TVET SKILLS FOR RENEWABLE ENERGY AND GREEN HYDROGEN IN NAMIBIA

Annexure 8: Welding

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CONTENTS

ACRONYMS

AfDB	African Development Bank
ASME	American Society for Mechanical Engineers
AWS	American Welding Society
BPVC	Boiler and Pressure Vessel Code
CBET	Competency-based Education and Training
CSWIP	Certification Scheme for Welding Inspection Personnel
EBW	Electron Beam Welding
EPC	Engineering, Procurement and Construction (prime contractors)
ETQ&C	Education, Training, Qualification, and Certification
FCAW	Flux-Cored Arc Welding
GH_2T	Green Hydrogen Technologies
GTAW	Gas Tungsten Arc Welding (TIG)
HAZ	Heat Affected Zone
HE	Hydrogen Embrittlement
HIC	Hydrogen Induced Cracking
HSLA	High-Strength Low-Alloyed
HV10	Vickers Hardness Test at 10 kgf load
H_2	Hydrogen
IAB	International Authorisation Board
IIW	International Institute of Welding
ISCED/EQF	International Standard Classification of Education / European Qualifications Framework
ISO	International Organization for Standardization
IIW	International Institute of Welding
IW	International Welder
IWP	International Welding Practitioner
IWS	International Welding Specialist
IWT	International Welding Technologist
IWE	International Welding Engineer
KPI	Key Performance Indicator
LBW	Laser Beam Welding
MIG/MAG	Metal Inert/Active Gas Welding
MS	Mild Steel
MT	Magnetic Testing / Magnetic Particle Testing
MTR	Mill Test Report (material traceability)
Ni	Nickel Alloys
NDT	Non-Destructive Testing
NSI	Namibia Standards Institution
NQA	Namibia Qualifications Authority
NQF	National Qualifications Framework (Namibia)
NTA	Namibia Training Authority
PT	Penetrant Testing / Dye Penetrant Testing
RPL	Recognition of Prior Learning
RT	Radiographic Testing
RWC	Responsible Welding Coordinator
SANS	South African National Standards
SAW	Submerged Arc Welding
SMAW	Shielded Metal Arc Welding
SOHC	Stress Oriented Hydrogen Cracking
SS	Stainless Steel
TVET	Technical and Vocational Education and Training
UT	Ultrasonic Testing
VTC	Vocational Training Centre
WIL	Work Integrated Learning
WPQR	Welding Procedure Qualification Record
WPS	Welding Procedure Specification
WPS/PQR	Welding Procedure Specification / Procedure Qualification Record

1

ANALYTICAL REPORT

1.1 Status quo, overview of existing training measures and training providers

Technical and Vocational Education and Training (TVET) in Namibia, under the regulation of the Namibia Training Authority (NTA), adopts a Competency-based Education and Training (CBET) system that focuses on developing practical skills and knowledge aligned with industry standards and performance requirements.

This system emphasises specific learning outcomes and competencies by following a national set of unit standard-based qualifications, which are offered by nationally accredited education, training centres both private and public.

Welding training under this system is offered through the qualifications "Metal Fabrication (Welding; and Boiler Making)," as registered qualification on the National Qualifications Framework (NQF) Level 1 to Level 4, with plans to expand to Levels 5 and 6.

It should be noted that, in general, Namibia's NQF levels are one to two levels higher than the International Standard Classification of Education (ISCED)/European Qualifications Framework (EQF) levels, as can be seen from the bachelor's level qualifications (NQF 7–8 compared to ISCED 6).

The ISCED and the EQF describe qualification levels and corresponding learning outcomes across education systems. Similarly, the Namibia Qualifications Framework (NQF) defines levels and descriptors for vocational education and training within Namibia. Based on these established definitions, Table 1 presents a comparison between the NQF and ISCED/EQF levels relevant to welding-related curricula.

This comparison provides an overview of how national qualification levels align with international standards, with the corresponding ISCED levels also detailed in Chapter 1.3.

Table 1. Welding NQF vs ISCED/EQF levels

Unit ID	Standard Title	NQF Level	ISCED/EQF Level
233	Interpret welding signs and symbols as part of metal fabrication operations	2	2
234	Assemble and test Oxy- Acetylene welding equipment as part of Metal Fabrication operations	2	2
235	Weld mild steel using the Oxy-Acetylene in the down hand position	2	2
236	Weld Mild steel using the manual arc welding process in the down hand position	2	2
1741	Demonstrate knowledge of engineering metals, properties and standards	2	2
1742	Demonstrate knowledge of the electrodes and filler rods	2	2
1743	Weld mild steel using the manual arc welding process in horizontal, vertical up and over-head position	2	2
1744	Weld mild steel work piece using the shielded metal arc welding process in flat position	2	2
2144	Weld cast iron using the manual arc welding process in the down hand position	3	3
2145	Estimate production costs	3	3

241	Join metals using oxy-acetylene brazing and silver soldering equipment as part of metal fabrication operations	3	3
242	Weld aluminum using the manual arc welding process in the down hand position	3	3
243	Weld stainless steel using the manual arc welding process in the down hand position	3	3
246	Weld stainless steel using the tungsten inert gas welding process in the down hand position	3	3
247	Weld mild steel using the metal inert gas welding process in the down hand position	3	3
244	Gouge metals using manual arc equipment as part of metal fabrication operations	3	3
248	Weld aluminum using the tungsten inert gas welding process in the down hand position	3	3
251	Weld mild steel using the tungsten inert gas welding process in all positions	3	3
1746	Weld thermoplastics with electrofusion equipment	4	3
252	Perform advanced manual arc welding on aluminium in all positions	4	3
253	Perform advanced tungsten inert gas welding on aluminium in all positions	4	3
254	Perform advanced manual arc welding on stainless steel in all positions	4	3
255	Perform advanced tungsten inert gas welding on stainless steel in all positions	4	3
256	Hard face surfaces as part of metal fabrication operations	4	3
1747	Weld stainless steel pipe in all positions using the tungsten gas arc welding process	4	3

Welding education in Namibia is offered by a wide range of training providers. Currently, the majority of surveyed NQA-accredited and NTA-registered welding training institutions use NQF-registered unit standards/qualifications, with the exception of the Namibia Institute of Mining and Technology (NIMT), which uses its own modular system of training.

Due to the number and geographic distribution of these institutions, a representative sample was selected for site visits. These visits provided valuable insights into the training measures, infrastructure, and overall quality of welding education, and are also representative of other institutions that could not be visited.

This section presents summarised overviews of the institutions visited, highlighting key observations. Table 2 below provides a complete list of all identified welding training providers and the NQF levels they offer in welding education.

- **NIMT Arandis:** The NIMT is offering both technical and vocational training. NIMT uses its own Level 3 modular training system and awards a NIMT certificate.

  NIMT also provides specialised practical welding training based on the American Society of Mechanical Engineers (ASME) Section IX coded procedures for early school leavers who do not qualify for general entry requirements at most TVET centers.

  Additionally, it offers skills-upgrading courses for employed individuals without formal education, recognising prior learning in accordance with the National Policy on Recognition of Prior Learning (RPL). The institute has one trainer and one assistant in the welding department.

  The trainer holds ASME Section IX certification and an NVC in boiler making, while the assistant has welding experience but no formal qualifications. NIMT lacks advanced or automated welding technologies and relies on conventional processes, including Manual Metal Arc (MMA), Metal Inert/Active Gas (MIG/MAG), Tungsten Inert Gas (TIG), and gas welding. The trainer oversees approximately 110 trainees annually.

- **Namibia Institute of Welding (NIW):** The Namibia Institute of Welding (NIW) in Swakopmund provides coded welder training based on the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (BPVC) Section IX standard [1], serving both industries and individual trainees.

  Although it does not follow the NTA unit standards for training nor appear on the list of NQA-accredited institutions as of 13 May 2025, it offers coded welding courses across basic, structural, and pipe welding competencies.

This coded welding training is practical and aligned with international standards such as ASME Section IX [1], ISO 9606 [2], and International Institute of Welding–International Authorisation Board (IIW-IAB) standards. NIW's training levels cover Shielded Metal Arc Welding (SMAW), Gas Tungsten Arc Welding (GTAW), and stainless steel GTAW, with varying durations depending on employment status.

The institute has one coded welder trainer, but is lacking formal teaching qualifications and access to advanced welding technologies. NIW trains about 70 trainees annually and offers welder retesting and qualification services, particularly for compliance with ASME Section IX.

- **Baumgartsbrunn:** This training centre, planned to focus on TVET in Green Hydrogen Technologies (GH_2T), is not yet operational. It is currently in the process of setting up workshops and training facilities, which are located approximately 30 km outside Windhoek.

  The institute has one welder who is not formally qualified or certified according to ISO 9606, IIW-IAB International Welder, or ASME Section IX.

  However, it has arrangements in place to obtain at least four certified international welders as practical and theoretical trainers. As specified by the leader of the Centre, the goal is to train and educate beyond international Level 3, particularly at Levels 4 and 5, which correspond to the curricula and syllabuses for the International Institute of Welding (IIW) International Welding Practitioner and International Welding Specialist, respectively, as shown in Chapter 1.3.

- **NICHE – Walvis Bay:** NICHE is registered with NTA to offer welding training up to NQF Level 4, following the national qualifcation. While it does not yet train according to international codes, plans are in place to certify trainers under ISO 9606, IIW-IAB, or ASME Section IX.

  To meet requirements, trainers must be qualified at least one level higher than the training they provide, ideally reaching NQF Level 5 (International Welding Expert) under IIW-IAB. For effective coordination, the employment of an International Welding Engineer (IWE) would be beneficial.

- **RIK Training Centre:** RIK Technical College (RIK) in Windhoek is NTA-registered for welding training up to NQF Level 4 [3]. It trains both company welders requiring international code training and private individuals seeking employment.

  The welding trainer holds Gas Tungsten Arc Welding (GTAW) and Shielded Metal Arc Welding (SMAW) certifications from RITC (Pty) Ltd, and guides welders in company procedures. However, it is unclear which NQF level these certifications correspond to. RIK can train 60 welders in two groups.

  Advancing from NQF Level 2 to Level 3 takes 10 months, including 2 months of job attachment. Level 3 welders can reach Level 4 in 6 months with job attachment. Semi- or fully-automated welding training is not offered.

- **Kai//Ganaxab Youth Training Centre:** The youth skills training Centre near Mariental offers basic welding training for out-of school youth but does not use NTA unit standards, providing only basic welding for now.

  Renovated through African Development Bank (AfDB) funding, the Centre operates under a Memorandum of Understanding (MoU) between NTA and the then Ministry of Youth and Sport, aiming to implement a dual training system — with NTA focusing on national qualifications and the Ministry continuing to focus on entry-level skills.

  With support from Hyphen Hydrogen Energy (Hyphen), the Centre plans to upgrade its welding programmes to meet international standards and improve the industry relevance and quality of training.

The following table provides an overview of the various TVET institutions in Namibia that provide welding training. It can be clearly seen that no training institutions is offering training beyond NQF Level 4, especially not in automised welding, as is required for Green Hydrogen Technologies (GH_2T). As outlined further below, the NQF levels do not reach the international ISCED levels.

Table 2: TVET institutions offering welding education in Namibia [4].

No.	Institution	Location	Region	NQF Level
1.	Eenhana VTC	Eenhana	Ohangwena	4
2.	Marco Mpollo VTC	Opoto	Oshana	2
3.	Namibia Defence Force Training Establishment	Okahandja	Otjozondjupa	3
4.	COSDEC	Rundu, Swakopmund	Kavango East	2
5.	Namibia Correctional Services	Tsumeb	Oshikoto	2
6.	NAMCOL Yetu Yama	Windhoek	Khomas	4
7.	NIMT	Tsumeb/Arandis/Keetmanshoop	Oshikoto/Erongo//Karas	3
8.	National Youth Service	Rietfontein	Otjozondjupa	3
9.	NICHE Training Academy	Walvis Bay	Erongo	4
10.	Okakarara VTC	Okakarara	Otjozondjupa	3
11.	Ongha VTC	Ongha	Ohangwena	2
12.	RIK Technical College	Windhoek	Khomas	4
13.	Rundu VTC	Rundu	Kavango East	4
14.	Valombola VTC	Ongwediva	Oshana	3
15.	Windhoek VTC	Windhoek	Khomas	4
16.	Zambezi VTC	Katima Mulilo	Zambezi	4
17.	Brave and Achiever College of artisans	Windhoek	Khomas	2
19.	Gobabis VTC	Gobabis	Omaheke	3

1.2 Stakeholder mapping and analysis in the RE and Hydrogen sector in welding

With respect to the applicability and acceptance of training and education provided by the institutions mentioned under 1.1, an industrial stakeholder mapping was conducted through site visits and interviews with Namibian industrial companies involved in welding and interested in entering the GH_2T sector.

The objective was to assess the capacity, readiness, and skills requirements of these companies in relation to the emerging green hydrogen (GH_2) industry.

This section presents a summary of each stakeholder consulted, highlighting key insights from the engagements. Based on the findings, Table 3 outlines the identified welding personnel needs required to build sufficient capacity and competence for the sector.

- **NAMDOCK:** Namibia Drydock and Ship Repair (NAMDOCK) is a public–private partnership serving the maritime and offshore oil and gas sectors. It employs 325 permanent and around 275 fixed-term staff, including up to 90 welders at peak demand. All welders are certified to ISO 9606 or ASME Section IX, and welding inspectors (trained at SAIW) oversee operations.

  For the large number of industrial welding applications, NAMDOCK lacks an in-house international welding engineer as a certified welding coordinator and outsources this position to South Africa. Most welding procedures involve mild steel (EH/AH 36), with additional capabilities in 316L stainless steel. The company is developing expertise in welding super duplex stainless steels and aluminium.

- **Kraatz Engineering:** Kraatz Engineering is a leading provider of comprehensive engineering solutions in Namibia. Its portfolio includes project management and operations, steel fabrication, hull repairs, marine electrical and technical services, SMPP (Structural, Mechanical, Piping, and Platework) construction, tank building (API 650 [5]), and mechanical work.

  The company employs around 15 welders, 8 of whom are coded according to international standards (ISO, API, ASME) depending on client requirements.

  The company is headed by an International Welding Engineer with a certificate from DVS in Germany and also employs one welding inspector and one international welder.

  Kraatz currently needs to upskill its welding staff to gain comprehensive knowledge of stainless-steel fabrication, orbital welding, and quality control. The table in the summary includes the current education levels of their welding staff and their projected needs for the immediate future.

- **3-C Metal Belmet:** As part of the multinational 3-C Metal group, the company operates as a largely independent Namibian enterprise and offers heavy fabrication capabilities, serving a range of industries including oil and gas, diamond mining, mineral processing, and marine sectors.

  It currently employs 15 welders, all of whom are coded to international standards, either according to ISO 9606 or ASME Section IX, depending on client needs. 3-C Metal Belmet also employs one welding inspector.

  The company is ISO 9001 [6] and ISO 45001 [7] certified by DNV, and also holds ISO 17020 [8] certification to carry out pressure testing. The table in the summary includes the current education levels of its welding staff and their projected needs for the immediate future.

- **RITC(Pty)Ltd.:** RITC (Pty) Ltd is a SANS 10227 [9] and ISO 17020-accredited inspection body that specialises in testing and qualifying welders according to company-specific procedures, mainly adhering to the ASME Boiler and Pressure Vessel Code (BPVC).

  It conducts visual evaluations and limited NDT (e.g., dye penetrant, ultrasonic, and eddy current testing), but lacks an X-ray facility, sending test pieces to South Africa for radiography and destructive testing.

  RITC offers a range of third-party inspection and NDT services across industries including petrochemical and power generation. The company employs two welding inspectors with CSWIP certification and several NDT technicians.

- **Metallum:** Metallum is a Namibian steel fabrication company serving architects, builders, and associated trades. Specialising in steel solutions for commercial projects, home renovations, and custom fabrications, the company employs over 100 workers, including 13 in-house trained welders. While not all welders are coded, Metallum qualifies them to ASME Section IX standards through a third party, Wavetech.

  The company aims to code its welders to ISO 9606 standards and seeks to hire welders with qualifications higher than NQF Level 3, along with a welding inspector. Metallum also plans to train one engineer as an International Welding Engineer for welding coordination tasks.

- **Hyphen and Cleanergy:** Exemplary of other companies operating in GH_2T, Hyphen and Cleanergy Solutions Namibia were consulted due to time restrictions for the present study.

  These two Namibia-based GH_2 companies, representative of the broader industry, focus on developing GH_2 projects for both domestic and international supply.

  Where they do not carry out work themselves, they facilitate workforce preparation through a registration database and their own skills development initiatives. Hyphen alone anticipates needing around 1,800 welders during the construction phase, specialising in stainless steel and carbon–manganese steel welding for applications such as piping joints, transport lines, and pressure vessels.

  Cleanergy Solutions Namibia also foresees a substantial need for welding personnel, although in lower numbers, which are included in the table below.

  Both companies emphasise the importance of training local Welding Engineers, Technologists, and Quality Assurers to an internationally comparable standard, while upgrading the existing welder workforce to meet ISO 9606 certification and GMAW standards in order to ensure high-quality welding procedures for prospective EPCs.

During the consultation of various enterprises operating in industrial welding applications, the needs for trained and educated welding personnel were also addressed, based on the assumption that these companies are already active in, or plan to enter, the GH_2T sector within the next two to five years. Table 3 summarises these needs for the companies consulted and includes an extrapolation (in brackets) reflecting an assessment of the requirements for the sector as a whole.

Table 3: Welding personnel needs for the industry based on the surveyed companies, with extrapolated values in brackets

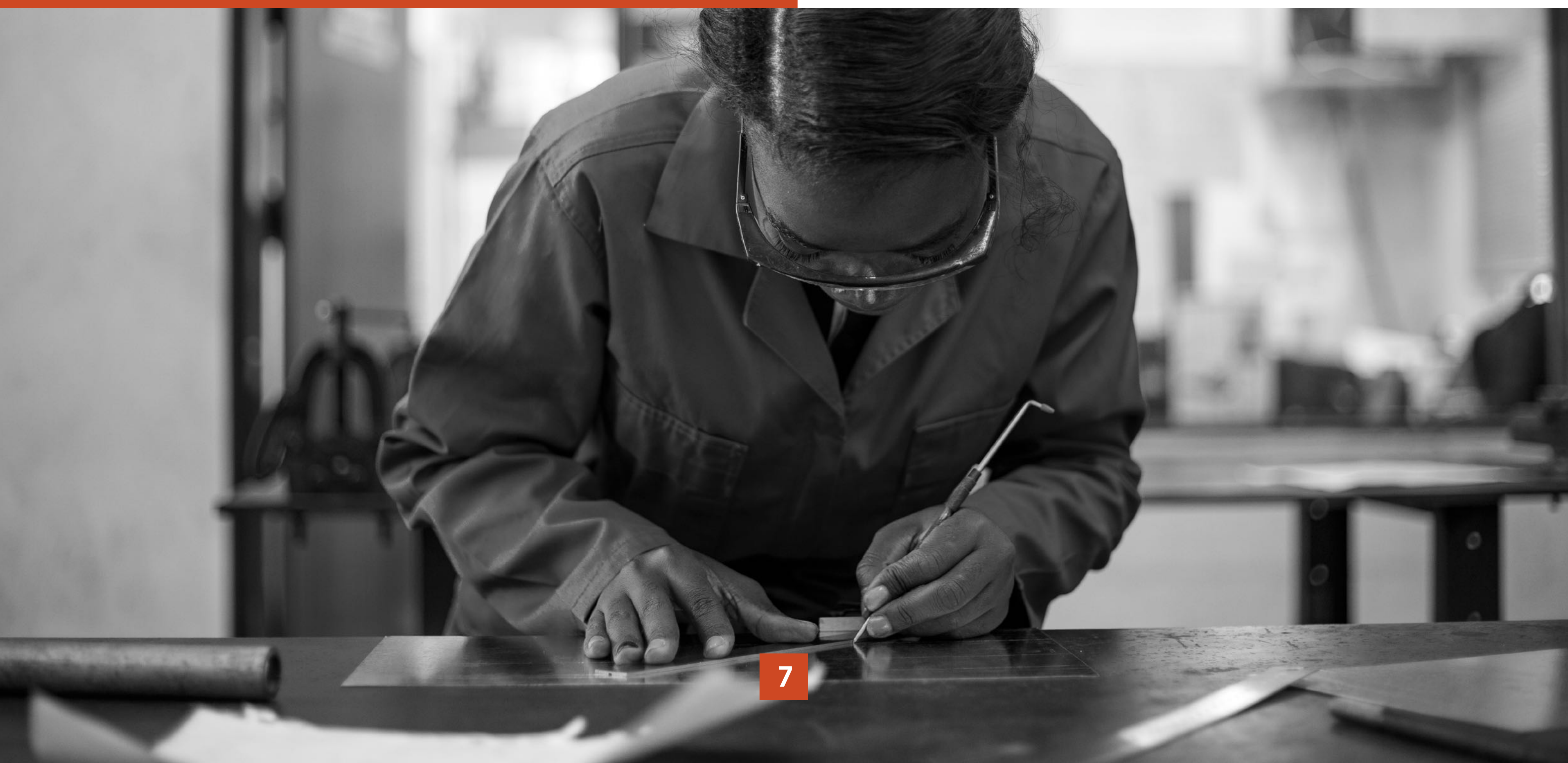
Education Level	Current	Needed in next 2 years	Needed in the next 5 years
International Welding Engineers (Welding Coordinators)	1	10 (70)	15 (105)
International Welding Technologists (Welding Supervisors, Coordinators by Exception)	0	10 (70)	15 (105)
International Welding Specialists (Welding Supervisors)	0	14 (98)	18 (125)
International Welding Practitioner (Welding Supervisors)	0	15 (105)	30 (210)
International Welders	0	28 (195)	57 (400)
Welding Inspectors	9	20 (140)	16 (112)
Welders acc. ISO 9606 or ASME IX	93	375 (2700)	595 (4100)

The consultation of seven companies in this study highlights a significant need for training and education of welding personnel in accordance with international standards and levels. All consulted companies emphasised an acute shortage of welding supervisory and coordinating personnel.

This is currently nearly absent in these companies due to a lack of appropriate education, and the needs therefore extend well beyond the NQF Level 3 welder training, covering requirements for ASME-coded or ISO-certified welders up to International Welding Engineers (IWE).

This need could be at least seven times greater than indicated in the numbers shown in brackets, since only seven of over 50 welding-related companies in Namibia were consulted. It is urgent to expand local welding capacity within the next 12 to 16 months, with a focus on industry participation in curriculum development, enhancing practical training, and establishing regulatory frameworks.

Nonetheless, it should be noted that these numbers may also be inflated, as some occupations could be streamlined across the value chain.



1.3 International Benchmarking in relation to welding

GH_2 projects around the world are creating new demand for skilled welders and welding technicians. Building electrolysers, pipelines, storage tanks, and other hydrogen infrastructure requires high-quality welding to prevent leaks and embrittlement.

Welding is, in fact, "indispensable for the transition to climate neutrality" — from assembling wind farms to manufacturing facilities for GH_2 production, storage, and transport. Many countries with emerging GH_2 sectors (e.g., South Africa, the Netherlands, China, Germany, Japan, Morocco) are launching training initiatives to prepare welders and other trades for these specialised roles.

The following sections detail how several nations are developing "hydrogen-ready" welding curricula, vocational training programmes, and certification standards at the TVET level, with mention of technician and engineering training where relevant.

South Africa

South Africa is actively aligning its vocational training with its GH_2 ambitions. In 2025, the country approved its first-ever hydrogen-focused qualifications through the Quality Council for Trades and Occupations (QCTO). Three new NQF Level 4 programmes were launched — Green Hydrogen Production, Green Hydrogen Storage and Transfer, and Green Hydrogen Technology — each comprising approximately 28–29 credits.

These courses were developed under the Chemical Industries Education and Training Authority (CHIETA) to equip advanced learners with the additional, critical technical and operational skills across hydrogen production, storage, and transportation.

Graduates will be prepared for hands-on roles such as plant operators, maintenance technicians, and artisans (skilled tradespeople) in the hydrogen value chain. While not explicitly a welding certificate, this curriculum covers relevant competencies (equipment operation, safety, regulatory standards, etc.) and is intended to future-proof the workforce for hydrogen projects.

Beyond these new programmes, South Africa is integrating hydrogen skills into existing vocational tracks. A government-backed study in 2024 identified welding as a critical trade that must be augmented with hydrogen-specific knowledge. For example, traditional welding and boiler-making programmes in TVET colleges "hone some but not all of the skills needed" for the hydrogen economy.

Topics such as hydrogen-compatible welding procedures, handling of hydrogen-induced cracking, and leak detection will need to be added to the curriculum. South Africa plans to achieve this either by updating legacy courses or creating new hydrogen-specific artisanal training.

This push aligns with the national goal of training 30,000 new artisans by 2030 to support industrial growth and a just energy transition. Welding graduates from TVET colleges are expected to fill many of these roles as hydrogen projects ramp up.

To coordinate these efforts, a specialised Green Hydrogen Skills Centre is being established. CHIETA — in partnership with the Mining and Transport Sector Education and Training Authorities (SETAs) — announced plans for a multi-million-rand Centre of Specialisation for Green Hydrogen Skills by 2025.

This centre will serve as a hub to train trainers, develop course material, and ensure South Africa has the 138 skills identified as necessary for its hydrogen economy (including engineers, technicians, and tradespeople such as welders). Importantly, hydrogen safety and standards will be a focus: the skills roadmap emphasises understanding hydrogen properties, hazards, and relevant codes for anyone working with or around hydrogen.

In short, South Africa's government and industry stakeholders are proactively building a pipeline of hydrogen-ready welders and technicians through new qualifications and upgrades to vocational programmes.

Testing and Certification Support: South African Partnerships

Notably, Namibia is already taking important steps with the establishment of WeldNAM, a partnership between UNAM and the International Institute of Welding (IIW) that aims to develop a National Welding Institute and give local industry direct access to international standards and certification pathways. At the same time, there are well-established materials testing and welding certification bodies in neighbouring South Africa that could act as potential partners. These institutions are an essential regional benchmark and could provide interim or complementary support to Namibia's emerging hydrogen industry through cross-border partnerships.

- **SecMet (Secunda Metallurgical Services)** is a SANAS-accredited metallurgical lab with expertise in welding engineering and failure analysis. SecMet offers weld procedure development and qualification services (PQRs), as well as welder certifications and weld integrity testing.

  Notably, SecMet's corrosion engineers can assess materials' susceptibility to hydrogen embrittlement — a critical capability for ensuring welded components can withstand hydrogen service without cracking.

  Fabricators can submit test coupons or components for full destructive testing (tensile, bend, impact, hardness, etc.) and receive detailed analysis of weld quality.

- **The Southern African Institute of Welding (SAIW)** is another institution. SAIW is a non-profit technical institute that trains welders, inspectors, and hosts an ISO 17025-accredited Materials Testing Laboratory. In 2018, the SAIW lab expanded its scope to include specialised diffusible hydrogen analysis in welds.

  Using a Bruker G4 PHOENIX analyser, SAIW can measure hydrogen content in weld metal per ISO 3690/AWS 4.3 standards, helping detect and prevent hydrogen-induced cracking.

  For companies welding high-strength steels or pressure vessels, the lab can perform many weld tests — from radiography and tensile/bend tests to hydrogen level determination — with independent, SANAS-certified results. SAIW is also an International Institute of Welding (IIW) Authorised National Body, meaning it can certify welders, inspectors, and fabricators to IIW and ISO standards.

  Currently, SAIW (through the African Welding Federation TWF) is promoting ISO 3834 certification across Africa, a quality standard crucial for manufacturers in the hydrogen and pressure equipment sectors.

Companies can collaborate with SAIW to ensure that their welding procedures and personnel are internationally qualified.

- **One Eighty Materials Engineering**, based in Cape Town is an ISO 17025-accredited metallurgical laboratory providing weld testing and materials analysis.

  Its scope covers a broad range of mechanical tests and advanced analytical methods, including tensile, impact, and hardness testing, as well as electron microscopy and failure investigations. The laboratory serves industries such as oil and gas, power generation, and renewable energy.

  Although it does not specifically market hydrogen-related services, its expertise with petrochemical pressure systems and high-strength steels positions it to test welds that may be applied in hydrogen service.

- **Advanced Materials Science (AMS),** also based in Cape Town, is an ISO 17025-accredited institution providing destructive weld testing and materials analysis.

  The laboratory conducts a range of tests commonly required for weld qualification, including tensile and bend tests for procedure approval, macro-etch examinations of weld cross-sections, Charpy impact tests (including at low temperatures relevant for hydrogen storage tanks), hardness surveys, and non-destructive evaluation of weld quality.

  In addition, AMS undertakes mechanical testing, environmental exposure assessments, metallographic examinations, and failure analyses. Its environmental testing services are relevant for hydrogen projects, as they include accelerated corrosion tests and hydrogen-induced cracking simulations to assess material resistance to hydrogen embrittlement.

The Netherlands

The Netherlands, as part of its national hydrogen strategy, is investing heavily in human capital development for hydrogen technologies. GroenvermogenNL (GVNL) — a public–private programme executing the Dutch Hydrogen Programme's skills agenda — has launched the "Make Hydrogen Work" initiative to coordinate education and training. This initiative offers professionals and vocational students with pathways to acquire hydrogen skills and operates through seven regional hubs across the country.

Each region has developed a roadmap for training technicians in hydrogen, ensuring that local colleges and industry collaborate on curricula. GVNL's integrated approach serves as a best-practice model, connecting companies, educational institutions, and government to deliver training aligned with industry needs. As a result, Dutch welding and engineering courses are increasingly embedding hydrogen-related modules (materials compatibility, safety, etc.) to create an H_2-ready workforce.

Dutch training organisations are already offering specialised courses for hydrogen applications. For example, Kiwa , a Dutch global testing, nsection and certification organisation headquartered in Rijswijk which acts as certification body in the gas sector, runs professional training programmes such as "Hydrogen and the Natural Gas Network" and "Hydrogen Vehicles Technician."

These courses, available in Dutch and English, cover safe handling of hydrogen in pipelines, appliances, and vehicles. Such programmes target existing gas plumbers, pipefitters, and welders, upgrading their skills for hydrogen-blended gas grids or 100% hydrogen systems. Similarly, the Energy Delta Institute (EDI) offers intensive courses and masterclasses on hydrogen technology, ensuring that engineers and technical managers (including welding engineers) understand the regulations, materials, and safety aspects of hydrogen projects.

These industry-led programmes complement formal vocational education, creating multiple pathways — from vocational diplomas to short courses — for Dutch workers to become hydrogen-proficient.

At the vocational college (MBO) level, hydrogen topics are increasingly embedded into relevant trade programmes. Welding technicians, for example, continue to train to international standards (e.g., ISO 9606 certification for weld quality), but now with additional emphasis on hydrogen's effects on materials and weld integrity.

Dutch institutions recognise that hydrogen embrittlement and leakage are critical concerns: pipelines must be hydrogen-ready, which in practice means welders need to apply appropriate procedures and filler metals to prevent cracks.

The country's emerging hydrogen projects, such as converting natural gas pipelines to hydrogen and building new H_2 pipelines between industrial clusters, will require large numbers of qualified pipeline welders. In anticipation, some Dutch technical schools have begun offering "hydrogen welding" workshops in partnership with industry, focusing on topics such as low-diffusible hydrogen electrodes, specialised steel grades, and advanced non-destructive testing (NDT) for hydrogen service.

GVNL notes in its Human Capital Agenda that training is being aligned with industry demand, stating that "professionals who want to acquire hydrogen skills [have] a route to obtaining the right skills" through coordinated regional programs.

Additionally, European projects based in the Netherlands are driving innovation in welding training. The INSPIRE project (an EU Erasmus+ initiative involving Dutch partners) is modernising training for welding inspectors through augmented reality and modular courses, specifically to ensure the safety of H_2 pipelines.

This highlights how the Netherlands and Europe are updating welding inspection qualifications (like the European Welding Inspector certification) to cover hydrogen-specific requirements. By blending classroom learning with new technology and industry input, the Netherlands aims to produce welders and welding inspectors who can guarantee the integrity of hydrogen infrastructure.

China

China's rapidly growing GH_2 sector is driving new training efforts for welders and technicians, often led by industry and state enterprises. The country is already the world's largest producer of hydrogen (mostly grey hydrogen) and is investing in GH_2 for transport and industry.

A flagship project is Sinopec's plan to build a 400 km hydrogen pipeline from Inner Mongolia to Beijing — the country's first dedicated H_2 pipeline. This pipeline (initially with a 100,000-ton-per-year capacity) underscores the need for advanced welding skills: engineers must address hydrogen embrittlement of steel and welded joints and hydrogen permeation and leakage issues.

In practice, this means Chinese pipeline welders will need to use high-grade materials and follow strict welding procedures (e.g., preheating, low-hydrogen electrodes) to maintain ductility in weld metal.
The project's scale also implies a large workforce of qualified welders will be required — potentially drawing from China's existing oil and gas

pipeline crews, but providing them with additional hydrogen-specific training. Chinese codes and standards (such as GB/T for pressure piping) are being updated to mirror international best practices for hydrogen service.

On the vocational training front, Chinese organisations have begun offering hydrogen energy courses to upskill the workforce. For example, the China Hydrogen Alliance hosts a "Hydrogen Academy," which conducts seminars and certificate programmes for industry personnel. In one recent session (April 2023), dozens of engineers from energy companies attended training on "Green Hydrogen & Ammonia Technology Routes, Engineering Practice, and Market Opportunities" and received completion certificates.

The curriculum included lectures by experts from universities and companies, covering hydrogen production technologies, storage and transport challenges, and safety and standards. While these are advanced seminars rather than entry-level welder courses, they indicate a trend: Chinese industry is actively disseminating hydrogen knowledge to its technical workforce.

Major state-owned enterprises such as Sinopec and China Energy are also likely conducting internal training for welders and technicians on topics including new welding materials, handling of high-pressure hydrogen, and safety protocols at hydrogen facilities.

China's technical universities and vocational institutes are beginning to integrate hydrogen topics as well. Some colleges have launched Fuel Cell and Hydrogen Technology programmes (for example, in Wuhan and Zhangjiakou, regions with hydrogen vehicle pilots) aimed at training technicians for fuel cell bus maintenance, electrolyser assembly, and related skills.

For welding specifically, China continues to rely on its robust existing welder qualification framework (often based on ISO 9606 or ASME Section IX standards, as many Chinese manufacturers are code-certified). The key enhancement is the addition of knowledge on hydrogen's properties.

Professors at leading engineering schools, such as Shanghai Jiao Tong University, are emphasising hydrogen in materials science courses and noting the "challenges faced by hydrogen storage and transportation technologies, including gaseous hydrogen pipeline transport and hydrogen embrittlement."

In short, Chinese welders do not obtain a separate hydrogen welder licence, but those working on hydrogen projects are expected to receive additional training in material science and safety.

Given China's scale — with plans for tens of thousands of hydrogen fuel cell vehicles and hundreds of refuelling stations — the country is likely to develop specialised training bases in the coming years to certify welders for high-pressure hydrogen tanks, cryogenic liquid hydrogen systems, and long-distance pipelines.

Germany

Germany is focusing on both upskilling its domestic workforce and supporting training in partner countries. Domestically, Germany's well-established apprenticeship and Meister systems are evolving to include GH_2 competencies. Industrial training bodies such as the DVGW (German Technical and Scientific Association for Gas and Water) have introduced new courses and certificates on hydrogen. For example, DVGW now offers certificate courses on hydrogen expertise for professionals — covering topics such as safe conversion of gas pipelines to H_2, materials selection, and the latest standards (e.g., the hydrogen supplement to the European Pressure Equipment Directive).

Through such courses, German gas pipeline welders, pipefitters, and plant technicians are learning the differences involved in working with hydrogen, such as tighter leak-testing criteria and the need to avoid high-carbon steels that can crack. The German Welding Society (DVS) and technical inspection agencies (TÜV) are also actively involved, issuing guidelines for welding in hydrogen service.

Welders in Germany continue to be certified to EN ISO 9606-1, ensuring a high baseline competency, while companies must also qualify welding procedures for hydrogen projects (e.g., according to standards similar to ASME B31.12 or ISO 19884 for hydrogen piping).

Overall, German industry is addressing hydrogen welding through rigorous application of existing standards, supplemented by targeted training modules.

German research institutions are also providing crucial knowledge to inform training curricula. The Federal Institute for Materials Research and Testing (BAM) is conducting research on hydrogen's effects on materials and welds. Experts note that hydrogen can "affect the mechanical properties, especially the ductility, of steel pipelines — particularly at welded joints."

This underscores why German welding engineers stress strict control of welding processes to avoid introducing flaws that hydrogen could exploit. Research is also exploring high-strength low-alloy steels with tougher weld metal for hydrogen service, and advanced robotic welding with in-situ monitoring to ensure defect-free seams.

These advancements eventually influence training: today's German welding apprentices may learn about hydrogen-induced cracking in theory classes, while future apprentices could train on new welding simulators that incorporate hydrogen scenarios.

Alongside national institutions, the IIW plays a central role in shaping global standards and harmonised training schemes for welders, inspectors, technologists, and engineers. Germany is deeply embedded in this network through DVS and its affiliated training centres, which deliver IIW qualifications alongside national ones.

Japan

Japan has been at the forefront of hydrogen energy, which has created unique welding challenges that its engineers and technicians are addressing. A landmark achievement is the world's first liquefied hydrogen carrier ship, the SUISO FRONTIER, launched by Kawasaki Heavy Industries. Welding played a critical role in this project: transporting liquid H_2 at −253 °C (20 K) required ultra-high-integrity welds and novel materials. Designers had to ensure that no part of the vessel would crack under such cryogenic conditions.

The ship's 1,250 m^3 spherical hydrogen tank is made of a special "super-strength steel" with a double shell and vacuum insulation. To fabricate it, Kawasaki worked with steelmakers to develop new welding technologies and improved insulation, addressing the risk of embrittlement in welds at near-absolute-zero temperatures.

Japanese welding technicians on this project underwent specialised training to handle advanced welding procedures, such as precise TIG welding for cryogenic stainless steels or aluminium alloys, combined with stringent QA/QC measures including X-ray and helium leak testing on every seam. This example highlights how engineering-level innovations in Japan filter down to welders, who must execute highly specialised techniques.

At the vocational level, Japan's training for hydrogen is integrated into existing industrial training programmes. The country maintains national qualifications for welders (Japan Welding Engineering Society certifications), which remain fundamental. However, as Japanese companies expand hydrogen technologies — fuel cells, storage tanks, and H_2 refuelling stations — they increasingly provide on-the-job upskilling for their workforce.

For example, companies manufacturing pressure vessels for hydrogen (such as Iwatani or Toyota for fuel storage tanks) train their welding crews to work with austenitic stainless steels and composite tank materials, which require different techniques from ordinary steel welding. Safety training is also prioritised: technicians learn about ventilation, sensor systems, and ATEX (explosive atmosphere) precautions when welding in hydrogen environments.

In addition, the Japanese government, through its Green Innovation Fund, has supported programmes in technical colleges on Hydrogen Energy Technologies. These cover the basics of hydrogen production and utilisation and include relevant trade skills — for example, educating pipefitters or welders on how hydrogen piping differs from natural gas piping (higher diffusion rate, need for double-sealed fittings, etc.).
In summary, Japan keeps its welding workforce up to date through a combination of rigorous baseline training and continuous specialisation. Its long-standing experience with liquefied natural gas (LNG) technology has been leveraged for hydrogen — much of the expertise in welding LNG tanks and cryogenic pipelines is being directly applied to liquid hydrogen, albeit with even tighter technical margins.

International Certification and Standards (ISO, IIW) for Hydrogen Welding

To benchmark TVET in Namibia against international standards, an overview of different international approaches is provided here. Generally, to ensure the quality, reliability, and safety of welded components — for which sufficient training and education of welding personnel are mandatory — two main routes are internationally applied, distinguished here for simplicity as the ISO-oriented and the non-ISO (ASME/AWS)-oriented systems, as shown in Figure 2.

Countries where hydrogen projects are already operating (e.g., South Africa, the Netherlands, Germany, China, Japan) have not created a new "hydrogen welder licence"; instead, they maintain existing qualification frameworks and add hydrogen-specific skills at the vocational level.

Customer Specification and / or Applicable Law

ISO ORIENTED (TRANSVERSAL STANDARDS)

- ISO 3834, ISO 15607-14, ISO 9606...: Any approach is appropriated, provided it is demonstrated to be safe
- Welding Coordinators contorl the process
- (Welding inspectors)
- Product standard specify applicable approaches

NON ISO ORIENTED (PRODUCTS COODES)

- Manufacturing CODES: The only approach is following prescription in the code
- Welding Inspectors assess the process against applicable standards
- (Welding Coordinators)

Welders and Welding Operations

Figure 1. Ways of quality assurance for welding personnel and welded components.

Up to the international ISCED Level 3, these routes are represented by "certified welders" according to ISO 9606 and AWS, or by "coded welders" under ASME BPVC Section IX. While the ISO 9606 and ASME IX systems are internationally applied standards, the AWS system was developed by industry practitioners.

Nevertheless, all tests under either ISO- or non-ISO-oriented systems up to ISCED/EQF Level 3 (NQF Level 4) are performance-based, focusing on practical welding skills, as indicated in Figure 1 under "Welders and Operators."

In addition, the International Welder (IW) curriculum provides a limited amount of theoretical knowledge but also falls under ISCED/EQF Level 3 (NQF Level 4). The qualification and certification (or coding) requirements for such welding personnel are largely comparable, and for harmonisation, ASME IX and ISO 9606 reference each other. The differences between Namibia's TVET levels and those applied internationally must, however, be kept in mind.

Due to the high safety relevance of components and systems in GH_2 technologies, the Education, Training, Qualification, and Certification (ETQ&C) of welding personnel beyond ISCED Level 3 becomes particularly critical, as in other safety-relevant sectors such as Oil and Gas Technologies (O&GT).

As outlined above, the two routes diverge significantly beyond ISCED Level 3: the ISO-based system is knowledge-driven and third-party-certified, while the non-ISO-oriented system is experience- and appointment-based. Consequently, both systems are applied by internationally operating welding companies, depending largely on customer or project requirements. In Namibia, this results in a heterogeneous workforce composed of personnel holding a variety of qualification types from both systems.

Non-ISO-oriented system

In GH_2T, O&GT, and many other industrial branches — especially for pressurised components — detailed knowledge and local supervision of welding personnel and procedures are required. In the non-ISO-oriented system, the supervision of coded or certified welders is generally achieved by welding inspectors, who are commonly appointed based on experience by the company.

The welding inspectors ensure that metallic components are manufactured following industry-specific building codes (e.g., ASME BPVC), with compliance provided by respective test series, as detailed in ASME BPVC Section IX with respect to welding processes, materials, and structural loads, frequently without third-party control.

While it is not mandatory for welding inspectors to hold certifications such as CSWIP, some companies assign skilled welders to this role without formal qualifications. As noted, companies sometimes operate under both systems, having both welding inspectors and coordinators (see below) based on customer-specific requirements.

ISO-oriented system

The ISO-oriented path, as shown in Figure 2, adopts a competence-based approach to controlling the quality of welding procedures, products, and personnel, with quality control carried out by a national third party.

The main standard is ISO 3834, which classifies and sets quality requirements for any company operating as a manufacturer or producer of welded components, facilities, or systems.

It also provides the fundamentals for the competence of personnel involved in welding, including welders, NDT personnel, inspectors, and coordinators. In the green hydrogen sector, ISO 3834-2 [10] is crucial, requiring the highest quality and competence standards ("comprehensive" in ISO 3834-2 and as referred to in Figure 2). The ISO approach emphasises a complete welding quality chain, from welders to coordinators, to ensure safety and durability.

ISO 3834-2, with reference to ISO 14731, also mandates appointing a Responsible Welding Coordinator (RWC), whose competence can be developed through a bottom-up or top-down approach. The bottom-up method includes advancing through the IIW scheme, from International Welder (IW) to International Welding Technologist (IWT) and International Welding Engineer (IWE).

The top-down approach leads to becoming an RWC by attaining the highest qualification, such as IWE. Only the IWT and IWE are normally qualified to take over the appointment as RWC. As shown in Figure 2, qualifications in welding always require a basic professional foundation as worker, welder, foreman, technician, or engineer.

Designated level of specialized technical knowledge in welding processes	Recommended general education according to ISCED level (minimum)	Examples of qualification
Basic	4	International Welding Practitioner (Professional worker)
	5	International Welding Specialist (Foreman)
Specific	6	International Welding Technologist (Technician)
	7	International Welding Engineer (Engineer)
Comprehensive		

1) ISCED level or its equivalent recognized by the national government.

2) A qualification in field of the metal-working industry of handcraft and a minimum of 3 years of experience is additionally required.

3) A qualification in the field of engineering, manufacturing or construction is required.

Figure 2. Welding knowledge and education levels provided by the ISO oriented ETQ&C system of the IIW

If it comes to international benchmarking in welding for GH_2T and other safety-relevant sectors, and to comparing the above ISO and non-ISO routes with Namibia's TVET training, it is evident that both routes require highly competent welders and welding operators with training and education beyond typical NQF Level 2 or 3 (metal fabrication) and coupled with sufficient practical experience.

In other words, while education and training obtained from Namibia's TVET system are sufficient for general welding of non-safety-critical equipment, they are not fully sufficient for the high safety demands in the GH_2 and renewable energy sectors.

This means that a graduate from the TVET system will require further training, practical experience, and possibly certification to perform at the required level in the GH_2 sector. Moreover, safety-relevant infrastructure increasingly employs mechanised and automated welding to minimise human error and ensure consistent quality.

In addition, green hydrogen infrastructure involves advanced materials such as austenitic stainless steels and nickel alloys that resist hydrogen degradation.

Therefore, welding education in countries involved in the GH_2 sector provides training on welding practices that address materials, mechanical, and safety challenges. (Identified knowledge and skills gaps in the TVET unit standards are outlined in the next section.)

However, for safety-critical welded components in GH_2T, as in other industrial branches, it becomes evident that ETQ&C beyond ISCED Level 3 is required. Also, according to ISO 3834, establishing national third-party quality and competence control is highly recommended. This is not provided by the non-ISO-oriented system.

Nevertheless, the International Institute of Welding (IIW) is currently harmonising the two routes, particularly for welding pressurised components as in GH_2T. This began with curricula for training and educating welding inspectors, distinguished by experience levels—basic, standard, and comprehensive.

Other education and training systems for welding inspectors can now be aligned with these curricula. The different education paths that welders can take towards international qualification are presented in Figure 3.

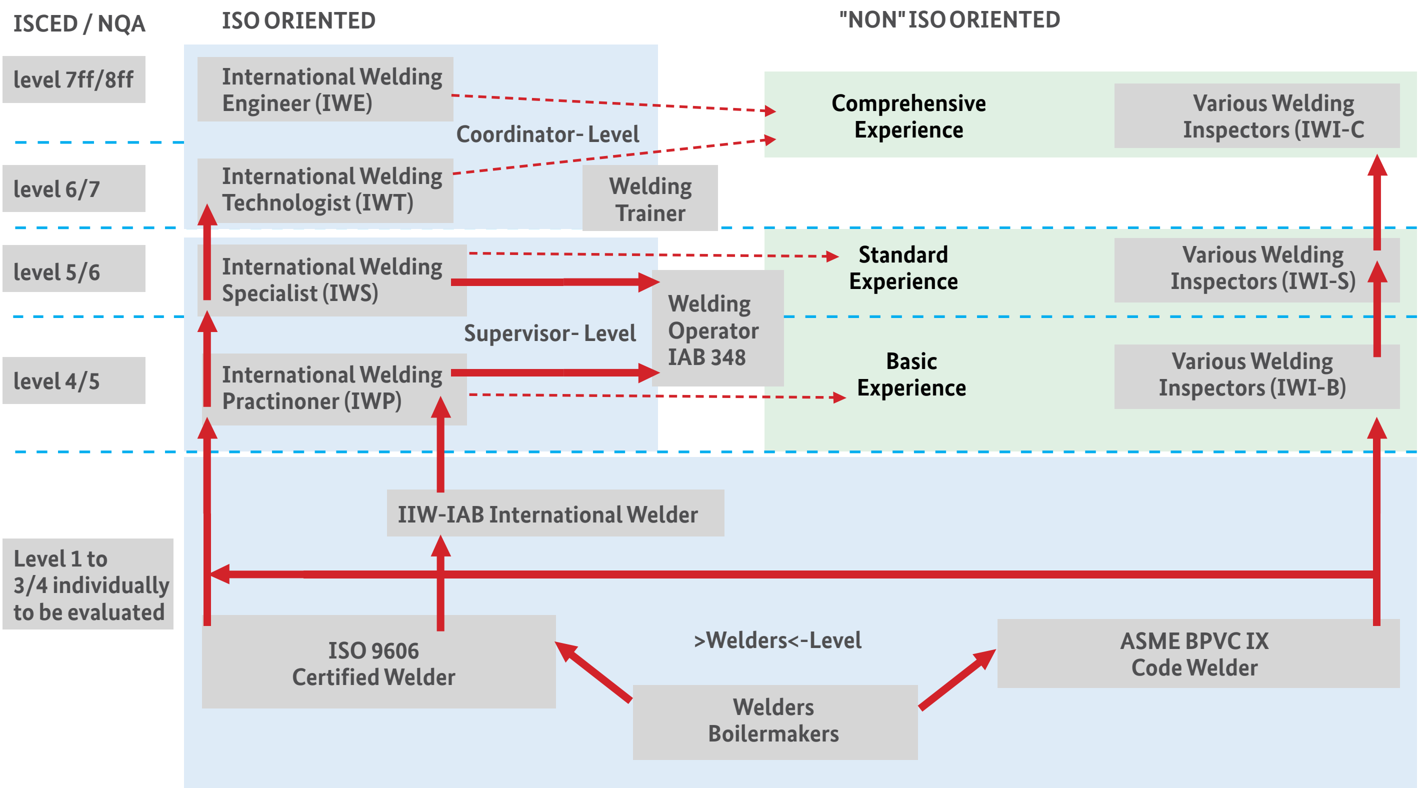
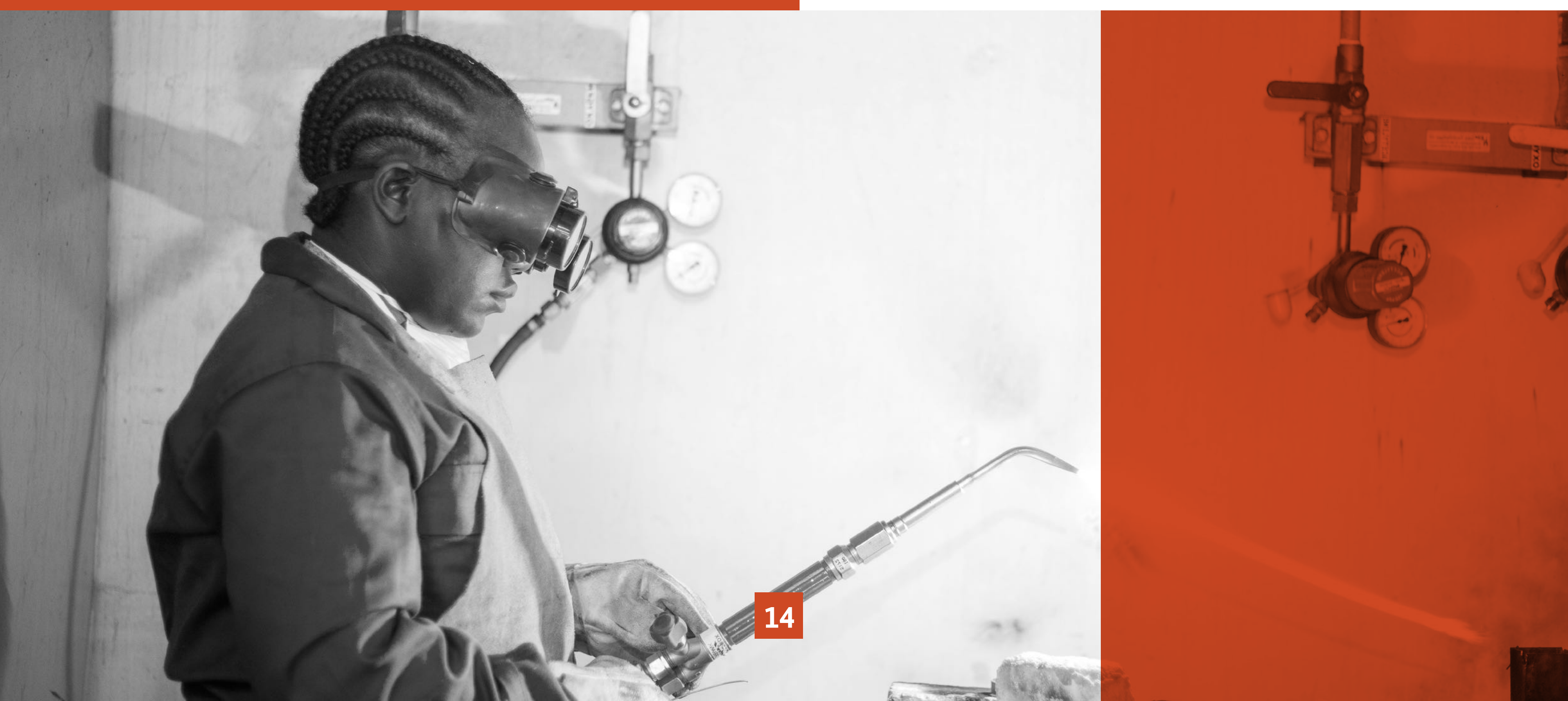


Figure 3. ISO-oriented ETQ&C route with respective ISCED and European versus NQA education levels and relations to non-ISO oriented routes.

Practical consolidation (integrated from the shortened section). There are two widely used assurance routes (ISO-oriented and non-ISO ASME/AWS-oriented).

Above entry level, the ISO route is third-party and competence-based and requires an RWC under ISO 14731; the non-ISO route relies more on company appointment and code compliance. Both routes are used globally, and many firms run both, depending on client requirements.

Hydrogen-specific skills are added at vocational level (e.g., purge control, orbital GTAW setup, embrittlement awareness, leak testing with proper documentation), while standards remain the acceptance yardstick. For Namibia's VTCs, the implication is to teach to measurable hydrogen outcomes (purge ppm, coupon acceptance, hardness caps, leak thresholds) and to keep the standards as the acceptance benchmark.



2

SKILLS GAP ANALYSIS IN THE FIELD OF WELDING

Welding for GH_2 infrastructure is a safety-critical activity. Most EPCs are expected to require a company quality system aligned with ISO 3834-2 (or equivalent), supported by coordinated welders (ISO 9606), mechanised operators where applicable (ISO 14732), and competent supervision (ISO 14731). In the context of TVET delivery, however, the most immediate gaps relate to practical, hydrogen-specific skills rather than theoretical knowledge.

The following qualifications were examined:

Table 3: Welding personnel needs for the industry based on the surveyed companies, with extrapolated values in brackets

Qualification No.	Trade Name	Level
Q0753	National Vocational Certificate in Metallurgy (Foundation)	Level 1
Q0754	National Vocational Certificate in Metallurgy (Operator Attendant)	Level 2
Q0755	National Vocational Certificate in Metallurgy (Junior Operator)	Level 3
Q0756	National Vocational Certificate in Metallurgy (Operator)	Level 3
Q0757	National Vocational Certificate in Metallurgy (Hydrometallurgical Processing - Senior Operator)	Level 4
Q0758	National Vocational Certificate in Metallurgy (Mineral Processing - Senior Operator)	Level 4
Q0036	National Vocational Certificate in Metal Fabrication	Level 2
Q0037	National Vocational Certificate in Metal Fabrication (Boilermaking)	Level 3
Q0038	National Vocational Certificate in Metal Fabrication (Welding)	Level 3
Q0039	National Vocational Certificate in Metal Fabrication (Boilermaking)	Level 4
Q0972	National Vocational Certificate in Metal Fabrication (Welding)	Level 4

Thus, based on international benchmarking and local industry consultations, the priority gaps are:

- **Pressure-class fabrication with hydrogen-grade practice:** Existing Level 3–4 curricula cover manual GTAW/SMAW but lack orbital setup, purge control, and digital weld logging. Welds on stainless steel or nickel piping for H_2 are defect-intolerant, making repeatability and traceability essential.
- **Hydrogen embrittlement awareness and hardness control:** Trainees require applied knowledge of hydrogen embrittlement, including root causes, HAZ hardness mapping, and repair options, using portable or micro-hardness routines with real coupons.
- **Commissioning and leak testing:** Hydro/pneumatic testing and H_2-sniffer practice are not part of current welding unit standards, yet these are critical at hand-over. Complete test dossiers are rarely taught or practiced.
- **Process safety and coordination at shop-floor level:** Permits-to-work, hazardous-area basics (IEC 60079awareness for supervisors), and welding coordination practices are weakly embedded in VTC delivery.
- **Trainer and assessor competence:** Many trainers are qualified at or below the level they teach; few have ISO 14732 mechanised welding experience, or hold RWC qualifications capable of implementing ISO 3834-2.
- **Facilities and SOPs:** Orbital heads, purge panels, borescopes, portable hardness testers, and hydro/sniffer rigs are generally absent, while SOPs and calibration regimes are limited.

To provide recommendations for specific short courses, it should be noted that hydrogen work is safety-critical. Company quality systems must be based on ISO 3834-2 (comprehensive), with competent coordination in line with ISO 14731 (Responsible Welding Coordinator, RWC).

There is no separate "hydrogen welder licence."

Instead, projects rely on the existing framework: ISO 9606 (welder performance), ISO 14732 (mechanised/orbital operators), ISO 9712 (NDT personnel), with acceptance criteria according to ISO 5817 (visual weld quality) and piping rules such as ASME B31.12 for hydrogen systems.

The table below provides a practical vocational, shop floor view of what Namibia's current NQF L2-L4 metal fabrication programmes actually deliver versus what hydrogen EPCs typically expect on critical piping work. Each row is a competency family; each column explains:

- where the local curriculum currently lands,
- what the welding reports emphasise (standards spine)
- the H_2 specific yardstick (practical KPIs you can assess in a booth/yard),
- why the gap matters,
- the possible immediate curriculum add on that can be proposed (short, tool specific modules).

Table 5: Competency family and gap analysis

Competency family	Evidence in current NQF units (IDs; level; credits)	Standards & roles implicated (acceptance focus)	H_2 specific yard-stick (what EPCs & good practice expect)	Gap severity & why it matters	Immediate curriculum action (where to land it)
Pressure class welding & fabri-cation (GTAW pipe incl. orbital; purge; weld logging)	Level 4 Welding (Q0972): TIG all positions on mild steel (251; L3; 6c); advanced Al & SS (252-255; L4; 6c each); stainless pipe all positions (1747; L4; 12c). Level 3 Welding (Q0038): TIG on SS (246; L3; 3c), MIG/MAG on MS (247; L3; 6c). No orbital/automation or purge KPI/logging anywhere in the unit lists.	Welder qualification: ISO 9606 Company QA: ISO 3834 2 (Comprehensive) Welding operator (mechanised/orbital): ISO 14732 Visual quality acceptance: ISO 5817 (Level B for critical tube/piping) Documentation: WPS/PQR; traceability to heats (MTRs).	Defect intolerant SS/Ni piping; stable purge; repeatability via mech-anised/orbital GTAW; purge $O_2 \leq$ 50-100 ppm at arc (project specific); $\geq$ 5/6 coupons to acceptance; digi-tal weld logs + borescope evidence for each weld.	High. There is reach manual pipe TIG at L4 (1747) but no ISO 14732 operator stream, purge instru-mentation or data logging, so repeatability/traceability are weak.	Add Module A: Hydrogen Orbital GTAW L1 (40 h) as WIL add on during 1747 deliveries; assess to ISO 5817 Level B, purge KPI and weld log export. Scope a later ISO 14732 operator route for trainers.
Metallurgy & materials (hydrogen embrittlement, hardness limits, repair choices)	L4 Welding (Q0972): Advanced Engineering Science (896; L4; 6c), Advanced Drawing (902; L4; 6c). L3 Welding (Q0038): Fundamental Eng. Science (894; L3; 6c), Fundamental Drawing (901; L3; 6c). No hardness testing or metallography units.	Embrittlement control: project specs; NACE TM0284/HIC awareness. Repair governance: WPS/PQR + acceptance limits (hardness caps in HAZ).	Recognise hydrogen induced cracking; apply hardness caps (e.g., HV10 $\leq$ project limit on SS/Cr Mo); select consumables/procedures that minimise HE risk; read HIC/SOHC evidence; choose compliant repair WPS.	High. Without portable/micro hardness routines, repairs risk exceeding caps; technicians can't diagnose root causes of HE.	Add Module C: Hydrogen Materials & HE Awareness (12 h)-HV10 mapping across HAZ on etched coupons; short annex unit Portable hardness testing for welds tied to Q0972 delivery.
Process safety & coordination (company sys-tem + welding coordination)	First Aid only in matrices (L3: 844; L4: 845). No units referencing ISO 3834 2 systems or RWC/ISO 14731 coor-dination.	Company QA system: ISO 3834 2. Coordination role: ISO 14731 Respon-sible Welding Coor-dinator (RWC). Progression spine: IIW (IWP→IWS→IWT/IWE) for staff who will coordinate.	Safety critical H_2 scope normally expects ISO 3834 2 shop approval (or equivalent) with a named RWC; module level acceptance linked to code clauses (what clause did today's task meet?).	High. Providers can produce individual coded welds but lack a system grade QA culture inside delivery.	Add Welding QA & Traceability (24 h) micro for L4 supervisors: weld maps, WPS/PQR basics, MTR control, dossier assembly. Keep standards as acceptance yardsticks; not theory heavy.
NDT & inspection literacy (PT/MT/UT/RT basics; read reports)	No NDT literacy units in L2-L4 Welding/Boilermaking matrices (only symbols/drawings and general science appear).	Personnel certification: ISO 9712 (NDT Levels 1-3). Acceptance: project code/QC plans reference PT/MT/UT/RT where applicable.	Shop floor staff can interpret NDT reports and dispositions; technicians progress on ISO 9712 routes.	Medium-High. H_2 joints are leak critical; artisans must know how to act on indications even if certification sits with NDT techs.	Add Read & Act on NDT (8-12 h) micro: basic PT/UT indication types, acceptance vs repair, traceability link back; integrate into QA/dossier module.

Commissioning & pressure testing (hydro/ pneumatic; H_2 sniffers; dossiers)	Absent from Welding L3-L4; Boilermaking L4 covers pipe layout/fabrication (262, 265) but no test/ sniffer practice.	Piping rules: ASME B31.12 (or client spec). Leak testing: helium/ H_2 mass spec sniffers; calibrated gauges/data loggers; pressure test dossiers.	Procedures adhered to; leak threshold met at test pressure; full traceable test pack (charts, holds, sign offs).	High. Without test skills/ instrumentation, commissioning risk and hand over quality are poor.	Add Module B: Hydrogen Leak testing & Test Dossiers (24 h) at a yard hub; pass/ fail on procedure adherence and complete dossier.
Workforce scale & routing	L2-L4 pipeline exists; WIL/apprenticeship 70/30 specified in L2-L4 quals; very few local IWT/IWE; no ISO 14732 operator path.	Progression: short, tool specific L3-L4 modules now; IIW spine as progression (not a gate) into coordination/ inspection; operators via ISO 14732.	Projects need many coded welders now; bite size upskilling prevents bottlenecks, while staff who will coordinate move onto IWS/IWT.	High. Without an on ramp, EPC demand creates constraints and rework risk.	Stand up Modules A-C as WIL add ons; publish KPI scorecards (purge, coupon pass rate, dossier com- pleteness); plan ISO 14732 trainer pathway.

Namibia's post-Level 4 gap is significant: Namibia's post-Level 4 gap is significant. The system needs an IIW/EWF backbone to develop supervisors, coordinators, and trainers through the IWP, IWS, IWT pathway (see previous chapter, ISO route). At the same time, leak-tight work is urgently required, and many artisans-whether with 3-4 years of training or many years of practical experience-cannot readily follow the traditional route toward higher qualifications.

EXPLANATION NOTE

What the H_2-specific standards mean in practice (examples):

- **Purge quality KPI (≤50–100 ppm O_2 at arc start/during weld):** Sets a measurable target for shielding gas quality in stainless steel tube welding. Instead of vague advice like "good purge," trainees and assessors use an oxygen meter to confirm the gas is clean enough before and during the weld.
- **Weld quality KPI (≥5 out of 6 coupons meet acceptance):** Ensures repeatability. Trainees weld test pieces ("coupons"), which are checked against the client's required standard (e.g., ISO 5817 level B or a specific project specification). Success means consistent results across the group, not just one lucky weld.
- **Hardness control KPI (HV10 ≤ project cap across HAZ):** A simple test to keep repairs within hydrogen service limits. Hardness is measured on the weld's heat-affected zone (HAZ) using portable or bench-mounted testers.
- **Leak testing KPI (passes sniffer test at pressure + complete dossier):** Combines safety and documentation. Welds must show no leaks under pressure (tested with a hydrogen "sniffer") and all supporting paperwork (charts, records, sign-offs) must be complete.

Why are these training gaps are rated as High:

- **Orbital/automation & digital QA:** Current Level 2–3 standards do not cover orbital welding equipment, weld logging, or purge monitoring. Yet these tools are essential for leak-tight hydrogen piping and efficient site productivity.
- **Materials/embrittlement practice:** Level 2–3 science and drawing units provide a theoretical base but do not include hardness mapping or hydrogen embrittlement case studies. Without these, artisans cannot verify whether a repair weld remains within hardness limits.

Possible immediate action:

- **Testing & dossiers:** Hydro/pneumatic pressure and hydrogen sniffer testing are missing from the current unit standards. Vocational training centres (VTCs) also lack the equipment and standard operating procedures (SOPs). This makes commissioning a "High" severity gap.
- **Immediate curriculum action:** The proposed solution is to add short, work-integrated learning (WIL) modules to existing Level 3–4 programmes. These bolt-on modules can close urgent gaps without waiting for a full qualification rewrite.

3

RECOMMENDATIONS FOR NECESSARY TRAINING MEASURES IN WELDING

As the previous chapter has shown, Namibia's post-Level 4 gap is significant. The system requires an IIW/EWF backbone to develop supervisors, coordinators, and trainers through the IWP → IWS → IWT pathway (see previous chapter, ISO route). At the same time, leak-tight work is urgently required, yet many artisans — whether with 3–4 years of training or many years of practical experience — cannot readily follow the traditional route toward higher qualifications.

Namibia's existing welding pathway already produces Level 3–4 artisans with strong manual GTAW, SMAW, and MIG skills. For example, Level 4 includes "Weld stainless-steel pipe in all positions using GTAW" (Unit 1747, 12 credits), alongside advanced TIG/SMAW on stainless steel and aluminium (Units 254–255; 252–253; 251), with underpinning theory (Units 896, 902). Level 3 covers down-hand TIG on stainless steel (Unit 246), MIG on mild steel (Unit 247), and related core skills, all delivered under a 70/30 work-integrated learning (WIL) model.

What is missing for GH_2 work are the hydrogen-critical techniques and controls. Current programmes do not include orbital or mechanised GTAW, purge quality and digital traceability, hydrogen embrittlement and hardness control, or commissioning procedures such as leak-testing and full dossier preparation. None of these appear in the current unit standards, which also lack modules on orbital/automation, hardness testing, NDT, or commissioning.

Internationally, short courses in welding and allied processes already exist and are offered in countries investing in green hydrogen, such as Sweden, Portugal, and Germany.

At the basic level up to ISCED Level 3 (equivalent to NQF Level 4), international curricula exist and are applied worldwide under frameworks such as ASME BPVC IX, ISO 9606, AWS, or the IIW-IAB International Welder (IW) course. These curricula are broadly similar in their test requirements and can be adapted into Namibia's NTA system — a task beyond the scope of this study but one that should be pursued.

To be fully competent for the GH_2 sector, however, welders holding these international certificates must attend additional short courses beyond ISCED Level 3 (NQF Level 4), ideally after pre-screening of their skills.

Thus, two pathways are recommended to run concurrently:

- **Short to medium term (Lane A):** Short, hydrogen-specific Level 3–Level 4 modules that provide a controlled on-ramp for bounded tasks EPCs require immediately (purge discipline, closed-head orbital setup on small diameters, cleanliness/passivation, and leak testing with dossiers). The scope of practice should be gated after each module, require supervision by a higher-qualified person (IWS/IWT/IWE/RWC), and be assessed against quantitative KPIs (O_2 ppm, ISO 5817 coupon pass rate, HV10 hardness caps, leak thresholds, and dossier completeness).

- **Medim to long term (Lane B):** In parallel, trainers and supervisors should be nominated into WP/IWS/IWT/MORW, so the backbone is strengthened while leak-tight work is delivered safely at Levels 3–4.

3.1 Lane A: Immediate Vocational On Ramp (Levels 3 to 4)

Building on the gaps and pathways outlined above, Lane A provides short, hydrogen-specific modules at Levels 3–4.

These are designed as work-integrated learning (WIL) add-ons within the existing 70/30 delivery model, giving artisans a controlled on-ramp into hydrogen-critical work without requiring immediate progression into IIW/EWF routes.

While Namibia's existing welding qualifications (Q0036–Q0038) produce Level 3–4 artisans with strong manual GTAW, SMAW, and MIG skills, they do not address hydrogen-specific requirements such as mechanised/orbital welding, purge instrumentation, hydrogen embrittlement and hardness control, commissioning leak testing, or dossier preparation.

Lane A addresses these gaps through short, tool-specific courses that EPCs can immediately recognise and value.

Rationale for Lane A

- **Current qualification limits:** The national Level 2–4 welding and boilermaking qualifications (Q0036–Q0038) focus on conventional manual processes. They exclude orbital/automation, purge monitoring, NDT literacy, commissioning procedures, or hydrogen-specific traceability. For example, Level 3 welding covers down-hand TIG (Unit 246) and MIG (Unit 247), while Level 4 welding includes stainless and aluminium TIG/SMAW and stainless steel pipe GTAW (Unit 1747, 12 credits). However, none of these unit standards include orbital welding, purge logging, hardness testing, or leak-testing practices.
- **Guardrails:** To ensure safety and consistency, these short modules should be limited to defined diameters and materials, use a fixed WPS/PQR library, and always require sign-off by IWS/IWT/IWE under RWC oversight.
- **Industry demand:** EPC packages will require large numbers of Level 3–4 artisans who can immediately: set up purges to a ppm target, run orbital heads to a procedure, and assemble basic pressure test run orbital heads to a procedure, and assemble basic pressure test dossiers. Short modules of 12–40 hours enable these outcomes faster than multi-week IWP/IWS/IWT routes.

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- **Provider readiness:** Current TVET Centres lack orbital systems, purge panels, borescopes, micro-hardness testers, and hydrogen sniffers. Therefore, investment in equipment and targeted training is essential.
- **Assessment yardsticks:** Hydrogen-critical work requires measurable outcomes at artisan level — e.g., purge ≤50–100 ppm O_2 at arc start, ≥5/6 coupons to ISO 5817 acceptance, HAZ hardness under project caps, leak test at thresholds, and dossier completeness. These KPIs can be integrated into short modules and directly assessed.
- **Standards as acceptance, not gate:** ISO 3834, ISO 9606 (welder qualifications), ISO 14731 (coordinators), ISO 14732 (automation operators), and ISO 9712 (NDT) remain the acceptance benchmarks and progression spine. However, they should not be a barrier to starting hydrogen-specific upskilling at Level 3–4.

Therefore, we would like to propose the following courses:

- **Course 1:** Orbital GTAW Set up, Purging & Weld Log Recording (40 h): Stainless/Ni pipe/tube weld integrity is the single biggest schedule & safety risk on GH_2 skids. L4 already teaches manual stainless pipe TIG (Unit 1747); adding orbital + purge control + digital logs turns a strong base into hydrogen ready practice. Outcome measured: ≤ 50-100 ppm O_2 at arc; ≥ 5/6 coupons to ISO 5817 acceptance; complete weld logs & borescope evidence.
- **Course 2:** High Purity Tube Prep, Cleaning & Passivation for H_2 Service (16 h): Cleanliness and passivation determine leak tightness and HE risk before anyone strikes an arc. It's fast to stand up, low capex (chemistry + borescope), and increases pass rates in Course #1. Outcome measured: water break free surfaces; borescope clean roots; simple field passivation tests passed.
- **Course 3:** High Pressure Hydro/Pneumatic Testing & H_2 Sniffer Leak Detection (24 h): Commissioning is the last barrier before hand over. VTCs have no rigs/sniffers and no dossier practice, yet EPCs will demand procedure-controlled tests and traceable packs. Outcome measured: procedure adherence; leak thresholds met; complete test dossier (charts/holds/sign offs).
- **Course 4:** Valve & Instrument Hook Up (V&IHU): Double Ferrule Fittings in H_2 Systems (16 h): A high share of leaks come from small bore fittings. Correct ferrule makes up, gaugeable pull up and documented leak checks cut rework dramatically. It's low capex, high impact, and complements #1-#3. Outcome measured: 5/5 fittings pass at test pressure; 0 crushed tubes; pull up verified and logged.

Please note: For institutions and contractors building towards ISO 3834 2 and ISO 14731 competence, the MORW automation course and Train the Trainer pathways are recommended. These follow — not precede — the L3-L4 hydrogen on-ramp modules recommended here and are lined out in chapter 3.2 below.

Course 1: Orbital GTAW Set-up, Purging & Weld-Log Recording

Course overview & competencies

Purpose: Convert L4 manual stainless pipe TIG capability (Unit 1747) into repeatable, leak tight hydrogen practice using orbital GTAW, purge control and digital QA.

On completion, the learner can:

- Select orbital head, collets and tungsten geometry for given tube/pipe OD and alloy (316L; Ni alloys).
- Configure power source/program and qualify a start-up coupon to a WPS (heat input, travel, rotation, wire/no wire).
- Achieve and maintain ≤ 50–100 ppm O_2 at arc start and during root with calibrated meter and documented readings.
- Execute ≥ 6 joints on 1–2 sizes (e.g., 25×1.6 mm and 38×2.0 mm 316L tube), with ≥ 5/6 to ISO 5817 Level B (project acceptance rules).
- Produce digital weld logs (parameters, batch/heat trace, operator ID) and borescope evidence of root profile/oxidation.
- Apply purge dam selection, venting strategy, trailing shield (when manual tie ins are required) and defect troubleshooting (lack of fusion, sugaring, oxide stringers).
- **Prepare a PQR/POE pack for client QA:** WPS, logs, O_2 charts, material certs (MTRs), visual/borescope images, NDT as required.

Standards spine (acceptance focus): ISO 9606 1 (welder), ISO 14732 (welding operator), ISO 5817 (Level B as default for H_2 critical), ISO 3834 2 (shop QA), shielding gases ISO 14175; hydrogen projects typically reference ASME B31.12 / ISO 19880 1: use project specific clauses for acceptance.

Recommended providers

Primary: NICHE Walvis Bay / Windhoek VTC / NIMT Arandis partnered with SAIW (IIW aligned) and for infrastructure with various institutions (e.g., SAIW Materials Testing Lab for DH analysis; One Eighty / SecMet / AMS for destructive coupon testing & macro etch).

Duration & delivery

40 h block: 8 h theory → 24 h booth practice → 8 h QA/borescope reporting.

- Theory (8 h): Orbital GTAW fundamentals, purge physics, O_2 measurement, data logging, ISO/IIW roles, common defects.
- Booth (24 h): Set up, purge panel use, O_2 trending, welding 6 coupons across two sizes, parameter tuning, rework scenarios.
- QA/reporting (8 h): Log export, weld map, borescope protocol, POE assembly; 1–2 coupons sent to Y for macro/hardness.

Target group & entry requirements

- Target: L4 welding learners (Q0972) and experienced L3 welders moving into hydrogen piping; contractor welders slated for EPC works.
- Entry: Evidence of manual GTAW proficiency (e.g., ISO 9606 1 141 P BW or L4 Unit 1747 pass), drawing/symbol literacy (Unit 233), fit for work medical, OHS induction.

Capacity building & partnerships

Infrastructure: 1 orbital power source with data logger + 2 heads (½–1½"), purge panel, two handheld ppm O_2 meters, borescope, weld log laptop, sample SS tube/pipe, purge dams, traceable consumables.

ToT: 2–3 trainers complete ISO 14732 operator upskilling and shadow at SAIW; 1–2 weeks attachment at industry observing PQR workflows.

Certifying body: SAIW/IIW micro credential for orbital operator; ISO 9606 test (if required by employer) run with various institutions (e.g., SAIW Materials Testing Lab for DH analysis; One Eighty/SecMet AMS for destructive coupon testing & macro etch) as independent lab.

Industry link: NAMDOCK/Kraatz/3 C Metal Belmet/Hyphen/Cleanergy host job attachments and recognise the POE pack as site onboarding evidence.

Assessment & KPIs:

- Purge KPI: ≤ 50–100 ppm O_2 at arc start/hold (logged).
- Quality KPI: ≥ 5/6 coupons to ISO 5817 B; no sugaring beyond acceptance; borescope image set per joint.
- Traceability KPI: Complete POE with logs, O_2 trend, MTRs, WPS/PQR refs; at least 1 macro etch returned acceptable.

Course 2: High Purity Tube Prep, Cleaning and Passivation for H_2 Service (16 h)

Course overview & competencies

Purpose: Eliminate "invisible" leak and embrittlement drivers by controlling surface condition before welding.

On completion, the learner can:

- Apply mechanical prep (square cut, deburr, ID cleaning) without embedding ferritic contamination.
- Execute solvent degreasing, alkaline cleaning, and controlled pickling/passivation (citric/nitric systems) safely.
- Verify water break free surfaces; perform simple field passivation checks and pH/rinse validation.
- Use borescope to confirm oxide/contamination free roots post weld; document with photos.
- Label, bag, and protect cleaned parts; manage lot traceability and time to weld windows.
- Record chemicals batches, dwell times, and neutralisation disposal logs to shop SOP.

Standards spine: Good practice per ASTM A380/A967 (cleaning & passivation), ISO 5817 (visual targets), ISO 3834 2 documentation discipline; acceptances per project spec.

Recommended providers

Primary: Namibian institution (e.g., NICHE/Windhoek VTC) partnered with SAIW for procedure oversight; infrastructure (e.g., One Eighty / AMS for surface verification/macros if sampled).

Duration & delivery

16 h block: 4 h theory → 10 h lab/booth → 2 h QA/reporting.

- **Theory (4 h):** Contamination pathways, chemistry choices, safety & PPE, neutralisation, documentation.
- **Lab/booth (10 h):** Cut/face/deburr; staged cleaning; pickling/passivation on 316L coupons; controlled drying; borescope inspection.
- **QA/reporting (2 h):** Water break test records, chemical lot logs, borescope photo sheets.

Target group & entry requirements

- **Target:** L3–L4 welding learners, pipefitters, QA techs, contractor helpers.
- **Entry:** Basic shop safety; familiarity with stainless handling; Unit 246 (down hand TIG on SS) beneficial.

Capacity building & partnerships

- **Infrastructure:** Orbital/bench tube saw, facing tool, lint free cleaning kit, conductivity checked DI water, chemistry kit (per approved MSDS), drying cabinet, borescope.
- ToT: 1–2 trainers complete a chemistry handling short course with SAIW; SOPs co developed and validated on site.
- **Certifying body:** Provider issued micro credential aligned to ASTM A380/A967 practice; recognition by SAIW partner.
- **Industry link:** Hyphen/Cleanergy accept the cleanliness dossier as a prerequisite for Course 1 orbital trials.

Assessment & KPIs:

- **Cleanliness KPI:** 100% water break free before purge fit up; borescope clean root on sample welds.
- **Documentation KPI:** Full chemical trace + rinse validation sheet for each lot; safe disposal record complete.

Course 3: High Pressure Hydro/Pneumatic Testing & H_2 Sniffer Leak Detection

Course overview & competencies

Purpose: Build commissioning ready artisans who can run code compliant pressure tests and assemble traceable test packs.

On completion, the learner can:

- Interpret client spec (e.g., ASME B31.12 / ISO 19880 1) to select hydro vs pneumatic test and compute test pressure and hold.
- Set up a safe test area (barricades, exclusion zones), choose calibrated gauges/data loggers, and manage venting/pressurisation ramps.
- Conduct a hydrotest (fill, vent, stabilise, hold, examine) and a helium or forming gas sniffer test for tightness.
- Demonstrate sniffer technique (probe speed, distance, wind shielding) and interpret thresholds per spec.
- Complete a pressure test dossier: P&ID extract, isometrics, calibration certs, permits, hold point sign offs, charts, punch list closeout.

- Coordinate with NDT/inspection (PT/UT/RT) and HSE, raising and clearing NCRs properly.

Standards spine: ASME B31.12 (or project code), ISO 19880 1 leak testing guidance, ISO 3834 2 documentation; personnel interfacing with NDT per ISO 9712 awareness.

Recommended providers

Primary: Namibian institution (e.g., NICHE/Windhoek VTC; or a yard hub at NAMDOCK/Kraatz) partnered with SAIW; infrastructure (e.g., RITC Namibia for PT/UT; SecMet/SAIW/One Eighty for calibration/macros where applicable).

Duration & delivery

24 h block: 6 h theory → 14 h rig practice → 4 h QA/dossier assembly.

- **Theory (6 h):** Code choices, energy risk (pneumatic vs hydro), instrumentation & calibration, leak mechanisms in H_2.
- **Rig practice (14 h):** Build test loop; hydro to target; depressurise safely; pneumatic with helium/forming gas sniffer; capture charts.
- **QA/dossier (4 h):** Complete test pack with checklists, charts, sign offs; mock client audit.

Target group & entry requirements

- **Target:** L4 welders/boilermakers, junior supervisors, QA/NDT assistants.
- **Entry:** OHS induction, pressure equipment awareness; ability to read isometrics and WPS; recommended completion of Course 1 or equivalent field experience.

Capacity building & partnerships

- **Infrastructure:** Portable hydro rig (pump, tank, calibrated gauges), mass spec or high sensitivity sniffer, data logger, test spools, blinds, calibrated relief.
- **ToT:** 2 trainers seconded for commissioning shadowing at NAMDOCK/Kraatz; procedure pack co signed by SAIW.
- **Certifying body:** Provider micro credential; client/owner sign off on test pack templates; optional SAIW endorsement.
- **Industry link:** EPCs (Hyphen/Cleanergy) pre approve the test dossier template for site use; RITC integrates NDT reports into packs.

Assessment & KPIs:

- **Procedure KPI:** Correct test selection, pressure calc and 100% compliance to sequence.
- **Leak KPI:** Meets specified threshold (sniffer/background corrected) with documented readings.
- **Dossier KPI:** Pack complete and audit ready (calibration certs current; charts legible; holds observed

Course 4: Valve and Instrument Hook Up (V&IHU): Double Ferrule Fittings in H_2 Systems

Course overview & competencies

Purpose: Eliminate the most common leak source-small bore fittings-through correct tube handling, make up, gauging and documentation. On completion, the learner can:

- Select tubing and fittings compatible with H_2 service (material/ pressure rating), confirm heat/lot trace.
- Perform correct cut/face/deburr/clean, alignment and clamp positioning to prevent galling and out of round.
- Execute first make up and re make per manufacturer procedure; use go/no go gauge or pull up indicator.
- Route and support small bore impulse lines; bend to radius without ovality; avoid vibration prone runs.
- Perform function tests (loop check) and leak tests at test pressure; complete hook up checklist and isometric red lines.
- Document torque/make up method and fitting batch in the POE.

Standards spine: Manufacturer installation specs (double ferrule systems), ISO 19880 1 (installation & leak integrity), ISO 3834 2 documentation discipline.

Recommended providers

Primary: Namibian institution (e.g., NICHE/Windhoek VTC; or industry academy at Kraatz/NAMDOCK) with SAIW oversight; infrastructure (e.g., vendor demo kits + sniffer; AMS/One Eighty for any validation cuts/ macro etch of swaged joints if needed).

Duration & delivery

16 h block: 3 h theory → 11 h bench/field practice → 2 h QA/reporting.

- **Theory (3 h):** Fitting anatomy, metallurgy, failure modes, manufacturer procedures, documentation.
- **Practice (11 h):** 12–15 connections (straight, elbow, tee, gauge), controlled re makes, tube bending & support, pressure/leak test.
- **QA/reporting (2 h):** Checklists, torque/make up records, red line updates, final POE.

Target group & entry requirements

- **Target:** L3–L4 welders/pipefitters, instrument techs, commissioning teams.
- **Entry:** Basic hand skills; completion of Course 2 preferred; OHS induction.

Capacity building & partnerships

- **Infrastructure:** Double ferrule training boards/kits, tube benders, gauge tools, alignment clamps, calibrated torque tools, sniffer, small hydro rig.
- **ToT:** Vendor led train the trainer (OEM fitting supplier) plus SAIW QA overlay.

- **Certifying body:** Provider micro credential referencing OEM procedure; optional vendor "approved installer" status.
- **Industry link:** EPC vendors accept POE for installer approval; Hyphen/Cleanergy agree hook up checklist format for site.

Assessment & KPIs:

- **Leak KPI:** 5/5 fittings pass at test pressure; 0 crushed tubes, acceptable ovality.
- **Documentation KPI:** Gaugeable pull up verified on 100% of connections; POE complete with batch/heat trace.

Delivery model

This applies to all four courses:

- **Cohort size & ratios:** Max 12 learners; 1:6 trainer to booth ratio (Course 1), 1:8 bench/rig ratio (Courses 2–4).
- **Evidence of learning (per learner):** Signed WPS/procedure adherence sheet, weld logs/O_2 trend, borescope gallery, checklists, calibration copies, and one external lab result (where relevant).
- **Recognition:** Provider-issued micro credentials cross-referenced to ISO/IIW roles (9606, 14732, 3834 2/14731 awareness). Employers/EPCs pre-agree that the POE meets site onboarding needs.
- **Sequencing:** 2 → 1 → 4 → 3 gives the fastest productivity uplift; courses 1 and 3 can run parallel for different crews.

3.2 Lane B: Backbone (12-24 months; trainers/supervisors)

Beyond the immediate hydrogen-specific modules at the artisan level, Namibia should also establish a long-term backbone of supervisors, coordinators, and trainers with internationally recognised qualifications.

This requires structured progression through the IIW/EWF pathway — from International Welding Practitioner (IWP) to International Welding Specialist (IWS) and International Welding Technologist (IWT). In parallel, a Mechanised/Orbital Welding (MORW) stream and targeted Train-the-Trainer programmes will ensure that both advanced technology and instructional capacity are embedded in the system.

This route follows the ISO-oriented model of third-party qualification and certification. It provides Namibia with the competence needed to implement ISO 3834-2 (comprehensive quality assurance in welding) and ISO 14731 (Responsible Welding Coordinator requirements), while also opening an ISO 14732 operator stream for mechanised/orbital welding.

Lane B is therefore essential for creating a sustainable quality framework in welding. By building national competence among centre staff and selected industry supervisors, Namibia will not only meet the requirements of Engineering, Procurement and Construction (EPC) companies but also develop the supervisory and training capacity to sustain hydrogen-ready welding over the long term.

Brief description of recommended courses

- **International Welding Practitioner (IWP) (ISCED Level 4 and NQF Level 5):** This qualification provides candidates with both factual and theoretical knowledge of welding and cutting processes, covering manual, mechanised, automatic, and robotic applications. It introduces the fundamentals of materials processing, their applications, and the behaviour of materials during welding and cutting.

  Candidates also gain a basic understanding of the theory and principles of welding design and construction. Overall, the course functions as a bridge, enabling welding personnel to progress from NQF Level 4 (ISCED Level 3) to NQF Level 5 (ISCED Level 4) and equipping them with the knowledge and competencies defined in IAB-252 [12].

- **International Welding Specialist (IWS) (ISCED Level 5 and NQF level 6):** This qualification equips candidates with specialised practical knowledge, enabling them to understand and apply the core principles of welding and cutting processes across manual, mechanised, automated, and robotic systems.

  It covers key concepts in materials processing, their applications, and how materials behave during welding and cutting operations. Candidates also develop an applied understanding of theoretical foundations and design considerations in welding technology and construction. The course is recommended for the advancement of instructors from ISCED Level 4 to Level 5, as outlined in IAB-252 and IAB-362 [13].

- **International Welding Technologist (IWT) (ISCED Level 6 and NQF level 7):** This qulaification develops candidates' advanced knowledge and critical analysis skills in the theoretical foundations of welding and cutting processes, including manual, mechanised, automated, and robotic applications. It examines materials processing, their performance in welding and cutting, and related applications, while also providing an overview of welding standardisation. Candidates will gain the ability to interpret, articulate, and critically evaluate the principles of welding design and construction. The course is designed to support the progression of instructors from ISCED Level 5 to Level 6, as outlined in IAB-252 and IAB-362.

- **Welding Trainer Qualification:** The qualifications listed above, particularly Courses 2 and 3, already represent an important step in updating and upskilling welding instructors at TVET centres in Namibia. However, with the introduction of these courses, it is advisable to also recommend a dedicated programme addressing the "Train-the-Trainer" requirement. This course, called "Welding Trainer," is offered by DVS-GSI in Germany as an addition to the International Welding Technologist qualification.

- **Additional Short Course:** Mechanized, Orbital and Robot Welding (MORW) (ISCED Level 4 and NQF Level 5): This course is recommended particularly in connection with GH_2T, as it provides students with a comprehensive understanding of welding automation and its associated technologies. Students will become familiar with key terminology, abbreviations, and definitions related to welding automation.

  The course covers the full spectrum of mechanisation — from manual welding through to fully adaptive systems — and explores their appropriate industrial applications. It provides insight into the principles and benefits of mechanisation, including orbital welding systems, equipment, and parameters affecting weld quality. Quality assurance and control are emphasised across all stages of welding, including standards, procedures, and traceability requirements. The course also introduces welding symbol interpretation and examines the relationship between productivity and economy in welding. Students will study various mechanised and robotic welding processes, their advantages and limitations, joint preparation techniques, and safety considerations.

  Furthermore, the course introduces industrial robotics, covering robot types, components, programming methods, and integration strategies to optimise welding efficiency in manufacturing environments. To access this course, candidates should have completed at least Course 1 (International Welding Practitioner).

  However, International Welding Specialists (IWS) will find it easier to acquire the knowledge provided in this course, as outlined in IAB-348 [14].

Recommend existing upskilling training measures related to the short course

The recommended short qualifications are high-quality, internationally recognised welding certifications offered by leading welding institutes worldwide — for example, the Istituto de la Saldatura in Italy or the training schools of the German Welding Society (DVS-GSI).

The skills required for the first four qualifications build progressively on one another, while the qualification in mechanised welding requires only Qualification 1, but preferably Qualification 2, as a prerequisite. All recommended qualifications are aligned with ISO standards, which are widely adopted in the green hydrogen and renewable energy industries (see Table 6).

Table 6: Related upskilling measures provided by the recommended short courses

Course	Requirements and upskilling measures
1 – IWP (ISCED Level 4 and NQF Level 5)	Welder ISCED Level 3 – Goal: Equip welders with the specific competencies required for high-quality welding in these sectors. Gain knowledge needed as a foreman and basics in welding supervising
2 – IWS (ISCED Level 5 and NQF level 6)	IWP ISCED Level 4 – Goal: Extend the knowledge further in safety-relevant welding in the field of GH_2T – Achieve knowledge for supervising larger workshop areas and to work as a foreman in welding
3 – IWT (ISCED Level 6 and NQF level 7)	IWS ISCED Level 5 – Goal: Extend the knowledge further in safety-relevant welding in the field of GH_2T – Achieve knowledge for supervising large workshops and to establish basic welding procedures specifications, take over basic functions as a welding coordinator
4 – Welding Trainer	IWS ISCED Level 6 – Goal: Extend the knowledge further in safety-relevant welding in the field of GH_2T – Enabling to build complete welding training and education programs in welding schools
5 – MORW (ISCED Level 4 and NQF Level 5)	IWP ISCED Level 4 – Goal: Extend the knowledge further in automized and safety-relevant welding in the field of GH_2T – Achieve knowledge for supervising larger automized workshop areas and to work as a foreman in welding

Brief outline of competencies required

Table 7: provides an overview of the skills to be gained through the respective short qualifications. From the listed target groups, it is clear that the qualifications build progressively on one another. Once one qualification has been completed, the next at the following ISCED level can usually be taken without repeating the same examinations.

Table 7: Related upskilling measures provided by the recommended short courses

Course and duration	Skills	Target Group and Required Competencies
1 – IWP (ISCED Level 4 and NQF Level 5) 150 h = 4 weeks	Identify and evaluate the suitability of different welding and cutting techniques for specific applications. Classify materials and assess their mechanical and physical properties relevant to welding. Apply theoretical knowledge to identify and troubleshoot welding and cutting process-related issues. Interpret the relationship between welding design, fabrication requirements, and structural integrity. Develop a foundational base to transition from operator-level roles to supervisory of basic or standard work.	TVET scholars who have completed their ISCED Level 3 or NQF Level 4. Experienced welders in industry who wish to specialize in advanced welding practices, quali-ty control, and basic welding su-pervision. TVET trainers who wish to enhance their knowledge and education level towards NQF Level 5 (ISCED Level 4) and beyond.
2 – IWS (ISCED Level 5 and NQF Level 6) 249 h = 6 weeks	Analyze material behavior during welding and cutting, with an emphasis on materials commonly used in hydrogen infrastructure, such as stainless steels and high-performance alloys. Evaluate design considerations in welded structures, including joint configuration, load-bearing capacity, and manufacturing feasibility for hydrogen systems. Apply theoretical foundations to solve practical welding problems and make informed decisions, particularly in contexts requiring high integrity and hydrogen compatibility. Interpret key concepts in materials processing and relate them to real-world welding and cutting applications, including those critical to emerging sectors such as green hydrogen.	Welding personnel and TVET trainers with international welding practitioners' certificate at NQF Level 5 and ISCED Level 4.
3 – IWT (ISCED Level 6 and NQF Level 7) 369 h = 10 weeks	Manage in detail the welding applications and related professional activities or projects. Integrate knowledge of materials processing and application to optimize welding procedures and ensure reliability in critical sectors like GH_2 infrastructure. Apply international standards and standardization principles in welding, including quality assurance frameworks.	Welding personnel and TVET trainers with International Welding Specialists' certificate at NQF Level 6 and ISCED Level 5.

Course and duration	Skills	Target Group and Required Competencies
4 – Welding Trainer	Achieve the knowledge required to become responsible for larger welding schools	Welding Technologists who want to lead a Welding School or large workshop requiring individual training
5 – MORW (ISCED Level 4 and NQF Level 5) 150 h = 4 weeks	Acquire a comprehensive understanding of welding automation technologies, particularly as applied in the context of green hydrogen technologies (GH_2T). Gain insight into the principles, advantages, and implementation of mechanized welding, including orbital welding systems and the parameters affecting weld quality. Examine various mechanized and robotic welding processes, their industrial advantages and limitations, and suitable joint preparation techniques. Apply quality assurance and control principles across all stages of welding, including adherence to standards, docu-mented procedures, and traceability requirements. Analyze the relationship between productivity and economic efficiency in welding, especially within high-demand sectors such as GH_2 infrastructure.	Welding personnel with national vocational certificate in welding at NQF Level 4 and ISCED Level 3. Better IWP (ISCED Level 4 and NQF Level 5) TVET trainers who wish to gain knowledge of mechanized and automated welding.

Potential capacity-building initiatives related to the training measures

Given the identified skills and knowledge gaps, it is clear that Namibia's welding expertise must be strengthened to develop a workforce capable of supporting the green hydrogen and renewable energy sectors.

Currently, welding education is limited to NQF Level 4 (ISCED Level 3), with little advanced welding knowledge available even at university level. To close these gaps with respect to the short qualifications listed above, the following steps are recommended:

- **Identify suitable welding education and training personnel for upskilling:** This can be achieved by (re-)contacting the relevant TVET institutions to nominate appropriate candidates.

- **Screen the nominated personnel for existing knowledge and skills:** Based on the results, assign individuals to the relevant short qualifications. This procedure would take about one or two days if carried out centrally at a TVET centre.

- Provide the recommended short qualifications abroad, as outlined in the table below through the respective partnerships. Given the current lack of local training providers, it is recommended to deliver this training for the first cohort of TVET instructors via the German Welding Society's School of Welding (SLV) in Duisburg, which already offers these courses to welding personnel worldwide.

- **Summarise the upskilling of TVET trainers through a targeted "Train-the-Trainer" programme in welding;** Sponsorships or partnerships should be sought to enable trainers to reach at least NQF Levels 5 and 6 (ISCED Levels 4 and 5), equipping them to effectively deliver training at NQF Levels 4 and 5 (ISCED Levels 3 and 4). At these levels, scholars will acquire the advanced knowledge and skills needed for the green hydrogen sector, ensuring a steady pipeline of competent workers.

  Such training could, for example, be provided at the German Welding Society's (DVS) welding school, if partnerships are established. This effort should later be followed by a reformed welding curriculum, with unit standards reviewed and upgraded across all levels (ISCED Levels 2–5), to ensure critical competencies for GH_2 technologies are developed.

- **Develop a national education and training system for welding in GH_2T and beyond, supporting the country's industrialisation:** This can begin with educating welding coordination personnel at higher education levels (NQF Levels 8–9, ISCED Level 7) to the level of International Welding Engineer (IWE).

  WeldNAM and UNAM are scheduled to launch such a programme in the second half of 2025, and it is highly recommended to link the initiatives outlined in Steps 1–4 to this programme.

It should also be noted that, in addition to training welding personnel at TVET levels (ISCED 3–6), it is strongly recommended to educate International Welding Engineers (IWE) at Level 7 and above of the NQF.

While this lies beyond the scope of the present study, it is essential to meet the international quality requirements outlined in ISO 3834-2, which mandates certified welding coordinators.

Education of IWEs will also contribute to the "educators-of-educators" principle and has already been integrated into the Master of Manufacturing Engineering programme at UNAM, following international models such as University West in Sweden and TU Graz in Austria. Although this extends beyond the study's mandate, it should be pursued in parallel.

Recommendations for potential partnerships for development and collaboration

To support welding skills development for the GH_2T and renewable energy (RE) sectors, the following strategic partnerships should be pursued.

It is recommended to advance the above-mentioned reforms through collaboration with Namibia's welding association (WeldNAM), which is organised as the Member Society for Namibia in the International Institute of Welding (IIW).

It is important to emphasise that WeldNAM, as the national organisation, and IIW are both non-profit and independent, and they do not deliver courses themselves. However, through its IIW membership, WeldNAM has direct access to the international welding knowledge base and platforms, maintains international contacts with welding education and training centres, and has an overview of the wide range of welding and allied training programmes offered worldwide.

WeldNAM is well-positioned to be a strategic partner given its strong international networks and expertise in welding education, training, qualification, and certification systems. WeldNAM can further contribute to the development of world-class unit standards and improve the system with high quality training of trainers, positioning Namibia as a regional centre of excellence in welding education, with the potential to attract international students.

In turn, this would help the NTA to continue improving its already strong curricula and ensure they are revised and benchmarked against internationally recognised programmes. Such cooperation would result in robust and internationally accepted curricula, supporting a reliable pipeline of highly skilled, hydrogen-ready welding professionals.

Namibian actors can also strengthen their emerging hydrogen industry by fostering regional partnerships with established testing and certification institutions in South Africa (see international benchmarking section above). Facilities such as the Southern African Institute of Welding (SAIW), SecMet, One Eighty Materials Engineering, and Advanced Materials Science (AMS) represent potential collaborators offering SANAS- and ISO-accredited services in welding, materials testing, and hydrogen embrittlement analysis.

Collaboration with these regional actors would enable Namibian institutions and companies to access internationally recognised testing and certification pathways while the country continues to develop its own capabilities for training and testing centres.

In addition, TVET institutions in Namibia must align under a common framework, together with industry partners entering the GH_2T sector and contributing to broader industrialisation. This alignment should be coordinated under the NTA.

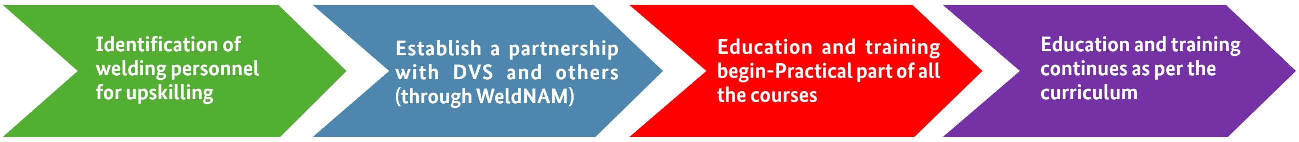
The following table provides a recommended number of qualifications for identified individuals as immediate action. One specific international partner mentioned for delivering a larger number of these qualifications is SLV-GSI in Duisburg, Germany.

However, it should be noted that other institutions, such as the Istituto de la Saldatura in Genoa, Italy, or institutions mentioned under the international benchmarking in South Africa can also provide similar quality of training. A particular benefit of SLV-GSI Duisburg is its integration of online knowledge transfer into courses, reducing the number of required presence days and making completion feasible more timely.

Table 7: Proposed Welding Training, Participants and Partnerships

Course and duration	Number First batch for the respective training centres in Namibia	Possible Partnerships (example Germany)
1 – IWP (ISCED Level 4 and NQF Level 5) 150 h = 4 weeks	Min. 2 per Training center, 50 in total	WeldNAM as a local contact partner SLV-GSI Duisburg, Germany
2 – IWS (ISCED Level 5 and NQF Level 6) 249 h = 6 weeks	1 per Training center, 25 in total	WeldNAM as a local contact partner SLV-GSI Duisburg, Germany
3 – IWT (ISCED Level 6 and NQF Level 7) 369 h = 10 weeks	1 per Training center, 25 in total	WeldNAM as a local contact partner SLV-GSI Duisburg, Germany
4 – Welding Trainer	1 per Training center, 20 in total	WeldNAM as a local contact partner SLV-GSI Duisburg, Germany
5 – MORW (ISCED Level 4 and NQF Level 5) 150 h = 4 weeks	Min. 2 per Training center, 50 in total	WeldNAM as a local contact partner SLV-GSI Duisburg, Germany

A rough roadmap for achieving this training-of-trainers initiative by March 2026 is outlined in Figure 4. The first qualifications could be completed by the end of 2025, depending on the capabilities of the selected participants.



Re-contact TVET centres for nomination of welding trainers to be upskilled. Target 50 IWP, 25 IWS, 25 IWT, 50 MORW, 20 TOT.

Liase with welding industry to nominate welders to be upskilled. Target 50 IWP, 25 IWS, 25 IWT, 50 MORW.

Liase with DSV and others for an arrangement for training of the selected batch of welding personnel and TVET trainers.

Establish sponsorships necessary for the education and training of the selected batch of welding personnel and TVET trainers

The selected batch travels to Germany for practical part of all the courses except for TOT.

Education and training continues as per calendar of the education center. At SLV-GSI Duisburg most of these are online, exams will be held in-person.

Figure 4: Roadmap for Training-of-Trainers

4 CONCLUSION

This study has shown that welding is a decisive enabler for Namibia's ambitions in green hydro-gen and renewable energy. Across industries, the demand for internationally certified welders, supervisors, and coordinators far exceeds current supply.

While Namibia's TVET system pro-duces competent Level 3–4 artisans with strong manual skills, these qualifications do not yet cover the hydrogen-critical techniques, quality systems, or mechanised processes required by Engineering, Procurement and Construction (EPC) contractors. International benchmarking con-firms that no separate "hydrogen welder license" exists; instead, hydrogen readiness is achieved by embedding hydrogen-specific skills into existing certification routes and quality as-surance frameworks.

To close the identified gaps, two complementary pathways are proposed:

- **Short to medium term (Lane A):** Immediate Vocational On-Ramp (Levels 3–4). Short, hydrogen-specific modules on orbital welding, purge control, hardness and embrittlement awareness, leak-testing, and dossier preparation can provide a rapid, controlled entry for existing artisans into hydrogen-critical work.

  These modules are limited in scope, assessed against measurable KPIs, and always supervised by higher-qualified coordinators. They address urgent industry needs and make it possible to deliver leak-tight work on GH_2 projects within the next 12–18 months.

- **Medim to long term (Lane B):** Backbone (12–24 months; supervisors and trainers). In parallel, Namibia must build a sustainable cadre of International Welding Practitioners, Specialists, and Technologists (IWP → IWS → IWT), complemented by Train-the-Trainer programmes and mechanised/orbital welding streams.

  This pathway provides the backbone for ISO 3834-2 quality systems and ISO 14731 welding coordination, ensuring that Namibia develops its own supervisors, coordinators, and trainers capable of sustaining hydrogen-ready welding in the long term.

Taken together, the two lanes provide both an immediate response and a long-term perspective. Lane A enables Namibia to address urgent EPC demand by equipping artisans with hydrogen-specific skills at Levels 3–4, while Lane B builds the supervisory and training backbone required for sustained competence at higher levels. Coordinated implementation with WeldNAM, the NTA, and international partners such as IIW and SLV-GSI will strengthen the national TVET system and ensure alignment with international quality requirements.

This dual approach supports Namibia's capacity to participate effectively in the green hydrogen and renewable energy sectors and contributes to the country's broader industrial development objectives.

5

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