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Skills development for renewable energy and energy efficient jobs

Discussion paper on solar energy demands

Education 2030

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BACKGROUND

The transition to greener economies requires action on the different dimensions of sustainability that can mitigate further deterioration of the environment and restore its capacity to support human life. The rational use of energy – like efficient water management, soil conservation, air-pollution control, preservation of natural resources, and biodiversity – can play a crucial role in a country's contribution to the global sustainable future. Energy use and efficiency is even more relevant given the fact that it is directly linked to some of the key global challenges that the world faces, such as poverty alleviation, climate change, and global environmental and food security.

The most significant global policy development in recent years affecting the transition towards renewable energy and energy efficiency has been the ratification of the Paris Agreement by 189 of the 197 parties (current in May 2020) to the United Nations Framework Convention on Climate Change (UNFCCC)[1]. This has consolidated the global commitment to curtail climate change and adapt to its impacts. As of May 2020, over 180 countries have put forward Nationally Determined Contributions stating that they will strengthen their efforts to limit temperature rise due to climate change to below 2 degrees Celsius above pre-industrial levels.

To do this, national and international efforts will need to focus on establishing the necessary financial flows as well as technological and capacity building frameworks.

Emissions from the burning of fossil fuels are major contributors to the unpredictable effects of climate change. By moving to more efficient production and energy use, switching to cleaner fuels, transportation that is more efficient and cleaner electricity supply, the further effects of global warming can be abated.

However, moving from today's fossil fuel-based economies towards a new paradigm of clean energy in low-carbon economies and societies presents a number of challenges that have to be tackled. These range from broader policy development and implementation strategies, to more specific and practical issues, such as the availability of market-ready technologies and countries' abilities and/or capacities to actually promote their uptake.

One of the key challenges is to develop a workforce that possesses the knowledge, skills and competences needed to render operational all the energy efficiency and renewable technology options available. There must be enough appropriately trained personnel to cope with the growing demand for 'green-collar' professionals, and particularly for specialists with advanced skills like engineers and technicians. Rapid growth in solar energy applications has led to skill shortages and deficiencies in solar installation and maintenance in many countries. Shortages in these occupations are common in developed countries, and they can easily occur in developing countries if there is to be a sudden increase in demand (ILO and EU, 2011).

Despite these challenges, the global transition to low-carbon and sustainable economies can create large numbers of green jobs across these sectors and become an engine for sustainable development. The creation of green jobs is occurring in both developed and developing countries (UNEP, ILO et al., 2008). Apart from some sectorial and/or regional differences, the trend in recent years seems clear: renewable energy sources increasingly figure in the process of greening the economy, while restructuring of employment in this area is most likely to continue to grow in the near future.

Green jobs in the energy sector

When it comes to establishing the necessary financial flows as well as technological and capacity building frameworks, one of the key efforts will be to increase investment in renewable energy and energy efficiency measures. It is estimated that USD 1 million invested in renewable energy and energy efficiency creates 7.49 and 7.72 full-time equivalent jobs respectively (compared to only 2.65 for fossil fuels), and this shift towards a more sustainable energy supply will also drive the creation of new employment opportunities.[2]

Indeed, the future for green jobs in the energy sector is promising: it is a growing market for both advanced skills and lower skilled professionals.

» Worldwide, the sector employed 11 million people at the end of 2018 (IRENA, 2019). Many governments pursuing reduced emissions to meet their climate goals and the socio-economic benefits have put the development of renewable energy at the top of the agenda

» The ILO has projected the creation of up to 24 million new jobs by 2030 in the renewable energy sector (ILO, 2018)

» With the phasing out of coal and ongoing transition towards sustainable energy sources in the European Union, the deployment of clean energy technologies in coal producing regions is projected to create up to 460,000 jobs by 2050 (European Union, 2020)

1 http://unfccc.int/paris_agreement/items/9485.php

2 http://timeforchange.org/

As markets develop and mature, the qualification level of workers in the renewable energy sector tends to exceed that of the average qualification level for the rest of the economy. This will also affect professionals with lower skill levels, who will be able to move towards an increasing specialization of competences and, consequently, better job conditions and opportunities (ILO, 2011).

Technical and vocational education and training (TVET) plays a crucial role in the transition to cleaner energy, as the skills needed in the provision of sustainable energy will be acquired through it. The speed of this transition will therefore be determined to some extent by the responsiveness of training organizations and practitioners in strengthening the available offer, and by the interest and willingness of professionals to engage in initial and/or continuing TVET.

ABOUT THIS PAPER

This paper discusses the developments in the renewable energy sector and their impact on jobs and training. It compiles and makes an analysis of how the available technologies in the market will further develop corresponding with global trends in the energy efficiency and renewable energy sectors, and the corresponding capacities that are needed to make the transition from fossil fuel-based consumption into another supported by renewable energy. The role of TVET in developing skills and qualified professionals for jobs in the renewable energy sector is a key vector of analysis.

Section 1 discusses the market demands for skills in the renewable energy sector, the changes that are shaping these demands and corresponding skills, as well as the competences and qualifications that are needed to meet the demands and fully seize the job opportunities. Models of how competency profiles are identified and used as bases for developing targeted training are also presented, as part of discussions to introduce the key intersections and degree of collaboration needed in the education and training sector and the labour market where technology uptake and demand for skills develop.

Section 2 presents an implementation-oriented scenario of the intersections between education and training on the one hand, and the labour market on the other. It offers specific guidance for institutions to become successful in developing skills interventions and understand the level of information, market-based analysis that goes into planning for robust and market-oriented training programmes in the renewable energy sector. Examples and steps described in this section are based on actual programmes and projects that were implemented in different countries by a renewable energy academy. They are not prescribed as absolute and easy to adapt to all types of TVET contexts and labour market status. Instead, they serve as reference points that can assist discussions related to opportunities, according to countries' TVET contexts and experiences in developing training for the solar energy sector. This section covers the important structure of market and gap analyses, considerations for planning and designing training and occupation standards, as well as quality assurance. These can inform the way ministries and national bodies design strategies.

It is important to note that this paper was developed compiling relevant knowledge of the global uptake of measures in energy efficient and renewable energy technology. The paper focuses on the most dominant renewable energy in the market and discusses two main active solar technologies: solar photovoltaics (solar PV) and solar thermal. These represent the largest and more evidently available opportunities for TVET. Other renewables are therefore not specifically covered.

This paper informs readers about the multifaceted issues, opportunities and essential considerations for embarking into skill development programmes in renewable energy sector. It discusses the competence areas that need to be developed in institutions to be able to effectively offer programmes that are market-oriented and demand-driven, as well as the competency required of professionals, who will engage in solar energy jobs. The aim is to inform future strategic TVET directions and efforts to mobilize technical and non-technical resources that can enable quality training for future professionals in this field area.

SECTION 1

Sustainable energy and TVET

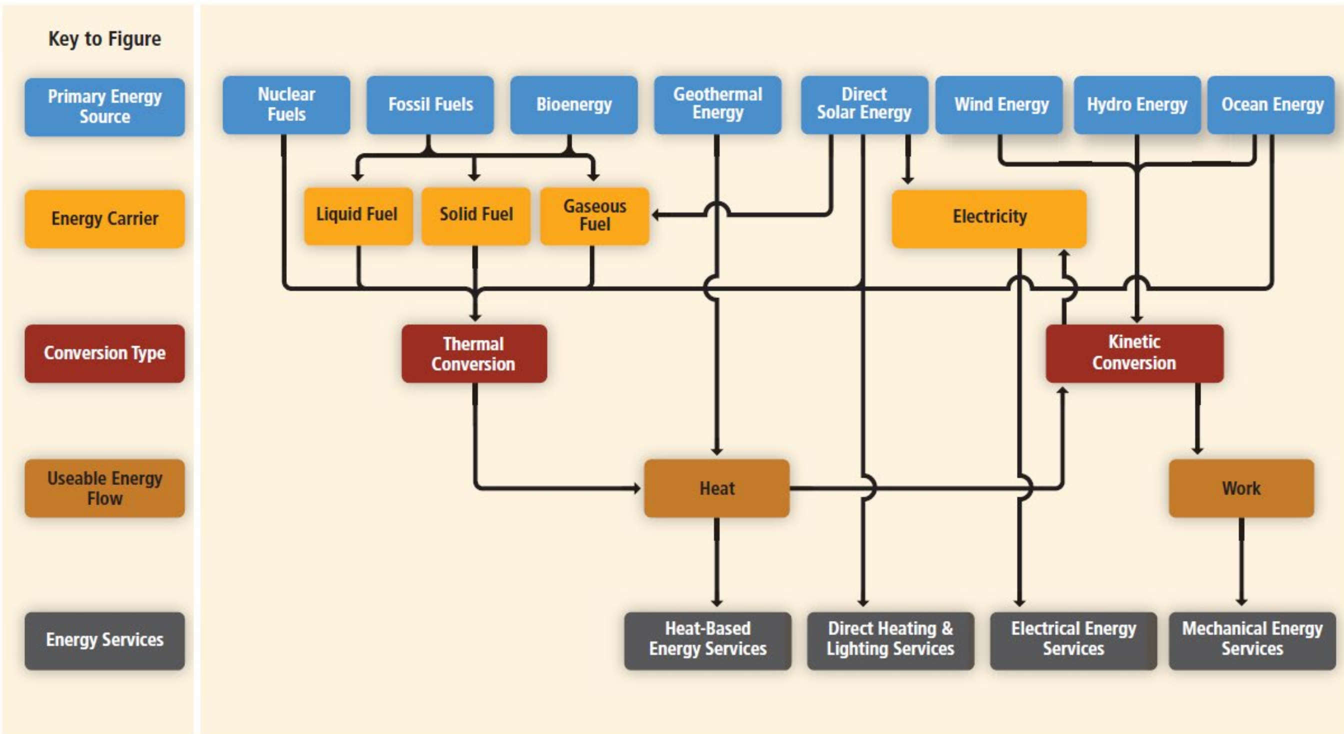
Energy is a fundamental driver of modern economies. As illustrated in Figure 1, societies resort to primary energy such as nuclear, fossil and renewable sources to generate a usable energy flow in the form of heat, power and work that supplies the energy services we depend on for our daily activities.

Society is shifting towards renewable energy given the serious climate change issues that surround the use of nuclear and fossil fuels. Complementary to this is the concern to make the best possible use of the consumed resources by means of energy-efficient technologies and behaviours. Energy efficiency and renewable energy sources offer opportunities that are bound to be part of any green growth policy.

Energy efficiency has and continues to play a strong and valuable role in the sustainable development of the global economy (REN21, 2014). Renewable energy provided an estimated 20.4% of global final energy consumption in 2016.

Energy efficiency and renewable energy are the two main vectors that determine the most evident opportunities to address sustainability in the energy sector. These two areas are intrinsically linked and need to be addressed together: reducing consumption by being more efficient paves the way for more effective uses of renewable energy sources. In other words, the beneficial impact of renewable energy generation is increased by means of a lower consumption baseline.

FIGURE 1: The paths of energy from source to service



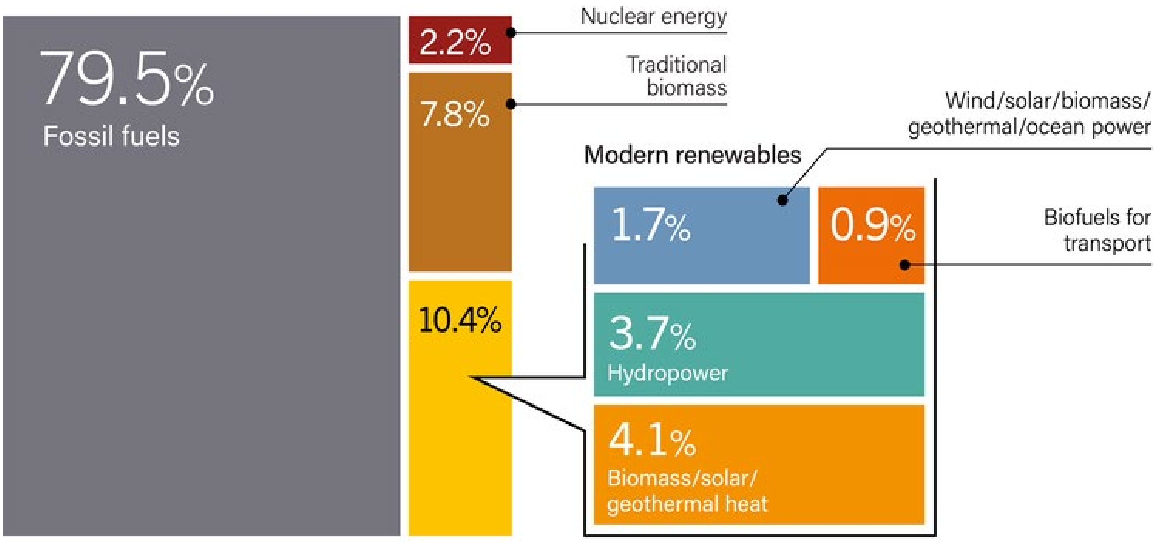
Source: IPCC (2011)

TABLE 1: Energy efficient and renewable energy

Energy efficient	Renewable energy
» A way of managing and restraining the growth in energy consumption » Energy efficiency is the delivery of more services for the same energy input, or the same services for less energy input » For example, when a light-emitting diode (LED) bulb uses one-third less energy than a compact fluorescent light to produce the same amount of light, the LED is considered more energy efficient	» Energy that is derived from natural processes (for example, sunlight and wind) and replenished at a higher rate than it is consumed » Solar, wind, geothermal, hydropower, bioenergy and ocean power are sources of renewable energy » The role of renewables continues to increase in the electricity, heating and cooling, and transport sectors

Source: http://www.iea.org/

FIGURE 2: The estimated share of renewable energy in the global final energy consumption, 2018



Source: REN21 (2020)

Shifts in the labour market

Green energy policies can affect employment in different ways. A policy shift towards a low-carbon green economy may create new green jobs in renewable energy sectors and energy-efficient technologies. However, this may affect employment in other sectors (IZA/ZEW, 2014).

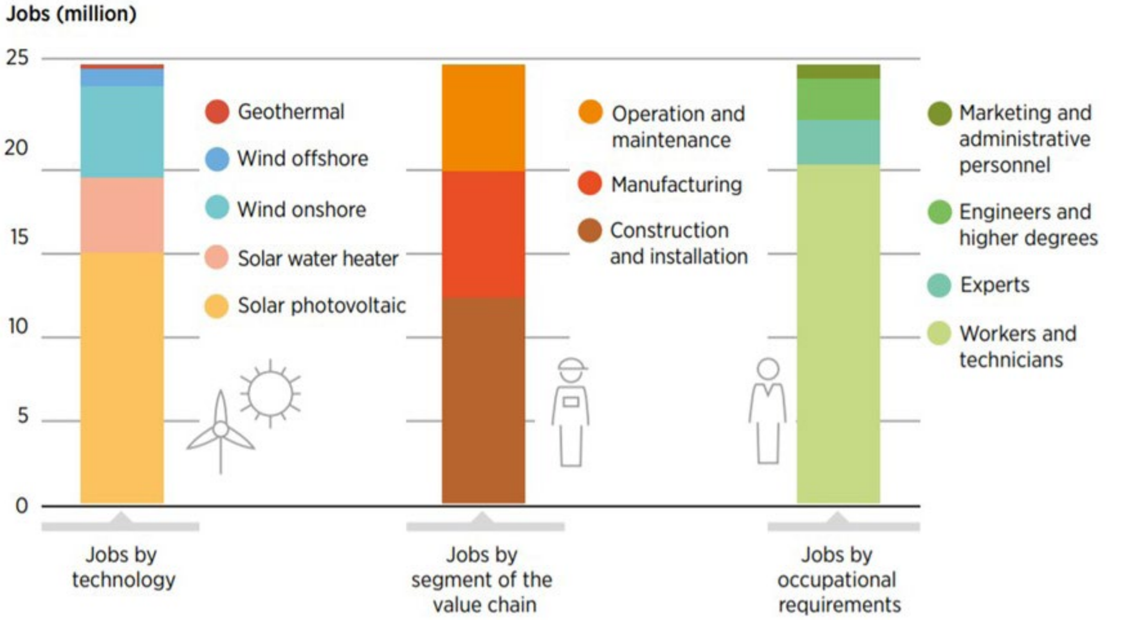
This tendency is clearer in countries that are more committed to replacing conventional power plants with renewable energy sources. As the transition to renewable energy progresses, it seems inevitable that there will be substantial reductions in employment in fossil energy.

An analysis by IRENA in 2020 (Figure 3) further confirms a steady increase in job opportunities in the field of solar energy technology, which dominates the renewable energy jobs the market. These jobs demand more technician-level skilled workforce to perform jobs tasks in the solar occupation value chain (manufacturing, construction and installation, operation and maintenance).

The retraining of workers in the fossil fuel industries and the training of young people entering the labour market are key elements for a smooth transition to a low-carbon economy. If sufficient quality and efficient training programmes are not provided, there is a serious threat of the renewable energy sector experiencing shortages not only in technical occupations, such as solar installers, but also in more general occupations, such as sales specialists, inspectors and auditors (ILO, 2011).

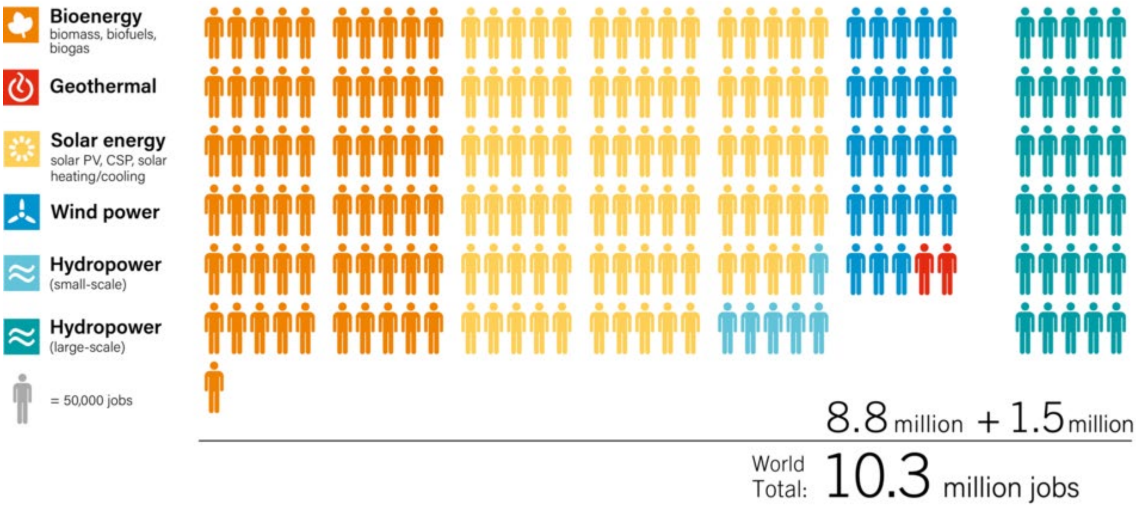
Looking at the status by technology, solar PV stands out by far as the largest renewable energy employer, accounting for 4.2 million jobs (Figure 4). The global production of solar panels keeps increasing and is concentrated in a number of countries, such as China, United States of America, India, Japan, Turkey, Germany, Australia, Republic of Korea, United Kingdom, and Brazil (REN21, 2018).

FIGURE 3: Jobs by technology, segment and occupational requirements, 2020



Source: IRENA (2020)

FIGURE 4: Jobs in Renewable Energy, 2018



Source: IRENA data as cited in Ren21(2018)

Implications of labour market developments

As renewable energy markets evolve and mature, the related jobs also become more specialized and better-skilled, preferably under formal certifications or qualification schemes. TVET is essential for this transition and can have a decisive contribution to particular aspects, as illustrated in Table 2.

TVET organizations and practitioners gradually understand the change that is taking place and are positioning themselves within this transition. Training opportunities in the formal, non-formal and informal sectors are rapidly being introduced, benefiting from this growing demand. Skilled professionals are increasingly in demand for different activities that aim to enhance energy efficiency and the transition to renewable energies.

In the case of energy efficiency, four sectors are usually considered: buildings, transport, commerce, and industry. In renewable energies, the main options are: solar energy, biomass, wind energy, hydropower and geothermal (tidal and wave energy is not yet commercially viable and does not provide widespread options). Within these, there are more specific areas that differ according to the application and/or technology used, as illustrated in Figure 5.

Considering the conventional industrial processes, the renewable energy value chain includes several key activities, as shown in Figure 6.

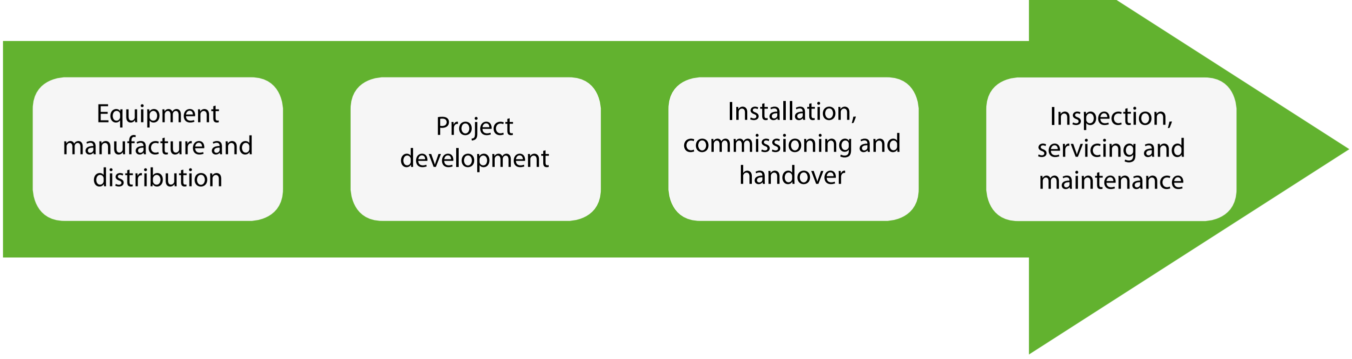
TABLE 2: The contribution of TVET to the labour market and social cohesion

Labour market: Meeting skills demand and jobs creation	Social cohesion: Just transition, gender equality and lifelong learning
» Coping with a growing market demand for trained and skilled professionals to manufacture, install, service and market renewable energy technologies. » Enabling better quality in the manufacturing of renewable energy equipment or products, as well as in the installation, marketing and distribution procedures. » Ensuring a lasting performance of installed renewable energy systems, thus increasing reliance and credibility for renewable energy technologies.	» Improving the workforce's knowledge in science, technology, engineering and mathematics (STEM), making them better prepared for adaptation to changes in technological requirements often associated with renewable energy businesses, and to acquire skills sets that increase workforce mobility across related sectors. » Creation of entrepreneurial activities, involving a market adapted to new or innovative renewable energy services and products. » Promotion of more attractive and better-quality jobs by inducing better remuneration conditions, increasing opportunities for moving up the occupational ladder, improving job stability and facilitating gender equality. » Allowing for a just and smooth transition to greener occupations in renewable energy industries for professionals working in (not-so-green) existing occupations.

FIGURE 5: Main type of plants/applications in renewable energy and energy efficiency

Solar energy	Biomass	Wind	Hydro	Geothermal	Energy efficiency
» Solar thermal » Photovoltaics	» Heat production » Power generation	» Small plants » Large windfarms	» Small plants » Large dams	» Thermal applications » Power generation	» Buildings » Transport » Industry » Commerce

FIGURE 6: Main activities in (most of) the renewable energy value chain



Other less specific cross-cutting enabling activities may also be required for some aspects, depending on the characteristics of the project being undertaken. Biomass energy projects are also a particular case, as they involve additional activities related to the management of the energy resource – the harvesting, processing and supplying of wood fuels, for example.

Challenges and opportunities in supporting the transition

According to the International Labour Organization (ILO), there are some challenges that may hinder TVET from becoming an effective contributor to the development of a qualified workforce in green energy technologies, largely because of the employment dynamics in the renewable energy sector (ILO, 2018). These are summarized in Box 1.

Despite these challenges, the future for TVET in the renewable energy and energy efficiency sectors is promising. Those skills that are often in demand are those related to the manufacturing/assembling, installation/commissioning and maintenance/inspection phases of the value chain (ILO, 2011; IRENA, 2015). These areas are relevant for TVET, as they generally require better-trained professionals with higher levels of specialization.

Besides these practical occupations, managerial positions or other high-level jobs can also be a potential area of focus for TVET, particularly given the possibility of 'topping-up' skills, preferably in a well-harmonized qualifications framework.

Many of the skills needed in the transition to green-energy technologies can be covered by the current job market. The topping-up of existing job-related skills, together with the strengthening of generic competences, can be effective

BOX 1: The dynamics that may affect the cost of training and acquiring skills

Global market conditions: Employment in the manufacturing and distribution of renewable energy technologies, particularly when a substantial share of sales is going to export markets, is essentially a function of global market conditions and the share of the market that a company's competitiveness allows it to occupy (ILO, 2011). This could result in some unpredictability, or at least to lower job stability, that TVET could help to overcome by providing the trained workforce with better tools and skills that make adaptation to change easier.

Flow of renewable energy projects in demand: Employment in project development, construction, and installation is project-based. Continuity of employment depends on a steady flow of projects, except for highly skilled people who are internationally mobile or able to move to other sectors—wherever work is available. An unstable flow of projects may be aggravated by variations in market incentives, such as subsidies and new/changing regulations (ILO, 2011). In more mature markets, a programmed and/or stepwise application of incentives (for example, the mandatory installation of solar systems in new buildings, followed by rehabilitation of existing buildings), combined with a progressive reduction of investment costs due to market competition, may contribute to a growing adoption of one or more renewable energy technologies.

Occupational stability: Employment trends in operations and maintenance are more stable. A renewable energy installation may have a twenty to thirty year lifetime, and even more if the equipment parts are regularly serviced. It will have to be operated and maintained over its working lifetime and, while there may be some improvement in productivity over the period, there is a reasonable prospect that most of the jobs that exist after commissioning will still exist a couple of decades later (ILO, 2011).

Technology diffusion: One should notice that, when the deployment of a renewable energy technology is first introduced in a region, it takes time to build up a supply of workforce with the skills, experience as well as specific knowledge needed to apply them effectively. Therefore, it is particularly important to promote skills forecasting as a way to supply before there is a need for specific skills. The supply of anticipated requirements is best done through close cooperation between the industry, training organizations and the government. In some situations or markets, renewable energy technologies and the associated workforce also face challenges related to credibility. Prior negative experiences with unreliable technologies and poor quality installations can sometimes lead to a bad reputation, and hinder further uptake by consumers and users. These situations are hard to reverse and affect the demand for professionals in these fields.

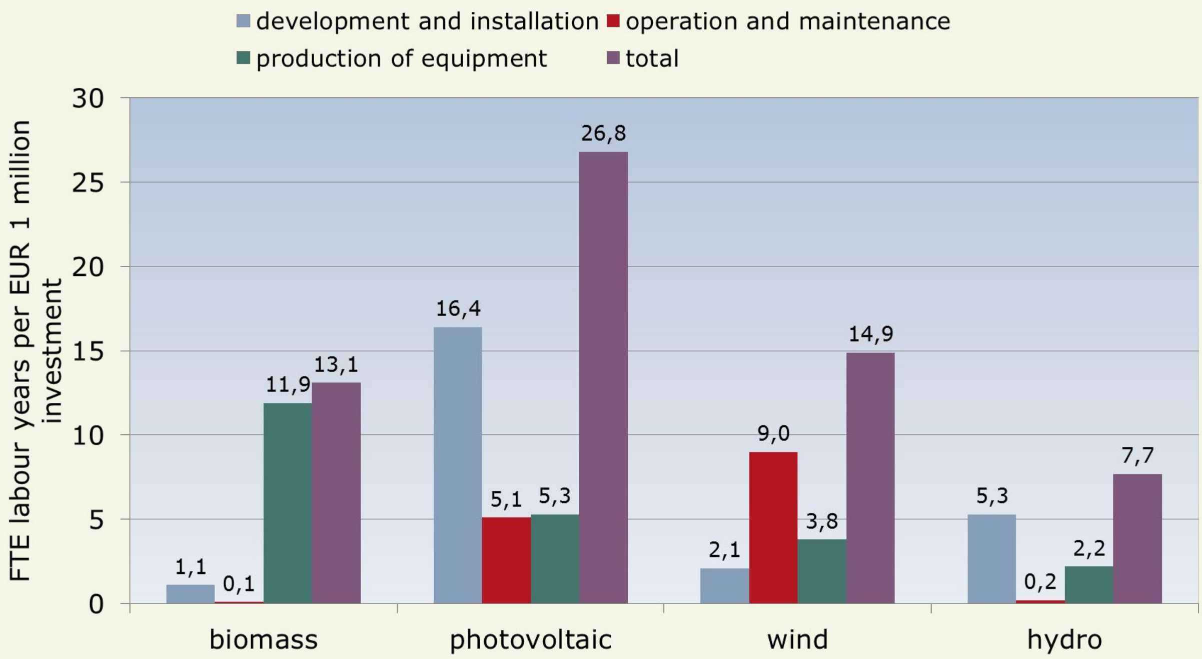
Unacceptable working conditions: As with other TVET-related occupations, jobs in the renewable energy sector also face challenges concerning decent working conditions, gender equality, job stability, and risks to occupational safety and health. Some tend to be sector specific (for example, the poorly remunerated day labourers on biofuel plantations working under hazardous conditions), but most concern all renewable energy areas.

BOX 2: Current and future skills gaps in the solar industry

In his 2016 report entitled *Renewable energy sources: Jobs created, skills required (and identified gaps), education and training*, Charalampos Malamatenios looks at the workforce required for renewable energy technologies in terms of full-time equivalent labour years, per EUR 1 million of investment. While the assumptions made are largely applicable for the Greek market and cannot be transferrable to other markets, the principle offers a fast method for making an initial assessment of the workforce requirements based on the magnitude of the planned investments.

Figure 7 shows the full-time equivalent labour years per EUR 1 million of initial investment in four renewable energy technologies. For each technology, it splits the full-time equivalent labour years into three areas of work: development and installation, production of equipment, and operation and maintenance. The figure shows that more jobs are created per EUR 1 million of investment for solar photovoltaic than other technologies, and that most jobs are in installation, as well as operation and maintenance.

FIGURE 7: Full-time equivalent labour years per EUR 1 million of initial investment in renewable energy technologies



Source: Adapted from Malamatenios (2016)

in developing a low-carbon economy (in addition to more specialized green skills) (GIZ and MBZ, 2013). These additional skills for specific sectors or technologies can be acquired relatively quickly through seminars, training, or on-the-job courses (OECD and IEA, 2011).

Although similar in context, TVET skills need to be addressed differently for each area of work in the energy efficiency and renewable energy sectors. Given the relative maturity and the size of the market, as well as the level of opportunity it presents, solar energy (comprising both solar thermal and PV power generation) should be considered as a first option.

A large and well-trained workforce is crucial to attain both a high level of market penetration for solar technologies, and to ensure good quality and durability of the installed capacity, thus allowing a more extensive exploitation of solar as a resource.

TVET for the solar energy sector

Applications and trends

Solar energy as a resource is widely available and abundant in large parts of the world. Solar energy technologies provide an increasingly attractive option as consumers become more aware of the environmental and economic benefits of using renewable energy sources for power and heat supply. In some part of the globe – like Europe and North America –, the solar energy market has reached a mature stage. In such contexts, enhancing the quality and reliability of installations by developing more sophisticated technical aspects is high on the market agenda.

However, for developing countries to take advantage of solar energy as a resource and to adopt active solar technologies to generate thermal and electrical energies, comprehensive training programmes should be prepared and implemented. Most developed countries have already adopted this strategy and created training programmes to attain these goals.

Energy from the sun can be used to heat homes through passive solar design, solar hot-water systems, solar space heating and electrical generation. Similarly, the sun's energy can also be used in commercial business and industrial activities, usually in larger and more complex applications. There are already mature, widely available solutions and technologies on the market to capture and use the sun's energy. The available options are:

» **Passive solar:** Techniques for optimal building orientation in relation to the sun, adequate use of windows and light, selection of materials with better thermal performance, selection of materials with favourable thermal mass and designing spaces that circulate air naturally.

» **Solar photovoltaic (PV) power plants:** For generating electricity, ranging from individual small stand-alone applications to larger grid-connected systems in buildings or on dedicated farms.

» **Solar thermal installations:** For water and space heating purposes, ranging from single family systems to larger hot-water production plants for buildings or for processing heat in industrial applications.

» **Concentrated solar power:** Concentrating light from the sun to create heat, which is used to run heat engines that turn generators to make electricity.

» **Solar cooling:** Use solar water-heating collectors and a thermal-chemical absorption process (normally in an absorption chiller system) to produce air-conditioning without using electricity.

Table 3 shows typical solar PV applications in developing countries. These and similar projects have been implemented through numerous rural electrification projects carried out in developing countries in South-East Asia, Sub-Saharan Africa and South America over the last thirty years. During the development of these projects, it was common to train a small group of local users to take care of and ensure the maintenance of the installed equipment. Although these practices might help to prolong the lifetime of installed equipment, it is recommended to adopt a more comprehensive approach, particularly if a larger usage of solar energy is anticipated. Such a comprehensive approach is important since it has become evident that many of these applications are not technically or financially sustainable over the long term.

The training of installers is crucial to ensure safe and high-quality solar PV systems, regardless of the size of the system and its application/market segment. In the case of solar PV in buildings (either a rooftop PV system where the building envelope is penetrated, or a fully integrated PV system where the PV components are the primary weatherproof layer and provide structural support), adequate and sufficient training is especially important.

TABLE 3: Typical solar PV applications in developing countries

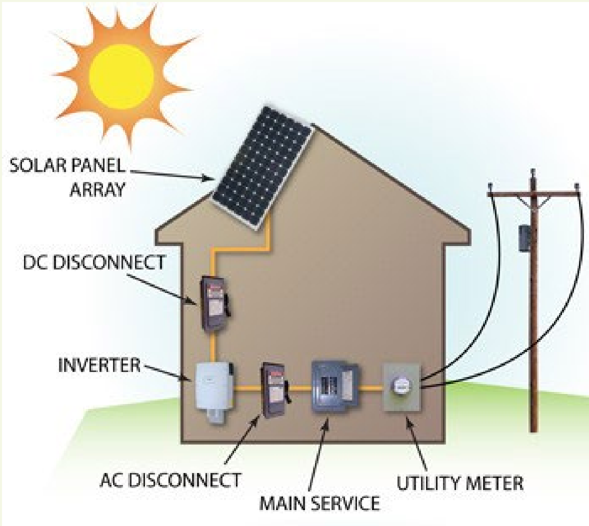
Solar PV applications	
» Centralized village PV power plant » Water supply system » Battery charging facility » Telecommunication facility » PV airport marker system » Pumping systems for irrigation and drinking water supply	» PV vaccine refrigerators » PV poultry incubator » Water desalination systems » PV video system for educational purposes » PV street lighting » PV rural electrification units

BOX 3: Solar PV systems

Solar PV systems can be used for different applications with various capacities, ranging from less than one watt to several gigawatts. Solar PV systems are usually categorized into grid-connected PV systems and off-grid or isolated PV systems (GIZ and BMZ, 2013).

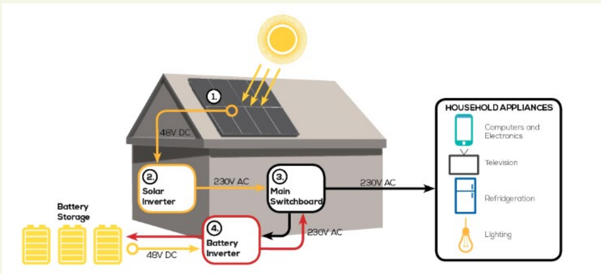
Grid-connected PV systems: The main aim of grid-connected PV system installations is to generate as much energy as possible, according to the physical space available and the cost of investment, and that this energy is fed into the grid. Depending on the legal framework, the entire production is exported to the grid – in which case electricity can be sold at the same price as the electricity bought from the grid (net metering) or at a different price (feed in tariff) –, or in a photovoltaic system building, energy production can supply the building's needs and any excess production is fed into the grid. Grid-connected systems require inverters to transform direct current power into alternating current. The balance of the system includes inverters, transformers, wiring and monitoring equipment, as well as structural components for installing modules, whether on the rooftops or facades of buildings, above parking lots or on the ground.

FIGURE 8: Layout of a typical grid-connected PV installation



Off-grid or isolated PV systems: The purpose of off-grid or isolated PV installations is usually to supply electric power to recipients where there is no electrical grid. Since a PV system will only produce electricity when exposed to sunlight, the building grid must be supplied by power stored in batteries at night. Off-grid connected systems require solar PV panels to be mounted on the roof of the house. These panels capture energy from the sun and convert this energy into direct current electricity. A solar inverter converts this direct current electricity into alternating current. The main switchboards take electricity from the solar inverter or battery inverter and send it to power homes. The battery inverter is two way: it can either take surplus electricity from the main switchboard and convert it into direct current electricity to be stored in batteries, or it can on demand convert stored direct current electricity from the batteries into alternating current. The design phase in isolated PV systems is very important to determine the demand for energy and electricity, to estimate generated energy and to establish the size of the storage system.

FIGURE 9: The layout of a typical off-grid PV installation



Source: http://powersmartsolar.co.nz/off-grid

Mapping skill needs in new and existing jobs

The solar energy value chain

Alongside their constant development, solar energy technologies have already reached a mature stage that make them a viable option for hot-water production, space heating and decentralized power production. Other applications, like solar cooling and concentrated solar power, have not yet reached the mainstream or may need additional time before they can be widely used as viable options. Therefore, the industry value chain relies primarily on the marketing of solar thermal and PV systems. This is also where the vast majority of job opportunities can be found, especially for technical occupations where TVET can be particularly relevant.

The solar energy value chain (Figure 10) is similar to the value chain for renewable energy depicted in Figure 5.

Main activities and skills in key occupations

For a comprehensive understanding of the occupations involved in the solar energy value chain, professionals carry out tasks and activities corresponding to the different occupations in the value chain (ILO, 2018). Understanding the content of these tasks makes it easy to form the basis for defining the skill level and the competence profiles that are needed in each occupation.

Equipment manufacture and distribution. Involves businesses undertaking the development, manufacture and sale of solar energy equipment. Activities differ depending on the technology:

- In solar PV, the manufacturing of solar cells and systems requires research skills (in chemistry, physics material science, system design, process engineering, etc.) and a range of manufacturing skills related to diffusing and processing silicon. The manufacturing of PV modules, as well as other equipment such as inverters, requires skills in electronics as well as fabricating, assembling and testing products at levels including those of professional engineer, technician and manufacturing operator.
- In solar thermal, activities mainly concern metal and plastics fabrication and finishing. These systems usually require electro-mechanical components such as pumps and electronic control equipment, which are often sourced from other sectors. Therefore, the occupations required include mechanical engineers (in system design) and production engineers, technicians and manufacturing operators (in manufacturing).

Sales skills are transversal for the different solar energy technologies, as businesses at this point of the value chain often sell high-value innovative projects at both national and international levels.

FIGURE 10: Key occupations and activities in the solar energy value chain

Equipment manufacture and distribution	Project development	Installation, commissioning and handover	Inspection, servicing and maintenance
» Research and Development » Design and manufacture of components, solar panels and other equipment » Modelling and testing » Quality assurance and quality control » Marketing » Sales » Delivery	» Solar system design » Site assessment (shadows, radiation, etc.) » Environmental and social impact assessment » Land agreements » Economics and financing » Permitting » Power purchase agreement and grid connection contract » Selection of supplies	» Construction of solar system » Solar panels installation » Quality assurance and quality control » Grid connection	» Operation and maintenance

Source: ILO (2018)

Project development. Involves advising, planning, system designing, procuring, negotiating, contracting and financing. These tasks are necessary for the practical development of solar energy projects. Activities tend to differ according to the size of the project:

- In small-scale projects, activities may range from simple consultations between the installer and a householder in a single building, to a set of skills similar to those required for larger-scale projects, as in cases of multiple installations in one or more buildings and of wider and more complex retrofitting operations.
- In large-scale projects, it may involve seeking and obtaining financial resources, sourcing suitable sites (purchasing, arranging to mount on buildings, or obtaining a license to use public land), obtaining permission, negotiating contractual arrangements on power supply, contracting for the commissioning of preparatory engineering works and services (like technical design and legal advice), purchasing solar panels and ancillary components, and influencing various interests.

The occupations involved at this stage of the value chain reflect the diverse range of activities carried out. The implementation of these activities require high-level skills, with the support of staff with medium-level skills.

Installation, commissioning and handover. Involves planning, preparing, installing (including testing and commissioning), and handing over to the owner or manager of the solar energy project. In small-scale and simpler projects, it often includes activities previously described for the project development stage. The main activities are both technological and scale dependent:

- In small-scale solar thermal projects, the main skills involved are related to plumbing. Although in more developed markets, the work is already carried out by a qualified and/or accredited solar thermal installer, it also frequently happens that the installation is carried out by a plumber (sometimes with specific training in solar energy) or a heating contractor. They often have skills in roofing and have sufficient electrical skills (or work with an electrician) to install necessary controls.
- In small-scale solar PV projects, electricical-related skills are relevant. As in solar thermal, work may be carried out by a specialist PV installer or, when no qualification and certification programmes are in place, by an electrician, often with roofing skills. The technical requirements will change depending on whether the installation will be grid-connected or not. This will therefore also have an impact on the skills required by the installer.
- On large-scale projects, businesses typically contract with construction companies, electrical contracting businesses and professional services firms to manage and undertake construction and installation works. The skills that the professionals involved will need depends on the type and size of the work do be carried out. In the case of solar PV projects, the electricity grid operator is likely to be involved in installing or upgrading power lines.

Installation (or construction) of solar systems usually includes site preparation and/or installing power lines, thus requiring professionals with civil, mechanical and electrical engineering skills, as well as a variety of types of technician, electrician and construction workers.

Inspection, servicing and maintenance. Involves system diagnostic activities, undertaken as part of routine maintenance, and inspection and service calls when problems occur. Activities are scale dependent: large-scale installations require maintenance skills appropriate to the technology, despite the fact that most of the skills involved are similar to those needed for installation purposes.

Table 4 summarizes the main occupations in each of the four stages of the solar energy value chain according to the skill level required. From this, and assuming that low to medium skill levels are better suited to TVET professionals, one can understand that activities related to installation, commissioning and handover, inspection, as well as servicing and maintenance represent the most relevant opportunities.

Upskilling (greening) for existing occupations

This analysis also highlights that there are some occupations that have long existed before the growth of the solar energy sector. Although not specific to solar energy, workers in these jobs are often involved in the installation and servicing of solar plants provided additional skills and qualifications are acquired. This is the case for plumbers, electricians and roofers. Such occupations are common activities in the building industry and, to lesser extent, in the industrial sector. A short appraisal of each of these profiles is presented in Figure 11.

TABLE 4: Energy efficient and renewable energy

Skill level	Equipment manufacture and distribution	Project development	Installation, commissioning and handover	Inspection, servicing and maintenance
High	» Researchers (chemists, physicists, engineers with specialization in electrical, mechanical, chemical, materials, system design or process engineering) » Modellers » Manufacturing engineers » Building systems specialists	» Project designers (engineers) » Architects (small projects) » Atmospheric scientists and meteorologists » Resource assessment specialists and site evaluators » Environmental consultants » Lawyers » Debt financing representatives » Land-development advisors » Land-use negotiators » Lobbyists » Mediators » Public relations officers	» Project designers and managers » Business developers » Construction professionals » Commissioning engineers (electrical) » System designers (electrical/ » mechanical/structural engineers)	» Recycling specialists
High/ Medium	» Software engineers » Manufacturing technicians » Manufacturing quality assurance experts » Logistics professionals » Procurement professionals » Marketing specialists » Sales personnel	» Developers/facilitators » Environmental and social NGO representatives » Procurement professionals	» Project and installation evaluators » Solar thermal system designers » PV system designers (electrical engineers or technologists) » Software engineers » Quality assurance specialists	
Medium	» Chemical laboratory technicians and assistants		» Installers (ST or PV) » Roofers specializing in solar » Welders » Pipe fitters » Plumbers specializing in solar » Electricians specializing in solar	» Solar thermal maintenance specialists (plumbers specializing in solar) » PV maintenance specialists (electricians specializing in solar)
Medium/ Low	» Manufacturing operators			» Inspectors
Low	» Logistics operators » Equipment transporters		» Transportation workers » Construction workers	

Highly skilled – Professional/managerial
Medium skilled – Technician/skilled crafts/supervisory
Low skilled – Semi-skilled and unskilled

Source: Adapted from ILO (2018)

FIGURE 11: Short description of the plumber, electrician and roofer occupations

Plumbers	Electricians	Roofers
» Plumbers are responsible for installing, repairing and maintaining pipers, fixtures and other plumbing used for wate distrubution and waste water disposal in residential, commercial and industrial buildings. » Plumbers also install solar water heating systems. These systems replace or augment a conventional water heater and must be connected to a house's or building's plumbing. » To install these systems, plumbers require specialized training to work with solar water heater equipment.	» Electricians install and maintain all of the electrical and power systems in a home or business. » Electricians are responsible for connecting the solar panels, inverter, and other equipment to a building's power supply. » If a new building or house is being constructed with a solar power generating system, electricians may be responsible for installing the solar power system along with the electrical wiring system, or they may be responsible for connecting the solar equipment.	» Roofers install and repair roofs, and they ensure that any cuts or holes made in the roof during the installation of solar panels and mounting racks are properly repaired and sealed. » They may also assist with the installation of mounting systems and structural supports. » Roofers typically work with a variety of materials including tar, asphalt, gravel, rubber, thermoplastic, metal and shingles. » Roofing work is very strenuous. It requires workers to be on hot roofs for long periods of time, and it carries the risk of falls and other injuries.

Source: BLS (2018)

These occupations can benefit from the new skills development agenda arising from the deployment and growth of the solar energy market. The skills workers possess can be upgraded (or "greened") to correspond to specialized occupations in the installation and maintenance of the solar energy system.

Workers in these traditional jobs can upskill and move to specialized jobs in the solar energy sector, for example:

» A plumber, electrician or roofer specialized (or with additional skills) in solar installations in relation to its specific activity

» A solar thermal or PV installer or maintainer, capable of conducting most (if not all) of the tasks involved in the installation and/or servicing of a solar plant

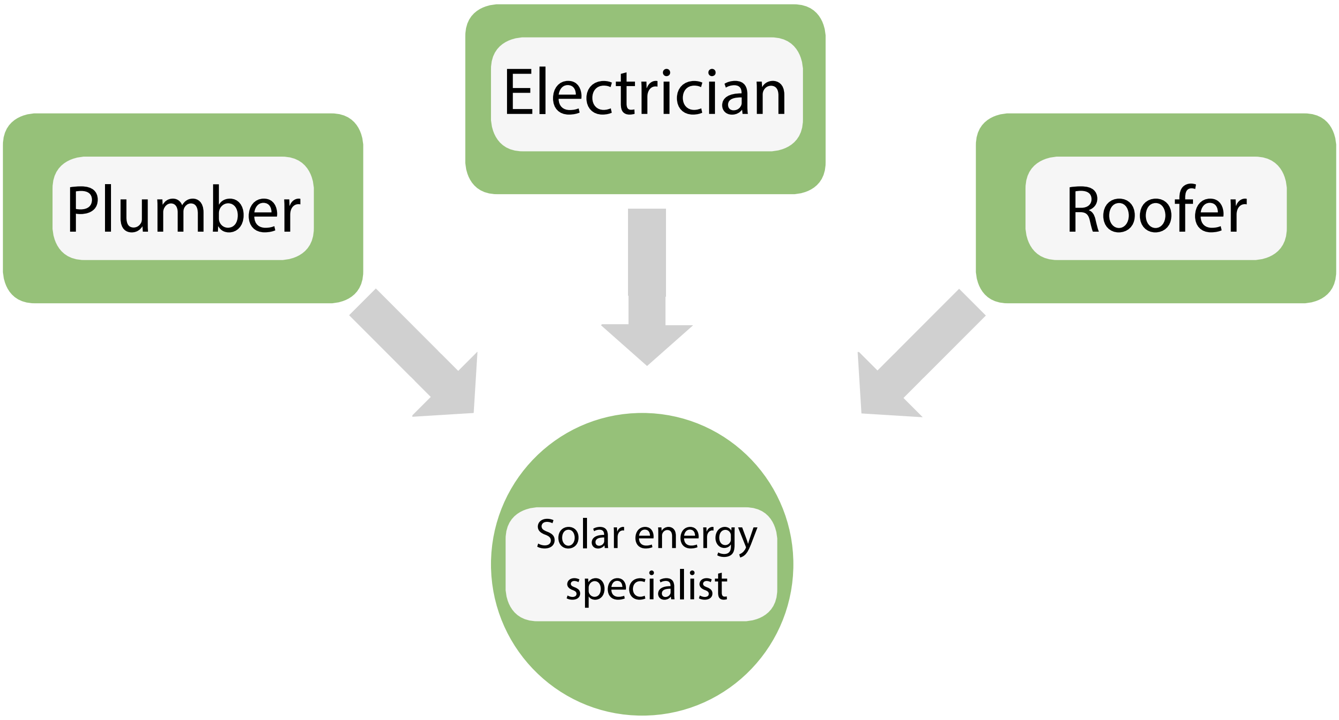
The relevant knowledge, skills and competences required for solar installation and maintenance professionals are described in the subsequent sections. They can serve as reference guidelines for use by TVET organizations and practitioners when planning or upgrading curricula for topping-up skills or new skills development programmes. Upskilling to new occupations has taken place in several cases through the greening of existing occupations for solar-energy entrepreneurs in Germany, as illustrated in Figure 13.

TVET can also contribute to other occupations in the solar energy sector that, despite not being core installation and maintenance jobs, are due to play a role in the future uptake of this technology. This is the case for:

» Less-skilled and experienced personnel, such as assistants or apprentices, usually engaged in practical training processes (either formal or informal) or apprenticeships to become qualified solar energy professionals.

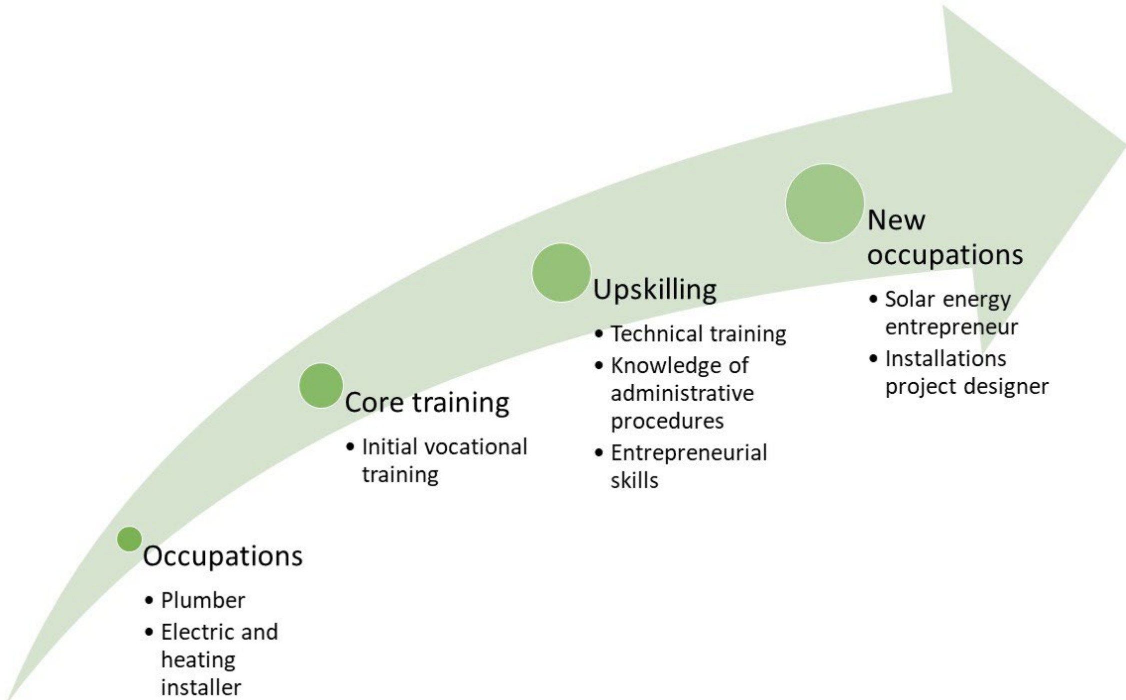
» Installation managers that top-up their technical skills as installers and maintainers with management competences in areas like entrepreneurship, business management, personnel management, procurement and contracting, commercial and customer management.

FIGURE 12: Solar energy specialists as an upgrade from some existing traditional occupations



Source: Authors

FIGURE 13: An example of upskilling practice in Germany to develop skills for new occupations in solar energy



Source: Authors

Skills training to meet the emerging demands

The anticipated growth in the uptake of solar energy in the future can only happen if a number of conditions are met. Besides aspects such as a stable long-term policy framework, the availability of incentives, and information and promotion campaigns, a well-trained workforce large enough to cope with the demand is crucial. This is where TVET is bound to play a key role.

Technical and vocational education and training (TVET) is understood as comprising education, training and skills development relating to a wide range of occupational fields, production, services and livelihoods. TVET, as part of lifelong learning, can take place at secondary, post-secondary and tertiary levels and includes work-based learning and continuing training and professional development which may lead to qualifications. TVET also includes a wide range of skills development opportunities attuned to national and local contexts. Learning to learn, the development of literacy and numeracy skills, transversal skills and citizenship skills are integral components of TVET.

TVET training interventions

Activities that support educational processes are usually categorized as initial and supplementary training. This includes continuous training opportunities for employees and additional training targeted at students who have just graduated.

Table 5 gives an overview of different training interventions and how they take place within the different modes of TVET delivery. These modes of delivery can be categorized into institution-based training, workplace-based training, or a combination of both.

TVET can be delivered by public schools, private providers (including profit-oriented training institutions), as well as not-for-profit bodies such as NGOs and faith-based organizations. Training that takes place in companies (internships or integrated apprenticeships, for example) form part of TVET systems in some countries. Formal, non-formal and informal TVET have, particularly in more developed infrastructures such as in Europe or the United States of America, a bigger market offer, largely promoted by the existing training organizations.

TABLE 5: Modalities for training skilled professionals

<table>
<tr><td rowspan="4">Institution-based training (initial and supplementary)</td><td rowspan="2">Provided by the formal education system</td><td colspan="2">Under Ministerial supervision</td></tr>
<tr><td colspan="2">Outside of Ministerial supervision</td></tr>
<tr><td rowspan="2">Provided outside the formal education system</td><td rowspan="2">Non public</td><td>For profit</td></tr>
<tr><td>Not for profit</td></tr>
<tr><td rowspan="3">Work-place based training (initial and supplementary)</td><td rowspan="2">Pre-employment training</td><td colspan="2">Modern apprenticeship</td></tr>
<tr><td colspan="2">Traditional apprenticeship</td></tr>
<tr><td colspan="3">In-service training</td></tr>
<tr><td colspan="4">Combination of multiple types of training (e.g. sandwich courses, dual systems)</td></tr>
</table>

Source: Adapted from ILO (2018)

In some countries, apprenticeships are a tradition, yet most of them take place informally and outside of the formal TVET system (in Mozambique, for example). Particularly in the informal economic sector, young people often enter employment as apprentices. While they may acquire practical skills through on-the-job-training, they rarely receive any theoretical education through this approach. Having said this, traditional apprenticeships often offer the best opportunity for the acquisition of employable skills in the informal sector. Both practical workplace-based training and apprenticeships are still a challenge with regard to their integration in TVET systems in some countries. With this in mind, certification/ qualification mechanisms are needed to prepare the workforce for solar energy professions (EUEI- PDF and GIZ, 2014).

BOX 4: Definition of formal, non-formal and informal learning

Formal TVET: Training typically provided by an educational or training institution, structured (in terms of learning objectives, learning time or learning support) and leading to certification. Formal learning is intentional from the learner's perspective.

Non-formal education and training: Education and training that takes place outside the formal system either on a regular or intermittent basis.

Informal learning: Learning resulting from daily activities related to work, family or leisure. Informal learning is part of non-formal learning. It is often referred to as experience-based learning and can to a certain degree be understood as accidental learning.

Quality assurance

The diversity in the types of TVET offered tends to cause challenges when it comes to comparing qualifications and the workforce's mobility between countries or regions. The European Qualifications Framework for lifelong learning (EQF) was implemented in 2012 to address this particular challenge in Europe. The EQF provides a framework and guides countries to ensure that qualifications correspond to the appropriate levels (European Commission, 2008).

BOX 5: The European Qualifications Framework for lifelong learning

The EQF is a common European reference framework that links countries' qualifications systems together, acting as a translation device to make qualifications more readable and understandable across different countries and systems in Europe. It has two principal aims: to promote citizens' mobility between countries and to facilitate their lifelong learning.

The EQF will relate different countries' national qualifications systems and frameworks together around a common European reference — it has eight reference levels. The levels span the full scale of qualifications from basic (Level 1, for example school-leaving certificates) to advanced (Level 8, for example doctorates) levels. As an instrument for the promotion of lifelong learning, the EQF encompasses all levels of qualifications acquired in academic and vocational education and training. Additionally, the framework addresses qualifications acquired in initial and continuing education and training.

The eight reference levels are described in terms of learning outcomes. The EQF recognizes that Europe's education and training systems are so diverse that a shift to learning outcomes is necessary to make comparison and cooperation between countries and institutions possible.

In the EQF, a learning outcome is defined as a statement of what a learner knows, understands and is able to do on completion of a learning process. The EQF therefore emphasizes the results of learning rather than focusing on inputs, such as length of study. Learning outcomes are specified in three categories: knowledge, skills and competences. This signals that qualifications — in different combinations — capture a broad scope of learning outcomes, including theoretical knowledge, practical and technical skills, and social competences where the ability to work with others will be crucial.

Source: European Commission (2008)

In more developed markets, there is a trend towards the implementation of certification or an equivalent qualification scheme to improve the quality provided by institutions. These schemes enable the development of institutional standards and best practices, while improving the skills and competences of professionals, thus increasing the general quality of institutions. Moreover, these schemes also increase consumer confidence in solar energy and gives consumers access to a network of qualified installers.

There is already a diversity of existing schemes, each with unique characteristics. For example, schemes might be implemented by public authorities or private organizations, and could be integrated with TVET or benefit from preparation provided by training organizations. Some certifying bodies comply with international norms (for example ISO 17024) or have been accredited by the national body. Other bodies have been established by the stakeholders themselves, following a collaborative initiative between installers' unions and industrial sectors (ADEME and EREC, 2011).

Certification or qualification schemes may be characterized as follows (ADEME and EREC, 2011):

» **Training.** The installer must participate in a specific training programme

» **Examination.** The installer must pass an examination (written or practical)

» **Technical references.** The installer must provide documentation about previous installations

» **Charter.** The installer must sign a quality charter

» **Proof of equivalent training.** Proof of competence that has not necessarily been acquired in the framework of a certification scheme

» **Documentation audit.** The installer is controlled regarding registration, tax compliance, insurances, etc.

» **On-site audit.** An installation by the installer has been audited

Training for solar installers in the framework of certification/qualification may be offered by a range of training providers, depending on the country. Training institutions, manufacturers, federations or guilds may offer different types of training, often integrated into the national or regional qualifications framework.

BOX 6: Definitions of accreditation, certification and qualification

Accreditation: Proof of competence given by a credible authority. Applies to an entity, training or education programme abiding by sufficiently stringent and uniform training standards, and suitably designed to reach their goals.

Certification: Proof of conformity. A procedure by which a third party gives written assurance that a product, process or service conforms to specified requirements.

Qualification: The formal outcome (certificate, diploma, title or label) of an assessment and validation process, obtained when a competent body determines that an installer has achieved the learning outcomes and possesses the necessary competence to carry out a job in a specific area of work. A qualification confers official recognition of education and training in the labour market.

Source: ADEME and EREC (2011)

Competency profile in solar energy professions

As the solar energy market in a region grows to maturity, its workforce increasingly gets certified and become qualified professionals. Formal recognition, either within the TVET system or as a complementary mechanism, must rely on a clear competence profile that, upon completion by students or trainees, gives them the ability to function within that market.

The installation and maintenance of small solar PV systems and solar thermal hot-water systems is one of the professions in high demand in the solar energy sector.

The competence profile is determined through an understanding of the tasks to be performed with the corresponding level of competences for different setups, sizes, work organizations of plants, and technical systems. The competence profile represents all work activities in technical systems, and it is therefore ideal for professionals in the solar energy sector to possess the required skills and competences applicable for the different work situations (Bauer W. et al., 2015).

The following information on competences were identified by experts during a project organized between the German Federal Ministry of Education and Research and the Israeli Ministry of Economy. They were deemed needed to perform the set of tasks in the field of solar energy:

1 Dimensioning and sizing solar energy systems

- Complete understanding of solar energy systems (PV and solar thermal) and all system components, their functions and operations, as well as an awareness of new systems and components
- Skills in dimensioning and sizing PV and solar thermal systems on the basis of field studies using typical software
- Knowledge of basic cost calculation and basic pay-off and profit analysis methods
- Skills in analysing geographical and constructive situations for the purpose of installing solar energy systems
- Knowledge of selecting suitable geographical locations for a system that blends in with the architecture of the building and has a sturdy surface upon which the system can be installed – bearing in mind lift force and the constant need for proactive protection against lift force
- Skills in reading and preparing technical documents, drafts such as construction diagrams, as well as detailed and electrical schematics, according to the required standards
- Communication skills and a well elaborated customer focus

2 Planning work orders and preparing equipment at enterprises

- Understanding organizational structures and functions of solar energy enterprises, and their personnel such as management, installers, team leaders, and maintenance and repairpersons
- Knowledge of planning work activities, project management and the use of relevant tools (for example, project schedules, work breakdown structure Gantt charts or network diagrams, PERT)
- Knowledge of analysing technical specifications and documents, as well as translating them into project plans and work activities
- Knowledge of performing cost and risk calculations
- Knowledge of reading and amending contracts, warranties and professional insurance
- Knowledge of work safety procedures
- Knowledge of purchasing required parts, materials and tools, and testing their integrity
- Skills in checking parts, materials and tools' availability, as well as prices according to the proposed schedule
- Skills in preparing and packaging appropriate parts, materials and tools for transportation to the installation site

3 Organizing work processes at sites

- Knowledge of purchasing and testing required general and special safety equipment
- Knowledge of creating appropriate and implementable site safety programmes, including identifying potential problem areas
- Knowledge of work safety procedures, in particular for working on roofs. A 'working at height' certification is mandatory
- Skills in scaffolding
- Knowledge of selecting suitable geographical locations for a system that blends in with the architecture of the building and has a sturdy surface upon which the system can be installed – bearing in mind lift force and the constant need for proactive protection against lift force
- Knowledge of accurately recording of parts and materials required for all systems
- Knowledge of materials, including safety devices and specific dedicated work tools
- Communication skills and ability to work in a team

4 Installing mechanical components for solar PV systems

For mechanical installations:

- Knowledge of positioning solar panel collectors. For example in geographical positioning, tilting and azimuth. Knowledge and use of accepted tolerances, use of correction coefficients as required in the event of deviation from acceptable deviations
- Knowledge of structural analysis
- Skills in metalworking, joining technology and plumbing
- Skills in system anchoring (stands, collectors, etc.)
- Skills in measurement and testing, including electrical measurements
- Knowledge of electrical circuits and electrical installation technologies
- Knowledge of electric protection measures
- Communication skills and ability to work in a team

5 Installing electrical components for solar PV systems

For electrical installations:

- Formal permission (certificate or licence) to perform electrical work
- Knowledge of electrical circuits and skills in electrical installation technologies
- Knowledge of solar PV systems, its components and functions
- Knowledge of operating electrical measuring instruments, including voltmeters measuring up to 1,000 volts and a current of up to 200 amperes
- General knowledge of electrical work safety measures and electric shock protection methods, in accordance with the relevant regulations
- Knowledge of electric protection measures. For example, knowledge of grounding requirements in open air electrical installations, in accordance with the relevant regulations
- Use of safety equipment during electrical work, including the use of insulated gloves and mats, and periodic testing of the equipment, in accordance with the relevant regulations
- Skills in insulation testing, including insulation requirements up to 1,000 volts
- Skills in installing inverters and connecting them to the utility grid, in accordance with the relevant regulations and procedures

6 Commissioning solar PV systems

- Knowledge of solar PV systems, its components and functions
- Knowledge of relevant technical standards and regulations for installing and operating solar PV systems
- Knowledge of electric work safety measures, including electric shock protection methods
- Knowledge of operating electrical measuring instruments, including voltmeters up to 1,000 volts and a current of up to 200 amperes
- Use of safety equipment during electrical work and periodic equipment testing
- Skills in inspecting and testing of electric circuits in accordance with the relevant technical standard
- Knowledge of applying commission reports

7 Installing solar thermal systems

- Knowledge of solar thermal systems, its components and functions
- Knowledge of relevant technical standards and regulations for installing and operating solar thermal systems
- Formal permission to perform plumbing work and electrical work (installer/electrician)
- Knowledge of health and safety regulations
- Skills in metalworking, joining techniques and plumbing, including insulating and sealing plumbing, in accordance with relevant technical standards
- General knowledge of electric work safety measures, including electric shock protection methods
- Skills in testing and measuring solar thermal systems, including roof construction, piping systems, water storages, heating systems and electric/electronic devices
- Knowledge of customer relations, including how to build reliable relationships, and provide complete and accurate information

8 Commissioning of solar thermal systems (usually the final step to installation of the system)

9 Handover solar energy systems to clients

- Knowledge of complete solar energy systems and operations
- Communication skills and a well-elaborated knowledge of customer relations, in particular the ability to explain system and technological processes and operations
- Knowledge of preparing and presenting technical documentations and drafts to customers
- Ability to train customers in operating systems

10 Maintaining solar PV systems

- Complete understanding of PV systems, its components and functions
- Knowledge of maintenance concepts and troubleshooting strategies
- Skills in performing maintenance work, in accordance with the requirements of relevant technical standards and safety issues
- Diagnostic knowledge required in the event of a malfunction – identification and diagnosis while providing reasonable efficient and cost-effective solutions
- Ability to describe malfunctions orally and in writing

11 Maintaining solar thermal systems

- Complete understanding of solar thermal systems, its components and functions
- Knowledge of maintenance concepts and troubleshooting strategies
- Skills in performing maintenance work in accordance with the requirements of relevant technical standards and safety issues
- Diagnostic knowledge required in the event of a malfunction – identification and diagnosis while providing reasonable efficient and cost-effective solutions
- Ability to describe malfunctions orally and in writing

12 Dismounting and recycling solar energy systems and components - the reverse process of mounting the system

Note: Recycling involves a complex matrix of operational and material-specific systems, including collecting, transporting, storing, recycling/producing in (commercial) recycling centres and material recovery facilities, as well as marketing, selling and disposal. The various waste material (for example, electronic waste, metal scrap, glass and semi-conductors) are recycled or disposed of in community-owned or private facilities in national and international markets. Future tasks that will be the responsibility of solar energy specialists are still unclear, unlike the tasks that are taken over by solar energy enterprises.

Upskilling of technical and non-technical competences

The knowledge, skills and competences mentioned in the previous sections can be used in the establishment of new jobs or for the greening of already existing occupations and competences, either by topping-up skills or by new skills development programmes.

There are a number of existing traditional occupations that may be particularly suitable for upskilling and/or greening through TVET. This is the case for plumbers, electricians, roofers, and, in some cases, heating installers and construction workers. The skills that need to be topped-up to upgrade those profiles to solar energy installation/maintenance professionals is job-specific and depends largely on the fundamental training and basic skills of the original occupation. Training plumbers on the checking of tanks, pipes and fittings for leaks, or training electricians to verify electrical installations for proper wiring, polarity, grounding or integrity of terminations, are most likely redundant and may be left out of upskilling programmes.

Upskilling may also include those professionals already working as installers and maintainers in the solar energy sector. In this case, professionals can be upskilled to acquire competences that can qualify them to become installation managers. Through TVET, upgrading essential technical skills can help enhance their professional and managerial competences, and therefore enhance their job prospects.

The work tasks and competence profiles discussed in this paper can serve as a reference when reforming existing curriculum or developing new skills programmes.

Examples of integrating solar technology training in TVET

TVET already plays a relevant role in the development of a skilled workforce in the solar energy sector. This has usually been done by:

- Improving existing career pathways through the greening of skills for low/medium/high skill within a given job cluster (in Belgium and Pakistan, for example)
- Strengthening the competences of the already skilled workforce to enter into new industry/sectors and/or to increase the quality of work (in Austria, for example)
- Applying industry-based competency models well suited to regional market needs and other specific circumstances (in Brazil, Kenya and Bangladesh, for example)

Short descriptions of examples are provided in Annex 1. They illustrate one or more of the above options, and cite potential innovation and changes taking place in TVET regarding the solar energy sector.

Revitalizing training for future demands

Employment projections for countries all indicate that there is a strong potential for widespread job creation in the coming decades in the installation and maintenance of solar PV and thermal systems. Having said this, these are also the types of occupations in the solar energy sector primarily identified by both IRENA and ILO as difficult to fill (ILO, 2013; UNEP, ILO et al., 2008).

Adequately trained professionals in the installation and maintenance of solar PV and thermal systems are crucial to bridge the gap between the demand for quality installations, and the skilled and qualified labour required to do the work. People working in installation-related areas, such as HVAC, engineering and architecture, often lack the knowledge and specialized skills to understand the safety risks, and designs and aesthetic requirements associated with solar systems.

Specific needs vary considerably from country to country. Installers and maintenance personnel are particularly important in developing countries. Rapid growth in solar energy applications has led to skill shortages and deficiencies in solar installation and maintenance in many countries. These have frequently led to problems with solar PV and thermal systems, particularly in domestic installations. Considering the current and future growth in market demand for a skilled workforce, it is anticipated that TVET institutions and practitioners will have to adapt or reinforce their strategic positioning and offer training courses in order to seize the opportunities in the solar energy sector.

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SECTION 2

Developing TVET curricula

Section 2 discusses a common process to developing TVET curricula for the renewable energy industry. The curriculum should be flexible enough that it can be applied to any context, regardless of the TVET system used in the country.

The procedure calls for the involvement of TVET institutions and other stakeholders from industry, trade associations, employers, employees, as well as the TVET regulatory body, in order to ensure that the curriculum is to fit into existing formal national education and training structures. This process requires more time but can guarantee national level recognition.

Alternatively, employing a fast-track process can be considered in cases where institutions have the scope to implement the curriculum, calling upon relevant stakeholders for support as and when required. In this scenario, the resulting TVET curriculum could be accepted by and fitted into national education and training structures, following assessment by the appropriate regulator once it is up and running.

While the first scenario has a tendency to lead to lengthy processes, the second scenario is faster. Having said this, while the first scenario ensures the acceptance of all stakeholders, the second scenario runs the risk of not being accepted by national education and training authorities or other stakeholders.

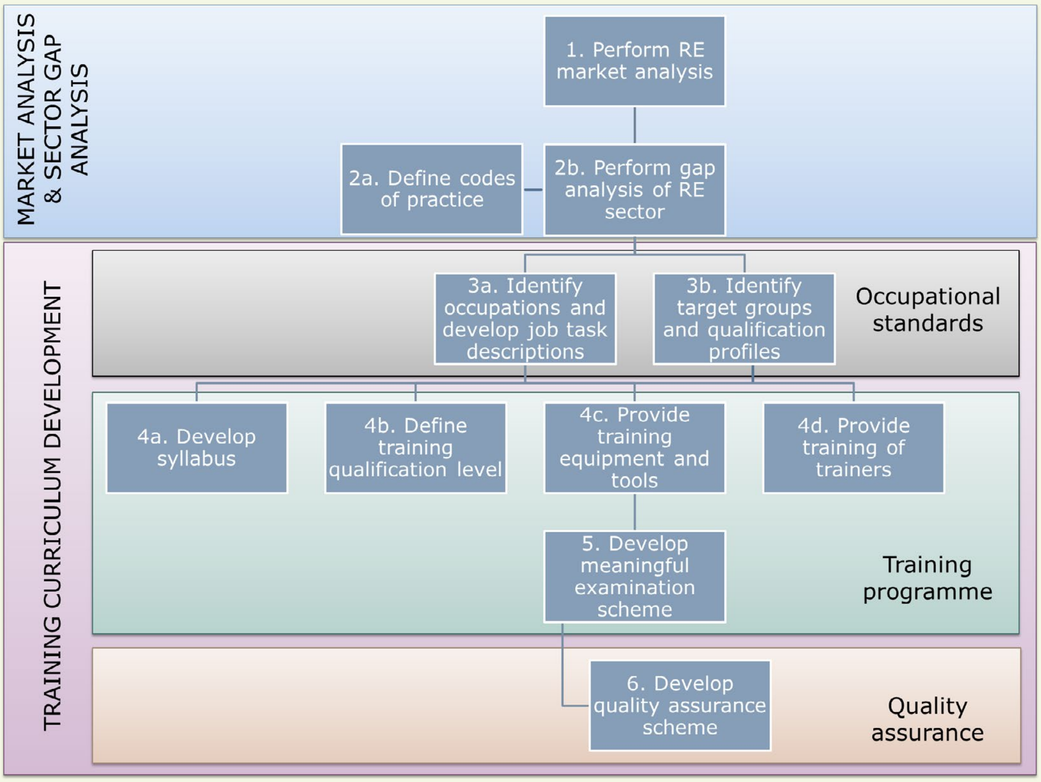
Establishing cooperation and networks with all stakeholders as early as possible is therefore important in both scenarios, since their contributions are more likely to lead to a complete and targeted training offer that is accepted by all and integrated into the national education and training system.

BOX 7: Developing the training curriculum for the renewable energy industry

The process of developing TVET curriculum for the renewable energy industry can be split into two main stages: (1) performing a market analysis and a sector gap analysis; and (2) developing the training curriculum (development of occupational standards, training programmes and quality assurance schemes). The chronological steps are outlined here and illustrated in Figure 14:

1. **Perform a market analysis** of the status of the local or regional renewable energy industry and its predicted growth in coming years. From this, identify the most critical training needs (due, for example, to sudden growth in the sector) and estimate the workforce demanded.
2. **Perform a gap analysis** for the target sector in the renewable energy industry to establish the necessary investments and improvements to bring the sector up to the desired level in terms of quality and performance. For example, a gap analysis for solar PV installations should look at the quality of the installation, identify the causes for poor quality, and make recommendations for improvements. At this stage, it is helpful if codes of practice have already been defined so that these can be used as a benchmark, against which existing installation quality can be measured.
3. **Identify occupations** in the target sector and develop detailed job task descriptions for these occupations. For example, typical vocational occupations required in solar PV installation include assemblers (mechanical and electrical), electricians and site managers. Identify the target workforce which will work in these occupations (for example, electricians are likely candidates to become PV electricians) and assess their qualification profiles in order to set the level of the new curriculum.
4. **Develop the main content of training programmes** and/or adapt the content from existing training programmes to meet the newly defined needs, and ensure that all resources are in place (training manuals, training equipment and trainers, for example) to implement it.
5. **Develop examination schemes** that will test the necessary knowledge, skills and competences that trainees will need to successfully perform the relevant occupations.
6. **Develop quality assurance schemes** to facilitate a continuous cycle of monitoring, review and adaptation of the training curriculum.

FIGURE 14: Overview of the main processes in performing market and sector analyses, and then developing a TVET curriculum



Market/sector analysis

Performing a renewable energy market analysis

In order to identify the most critical training needs, each sector in the renewable energy industry should be analysed. The market analysis should focus on workforce demands, the current status of the market, as well as future trends and growth predictions. Our examples focus on solar PV installations.

a. Estimating future workforce demand
The future workforce demand can be estimated by researching countries' renewable energy targets, government policies (annual quotas for feed-in tariffs, for example), and secured investments. The accuracy of the estimate will depend largely on the quality of the information that is available in the public domain, as well as on government policies and investments going as planned.

Box 8 shows an example of estimating the workforce requirement in solar PV installations in Egypt, an emerging market in solar technology.

b. Determining the market's current workforce status
The current status of the market can be best established by carrying out surveys and interviews. In the case of solar PV installations, information can be gathered from companies and trade associations, as well as from training establishments that may already be delivering relevant training.

Questions to ask include:

- How many solar PV installation companies are currently active in the region?
- How many employees does each company have?
- What jobs do the company employees perform and what is their current qualification and/or competency level?
- How many, what size, and what type of installations does each company complete per year?

Box 9 gives an example of a workforce survey performed for the solar PV sector in the USA. When the results from this kind of survey are compared against the predicted future demand, a clearer picture of the workforce demand emerges.

BOX 8: Estimating the workforce demand in the solar PV installation sector

In 2015, Egypt had a PV installed capacity of around 15 megawatts with a target, according to its Solar Energy Plan, of 2.8 gigawatts of installed PV capacity by 2022. A condition of Egypt's feed-in tariff is that developers must use at least 30% local content in their installations.

Assuming linear roll out in the years from 2017 to 2022, this means around 464 megawatts of newly installed capacity each year.

Based on the assumption that 18.2 job years are required in PV installation for each megawatt of installed capacity, this means that there will be a demand for just over 8400 PV installers each year. Since at least 30% should come from the local population, this means a demand for at least 2500 Egyptian PV installers. This is, initially at least, the entire demand since the same people will presumably continue working in the field year on year up until 2022 or as long as projects continue to be developed.

Current installed PV capacity [Megawatts]	15
Targeted installed capacity by 2022 [Megawatts]	2800
Annual new capacity (assuming linear deployment each year) [Megawatts]	464
Number of job years per installed [Megawatts]	18.2
Size of PV installation workforce required	8400
Minimum % of workforce from local content	30%
Minimum required local workforce	2500

In reality, deployment will not be linear but will be influenced by government policy and market demands, as well as project-related factors such as availability of investment and time required to gain all planning consents and approvals.

BOX 9: Solar PV jobs census – Using real data to assess the status of solar jobs in the USA

The Solar Foundation in the USA is an independent non-profit organization formed of solar industry representatives. It has been performing an annual national solar PV jobs census since 2010. The census is derived from real data collected by a survey among establishments involved in solar activity in the USA. It provides current employment, trends and projected growth in the US solar sector. The census results also include data on hiring difficulties (how difficult solar PV employers find it to hire suitable workers across the PV value chain), a breakdown of the reasons for difficulties in hiring (for example, lack of experience and insufficient qualifications), as well as a breakdown of hiring difficulties across states. This information, along with projections for the coming year, helps solar PV training providers to plan how to adapt their training offers to changing demands.

Source: Solar Foundation (2020)

However, before a suitable training curriculum can be developed, the current quality of the workforce in the sector and the areas requiring improvement need to be assessed. This can be followed by a gap analysis.

Performing a gap analysis to establish the quality and scope for improvement

The gap analysis aims to gather information on the current quality and performance of the sector, and to make suggestions for improvements to achieve the desired standard. At this point, the following question arises: what is the desired standard? This is where codes of practice come in. Codes of practice provide a best practice benchmark against which it is possible to measure installation quality and performance. Please refer to Box 10 for more on codes of practice.

For solar PV installations, the national health and safety as well as electrical regulations provide a benchmark for a large proportion. If codes do not yet exist for PV-specific elements of the installation, it is possible to use internationally recognized standards and guidelines in the interim. The installation manuals provided by high-quality equipment manufacturers are themselves a good source of international best practice. They provide detailed installation instructions which should be adhered to, and which, in the absence of other codes, can be used as an initial quality and performance benchmark.

A gap analysis for PV installations involves visiting and assessing a large number of installations. The results of the gap analysis will clarify the training needed.

Completing the market analysis and the gap analysis will provide a reliable information base on the workforce demand and areas of the sector that need to be improved. Tasks for developing the new training curriculum can now be started.

BOX 10: Steps in preparing and performing a gap analysis

1 Compile a checklist of criteria to be assessed. Criteria can be grouped into categories. For example: health and safety, equipment quality, mechanical installation of equipment, electrical installation of equipment, installation of ancillary equipment (cables, fuses, combiner boxes, etc.).

2 Give each criterion a weighting based on how important it is to the quality and performance of PV installations. For example: PV module orientation and inclination is critical to performance, so will have a higher weighting than the labelling of cables, which is important for ease of maintenance but not critical to performance.

3 Assign a scoring model. For example from 0 to 4, where 0 indicates that a criterion is completely unfulfilled and 4 indicates that a criterion is perfectly fulfilled.

4 Perform as many assessments of existing PV installations as possible with this checklist.

5 Analyse the results and identify the areas in PV installations requiring the most improvement.

Sources of information that can be helpful when compiling the checklist include:

- National health and safety codes
- National electrical regulations
- Installation manuals from high quality module and inverter manufacturers, which give detailed instructions for correct installation
- Results from previous surveys of common faults in PV installations. For example, the Catalogue of common failures and improper practices on PV installations and maintenance, produced as part of the PVTRIN project (2011-2013) supported by the European Commission's Intelligent Energy Europe programme (PVTRIN, 2011)

Codes of practice

Codes of practice are put in place to ensure that systems are designed, installed and operated safely, reliably and to a high-quality standard. Codes of practice can be relevant laws or regulations that have been passed by the legislator, for example national, regional or international norms that have been published by recognised standardization bodies (ISO or EMS). Alternatively, they can be rules that, though they have never been written down, have become established and proven over many years of experience and are thus considered to be valid.

Codes of practice will typically comprise three components:

1. Technical codes relating to technical characteristics and procedures
2. Occupational health and safety codes including regulations for safe work practices in system installation, operation and maintenance
3. Laws or directives issued directly from the legislator

In newer sectors of the renewable energy industry, it can be observed that stakeholders are interested in having a set of well-defined codes in place. The legislator wants to deploy funds or subsidies to generate the highest possible yields or savings, customers want investment security, and the industry needs legal certainty with regards to possible liability claims from customers. In addition, renewable energy applications are unique in that the value chain involves a relatively large number of people who all need to be appropriately trained to perform their work activities.

Training Development

Developing occupational standards and job tasks

This part addresses the development of standards for occupations that are relevant for solar PV installation. As stated previously, in top-down approaches occupational standards will typically be developed by working groups made up of employer and employee representatives from industry, trade associations, TVET employees, and other technical and educational experts. In bottom-up approaches, TVET providers will initiate this process with minimal external input.

Occupational standards. The tasks that people are required to fulfil in their job or occupation. Occupational standards should ideally be defined in terms of the knowledge, skills and competences a person should possess in order to perform his/her role effectively. The terms 'competency models' and 'occupational standards' are often used synonymously.

Different approaches to developing occupational standards exist, the main ones being Job Task Analysis, DACUM (Developing A CurriculUM), and Functional Analysis. These approaches are briefly described in Box 11. Although each approach has its merits, this paper uses the Job Task Analysis approach since it is appropriate where:

- Failure to perform the task or job exactly as required can mean considerable liability
- The approach encourages the development of specific occupational standards, which can be beneficial. Occupational standards resulting from the other two approaches are more general

BOX 11: Choosing the approach to developing occupational standards

- **Job Task Analysis** is an assessment of the core knowledge areas, critical work functions, and skills typically found across a representative sample of current practitioners or job incumbent workers. The Job Task Analysis approach requires repeated on-site observations to identify all tasks that can then be generalized into an occupation. It divides and subdivides jobs and tasks into their constituent parts. Empirical results from a Job Task Analyses provide valid, reliable, fair and realistic assessments that reflect the skills, knowledge, and abilities required to competently perform jobs.

- **DACUM approach (Developing A CurriculUM)** uses guided group discussions with experts to define occupation-specific and general skills, general knowledge, and the tools and equipment required for occupations. The tasks identified form the basis of the curriculum development process.

- **Functional Analysis** approach identifies the key purpose of an occupation, and then breaks this down into key functions and modules. The modules are analysed to identify performance requirements.

For more information on the development of occupational and training standards, refer to the European Training Foundation (ETF) and its comprehensive document library. For example, Volumes 1-3 of ETFs series on *Development of Standards in Vocational Education and Training*, *Linking Vocational Education and Training Standards and Employment Requirements*, and *A Framework for Defining and Assessing Occupational and Training Standards in Developing Countries*.

These points are relevant and important for occupations in the renewable energy industry, where comprehensive regulations and guidelines must be adhered to in order to ensure high quality and reliable system design, installation and operation.

In parallel to developing the Job Task Analyses for the relevant occupations, the target group for the respective training programmes should also be identified and profiled (assess current competences).

a. Developing a job task analysis[3]

A training programme intended for skilled professionals responsible for designing complex systems should be closely oriented to the tasks required for conducting the job on-site. Performing these tasks requires the support of engineers, technicians and installers with the relevant knowledge, skills and competences.

Figure 15 illustrates how tasks within a company are delegated. Fields A to J represent tasks required to build a system. Field A could, for example, represent technical design using specialist software. Field F could be the installation of various system components. It will often be the case that each employee is assigned several tasks (see here A to C), or that many employees share one task (see here Task E). All tasks should be performed in accordance with relevant regulations and guidelines (codes of practice).

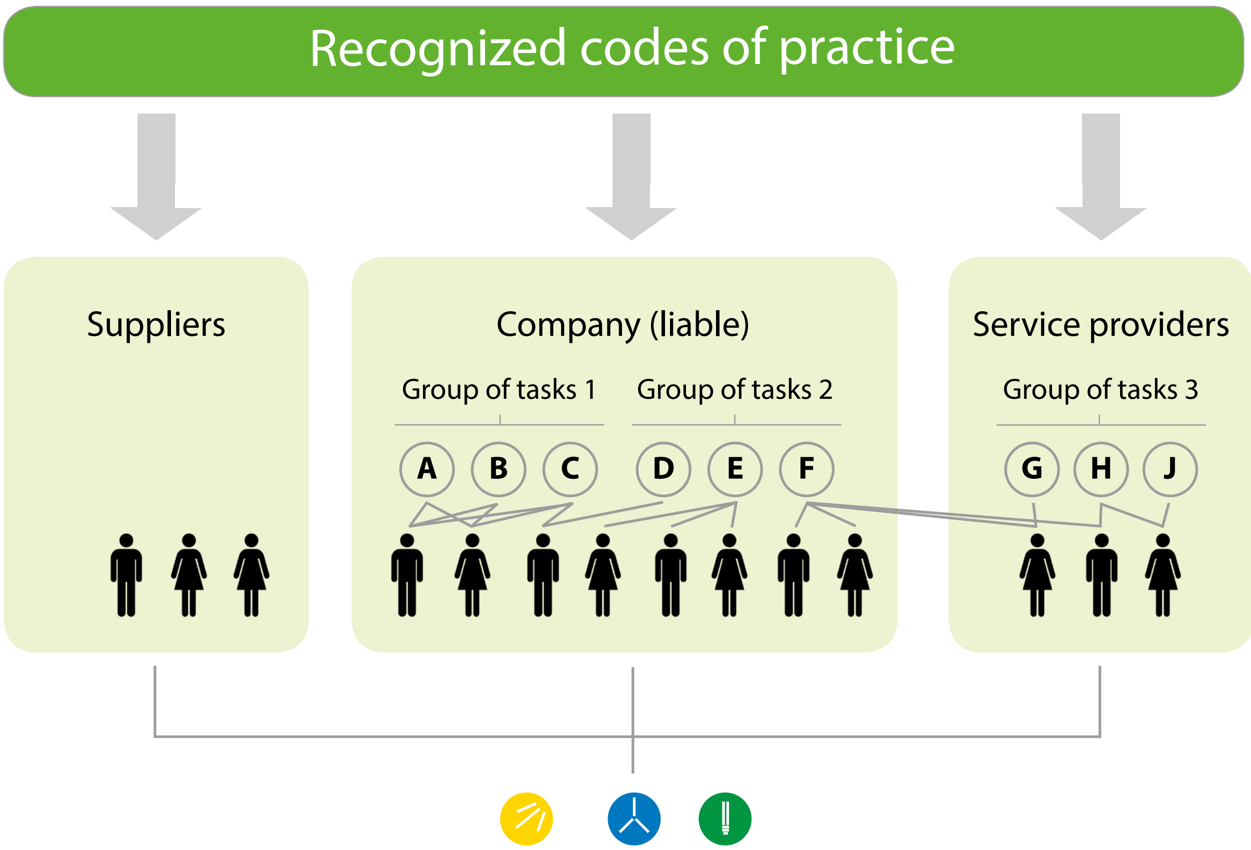
Tasks in a value chain can often be classified into separate groups. For example, Group 1 could be responsible for all design tasks, while Group 2 carries out all installation tasks.

These considerations inform the development of occupational standards into useful and training programmes:

- It is important to know how tasks and task groups are organized within the selected job sector. This makes it easier to define a precise target group and what relevant training programme should be developed.
- If market information is available about frequent faults in a certain application (this would require a market analysis), these can often be traced back to certain tasks or task groups. For example, a system could be well designed but badly installed. A training programme should then focus on installation activities.

3 This section has been adapted from GIZ Study 'International Quality Standards and Quality Assurance Mechanisms for RE/EE Training Programmes, Market Assessment & Benchmarking' from 2015 authored by RENAC.

FIGURE 15: Tasks A to J are delegated by a company to its employees



These analyses result in a set of priority tasks. There can be several qualification levels within a Job Task Analysis (for example, EQF/ISCED Levels 1 to 5, where Level 3 corresponds to the expected competency level of a skilled worker).
The definition of these can help to structure the training programme later.

Once the Job Task Analysis is complete, the individual task steps in the analyses must be described more closely. These form the basis for defining the learning outcomes of the training programme.

Identifying and profiling target groups[4]

The previous part explained how a Job Task Analysis is implemented and how the results can be used when developing training programmes. The focus will now shift to the workforce who carries out these tasks. First, the target groups within this workforce must be identified and profiled.

a. Target group identification
The following considerations should help to identify the possible target groups for future training programmes:

» Tasks in renewable energy companies are generally very specialized. Modular training programmes could be developed, where each module covers certain tasks or work areas.

» Designing a training programme that attempts to teach everyone everything should be avoided. No one needs to be able to do everything. It is more important that the appropriate competences are transferred to the appropriate individuals.

» Employees of engineering and installation companies are generally split into different areas and levels of responsibility. For example, a site manager should have the appropriate level of competency to manage a group of workers. The workers on the other hand do not necessarily need this.

» It is crucial that the groups of tasks are well defined and well separated. It is then possible to carry out accurate target group identification, and from this, to develop a suitable, modular training programme.

4 This section has been adapted from GIZ Study 'International Quality Standards and Quality Assurance Mechanisms for RE/EE Training Programmes, Market Assessment & Benchmarking' from 2015 authored by RENAC.

BOX 12: Example of how the North American Board of Certified Energy Practitioners' (NABCEP) develops its Job Task Analyses

NABCEP structures its Job Task Analyses as follows:

» The Job Task Analysis defines precisely for which occupation or work activity it is relevant

» The responsibility of the worker is described for each task

» An estimated importance weighting is allocated to each task

» Each task is broken down into a series of sub-tasks, each of which is listed and categorized according to its importance as critical, important or useful

The complete list of tasks and their categorizations are particularly helpful in the development of training programmes and should be included.

TABLE 5: Example: excerpt from the tasks list from the NABCEP Job Task Analysis for PV installers

Task step	Category
Confirm conductor ampacity calculations	Critical
Confirm conduit fill calculations	Critical
Confirm conductor run distance	Critical
Confirm continuous current calculations	Important
Confirm continuous load calculations	Important
Confirm conditions of use calculations	Important
Confirm thermal expansion calculations	Useful

For example:
PV Installer Job Task Analysis. Available from: http://www.nabcep.org/news/nabcep-publishes-revised-jta-for-pv-installer-certification

Source: www.nabcep.org

b. Target group profiling
Target groups must be profiled in order to assess their current levels of skills, knowledge and competences, and in order to categorize these levels in ideally an internationally recognized and understood framework to determine the entry level for the training programme.

Target group profiles should include the following information:

» Subject of the TVET qualification
» Maximum qualification level of the target group (high school, vocational and/or academic)
» Type and duration of relevant on-the-job experience
» Level of responsibility held within the company
» Further training that the target group may have already undertaken
» Expected age group (where appropriate)

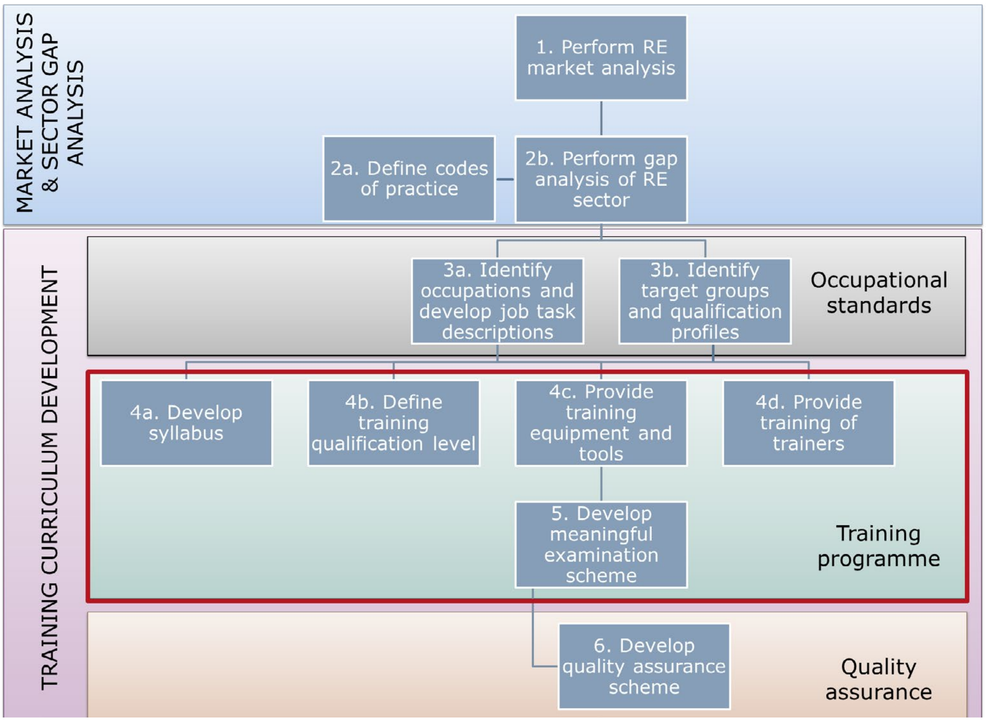
It is also important to get an estimate of the target group's availability and mobility. For example, an employed installer will only have limited time to take part in a training programme. On the other hand, a person who is currently in full time education may be available to participate in a longer-term training programme. Information about a target group's mobility will help to select the best training and examination location(s).

Developing TVET programmes

Training programmes are typically developed by the TVET provider and are designed to meet the needs of a particular target group profile, as defined in the previous chapter. Referring to our overview of the main processes, this part explains the elements of training programme development (within the red border in Figure 16). These are summarized as:

» Developing the syllabus
» Defining the training qualification level
» Providing training equipment and tools
» Training of trainers
» Developing a meaningful examination scheme

FIGURE 16: Overview of the main processes in developing a TVET curriculum for the renewable energy sector



BOX 13: Developing Job Task Analyses and performing target group identification and profiling for a new training curriculum for the PV installation sector in Egypt

Developing a training curriculum

The following is an example of how RENAC Renewable Academy AG developed a training programme for solar PV installations in Egypt. There tends to be a rather fragmented offer of PV training programmes in younger solar PV energy markets. Although important aspects of PV technology are taught, they frequently are restricted to stand-alone skill sets along the value chain. Further to this, PV training programmes sometimes contain content with only little relevance for the actual jobs in the PV solar sector.

The provider looked into the whole work process to orient the training curriculum towards tasks performed along the work process chain. The occupational standards was developed as a basis to develop the training programme and its learning outcomes.

1 Identify key vocational occupations for solar PV installations

» Electricians with solar expertise responsible for electrical works
» Site managers leading electrical and mechanical installation teams
» Electrical and mechanical assemblers responsible for tasks such as laying cables, erecting PV mounting frames, installing PV modules, inverters, etc.

2 Compile Job Task Analyses for each occupation

» Job Task Analyses were compiled by drawing experience from the industry and by analysing actual job offers (for example, from the job database O*NET OnLine, www.onetonline.org), as well as existing Job Task Analyses from bodies such as NABCEP

3 Identify and profile target groups for each occupation

» The tasks for each occupation were analysed further and compared against the knowledge, skills and competences required by persons working in similar trades. The appropriate EQF qualification level was then assigned. Table 6 summarizes the target group identification and profiling for each occupation.

TABLE 6: Summary of target group identification and profiling for each occupation

Occupation	Target group	Qualification level
PC electrician	Highly qualified electrician	EQF 4-5
PV site manager	Qualified electrician with management experience	EQF 3-4
PV mechanical/electrical assembler	Basic education and some vocational training	EQF 2-3

4 Develop learning outcomes for training modules based on the job tasks for each target group

If the Job Task Analyses are comprehensive and detailed enough, then most of the work in developing learning outcomes for the relevant training module has already been done. The next step is to develop these learning outcomes into lesson plans for training sessions that form part of the overall training module.

The content and methodology draws on RENAC's long-standing and continuously evolving experience in training curricula development, as well as on other industry standards, for example from NABCEP, the Interstate Renewable Energy Council, and the Windskill Initiative (G. M. et al., 2009).

a. Developing the syllabus

A syllabus encompasses course outlines, lesson plans and in-class teaching material, and teaching methods. Course outlines should be defined in terms of learning outcomes.

» Developing course outlines in terms of learning outcomes

The Job Task Analyses developed for each occupation contribute significantly towards forming the course outlines. Each subtask from the Job Task Analyses should be defined in terms of the desired learning outcomes. Table 7 shows how each subtask from a Job Task Analysis can produce many learning outcomes. The table is based on a Job Task Analysis developed by NABCEP for solar heating installers. Additional input from industry experts is necessary to develop a comprehensive set of learning outcomes.

» Lesson plans and in-class teaching material

It is essential in TVET that lesson plans incorporate significant amounts of practical, hands-on training where learners get to work with training rigs as well as real-life working systems. Lesson plans should be accompanied by trainer and learner handbooks that provide technical content on precisely how each learning outcome is to be interpreted and implemented, as well as a set of exercises that learners can do to test their own learning. They should include detailed technical descriptions as well as references to all relevant parts of the codes of practice (as defined in the relevant occupational standard) that the trainer and learner must be familiar with.

Some examples of in-class teaching and learning materials include:

→ **Detailed lesson plans.** Plans should contain what will be covered in each lesson, as well as information on the appropriate training method used (for example, lecture, hands-on exercise, pen and paper exercise, discussion, or demonstration). These plans are an essential tool as they guide trainers on how to teach and train.

→ **Practical hands-on exercise instructions.** Instructions should include detailed descriptions about the steps, materials, safety notes, and the tools and instruments required for each exercise. Hands-on exercises can range from demonstrations by the teacher/trainer, to hands-on work by the students (Figure 17 shows an excerpt from hands-on instructions).

→ **Case study for pen and paper exercises.** Case studies help to describe sample projects. Students use this information to perform design and sizing exercises, for instance (Figure 18 shows an excerpt from a case study).

→ **Answer sheet** for pen and paper exercises and accompanying information on implementing hands-on exercises.

→ **Set of accompanying documents** that are needed to carry out hands-on as well as pen and paper exercises. These include data sheets, manuals of components and drawings.

→ **Power Point slides** for theoretical presentations and explanations

In addition to these, a list of books and other technology-specific publications for reference should be provided.

TABLE 7: Training programme development: Learning outcomes as defined for a particular subtask from the NABCEP Job Task Analysis for solar heating installers

From occupational standard	From training programme
Job Task Analysis: Solar Heating Installer Area D: Install system Task 8: Implement site safety plan	Learning Outcomes
Subtask: Identify unsafe practices	Demonstrate safe and accepted practices, and safety equipment for personnel protection
	Identify appropriate codes and standards concerning installation, operation and maintenance of solar thermal systems and equipment
	Identify physical personnel safety hazards associated with solar heating installations
	Identify environmental hazards associated with solar heating installations
	Determine components that require identification tag

FIGURE 17: Excerpt from the instructions for a hands-on exercise

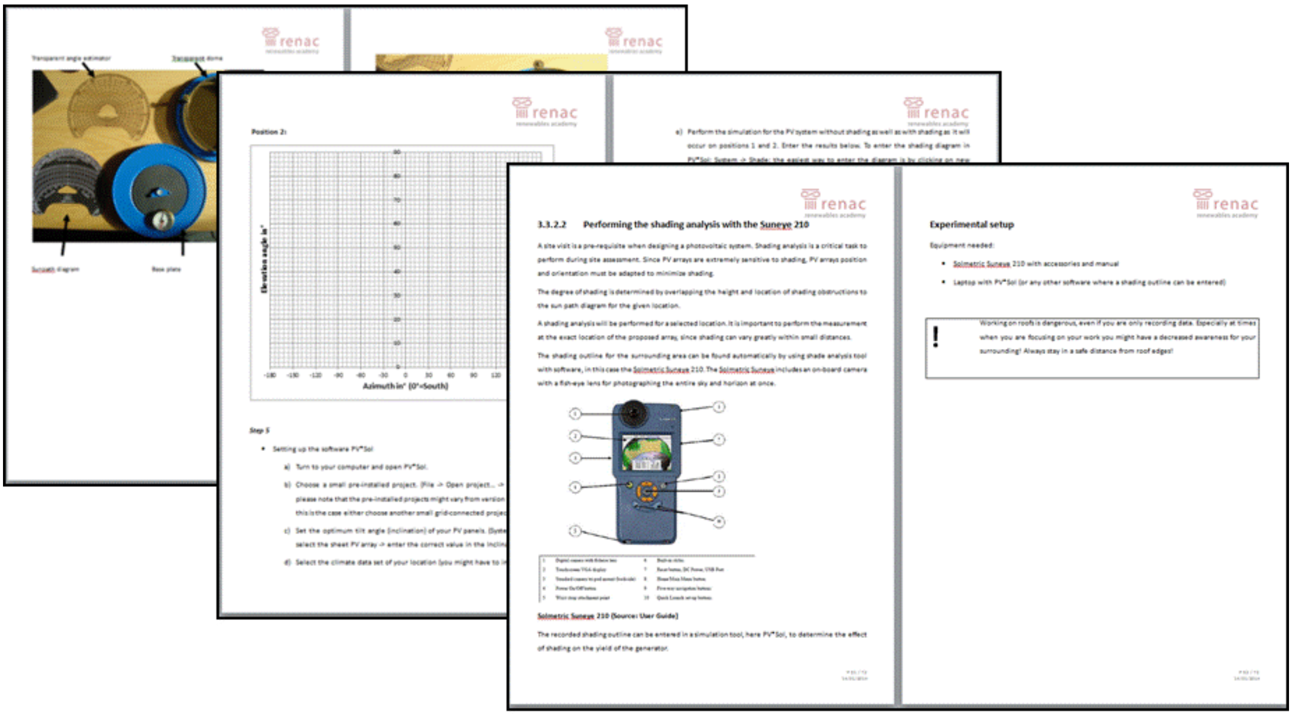
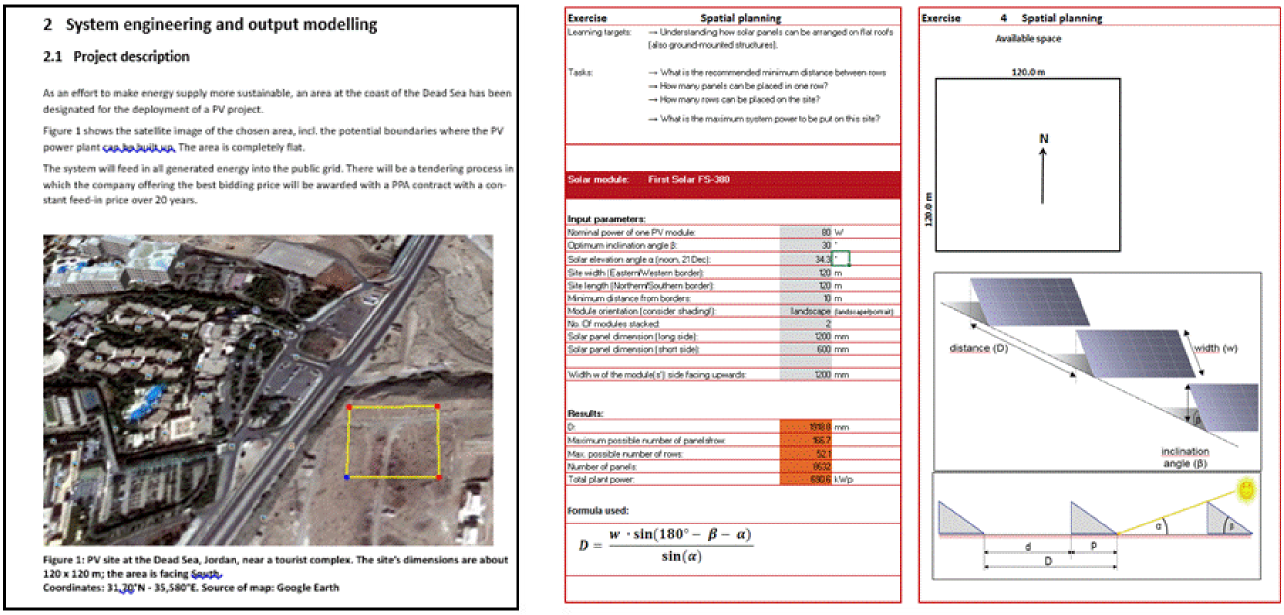


FIGURE 18: Excerpt from a case study

The page on the left describes the project a class will work on during the training. The pages on the right are the tables the trainees will use to calculate the results of their assignments.


2 System engineering and output modelling

2.1 Project description

As an effort to make energy supply more sustainable, an area at the coast of the Dead Sea has been designated for the deployment of a PV project.

Figure 1 shows the satellite image of the chosen area, incl. the potential boundaries where the PV power plant can be built up. The area is completely flat.

The system will feed in all generated energy into the public grid. There will be a tendering process in which the company offering the best bidding price will be awarded with a PPA contract with a constant feed-in price over 20 years.

Figure 1: PV site at the Dead Sea, Jordan, near a tourist complex. The site's dimensions are about 120 x 120 m; the area is facing South.
Coordinates: 31,70°N - 35,580°E. Source of map: Google Earth

Exercise — Spatial planning

Learning targets: → Understanding how solar panels can be arranged on flat roofs (also ground-mounted structures).

Tasks:
→ What is the recommended minimum distance between rows
→ How many panels can be placed in one row?
→ How many rows can be placed on the site?
→ What is the maximum system power to be put on this site?

Solar module: First Solar FS-380

Input parameters:		
Nominal power of one PV module:	80	W
Optimum inclination angle β:	30	°
Solar elevation angle α (noon, 21 Dec):	34.3	°
Site width (Eastern/Western border):	120	m
Site length (Northern/Southern border):	120	m
Minimum distance from borders:	10	m
Module orientation (consider shading!):	landscape	(landscape/portrait)
No. Of modules stacked:	2	
Solar panel dimension (long side):	1200	mm
Solar panel dimension (short side):	600	mm
Width w of the module(s') side facing upwards:	1200	mm

Results:		
D:	1918.8	mm
Maximum possible number of panels/row:	166.7	
Max. possible number of rows:	52.1	
Number of panels:	8632	
Total plant power:	690.6	kWp

Formula used:

$$D = \frac{w \cdot \sin(180° - \beta - \alpha)}{\sin(\alpha)}$$

Exercise 4 Spatial planning

» Teaching methods

The shift away from traditional teacher-based teaching and towards a learning outcomes-oriented experience brings with it more learner-based teaching methods. An example of traditional teacher-based methods is when a teacher speaks and explains while learners passively listen and repeat. Learner-based methods on the other hand require learners to actively participate in the experience. Examples of learner-based methods include practical exercises, group activities, role-play, and computer assisted learning. The objective of such methods is to motivate learners so that they 'develop their creative, innovative and initiative-taking skills, while assuming direct responsibility for their actions' (Tippelt and Amorós, 2011).

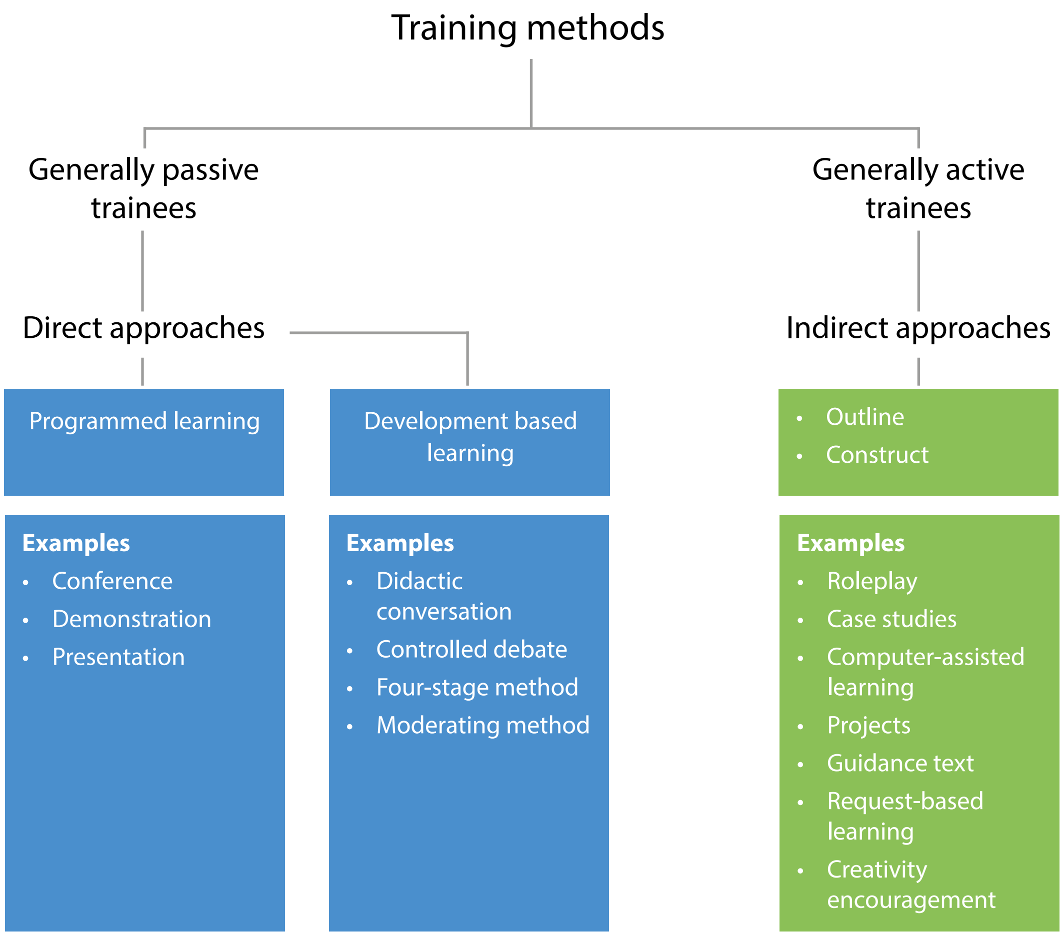
Learner-based methods should not replace teacher-based methods entirely, but should complement them. It is the trainer's role and responsibility to select and facilitate the most appropriate combination of teaching methods to effectively allow the learners to gain the knowledge, skills and competences defined in the learning outcomes. Figure 19 gives an overview of direct and indirect training methods that can be adopted, depending on the training content and the type of learners in the class.

The GIZ Lehrbrief 3 publication on *Innovative and participative learning-teaching approaches within a project based training framework* is a good resource for further information (Tippelt and Amorós, 2011).

Training qualification

The qualification level at which the training programme is set will depend on the entry level of the target group, the programme duration, and on the learning outcomes (defined in terms of the skills, knowledge and competences which the learner should gain).

FIGURE 19: Direct and indirect training methods for different learners



Source: Adapted from Tippelt and Amorós (2011)

» Training entry level

A common framework helps to define entry level requirements. The European Qualifications Framework provides a standard that is widely used and referenced across EU Member States and other parts of the world. The framework has 8 levels covering all types of qualifications, ranging from those acquired at the end of compulsory education (Level 1) to the highest qualifications such as Doctorate (Level 8). The framework is focused on learning outcomes and the learner's actual knowledge, skills and competences, rather than on the amount of study needed to complete the training programme.

» Training course duration

The training course duration will depend on the content imparted and on the availability of the target group. It may be necessary or desirable to split a training programme into a series of learning units to make attendance more manageable for learners. For example, a training programme might be split to take place over a series of five weekends. The successful completion of each weekend will earn the learner 1 credit point. At the end of the training programme, the learner will have therefore earned 5 credit points and will thus be eligible to receive the qualification. This modular approach to training delivery allows for greater flexibility, both for the learner who can choose exactly the combination of learning units they want to complete, and also for the TVET provider who can offer different combinations of units depending on demand.

Online learning is another option - the training programme developer will define the length of time that each unit of learning should take, but students can decide on the amount of time that they invest.

» Training qualification level

As previously shown, the target group profiling defines the typical qualification level of a particular target group. For example, the entry level for programmes to become electricians must be set according to the prevailing skills qualification framework, if existing. If a training need is identified for those with lower or no relevant qualifications, then the existing training programme will either need to be adapted or an entirely new training programme will need to be developed.

The level of a training programme can be reduced by:

→ Reducing the number of learning modules
→ Removing complex elements of modules

The level of a training programme can be increased by:

→ Adding modules relating to additional tasks
→ Adding modules relating to management tasks
→ Adding modules relating to increased technical specializations

Providing training equipment and tools

The simulation of real-life tasks regarding PV equipment, tools and instruments is vital to the success of the TVET training programme. The assembly of equipment, testing and commissioning, among other tasks, must be learnt by doing. Extra flexibility can be achieved by making the training equipment transportable so that practical training can take place at different locations.

Using the example of PV technology, the following kinds of equipment and tools should be available at the TVET training location:

1 **Stationary knockdown PV systems**[5], including all required tools and instruments. Provided in grid and off-grid variations.

2 **Mobile knockdown flat roof PV arrays**, 1.5 kilowatt-peak for installation and testing simulation. These mobile units can be transported to locations away from the TVET facility. Provided in grid-tied and off-grid variations.

3 **Indoor installation training workstations** represent parts or sub-systems of PV systems for simulating selected installation tasks. For example, wiring combiner boxes, learning the termination of cables, and grounding set installation.

4 **Training kits to teach the fundamentals of PV technologies**, such as shading, orientation, inclination, and series and parallel connection.

5 **All instruments, tools and consumables** needed to perform installation, measurement and testing exercises (for stationary and mobile use).

6 **Other** equipment:

→ Personal protective equipment (hard hats, harnesses, safety goggles and gloves)
→ PV modules for inspection and measurement exercises
→ Instruments for shading analysis

7 **Laptops and software licenses** (for example, simulation software PVsyst)

5 A knockdown system is a system that can be completely built up during a training course and dismantled again afterwards for the next training session. It should also allow for the training of testing and commissioning procedures.

Training of trainers

In an emerging renewable energy market, there will inevitably be a significant deficit in competent personnel to conduct training courses. There will therefore be a need for train-the-trainer programmes so that trainers are:

- » Technically competent in the relevant task areas
- » Knowledgeable about the relevant codes of practice
- » Didactically competent to train the target group

Ideal candidates from training should have the:

- » Appropriate educational background
- » Experience in the relevant field
- » Licenses or certifications to responsibly guide trainees through potentially dangerous tasks
- » Experience in teaching

The team responsible for conducting the training should cover all responsibilities. Master trainers should have extensive experience and should be licensed or certified to perform certain tasks (for example, connecting a PV system to the grid). Master trainers will be responsible for the implementation of defined training subjects and for the safety when implementing a course module. Instructors are comparatively less experienced but have sufficient knowledge and skills to deliver defined training subjects. Instructors will not be authorized to carry out potentially dangerous tasks but can assist Master trainers during such exercises.

Trainers-to-be should attend train-the-trainer workshops that serve the following objectives:

- » Transfer methodological and didactical knowledge
- » Familiarize trainers with newly available training resources, especially training equipment as well as in-class teaching and learning material
- » Transfer additional technology-specific knowledge, skills and competences
- » Select and categorize trainers into, for example, Master trainers and instructors

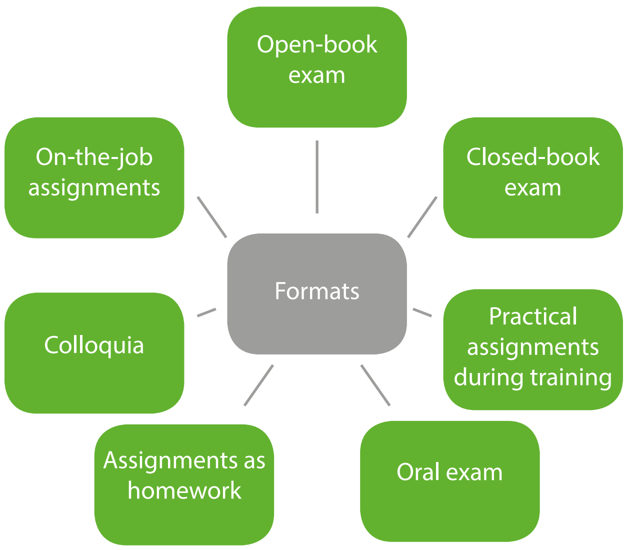
Developing examination schemes

Examinations aim to test whether a candidate has acquired the knowledge, skills and competences to achieve the learning outcomes of the course. There are different examination formats: open and closed book examinations, multiple choice tests, practical assignments during training, oral examinations, assignments as homework, or on-the-job assignments (see also Figure 20). Depending on the respective learning outcomes, these formats should be combined in a meaningful way so that a practice-oriented assessment of a learner's skills, knowledge and competences is achieved. Particular emphasis should be placed on practical examinations, since these allow for knowledge and skills to be assessed. This is especially important for TVET.

- » **Example of an examination for a practical learning module** (for example, PV system assembly): Learners could receive a list of hands-on assignments at the beginning of the course. The trainer will observe the learner while he/she performs each assignment and after successful completion will sign it off on the list.
- » **Example of an examination for a practical learning module** (for example, PV system assembly): Assessment could be in the form of an open or closed book examinations. Especially in courses that are not offered as block courses, examination formats such as homework assignments or colloquia are conceivable.

The trainer assessing practical examinations must have the requisite levels of knowledge, skills and competences.

FIGURE 20: Possible examination formats



BOX 14: Project case - Costing the integration of a solar PV curriculum in TVET

When planning to implement a new training curriculum, it is important to first understand the existing level of skills of the target group and the corresponding skills they need, including any gap in existing qualifications. This will help determine factors that may have an impact on the overall costs. Once this is factored in, consider calculating any additional or supplementary costs that may be required to be able to run the programme successfully.

If the training facility and infrastructures are already in place, the training provider is expected to add the PV element. The following elements would need to be costed:

Purchasing training equipment

- Depending on the context, considerations include transport and import fees

Installing the equipment

- Installing of prefabricated equipment
- Customizing or adapting equipment to existing infrastructure

Training of staff

- Training of teaching staff (train-the-trainer programmes)
- Training of technicians using/maintaining the equipment
- Training of administrative/marketing staff about the new programmes

Syllabus costs (including course outlines, lesson plans, in-class teaching material, and course handbook)

Administrative and marketing infrastructure to run the planned programme

- Marketing personnel
- Customer/participant relations and management personnel
- Advertising programmes and material costs

Quality assurance and maintenance of the new programme

- Equipment maintenance and updates
- Staff/personnel quality checks/re-qualifications
- Revision and updating of training syllabus elements
- Possible costs for accrediting the programme to a national/international standard

Quality assurance

The quality assurance of training programmes is performed by the TVET providers through self-evaluation. If the new training curriculum is to be recognized in the national TVET context, the TVET provider is assessed by the regulatory body at the start of implementation and then again at regular intervals, depending on the regulatory body standard of procedures. This part looks at what happens during quality assessment processes.

The level of quality of the training programme and the TVET provider can be measured against different indicators, such as examination results and feedback from learners. The assessment criteria are defined in parallel with initial training programme development.

Special emphasis is placed on efficient procedures that ensure that identified requirements for improvement are followed by actual actions:

- Trainers receive feedback on their performance and must make proposals for improvement
- Feedback on other aspects of training delivery are evaluated and suggestions for improvement made
- Trainers and industry representatives are asked to make suggestions for further improvement

The aim is to compile a binding plan that is implemented by the TVET provider.

In addition to assuring the quality of training programmes, an established quality assurance process should also be in place for the wider training curriculum, encompassing the occupational standards and the quality assurance scheme. Ideally, this is supported by a network of industry and trade bodies, technical and didactical experts, as well as TVET employees. These actors should also communicate with each other in a systematic process of continual learning, review and improvement.

Assessment criteria

Clear assessment criteria should be defined for training programmes and TVET providers. Criteria are largely defined from the training programme content and should also include requirements for trainers, training facilities, theory and practical examinations, as well as general management and administrative duties.

» Trainer requirements

Trainers should be:

- Technically competent in the relevant task areas
- Knowledgeable about relevant health and safety as well as technical standards, regulations and guidelines (the codes of practice)
- Didactically competent to train the target group

It is recommended that trainers be classified into, for example, assistant and master trainers, where an assistant trainer has enough technical and didactical experience to assist the master trainer. With continued experience, the assistant trainer should have the opportunity to undergo an assessment to graduate to master trainer.

Implementing outcome-oriented curricula depends on having well-trained trainers who apply appropriate didactical practices. Syllabi defined in terms of learning outcomes make it easier to assess the trainer's technical knowledge, skills and competences. In addition to technical expertise, a good trainer should also have a broad range of didactical tools at their disposal and should display an appropriate attitude towards supporting learners in achieving the learning goals. Trainers themselves should therefore be integrated into a cycle of continuous evaluation, learning and improvement, and should be systematically upskilled in new didactical and assessment methods (CEDEFOP, 2011).

» Facility requirements

Training provider facilities include:

- Classrooms and training laboratories fitted with required safety features
- Training kits to teach basic principles
- Models of real equipment and tools
- Knockdown systems for mounting/installation/ operation and maintenance training
- Technology-specific software used, for example, in system design

» Examination requirements

In-house practical examinations will mainly be regulated by assessment documentation that the TVET provider completes for each trainee and then submits for review to the TVET regulator (if relevant). This regulation can be supplemented by planned and random surveillance visits from an approved examiner/assessor. This should be especially considered if the training curriculum is to fit into a wider national TVET curriculum framework.

The external theory examination provides another layer of quality assurance – significant discrepancies between a trainee's practical performance and theoretical performance can be identified and addressed by the TVET regulator.

Requirements that TVET providers should meet include:

- All equipment that is needed for hands-on examinations is available
- Enough time is allocated for the completion of hands-on tasks
- Learners are given sufficient guidance and preparation time to understand how to execute the hands-on tasks
- An approved examiner supervises the completion of the tasks
- Results are documented and delivered on time to the examination board
- Examinations comply with regulations for in-house examinations

» Administrative and management requirements

Requirements include:

- Organizational, training and quality goals should be documented
- Quality management system is in place
- Records are retained (for example, complaints and appeals, contracts, internal audits, learner records)
- Systems for providing learners with organizational information and support are in place

TVET provider assessment

Once the assessment criteria have been defined, TVET providers should ensure that all their resources and facilities have been developed in accordingly. This should be done through a self-assessment by TVET providers or by the TVET regulator if the new curriculum is to fit into the wider national TVET curriculum framework. The self-assessment can be evaluated using a scoring model.

BOX 15: Example from practice: Capacity assessment of existing TVET provider

RENAC Renewable Academy AG carried out an in-depth assessment of capacities and infrastructure for renewable energy training curricula offered by a TVET provider in Indonesia. A scoring model was applied to evaluate the information obtained during the capacity assessment and to describe the initial situation (see Table 8). The scoring model took into account all areas of training curriculum development as shown in Figure 20. Each area was split into sub-elements that were weighted according to their importance.

TABLE 8: Scoring scale for the evaluation of existing capacities and resources

Score	Meaning
0	Capacity or resource non-existent
1	Capacity or resource exists only in fragments and/or substantial revision/improvement/ adaptation needed
2	Capacity or resource exists in parts and/or revision/improvement/adaptation needed
3	Capacity is available or resource is complete, but little revision/improvement/ adaptation needed
4	Capacity is available or resource is complete and ready to be deployed or used

An excerpt from the capacity assessment is provided in Table 9. The area shown is 'Training syllabi', which is part of the section on 'Training programme'. The area is further split up into elements that make up the syllabus.

Each of these elements has been given a weighting based on how important it is relative to the other elements in the area. The weighting percentages should add up to 100%. In this assessment, the learner and trainer guides were considered most important (a weighting of 20% each). Each element has also been given a score based on how available it is. Importantly, guidance notes are provided for each element on what the gap is and how it can be closed.

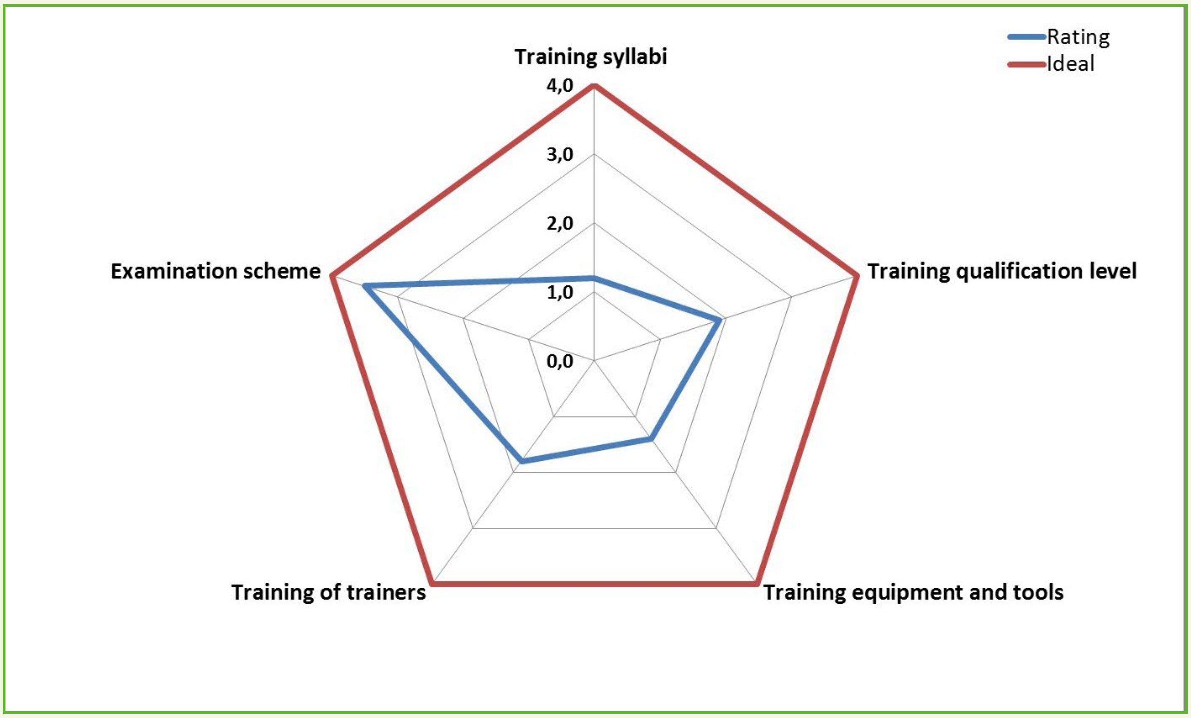
The final score is calculated by multiplying the weight and score for each element together and summing up the values. This same procedure was carried out for all the other areas with their sub-elements.

The results of the capacity assessment can be presented in the form of spider diagrams. The spider diagram in Figure 21 shows the results for all areas making up the 'Training programme'. From this, it can be seen that the TVET provider is performing well with respect to the examination scheme, but that there is room for improvement in other areas.

TABLE 9: Results of the capacity assessment for the area 'Training syllabi'

Area	Element	Capacity/resource gap; to dos	Weight	Score
Training syllabi	Course outlines	Course outlines exist but have not been formulated sufficiently, in terms of learning outcomes. Should clearly state the knowledge, skills and competences that learners will gain	15%	2
	Lesson plans	Do not exist in a detailed form	10%	1
	Lecture notes and slides	Inappropriate and take too much training time. Transfer much of this information to learner and trainer guides. Present in a way to improve information transfer to learners	15%	2
	Practical exercise instructions	Some available but could contain precise instructions for learners to work independently	5%	3
	Learner guides	Not available	20%	0
	Trainer guides	Not available	20%	0
	Teaching methods	Too much focus on PowerPoint lectures. Increase use of other hands-on or interactive methods (such as brainstorming, discussions, group and individual work) and media (flip charts, pin boards, white boards)	15%	2
	Total weighted score			1.2

FIGURE 21: Results of the capacity assessment for the area 'Training syllabi'



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ANNEX

Annex 1

Examples of practices in TVET

AIT certification in Austria

The certification scheme is managed by the Austrian Institute of Technology (AIT), a private non-profit body co-financed by the Austrian Ministry for Transport, Innovation and Technology (BMVIT), and by the Federation of Austrian Industries. As part of the EUCERT.HP (EU Certified Heat-Pump Installer) project, AIT has developed specific training courses and certification schemes for installers and planners of heat pumps (since 2005) and for installers and planners of solar thermal and PV installations (implemented in 2010).

The training programme "Certified Solar Heating Installer and Planner" and the compact course "Solar Heating Practitioner" provide students with theoretical and practical expertise needed for proper planning, assembly and installation of high-quality solar thermal systems. These courses target plumbers and fitters, planning engineers, roofers, architects, engineering firms, heating, ventilating, and air-conditioning companies and retailers. Course contents include the topics listed in Table 10.

TABLE 10: Scoring scale for the evaluation of existing capacities and resources

Certified Solar Heating Installer and Planner	Solar Heating Practitioner
» Traditional and new applications (single-family house, multi-storey buildings) » Determination of consumption, key data and efficiency » Components of solar thermal systems » Hydraulics and specifications of solar thermal systems » Building integration, dimensioning of systems and components » Installation and commissioning » Cost-effectiveness, framework conditions and subsidies	» Key components of solar systems » Determination of heat demand for water and space heating » Fundamentals of solar system hydraulics and dimensioning for single- and two-family houses » Customer handling: frequent customer questions, marketing, quotation » Installation: mounting types, materials and tools, safety at work » Installation of a model system » Commissioning and maintenance

AIT is accredited by the appropriate Austrian body and the certification process follows the ISO 17024 standard. The certificate is delivered to the installer or the planner, while the scheme also involves training, examinations and random on-site audits.

PV training in Kenya

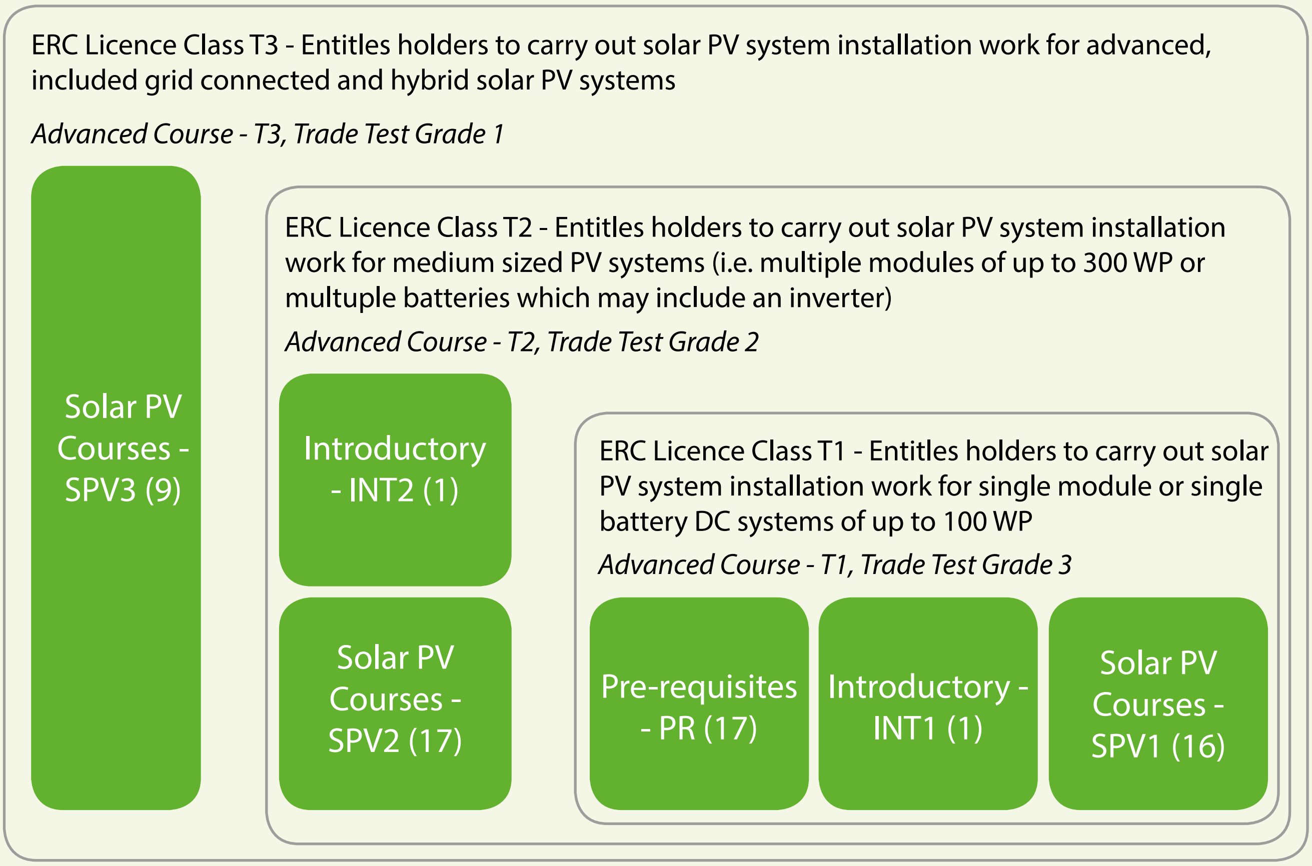
The German Solar Academy (GSA) in Nairobi was established by three companies within the framework of a public-private partnership. The GSA offered its training activities to artisans and engineers from Kenya, Tanzania and Rwanda employed in the ministries (of energy), utilities and rural electrification projects, as well as to participants from private companies. After a first phase of training, the project was discontinued as there was no link to the institutional structure of TVET and the commercial viability could not be achieved.

Since then, with strong support from the Kenyan Renewable Energy Association (KEREA), solar training has been integrated into an institutional framework, building on the needs created by the Energy (Solar Photovoltaic Systems) Regulations (2012), which introduced compulsory licensing for the following professions regarding solar PV systems: technicians (three different types of licenses); manufacturers and importers; vendors or contractors (three different types of licenses).

The 2012 regulations stipulated that only licensed technicians were allowed to design and install solar PV systems. To be licensed, technicians are required to have undertaken a solar training course allowing them to practice in one or more of the defined classes (T1, T2 and T3).

A proposal for the solar PV training curriculum has been developed and structured to meet the Energy Regulatory Commission's licensing requirements, as well as the National Industrial Training Authority's trade test guidelines and structure. The summary of the testing and licensing aspects of each class is illustrated in Figure 22.

FIGURE 22: The three classes of license for professional solar PV installations in Kenya



» T1 – the basic course – is designed on the premise that the trainee has some fundamental understanding of electrical concepts. This is therefore the first section of the curriculum, which introduces technical considerations, selection and application of components and correct procedures to be followed when designing, installing, testing and commissioning, trouble-shooting and maintaining basic solar PV systems.

» T2 – the intermediate course – builds on the courses offered at the T1 level, and introduces and develops concepts related to the installation of multiple modules and batteries, and the use of inverters in solar PV systems. It additionally goes into the relevant Kenyan policy, legal and regulatory frameworks for electrical installations as a way of proceeding to T3. The second section of the curriculum highlights the matters that have been added to the T1 course, leading up to the T2 curriculum. The advanced T3 curriculum appears in the third and final section.

» Applications to receive licensing need to be made to the Energy Regulatory Commission, which grants licenses according to minimum educational (academic) qualification and professional (job) experience, as defined in the specific energy sector.

Vocational training for solar technicians in Punjab

Pakistan's energy crisis is having a significant impact on its economy and severely affects the quality of life. It is therefore crucial to explore alternate sources of energy. Pakistan receives between 1,500 and 3,000 hours of sunshine equivalent to 1.9–2.3 megahertz per year. Considering this scenario, solar energy seems to be an appropriate solution to Pakistan's energy crisis.

The Technology Up-grade and Skill Development Company (TUSDEC) is undertaking a project to train electricians and other relevant skilled workers in solar technology. The project aims to develop well-trained and skilled technicians who are able to address the skills gap regarding solar technologies and provide professional support for the on-going efforts of the Government of Pakistan and its development partners. The project also aims to support financially vulnerable sectors of society, especially those who cannot afford such training. These training courses are therefore free of charge to semi-skilled people with limited financial means.

The current electricians and skilled workers in similar trades have very limited knowledge and skills applicable to solar technologies, and are thus not filling the training gap in the industry. According to the agreement, TUSDEC is training seventy-five trainees on solar PV systems over a one-year period. The training is being carried out in the districts of Lahore, Sheikhupura, Faisalabad, Chiniot, Sargodha, Gujranwala and Narowal. The training sessions are divided into three groups counting twenty-five trainees in each group, while the duration of each session is three months. A Memorandum of Understanding was signed with industries to support a work-based practical component of the training.

During this training, the focus is on feasibility designing, site inspections, system sizing, system installation, system handover and trouble-shooting of grid-tied systems, off-grid systems, hybrid systems, tube-well systems and lighting systems. Modules like safety and entrepreneurship are added to the training curricula to make this training more effective. TUSDEC will provide training for the trainees in its state-of-the-art high-tech solar technology laboratory.

It is expected that the project will develop skilled solar technicians who will have acquired the appropriate expertise in the installation, repair/maintenance and trouble-shooting of the solar equipment currently in use in the country. The graduates should also be able to set up workshops and service centres for solar equipment, and to run their own businesses.

Solar PV training for rural areas in Bangladesh

Energy security is a fundamental issue in Bangladesh. Gas shortages already affect industries and the size of the country's gas reserves remains uncertain. In many areas, coal, kerosene and firewood are still being used, which have significant environmental impacts and risks. The Government of Bangladesh, supported by the ILO, is working to transition sustainable and renewable energy sources. This is essential in addressing the current energy crisis; 51% of areas in Bangladesh are not connected to the national grid, which contributes to the overall reduction of poverty in the country. Solar home systems can significantly improve the living standard of rural families.

Building on the ILO Green Jobs Asia Project, the TVET Reform Project aims promote the use of renewable energy in Bangladesh by developing nationally recognized qualifications for solar home-servicing personnel. The Bangladesh Skills Development System has two components: the National Training and Vocational Qualifications Framework, and the National Skills Quality Assessment System. Together, these ensure the provision of quality, demand-based skills development in Bangladesh. The qualifications framework is a comprehensive, nationally consistent, yet flexible framework for all qualifications in TVET (see Table 11).

TABLE 11: A short description of the different levels of the National Training and Vocational Qualifications Framework

Level #	Description
Level 6	Supervisor/Middle-Level Manager Manage a team or teams in a workplace where unpredictable changes occur
Level 5	Highly Skilled Worker Take overall responsibility for completion of tasks in work or study
Level 4	Skilled Worker Take responsibility, within reason, for completion of tasks in work or study
Level 3	Semi-Skilled Worker Work under supervision with some autonomy
Level 2	Medium-Skilled Worker Work under indirect supervision in a structured context
Level 1	Basic-Skilled Worker Work under direct supervision in a structured context
Pre-Vocational Level 2	Pre-Vocational Trainee Work under direct supervision in a well-defined, structured context
Pre-Vocational Level 1	Pre-Vocational Trainee Simple work under direct supervision in a well-defined, structured context

Qualifications are defined against nationally recognized competency standards and are created by combining units of competency into groups. In collaboration with the Skills Development Project funded by the Asian Development Bank, both Level 1 and Level 2 courses have been developed which are being piloted in the mainstream vocational education and training system.

In the first phase of Green Jobs Initiatives (2008–2010), eighty-eight servicing personnel were trained in Khulna and Faridpur Technical Training Centres. In the second phase (2011–2012), an additional 1,500 servicing personnel were trained in ten locations across Bangladesh. The project involved:

» Developing standards and qualifications. Competency Standards for solar home servicing personnel at Level 1 and Level 2 were developed. These standards met industries' demands for skills while also developing qualifications that could be recognized within the new qualifications framework.

» Ensuring sustainability. Competency Skills Log Books for Level 1 and Level 2 were developed in close consultation with training providers and industry representatives. These logbooks guide trainers and learners through the skill development process, record evidence about learners' competency and ensure that trainers address all the necessary areas.

» Recognition of Prior Learning. Under the new qualifications framework, this process conducts a process that recognizes prior skills and formal qualifications so that the servicing personnel may be trained earlier than under the previous Green Jobs Initiatives programme.

The Bureau of Manpower, Employment and Training, as well as other private and public training providers are making use of the competency standards and learning resources developed to upscale training so that a greater number of people benefit across all rural areas of Bangladesh. Because of this and other actions, nearly 3.5 million solar home systems have been installed in Bangladesh.

Annex 2

Codes of practice

When compiling codes of practice, it is not necessary to develop an entirely new set of regulations. The following figure illustrates what codes of practice would be comprised of. Explanations of Areas A to G are provided in Figure 23.

Only the elements which are contained within the green circle are part of the application-specific codes of practice.

The Areas A to G are areas of regulation that are either partially or fully applicable to the relevant codes of practice. Table 12 describes these areas and illustrates them with examples from the PV sector.

The majority of the codes of practice can be taken from existing recognized regulations (for example, accident prevention regulations or general construction regulations), international technology-specific norms and standards (for example, IEC test standards for PV modules), or existing laws and directives (for example, directives on electromagnetic compatibility). Such codes of practice can of course also contain additional non-binding recommendations that can provide the impulse for further improvements in quality.

The challenges when developing these codes of practice include:

- Codifying new technology-specific regulations if these do not yet exist, or if existing regulations are not appropriate to the application or need to be adapted
- Identifying relevant regulations which define a consistent minimum standard without creating unnecessary barriers due to wrong or over-regulation
- Finding consensus across all stakeholders who may be pursuing different interests

FIGURE 23: The codes of practice are comprised of technical codes, occupational health and safety regulations, laws and directives

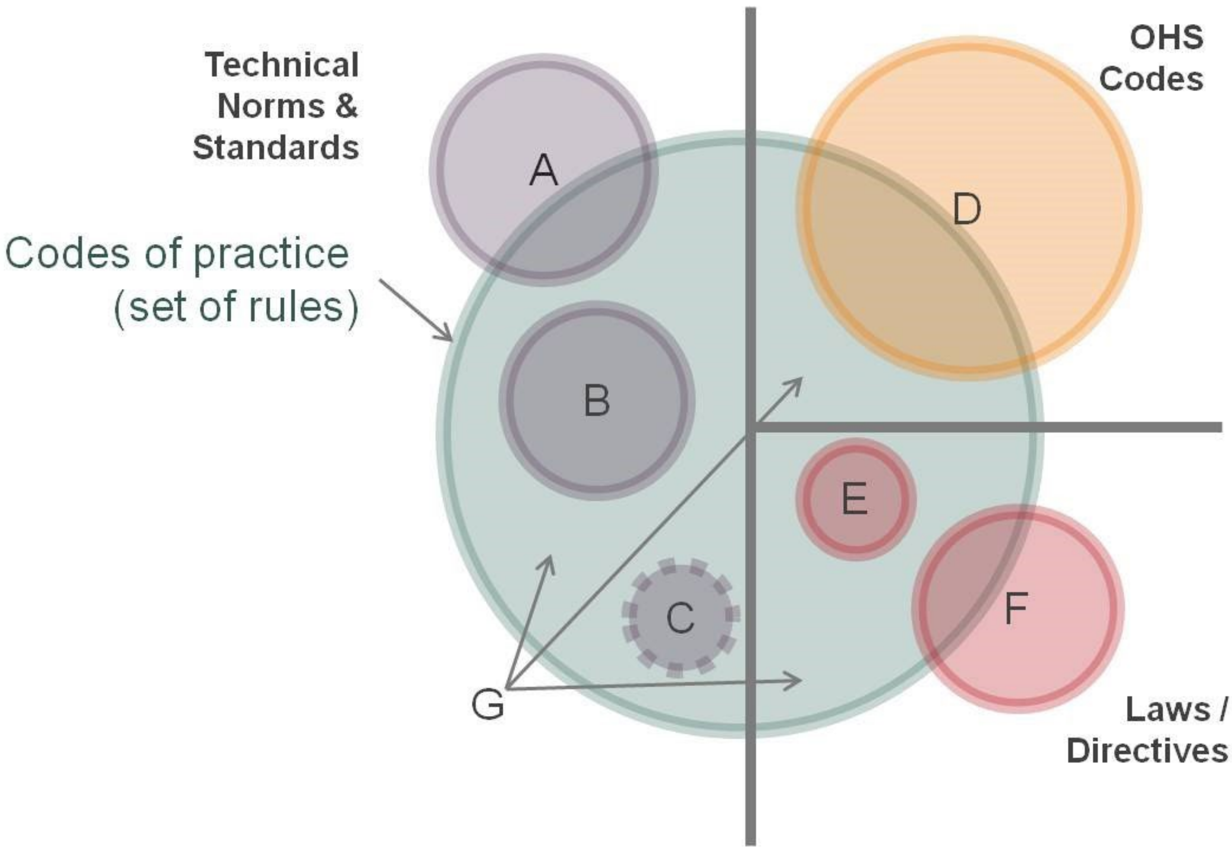


TABLE 12: Descriptions of the different areas of regulation illustrated with examples from the PV sector

Area	Description	Example from the PV sector
A	Technical norms and standards that are not application- or technology-specific but are nevertheless relevant	Regulations on protection provided by enclosures can be taken from Norm IEC 60529 (Degrees of protection provided by enclosures). The norm is not specific to the PV sector but is generally valid for the protection of enclosures.
B	Technical norms and standards that are purely application-specific	The norm on design and type approval tests of crystalline silicon modules is defined in international Norm IEC 61215. This norm is purely PV-specific.
C	Additional, non-binding recommendations	The German code of practice for obtaining the RAL solar system certification (RAL GZ 966) recommends in its set of rules for mounting systems that there should be a possibility for weather protected cable routing integrated in the mounting system. If there is no such feature, the binding rule is that there must be at least a possibility to fasten cables at the mounting system with fastening material that is weather-resistant.
D	Occupational health and safety regulations	Accident prevention regulations are typically applied for electrical and roof work in the PV sector and are included in the relevant code of practice. These regulations are universally valid and not technology-specific.
E and F	Laws and directives	PV equipment, as any other electronic equipment, can cause electro-magnetic disturbances or be disturbed by other equipment. Since such disturbances may have severe effects on other equipment (for example, the destruction of electronic equipment or failure of vital devices) the European and consequently the German legislators have released the Act on the Electromagnetic Compatibility of Equipment which also applies to PV equipment. The act refers to other norms deemed as acknowledged codes of practice. In addition to this, it also regulates penalties for non-compliance and official responsibilities.
G	Application-specific mandatory requirements that are not regulated in any other code	Shading analysis is an essential part of PV system design. Since this is a very application-specific task, there are no reference standards available. It may be advisable to include such mandatory requirements in good codes of practice based on practical experience.

Annex 3

Job Task Analysis: Planning and supervising the PV system installation process

PROCESS: SYSTEM INSTALLATION PLANNING AND SUPERVISION

Target group(s): **Electricians with solar expertise**
Engineers

Electrical Installation	
Process steps	Sub-steps
Preparing and planning electrical installation work	» Checking completeness of planning documents (including time and schedule) » Verifying sizes, ratings and locations of all electrical BOS components » Familiarizing with sub-contractors and staff on site, clarifying responsabilities » Preparing work-time plans » Organizing plans and communicating them to installation teams » Developing or reviewing and communication health and safety plans » Reviewing applicable codes and standards
Supervising, guiding and inspecting electrical installations	» Handing over and explaining plans to sub-contractors and staff » Enforcing implementation of health and safety plans » Regularly meet with sub-contractors and responsible staff; training specific tasks if needed » Verifying if delivered electrical components are compliant with specifications » Observing progress of electrical installation, reporting deviations from plan » Ensuring that all electrical BOS components are correctly stored, handled, mounted, connected, wired and labelled
Adjusting settings and ensuring proper labelling /signage	» Verifying / adjusting inverter settings according to specifications » Attaching required lables / installing signage on components and system parts
Inspecting and functional testing of installed electrical equipment, commissioning	» Visually inspecting finished work, verifying correct wiring and labelling » Inspecting and testing DC system, protection devices and AC system » Interpreting test information, identifying and resolving any issues in the PV system installation » Performing commissioning procedure according to IEC standard » Demonstrating client system functionality and procedures
Operations and maintenance documentation	» Measuring and analysing system performance and operating parameters to assess operating condition of systems or equipment » Compiling or maintaining records of system operation, performance and maintenance

Annex 4

Inventory of learning outcomes in PV system installation planning and supervision

INVENTORY OF LEARNING OUTCOMES

Module: PROCESS: SYSTEM INSTALLATION PLANNING AND SUPERVISION

Process steps	Learning sequence	Sequence of learning objectives	Relevance
Checking completeness of planning documents (including time and schedule)	Review installation planning documents	» List of required plans for electrical installation » Develop installation time schedule » Identify critical pathww » Propose measures to avoid delays	Critical
Verifying sizes, ratings and locations of all electrical BOS components	Verifying sizes, ratings and locations of all electrical BOS components	» Recognize relevant standards and codes » Compare given design and specifications with standard and code requirements » Identify any potential non-compliances in design » Propose changes to be made	Critical
Familiarizing with sub-contractors and staff on site, clarifying responsabilities	Assigning installation tasks and responsabilities	» Identify all electrical installation assignment categories (from simple none-dangerous tasks to tasks requiring experience and/or special training / certification) » Atttribute assignments to respective staff categories » Define responsabilities	Critical
Organizing plans and communicating them to installation teams	Organizing flow of planning documents	» Create a table / checkist to organize flow of planning documents	Critical
Developing or reviewing and communication health and safety plans	Ensure health and safety during construction	» List and explain all potential health and safety risks on a construction site » Assess applicable health and safety standards » Choose appropriate personal protective equipment » Explain how to use PPE » Develop appropriate signage plan » Explain standard procedures when handling electrical equipment » Identify potential PV specific health and safety risks » Identify procedures to mitigate them	Critical
	Reacting in case of emergency	» List typical accident / injuries that may occur during construction » Apply first aid procedures » Develop emergency procedures	
Verifying if delivered electrical components are compliant with specifications	Checking delivered electrical BOS components	» Develop a plan and checklist for incoming goods inspection	Critical
Ensuring that all electrical BOS components are correctly stored, handled, mounted, connected, wired and labelled	Correct storage, handling, mounting, connection, wiring and labelling of electrical components	» (Identical with learning module 'Assembly of electrical BOS components')	Critical

4 QUALITY EDUCATION

Sustainable Development Goals