations. In addition, several focus group discussions were held with TVET managers, trainers, and students. Furthermore, the team engaged in participant observation during company and TVET visits and organised multi-stakeholder and policy dialogues in each of the three countries. This iterative research approach allowed for a continuous process of validation and engagement and ensured the research was grounded in contextual and multi-stakeholder dimensions.

Below the main insights from the three case studies are presented after which a comparative analysis and synthesis highlights key findings and major lessons learned about greening TVET in Africa.

3.1 Greening TVET for the solar energy sector in Ghana

Ghana is one of the highest performing countries in Sub-Saharan Africa when it comes to the ambition of universal energy access, with an energy access rate of 87%.[18] The country has made major strides over the last decades in increasing access to the grid; from a mere 61% electricity access rate in 2011 to 79% in 2016 and 87% today. Ghana relies on a diversified energy mix, dominated by hydropower, thermal energy and gas.[19] However, despite hosting the largest hydropower project of the Western African region, more than two thirds of Ghana's energy sources come from burning fossil fuels, which generates significant Greenhouse Gas (GHG) emissions. Furthermore, although Ghana receives some of the highest levels of solar radiation globally, renewable energy sources like wind and solar contribute to less than 1% of its total energy supply.[20]

The increasing demand for reliable and affordable electricity in Ghana and the need to reduce GHG emissions have resulted in significant investments and policy engagement in supporting the

17 *The full case studies can be found on the website of INCLUDE: https://includeplatform.net/theme/shine/*

18 *International Energy Agency: https://www.iea.org/reports/sdg7-data-and-projections/access-to-electricity*

19 *International Energy Agency (IEA): https://www.iea.org/countries/ghana*

20 *Asumadu-Sarkodie, S., Asantewaa Owusu, P (2016)*

development of the renewable energy sector. In 2019, the government launched its Renewable Energy Master Plan which was supplemented by the Energy Transition and Investment Plan in 2023. Both these strategic documents set ambitious targets, including the achievement of net-zero carbon emissions by 2060 and achieving 10% renewable energy penetration by 2030. Additionally, the government has launched policies, partnerships and regulations supporting solar adoption, such as feed-in tariffs, net metering and public-private partnerships (PPPs) which have contributed to the growth of the industry. Despite these efforts, Ghana's solar energy potential remains vastly untapped and the solar market is anticipated to grow substantially over the next decade.[21]

Solar energy labour market trends, challenges and opportunities

With the growth of the solar energy sector in Ghana, there is an increased need for a skilled workforce that can keep up with the industry's innovations and rapid advancements. As solar panels and equipment are primarily manufactured abroad and imported to Ghana by various national and international companies, the majority of professionals in the solar industry work in the installation and maintenance of solar photovoltaic (PV) technologies. As the market expands, however, other occupational profiles become increasingly relevant and it is crucial to develop labour market intelligence through foresight analysis to understand where the new jobs will be created and what skills would need to be developed. A labour market analysis of Ghana's solar industry highlighted the following critical skills gaps:

- Practical Installation Skills: Basic practical skills in designing solar PV systems, covering aspects such as system sizing, site analysis and placement optimisation for maximum energy generation are often only read about but not sufficiently practiced. Additionally, proper use of tools and adherence to health and safety standards are lacking. Knowledge of diverse system set-ups, including both on-grid and off-grid setups and net metering, is also missing.

- Analytical and problem-solving skills: Maintenance and troubleshooting of solar systems to identify faults and inefficiencies require strong analytical abilities, which are often underdeveloped in current training programs.

- Innovation and entrepreneurship skills: There is also a skills gap in productive use of solar energy to create tangible value, by enhancing productivity, generating income, and creating employment opportunities. Application of solar in other industries such as heating and cooling systems, solar-powered irrigation and e-mobility is also not well-developed

- Transversal and soft skills: While technical skills are essential, the ability to manage projects, communicate effectively with clients, and innovate for new solutions is equally important in the solar sector. While entrepreneurship is included in (most of) the TVET curricula, more real-life engagement and workplace learning experience opportunities are needed.

- Green awareness: Environmental awareness, knowledge about sustainable practices, other renewable energy technologies, and energy efficiency is often missing.

[21] *Mordor Intelligence (2021)*

TVET ecosystem: policies, perceptions and pathways

A key factor in addressing these skill gaps and fostering the growth of Ghana's solar sector is the development of a strong and supportive TVET system. This system should focus on developing green skills to prepare Ghana's youth for working in the expanding solar energy market. In this regard, Ghana's TVET system has undergone substantial reform in recent years, particularly through the 2019 Harmonization of TVET initiative, which centralized all 218 institutions under the Ministry of Education and appointed two agencies with the responsibility of managing the TVET system in Ghana: The Commission for TVET (CTVET), responsible to regulate, promote and administer TVET and the Ghana TVET Service (TVETS), responsible for management, oversight and implementation of approved national policies and programmes relating to pre-tertiary TVET.

Another relevant change has been the introduction of the Free Senior High School (SHS) policy in 2017 when president Nana Addo Dankwa Akufo-Addo declared that secondary education, including TVET, would be freely accessible to all students. The free element of the policy refers to free tuition, admission, library fees, facilities fees such as ICT, examination fees, boarding, and meals. As a result, the number of students for SHS including TVET drastically increased. However, despite the increasing enrolment rates, the TVET system in Ghana still suffers from a poor public image as a place 'for the academically weak' and most parents believe that students attending TVET institutions do so as a last resort after failing to secure a university placement.

Another important development is the increased focus on competency-based training (CBT) in Ghana, which is an outcome-based education and training where the learner is educated and assessed based on demonstrated ability rather than on that of elapsed time. The CBT approach has helped align TVET programs better with labor market demands, which is particularly important in emerging sectors like renewable energy. However, solar energy TVET training remains in its nascent stages in Ghana. Currently, training in solar PV technology is scattered across public institutions, private providers and through informal apprenticeships. In TVET, solar courses are integrated into broader electrical engineering curricula, leaving a gap in specialized solar training.

Recent initiatives have attempted to address this. A comprehensive three-year competency-based solar PV curriculum is currently piloted in selected TVET institutions, with plans for a nationwide rollout beyond 2025. In addition, short courses (1- 4 weeks) are offered by private sector-led initiatives that focus on basic technical skills, primarily for installation and maintenance. Despite these advances, much of the solar training remains theoretical, with insufficient opportunities for hands-on learning. This lack of practical exposure is a major barrier to young people entering the labour market and is recognised by industry leaders as a significant skills gap.

Remaining barriers

As the case study research in Ghana shows, greening TVET provides a promising avenue for generating green jobs for the country's expanding youth workforce and advancing towards a low-carbon economy. However, substantial barriers to fulfilling this potential remain. To overcome these challenges and unlock the power of solar energy and TVET in Ghana, the following recommendations outline potential pathways for driving meaningful change.

Need for more coordination between programmes and increased stakeholder engagement. In recent years, numerous solar trainings have emerged in Ghana. However, these efforts often lack alignment with existing programs, leading to issues with accreditation, and quality assurance.

Limited industry -TVET linkages and workplace learning opportunities. Despite the increased focus on competency based training and the establishment of a solar industry relevant sector skills body, the collaboration between TVET institutions and solar companies is still limited. Especially in the provision of workplace experience and learning opportunities for students, industry-TVET partnerships are insufficient to provide students with the necessary practical, hands-on experience.

Limited capacity building opportunities for TVET trainers. Many TVET teachers in Ghana lack up-to-date knowledge and hands-on experience with solar PV systems, which impedes their ability to effectively teach the latest techniques and technologies. In addition, teacher retention is an issue, leaving TVET institutions struggling to maintain a knowledgeable teaching workforce.

Shortage of funding for Solar PV equipment. Many TVET institutes are also constrained by inadequate financial resources, which limits their ability to acquire and maintain up-to-date solar PV systems and related tools. Especially for solar training, where equipment is more costly than in many other professions, this results in many TVET institutions having outdated solar systems that do not meet current industry standards.

Insufficient focus on inclusivity in TVET institutes. Despite progressive TVET policies, inclusivity remains an issue, which is essential for fostering a diverse and equitable workforce. This involves addressing several critical dimensions: gender responsive training opportunities, in particular access to TVET training by young women, support for individuals with disabilities, outreach to people from remote communities and engagement of youth in decision making processes around TVET policies.

Lack of data and analyses of labour market and green jobs potential and lack of skills identification. Creating a supportive business environment for solar companies and raising awareness among youth and the public about career opportunities in the sector is key to support employment in Ghana's solar sector. In-depth research on the labour market to understand job demands and trends is still missing and data on the decency and sustainability of green jobs is scarce.

Policy implementation to support greening TVET in Ghana is still insufficient. Establishing a supportive policy and funding environment is crucial for advancing the solar industry and greening TVET in Ghana. Despite key interventions and progressive policy frameworks, policy implementation that guides the transition to a green economy remains challenging.

Need for enhancing green awareness. Increased environmental awareness is essential for greening TVET programs to design and implement sustainable practices into curricula and TVET systems. While the topic of sustainability is gaining a foothold in political discourse, broader green awareness is needed to enhance the relevance of solar TVET education and promote a culture of sustainability.

3.2 Greening TVET for the solar energy sector in Uganda

The government of Uganda is dedicated to a just and inclusive energy transition, as outlined in Uganda's Energy Transition Plan (2023).[22] The plan sets out a strategy to achieve universal access to electricity and carbon neutrality by 2050. This is highly needed as currently around 43% of the population is still lacking access to electricity which is disproportionately affecting people in rural areas, as only 8% of the rural population has electricity access.[23] Solar energy can play a key role in the energy transition, given Uganda's abundant solar potential. By harnessing this resource and developing the solar energy sector, the country can address multiple pressing challenges simultaneously, including youth un(der)employment, climate change, and energy scarcity.

A significant barrier to this potential is the huge shortage of qualified and skilled young people able to drive the growth of the solar energy sector. Remarkable, as over a million youths enter the labour market in Uganda every year.[24] While only 6.58% of Ugandan youth (ages 15-24) were officially unemployed in 2022,[25] underemployment remains a salient issue. Many young people are compelled to accept jobs that are below their skill level, pay grade, and preferred quality of work. Furthermore, nearly 90% of youth in Uganda work informally, lacking formal contracts and social security.[26]

TVET holds a key role in bridging the skills gap and addressing youth un(der)employment in Uganda. However, there are many obstacles in Uganda's renewable energy and TVET landscape that require a combined effort of government, private sector, civil society, TVET providers and international organizations to overcome.

Uganda's Energy Landscape and Solar potential

Bioenergy is accounting for 94% of Uganda's total energy use. This primarily comes from charcoal and firewood, which, albeit technically renewable, is not sustainable as it can greatly contribute to greenhouse gas emissions and environmental degradation.[27] Solar energy offers a promising alternative as the average amount of solar energy received is 5.1 kWh per square metre each day. Solar energy levels stay high all year round in Uganda, with only a 20% difference between the lowest and highest months.[28] Therefore, solar energy also has the potential to contribute towards realising universal access to electricity in Uganda within a certain timeframe. Additionally, while over 82% of Uganda's electricity is derived from hydropower, solar energy still only accounts for about 3%. This makes the electricity supply highly vulnerable to environmental disruptions like flooding and droughts.[29] Diversifying the energy sector by enhancing the solar energy capacity is therefore crucial.

The promotion of the solar energy sector is also seen as an important strategy in providing viable alternatives for rural and remote areas not connected to the national grid through off-grid solar systems.[30] Moreover, beyond meeting domestic household needs, solar energy can greatly enhance social and economic well-being. It can improve healthcare services by enabling solar water pumping and refrigeration to alleviate power shortages in health centres. Widespread adoption of off-grid systems, such as solar-powered water pumps and refrigeration by smallholder farmers could significantly boost agricultural productivity, strengthen crop value chains, and improve both

22 *International Energy Agency, 2023*
23 *GIZ in Ministry of Energy and Mineral Development Uganda, 2023*
24 *World Bank in Challenge Fund for Youth Employment, 2021*
25 *Uganda board of statistics in Namuleme, H., 2023*
26 *Challenge Fund for Youth Employment, 2021*
27 *GIZ, 2022a.*
28 *Ibid*
29 *Rüdenauer, S, H., 2024*
30 *Ibid*

food security and export capacity.[31] To promote the use of solar energy, public-private partnerships, including demand and supply subsidies, loans, and tax exemptions for solar equipment are supporting both companies and households by making solar energy more accessible to a larger portion of the population that could otherwise not afford gaining solar energy access.[32]

Solar energy labour market trends, challenges and opportunities

With the growing demand for solar energy and its promotion by the national government, the sector presents significant labour market opportunities in both the productive use of solar energy (PUSE) and the domestic household market. Until recently, PUSE did not receive much policy attention but the National Road Map on Scaling Up Productive Use of Solar Energy (PUSE), which was co-developed by both governmental and national and international actors,[33] provides key recommendations for stakeholders in supporting the 'agricultural, commercial, and industrial activities involving [solar] electricity services as a direct input to the production of goods or provision of services.'[34] In terms of the domestic household market for solar energy the government is promoting a more decentralised approach, with strong focus on rural areas. The Rural Electrification Programme aims to add 300,000 new electricity connections each year, with about one-third of these coming from off-grid solutions.[35]

Decreasing costs of solar solutions and innovations across the sector are also contributing to expansion of the solar energy sector.[36] For example, over the past 15 years, the off-grid sector—including solar home systems and mini-grids—has seen substantial growth and attracted foreign investment, with more than 400 off-grid solar companies now operating in Uganda.[37] Additionally, various actors, including solar energy sector associations, research institutes, and civil society organisations, are actively promoting green awareness and solar energy usage. They also provide knowledge, coordination, and strategic guidance to support solar energy companies.

Despite these positive developments, solar companies still face significant barriers, including limited access to finance and a shortage of qualified young people for various roles in the solar energy market. Furthermore, many non-qualified electricians offer solar PV services in the informal economy, leading to inconsistent installation techniques. These informal jobs often lack decent working conditions, including adequate safety measures, job longevity, and fair compensation. Nevertheless, solar professionals are highly sought after in Uganda, particularly solar installation and maintenance technicians, solar engineers and managers, technical sales representatives, and solar energy researchers. The following essential skills were identified as required for these positions.[38]

- Technical knowledge and practical skills: Essential competencies include solar panel installation and maintenance, proper handling of batteries to prevent overheating, product quality assessment, expertise in solar thermal systems, knowledge of solar pumping systems, and the ability to repair solar components.[39]
- Green and transferable skills: skills like strategic thinking and programme management are valuable in the solar sector and across other green industries. Incorporating environmental awareness into curricula enables youth to advocate for sustainable practices.

31 *Ministry of Energy and Mineral Development Uganda, 2023*
32 *Ibid.*
33 *Ministry of Energy and Mineral Development Uganda, 2023*
34 *Building on a definition of GIZ for PUSE in Ministry of Energy and Mineral Development Uganda, 2023*
35 *Ministry of Energy and Mineral Development Uganda, 2023*
36 *Gupta, 2023*
37 *Ministry of Energy and Mineral Development Uganda, 2023*
38 *Interviews with Centre for Research in Energy and Energy Conservation, the Women in renewable Energy Association and SolarNow in June 2024*
39 *Final roadmap development workshop with study visit participants (TVET institutes, teacher training companies, solar experts and researchers in June 2024*

- Entrepreneurial and soft skills: As many technicians work informally under indecent working conditions and many students aspire to start their own businesses, there is a need to develop soft and entrepreneurial skills like communication and sales skills.

TVET ecosystem: policies, perceptions and pathways

The TVET system in Uganda is nationally organised under the Ministry of Education and Sports and supported by the establishment of relevant governmental bodies aimed at guiding and regulating TVET. Since 2008 the Uganda Vocational Qualification Framework (UVQF) has been guiding the structure and quality of different levels of vocational training in the country. This framework falls under the Directorate for Industrial Training (DIT) which is responsible for developing occupational standards, accrediting assessment centres, and conducting competency-based assessments. The Uganda Business and Technical Examinations Board (UBTEB) is the coordinating body for TVET programmes in Uganda. All the nationally recognized curricula are developed by the National Curriculum Development Centre (NCDC). TVET providers, ranging from public institutions to private and non-formal providers develop their own programmes following these guidelines and submit them for approval to DIT or UBTEB.[40] The newest TVET policy focuses on facilitating an employer-led TVET system in which private sector employers make up 66% of the newly established sector skills councils that are responsible for stimulating 'the development of national occupational standards and competency based curricula and qualifications.[41] This should ensure that TVET programmes meet the needs of the labour market.

Indicative of the state of TVET for the solar energy sector is the fact that there is only one nationally recognised curriculum under NCDC that is solely focused on solar energy, which was developed over five years ago.[42] Various TVET providers have since developed a range of short courses (ranging from one week to 12 months) based on this national curriculum and incorporating additional solar related information and skills to enhance and differentiate their offerings from those of other providers. However, there are no dedicated TVET programmes longer than one year that focus solely on solar energy. Solar energy in these cases, is only offered as a module within broader energy and electric engineering programmes.[43]

While government promotion and investment in TVET have increased public awareness of its opportunities compared to traditional academic pathways, the perception of youth towards TVET remains mixed due to a lack of resources, educational materials, qualified teachers, and difficulties in securing internships. Youth remain sceptical about whether their education would lead to job opportunities in the solar sector. Additionally, the high costs and frequent breakdowns of solar systems have negatively affected perceptions of the solar energy sector, influencing how both TVET programmes and employment prospects in the field are viewed.[44]

Remaining barriers

Despite the great potential for Greening TVET for the solar industry in Uganda, there are multiple barriers that hinder its ability to close the skills gap and prepare youth for the solar labour market.

40 *Republic of Uganda, 2008*

41 *Ministry of Education and Sports Uganda, 2019.*

42 *Meeting with the Directorate of Industrial Training in June 2024*

43 *Visits to Huys Link Community Initiative, Kiryandongo Technical Institute, St. Joseph's Technical Institute and Uganda Technical College Kyema in June 2024*

44 *Conversations and Focus Group Discussions with students of Kiryandongo Technical Institute and Uganda Technical College Kyema in June 2024*

Fragmented efforts and limited coordination: Despite attempts at coordination through sector associations and government initiatives, there is a lack of integrated collaboration, monitoring of efforts and comprehensive knowledge sharing in the solar TVET landscape.

Insufficient private sector collaboration: despite efforts like facilitating a demand-led TVET system, there is limited private sector engagement in curriculum development, leading to outdated curricula. Although industrial training is mandatory, securing placements remains challenging, and lacking internship opportunities result in graduates missing practical skills.

Shortage of qualified teachers, inadequate teaching material and training: the TVET system faces a significant shortage of qualified teachers in solar energy, further exacerbated by limited opportunities for teacher training and a lack of quality teaching materials.

Limited financial resources for greening TVET: Insufficient funding and investment in greening TVET for the solar industry lead to significant resource shortages across TVET institutions.

Limited inclusivity and Uganda's TVET system: The TVET system in Uganda encounters significant barriers to inclusivity, including gender, spatial, and economic challenges, which hinder its effectiveness in preparing all youth for emerging labour market opportunities.

Mixed perception of potential of solar energy: Despite the promotion of TVET for renewable energy and growing public awareness of solar energy's potential for providing access, perceptions of its economic and environmental benefits remain mixed due to high costs and low-quality products with a short lifespan that can end up in the environment.

Lack of a supportive business environment: Particularly the PUSE and off-grid market are lacking comprehensive regulatory frameworks. Second, new policies and regulations in combination with limited expertise among civil servants result in a confusing policy environment. Third, financing options for companies remain limited. Fourth, solar systems remain out of reach for large parts of the population due to high costs and insufficient infrastructure in rural areas.

3.3 Greening TVET for the solar energy sector in Nigeria

Nigeria's renewable energy sector, underpinned by key policies such as the National Renewable Energy and Energy Efficiency Policy (NREEEP) of 2015, the Mini-Grid Regulation by the Nigerian Electricity Regulatory Commission (NERC), and the Renewable Energy Master Plan (REMP), has set ambitious targets for integrating solar energy into its energy mix. Currently, Nigeria's electricity generation relies primarily on non-renewable energy sources, including gas, contributing 79.46% to the energy mix. Hydropower is the second largest source, accounting for 20.37%. Solar energy makes up 0.12%, bioenergy contributes 0.05%.[45] In recent years, renewable energy development has focused on off-grid and mini-grid solar projects, but efforts to drive private sector-led on-grid renewable energy have seen limited success. due to infrastructure challenges, with rural areas particularly underserved.[46] This gap between demand and supply has led to widespread use of costly, environmentally unfriendly energy sources, particularly diesel powered generators.[47]

[45] *Sasu, 2024*

[46] *NERC, 2022, World Bank, 2023*

[47] *Nnodim, 2021*

In Nigeria, only 60% of the population has access to electricity, leaving over 85 million people unserved, necessitating substantial investment—estimated at $100 billion over the next 20 years.[48] In light of these challenges, efforts to diversify Nigeria's energy sources are gaining momentum, particularly with the gradual shift toward renewable energy. Solar power, in particular, has emerged as a promising alternative, driven by both public and private sector initiatives.[49] The decentralized nature of renewable energy solutions, such as off-grid solar home systems and mini-grids, makes them particularly effective for rural electrification, where access to the national grid is often limited,[50] and in urban areas where they offer flexible, scalable, and reliable electricity in regions with an unreliable national grid. The Rural Electrification Agency (REA), has been instrumental in promoting these decentralized solutions. In 2023, over 100 solar mini-grids had been deployed in rural areas, providing electricity to previously underserved communities.[51] The private sector has also played a crucial role, with solar companies leading the way in delivering solar energy solutions to both urban and rural populations.[52]

Solar energy labour market trends, challenges and opportunities

The solar industry's expected expansion in Nigeria presents diverse opportunities for different segments of the workforce, each requiring specific skills and qualifications. However, as industry players recognise, important skills gaps in TVET graduates remain:

- Energy system design: Beyond installation, professionals should be able to design solar energy systems, calculating energy requirements based on consumption patterns, determining optimal panel placement, and sizing the systems to create efficient, tailored solar energy solutions for diverse environments. This skill is often missing in TVET graduates.

- Knowledge of industry standards and regulations: While basic safety tips are adhered to, the lack of adequate knowledge of national and international regulations and standards, which is essential for ensuring safe, high-quality, and legally compliant installations, have led to damages to installation sites. This gap is caused by the absence of standardized training.

- Solar Installation and Maintenance: A lack of knowledge about basic maintenance, such as cleaning solar panels, often leads to system failures. Technicians must be trained not only in the solar PV installation, but also in routine maintenance and troubleshooting to ensure long-term performance, particularly in regions with limited access to technical support.

- Energy auditing and analysis: Many of the TVET graduates are unable to conduct energy audits to analyze energy usage and how solar systems can be sized and configured to meet that demand. This is because they have not been adequately taught by skilled trainers trained in data collection, analysis, and long-term system performance evaluation.

- Performance monitoring and optimization: In current solar PV training, there is a limited focus on performance monitoring and optimization, analyzing data to detect inefficiencies or malfunctions, and suggest improvements. As a result, technicians lack expertise to maintain system efficiency and longevity, leading to reduced effectiveness of solar installations.

48 *International Trade Administration, 2023*
49 *Osunmuyiwa & Kalfagianni,2017*
50 *Olanipekun & Adelakun, 2020*
51 *REA, 2023*
52 *Ogunleye, 2021*

- Problem-solving and critical thinking: When TVET graduates face unexpected challenges such as equipment failures, weather impacts, or logistical problems they tend to panic due to the absence of preparedness and lack of troubleshooting protocols and a lack of analytical thinking which is necessary to troubleshoot these issues effectively.

- Attention to detail: Companies highlighted the lack of attention to detail in both system design and maintenance, leading to a lack of accuracy in energy calculations, panel placement, and compliance with regulations.

TVET ecosystem: policies, perceptions and pathways

The perception of Solar TVET in Nigeria reflects both optimism and skepticism. The optimism stems from a desire for a viable solution to the ongoing power challenges and its promise for job creation, a priority in a country facing high youth unemployment. Many Nigerians, particularly youth, view solar TVET as a direct pathway to meaningful employment or entrepreneurship. Further bolstering the positive perception of solar TVET is the support from international organizations, such as the World Bank, GIZ, and the Nigerian government, launching programs to promote capacity building in the renewable energy sector. These efforts not only provide financial and technical assistance but also legitimize solar TVET as a crucial component of Nigeria's development strategy.

Despite this optimism, skepticism and challenges still persist, limiting its full potential. One of the primary concerns is the limited infrastructure and resources available for solar TVET programs. Despite growing interest, many training centers are underfunded and lack the necessary equipment and modern facilities to provide hands-on experience with the latest solar technology. The curriculum in many institutions is also outdated with solar as a mere module within broader renewable energy courses. This disconnect between education and practical application fuels doubts about whether TVET graduates will truly be prepared for the workforce, leaving some employers hesitant to hire them without additional on-the-job training.[53]

Another challenge is the perceived low prestige of vocational education, seen as a last resort for those unable to gain admission into traditional universities.[54] This societal bias discourages many young people from pursuing solar TVET, even though it offers practical, in-demand skills. This perception problem is deep-rooted, affecting enrollment and engagement with these programs. In addition, cost and accessibility, especially for low-income households and rural communities, create significant barriers to solar TVET in Nigeria. Finally, uncertainty about long-term career pathways in the solar industry adds to public skepticism. While the demand for solar energy technicians is growing, there are doubts about the stability and sustainability of these jobs, especially given Nigeria's slow adoption of renewable energy policies and the dominance of the fossil fuel industry.

Remaining barriers

Stakeholder Engagement and Coalition Building. A challenge facing the Nigerian solar market is the fragmentation of training efforts. While many private sector firms have initiated their own training programs, these efforts are often inconsistent and lack standardization, leading to uneven

[53] *Trainer at JOBITECH*

[54] *MOA Professional Institute (2024)*

skill levels among workers. The lack of a unified certification process means that solar technicians have varying degrees of competency, which has negatively impacted the quality of solar installations. This lack of uniformity not only hampers operational efficiency but also undermines trust in solar energy as a reliable solution, particularly in rural areas where energy needs are most critical.

Development of Green Skills Identification for the Solar Industry. Industry-TVET partnerships are underdeveloped in Nigeria due to unclear regulatory frameworks, limited communication between stakeholders, bureaucratic inefficiencies, and competing interests among government agencies, private companies, and educational institutions. The lack of coordination leads to fragmented efforts in developing the solar sector.

Development of Green Curricula for the Solar Industry. There is an absence of a standardized national curriculum for solar energy in Nigeria and solar PV training is typically bundled into broader engineering courses without sufficient focus on the specific skills required for solar installations and maintenance. This misalignment between the educational system and the solar industry's needs has led to a workforce that lacks the technical proficiency required to handle complex solar installations. This skills gap is particularly acute in the mini-grid and commercial & industrial (C&I) segments, where specific training programs are less developed.

Supporting Inclusivity in TVET Institutes. Cultural barriers and gender stereotypes continue to restrict the participation of women and marginalized groups in the solar workforce.This limits the potential talent pool for a diverse and skilled labor force in the solar industry. In many cases, societal expectations dictate that technical roles, especially in industries like solar energy, are seen as "male" jobs, which discourages women from pursuing these opportunities. Moreover, economic challenges such as poverty prevent many individuals from accessing quality training due to the high costs associated with these programs.

Capacity Building for TVET Trainers. Few TVET instructors in Nigeria have received adequate training in the latest solar technologies or sustainable practices, which limits their ability to provide high-quality education. A lack of investment in teacher training and professional development programs and the limited funding for technical education, means that institutions often cannot afford to send instructors for upskilling or certification in the latest industry trends.

Green Job Creation and Employment in the Solar Industry. While the solar industry in Nigeria presents substantial opportunities for employment, significant challenges remain in aligning labor market supply with demand. Many solar firms need to invest heavily in on-the-job training to bridge the skills gap, which increases operational costs and slows the pace of growth.

Policy and Funding Environment for the Solar Industry. In Nigeria, the absence of clear and consistent government policies around renewable energy creates significant confusion for investors and businesses, stalling the growth of the solar industry. Without well-defined regulations and long-term commitments from the government, both local and international investors hesitate to commit resources to solar projects. Another related challenge in Nigeria's solar energy sector is

the high import duty on solar components, which significantly raises the cost of solar installations and hampers the growth of the industry. The high import duty on solar components increases costs, making it harder to integrate affordable solar technologies into TVET and posing a challenge to private sector actors.

Raising Awareness and Shifting Perceptions for Solar Adoption. A significant challenge to the adoption of solar energy in large institutions arises from sabotage by entrenched interests in the fossil fuel industry, particularly those involved in procuring diesel for electricity generation in higher institutions. This not only undermines efforts to promote renewable energy but disrupts solar adoption and discourages investment in the necessary skills for local manufacturing and sustainable energy development.

4. Lessons learned & pathways for change

Building on the insights from the case studies in Ghana, Uganda, and Nigeria, this section offers a comparative analysis that highlights key findings and major lessons learned about greening TVET in Africa. It contextualizes and synthesizes these findings, examining both the unique challenges each country faces in greening TVET for the solar industry and the commonalities that emerge. As such, this section provides the basis of the roadmap and pathways for change featuring in the next chapter.

The solar energy and policy landscape; vast, but untapped potential

While there is in all three countries a great potential and appetite for the further expansion of the solar energy sector, the percentage of renewable energy in the energy mix remains small, particularly in Ghana and Nigeria which are still dominated by fossil fuel. Access to electricity is also markedly different; Ghana leads with 87% coverage, followed by Nigeria at 60%, and Uganda at 57%. This disparity in access might explain why the Nigerian and Ugandan governments are promoting off-grid energy solutions to address spatial inequalities affecting rural populations, whereas in Ghana, the government is pursuing a centralized, mostly on-grid approach to electricity access.

Despite these differences, there are also notable similarities across the three countries. Governments in all three countries are taking steps to promote the use of solar energy and recognise the need for a low-carbon transition. This commitment is evident in their national energy transition strategies and policies and interventions aimed at regulating and facilitating the solar energy market. However, questions remain regarding implementation and the effectiveness of these policies in promoting truly inclusive and equitable practices and market growth.

Additionally, it is worth noting that none of the countries are involved in the manufacturing or assembly of solar products. This situation results in minimal local value addition and an influx of inexpensive, low-quality imported products. While these products make solar energy more affordable for many, they also pose environmental challenges and can negatively impact public perception due to their often short lifespan.

The labour market context; significant barriers to overcome

Despite the growth in the solar energy sector and the proactive roles of the governments, the solar industry still faces significant barriers to growth. These include limited access to finance and inconsistent policies and regulations, which negatively affect the private sector's ability to create decent jobs for youth. For example, in Uganda, while there are tax incentives for certain solar products, the lack of clarity on the preconditions leads to inconsistent implementation and confusion in the market. In Nigeria, although basic safety protocols are followed, insufficient knowledge of national and international regulations and standards has resulted in vandalism of installation sites.

Moreover, in all three countries, the informal sector is still the largest employer of young people and also the place where they are most likely to find jobs and apprenticeships in the solar energy field. However, many solar installers are not specifically trained in solar energy and often combine solar panel installation with general wiring services, leading to varied installation techniques. Additionally, these jobs often lack adequate safety measures, longevity, and fair payment.

As the manufacturing and assembly is done abroad, most job opportunities manifest itself in the installation and maintenance of solar PV systems. As these jobs are of a temporary nature, there is a question to what extent the solar industry can create decent jobs and sustainable livelihoods. As the market continues to grow, there is a rising demand for specialized roles such as energy auditors, solar engineers, programme managers, and technical sales representatives.

Missing skills; practical, hands-on experience and transversal competencies

The skills mismatch is pertinent across all three countries and many similarities emerge. Both industry leaders and education professionals in the three countries recognise that TVET graduates often still lack salient technical knowledge of solar equipment and installation techniques. Although TVET programmes are meant to cover basic skills and understanding the operation of electric batteries, graduates often struggle with effective installation, maintenance, and product quality assessment. Furthermore, a lack of practical, hands-on experience is notably lacking. Important requirements for designing solar PV systems, covering aspects such as system sizing, site analysis, shading analysis, and placement optimization for maximum energy generation are often only read about, but not sufficiently practiced due to limited internship opportunities and insufficient and outdated solar equipment in TVET institutions.

Additionally, as most TVET graduates in the three countries will end up self-employed, there is an urgent need to further develop and integrate green, transversal, and entrepreneurial skills into curriculum development for the solar energy sector. Furthermore, in light of the broader green transition, it is crucial to prepare youth not only for careers within the solar industry but also to contribute to a more sustainable and adaptable workforce.

Although the three countries require similar occupational profiles and face comparable skills mismatches, there are specific national priorities. In Uganda and Nigeria, there is a high demand for

qualified solar technicians to install off-grid and mini-grid solar systems in rural areas, driven by limited energy access and government support for such solutions. In Ghana, there is an urgent need for specialists in net metering, which is planned for a nationwide rollout in 2025.

The TVET ecosystem: diverse and dispersed

The TVET ecosystems in Uganda, Ghana, and Nigeria exhibit a diverse landscape characterized by a variety of providers, courses, and training modalities. In all three countries, TVET is divided among formal, non-formal, and informal training systems, yet coordination and standardization between those different modalities remains limited. In formal TVET courses across Uganda, Ghana, and Nigeria, solar PV training is often integrated as a module within broader subjects such as electrical engineering or renewable energy. Ghana stands out with its recently implemented 3 year competency-based Solar PV program, offering a structured and longer curriculum specifically for solar technology. In all three countries, the majority of solar PV training is offered as a short course, both through formal TVET institutions and private providers and informal courses through apprenticeship and on-the-job training. The short courses mainly focus on . practical skills and hands-on experience, and range from 1 to 4 weeks in Ghana, 3 weeks to 6 months in Uganda, and extending from 6 to 24 months in Nigeria.

Due to its fragmented nature, accreditation and quality assurance remains a significant concern, especially for short courses offered by private training centres. Moreover, despite growing interest in providing solar training, many training centers are underfunded and lack the necessary equipment and modern facilities to provide hands-on experience with the latest solar technology. The limited integration of solar energy into formal curricula has impeded the ability to swiftly adapt to industry needs, as existing programs often lack the foundational framework necessary to keep pace with rapidly evolving technologies. This variation and lack of standardization highlight the urgent need for coordinated approaches to improve the effectiveness and reach of solar education across Africa.

Limited technical expertise of trainers and inadequate teaching materials

A significant challenge faced by TVET institutions in all three countries is the limited technical expertise of trainers in solar PV technologies and the reliance on outdated training materials. Many TVET teachers struggle with up-to-date knowledge and hands-on experience with modern solar PV systems, which hampers their ability to effectively impart the latest techniques and technologies. This issue is exacerbated by limited investment in teacher training and professional development programs. With constrained funding for technical and vocational education, institutions frequently lack the resources to provide instructors with upskilling opportunities or certification in the latest industry trends. Finally, compounding these challenges is the high turnover of skilled trainers, as the industry often attracts top talent with competitive offers, leaving TVET institutions struggling to retain a knowledgeable teaching workforce. Consequently, these factors not only diminish the quality of education but also impede the development of a skilled workforce essential for advancing the solar energy sector.

Weak industry linkages; outdated curricula and lack of workplace learning

Weak industry linkages in TVET systems across Ghana, Nigeria, and Uganda significantly undermine the effectiveness of vocational training programs. In all three countries, there is a notable disconnect between educational institutions and the industries they serve, resulting in curricula that often fail to reflect current market demands. This gap hampers the practical relevance of training, leaving graduates ill-prepared for the workforce and exacerbating the mismatch between labor supply and industry needs. The lack of robust partnerships with industry stakeholders further limits opportunities for curriculum updates, hands-on experience, and job placement.

In Ghana, concerted efforts are made to align Solar PV curricula with industry needs by building on the knowledge of industry leaders, TVET providers and solar entrepreneurs in developing a formal competency-based solar training. However, despite the focus on more demand-led TVET in Uganda and the establishment of sector skills bodies in Ghana, labour market intelligence through skills forecasting is still in its infancy in all three countries, and there is still a long way to go in terms of knowledge management, especially in the documentation of occupational profiles and skills gaps in the solar industry.

Securing internships and workplace learning opportunities is a significant challenge for TVET institutions striving to provide students with industrial experience. In Uganda, companies frequently demand payment from students or TVET schools for placement, and the scarcity of solar companies means that students often have to seek relevant internships abroad to gain the necessary experience.

Limited awareness of the potential of solar training; mixed messages

While government policies and investment in TVET have increased public awareness of the opportunities of TVET compared to tertiary education pathways across all three countries, youth perceptions of TVET remain mixed due to a lack of resources, educational materials, qualified teachers, and difficulties in securing internships. Interactions with students did show that they recognize the economic potential of solar energy, which motivates them to pursue solar TVET. However, they are also aware of the limited job opportunities in the sector and the perceived lack of quality in solar TVET, which affects their view on their labour market prospects. In this respect, promoting green awareness in TVET offers an opportunity to both improve the perception of TVET and promote its broader relevance, encouraging interest for sustainable practices and thereby supporting the green transition.

Inclusiveness of TVET institutions; a world to win

Ensuring inclusivity within TVET systems is crucial for building a diverse and equitable workforce. This involves addressing several critical dimensions, including gender-responsive training opportunities, support for individuals with disabilities, outreach to remote communities, and the engagement of youth in TVET policy decision-making. Inclusivity and accessibility of TVET

institutes remains work in progress in all three countries and significant barriers to entry and success still remain.

Most TVET institutions struggle with meeting the disability friendly criteria and acknowledge the need for improved facilities and support mechanisms for individuals with disabilities. Gender disparities also persist, with inadequate facilities for women, limited mentorship opportunities, and a lack of female role models in solar energy exacerbating the gender gap. The implementation of gender-responsive education systems and curricula has lagged behind, leaving women and girls with fewer opportunities to enter and thrive in technical professions. In all three countries specific training opportunities for women are provided in solar PV technologies. Although these expand the access for female engineers in a male dominated field, as most of the courses are offered by international donors, questions about the sustainability of these remain.

Spatial inequalities further complicate access to TVET as institutes offering solar PV training are exclusively located in urban areas, making them difficult to reach for those in rural communities where the need for solar energy is often greatest. In addition, tuition fees for solar PV programmes can provide a barrier to entry, particularly for lower-income families who without subsidies or scholarship opportunities cannot benefit from training. An exception to this is Ghana, as the free TVET policy ensures that all Ghanaians wanting to engage in TVET training are able to do so for free.

Finally, the lack of youth engagement in TVET policy-making processes limits the relevance and effectiveness of training programs. Addressing these issues requires a concerted effort to enhance inclusivity and accessibility across all dimensions of the TVET system in all three countries.

Coordination, collaboration and cohesion

The case studies in Uganda, Ghana, and Nigeria reveal the urgent need for a comprehensive and unified approach to advancing green education across Africa. It highlights that current challenges such as fragmented curricula, limited technical expertise, and accessibility issues significantly hinder the effective integration of renewable energy training. To overcome these barriers, a collaborative effort involving governments, educational institutions, and industry stakeholders is crucial. Such a concerted approach can ensure the development of cohesive standards and practices, ultimately fostering a more skilled and inclusive workforce ready to support Africa's green transformation.

5. A roadmap for Greening TVET for the solar energy sector in Africa

As this paper shows, greening TVET provides a promising avenue for preparing Africa's youth for the growing solar energy labour market and contributing to a just and inclusive energy transition. However, substantial barriers to fulfilling this potential remain. This chapter presents the Greening TVET in Africa Roadmap, which features seven interconnected pathways for change to enhance TVET for the solar industry in Africa.

These pathways are grounded in the case studies on the solar energy and TVET landscapes in

Ghana, Nigeria, and Uganda, and provide both tailored recommendations and more general insights for greening TVET for the solar industry. The roadmap thereby serves both as a guide and as a conversation starter for stakeholders committed to greening TVET for the solar energy sector in Africa. Successful implementation requires tailoring approaches and intervention strategies for each pathway to fit the unique policy environments and practical realities of individual countries.

Highlighting the importance of multi-stakeholder collaboration, contextualisation and meaningful youth engagement, this roadmap supports an African and youth-centred approach to greening TVET.

1. Strengthen stakeholder engagement and coalition building

Collaboration among key players in the solar energy and TVET sectors is crucial for aligning TVET programmes with industry demands, developing cohesive policies, and advancing green economy opportunities. Stakeholders should work together to set a strategic direction, share knowledge, and advance greening TVET efforts. An example of how this can be achieved is through the development of a centralized solar energy TVET network and a national greening TVET strategy for the solar energy sector, backed by government funding and setting clear goals, priorities, and guidelines. Additionally, creating a comprehensive database and monitoring system will provide an overview of current TVET programmes and their outcomes, promoting continuous improvement.

2. Development of green curricula and green skills identification

Close collaboration between the private sector and other TVET system players is instrumental in forecasting skills needs and therefore key in developing relevant TVET programmes for the solar labour market. In addition, expanding TVET-industry partnerships can help in facilitating relevant internship opportunities and practical experiences for students which is crucial to bridge the practical skills gap. Meaningful youth engagement in curriculum development is also critical to ensure the curriculum does not only match industry standards but also the needs of learners.

3. Capacity building for TVET trainers

Invest in specific solar energy teacher training that is up-to-date with the latest sector developments, and provide regular refresher courses. Ensure these training programs meet teachers' needs by assessing their skill levels and requirements. Additionally, collaborate with solar energy companies to offer internships for trainers, enabling them to gain hands-on experience, understand practical applications, and build networks within the industry. Another key aspect of capacity building for teachers is providing them with the necessary and relevant solar energy equipment and teaching materials to ensure they can teach both effectively and practically.

4. Fostering inclusivity in TVET institutes

Promoting inclusivity within TVET is crucial for building a diverse and equitable workforce. This involves addressing barriers such as admission fees, spatial inequality, and unsuitable facilities. Recognize and accommodate differences among students by for example offering programs in local dialects, providing part-time courses for women with household responsibilities, ensuring

availability of TVET in rural areas and fostering student engagement in TVET institutions and decision-making through student bodies and effective feedback mechanisms. Additionally, strengthen the inclusion of informal workers by supporting TVET providers with financing and resources to offer formally recognized programmes to informal workers who lack formal qualifications. This will help expand their skill sets, validate existing skills, and provide them with nationally recognized certificates.

5. Facilitating green job creation and employment in the solar industry

Creating a supportive business environment for solar companies through finance opportunities and policy development and raising awareness among youth and the public about career opportunities in the sector to support employment in the solar sector. In-depth research on the labour market to understand job demands and trends, focusing on the decency of green jobs and advocating for stable employment and service contracts over temporary positions will be instrumental in creating sustainable livelihoods. Furthermore, provide additional support to solar energy technicians employed in the informal sector and willing to start a formal business.

6. Enabling policy and funding environment for the solar industry

Establishing a supportive policy and funding environment is crucial for advancing the solar industry and greening TVET in Africa. Key steps include developing education and training policies and standards, as well as implementing policies that guide the transition to a green economy. TVET providers need financial resources and policy guidance to build the capacity of their trainers, invest in solar equipment in the classroom, and ensure an inclusive approach. Furthermore, other key actors in the solar energy TVET system need support as well, for example to conduct research and stay up to date in an ever changing global renewable energy market.

7. Green awareness building

Fostering green awareness and embedding sustainability into curricula are crucial for greening TVET strategies. Amplifying the environmental benefits of solar and renewable energy strengthens the impact of solar TVET education beyond economic enhancement. Supporting youth in understanding climate change can ignite interest in other green sectors and enable them to advocate for sustainable practices within their communities. Additionally, grassroots campaigns with community leaders and NGOs can build trust in solar technology and promote environmentally friendly practices."

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