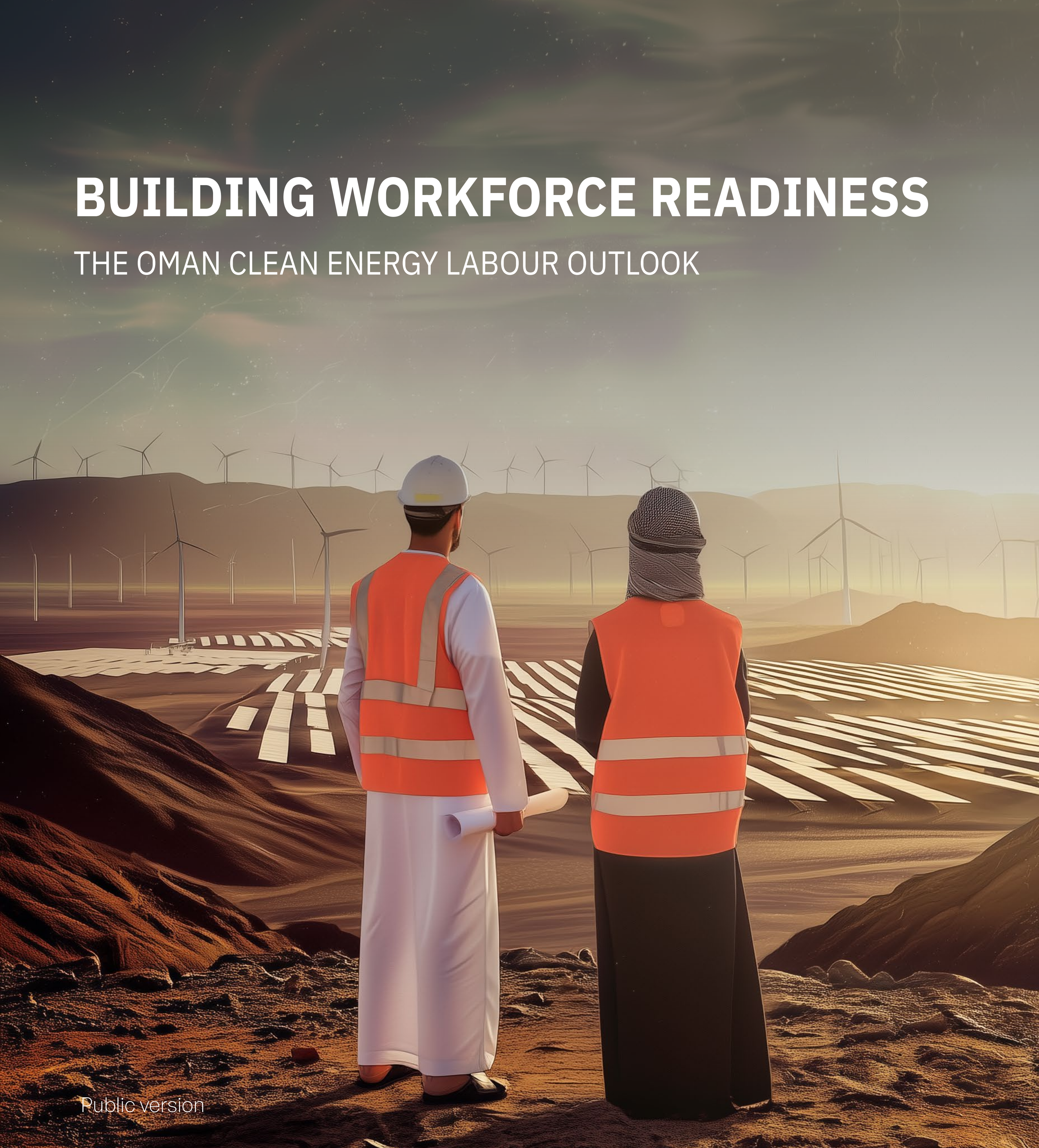
BUILDING WORKFORCE READINESS

THE OMAN CLEAN ENERGY LABOUR OUTLOOK



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QUALITY ASSURANCE & STANDARDS OF EXCELLENCE
This report has undergone a rigorous process of professional fact-checking and copy-editing to ensure the highest standards of accuracy, relevance, and clarity.

Contents

List of Figures

List of Tables

Executive Summary

THIS REPORT CONSTITUTES OMAN'S MOST COMPREHENSIVE AND FORWARD-LOOKING ASSESSMENT OF EMPLOYMENT POTENTIAL IN THE CLEAN ECONOMY TO DATE.

Developed under the Labour Market Intelligence Analysis (LMIA), it combines international benchmarks with local data and sector insights to produce robust employment projections across key green sectors. Structured in two parts, the report presents a national employment outlook using a bottom-up employment factor model, followed by sector-specific deep dives that examine value chains, occupational structures, and skill requirements. It is intended as a foundational tool for policymakers, educators, and investors seeking to align workforce development with Oman's economic diversification and net-zero commitments.

THE CLEAN ECONOMY HOLDS REAL, THOUGH NOT UNLIMITED, POTENTIAL FOR EMPLOYMENT CREATION IN OMAN. While the sector will not single-handedly resolve employment imbalances, it represents a strategic pillar for long-term job creation, skill development, and industrial diversification.

SIGNIFICANT EMPLOYMENT CAN BE GENERATED ACROSS A RANGE OF CLEAN ENERGY SCENARIOS. However, turning this potential into sustainable jobs for Omani nationals requires the right policy frameworks, sequencing, and close coordination between education, investment, and regulatory stakeholders.

SCENARIO ANALYSIS SHOWS THAT EMPLOYMENT OUTCOMES ARE HIGHLY SENSITIVE TO EXTERNAL AND STRUCTURAL FACTORS, including geopolitical developments, global climate and trade policies, market dynamics, and the sequencing and scale of domestic project rollouts.

TO SUSTAIN EMPLOYMENT AND DEVELOP A STABLE NATIONAL WORKFORCE, PROJECT DEPLOYMENT MUST BE STRATEGICALLY SEQUENCED OVER TIME. In many sectors, employment peaks early—during construction and planning—and cannot support long-term job creation unless investments are distributed predictably across multiple years.

CURRENT GREEN ENERGY SECTORS IN OMAN REMAIN THINLY STAFFED BY INTERNATIONAL STANDARDS. While this may be perceived as a sign of cost-efficiency, it also introduces operational risks and suggests that even existing projects hold unrealised employment potential.

VOCATIONAL-LEVEL LOCALISATION IN THESE SECTORS REMAINS PARTICULARLY LOW. Despite increasing demand in solar deployment, green manufacturing, and hydrogen-related activities, many roles continue to be filled by expatriates.

MOST LONG-TERM EMPLOYMENT LIES IN OPERATIONS AND MAINTENANCE (O&M), WHERE VOCATIONAL ROLES DOMINATE. This contrasts with short-term labour peaks in Project Development and Construction phases, which are harder to localise without strategic planning.

OMAN'S VOCATIONAL EDUCATION SYSTEM IS NOT YET PREPARED TO MEET DEMAND FROM CLEAN ECONOMY SECTORS. Rapid programme development, curriculum adaptation, and training infrastructure are required in sectors such as wind, solar, hydrogen, and energy efficiency.

THE SKILLS NEEDED IN GREEN SECTORS ARE NOT ENTIRELY NEW. Many are adapted from existing engineering, IT, and management profiles. Rather than launching new academic degrees, short-term certifications and targeted programme enhancements are more efficient.

OMANISATION REMAINS LOW ACROSS MANY SEGMENTS OF THE CLEAN ECONOMY VALUE CHAIN, INCLUDING MANUFACTURING, PROJECT DEVELOPMENT, AND PLANT OPERATIONS. Expatriates continue to dominate roles even in positions that could be accessible to Omanis with appropriate training and support.

UPSKILLING AND REDEPLOYMENT OF GRADUATES IN OVERSUPPLIED FIELDS OFFER A PATH TO IMPROVE EMPLOYMENT ALIGNMENT. Fields such as IT, business, and general engineering can be adapted toward green energy project management, monitoring, and system integration.

EDUCATION SYSTEMS MUST ADAPT WITHOUT OVEREXPANDING. Oman does not require entirely new university faculties to meet green sector demand—but it urgently needs better alignment, career guidance, and flexibility in responding to skill gaps.

POLICY FRAMEWORKS MUST BALANCE PROFITABILITY WITH EMPLOYMENT OUTCOMES. Even modest shifts in margin expectations—especially in capital-intensive sectors—could unlock additional job opportunities and accelerate workforce localisation.

Introduction

Employment plays a central role in shaping economic development and social cohesion. It is not only a mechanism for income generation and a driving force for well-being and prosperity, but also a critical factor for productive capacity, skills development, social welfare, and long-term planning. In the context of Oman's emerging clean economy, understanding employment dynamics is essential for aligning investment strategies, education planning, and labour market development.

This report forms part of the Oman Labour Market Intelligence Analysis (LMIA) and provides a comprehensive assessment of employment potential across key sectors in Oman's clean economy. It is structured in two main parts.

The first part presents a national employment outlook. It begins with an overview of Oman's current labour market structure and workforce composition. It then introduces the concept of employment factors—quantitative estimates of the number of jobs generated per unit of capacity investment—and provides benchmarks based on international evidence and local data.

Based on these parameters, the report applies a bottom-up modelling approach to project employment potential across key sectors. These projections are structured under multiple scenarios, reflecting alternative futures craved by different policy settings and external developments. The analysis allows for an understanding not only of how many jobs may be created, but also how employment patterns vary across sectors, technologies, and project stages. This outlook is particularly relevant for high-level stakeholders involved in investment, planning, and policy design. Insights into employment trends and occupational demand help determine which sectors to prioritise—both in terms of leveraging domestic capabilities and generating new job opportunities.

The second part of the report provides sector-specific deep dives. For each sector, the report outlines the market structure and value chain, followed by a detailed analysis of skills requirements, job roles, qualification pathways, and relevant certification frameworks. For education and training institutions, the findings offer a basis for adapting programmes to emerging skill requirements. Likewise, project developers and investors benefit from a clearer view of workforce needs when planning human resources and local talent development.

Together, these two parts offer a structured, data-driven foundation for understanding employment dynamics in Oman's clean economy—supporting both strategic decision-making and sectoral workforce planning. The report is intended to inform workforce development, policy design, and investment coordination in support of Oman's clean economy transition. While it is directed primarily at national stakeholders in labour market, education, and industrial development, it also aims to contribute to the broader international discourse on green jobs, skills systems, and sustainable economic transformation.

The sectors examined in this report were selected based on the findings of the Labour Market Intelligence Analysis (LMIA) Oman Clean Energy Strategic Outlook, as well as current policy priorities and strategic initiatives of the Omani government. They reflect areas of high relevance for future economic development and employment creation within the clean economy. While each sector differs in technological maturity, investment profile, and workforce needs, all share a central role in shaping Oman's future labour market and contribute to its social cohesion and well-being.

The scope of analysis covers six groups of sectors across clean energy production, energy efficiency, low-emission industrial manufacturing, and component production. These include:

» **Hydrogen production and infrastructure, encompassing the production, storage, transport, and distribution of hydrogen for energy and industrial applications.**

» **Solar PV development and wind power development, covering the planning, installation, maintenance, and operation of solar and wind energy systems for electricity generation.**

» **Building energy efficiency, including both digital management systems and straightforward efficiency measures to ensure more sustainable building performance.**

» **Clean steel, clean aluminium, and clean cement production, each involving the application of low-emission processes, emissions capture technologies, and renewable energy integration in traditionally high-emission sectors.**

» **Electrolyser manufacturing, which involves assembling the technical components required for hydrogen production via water electrolysis.**

» **Solar PV manufacturing and wind turbine manufacturing, covering the assembly of photovoltaic modules and wind energy systems, respectively, as part of the broader clean technology value chain.**

1 Employment outlook: The clean energy economy

This chapter examines Oman's potential for job creation in the clean energy economy and situates it within the broader context of the country's workforce. It sets out a concise framework for understanding how emerging sectors could reshape employment opportunities, drawing on evidence from both literature and local facilities.

The analysis centres on four core questions:

- **What does Oman's current workforce look like?**
- **How many jobs can be expected from investment in selected sectors?**
- **How does the existing employment in these emerging sectors compare to empirical benchmarks?**
- **How much possible employment can be anticipated under current government plans and in different future scenarios?**

First, the chapter provides an overview of Oman's workforce structure, highlighting sectoral composition and unemployment levels. Next, it introduces *employment factors*—a set of data-derived parameters that indicate how many jobs may result from each unit of capacity investment in various clean energy segments. The report then compares these estimates with observations from existing facilities in Oman to assess local conditions and identify immediate growth potential. Finally, the chapter presents a bottom-up modelling exercise that projects overall employment outcomes under prevailing policy targets and alternative scenarios, illustrating both the total job impact and the variability across different sectors.

1.1 STRUCTURE AND DYNAMICS OF THE OMANI WORKFORCE

Oman's labour market has undergone significant expansion over the past decade, fuelled in large part by a rapidly growing expatriate workforce. Despite demographic growth among Omani nationals, the proportion of expatriate workers nearly doubled from 2010 to 2024, stabilising briefly between 2016 and 2019 before rebounding to record levels in 2023 (Dashboard 1). Meanwhile, the national workforce has grown more modestly, highlighting a continuing reliance on foreign labour across key sectors.

A second notable trend is the gradual rise in female labour force participation. Although men still comprise the majority of workers (approximately seven men for every woman), female participation has increased among both nationals and expatriates. This suggests that, over time, women could become a more influential segment of the workforce. The perhaps most significant trend, however, is demography—a continuously

The composition of the workforce varies significantly by governorate. Muscat and North Al Batinah account for the largest share of the country's workforce. Muscat also has one of the highest proportions of Omani nationals, with a ratio of approximately one national for every three expatriates. Other regions show much lower national-to-expatriate ratios, in some cases approaching one to eight. In governorates such as Al-Dhahirah and South Al Batinah, a relatively high number of registered jobseekers coexists with a substantial expatriate presence, suggesting that targeted regional interventions could help support Omanisation in select areas.

The distribution of the workforce across sectors reflects a clear segmentation between national and expatriate labour, as data generated by public authorities show. Sectors such as construction, trade, and manufacturing rely predominantly on expatriate workers. In the construction sector, for instance, the number of expatriates exceeds nationals by a significant margin. By contrast, higher Omanisation rates—often above 60%—can be observed in sectors such as mining, electricity, and financial services. Other sectors, including healthcare, education, and professional services, show more mixed patterns, with moderate progress in national workforce integration.

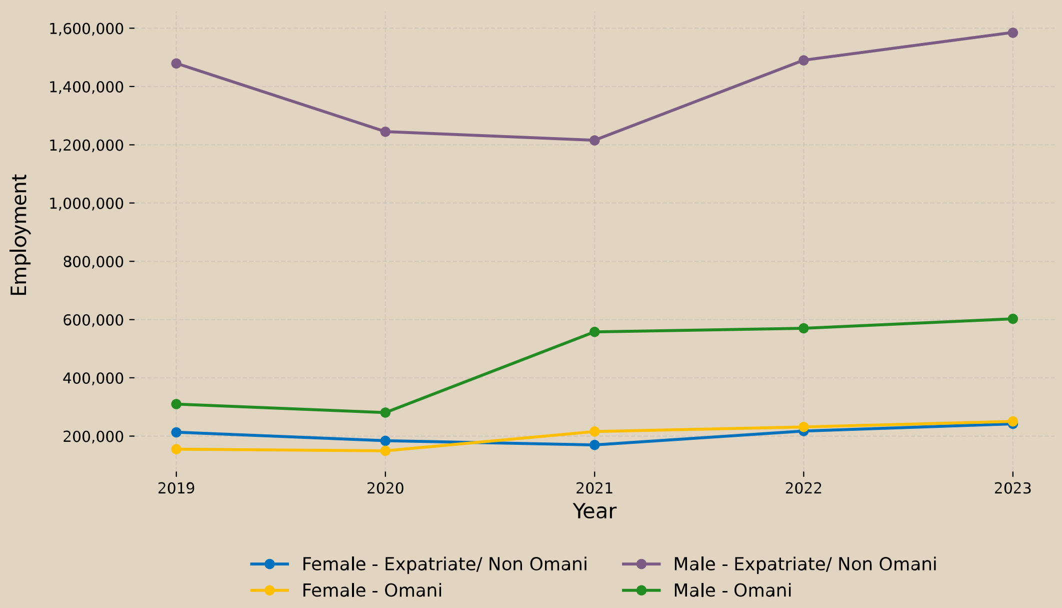
The structure of Oman's labour market broadly follows a pyramid shape, with the majority of jobs requiring lower qualification levels. These roles are largely filled by expatriates, especially in labour-intensive sectors. At the other end of the skills spectrum, many high-specialisation roles in fields such as engineering and advanced manufacturing are also held by expatriates, reflecting current gaps in national technical capacity. Omani nationals, by contrast, are more prominent in mid-level administrative, public sector, and service-oriented roles.

As educational attainment rises, so too does the representation of Omanis in the workforce. Nationals account for a growing share of positions requiring bachelor's or master's degrees, particularly in public administration, education, and finance. Expanding this trend—particularly in technical fields relevant to clean industry and energy—would support long-term efforts to align workforce capabilities with national development priorities.

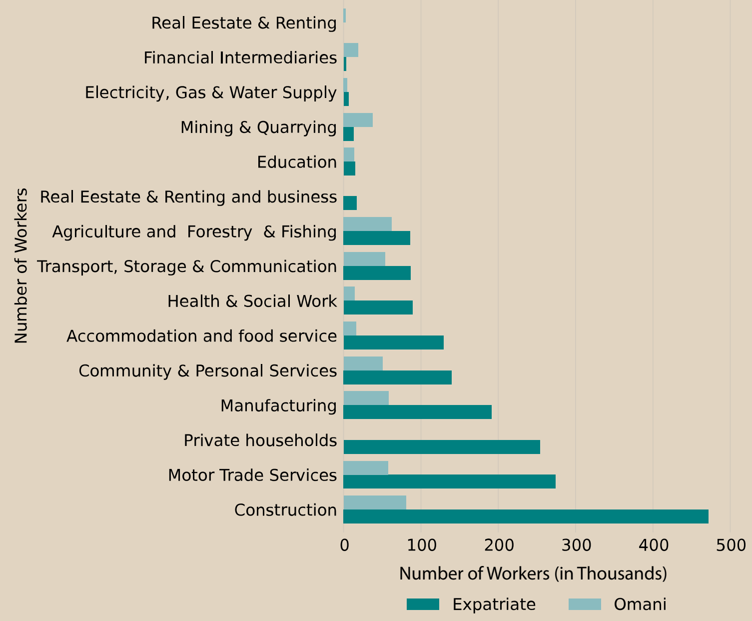
Jobseekers—especially younger cohorts—represent a significant asset for the country's evolving labour market. While integrating this group into productive employment remains a challenge, many jobseekers are recent graduates or possess mid-level qualifications that could be well aligned with emerging opportunities in clean energy, energy efficiency, green manufacturing, and related sectors. Regionally, Al Batinah South, Dhofar, and Muscat together account for more than half of the country's registered jobseekers. This concentration offers strategic entry points for targeted skills development and placement initiatives that respond to local labour supply and regional sectoral needs.

Taken together, these patterns depict a dual structure within Oman's workforce: a sizeable expatriate labour force, particularly in lower-skilled and specialised technical roles, and a growing population of national workers concentrated in administrative, public, and mid-level functions. Enhancing Omanisation will depend on strengthening the pathways into higher-skill and higher-value roles—especially in sectors central to the clean economy. At the same time, encouraging broader participation across underrepresented regions and among women will be essential to building a more inclusive, resilient labour market.

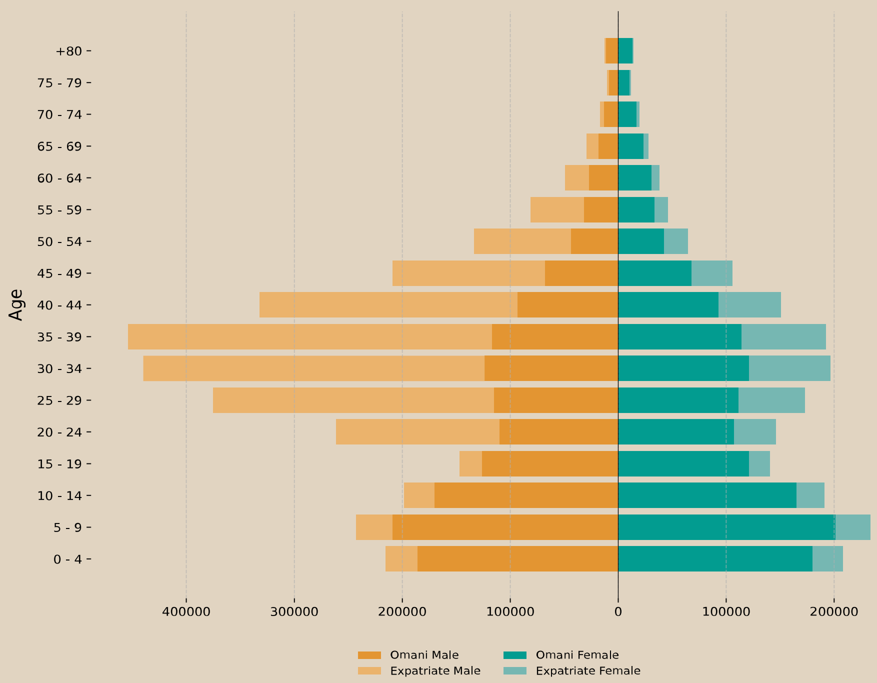
Dashboard 1: Workforce and demographics



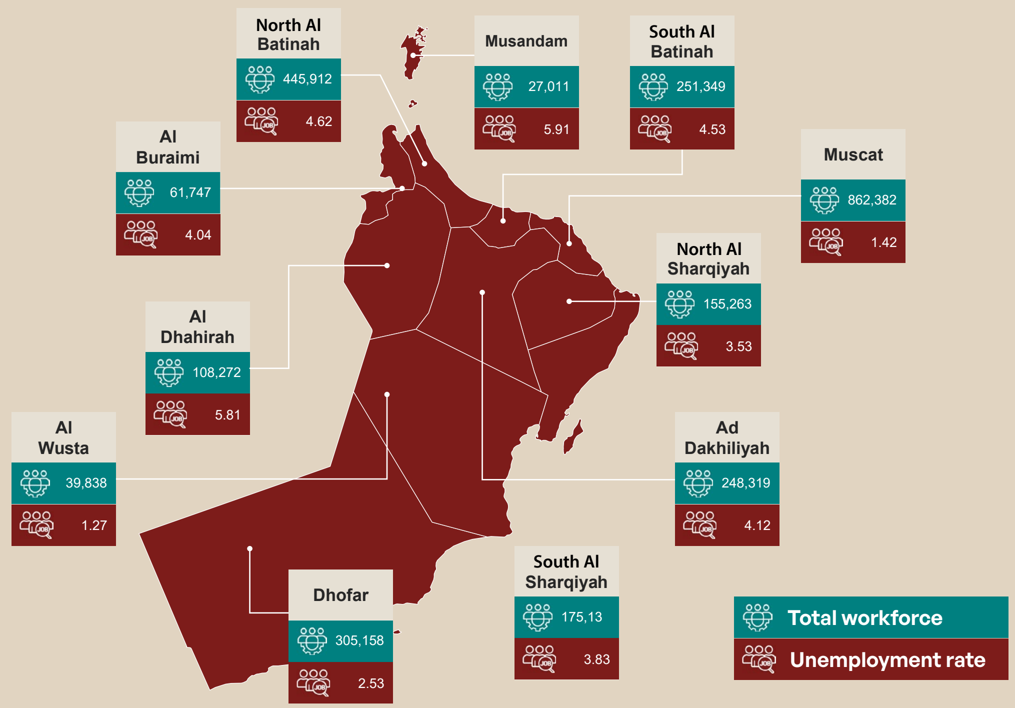
Trends in national vs. expatriate employment by gender (2019–2023)



National vs. expatriate employment per sector in 2023



National vs. expatriate population by gender (2023)



Total workforce and unemployment rate across governorates

Data: Majan Council analysis based on data from the Government of Oman

1.2 EMPLOYMENT FACTORS & SECTORAL JOB INTENSITY

Analysing data from previous and ongoing projects and facilities worldwide provides important insights into the employment potential of different sectors. These insights are commonly summarised through so-called employment factors (see Box 1 and Dashboard 2), which indicate the number of jobs associated with a given level of capacity investment in a specific sector. These factors vary considerably across sectors, reflecting differences in value chains, labour intensity, and project structures.

A defining feature of the solar PV sector is the high share of employment concentrated in the planning and construction phases. These include roles such as project developers, planners, and installation workers. In contrast, long-term employment in operations and maintenance (O&M) — such as monitoring, control, and cleaning — remains comparatively limited. The employment profile highlights a significant imbalance across project phases. For each full-time equivalent (FTE) job in operations and maintenance (O&M), approximately 19 FTE jobs are created during the planning and construction phase of utility-scale solar PV projects. On average, the development of one megawatt of solar capacity generates about seven FTE jobs during the development and construction phase, but yields fewer than 0.5 FTE jobs in long-term operations.

This imbalance between short-term and long-term employment is typical and especially pronounced in clean energy sectors. Owing to their capital-intensive nature, these sectors tend to generate the majority of jobs during the planning, construction, and installation phases, with a decline in workforce demand once projects enter the O&M stage. This results in a characteristic employment profile marked by a temporary surge—or “peak”—in job creation, followed by a significantly lower but more stable demand over the long term. Figure X illustrates this dynamic across the different project stages (Figure 1).

The development of wind power presents a more balanced distribution of employment between project development and operations, although the overall number of jobs remains lower than in the solar PV sector. On average, one megawatt of onshore wind capacity results in approximately three jobs during planning and construction, and slightly more than one-third of a full-time equivalent in operations and maintenance. This implies a ratio of roughly 10 construction-related jobs for every operations and maintenance role — a lower disparity than in solar PV, but still indicative of the dominance of short-term employment during the project implementation phase.

For both solar PV and wind power development, a variety of factors—including project conditions, geographic location, and financial parameters—influences the employment intensity. The resulting the distribution of employment factors in the survey is generally symmetric to slightly right-skewed. This indicates that, in most cases, reported employment outcomes per unit of capacity tend to fall slightly below the average, rather than above it. With the exception of solar PV construction—where job intensity is highly sensitive to factors such as local labour regulations and social standards—the distributions are relatively well-centred around the mean. This suggests a reasonable degree of confidence in the underlying estimates.

Estimating employment from the production and potential export of hydrogen and its derivatives remains challenging, given the wide range of possible sector configurations and the significant variation in employment intensity across different components of the value chain.

Based on the currently anticipated energy mix for green hydrogen production in Oman, and drawing on international employment factor surveys, the largest share of employment is expected to arise in the production of derivatives—such as ammonia—averaging more than 3,000 jobs per one million ton of annual hydrogen output. This is followed by employment associated with solar energy inputs, and to a lesser extent, wind power generation. The hydrogen production process itself—specifically the operation and maintenance of electrolysers—is estimated to generate just over 1,000 jobs per one million ton of annual hydrogen production.

Notably, employment factor estimates for both ammonia production and electrolysis display considerable variation and are strongly right skewed. This implies that while high employment numbers are possible in some cases, actual job creation in practice may fall significantly below average figures.

Energy efficiency in buildings—including activities such as energy audits, retrofitting, and the smart management of building energy systems—is associated with strong economic returns. In addition to the broader cost savings achieved through improved efficiency, the survey suggests that each million-dollar investment in this sector generates, on average, more than 10 jobs. However, given the wide range of approaches and job types involved, the actual employment impact depends heavily on the specific measures implemented. In practice, the employment effect can vary substantially—ranging from half to double the average figure. In markets with strong regulatory frameworks, there are increased opportunities for small and medium-sized enterprises (SMEs) to enter the sector, driving job creation. These regulations encourage investment in energy management systems, which in turn require a larger workforce for installation, maintenance, and monitoring. Further differences stem from the type of building.

The operation of clean steel and aluminium plants also offers significant employment potential. On average, approximately 1,600 jobs are generated per annual one million ton of steel production, and more than 3,000 jobs per annual one million ton of aluminium output. In comparison, the employment effect is lower in the cement sector, where the average stands at around 250 jobs per annual one million ton of production. While employment factor estimates for the steel sector show relatively low variation, the aluminium sector displays wide divergence, with observed figures ranging from one-third to nearly three times the average. A similar degree of uncertainty applies to clean cement production, where case-specific factors substantially influence employment outcomes.

The manufacturing of clean energy technologies—such as the assembly of electrolysers, and the production of solar panels and wind turbines—has a more noticeable employment impact compared to the operation of these facilities. Employment factors vary significantly across technologies. For electrolysers, each megawatt of assembled capacity generates, on average, approximately 0.4 full-time equivalent jobs. In the solar sector, manufacturing is associated with around eight jobs per megawatt, while wind turbine production yields more than four jobs per megawatt. These rather large effects materialise if the entire value chain is to be pursued, as each stage adds additional labour demands. However, if only partial manufacturing—e.g., assembly—is undertaken, the employment effect will be smaller.

However, these figures are highly sensitive to the scope and depth of domestic value addition. Employment outcomes differ depending on whether local activity involves basic assembly or extends to the production of key components. Moreover, these manufacturing activities are capital-intensive and require specialised technological capabilities, which are not only difficult to acquire but also demand substantial upfront investment.

The employment factors presented above serve as an international benchmark, based on scientific literature and project data from around the world. Benchmarking against this global evidence reveals that employment intensities in many Omani facilities are significantly below international averages.

Across the full solar PV value chain—from project planning to operations and maintenance—Oman’s employment levels are situated in the lowest 20 percent of the global sample. In the planning and operations phases specifically, figures fall at the very bottom of the distribution. For wind power, the pattern is less pronounced: construction employment lies below the median but remains within the upper 75 percent range, while operations and maintenance reach the top 25 percent internationally.

In contrast, employment factor estimates for ammonia production, aluminium manufacturing, and cement production in Oman also fall toward the lower or very lower end of international benchmarks.

As output levels—such as electricity generation capacity or production volumes—are held constant in these comparisons, the results point to strong labour efficiency in financial terms, suggesting that production is being achieved with comparatively low employment input. However, this also implies considerable untapped potential to increase the economic contribution of these sectors through job creation. In cases where employment intensity in Oman is substantially lower than international norms, this not only signals room for additional employment but may also highlight opportunities to improve operational outcomes. Enhancing staffing levels in certain functions—particularly in operations and maintenance—could contribute to improved system performance, including reduced downtime, higher reliability, and increased revenue stability.

Box 1: Understanding employment factors

Employment factors are a core metric used to estimate the number of jobs generated per unit of capacity investment — for example, per megawatt of installed energy capacity or per tonne of industrial output. They provide a structured means of linking investment volumes to employment outcomes, making them an essential tool for workforce planning and sectoral analysis.

Importantly, employment factors are responsive values. They vary depending on a range of factors, including project size, technology type, local labour market characteristics, site conditions, supply chain structures, and the degree of domestic value addition. As such, any meaningful assessment of employment potential must account for this inherent variability.

To reflect this complexity, the report draws on a wide-ranging review of peer-reviewed academic studies, industry analyses, and grey literature. Employment factors were compiled from multiple sources for the specific sectors analysed in this report, ensuring broad coverage and methodological robustness. In several cases, sectoral disaggregation also allowed for distinctions between different branches or project types within a given sector.

The results are presented as box plots, which illustrate not only central estimates but also the distribution and range of values across sources. This approach highlights the uncertainty inherent in employment factor estimates and provides a realistic picture of possible outcomes rather than a single deterministic figure.

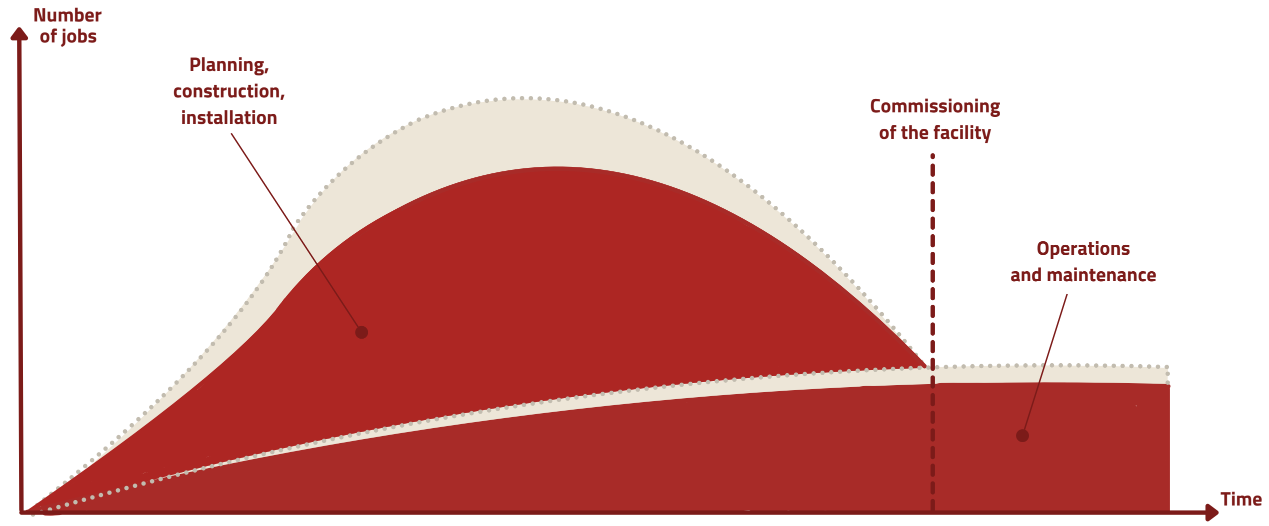
In addition to the international literature, the analysis incorporates empirical data from facilities operating in Oman. Collaborations with Omani stakeholders provided access to employment figures from existing installations, enabling a benchmarking exercise that compares local employment intensities with international reference values. This comparison offers insights into the specific conditions shaping workforce dynamics in Oman and helps to contextualise the projections presented in the report.

Jointly, this methodology provides a comprehensive and evidence-based foundation for estimating employment potential across the sectors addressed in this study.

Dashboard 2: Employment factor distribution and Omani case study

Source: Majan Council analysis based on international literature, industry cases, and data from Omani companies and public authorities

Figure 1: Schematic of employment dynamics across typical green energy project phases

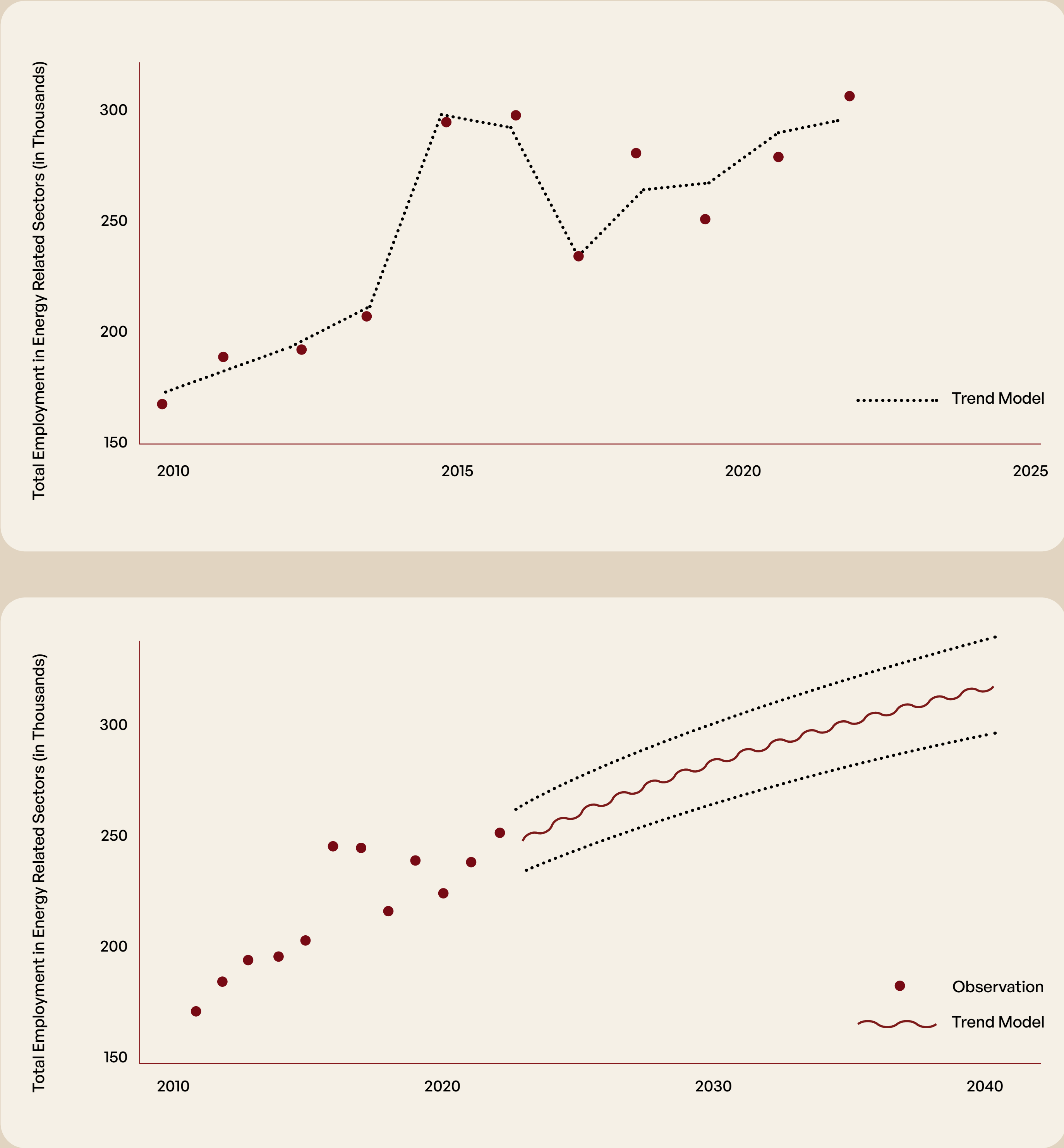


1.3 EMPLOYMENT PROJECTIONS

How many employment opportunities can be expected from the expansion of Oman's clean economy? This question is central not only for policymakers—especially in view of the country's demographic dynamics and employment targets—but also for project developers, planners, and institutions tasked with workforce development and investment planning.

The energy sector has long served as a cornerstone of Oman's labour market. Historically, it has accounted for a substantial share of the country's job creation and is expected to remain a major contributor. Projections based on a time-series model of past employment trends (see Figure 2 and Box 2) suggest that, in aggregate terms, energy-related employment may continue to grow steadily. At the same time, changes within the energy system are gradually reshaping the nature of employment: the pace of growth in oil and gas production is becoming more measured than in previous decades, and technological advances—particularly in automation and digitalisation—are enabling production with fewer on-site labour requirements. Against this backdrop, the development of clean energy sectors may increasingly complement the broader energy system's role in sustaining long-term employment growth.

Figure 2: Modelled tend and extrapolation of total employment in energy-related sectors, 2025–2040



Source: Majan Council analysis

Box 2: Autoregressive modelling of macroscopic employment trends

To establish a high-level view of employment developments in the energy sector, we estimate a time-series model using historic labour force data. Energy-related employment is constructed as an aggregate of relevant activities drawn from official labour force surveys.

The selected specification is a trend-augmented autoregressive model, designed to capture both long-term trends and short-term persistence in employment levels. It also accounts for structural changes observed in the mid-2010s. The model balances simplicity and robustness, supporting credible extrapolation:

$$E_t = \beta_1 * t + \beta_2 * t^2 + \rho * E_{t-1} + \gamma * D_{2016,2017} + \epsilon_t,$$

Here, E_t represents employment in year t, and e_t is an error term. The term is a $D_{2016,2017}$ dummy variable that captures temporary structural effects observed in the years 2016 and 2017. The model fits the historical data well, capturing a steady upward trajectory alongside year-to-year volatility. While not suited for sector-specific projections, it offers a useful macro-level perspective on how energy-related employment may evolve under a continuation of past trends.

This chapter presents employment projections across key sectors under multiple scenarios, including Oman's current policy plans and alternative development pathways. The estimates are generated using a newly developed bottom-up employment model (Box 4), which links sectoral investment volumes to labour demand over time. The model incorporates dynamic employment patterns that reflect how jobs evolve from project initiation to long-term operations.

A key component of the model is the use of a Bayesian estimation approach (Box 3) to derive employment factors. This method allows the model to draw on two sources of information: empirical data from existing and planned facilities in Oman, and a comprehensive international benchmark study based on academic and grey literature. Bayesian inference assigns weights to each data source and produces employment factor distributions with confidence intervals—capturing the inherent uncertainty in projecting labour demand in emerging sectors.

The employment factors and investment trajectories are then combined through a dynamic allocation mechanism that simulates how employment unfolds over time. This process reflects the sequencing of job creation—spanning early planning and construction, infrastructure rollout, and operations and maintenance—allowing for time-sensitive employment outlooks across a range of scenarios.

Box 3: Bayesian approach for employment factor estimation

Employment factors vary considerably across contexts—depending on labour practices, supply chain structures, technology choices, and sector maturity (see Box 1). To ensure realistic estimates for Oman's clean economy sectors, this report applies a Bayesian estimation approach that combines:

- **Local data from facilities—both planed and in operations— , capturing domestic labour structures and implementation models**
- **International benchmarks from peer-reviewed literature, grey sources, and global datasets**

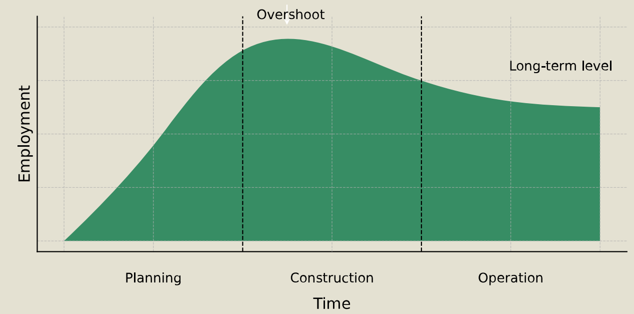
The method treats Omani data as priors—initial estimates grounded in local conditions. These are updated using international evidence, with weights based on sample strength and contextual relevance. The resulting posterior distributions reflect the weighted likelihood of employment factor values, integrating both sources. This approach is particularly valuable in sectors such as solar PV, wind power, and hydrogen, where workforce needs can diverge based on project design and supply chain maturity. It avoids over-reliance on either limited local samples or generalised global averages.

Final results are expressed as posterior distributions with 95% credible intervals, representing the range within which the true employment effect is likely to fall with 95% probability. These intervals account for both statistical uncertainty and real-world variability across projects. Bayesian updating thus produces employment factors that are statistically grounded, locally relevant, and suitable for robust scenario modelling and workforce planning.

Box 4: Modelling employment dynamics from green investments

For this employment outlook, a dynamic employment model was developed to translate capacity investments into projected job creation over time. Unlike static multipliers, this approach reflects how jobs emerge and taper across the full project lifecycle—ramping up during development and construction, peaking near completion, and stabilising into long-term operation and maintenance (O&M). This structure is critical for planning. Employment trajectories differ across sectors and depend on the timing of investment, the duration between final investment decision (FID) and commercial operation, and the intensity of labour needs across different phases. Capturing these variations allows for more realistic workforce projections—particularly in emerging sectors with complex implementation timelines.

The model maps an annual investment schedule into the number of jobs using a transition matrix , where . The matrix encodes a set of time-dependent response profiles , which determine how a unit of capacity investment initiated in year contributes to employment in year . These profiles are based on employment factors estimated through a Bayesian framework (see Box 3), combining Omani facility data with global benchmarks. They are then adjusted to reflect sector-specific dynamics—such as peak workforce requirements, lead times, and construction durations.



In sectors where even more detailed data are available, the model disaggregates employment into job roles. Each role—such as permitting, engineering, or operations—is assigned its own time structure within the project lifecycle, allowing for role-specific employment trajectories based on start dates, durations, and tapering patterns.

Box 5: Summary of LMIA scenarios

Scenarios are hypothetical, often extreme yet plausible narratives designed to stretch strategic thinking. They do not aim to predict the future or reflect government preferences, but to explore a range of potential external developments that could impact Oman's clean economy. By working with contrasting storylines, stakeholders can prepare for uncertainty, build institutional resilience, and ensure adaptability in decision-making.

The four scenarios—**Constant Current**, **Raging Storm**, **Rising Tide**, and **Shifting Winds**—form part of the *Labour Market Intelligence Analysis (LMIA) Oman Clean Energy Strategic Outlook*. They reflect external conditions to which the government and other actors may need to respond, rather than different national strategies. Together, they illustrate how global market dynamics, geopolitical changes, innovation pathways, and climate ambition could reshape clean energy deployment and employment in Oman.

Constant Current projects a future of gradual change. Fossil fuel production and prices remain stable, innovation is concentrated among a small group of global actors, and geopolitical alliances fragment. Oman faces a partially isolating environment, with tensions even within the GCC. However, a temporary closure of an important seaway disrupts regional trade and logistics, unexpectedly benefiting Oman's strategic position. In response, some industries begin relocating, strengthening the country's industrial and logistics base under competitive regional conditions.

Raging Storm depicts intensifying global and regional conflict, coupled with weak innovation. Despite a firm national commitment to climate goals, Oman struggles to access international markets and advanced technologies. This external isolation compels the country to build greater self-sufficiency, forming new alliances and investing in domestic capabilities. Over time, these constraints catalyse internal resilience, and Oman lays the foundation for a more robust, if inward-looking, economic structure.

Rising Tide envisions a world where fragmentation continues, but global cooperation increases. Innovation accelerates, climate policies gain traction, and Oman successfully leverages its oil and gas revenues to build a diversified green economy. Regional partnerships flourish, especially within the GCC, where countries co-invest in research, technology, and clean infrastructure. Oman benefits from growing international demand for hydrogen and becomes a recognised supplier of both traditional energy and advanced green technologies.

Shifting Winds follows a downturn sparked by an economic slowdown in China, Oman's largest oil buyer. The resulting depression in fossil fuel markets puts strain on the national economy. Security remains relatively stable, but global climate ambition is tempered by slow technological progress. Oman turns to domestic fossil fuels while incrementally investing in low-carbon solutions. In this environment of sluggish global demand and uneven transition, Oman emerges as a niche exporter of both clean and conventional goods, maintaining competitiveness through adaptability.

These scenarios are intended to inform foresight and planning under uncertainty. They provide a reference framework for aligning long-term education, workforce, and investment strategies with plausible external developments.
Full scenario narratives and background on the scenario development process can be found in the *LMIA Oman Clean Energy Strategic Outlook*.

1.3.1 Scenario-Based Employment Pathways

In addition to current investment trajectories, this report assesses the employment implications of four long-term foresight scenarios. Each scenario reflects a distinct combination of global economic conditions, technological developments, climate ambition, and regional collaboration. Taken together, these projections provide a structured lens through which to consider the labour market opportunities that may emerge across Oman's clean economy sectors—particularly in solar PV development, wind energy, hydrogen, energy efficiency, manufacturing, and clean goods production.

Solar PV Development

Across all but one of the four scenarios, projected employment in solar PV development exceeds the levels reflected in current investment trajectories. However, the pattern of job creation varies considerably depending on the scenario, underlining the importance of timing and project phasing.

In the **Constant Current** scenario, employment rises steadily—particularly during the early 2030s—driven by increased energy demand linked to an influx of foreign industries. While this surge stabilises later, the overall pattern supports sustained labour market activity, offering a relatively balanced employment trajectory.

The **Rising Tide** scenario shows the highest employment potential, with total solar jobs reaching around 13,000 by the late 2030s. This growth is supported by strong regional integration, high climate ambition, and financial resources enabling gigascale project implementation. However, much of this growth remains concentrated in construction activities, reinforcing the importance of long-term workforce strategies.

In the **Raging Storm** scenario, a swift push to decarbonise the power system leads to early employment gains. Still, sustaining these levels proves difficult due to constrained resources. Conversely, in the **Shifting Winds** scenario, while climate action remains limited, a baseline level of solar-related employment persists throughout the forecast period—driven by minimal but continuous domestic demand.

Wind Energy

Employment in wind energy follows a broadly similar logic. Even in more modest trajectories, job creation exceeds baseline expectations due to the inherent requirements of project development, construction, and maintenance.

In **Constant Current**, demand-side growth triggers employment gains in the early 2030s, while in **Raging Storm**, early investments lead to an initial employment spike that proves difficult to sustain without long-term support mechanisms. **Rising Tide** again shows the highest job potential, with employment in wind reaching up to 19,000 by 2040 under conditions of stable governance, strong capital flows, and regional coordination. Even **Shifting Winds** supports a modest but continuous employment baseline, suggesting that wind energy can serve as a stable—albeit smaller—pillar of the green labour market.

Hydrogen Economy

Employment in hydrogen is shaped by a distinct set of considerations. Across all scenarios, job creation depends critically on final investment decisions, which themselves hinge on offtake agreements, financing conditions, and global demand trajectories. In this context, employment potential varies widely.

In **Raging Storm**, employment in hydrogen remains limited. Fiscal constraints and weak international markets result in hydrogen being used primarily to substitute domestic feedstocks. In contrast, **Constant Current** assumes a sharp increase in hydrogen demand toward the 2040s, triggered by industrial relocation and increased local use of hydrogen derivatives.

The **Shifting Winds** scenario sees hydrogen employment emerge largely from early demand for clean goods and regional interest in hydrogen-based products, albeit without deep structural shifts. Meanwhile, **Rising Tide** projects the highest employment figures in the hydrogen sector. Under favourable financial, geopolitical, and institutional conditions, the sector becomes a major employment driver across the full value chain—from electricity generation to ammonia conversion.

Notably, across all scenarios, job growth in hydrogen occurs with a delay, given the complexity and duration of project construction. This highlights hydrogen's potential as a significant mid- to long-term employment pillar rather than a near-term source of job creation.

Building Energy Efficiency

The employment outlook for building energy efficiency and energy management systems is comparatively robust. This is largely due to the sector's inherent economic appeal: energy savings translate directly into financial returns, creating strong incentives for both private and public action.

In **Shifting Winds**, weak policy pressure results in minimal employment growth in this area. In all other scenarios, however, building energy efficiency employment rises markedly. **Constant Current** sees growth in the 2030s as industries expand. **Rising Tide** and **Raging Storm** experience on similar job growth toward 2040—both exceeding 10,000 roles—even though their motivating factors differ. In **Rising Tide**, investments are proactive and growth-oriented; in **Raging Storm**, energy efficiency is a necessary efficiency strategy under financial pressure. This convergence suggests that energy efficiency is a resilient source of employment across a broad spectrum of future conditions.

Clean Energy Manufacturing

This analysis also explores employment potential in the domestic manufacturing of solar panels, wind turbines, and electrolysers under different scenarios. Outcomes are highly sensitive to assumptions about localisation rates and export capacity.

In a 100% localisation scenario, solar and wind manufacturing could each generate a large number of jobs in the mid- to long-term, while electrolyser manufacturing would add a smaller albeit relevant number of jobs.

However, manufacturing industries of this scale require sustained demand and access to export markets to remain viable. Among the scenarios, only **Constant Current** and **Rising Tide** show positive employment trajectories in this domain. In **Rising Tide**, strong regional collaboration and a favourable investment environment enable growth beyond domestic demand. In **Constant Current**, the focus is more limited, targeting the national market, which in turn constrains the sector's employment potential. Other scenarios do not generate sufficient demand to sustain domestic manufacturing.

Clean Goods Production: Steel, Aluminium, and Cement

Finally, clean industrial production—steel, aluminium, and cement—shows differentiated employment dynamics across the scenarios.

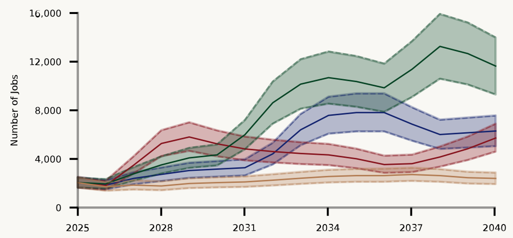
Clean steel emerges as a particularly promising sector. Scenarios such as **Shifting Winds**, **Constant Current**, and **Rising Tide** all show strong potential, with employment reaching up to 20,000 jobs in some cases. This is contingent on the emergence of carbon border mechanisms or regional carbon markets that increase demand for clean industrial products. **Raging Storm**, by contrast, struggles to generate comparable employment, as domestic demand alone proves insufficient.

Aluminium displays a broader range of uncertainty. Across all scenarios, the employment potential is lower than for clean steel, with outcomes shaped by the sector's cost structure and energy intensity. Cement, meanwhile, shows moderate but steady employment growth, with differences between scenarios largely disappearing after the construction phase.

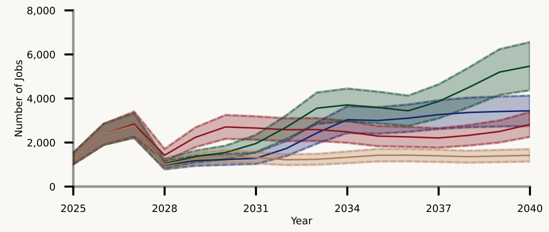
Dashboard 3: Projected employment across LMIA scenarios, 2025–2040

RENEWABLE ENERGY GENERATION

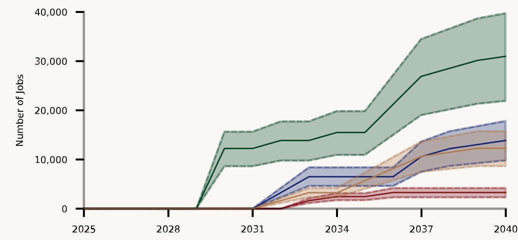
SOLAR PV



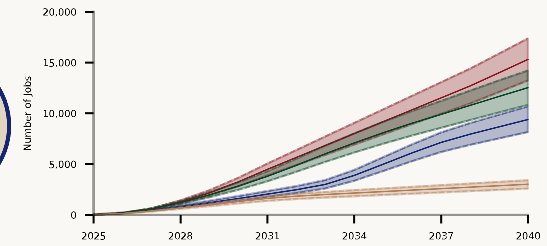
WIND



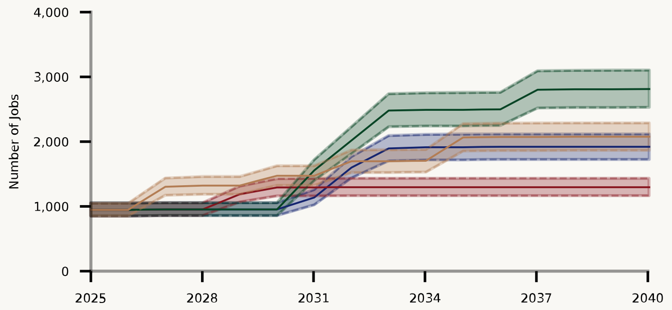
HYDROGEN



BUILDING ENERGY EFFICIENCY

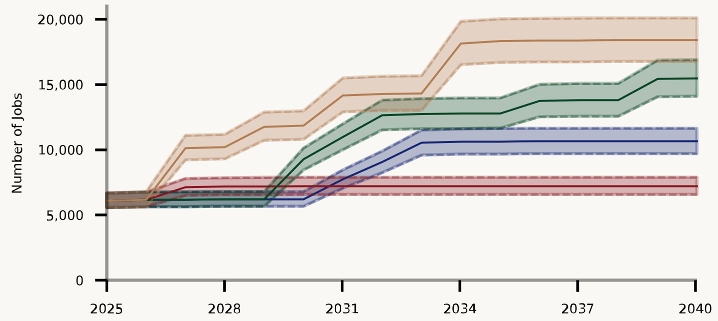


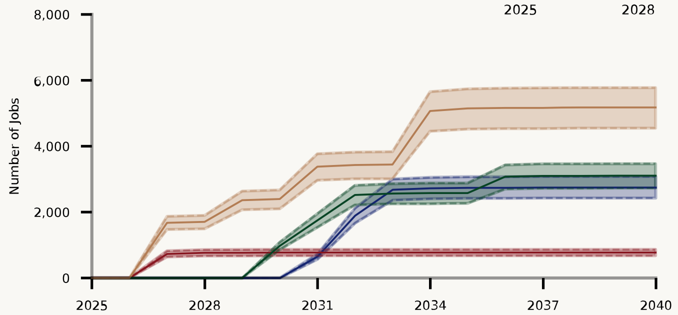
FINAL PRODUCTS



CEMENT

STEEL

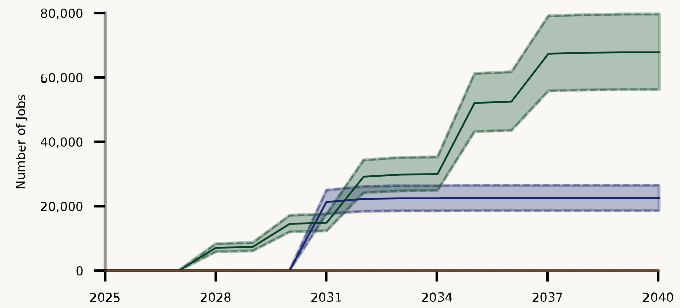




ALUMINIUM

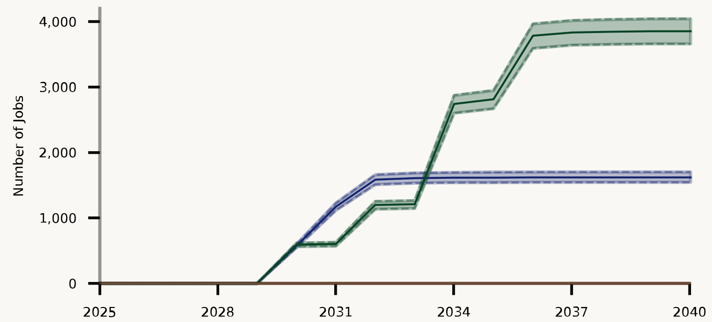
Source: Majan Council analysis

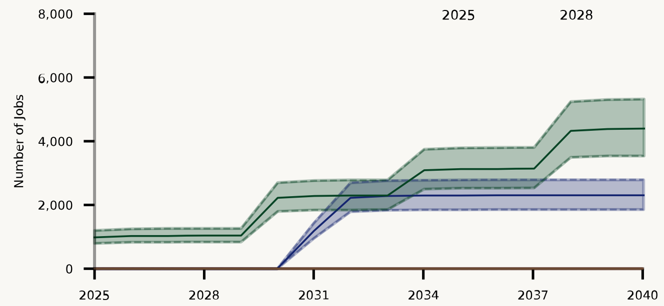
MANUFACTURING



SOLAR PV

WIND TURBINES





ELECTROLYZER

CONSTANT CURRENT | RANGING STORM | RISING TIDE | SHIFTING WINDS

2 Industry & Skills

2.1 SOLAR PV DEVELOPMENT

2.1.1 Value chain and market

Solar PV technology is the most prominent and rapidly advancing renewable energy source, offering the highest potential among all renewable technologies to address environmental challenges and growing energy demands. In 2023, approximately 345.5 GW of new solar PV capacity was added globally—the largest increase of any renewable energy source. A key advantage of solar PV is its scalability: systems can range from large utility-scale plants to smaller commercial and residential installations, allowing for flexible deployment across different settings.

Roughly half of global PV additions in 2022 came from utility-scale projects, with the rest divided between commercial and industrial (25%) and residential (23%) systems. Utility-scale refers to large, centralised installations feeding directly into the grid; commercial and industrial systems are typically mid-sized installations serving on-site energy needs in business or industrial facilities; residential systems are small-scale rooftop units installed on private homes. In many countries, high energy prices and limited availability of suitable sites for large-scale projects have contributed to increased interest in smaller, decentralised rooftop systems. This development was, in part, enabled by significant reductions in costs—which may continue to decline throughout the coming decades (Table 1).

Table 1: Cost metrics for utility-, commercial-, and residential-scale solar PV systems, 2010–2050

	Utility-scale PV				Commercial-scale PV				Residential-scale PV			
	2010	2023	2030	2050	2010	2023	2030	2050	2010	2023	2030	2050
Capacity (GW)	40.3	45	100	200	10.7	12	25	50	2	2	10	20
LCOE (US$/kWh)	0.378	0.033	0.020	0.015	0.450	0.055	0.038	0.03	0.600	0.07	0.05	0.04
Total Cost (US$/kW)	4000	900	800	600	5000	1300	1200	1000	6000	1700	1500	1200
Capex (US$/kW)	3500	750	700	500	4200	1100	1000	800	5000	1400	1300	1000
OPEX (US$/kW/year)	30	13.1	8	5	35	13.5	12	10	40	17	15	12
Investment (US$ billion)	1.0	1.8	2.0	2.5	0.6	0.9	1.0	1.2	0.4	0.7	0.8	1.0
Capacity Factor (%)	20	25	30	35	15	20	25	30	10	15	20	25
Employment Opportunities (In thousands)	100	120	150	200	50	60	80	100	20	30	40	50

Source: Historical data and projections from selected external sources, including references 2, 3, 4, 5, 6, 7 and 8

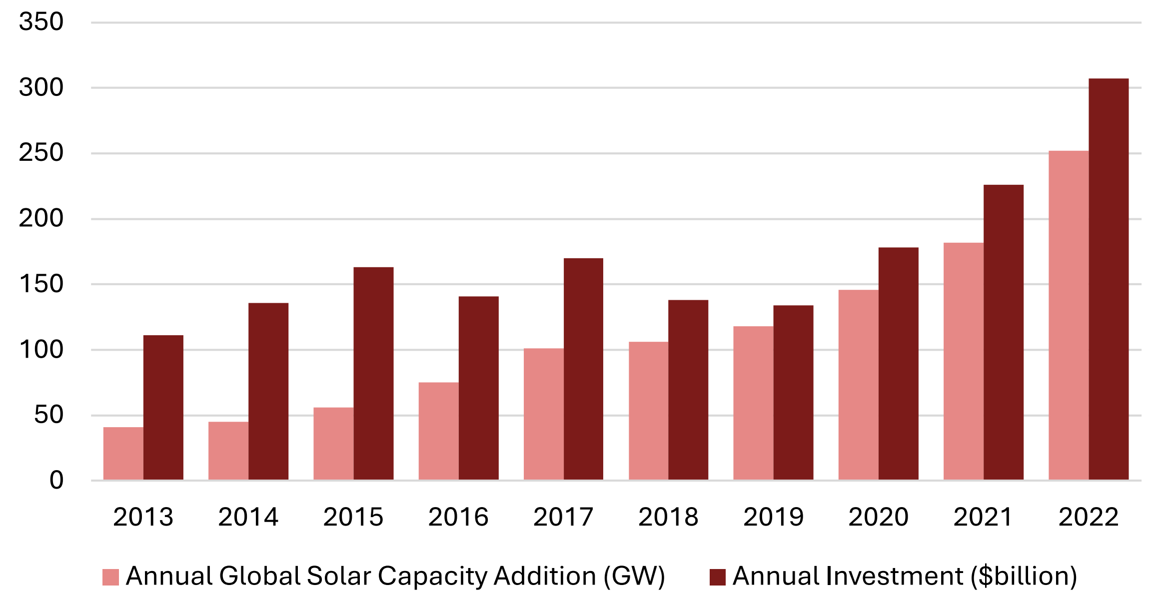
Box 6: Understanding the levelised cost of energy (LCOE)

The Levelised Cost of Energy (LCOE) is a key metric for evaluating the economic performance of energy generation technologies. It measures the average cost of producing one kilowatt-hour (kWh) of electricity over the full operational lifetime of a project, incorporating capital costs, operating expenses, and system performance.

LCOE enables a like-for-like comparison between renewable energy technologies and conventional power sources. It is widely used by investors and policymakers to assess the financial viability of projects and to inform decisions on energy planning and policy support. A lower LCOE signals greater cost competitiveness, often translating into stronger investment interest and faster market uptake.

For solar PV, the global weighted-average LCOE has declined substantially—from US$0.445/kWh in 2010 to US$0.049/kWh in 2022—making it cost-competitive with, and in many cases cheaper than, fossil fuel-based generation.

Figure 3: Annual investments and capacity additions in solar PV energy, 2013–2022



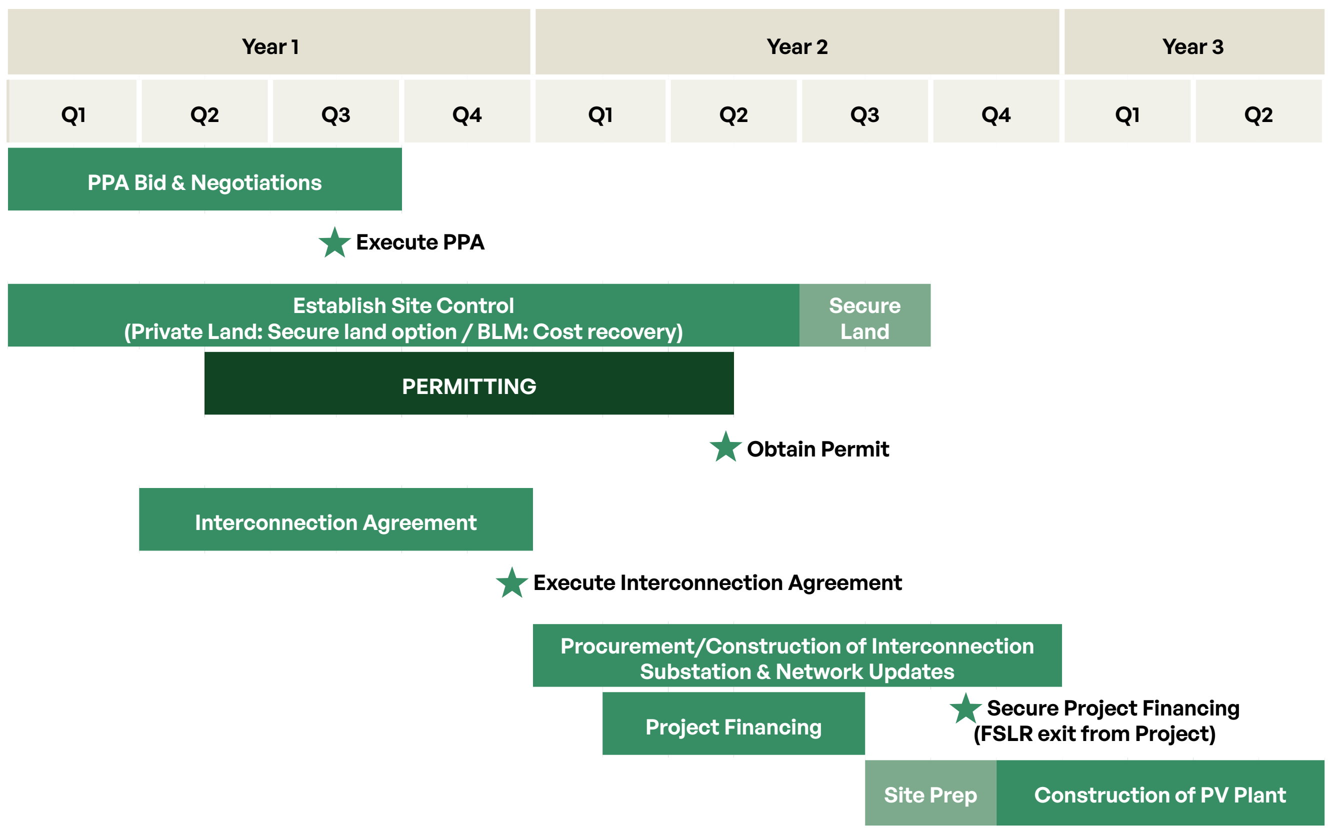
Source: Reference 3

Solar PV—across both rooftop and utility-scale applications—continues to attract the largest share of renewable energy investment. In 2022, global investment in solar energy reached over US$300 billion, representing a 36% increase compared to 2021. Meeting international climate targets will require annual investment in solar PV to rise to approximately US$333 billion by 2050—about 2.6 times the 2021 level. Projections suggest a rise in annual investment flows to around US$505 billion by 2030, with cumulative investment reaching an estimated US$10 trillion between 2030 and 2050 (Table 1). Solar PV's growing cost competitiveness, combined with policy support in many countries, continues to underpin its strong investment appeal.

The solar PV development value chain consists of four main stages, each involving distinct activities and timeframes—from initial project planning through to long-term operations (Figure 4):

- Project Planning and Development: This phase includes concept design, site selection, market assessment, permitting, and overall project development. It typically lasts between one and two years, depending on the permission process.
- Construction and Installation: Activities in this stage include project and construction management, site preparation, infrastructure development, and installation of major components such as solar panels and mounting systems. The construction phase usually spans six to twelve months.
- Grid Connection: This stage involves electrical work, cabling, grid integration, and commissioning. The duration can vary widely, ranging from several months to over a year, depending on the scale and location of the project.
- Operation and Maintenance (O&M): Once commissioned, the facility enters a long-term operational phase involving continuous monitoring, routine cleaning, repairs, and breakdown management. The O&M phase may extend up to 30 years, covering the full operational lifespan of the plant.

Figure 4: Exemplary timeline of solar PV project development

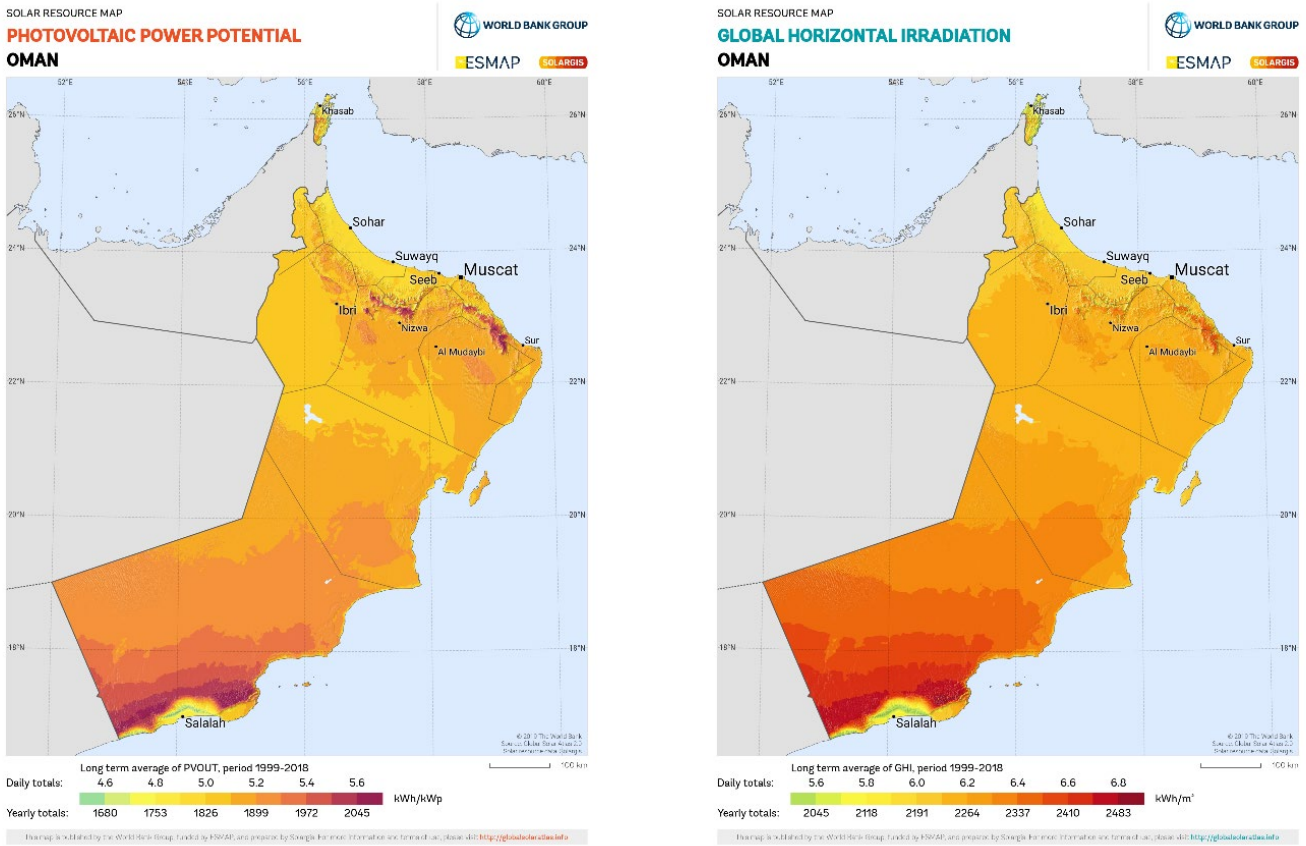


2.1.2 Solar PV Development in Oman

Oman's geographical position and climatic conditions provide a strong foundation for solar PV development. With average daily solar irradiation ranging from 6 to 6.5 kWh/m^2—equating to roughly 2,400 kWh/m^2 annually—the country ranks among the most promising locations for solar energy deployment in the region. Inland desert areas receive particularly high levels of insolation, making them suitable for large-scale utility projects.

The expansion of solar PV is expected to play a central role in Oman's future power mix and its broader clean energy strategy, including hydrogen production. Independent power projects in the solar sector are being pursued to improve energy security, rationalise consumption, and diversify the energy base.

Figure 5: Spatial distribution of photovoltaic output (left) and global horizontal irradiation (right) across Oman



Source: Solargis/Global Solar Atlas, Version 2.11

Oman has witnessed a notable expansion in small- and medium-scale solar PV deployment in recent years, supported by regulatory improvements, growing market interest, and gradual cost reductions. Solar PV plays an increasingly visible role in the country's evolving electricity mix, with policy frameworks and institutional support mechanisms helping to facilitate uptake across various segments.

Several measures have contributed to this trend:

» **Net metering**, allowing consumers to offset electricity consumption through self-generation;

» **Land allocation policies**, easing access to suitable project sites;

» A formal **regulatory framework** for grid connection and system registration, with Nama Electricity Distribution Company (NEDC) overseeing implementation and technical support, developed by Authority for Public Services Regulation (APSR)

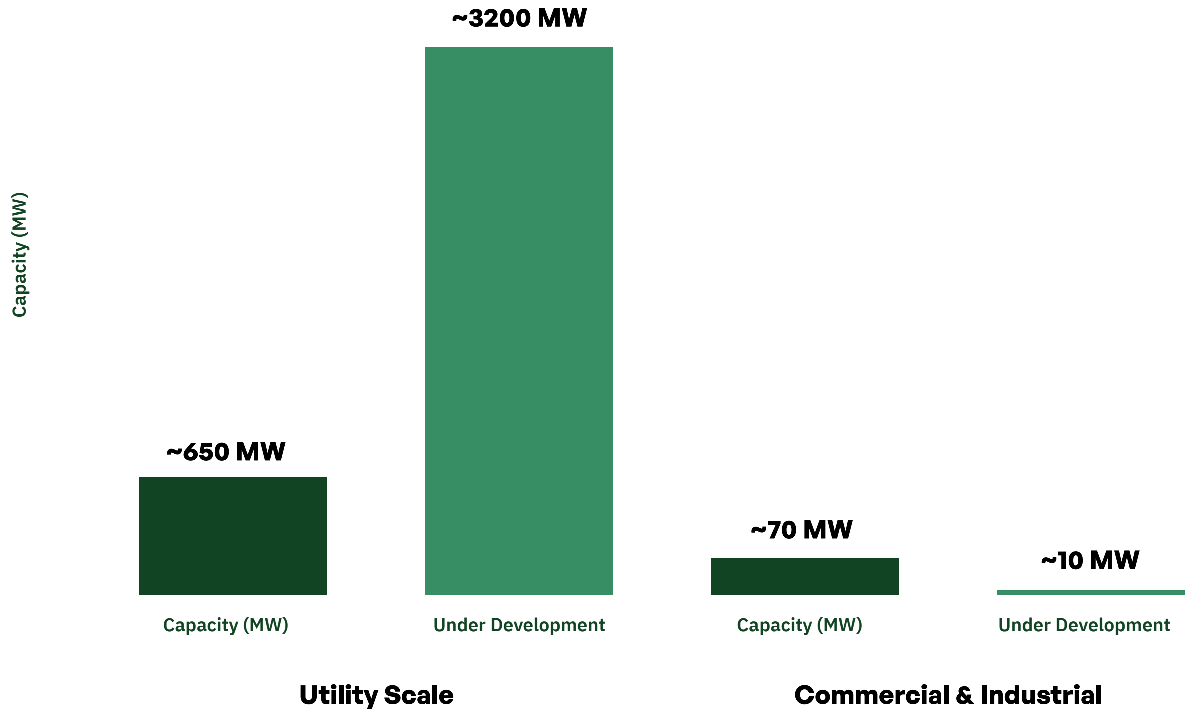
By 2022, Oman generated over 1.8 TWh from solar PV. In 2023, installation applications nearly doubled, reaching 490 across residential, commercial, governmental, and agricultural categories. Installed capacity connected to the NEDC network reached 29.65 MW in 2023 and is expected to increase to over 50 MW by the end of 2024.

Alongside distributed systems, larger PV installations are being developed, including for integration into hydrogen-related infrastructure. National planning documents outline long-term targets for renewable capacity: 16–20 GW by 2030, 65–75 GW by 2040, and 175–185 GW by 2050. Official projections suggest solar PV may account for the majority share of this buildout. Oman's power sector also aims to meet a 30% renewable energy share by 2030, a target that positions solar PV as a key technology within the national energy mix. This expansion includes both utility-scale plants and decentralised installations (Figure 6).

In addition to utility-scale projects, current plans foresee continued expansion of distributed solar PV systems, particularly in the commercial and industrial sector. The plans include integration with other renewables through hybrid systems, as well as deployment of storage solutions to manage variability and improve system efficiency.

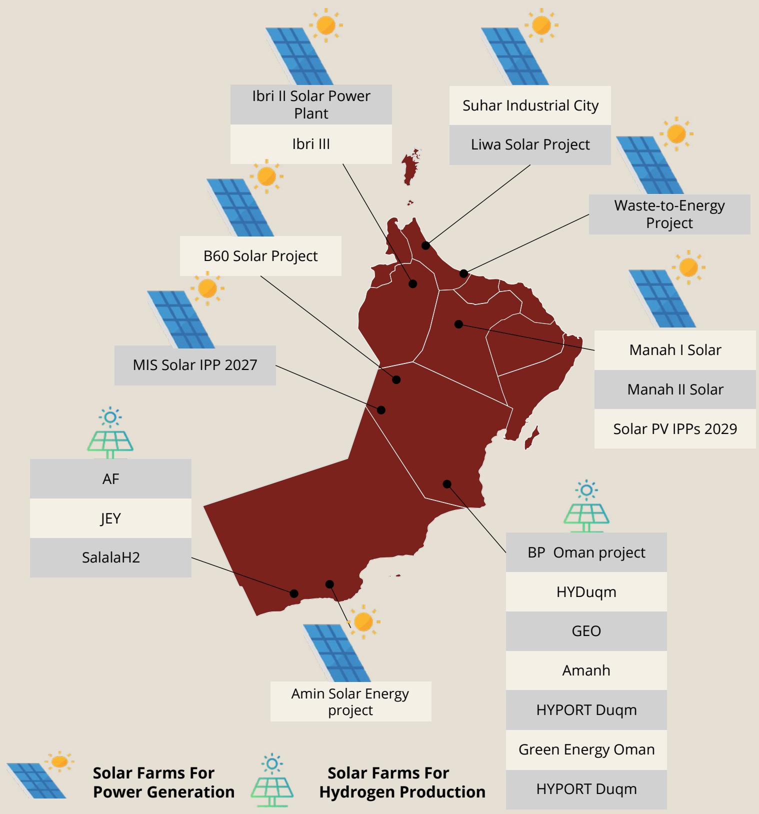
Recent assessments highlight the significant rooftop solar potential within Oman's C&I landscape. Analysis of rooftop distributions indicates that most available roof surfaces fall under 2,500 m^2, with a steep decline in frequency for larger rooftops. Despite their smaller size, these rooftops collectively represent the largest share of untapped solar potential. The findings point to a decentralised opportunity space, where smaller-scale systems could play a substantial role in supporting national targets for clean electricity deployment.

Figure 6: Comparison of operational and planned power capacities in utility-scale and commercial and industrial segments in Oman



Source: Reference 9

Figure 7: Current and planned utility-scale solar projects for power and hydrogen sectors in Oman



Source: NEDC

01 Apply for the Service
Submit an application to Mazoon Electricity Company to initiate the solar PV installation process

02 Consultation and Design
Engage an approved contractor to design the system and obtain the necessary approvals

03 Submit Initial Request
Send the approved design and required documents to Mazoon Electricity Company

04 System Installation
The contractor installs the system after receiving preliminary approval from Mazoon

05 Grid Connection Request
Request inspection and grid connection; once approved, sign the energy export agreement

06 Begin Energy Production
After connection, export electricity to the grid and receive compensation per government regulations

2.1.3 Solar PV in the GCC

The GCC countries have experienced a considerable momentum in solar PV deployment (Table 2). In 2010, solar PV capacity across the GCC stood at less than 50 MW, largely limited to pilot projects and research initiatives. By 2023, that figure had risen to approximately 5.7 GW, reflecting a major shift in energy strategies and investment priorities.

This rapid expansion is supported by renewable energy targets, job creation agendas, and industrial development policies. Saudi Arabia and the United Arab Emirates lead the region in installed capacity, with both countries investing in large-scale solar projects. In Saudi Arabia, so far, 21 solar PV projects totalling 19 GW have been awarded: 4.1 GW are operational, 8.2 GW under construction, and 7 GW approach financial closure.

Looking ahead, solar PV is expected to remain a cornerstone of renewable energy strategies across the GCC. Most countries in the region have set explicit targets for renewable energy deployment by 2030 and beyond, with solar PV accounting for a substantial share of planned capacity additions.

Favourable policy frameworks, declining technology costs, and continued infrastructure investment provide a strong basis for further expansion. As solar PV development accelerates, it is also expected to contribute to broader policy objectives—ranging from increased energy security to economic diversification. In particular, the sector offers opportunities for job creation in areas such as component manufacturing, system installation, and long-term operations and maintenance.

Table 2: Solar PV capacity in GCC countries, historical values, and projections from selected sources

Country	Capacity in 2018 (MW)	Capacity in 2024 (MW)	Capacity in 2030 (MW)
UAE	494	5,000	7,300
KSA	89	1,028	40,000
Kuwait	31	93	2,000
Sultanate of Oman	8	722	4,500
Qatar	5	1,675	2,400
Bahrain	5	200	392

Source: Multiple sources, including Oman Observer, IRENA, PV Tech, PV Magazine, Solar & Storage XTRA, Enerdata, Mordor Intelligence, MEES, Oxford Business Group, and reference 11

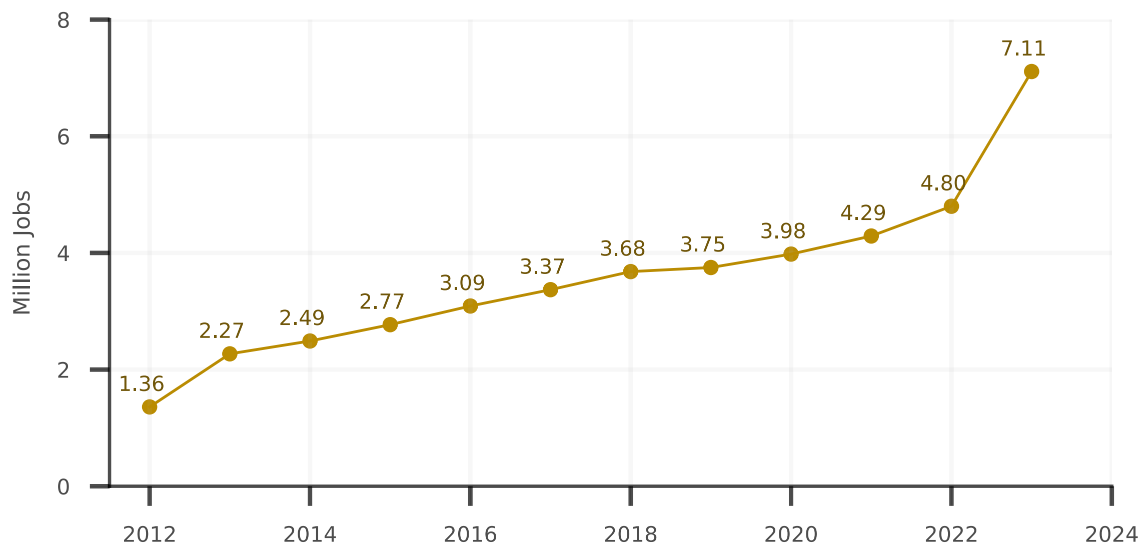
2.1.4 Occupational mapping

Among all renewable energy technologies, solar PV remains the largest source of employment. In 2023, the global solar PV sector supported approximately 7.1 million direct and indirect jobs—accounting for 44% of all employment in renewable energy (Figure 8). (This marks a substantial increase from 1.36 million jobs in 2012, underscoring the sector's rapid expansion over the past decade.

Cumulative installed solar PV capacity reached 1,047 GW by the end of 2022, with an additional 347 GW added in 2023. The corresponding growth in employment is linked to rising investments, falling technology costs, and the broader transition toward low-carbon energy systems. Notably, the increase in 2023 reflects both an acceleration in capacity deployment and the labour intensity of solar PV development.

Employment in the sector is concentrated in a handful of major economies. China accounts for 7.4 million jobs—roughly 46% of the global total—followed by the European Union (1.8 million), Brazil (1.6 million), and the United States and India (just over 1 million each).

Figure 8: Employment growth in the solar PV sector, 2012–2023



Source: Reference 12

The development of a PV solar power project consists of multiple stages, each involving a range of technical tasks and specialised sub-sectors. From site selection and permitting to installation, commissioning, and long-term operation and maintenance (O&M), each phase requires coordinated inputs from distinct occupational groups. Understanding these components is essential for assessing workforce needs and evaluating the alignment between labour market supply—such as universities and vocational training providers—and demand from project developers, investors, and contractors. Table 3 highlights key activities and related job roles and associated skill requirements.

Table 3: Key tasks and activities in solar PV project development

	Planning & Development	Construction & Installation	Operation & Maintenance
	- Concept development, feasibility studies, financing and funding arrangements, permits, and licensing - Energy yield estimates, site selection, and risk assessments **Pre-Planning** **Design & Engineering** - Specification, detailed design, and engineering of the solar plant - Energy estimates, component selection, and electrical and structural design	- Procurement, contracting, and logistics management - Site preparation, environmental mitigation, mounting structure assembly, and subsystem assembly - Grid connection, including the electrical work, cabling, "grid integration, and commissioning.	- Running and maintaining the solar power plant - Ensuring compliance with performance expectations and applicable regulations; maintenance activities
Required Job roles	Solar Project Developer, Procurement Manager, Solar PV Business Development Manager, Sales and Marketing Specialist, Solar PV Designer, Solar PV Electrical Design Engineer, CAD/Draughtsman (Mechanical/ Electrical), Solar PV Engineer, Structural Engineer, Site Surveyor, Building Inspector, Code Official with Solar Expertise, Internal Auditor, Legal Advisor, Financial Analyst, Software Developer, Environmental and Health Specialist, Battery Energy Storage System (BESS) Specialist.	Construction Manager, Grid Connection Manager, Site Manager, Safety, Health, Environment, and Security Specialist, Procurement Specialist, Solar PV Engineer (Grid Interconnection), Solar PV Engineer (HSE), Solar PV Engineer (Quality Assurance), Field Project Engineer / Site Engineer, Structural Engineer, Electrical Engineer, Civil Engineer, Energy Storage Installer, Grid and Power Systems Engineer, Control System Technician, Off-Grid Systems Technician, PV Construction Inspector, Structural Iron and Steel Worker, Mechanical Assembler, Pipefitter, Plumber, Solar PV Installer (Civil), Solar PV Installer (Electrical), Solar Service Technician, PV Construction Supervisor, Solar Construction Worker, Solar Installer, Roofer with Solar Expertise, Welder, Environmental Expert and Inspection Coordinator.	Plant General Manager, Solar Operations and Maintenance Manager, Accountant, Operations & Maintenance Technicians, Operations & Maintenance Engineer, Solar PV O&M Engineer, Solar PV Maintenance Technician (Electrical), Solar PV Maintenance Technician (Civil/Mechanical), Control Room Operators, Solar Project Helper, Solar SCADA & Automation Engineer, Electrical Engineer, Transmission & Distribution Engineer, Electrical Technicians, HVAC Technician, Health, Safety, and Environment Manager, HSE Engineer, Logistics Supervisor.

Source: Majan Council analysis

Understanding how skills and knowledge for solar PV components align with those from other industries is essential for leveraging cross-sectoral expertise and building an adaptable workforce. This alignment helps identify transferable skills, reduce training needs, and accelerate workforce readiness—particularly important as Oman scales up solar PV deployment.

Table 4 summarises the degree of skill alignment across different project phases: design and planning, construction and installation, and operation and maintenance (O&M).

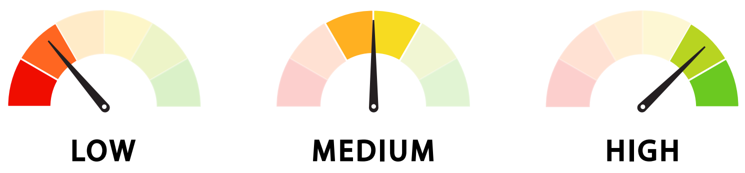
The findings suggest a mixed picture. Components such as transformers, switchgear, and protection systems show consistently high alignment with existing capabilities in electrical engineering and utilities—indicating strong potential for labour reallocation. In contrast, key technologies like solar modules, inverters, and batteries exhibit low alignment across all project phases. This reflects limited availability of transferable skills and underscores the need for targeted upskilling—particularly as energy storage and advanced control systems become more central to solar deployment.

In the construction and installation phase, many components benefit from moderate to high alignment, especially cabling and mounting structures. However, persistent gaps in battery and inverter installation signal the need for focused technical training. The pattern continues in the O&M stage, where traditional competencies suffice for some systems (e.g. transformers), but not for core PV components like modules and inverters.

Overall, while a significant share of solar PV workforce needs can be met by traditional sectors—especially electrical, power, and mechanical engineering—some areas remain structurally underprovided. Addressing these gaps through dedicated training and certification efforts will be essential to ensure that Oman's solar PV workforce can scale effectively and meet the evolving demands of the sector.

Table 4: Skill synergies between solar PV systems and the existing industrial workforce

	Solar PV Module	Inverters	Mounting and Mechanical Structures	Cabling and Wiring, Combiner and Junction Boxes (LV)	Transformers and Switchgear (HV)	Monitoring and Control Systems, Metering System	Batteries and Charge Controllers (Optional)	Protection and Earthing Systems
Design & Planning	Low	Low	Medium	Medium	High	Medium	Low	High
Construction & Installation	Medium	Medium	Medium	High	High	High	Low	Medium
Operation & Maintenance	Low	Low	Medium	High	High	Medium	Low	High

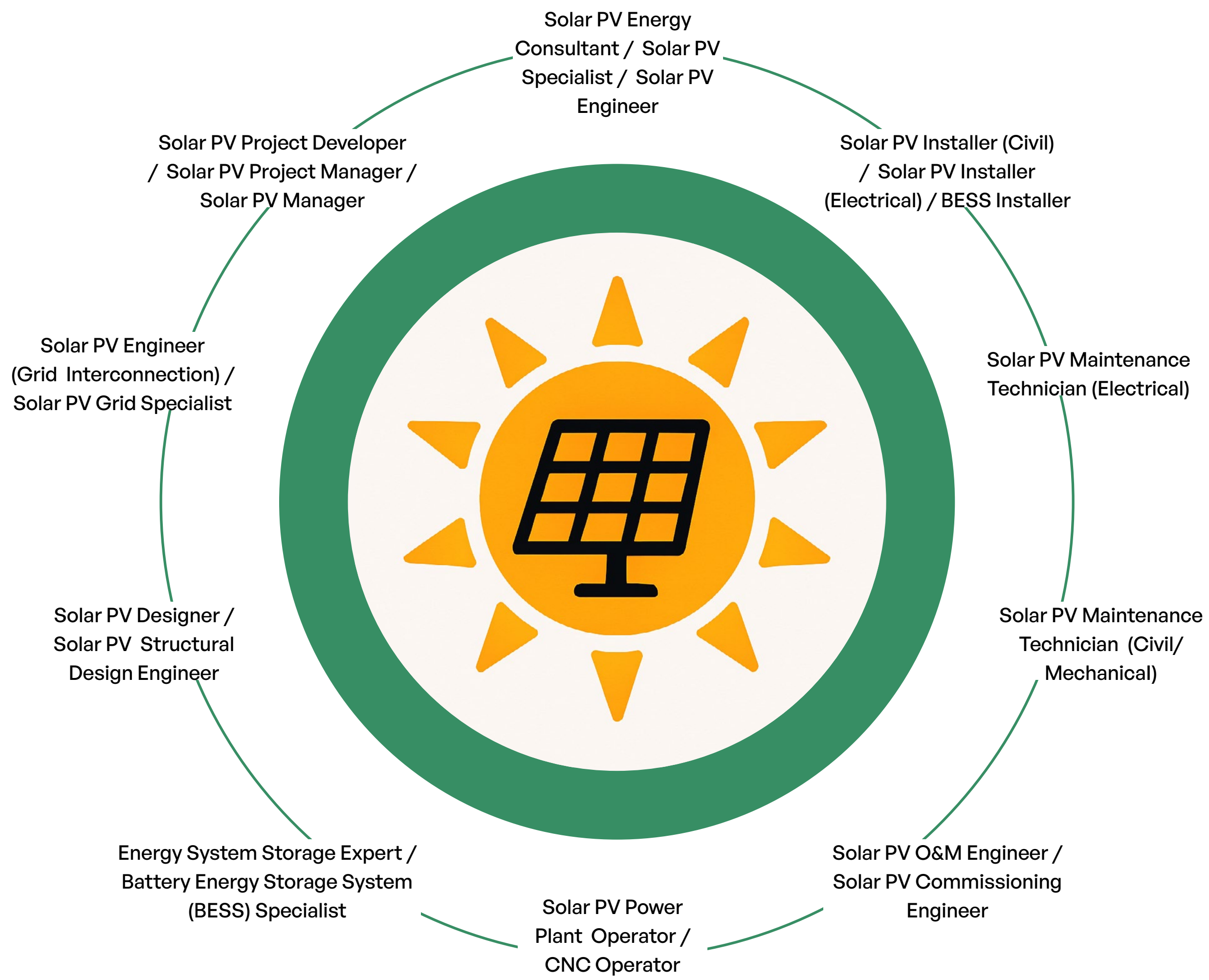


Source: Majan Council analysis

As Oman's solar PV sector expands, the demand for skilled professionals across the value chain is growing rapidly. Key roles such as Solar PV Installers and Electrical Engineers are critical for the planning, construction, and long-term operation of solar energy systems. Understanding the specific responsibilities, skill requirements, and qualification pathways associated with these positions is essential for aligning workforce development efforts with the evolving needs of the industry.

In addition to core technical roles, the solar PV sector increasingly requires specialised professionals in areas such as project management, systems integration, and storage solutions. Emerging functions include Solar PV Project Developers, Operations and Maintenance (O&M) Managers, and experts in battery storage systems—underscoring the sector's growing complexity and the need for multidisciplinary competencies.

Figure 9: Key job roles in the solar PV energy sector



Oman's workforce development strategy must therefore focus on both upskilling existing professionals and equipping new entrants with the competencies needed to fill critical gaps. This includes strengthening vocational and higher education pathways, introducing targeted certification schemes, and promoting cross-sectoral training for roles that draw from adjacent industries such as electrical, civil, and mechanical engineering.

Figure 9 provides an overview of the most relevant and emerging job roles in the solar PV sector. These range from technical specialists—such as Grid Interconnection Engineers and Maintenance Technicians—to project-focused roles like Solar PV Project Managers. The figure also reflects the increasing importance of energy storage, with dedicated roles for Battery Energy Storage System (BESS) specialists and energy systems consultants. Together, these roles illustrate the sector's transition toward more integrated and technologically advanced systems and highlight the need for a responsive and forward-looking skills development agenda.

Central occupations in the solar PV sector are defined by their technical significance, contribution to project execution, and relevance for safety and regulatory compliance. Roles that directly affect the design, construction, operation, and maintenance of solar PV systems—such as electrical, mechanical, and civil engineers, installation technicians, O&M engineers, and SCADA specialists—are considered core due to their direct impact on system performance and reliability.

Health, safety, and environmental (HSE) professionals, as well as quality assurance specialists, are also critical, as they ensure that systems meet regulatory standards and maintain long-term operational integrity.

In addition, project management roles—including procurement, logistics coordination, and O&M management—are vital for aligning execution timelines with technical and financial plans. These functions are essential to ensuring that solar PV projects proceed efficiently, remain within budget, and meet technical specifications.

The educational and training requirements for these occupations vary. Vocational or technical certifications are typically sufficient for installation and technician roles, while engineering, compliance, and managerial functions generally require a university degree and relevant sector-specific training. Specialised expertise in areas such as solar system design, energy storage integration, and grid interconnection is often developed through targeted certifications and on-the-job experience.

To support workforce development and skills alignment, the core competencies required across job roles in the solar PV sector have been identified. These include academic qualifications, sub-specialisations, relevant certifications, and key occupational tasks, with a focus on ensuring alignment with sectoral demands. Selected findings are presented in Table 5.

Box 7: Online Occupational Mapping Tool for Green Jobs

Preparing a workforce for the green economy requires coordinated planning across sectors. To support this, the LMIA project has developed an interactive, user-friendly, and online-accessible database that maps job roles, occupations, and required skills across key green sectors.

This tool captures the occupational mapping conducted during the project, providing detailed information on sector-specific jobs, associated qualifications, and skill requirements. It supports sectoral planning, highlights workforce gaps, and informs upskilling and reskilling strategies for both jobseekers and the current workforce.

A core feature is the use of automated algorithms to identify career transition pathways. With a single click, users can explore how existing skills align with other occupations, simplifying workforce development planning. The platform offers an intuitive, accessible overview of key roles, enabling decision-makers to quickly grasp workforce dynamics in emerging green sectors.

LOW – SKILL GAP
Minimal task changes are required, though some additional domain knowledge may be necessary.

MEDIUM – SKILL GAP
Some new responsibilities are introduced, and upskilling or reskilling is needed to handle these new tasks.

HIGH – SKILL GAP
Significant new responsibilities and unfamiliar areas of expertise are introduced, requiring substantial upskilling or reskilling.

Table 5: Key job roles and upskilling opportunities in the solar PV sector

Job Roles	Description	Required Education	Skills	Level of Skill Gap
Solar PV Business Development Executive / Solar PV Project Developer	Responsible for identifying new opportunities, developing solar PV projects from concept to completion, and managing stakeholder relationships to ensure project viability and profitability in the solar energy sector.	MSc/BSc in Business Administration/ Economics	• Leading large-scale solar energy project development from conception to completion • Managing project lifecycles using MS Project and Office Suite • Creating business models and financial plans specific to PV projects • Applying GIS and ArcGIS for surveying and data analysis • Financing PV projects and conducting feasibility analyses • Knowledge of renewable energy, PV system design, and energy regulations • Proficiency in surveying systems and GIS • Project management and financial modelling	MEDIUM
Solar PV Designer (Civil) & (Electrical) / Solar PV Structural Design Engineer	Responsible for creating detailed designs and specifications for civil, electrical, and structural components of solar PV systems, ensuring safety, efficiency, and regulatory compliance.	BSc / Vocational Diploma/ Vocational Certificate in • Civil Engineering / Structural Engineering (Civil &Structural) Electrical -Engineering / Renewable Energy Engineering (Electrical)	• Expertise in solar PV system layout and optimisation • Structural design and analysis for mounting systems • Electrical circuit design and grid integration • Proficient in AutoCAD, PVSyst, Helioscope, Homer • GIS tools for site analysis (ArcGIS, AutoCAD Map 3D) • Familiar with MS Office Suite and Adobe for project planning	HIGH
Electrical Engineer	Responsible for designing, installing, and maintaining electrical systems to ensure safe, efficient integration of solar PV installations with the grid.	BSc / Advanced Diploma Electrical Engineering / Electrical and Electronic Engineering	• Proficient in solar electrical systems and related components • Experience with instrumentation, control systems, and power conversion • Familiar with National Electrical Code and schematic diagrams • Skilled in testing, diagnostics, and troubleshooting • Knowledge of design standards and safety compliance	LOW

LOW – SKILL GAP Minimal task changes are required, though some additional domain knowledge may be necessary.

MEDIUM – SKILL GAP Some new responsibilities are introduced, and upskilling or reskilling is needed to handle these new tasks.

HIGH – SKILL GAP Significant new responsibilities and unfamiliar areas of expertise are introduced, requiring substantial upskilling or reskilling.

Job Roles	Description	Required Education	Skills	Level of Skill Gap
Procurement / Sourcing Specialist / Logistics Supervisor	Responsible for sourcing, procuring, and managing the supply chain of materials, equipment, and services to ensure timely, cost-effective acquisition and smooth project execution.	MSc/BSc in Supply chain management / Economics / Business Administration BSc /Diploma in Logistics and Supply Chain Management	• Procurement expertise: Proficient in sourcing, RFQs, contracting, supplier management, and procurement workflows • Supply chain management: Strong grasp of inventory, transportation, and logistics principles • Logistics and warehouse operations: Knowledge of standards and best practices • Software: Skilled in SAP, Passport, and eSourcing tools • Documentation and reporting: Ability to maintain procurement records and reports • Understanding of solar energy markets, distribution, and infrastructure	LOW
Mechanical Engineer / Mechanical Supervisor	Responsible for designing, installing, and supervising the maintenance of mechanical systems, such as mounting structures and cleaning systems, ensuring efficient operation, safety, and adherence to quality standards	BSc/ Diploma in Mechanical Engineering	• Strong mechanical engineering background in solar PV systems • Proficient in CAD and simulation tools for mechanical system design • Quality control and assurance for mechanical construction • Skilled in pile driving and handling heavy materials • Ability to interpret plans and manage execution on site • Hands-on installation experience with tracking and cleaning systems • Knowledge of photovoltaic technology and renewable energy systems	MEDIUM
Solar O&M Technician / Solar PV Maintenance Technician (Mechanical) & (Electrical)	Responsible for maintaining, troubleshooting, and repairing solar PV systems to ensure efficient operation, safety, and optimal performance.	Advanced Diploma / Diploma / Vocational Diploma / Certificate in Renewable Energy / Electrical Engineering / Mechanical Engineering/ Industrial Maintenance / Electrical wiring (Industrial)	• Troubleshooting and diagnostics of solar PV systems • Mechanical and electrical maintenance experience • Understanding of PV systems, medium voltage power, and energy storage • Familiarity with SCADA, HMI, PLC systems, and control software • Knowledge of electrical codes and standards • Instrumentation and controls for monitoring and performance assurance	MEDIUM

LOW – SKILL GAP Minimal task changes are required, though some additional domain knowledge may be necessary.

MEDIUM – SKILL GAP Some new responsibilities are introduced, and upskilling or reskilling is needed to handle these new tasks.

HIGH – SKILL GAP Significant new responsibilities and unfamiliar areas of expertise are introduced, requiring substantial upskilling or reskilling.

Job Roles	Description	Required Education	Skills	Level of Skill Gap
Solar PV Project Engineer / Solar PV Specialist / Consultant	Provides expert technical advice, support, and oversight throughout the planning, design, and development stages of solar PV projects, ensuring feasibility, optimization, and compliance with industry standards	BSc in Electrical Engineering / Mechanical Engineering / Renewable Energy Engineering	• Solar PV system design, layout optimisation, and compliance • Financial modelling and cost-benefit analysis • Project management across planning, budgeting, and execution • Power system modelling and performance analysis • Skilled in risk management tools (e.g., PertMSc Risk Expert, Primavera, MS Project) • Proficient in PV software tools (PVsyst, HOMER, AutoCAD, PVGIS, IV curve tracing, battery testers)	HIGH
Solar PV Installer (Civil) & (Electrical)	Responsible for installing solar panels, electrical systems, and structural components, ensuring proper setup, alignment, and connection for optimal performance and safety in solar PV projects.	Vocational Diploma / Vocational Certificate/ Certificate with High School Diploma	• PV installation practices: Skilled in installing mechanical and electrical components • Construction and engineering basics: Competent in structural and electrical work • Geotechnical and structural engineering: Proficient in foundation and rebar planning • Electrical system expertise: Understanding of modules, inverters, transformers, switchgear, and control systems • Mechanical and technical aptitude for tools and equipment used in PV installation	HIGH
Battery Energy Storage System (BESS) Specialist / Energy System Storage Expert	Responsible for designing, integrating, and optimizing battery storage solutions to enhance the efficiency, reliability, and scalability of solar energy storage and distribution systems	MSc / BSc Business Administration / Finance Electrical Engineering / Renewable Energy Engineering"	• Asset and project management for BESS and PV systems • Technical expertise in lithium, flow batteries, and system design • Installation and commissioning of solar and storage systems • Techno-economic feasibility studies and optimisation • Proficiency with PVsyst, HOMER, AutoCAD, PVGIS, power analysers, IV curve tracing, battery testing	HIGH

LOW – SKILL GAP
Minimal task changes are required, though some additional domain knowledge may be necessary.

MEDIUM – SKILL GAP
Some new responsibilities are introduced, and upskilling or reskilling is needed to handle these new tasks.

HIGH – SKILL GAP
Significant new responsibilities and unfamiliar areas of expertise are introduced, requiring substantial upskilling or reskilling.

Job Roles	Description	Required Education	Skills	Level of Skill Gap
Solar SCADA & Automation Engineer / Grid & Power Systems Engineer	Responsible for designing, implementing, and managing SCADA and automation systems for monitoring solar PV operations, while also optimizing grid and power systems to ensure effective integration and sTable distribution of solar energy to the electrical grid	MSc/ BSc in Electrical Power Engineering Electrical Engineering Control Engineering Automation and Robotics Engineering	• SCADA expertise: Skilled in Modbus, DNP3, fibre optics, and commissioning SCADA networks • Power and control system design and analysis (PSS/E, PSCAD, PowerFactory) • Integration of renewable energy into power grids (11kV–33kV+) • Renewable energy systems (BESS, PV, wind) from feasibility to specification • Knowledge of international standards and codes • Telecommunications and SATCOM for data acquisition • Grid connection and transmission planning for multiple electricity markets (e.g., ERCOT, PJM)	LOW
Quality Assurance/ Quality Control Engineer (Civil & Electrical)	Responsible for inspecting, verifying, and ensuring that all civil and electrical components, materials, and installation practices meet quality standards and project specifications to guarantee optimal performance, safety, and reliability.	BSc in Electrical Engineering / Electronic Engineering / Control Engineering / Automation and Robotics Engineering / Mechanical Engineering / Electronics and Instrumentation Engineering	• Quality control certification and industry standards compliance • Electrical and automation engineering including PLC, SCADA, and fault-finding • Process optimisation, including cybersecurity for control systems • Construction supervision and infrastructure inspection • HSE compliance and documentation of non-conformance • Knowledge of IEEE and National Electrical Code • Root cause analysis, alarms, and analytical systems	LOW
Health, Safety, and Environment Engineer/ Specialist	Responsible for developing, implementing, and enforcing safety protocols, conducting risk assessments, and ensuring compliance with health, safety, and environmental regulations to protect workers and maintain a safe project environment.	MSc/BSc in Health and Safety Management / Environmental Health and Safety	• Strong knowledge of health, safety, and environmental regulations • Certified in Occupational Health and Safety (e.g., NEBOSH) • Experience with HAZOPs, safety audits, PTW systems, and risk analysis • Quality assurance (QA/QC) within HSE frameworks • Documentation, incident reporting, and system maintenance • Skilled in Microsoft Office and report generation • Root cause analysis (e.g., TapRooT®), SHES auditing	LOW

Building on this, accredited certifications (Table 6) serve as a foundational mechanism for ensuring workforce readiness and alignment with sectoral standards. Accredited certifications are essential to building a skilled and reliable workforce for Oman's solar PV sector. By formalising the competencies required at various stages of project development, certifications help ensure that practitioners are equipped to execute their tasks safely, efficiently, and in line with international best practices. They support the sector in several key areas:

ENHANCING WORKFORCE QUALITY AND EMPLOYABILITY

Certifications provide individuals with recognised qualifications that improve their prospects of securing employment. In a specialised and technically demanding sector such as solar PV, certified professionals are more likely to contribute effectively across roles ranging from system design and installation to operations and maintenance.

IMPROVING PROJECT PERFORMANCE AND LONG-TERM VIABILITY

In the absence of structured training, early solar PV projects in many countries encountered frequent performance issues and equipment failures. Accredited certification programmes address these challenges by equipping the workforce with standardised technical knowledge and practical skills, leading to higher-quality installations and improved system reliability—an especially important factor in securing the sustainability of Oman's investments.

BOOSTING INVESTOR AND MARKET CONFIDENCE

Certifications enhance trust among investors, developers, and other stakeholders by ensuring that projects are delivered by qualified personnel. This institutional reliability can improve risk perception and attract additional investment into the sector.

SUPPORTING NATIONAL STANDARDS AND REGULATORY FRAMEWORKS

Certification systems contribute to the establishment and enforcement of technical standards in the solar PV sector. They define clear qualification pathways for different roles, enabling consistent benchmarks for regulatory authorities and training institutions.

REDUCING DEPENDENCY ON INFORMAL LEARNING

According to ARABRENA, 60–70% of engineers in the MENA solar PV sector acquired skills through on-the-job learning rather than structured certification. While practical experience remains valuable, this approach can lead to variable quality and increased system inefficiencies. Accredited certifications offer a structured alternative, improving technical consistency across the workforce.

ENABLING LONG-TERM SECTORAL GROWTH

Certifications provide a scalable mechanism for onboarding new workers and maintaining standards as the sector grows. They also offer a foundation for continuous professional development, ensuring that the workforce can adapt to emerging technologies and evolving industry needs.

Accredited certifications underpin the professionalisation of the solar PV workforce. They reduce performance and financial risks, strengthen regulatory oversight, and support the development of a competitive and sustainable solar energy sector in Oman.

Table 6 Solar PV industry certifications and job roles

	Planning & Development	Construction & Installation	Operations & Maintenance
Certificate	• PV Design Specialist Certification	• PV Commissioning & Maintenance Specialist Certification	• PV Commissioning & Maintenance Specialist Certification
	• PV Installation Professional Certification	• PV Design Specialist Certification	• PV Installation Professional Certification
	• PV System Inspector Certification	• PV Installation Professional Certification	• PV System Inspector Certification
	• PV Technical Sales Certification	• Energy Storage Installation Professional Certification	• Energy Storage Maintenance Professional Certification
	• Managing and Financing PV Projects Certification	• PV Installer Specialist Certification	• Troubleshooting of PV Systems
	• PV Entrepreneurship / Business Development Certification	• PV System Inspector Certification	• Grid Interconnection Procedures and Standards
	• Design of Grid-Connected PV Systems	• Planning & Installing (Hybrid) Micro-/Mini-Grids	
	• Design of Off-Grid PV Systems	• Planning & Installing of PV-Diesel Hybrid Systems	
	• Planning & Design of Large-Scale PV Grid-Connected Systems	• Planning & Installing of Solar Pumping Systems	
	• Planning & Design of PV-Diesel Hybrid Systems	• Troubleshooting of PV Systems	
	• Planning & Installing (Hybrid) Micro-/Mini-Grids	• Grid Interconnection Procedures and Standards	
	• Planning & Installing of Solar Pumping Systems		
Target	Building Inspector with Solar Expertise, Business Development Associate, IT Engineer, Interconnection Manager, Marketing Manager, PV Design Manager, PV Electrical Designer, PV Solar Inspector, PV System Designer, PV Technical Salesperson, Project Accountant, Project Assistant, Project Developer, Project Director, Project Manager, Sales and Marketing Specialist, Software Developer, Solar Energy Consultant / Solar Electrical Engineer, Solar PV Designer, Solar PV Engineer, Solar PV Site Surveyor, Solar PV Specialist, Solar PV Structural Design Engineer, Solar Project Developer, Solar Project Engineer, Structural Engineer	Battery Energy Storage System (BESS) Specialist, Building Inspector with Solar Expertise, Electric Distribution Engineer, Electrical Engineer, Energy Storage Installer, Field Project Engineer, Grid Connection Engineer, Installation Site Supervisor, Mechanical Engineer, PV Construction Inspector, PV Electrician, PV Engineer, PV Installer, PV Site Inspector, Planning Manager, Power System Engineer, Project Developer, Project Director / Project Manager, Quality Control Expert, Renewable Grid Specialist, Roofer with Solar Expertise, Site Engineer, Solar Commissioning Engineer, Solar Crew Chief, Solar PV Project Engineer, Solar PV Site Surveyor, Solar PV Structural Design Engineer, Solar Project Engineer, Solar QA Inspector, Solar Service Technician, Solar Site Assessor, Structural Engineer, Systems Architect, Utility Interconnection Engineer	Solar Fleet Manager / Fleet Maintenance Manager, Mechanical Engineer, Electrical Engineer, Technical Engineer, Solar Operations and Maintenance Manager, Solar Operation and Maintenance Technician, HVAC Technician with Solar Expertise, Instrumentation and Electronics Technician, Control Technician, Project Director, Transmission & Distribution Engineer, Solar SCADA & Automation Engineer, Battery Energy Storage System (BESS) Specialist, Energy Storage Installer, Solar Project Developer, Solar Site Assessor, Utility Interconnection Engineer, PV Service Technician, PV Site Inspector, Solar QA Inspector, Project Manager, Project Developer

Source: Majan Council analysis

EDUCATION, UPSKILLING POTENTIAL & OMANISATION

Oman's commitment to diversifying its economy and expanding the use of renewable energy has driven notable growth in the solar PV development sector. However, the expansion of this sector also underscores the need for a workforce equipped with skills and qualifications aligned to evolving industry requirements. While Oman's educational institutions—ranging from universities to vocational colleges—already offer foundational training, a gap persists between the qualifications delivered and the skills required for key solar PV roles.

Job roles such as solar PV engineers and solar operation and maintenance technicians often require specific degrees in electrical engineering, relevant certifications, and practical experience. These expectations are not always fully reflected in existing academic curricula or training programmes. Institutions may offer degrees in relevant fields, but may not address the applied, sector-specific skills demanded in project design, grid integration, or field maintenance.

Figure 10 maps how required specialisations align—or fail to align—with current educational qualifications (such as BSc, MSc, Diploma, Certificate, High School Diploma), occupational skill categories (Professional, Technician, Skilled, Semi-skilled), and specific job families including Engineering and Technology, Management and Leadership, Construction and Installation, Operation and Maintenance, and Grid Connection.

Professional-level roles are primarily linked to engineering and technology, planning, project development, and management. Technician-level roles are mostly associated with construction, operation and maintenance, and commissioning and connection, while semi-skilled and skilled roles are concentrated in construction, installation, and selected O&M functions.

A BSc is typically aligned with engineering and project management roles, whereas Diploma and Certificate holders are more commonly linked to hands-on technical roles such as construction, installation, and O&M. Critical gaps appear in the "Unavailable" segments—particularly for Diploma holders and semi-skilled/skilled categories—where education or training pathways are missing. These are most pronounced in construction and installation, grid connection, and O&M, potentially constraining project execution and deployment timelines.

While Figure 10 outlines qualification requirements for job roles, it does not indicate the number of positions required per project stage. Some positions, such as a solar PV maintenance technician (electrical), may require a large number of workers, while others, like a SCADA engineer, may demand only one. However, the latter may involve a broader set of required specialisations, such as electrical engineering, control engineering, or computer science. The diagram visualises qualification diversity, not role volume.

Although most required specialisations for the solar PV sector are offered in Oman, there remains a significant gap in how existing programmes address sector-specific skills (see Table 7). For example, vacancies for positions such as solar PV maintenance technician (electrical) often require backgrounds in electrical engineering, mechanical engineering, or industrial maintenance. While these specialisations are available through vocational colleges—9 institutions offer electrical engineering, 11 offer mechanical engineering, and 8 offer industrial maintenance—they do not incorporate solar PV-specific training in areas such as system inspection, commissioning, and fault diagnostics.

Graduates from these institutions therefore require additional upskilling or certification. The industry demands skills such as PV system inspector certification, commissioning and maintenance credentials, and hands-on proficiency in system operation and troubleshooting. These requirements are currently not addressed in most training programmes.

Targeted training and certification schemes are needed to bridge this gap. Equipping graduates not just with general technical knowledge but also with specialised solar PV competencies will be critical for meeting sector demand. In addition, the planning and development phase of solar PV projects is more strongly associated with professional roles that require higher academic qualifications, while the construction and installation (C&I) and operations and maintenance (O&M) stages demonstrate significantly higher demand for technicians and skilled workers. Despite this, current academic programmes do not sufficiently address the volume and type of training needed for these roles. For instance, local demand for technicians in the C&I and O&M stages is estimated at 65% and 76% respectively, yet vocational programmes often lack the specialised content necessary to meet this need.

Meanwhile, there appears to be an oversupply of graduates for professional roles concentrated in the planning and development phase, suggesting a mismatch between qualification outputs and workforce demand. This imbalance may result in underemployment for academically trained professionals, alongside shortages in critical technical positions such as PV maintenance technicians and installers.

To address this, education and training institutions should place greater emphasis on aligning their programmes with workforce needs in the C&I and O&M phases, including through upskilling and certification schemes focused on practical, sector-specific competencies. Closing this gap will be essential for ensuring a well-balanced and job-ready workforce to support Oman's solar PV development objectives.

Building on this, the development of the solar PV sector in Oman also depends on identifying concrete upskilling opportunities for Omani jobseekers across different specialisations. A well-prepared workforce not only supports the sector's technical needs but also addresses broader labour market challenges by creating sustainable employment pathways for nationals.

An analysis of the availability, demand, and qualifications of jobseekers reveals several areas for targeted training. Graduate-to-industry alignment highlight the balance—or imbalance—between graduate supply and industry demand. In some fields, educational institutions produce more graduates than the sector can absorb, while others face shortages that could constrain development.

Oversupply in areas such as business administration and information technology suggests that institutions may be producing more graduates than the solar PV sector can integrate. Without sufficient industry demand, this could result in underemployment or misalignment between qualifications and available roles. Programme adjustments and reorientation towards solar-specific applications of these disciplines—such as renewable energy finance or digital monitoring—may help improve alignment.

In contrast, undersupply is evident in technical fields directly relevant to solar PV development, such as vocational electrical and mechanical engineering and renewable energy engineering. Inadequate graduate numbers in these areas can create bottlenecks in project execution, especially in construction, installation, and operations. Developing or expanding programmes in these fields is essential to meet sectoral labour demands.

Table 9 outlines current upskilling opportunities for Omani jobseekers, identifying gaps across various sub-majors and estimating the level of additional training required to align qualifications with market needs. The table provides a reference for aligning training investments with sector growth.

In addition to formal education, Oman's existing labour force—particularly those with experience in oil and gas or general technical industries—offers a pool of talent with transferable skills. Targeted upskilling in renewable energy systems, PV installations, and energy storage technologies can facilitate the redeployment of this workforce into the solar sector. Such efforts will reduce reliance on expatriate workers and support national workforce objectives.

To operationalise these findings, several targeted measures are recommended to align jobseeker qualifications with solar PV sector needs and to build a sustainable national workforce:

» **Expand vocational and technical training:** Low specialisation availability ratios in hands-on technical areas—such as process operations and maintenance, welding and metal fabrication, and mechanical engineering—highlight the need to scale up short-term certification and vocational training programmes focused on solar installation, operations, and maintenance.

» **Expand solar-specific programmes:** Institutions should establish solar-focused training for electrical, mechanical, and civil engineers, where jobseeker supply is strong but solar-specific competencies are lacking.

» **Align education with industry needs:** Stronger cooperation between industry and academic institutions is needed to ensure curriculum development reflects current technical requirements. Integrating solar PV system design, energy storage, and grid integration into existing programmes—particularly in mechanical, industrial, and electrical engineering—would help bridge this gap.

» **Targeted upskilling for existing skillsets:** Many jobseekers have backgrounds in engineering, management, or IT. Short-term programmes in solar project management, grid systems, and SCADA applications could facilitate rapid entry into solar PV roles.

» **Develop specialised programmes for critical roles:** Universities and technical institutes should introduce dedicated programmes in renewable energy engineering, solar project management, and sustainability studies, tailored to the technical and operational needs of Oman's solar PV sector.

» **Support transition training for other sectors:** Workers from traditional industries, particularly oil and gas, can be redeployed into solar PV with focused training. Electricians and O&M technicians can be reskilled through short certification programmes targeting solar installations, maintenance, and energy system operations.

» **Reskilling for non-technical roles:** Graduates from business administration, law, or marketing can enter the solar sector through training in project finance, legal frameworks, and solar-specific marketing strategies.

By aligning training pathways with market demand, Oman can maximise the participation of its national workforce in solar PV development and reduce long-term dependency on foreign labour.

An additional consideration involves identifying where Omanisation potential is currently strong or constrained. Table 11 and Table 12 evaluate workforce readiness and localisation potential across different job categories and stages of the solar PV value chain. These tables assess metrics such as availability, criticality, longevity, workforce share, and Omanisation potential. This provides a structured basis for determining where the national workforce is well positioned and where capacity-building measures are most urgently required. The findings help prioritise workforce development efforts and policy interventions to ensure Oman's solar PV growth is underpinned by a resilient and localised labour base.

Another factor shaping Omanisation outcomes is the duration and nature of employment across different project phases. The type and length of employment not only determine job attractiveness but also influence the feasibility of workforce localisation. Short-term, low-skill jobs—particularly in the construction and installation (C&I) phase—often involve physically demanding work under harsh conditions and typically last only 6 to 12 months. These positions, while large in number, are less suited for Omanisation due to their temporary nature and relatively low wages (Figure 12).

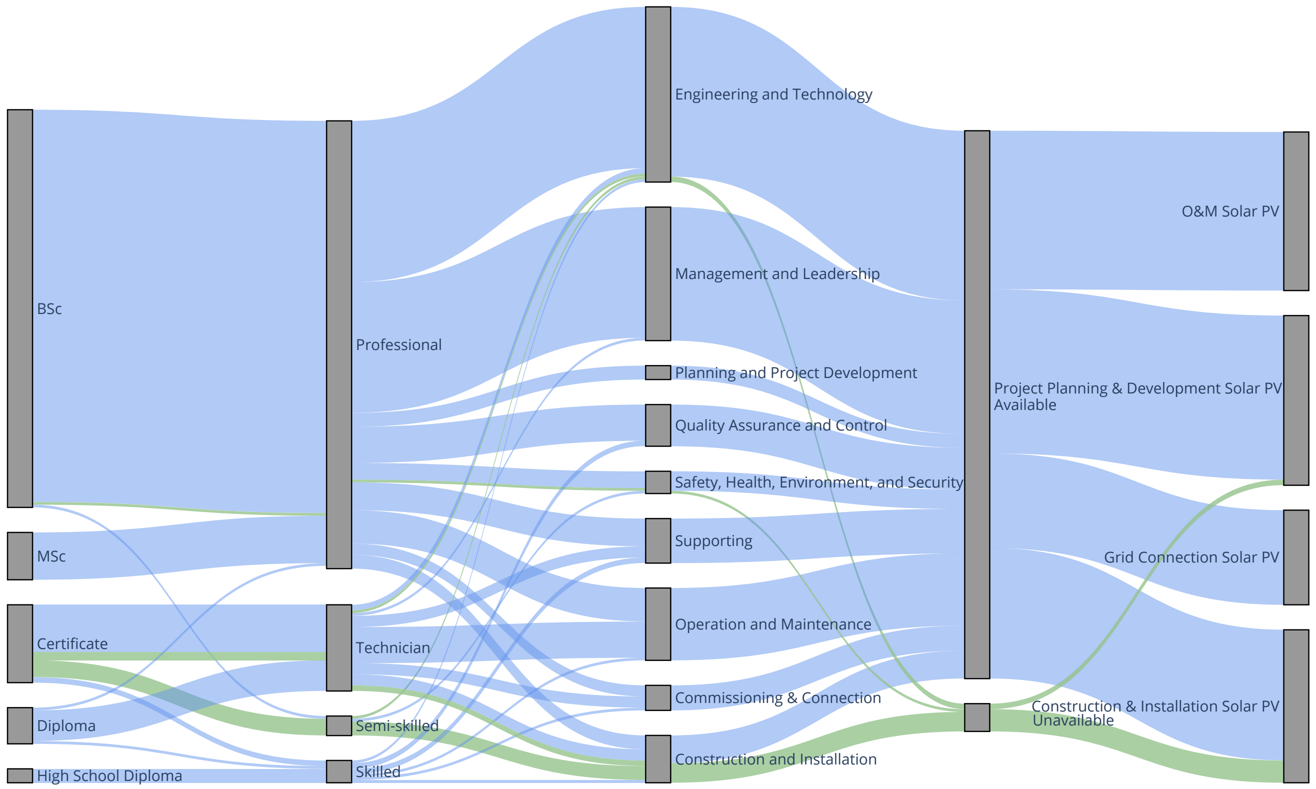
In contrast, higher-skill roles during the C&I phase offer better pay and more opportunities for localisation, although their limited duration still poses challenges. Strategic project sequencing—ensuring that new projects begin as others end—would help maintain employment continuity, especially in large-scale solar developments. For instance, a 500 MW solar PV project may require around 1,500 workers during the C&I phase but only about 35 across the planning, development, and O&M stages.

Figure 12 also shows that while the planning and development (P&D) phase is dominated by professional roles, the C&I and O&M stages are more reliant on technicians and skilled workers. This underscores the need to invest in local vocational training and international certification schemes that equip the workforce with practical, solar-specific skills.

Although Oman has a strong technical base, particularly from the oil and gas sector, several challenges remain. The absence of dedicated PV certifications and solar-specific degree programmes continues to slow workforce transition, and reliance on expatriate labour persists in several technical domains.

To address these barriers, Oman should expand local certification programmes in partnership with international standards bodies and strengthen local, regional and vocational education in solar-relevant disciplines. Such initiatives will enhance Omanisation outcomes while supporting the broader transition to a green economy.

Figure 10: Alignment of educational qualifications with solar PV sector requirements in Oman



Source: Majan Council analysis

Table 7: Share of required specialisations by skill category across solar PV project development stages

	Technician & Skilled (%)	Professional (%)
Planning & Development (P&D)	16	84
Construction & Installation (C&I)	43	57
Operations & Maintenance (O&M)	44.4	55.6

Source: Majan Council analysis

Table 8: Alignment of education programmes with solar PV industry needs

Educational Preparedness &Alignment of Qualifications with Industry Needs	Insight into Vocational Training and Higher Education Needs	Preventing Mismatch and Oversupply
By mapping qualifications against job roles, it is possible to assess whether the current educational system is equipping the workforce with the necessary skills and training.	Vocational training and higher education institutions must respond not only by offering appropriate specialisations, but also by adjusting programme capacity to align with real industry demand.	This diagram illustrates how a mismatch between qualifications and job demand can lead to oversupply. For example, if only one accountant is needed but many Finance or Accounting graduates exist, it results in excess supply. Consequently, qualified candidates may struggle to secure employment.

Source: Majan Council analysis

Table 9: Analysis of upskilling opportunities for Omani jobseekers in the solar PV sector

Specialization/ Sub major	Availability	Demand	Job seekers level	Upskilling efforts*	Industry Needs & Required Upskilling
Electrical Engineering	Mid	High	High	Low	Strong alignment with solar PV demand for roles such as Solar PV Engineer, Grid Engineer, and Solar PV Electrical Engineer. Requires solar PV-specific training, grid integration knowledge, and renewable energy systems expertise.
Mechanical Engineering	High	Mid	High	Mid	In demand for roles in construction, installation, and O&M. Needs training on solar technologies, maintenance practices, and energy storage systems.
Accounting	High	Low	High	Mid	Relevant for solar project finance, accounting, and auditing roles. Upskilling should focus on renewable energy finance and solar-specific financial modelling.
Information Technology / Computer Science	High	Mid	High	High	Critical for data management, system integration, and cybersecurity in solar PV projects. Requires knowledge of solar data analytics, SCADA systems, and energy-specific cybersecurity.
Business Administration	High	Low	High	Low	Important for roles such as Solar Project Manager and Procurement Specialist. Needs solar-specific project management and procurement training.
Civil Engineering	Mid	Low	High	High	Essential for structural and project management roles. Requires solar civil engineering training, including structural support systems and solar project execution.
Marketing& Public Relations	Low	Low	High	High	Key for public engagement and market growth in the solar sector. Upskilling should cover communications for renewable energy projects and solar product marketing.
Renewable Energy Engineering	Low	High	Low	Low	High demand with low supply. Needs targeted qualifications in solar PV design, installation, and systems integration.
Process and Maintenance Engineering	Low	Mid	Mid	Mid	Supports long-term performance and reliability of PV systems. Requires training in inverter and panel maintenance, troubleshooting, and system performance tools.
Welding & Metal Fabrication	Low	Mid	Low	Low	Critical in installation stages. Vocational programmes should focus on hands-on welding, fabrication, and structural assembly for solar infrastructure.

* Evaluates the extent of upskilling necessary for individuals from this submajor

Source: Majan Council analysis

Table 10: Upskilling and reskilling needs for jobseekers in the solar PV sector

Category	Jobseekers with Direct Fit	Jobseekers Requiring Moderate Upskilling in Supporting Roles
Type	Short-term certifications (Solar-Specific Training Programs)	Medium-term vocational training
Targeted	Electrical Engineering, Mechanical Engineering, Civil Engineering, Business Administration, Accounting: These specialisations are closely aligned with solar PV sector needs. Jobseekers from these backgrounds require only moderate upskilling to transition into relevant roles.	Information Technology, Human Resource Management, Marketing, Public Relations: While applicable to the solar PV sector, these specialisations require targeted, sector-specific training (e.g., solar project management, solar marketing strategies, or workforce development in renewable energy) to ensure alignment with industry expectations.

Source: Majan Council analysis

Table 11: Strengths and weaknesses vis-à-vis Omanisation in solar PV sector

Job Category & Stage of the Value Chain	Availability	Criticality	Longevity	Share of Workforce	Omanisation Potential
Planning & Development (P&D)					
Management and Leadership	High	High	Mid	High	High
Planning and Project Development	Mid	High	Mid	Mid	High
Engineering and Technology	Mid	High	Mid	High	Mid
Quality Assurance and Control	Low	Mid	Low	Low	Low
Safety, Health, Environment, and Security	Low	Low	Low	Low	Low
Supporting	Mid	Low	Low	Low	Low
Construction & Installation (C&I)					
Management and Leadership	Low	High	Mid	Low	High
Construction and Installation	Low	High	Low	High	Low
Commissioning & Connection	Low	High	Low	Mid	Low
Engineering and Technology	Low	High	Mid	Mid	Mid
Quality Assurance and Control	Mid	Mid	Low	Low	Low
Safety, Health, Environment, and Security	Low	Mid	Low	Low	Low
Supporting	Low	Low	Mid	High	Low
Operation & Maintenance (O&M)					
Management and Leadership	High	High	High	High	High
Operations and Maintenance	Low	High	High	High	Mid
Engineering and Technology	Mid	High	High	Mid	High
Quality Assurance and Control	High	High	High	Low	High
Safety, Health, Environment, and Security	Low	High	High	Low	Mid
Supporting	Low	Mid	High	Low	High

Source: Majan Council analysis

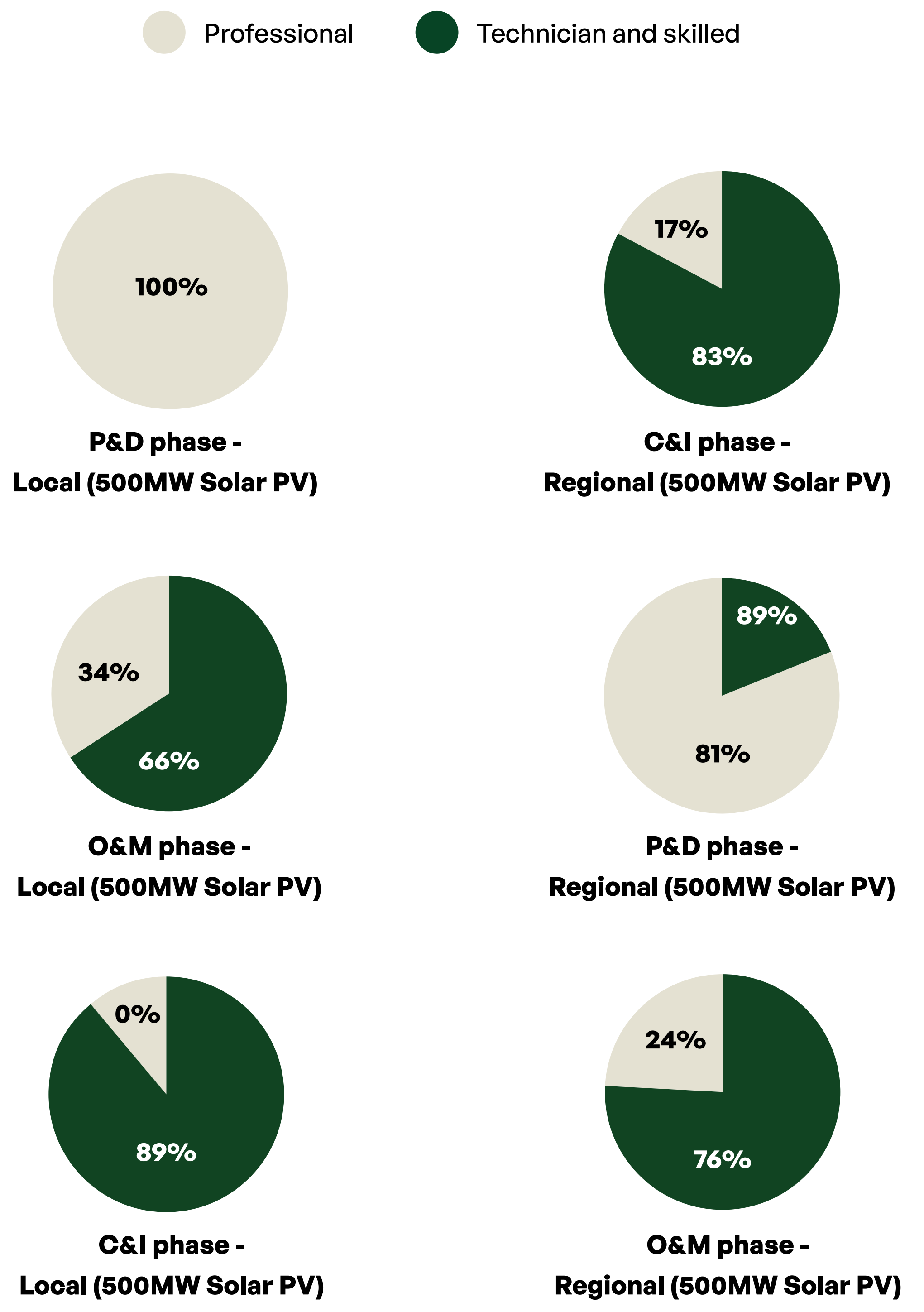
Table 12: Job role assessment criteria

Category	Description	Rating Criteria
Availability/ Supply	Assesses the current availability of relevant sub-majors or qualified professionals in the labour market for the job category, based on the existing talent pool.	High to Not available
Criticality	Measures the importance and impact of the job category on project success. Roles with high criticality are considered essential to successful project execution.	Low to High
Longevity	Evaluates the expected long-term demand for the job role, indicating its sustained relevance within the industry.	Short term to Long term
Share of Workforce	Refers to the proportion of the overall workforce that a specific job role or category represents within the industry.	Low to High
Omanisation Potential	Indicates the potential to increase the employment of Omani nationals in a specific job category, as aligned with Omanisation policy targets set by the Ministry of Labour (MoL).	Low to High

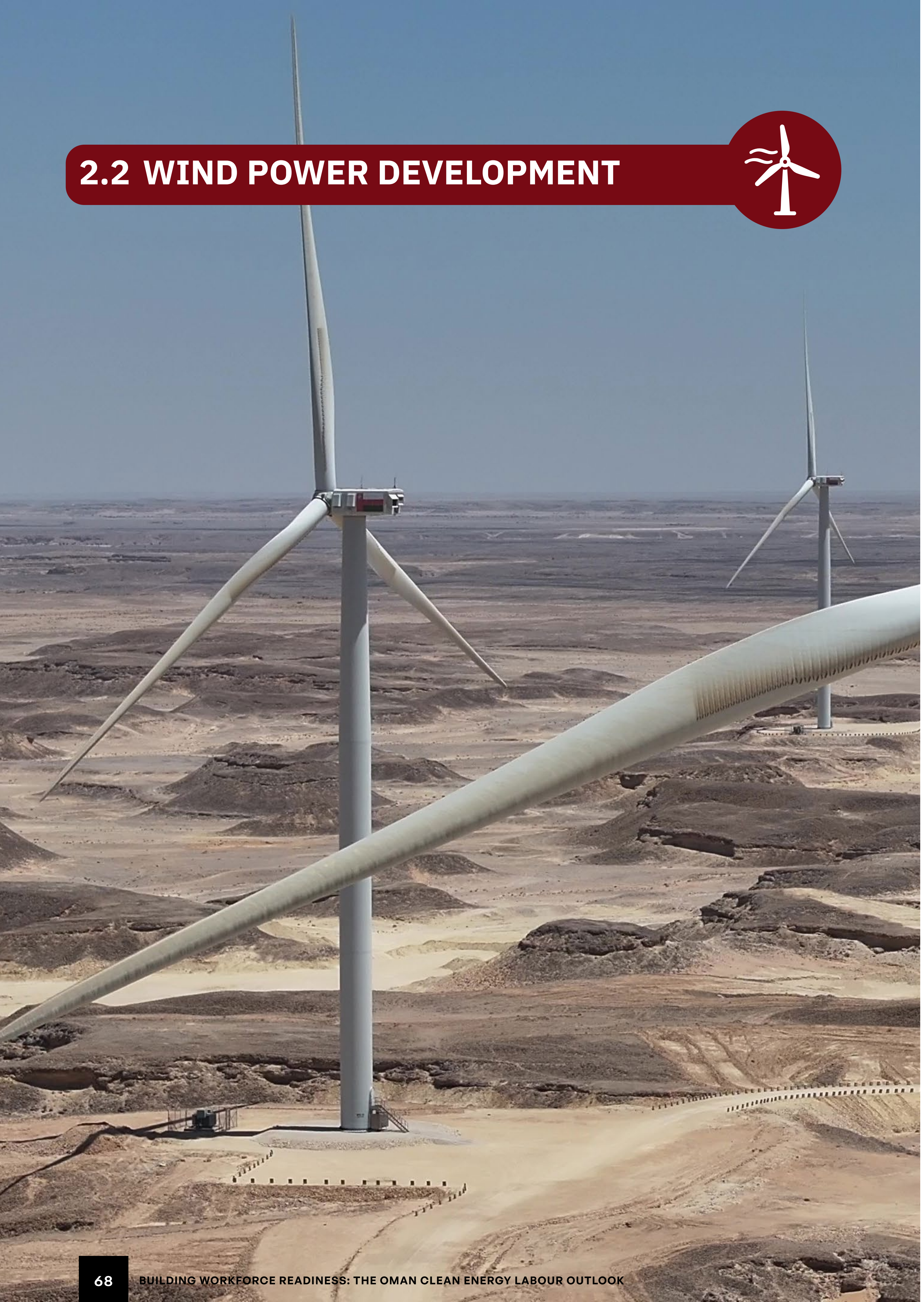
* The first category corresponds to high-level administrative jobs, which are in high demand among Omanis-60%, second category includes technical and specialist jobs- 45%, third category consists of basic jobs, which have less interest from Omanis, 20%.

Source: Majan Council analysis

Figure 11: Local and regional workforce distribution by project phase for representative solar PV projects in the GCC and Oman



Source: Majan Council analysis



2.2 WIND POWER DEVELOPMENT

2.2.1 Value Chain & Sector

Wind power has become a central component of the global shift towards cleaner energy systems. Over the past two decades, deployment has accelerated significantly, driven by declining costs, technological advances, and supportive policy frameworks. Global installed wind capacity—across both onshore and offshore segments—rose from 181 GW in 2010 to approximately 1,017 GW by 2023. Following several years of additions below 100 GW, 2023 marked the strongest annual growth in a decade, with 116 GW of new capacity installed. This includes, for the first time, more than 100 GW of new onshore installations in a single year, underscoring wind power's expanding contribution to global electricity systems.

In contrast to solar PV, wind energy development remains primarily centralised and in large scale. Utility-scale installations dominate both onshore and offshore segments, while small wind turbines play a minor role in residential and commercial applications.

Onshore wind continues to represent the most mature and widely adopted form of the technology. Offshore wind offers substantial long-term potential due to stronger and more stable wind conditions at sea, but its uptake remains limited by higher installation and maintenance costs. As of 2023, offshore wind accounted for approximately 75.2 GW—about 7.1% of total wind capacity and 1.9% of global renewable power capacity.

Future growth is expected to be driven by natural resource availability, declining CAPEX and OPEX, advances in storage technologies, and continued policy support. Key cost indicators—including total installed costs, O&M costs, and LCOE—have steadily declined over time (Table). Offshore wind remains considerably more expensive, with average installed costs of US$3,460/kW—significantly above other renewable technologies such as bioenergy, hydropower, and solar PV.

These cost reductions are mirrored in the levelised cost of electricity (LCOE). In 2010, the global weighted average LCOE for onshore wind was US$0.107/kWh, nearly double the lowest-cost fossil fuel option at the time. By 2022, this had fallen to US$0.033/kWh, significantly undercutting fossil fuel-fired alternatives.

To maintain current growth trajectories, investment levels must rise considerably. Under the Planned Energy Scenario, average annual investment in onshore wind would need to increase from US$67 billion in 2018 to US$146 billion by 2030, and reach US$211 billion by 2050. Wind power has also been prominently featured in recent international commitments, including global targets to triple renewable capacity by 2030.

Despite favourable cost trends and policy momentum, the medium- to long-term expansion of wind power faces several structural challenges. These include bottlenecks in supply chains, delays in grid infrastructure, and restrictions related to land and seabed access. Public acceptance also poses a growing constraint. Compared to solar PV, wind projects tend to generate more opposition due to their visibility and perceived impact on landscapes and ecosystems. In some countries, this resistance has moved beyond local "not-in-my-backyard" sentiment to more organised political opposition. In parts of Europe, for example, calls have emerged for the removal of existing turbines—highlighting the extent to which social acceptance may influence long-term deployment potential.

Table 13: Cost metrics for onshore and offshore wind energy systems, 2010–2050

Wind Project Type	Onshore Wind				Offshore Wind			
Year	2010	2023	2030	2050	2010	2023	2030	2050
LCOE (US$/kWh)	0.107	0.033	0.025	0.02	0.197	0.081	0.065	0.05
CAPEX (US$/kW)	1,750	1,501	1,100	850	4,500	3,871	2,750	2,000
OPEX (US$/kW/yr)	40	30	26.5	22.5	125	111	60	45
Capital Cost (US$/kW)	1,800	1,274	1,000	900	5,000	3,461	2,500	2,000
Total Installed Capacity (GW)	200	700	1,000	1,500*	3	50	150	300*
Capacity Factor (%)	27.5	32.5	34	37*	37.5	42	44	47*
Annual Deployment (GW/year)	10	20	30	60*	1	5	10	25*
Average Annual Investment (billion US$)	40	50	60	65*	20	30	40	45*
Employment Opportunities (million)	0.5	1.2	1.5	2	0.1	0.3	0.5	1

* values correspond to projections for the year 2040, as no data are available for 2050.

Source: Historical data and projections from selected external sources, including references 1, 2, 3, 4, 5

The wind power value chain consists of interlinked stages spanning project planning, construction, grid connection, and ongoing operations (Figure 12). Each phase involves distinct activities and actors—ranging from developers and contractors to utilities and service providers—and reflects varying labour requirements and skill profiles across technical, managerial, and operational domains.

PROJECT PLANNING AND DEVELOPMENT

The development of commercial-scale wind farms is a complex, multi-year process requiring coordination across regulatory, technical, and financial domains. Developers are responsible for conducting feasibility studies, selecting sites, designing the wind farm layout, and specifying turbine technologies. Additional tasks include securing permits, land leases, and wind rights, negotiating project financing, and managing early-stage stakeholder engagement. These activities typically involve a mix of engineering, environmental assessment, legal expertise, and financial planning.

CONSTRUCTION AND INSTALLATION

This phase includes civil works, foundation laying, and turbine installation. Turnkey contractors often oversee the full engineering, procurement, and construction scope, which also includes internal road construction and electrical cabling. The construction stage is labour-intensive and time-sensitive, requiring skilled personnel in areas such as heavy machinery operation, electrical systems, and structural assembly.

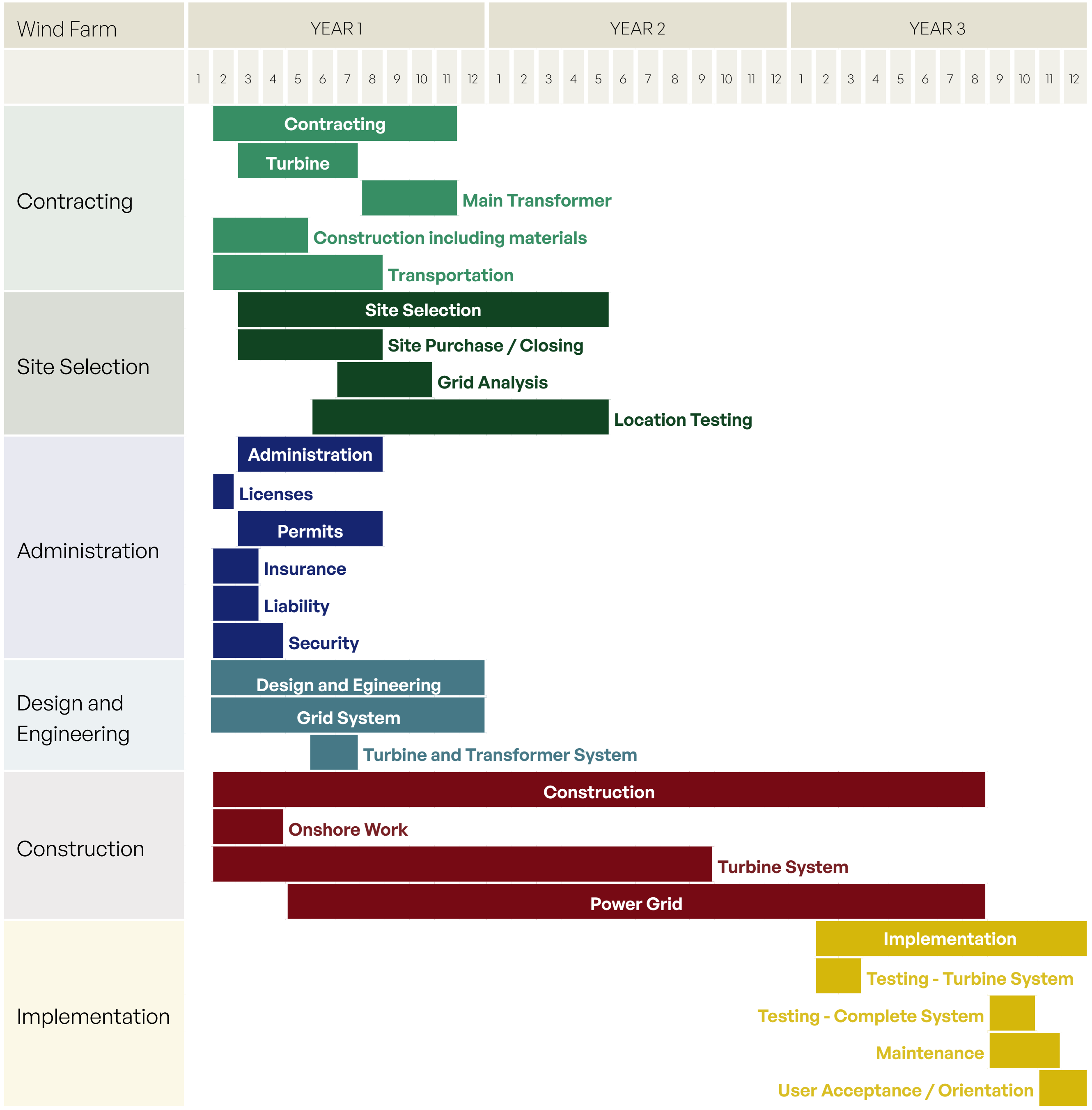
GRID CONNECTION

Integrating wind projects into the grid requires transmission infrastructure and coordination with grid operators. Key steps include grid impact assessments, permitting for interconnection, and commissioning. Utilities and transmission system operators are responsible for ensuring grid stability and addressing technical constraints associated with variable wind generation.

OPERATIONS AND MAINTENANCE (O&M)

O&M services are essential to ensuring project reliability and performance over the system's lifetime. Operations typically include turbine monitoring, site coordination, and response to grid curtailments or outages. Maintenance spans both scheduled tasks—such as inspections, lubrication, sensor calibration, and blade cleaning—and unscheduled repairs. O&M activities require a consistent presence of technicians and site personnel, supported by logistics, diagnostics, and data management systems.

Figure 12: Timeline of wind farm project development process



2.2.2 Wind power development in Oman and the GCC

Oman's geographic and climatic conditions provide a strong foundation for wind energy development (Figure 13). With a 1,700 km coastline, low population density in key regions, and seasonal monsoons from both the northeast and southeast, the country benefits from favourable wind regimes across multiple zones. Wind speeds typically range from 4 to 6.3 m/s at 10 metres height, with some locations reaching up to 11 m/s. Particularly promising areas include the southern and south-eastern coasts, the coastal highlands facing the Arabian Sea, and the mountains north of Salalah, where average wind speeds exceed 8 m/s—comparable to established commercial wind sites in Europe.

These conditions translate into strong technical performance. Capacity factors at Al Jazer (53%), Duqm (48%), and Salalah (46%) significantly exceed global averages (Figure 16), reinforcing the viability of utility-scale deployment. Combined with growing domestic energy demand, declining technology costs, and improved turbine performance, these characteristics create a favourable environment for wind investment.

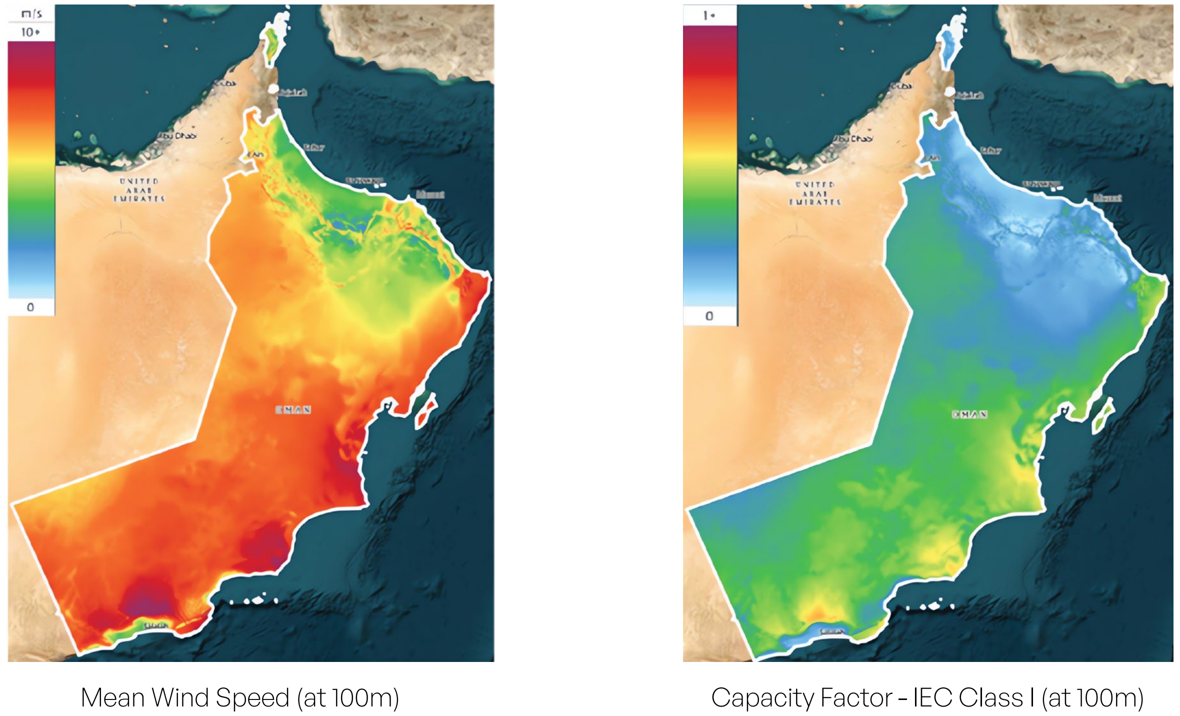
The wind sector in Oman is, however, at an earlier stage of development than solar PV. The country's first commercial onshore wind farm—located in Dhofar—began operations in December 2020 with a capacity of 50 MW (Figure 14). An expansion to 250 MW is planned by 2025. Additional utility-scale projects are under development: Nama Power & Water Procurement Company (PWP) has announced plans to acquire five wind farms totalling 1,171 MW. By 2027, three further projects are expected to come online—a 100 MW plant in South Al Sharqiyah, a 200 MW installation in Duqm, and a 200 MW facility in Ras Madrakah.

These developments are aligned with Oman Vision 2040, which targets 20% renewable electricity consumption by 2040 and identifies wind energy as a strategic contributor to national diversification and decarbonisation objectives. More recent capacity targets linked to green hydrogen development call for 16–20 GW of solar and wind by 2030, scaling to 175–185 GW by 2050, with wind expected to contribute around 30%. Over 50,000 km^2 have been allocated for hydrogen-linked energy zones in Al Wusta and Dhofar.

Supportive policies and regulatory reforms have accompanied these ambitions. Measures include long-term PPAs, streamlined permitting procedures, and efforts to enable private sector participation. Technological improvements and declining LCOE further enhance the sector's competitiveness. Wind energy also contributes to wider national goals, including job creation, local industrial development, and reduced dependence on fossil fuels. Hybrid systems combining wind and solar are being explored as a means to enhance system flexibility and resilience.

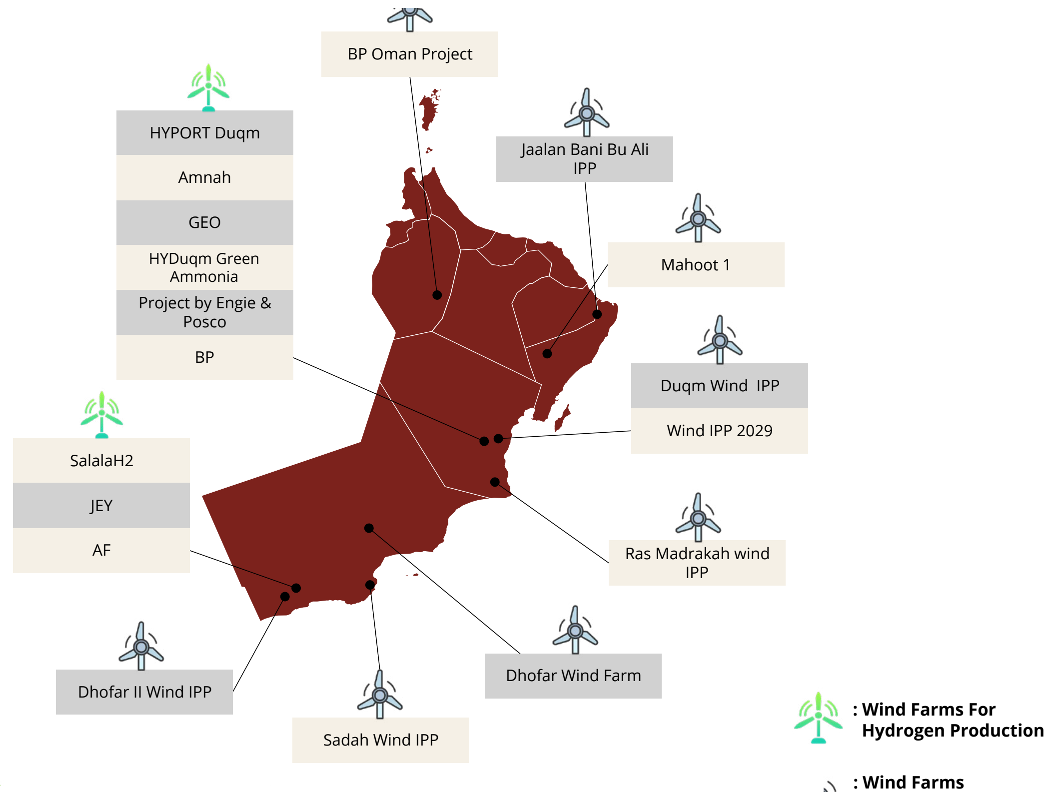
Nonetheless, several structural challenges persist. Grid integration, infrastructure readiness, and access to project finance remain critical areas for attention. With sustained investment and institutional support, Oman is well positioned to expand its role in the regional wind energy landscape.

Figure 13: Spatial distribution of mean wind speed (left) and wind energy capacity factor (right) at 100 metres in Oman



Source: Global Wind Atlas, Version 3.3

Figure 14: Current and planned wind projects in Oman for electricity generation and hydrogen production



Source: Majan Council analysis

Across the GCC, wind resources are generally more limited than solar, but selected regions demonstrate promising potential. Bahrain, Qatar, and the United Arab Emirates (UAE) exhibit moderate wind speeds, with relatively constrained onshore wind development prospects. In contrast, northern and central Saudi Arabia, northwestern Kuwait, and parts of Oman display favourable wind regimes, with average speeds exceeding 7.5 m/s.

Recent developments point to increasing regional engagement with wind energy. In October 2023, the UAE commissioned its first commercial wind project—a 103.5 MW installation across four sites, led by Masdar. The project is expected to supply electricity to over 23,000 households annually. In Saudi Arabia's most recent renewable energy procurement round, 18 developers were selected for a total of 1,800 MW of wind capacity, alongside 1,500 MW of solar.

Cost trends across the region have varied considerably. Between 2014 and 2022, installed costs for wind projects ranged from US$1,085/kW (in 2017) to US$3,291/kW (in 2015). More recently, the commissioning of the Dumat al Jandal wind farm in 2022 achieved a competitive installed cost of US$1,338/kW, highlighting the viability of wind energy in select GCC locations with adequate resource potential and supportive regulatory frameworks.

Table 14: Current wind power capacities in GCC countries and projections from selected sources

Country	Wind Energy Capacity (MW)	
	2024	2030
UAE	103.5	6,700
KSA	1,800*	16,000
Kuwait	12.4	2,500
Oman	50	1,000
Qatar	-	-
Bahrain	0.7	2,000

* accounts for three projects currently planned under Round 4 of the NREP: the 700 MW Yanbu Wind Farm in Al Madinah, the 600 MW Al-Ghat Wind Farm in Riyadh, and the 500 MW Waad Al Shamal Wind Farm in the Northern Borders region.

Source: Masdar Wind Program, UAE Government Data, TechSci Research, Oman Energy Magazine, Oxford Business Group

2.2.3 Occupational mapping

Wind energy is emerging as a significant source of employment worldwide, with considerable implications for workforce development in countries like Oman.

Global employment in wind power generation reached an estimated 1.5 million jobs in 2022, reflecting an increase of more than 100,000 jobs (7%) compared to 2021 (Figure 14). The Asia-Pacific region accounts for the majority of this employment, with China alone representing around 40% of global wind jobs. Europe follows with 20%, while North America and Central and South America each contribute approximately 10%.

Outside Asia, employment growth was particularly notable in Central and South America, which added over 20,000 onshore jobs in 2022 in anticipation of around 25 GW of new capacity over the next five years—primarily in Brazil, Chile, and Colombia. In Africa, the wind workforce expanded by more than 75%, driven by activity in South Africa and other emerging markets.

Onshore projects account for approximately 80% of total wind energy employment, although offshore wind jobs are growing at a comparable pace. Around two-thirds of the wind energy workforce is employed in manufacturing or construction-related roles. These roles require specialised expertise, particularly in turbine erection, mechanical assembly, and the transport and handling of large components. Compared to other renewable sectors, wind construction imposes distinct workforce development demands that must be reflected in education and training strategies.

For Oman, understanding the global context and the development process of wind projects is critical for workforce planning. Wind power development involves multiple stages—from site selection and technical design to construction, commissioning, and long-term maintenance—each requiring distinct roles and competencies. Mapping these stages provides a framework to assess the country's labour market readiness and to identify potential gaps in both vocational and higher education systems, as well as among developers, investors, and service providers.

Table 15 provides an overview of the key activities and tasks across the wind project development cycle, offering a structured reference for identifying required skill sets at each phase.

Cross-sector expertise plays a significant role in accelerating workforce preparation. Many capabilities in wind energy—particularly those related to civil infrastructure, automation, and power systems—overlap with competencies in adjacent industries. Recognising these linkages allows Oman to develop more efficient and targeted training pathways.

Table 16 outlines the degree of alignment between wind farm components and skills from other sectors. Components such as transformers and switchgear, foundations and towers, and protection and earthing systems demonstrate strong alignment with the design, construction, and operational stages of wind projects. These roles can be supported by expertise already present in the construction, utilities, and power generation sectors.

In contrast, blades and nacelles present lower alignment, particularly in design and installation stages, due to their specialised aerodynamic and mechanical properties. These areas will require new, targeted training programmes that focus on the unique characteristics of wind energy technology. Similarly, monitoring and control systems show only partial alignment with industrial automation skills, requiring supplementary training to address wind-specific digital integration, diagnostics, and data systems.

Overall, the available evidence suggests that Oman can build on existing industrial and educational capacities to meet a portion of the wind sector's workforce needs. However, strategic investments in dedicated training—particularly for turbine-specific components—will be essential to support sector growth and ensure the long-term reliability of wind power infrastructure.

The expansion of wind power requires a diverse range of technical and managerial roles across the project lifecycle—from design and development to long-term operations. As the sector matures, demand is growing for professionals with specialised skills in engineering, maintenance, and financial planning.

Figure 17 illustrates key emerging job roles essential to wind power development. These include core engineering and design positions such as wind design engineer and wind turbine engineer, as well as site-based roles like wind site manager and operation and maintenance engineer. Specialised technical positions—such as blade technician, mechanical wind technician, and blade engineer—play a central role in the upkeep, repair, and optimisation of turbine systems. These roles are particularly critical in the O&M phase, which requires consistent on-site capacity to ensure reliability and performance.

Table 21 highlights selected occupations along the wind energy value chain that are especially relevant for upskilling and reskilling efforts in Oman. These range from technical engineering roles to operational and managerial positions. Each role is associated with specific educational requirements, skills, and certifications that will need to be integrated into national training and workforce development strategies.

Beyond identifying occupational categories, targeted skill development strategies will be needed to build domestic capacity in roles that are difficult to import or outsource. In Oman, this should include a particular focus on hands-on and site-based functions such as blade engineers, project managers, and maintenance technicians. These roles are pivotal to the success of wind power deployment and remain underrepresented in many national labour markets.

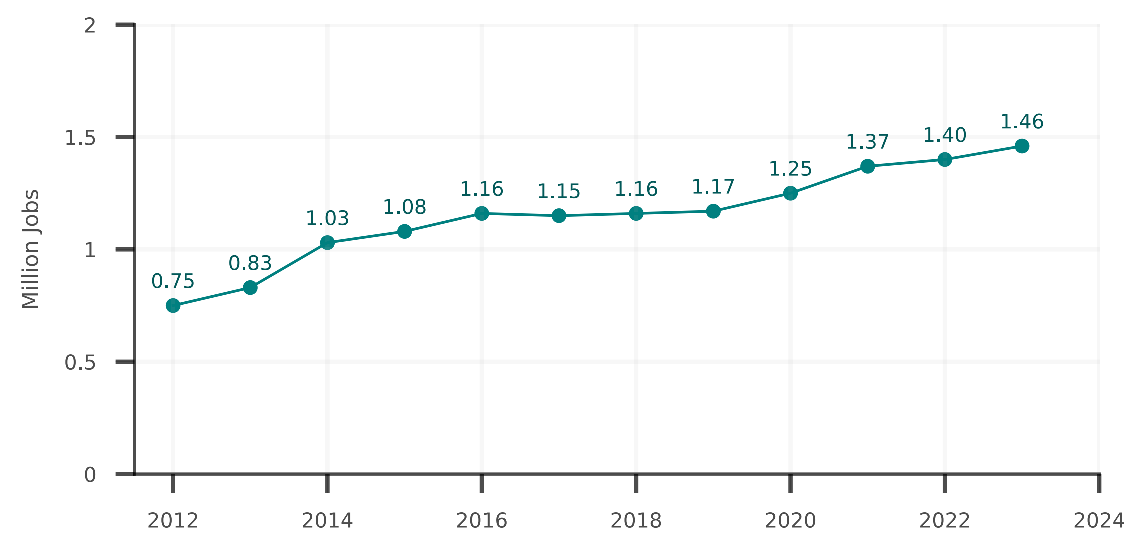
Accredited certifications play a critical role in advancing Oman's wind power sector by providing a structured framework to assess and verify the skills required across all stages of project development. Certification schemes improve workforce quality and safety, reduce on-the-job learning curves, and enhance employability by ensuring professionals meet recognised technical standards.

In practical terms, certified workers are better equipped to contribute effectively to the design, installation, and maintenance of wind power systems. For employers and investors, certifications offer assurance that projects are managed by qualified personnel, improving operational reliability and minimising risk.

Beyond immediate skill development, certification systems support the long-term sustainability of the sector (Table 22). By promoting quality assurance, reducing inefficiencies, and fostering consistent project performance, they contribute to Oman's broader objectives for a resilient and well-regulated green energy industry. Certifications also help align workforce training with national standards and regulatory frameworks, laying the foundation for industry benchmarking and quality control.

In this context, building a certification ecosystem—linked to both vocational and higher education systems—will be essential to support workforce readiness, attract investment, and enable sustained sectoral growth.

Figure 15: Employment growth in the wind energy sector, 2012–2023



Source: Reference 12

Table 15 :Key tasks and activities in wind power project development

	Planning & Development	Construction & Installation	Operation & Maintenance
Tasks & Activities	• Site selection • Technical and financial feasibility studies • Engineering design • Project development • Specification identification • Assessment of local material availability • Environmental impact assessments	• Site preparation, foundation, and civil works • Supply of tower, nacelle, hub, and blades • Foundation, cabling, and substation supply • Equipment assembly • Installation of turbines, array cable, export cable, and substation foundation • Cabling and grid connection • Commissioning	• Operation and maintenance of the wind farm • Compliance with performance standards and regulations • Maintenance activities including: • Turbine maintenance • Structural inspection and repair • Logistics for service and maintenance • Array and export cable inspection • Substation operation and maintenance
Required Job Roles	Wind Design Engineer, Project Engineer, Civil Engineer, Lead Mechanical Engineer, Lead Yaw System Mechanical Design Engineer, Electrical-Transmission Engineer / Power Systems and Transmission Engineer, Wind Turbine Engineer, Finance Manager, Asset Manager / Asset Integrity Manager, Wind Site Manager, Training and Development Manager, HR Specialist / HR Generalist, Business Administrator, Power Market Analyst / Wind Yield Performance Analyst, GIS Specialist / Geographer, Financial Analyst / Wind Investment Analyst, Meteorologist, Wind Resource Analyst / Wind Yield Performance Analyst, Technical Recruiter, Risk Management Specialist / Risk Manager, Atmospheric Scientist, Environmental Consultant, Geologist, Contract Specialist, Land Acquisition Specialist, Regulatory Expert / Lawyer, Communication / Community Engagement Specialist, Logistician.	Mechanical Assembler, HR Specialist / HR Generalist, System Operator, Electrician, Cable Jointer, Fibre Optic Technician, Substation Technician, Metering Technician, Utility Interconnection Engineer, Electrical-Transmission Engineer / Power Systems and Transmission Engineer, Lead Design Engineer, Civil Engineer, Cable Testing Engineer, Protection and Control Engineer, Commissioning Engineer / Control and Automation Engineer, Grid Connection Specialist / Consultant, High Voltage Lead Engineer, IT Specialist / Software Developer, Lead LV Secondary System Engineer, Grid Compliance Specialist, Grid Automation Field Service Engineer, Grid Integration Applications Engineer, Grid Connection Manager, Training Manager, Technical Support Team Lead, Safety Inspector / HSE Specialist, Project Field Support Coordinator, Administrative Assistant, Jointing Supervisor.	IT Specialist / Software Developer, SCADA Software Developer, Senior SCADA Engineer, Data Analyst, Facilities Maintenance Engineer / Coordinator, Meteorologist, Blade Engineer, Wind Turbine O&M Engineer, Reliability Engineer, Asset Manager / Asset Integrity Manager, Site / Power Plant Manager, O&M Manager, HR Manager, Contract Administrator, IT Administrator / Manager, High Voltage Operator, Mechanical / Hydraulic Wind Technician, Electrical Wind Technician, Power Plant Operator, Control Room Technician, Communications Network Technician, Blade Technician / Rope Access Technician, Crane / Lifting Contractor, Substation Operator, Meteorological Technician, Component Technician, Lead Wind Technician, Quality Engineer, O&M Technician, Control Room Operator, Crane and Rigging Inspector, Instrumentation and Controls Technician, Security Personnel, Fire Safety Technician, Environmental Technician, Lawyer, Accountant, Purchasing / Logistics Coordinator, Receptionist, Administrative Staff, Sales Engineer, Salesperson, Electrical-Transmission Engineer, Communication / Community Engagement Specialist, HSE Specialist.

Source: Majan Council analysis

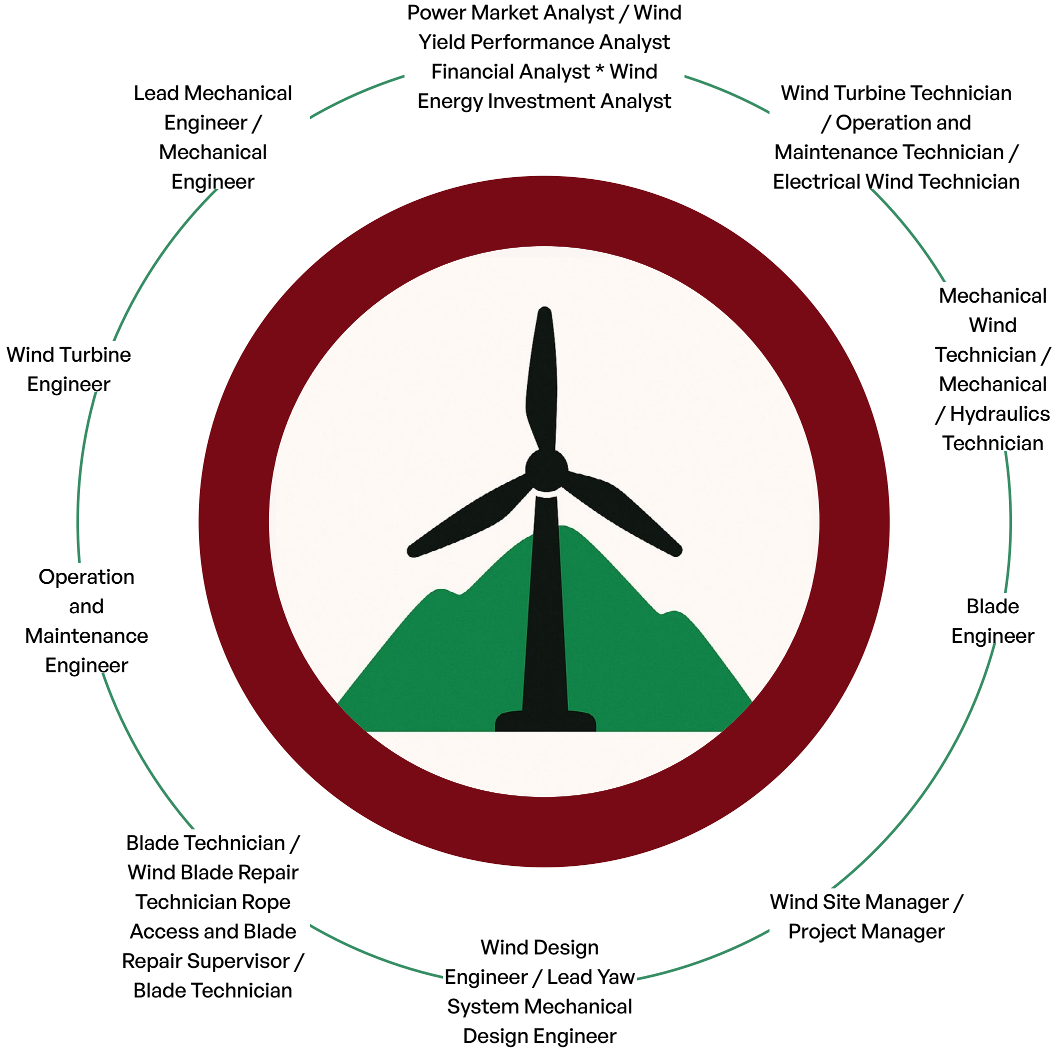
Table 16: Alignment of skills and knowledge for wind farm components with the conventional energy industry

	Blades	Hub	Nacelle	Foundation & Tower	Array and Export Cabling and Wiring	Transformers and Switchgear (HV)	Monitoring and Control Systems	Protection and Earthing Systems
Design & Planning	Low	Medium	Low	Medium	Medium	High	Low	High
Construction & Installation	Low	Low	Medium	High	High	High	Medium	Medium
Operation & Maintenance	Low	Medium	Low	High	High	High	Low	High

LOW MEDIUM HIGH

Source: Majan Council analysis

Figure 16: Key jobs in the wind power development sector



Source: Majan Council analysis

Table 17: Key job roles and upskilling opportunities in the wind power sector

LOW – SKILL GAP Minimal task changes are required, though some additional domain knowledge may be necessary.

MEDIUM – SKILL GAP Some new responsibilities are introduced, and upskilling or reskilling is needed to handle these new tasks.

HIGH – SKILL GAP Significant new responsibilities and unfamiliar areas of expertise are introduced, requiring substantial upskilling or reskilling.

Job Roles	Description	Required Education	Skills	Level of Skill Gap
Wind Design Engineer	Optimises wind farm layouts, turbine con-figurations, and electrical systems, considering site-specific conditions, energy yield, and project economics to maximise return on investment.	Bsc in Engineering (civil, structural, mechanical, or electrical)	• In-depth knowledge of wind turbine technology, focusing on design, performance analysis, and control systems. • Proficiency in industry-standard software for wind resource assessment, turbine layout optimisation, and structural analysis (e.g., WindPRO, WAsP, ANSYS). • Familiarity with regulatory permitting and environmental impact assessments for wind projects. • Strong project management abilities to prioritise tasks, meet deadlines, and coordinate multidisciplinary teams. • CAD software expertise (e.g., SolidWorks, AutoCAD, Siemens NX). • Experience in reliability analysis, including FMEA and RCM methods.	HIGH

Source: Majan Council analysis

LOW – SKILL GAP Minimal task changes are required, though some additional domain knowledge may be necessary.

MEDIUM – SKILL GAP Some new responsibilities are introduced, and upskilling or reskilling is needed to handle these new tasks.

HIGH – SKILL GAP Significant new responsibilities and unfamiliar areas of expertise are introduced, requiring substantial upskilling or reskilling.

Job Roles	Description	Required Education	Skills	Level of Skill Gap
Wind Turbine Engineer / Lead Yaw System Mechanical Design Engineer	The Wind Turbine Engineer selects, designs, and optimises turbine models for specific sites to maximise energy output, while the Lead Yaw System Mechanical Design Engineer focuses on designing and optimising the yaw system to ensure reliability and efficiency aligned with project goals.	BSc in Mechanical Engineering	• Wind Turbine Engineer: • Experience in the renewable energy sector. • Strong writing skills for clear documentation and reporting. • Proficiency in office and engineering analysis software. • Familiarity with FEA, aeroelastic, and CAD modelling tools such as AutoCAD, SolidWorks, ANSYS, Flex, and Bladed. • Knowledge of testing and measurement equipment. • Lead Yaw System Mechanical Design Engineer: • Proficiency in interpreting technical drawings, GD&T, and manufacturing processes. • Experience with 3D-CAD tools like Unigraphics/Siemens NX. • Working knowledge of FEA tools such as ANSYS. • Design experience with rotating components in the yaw subsystem, including yaw drives, bolted joints, and braking systems (hydraulic and mechanical). • Skills in system design, including interface definition, system stiffness, DFMEA, and design for manufacturability, installation, and serviceability.	HIGH

LOW – SKILL GAP Minimal task changes are required, though some additional domain knowledge may be necessary.

MEDIUM – SKILL GAP Some new responsibilities are introduced, and upskilling or reskilling is needed to handle these new tasks.

HIGH – SKILL GAP Significant new responsibilities and unfamiliar areas of expertise are introduced, requiring substantial upskilling or reskilling.

Job Roles	Description	Required Education	Skills	Level of Skill Gap
Wind Site Manager	Identifies, assesses, and develops suitable wind farm locations, conducting thorough site evaluations, feasibility studies, and stakeholder engagement to optimise project potential.	Bsc in Project Management / Mechanical Engineering / Electrical Engineering	• Knowledge and experience in wind power generation. • Proficiency in budgeting, business planning, and financial reporting. • Ability to oversee project management analytics, reporting, and deliverables. • Experience in budget management, with collaboration skills for working closely with finance teams to optimise costs. • Strong relationship management with local agencies, landowners, and community stakeholders. • Proficiency in overseeing commercial operations, including project contractors, agreements, financials, and regulatory compliance.	LOW
Wind Project Manager	Oversees all aspects of wind energy project development, from site selection and feasibility studies to permitting, financing, and construction planning, ensuring project goals are achieved within budget and timeline.	Bsc in Environmental Engineering / Project Management / Business Administration	• Ability to develop project schedules, including Gantt charts and critical path analyses. • Experience in budget development, cost estimation, and financial management. • Knowledge of risk assessment methodologies. • Understanding of QA/QC processes, inspections, and quality standards. • Familiarity with contract administration. • Strong stakeholder engagement skills. • Experience in resource allocation, team coordination, and task assignment. • Proficiency in project management software tools.	LOW

LOW – SKILL GAP Minimal task changes are required, though some additional domain knowledge may be necessary.

MEDIUM – SKILL GAP Some new responsibilities are introduced, and upskilling or reskilling is needed to handle these new tasks.

HIGH – SKILL GAP Significant new responsibilities and unfamiliar areas of expertise are introduced, requiring substantial upskilling or reskilling.

Job Roles	Description	Required Education	Skills	Level of Skill Gap
Financial Analyst / Wind Energy Investment Analyst / Wind Yield Performance Analyst	Assesses project feasibility, profitability, and financial risks, providing critical financial insights to inform investment decisions during the project planning and development stage.	Bsc in Finance / Accounting Economics / Business Administration / Finance (Financial Analysis)	• Proficiency in energy market analysis and financial modelling, including project economics, cash flow forecasting, and investment return evaluation. • Advanced skills in Excel for financial modelling, data analysis, and spreadsheet automation. • Knowledge of statistical methods, data analysis techniques, and forecasting methodologies. • Familiarity with PPA structures, contract terms, pricing mechanisms, and renewable energy incentives (policies, tax credits). • Ability to assess project and investment risks, including market, regulatory, and operational risks. • Proficiency in data visualisation tools (e.g., Tableau, Power BI, Matplotlib, Seaborn) and financial analysis software (e.g., DCF models, financial statement analysis tools). • Skill in conducting cost-benefit analysis for financial impact assessment and risk mitigation strategies.	MEDIUM
Mechanical Engineer	Manages the assembly, installation, and commissioning of wind turbine components, ensuring functionality, alignment, and adherence to specifications while coordinating with other engineering teams.	Bsc in Mechanical Engineering	• Proficiency in designing, constructing, and installing wind turbine components. • Ability to interpret technical drawings, schematics, and specifications. • Familiarity with safety standards and regulations. • Understanding of testing procedures and commissioning protocols. • Capability to conduct root cause analysis. • Awareness of maintenance practices. • Proficiency in CAD software.	MEDIUM

LOW – SKILL GAP Minimal task changes are required, though some additional domain knowledge may be necessary.

MEDIUM – SKILL GAP Some new responsibilities are introduced, and upskilling or reskilling is needed to handle these new tasks.

HIGH – SKILL GAP Significant new responsibilities and unfamiliar areas of expertise are introduced, requiring substantial upskilling or reskilling.

Job Roles	Description	Required Education	Skills	Level of Skill Gap
Blade Engineer	Designs and analyses wind turbine blade structures and performance to enhance reliability and efficiency.	Bsc in Chemical Engineering / Mechanical Engineering	• Experience in blade engineering, providing technical support and assistance to service departments. • Capability in technical troubleshooting for various wind turbine manufacturers. • Skills in blade damage assessment, repair methods, and onsite support. • Ability to validate and approve Component Inspection Reports (CIR) related to blades. • Experience in creating local documentation (e.g., job-specific method statements, procedures). • Knowledge of best practices for blade inspection and repair. • Proficiency in composite materials analysis and manufacturing. • Significant experience in blade inspection and repair.	HIGH
Wind Operation and Maintenance Engineer	Develops and implements maintenance plans and improvements for wind farm systems.	Bsc in Mechanical Engineering / Industrial Engineering / Process Operations and Maintenance	• Proficiency in FEA, aeroelastic, and CAD modelling tools (e.g., AutoCAD, SolidWorks, ANSYS, Flex, Bladed). • Familiarity with testing and measurement equipment. • Physical ability to climb 100-metre towers, lift up to 50 lbs, and travel up to 20%. • Expertise in technical support for fault finding and maintenance work instructions. • Ability to interpret wind turbine technical drawings and OEM manuals. • Advanced knowledge of Wind Turbine Safety Rules (WTSR) and compliance with safety standards. • Skills in performing corrective and major repairs on wind turbines, using specialised tools for maintenance tasks. • Strong diagnostic skills to promptly address and resolve issues. • Authorised Engineer with at least 5 years of experience or equivalent technical support experience in a wind turbine environment.	MEDIUM

LOW – SKILL GAP Minimal task changes are required, though some additional domain knowledge may be necessary.

MEDIUM – SKILL GAP Some new responsibilities are introduced, and upskilling or reskilling is needed to handle these new tasks.

HIGH – SKILL GAP Significant new responsibilities and unfamiliar areas of expertise are introduced, requiring substantial upskilling or reskilling.

Job Roles	Description	Required Education	Skills	Level of Skill Gap
Wind Turbine Technician / Operation and Maintenance Technician / Electrical Wind Technician	Diagnoses, repairs, and maintains wind turbines and related electrical systems to ensure operational efficiency and safety.	Diploma / Vocational Diploma in Mechanical Engineering or Electrical Engineering	• Performs scheduled and unscheduled electrical/mechanical maintenance on various wind turbine models. • Diagnoses and troubleshoots electrical faults and malfunctions in wind turbine systems. • Works with SCADA systems, programmable logic controllers (PLCs), and distributed control systems (DCS). • Knowledge of electrical safety protocols, including lockout/tagout (LOTO), arc flash protection, and PPE usage. • Proficiency with electrical test equipment such as multimeters, insulation testers, oscilloscopes, and thermal imaging cameras. • Coordinates service operations, supervises technicians, and manages contractors for maintenance tasks. • Proficiency in reading and interpreting electrical schematics, wiring diagrams, and technical manuals. • Uses computerised maintenance management systems (CMMS) and electronic workflow systems (e.g., MORS, Fluix). • Documents maintenance activities and ensures accurate reporting. • Ensures compliance with Occupational Health and Safety standards and understanding of backup power systems in wind turbines.	LOW

LOW – SKILL GAP Minimal task changes are required, though some additional domain knowledge may be necessary.

MEDIUM – SKILL GAP Some new responsibilities are introduced, and upskilling or reskilling is needed to handle these new tasks.

HIGH – SKILL GAP Significant new responsibilities and unfamiliar areas of expertise are introduced, requiring substantial upskilling or reskilling.

Job Roles	Description	Required Education	Skills	Level of Skill Gap
Blade Technician / Wind Blade Repair Technician	Performs rope access to inspect, repair, and maintain wind turbine blades to ensure their efficiency and safety.	Diploma / Vocational Diploma in Industrial Maintenance	• Mechanical systems expertise in composite materials (fibreglass and carbon fibre). • Blade repair and maintenance experience. • Rope Access certification (e.g., IRATA) and GWO Blade Repair and Safety certifications. • Physical fitness for working at heights and in outdoor conditions. • Problem-solving skills for troubleshooting and repair under pressure. • Strong safety mindset with adherence to protocols and regulatory standards. • Proficiency in rope access methods (SRT, DRT, work positioning). • Blade inspection skills using visual and non-destructive methods (e.g., tap testing, ultrasound, thermography). • Competence in handling specialised tools for blade repair. • Accurate documentation of inspection and maintenance activities.	HIGH
Mechanical Wind Technician / Mechanical / Hydraulics Technician	Performs mechanical and hydraulic maintenance and repairs on wind turbine systems to ensure reliable operation.	Diploma / Vocational Diploma in Mechanical Engineering	• Understanding of blade pitch control mechanisms, including hydraulic systems, actuators, pitch bearings, and sensors. • Familiarity with yaw drive systems, including motors, gears, brakes, and yaw bearings. • Proficiency in safely climbing and descending wind turbine towers with fall protection equipment. • Skill in using torque wrenches, tensioning tools, and hydraulic bolt tensioners. • Knowledge of precision alignment methods. • Basic welding skills (MIG, TIG, stick welding) and metal fabrication techniques. • Knowledge of rigging principles and experience with lifting equipment, such as cranes and hoists.	HIGH

LOW – SKILL GAP
Minimal task changes are required, though some additional domain knowledge may be necessary.

MEDIUM – SKILL GAP
Some new responsibilities are introduced, and upskilling or reskilling is needed to handle these new tasks.

HIGH – SKILL GAP
Significant new responsibilities and unfamiliar areas of expertise are introduced, requiring substantial upskilling or reskilling.

Job Roles	Description	Required Education	Skills	Level of Skill Gap
Crane and Tower Operator	Safely and efficiently operates cranes to lift, transport, and position heavy wind turbine components during the construction and installation phase, ensuring precise placement and adherence to safety protocols.	Vocational Diploma Vocational Certificate/ Certificate in Process Operation	• Proficiency in operating various types of cranes and tower equipment. • Knowledge of routine maintenance procedures and troubleshooting techniques. • Skill in lifting, positioning, and securing heavy loads with cranes and tower equipment. • Ability to navigate construction sites safely. • Proficiency in setting up and assembling cranes and tower equipment. • Capability to diagnose equipment malfunctions and implement corrective actions. • Knowledge of emergency procedures and protocols. • Proficiency in rigging techniques for secure load attachment. • Skill in load calculations for determining total weight. • Proficiency in hoisting heavy loads. • Knowledge of hand signals for communication. • Familiarity with safety rules and regulations.	MEDIUM
GIS Specialist / Geographers	Creates detailed maps and conducts spatial data analysis to support site selection, environmental impact assessment, and infrastructure planning during the wind energy project development phase.	Bsc in Geography Earth and Environmental Science	• Expertise in GIS software (e.g., ArcGIS, QGIS) for data management, spatial analysis, and map production. • Ability to perform spatial analysis techniques (e.g., interpolation, overlay analysis, suitability modelling) for wind resource and site assessments. • Experience in managing spatial datasets, including data acquisition, integration, cleaning, and quality assurance. • Knowledge of remote sensing techniques and satellite imagery analysis for environmental data collection. • Skill in creating maps, charts, and visualisations to effectively communicate spatial information to stakeholders.	LOW

LOW – SKILL GAP
Minimal task changes are required, though some additional domain knowledge may be necessary.

MEDIUM – SKILL GAP
Some new responsibilities are introduced, and upskilling or reskilling is needed to handle these new tasks.

HIGH – SKILL GAP
Significant new responsibilities and unfamiliar areas of expertise are introduced, requiring substantial upskilling or reskilling.

Job Roles	Description	Required Education	Skills	Level of Skill Gap
Wind Resource Analyst / Wind Resource Engineer / Wind Yield Performance Analyst	Assesses wind patterns, speed, and turbulence to evaluate site suitability, predict energy production, and optimise turbine configuration for maximum project profitability during the planning and development phase.	MSc in Mechanical Engineering / Computer Science / Aeronautical Engineering (Mechanical) / Renewable Energy / Resources and Process Engineering	• Expertise in wind resource assessment and wind farm energy production modelling according to industry standards. • Proficiency in wind farm design and turbine layout optimisation. • Advanced skills in scientific programming languages (e.g., Python, MATLAB). • Familiarity with common analysis tools (e.g., WindPro, OpenWind, Windographer). • Experience with open-source tools for wind farm modelling and optimisation (e.g., PyWake, FLORIS, WISDEM, TOPFARM) is an advantage.	MEDIUM

Table 18: Wind power development certifications and job roles across different stages

Source: Majan Council analysis

	Planning & Development	Construction & Installation	Operations & Maintenance
Certification	• Design, Installation, and Maintenance of Wind Turbines • Performance & Load Calculation for Wind Turbines • Wind Power Planning and Measurement • Wind Power Projects and Finance • Certification in Project Management (e.g., PMP, Agile Certified Practitioner) • Planning & Scheduling Professional (PSP) • Wind Resource Assessment and Wind Farm Planning	• Advanced Rescue Training Standard (ART) • Basic Technical Training Standard • Blade Repair Training Standard • Control of Hazardous Energies Standard (CoHE) • Crane and Hoist Standard • Slinger Signaller Standard • Service Lift Training Standard • Instructor Qualification Standard • Enhanced First Aid Training Standard • Entry Level Wind Technician Framework (Pre-assembly & Installation modules) • Onshore Limited Access Standard (for supervised visits during construction)	• Advanced Rescue Training Standard (ART) • Advanced Rescue Training Refresher Standard (ARTR) • Basic Safety Training Standard (BST) • Basic Safety Training Refresher Standard (BST Refresher) • Enhanced First Aid Training Standard • Blade Repair Training Standard • Control of Hazardous Energies Standard (CoHE) • Service Lift Training Standard • Entry Level Wind Technician Framework (Operations & Maintenance modules) • Wind Farm Monitoring and Optimization
Targeted	Wind Design Engineer, Project Engineer, Civil Engineer, Lead Mechanical Engineer, Lead Yaw System Mechanical Design Engineer, Electrical-Transmission Engineer / Power Systems and Transmission Engineer, Wind Turbine Engineer, Finance Manager, Asset Manager / Asset Integrity Manager, Wind Site Manager, Training and Development Manager / Training and Resource Manager, Project Manager, Business Administrator, Power Market Analyst / Wind Yield Performance Analyst, GIS Specialist / Geographers, Financial Analyst / Wind Energy Investment Analyst, Meteorologist, Wind Resource Analyst / Wind Resource Engineer / Wind Yield Performance Analyst, Atmospheric Scientist.	Crane and Tower Operator, Scaffolder, Assemblers and Fabricators, Welder / Welding Worker, Construction Equipment Operator, Construction Labourer, Storeperson, Rigger, Concrete Worker, Electrician, Meteorological Technician, Construction Inspector, Transport Operative, Mechanical Engineer, Industrial Engineer, Civil Engineer, Electrical Engineer, Technical Earthing Engineer, Fleet Maintenance Engineer, Structural Engineer, Quality Assurance Engineer, Health and Safety Expert / Safety, Health, Environment and Security Specialist, Logistics Coordinator, Draughtsman, Foundation Contractor, Site Manager / Site Administrator, Instructor, Training and Resource Manager / Training and Development Manager, Security Personnel, Logistics Coordinator, Heavy and Tractor-Trailer Truck Driver, Facilities Manager, Procurement Manager, Project Manager, Construction Manager.	Facilities Maintenance Coordinator / Engineer / Operation and Maintenance Engineer, Blade Engineer, Wind Turbine Engineer / Operation and Maintenance Engineer, Site / Power Plant Manager, Operation and Maintenance Manager, High Voltage Operator – Power Generation, Mechanical Wind Technician / Mechanical / Hydraulics Technician, Electrical Wind Technician, Power Plant Operator, Control Room Technician, Communications Network Technician, Rope Access and Blade Repair Supervisor / Blade Technician, Crane / Lifting Contractor, Substation Operator, Meteorological Technician, Blade Technician / Wind Blade Repair Technician, Component Technician, Lead Wind Technician, Wind Turbine Technician / Operation and Maintenance Technician, Operation and Maintenance Technician, Operation Controller, Instrumentation and Controls Technician, Environmental Technician, Crane and Rigging Inspector, Quality Engineer, Fire Safety Technician.

2.2.4 Education, upskilling potential & Omanisation

As Oman's wind energy sector expands, ensuring the workforce is equipped with the right technical qualifications and skills will be critical. Existing academic programmes cover relevant fields such as engineering, energy systems, and project management, but there are clear gaps in practical training and sector-specific expertise.

Figure 17 shows that professional-level roles are concentrated in engineering, planning, and project management, while technician-level roles dominate in construction, commissioning, and O&M. Skilled and semi-skilled roles are largely tied to construction, installation, and support functions. BSc qualifications are mostly associated with professional roles, whereas Diplomas and Certificates link to technical and hands-on job functions.

Several key roles—particularly in construction and O&M—lack corresponding educational pathways. These gaps, indicated as "Unavailable" in the diagram, highlight missing links between industry needs and current academic offerings.

The diagram outlines qualification requirements but does not reflect workforce volume. A single logistics manager role may show links to multiple qualifications, while technician roles—although more numerous—appear underrepresented. This visual imbalance underscores the need to prioritise technician-level training.

Most required specialisations, such as electrical engineering, mechanical engineering, operations engineering, and industrial maintenance, are offered in Oman. There are nine vocational colleges offering electrical engineering, eleven offering mechanical engineering, eight offering industrial maintenance, and only one offering operations engineering. However, these programmes typically lack the technical depth and practical orientation required for wind-specific roles.

Graduates from these disciplines often need additional certification or on-the-job training to meet industry standards. Without intervention, this mismatch will limit the availability of job-ready candidates for wind energy development.

Demand for technicians and skilled workers is particularly high during the construction and installation (C&I) and operations and maintenance (O&M) phases (see Table 19). The current oversupply of generalist qualifications contrasts with a shortage of specialised, job-ready candidates in these critical phases. Addressing this will require targeted curriculum updates, sector-focused vocational programmes, and certification pathways aligned with the operational realities of wind energy projects.

Without such alignment, Oman risks relying on expatriate labour to fill essential technical roles. Bridging this gap is essential to support both project delivery and Omanisation objectives.

The Specialisation Availability provide insight into how well Oman's educational institutions meet the skill demands of the wind energy sector (see Table 20). While certain fields—such as Business Administration and IT—show signs of oversupply, technical areas like vocational mechanical and electrical engineering remain underrepresented. These imbalances, if left unaddressed, could delay project development and increase dependence on foreign labour.

Oman's existing workforce, especially those with experience in oil, gas, and industrial sectors, already possesses transferable skills that can be adapted to the wind energy sector. Targeted upskilling initiatives in renewable energy, wind system installations, and energy storage can help channel this talent into the clean energy transition.

To support this effort, the following recommendations outline how Oman can strategically align jobseeker qualifications with labour market needs in the wind energy sector:

» **Expand vocational and technical training:** Focus on short-term certifications in fields like process operations, welding and metal fabrication, and wind-specific mechanical and electrical roles.

» **Develop wind-specific programmes:** Integrate wind energy content into existing electrical, mechanical, and civil engineering tracks.

» **Align education with industry needs:** Strengthen ties between industry and academia to ensure that curricula reflect actual project requirements. This includes promoting internships, co-op programmes, and applied research partnerships.

» **Targeted upskilling of existing professionals:** Provide certification in wind project management, grid systems, and SCADA technologies to engineers, managers, and IT professionals from other sectors.

» **Develop specialised programmes:** Introduce degrees and diplomas in renewable energy engineering, wind energy project management, and sustainability fields, with clear input from industry stakeholders.

» **Support transitions from legacy sectors:** Train electricians, technicians, and field workers from the oil and gas sector to meet the labour demands of wind power projects.

» **Enable non-technical transitions:** Design short courses for professionals in law, business, and marketing to contribute to the wind sector through project management, regulatory affairs, and communications.

With a coordinated approach to training and workforce planning (Table 21), Oman can reduce reliance on expatriates, strengthen domestic capabilities, and accelerate the localisation of its wind energy sector.

Table 22 and Table 23 evaluate the strengths and weaknesses associated with Omanisation in the wind power sector, focusing on different job categories and stages of the value chain. These tables highlight key metrics such as availability, criticality, longevity, share of workforce, and the potential for Omanisation. This analysis helps identify where Oman's workforce is adequately prepared and where challenges remain in ensuring a fully localised and capable workforce. These insights are essential for defining strategic priorities in workforce development, designing effective training programmes, and informing policy interventions to support Omanisation in roles most critical to the sector's growth and sustainability.

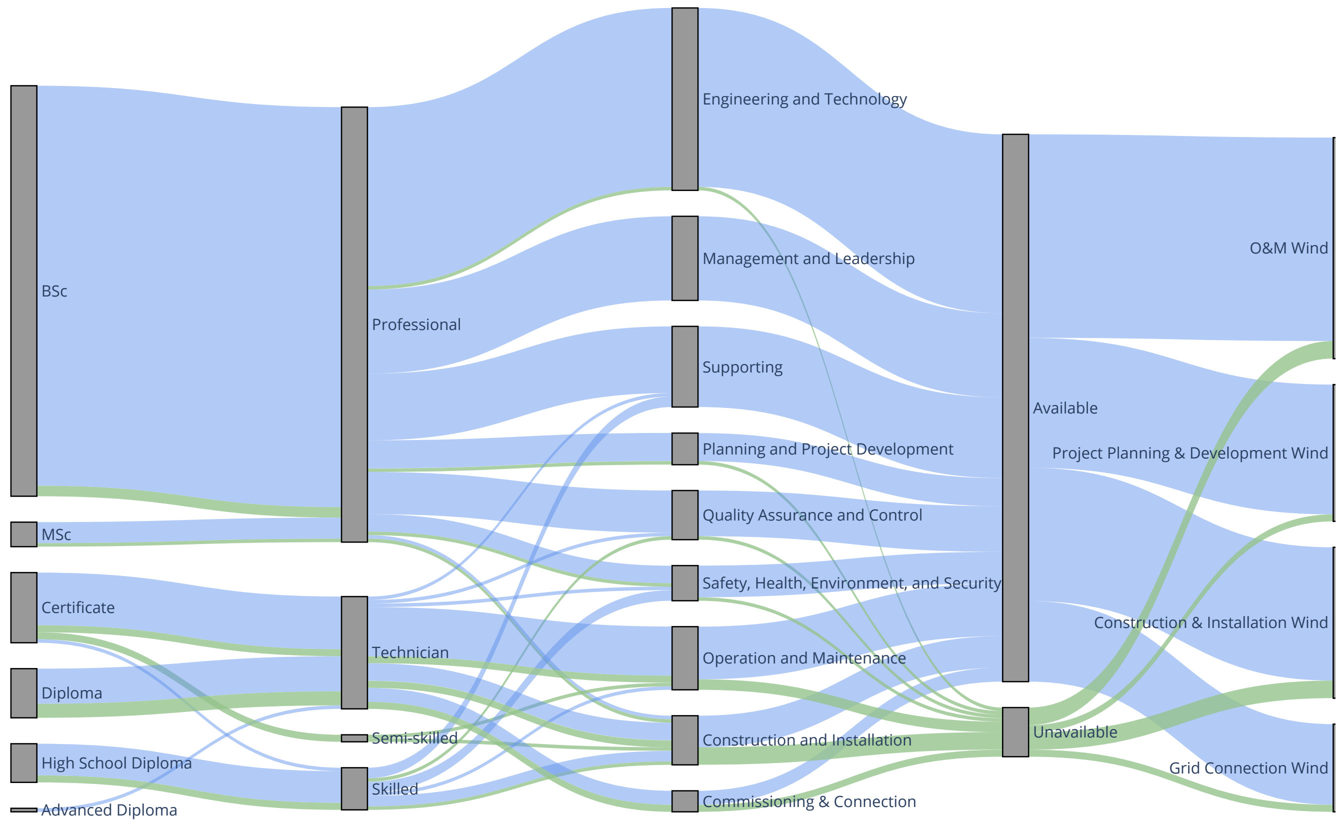
Another factor influencing Omanisation outcomes is the duration and nature of employment across different project phases. The construction phase of wind energy projects typically requires a large workforce, but many of these roles involve physically demanding tasks under challenging conditions and are of short duration—often lasting just 12 to 18 months (Figure 18). These positions tend to offer limited opportunities for Omanisation due to their temporary nature and lower compensation.

Conversely, construction-phase roles that require higher technical skills and offer better wages provide more viable opportunities for localisation. However, short project timelines mean that without new projects in the pipeline, workers face risks of unemployment between phases. This underscores the need for strategic sequencing of wind and green hydrogen projects to ensure continuity of employment.

Table 19 also shows that the Planning & Development (P&D) phase is dominated by professionals, while the Construction & Installation (C&I) and Operations & Maintenance (O&M) phases rely more heavily on technicians and skilled workers. This distribution points to the importance of vocational training and wind-specific certifications to meet the needs of C&I and O&M phases and support sustainable Omanisation.

In addition, sustained employment generation is more likely in the industrial, commercial, and building-scale segments of the wind and clean energy market, where projects are distributed and continuous rather than centralised and episodic. This reinforces the importance of supportive regulation, competitive tariffs, and targeted incentives to stimulate year-round project development and job creation.

Figure 17: Alignment of educational qualifications with wind power sector requirements in Oman



Source: Majan Council analysis

Table 19: Share of required specialisations by skill category for wind project development stages

Stage	Technician & Skilled (%)	Professional (%)
Planning & Development (P&D)	10	90
Construction & Installation (C&I)	43	57
Operations & Maintenance (O&M)	54	46

Source: Majan Council analysis

Table 20: Analysis of upskilling opportunities for Omani jobseekers in the wind energy sector

Specialization/ Sub major	Availability	Demand	Job seekers level	Upskilling Level of Job seekers	Industry Needs & Required Upskilling
Business Administration	High	Low	High	Mid	Oversupply observed; upskilling in energy-sector administration could improve alignment with wind industry roles.
Computer Science & Information Technology	High	Low	High	Mid	Relevant for digital roles; training in SCADA systems, data analytics, and IoT applications tailored to wind energy is recommended.
Construction Engineering	Mid	Mid	Low	High	Crucial for wind farm construction; upskilling in turbine foundations, site logistics, and wind farm layout planning is essential.
Supply Chain Management	Low	Low	Mid	Mid	Important for logistics operations; training should focus on wind-sector supply chain processes to increase employability.
Engineering Project Management	Low	Mid	Low	High	Vital for project execution; requires upskilling in wind project lifecycles, budgeting, and risk mitigation strategies.
Electrical Engineering	Mid	High	High	Mid	High demand for roles such as Grid Engineer; training in grid integration, wind energy systems, and power electronics is essential.
Environmental Engineering	Low	Mid	Low	High	Needed for environmental compliance; upskilling in wind-specific assessments and regulations is beneficial.
Mechanical Engineering	Mid	High	High	Mid	In high demand for turbine O&M; specialised training in turbine mechanics, aerodynamics, and drivetrain systems is required.
Economics & Finance	High	Low	Mid	Mid	Oversupply; relevant for project finance roles. Upskilling in renewable energy economics, risk analysis, and financing models is recommended.
Structural Engineering	Low	Low	Low	Mid	Limited but niche relevance for turbine foundations and structural safety. Upskilling in wind energy foundation design would be useful.
Electrical Wiring (Industrial)	Low	Mid	Low	Mid	Required for turbine wiring and electrical maintenance. Sector-specific training in industrial systems for wind applications is advised.

Source: Majan Council analysis

Table 21: Upskilling and reskilling needs for jobseekers in wind power

Category	Jobseekers With Direct Fit	Jobseekers Requiring Moderate Upskilling in Supporting Roles
Type	Short-term certifications (Wind-Specific Training Programs)	Medium-term vocational training
Targeted	Electrical Engineering, Mechanical Engineering, Civil Engineering, Environmental Engineering: These specialisations are well aligned with wind industry needs. Jobseekers from these fields require moderate upskilling to transition into technical wind energy roles.	Information Technology, Human Resource Management, Marketing, Supply Chain Management: These specialisations are relevant to wind energy but require targeted industry-specific training (e.g., wind project management, logistics for wind infrastructure) to ensure alignment with sector requirements.

Source: Majan Council analysis

Table 22: Strengths and weaknesses vis-à-vis Omanisation in the wind power sector

Job Category & Stage of the Value Chain	Availability	Criticality	Longevity	Share of Workforce	Omanisation Potential
Planning & Development (P&D)					
Management and Leadership	High	High	Mid	Mid	High
Planning and Project Development	Mid	High	Mid	Mid	High
Engineering and Technology	Mid	High	Mid	High	Mid
Quality Assurance and Control	Mid	Mid	Low	Low	Mid
Safety, Health, Environment, and Security	Low	Low	Low	Low	Low
Supporting	Low	Low	Low	Mid	Low
Construction & Installation (C&I)					
Management and Leadership	Low	High	Mid	Low	High
Construction and Installation	Low	High	Low	High	Low
Commissioning & Connection	Mid	High	Low	Mid	Low
Engineering and Technology	Mid	High	Mid	Mid	Mid
Quality Assurance and Control	Mid	Mid	Low	Mid	Low
Safety, Health, Environment, and Security	Low	Mid	Low	Low	Low
Supporting	Low	Low	Mid	High	Mid
Operation & Maintenance (O&M)					
Management and Leadership	Low	High	High	Mid	High
Operations and Maintenance	Low	High	High	High	Mid
Engineering and Technology	Mid	High	High	High	High
Quality Assurance and Control	Low	High	High	Low	High
Safety, Health, Environment, and Security	Low	High	High	Low	Mid
Supporting	Low	Mid	High	Mid	High

Source: Majan Council analysis

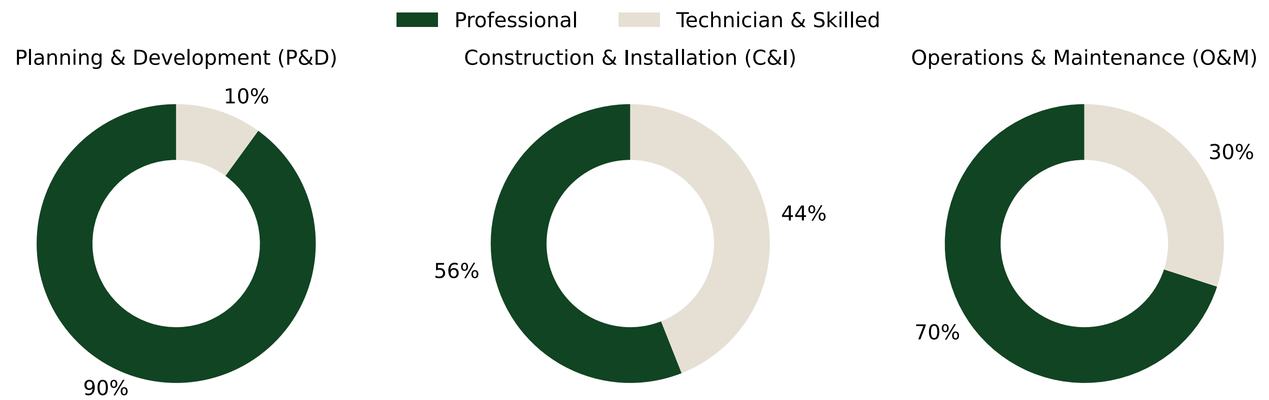
Table 23: Job roles assessment criteria

Category	Description	Rating Criteria
Availability/ Supply	Evaluates the current availability of relevant sub-majors or qualified professionals in the labour market for a given job category, based on the existing talent pool.	1 to 3 = High to not available
Criticality	Measures the importance of the job category to the success of a project. Roles with higher criticality are considered essential to achieving key outcomes.	1 to 3 = Low to High
Longevity	Indicates the projected long-term demand for the role, based on the role's future relevance and stability within the industry.	1 to 3 = short term to long term
Share of Workforce	Represents the proportion of the overall workforce occupied by a particular role or category within the industry.	1 to 3 = Low to High
Omanisation Potential	Reflects the potential to increase employment of Omani nationals in specific job categories, based on the Omanisation policy rates set by the Ministry of Labour (MoL).	1 to 3 = Low to High (more)

* The first category corresponds to high-level administrative jobs, which are in high demand among Omanis (60%). The second category includes technical and specialist jobs (45%), while the third category consists of basic jobs, which attract less interest from Omanis (20%).

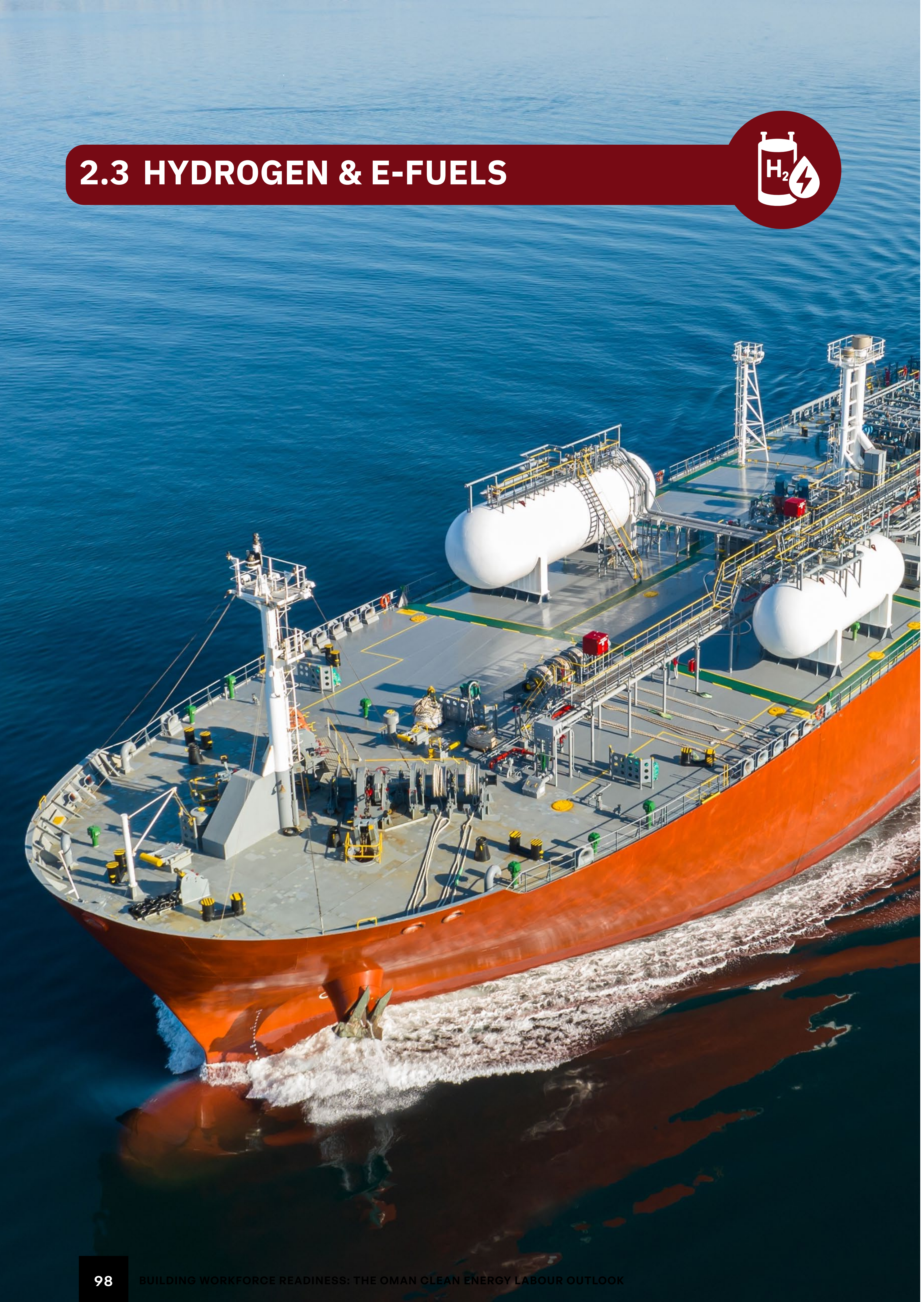
Source: Majan Council analysis

Figure 18: Local and regional workforce distribution by project phase for an representative 90 MW wind project in the GCC



Source: Majan Council analysis

2.3 HYDROGEN & E-FUELS



2.3.1 Value Chain & Sector

Hydrogen is a versatile energy carrier with growing relevance across energy, industry, and transport systems. Its flexibility in production pathways—ranging from fossil fuels with carbon capture to electrolysis using renewable electricity—makes it a critical technology for decarbonising sectors that are difficult to electrify, such as heavy industry and long-distance transport. Toward 2050, hydrogen could contribute more than 20% of annual global emissions reductions. Figure 19 illustrates the global distribution of hydrogen production by source, highlighting the dominance of fossil-based hydrogen and the emerging role of low-emission alternatives.

Although hydrogen has long been used in traditional applications such as oil refining and chemical production, its strategic importance is expanding. In industrial sectors, it serves as a feedstock for ammonia, methanol, and fertiliser production, and as a reducing agent for producing direct reduced iron (DRI)—a method for steelmaking that avoids the use of coal-based blast furnaces. DRI can now be produced using 100% hydrogen, significantly reducing emissions. Hydrogen is also used in smaller quantities in sectors such as glassmaking, electronics, and metal processing.

Clean hydrogen—produced either from renewables (green hydrogen) or fossil fuels with carbon capture (blue hydrogen and others, see Table 24)—offers a pathway to reduce emissions across a growing range of new applications. These include high-temperature heating in industrial processes, the upgrading of biofuels, the production of hydrogen-based synthetic fuels such as ammonia or methanol, and its role as a long-duration electricity storage solution. These uses complement hydrogen's growing importance in the transport sector, where it powers fuel-cell electric vehicles and may serve as a basis for low-emission fuels in maritime and aviation contexts.

Hydrogen's production pathways are often classified using a colour-based system, reflecting the feedstock and emissions profile (Table 24). Green hydrogen—produced via electrolysis using renewable electricity—has near-zero emissions. Blue hydrogen is derived from natural gas with carbon capture, while grey and black hydrogen—produced without emissions control—have high environmental footprints.

Today, hydrogen is still primarily produced from fossil fuels, particularly natural gas and coal, accounting for substantial CO_2 emissions. Scaling up clean hydrogen production will require investment in electrolysers, carbon capture systems, and associated infrastructure, along with regulatory frameworks and demand-side incentives. This transition is essential to reduce the costs of key technologies and enable the integration of clean hydrogen into energy systems at scale.

Hydrogen's role is not limited to high-demand sectors. It can also serve smaller but strategically important uses in electronics, glassmaking, and niche chemical processes—particularly where low-emission alternatives are limited.

While hydrogen is widely seen as a cornerstone of future decarbonisation strategies, its development continues to face major challenges. A key bottleneck lies in the limited emergence of firm off-take agreements, largely due to policy uncertainty and the absence of robust support schemes in potential importing countries. This has contributed to a slower-than-expected demand build-up, leaving many announced projects without committed buyers. Although infrastructure development—in areas such as transport, storage, and electricity supply—remains important, the slower pace of market formation and the high capital requirements continue to dampen investment momentum. Additionally, the lack of harmonised certification systems for low-emission hydrogen complicates international trade and investment planning. However, beyond export models, producers can explore alternative strategies such as manufacturing hydrogen-derived 'green goods'—including steel or cement (see later chapters)—which could become globally competitive under emerging carbon pricing schemes like the EU's planned Carbon Border Adjustment Mechanism.

The hydrogen value chain, ultimately leading to those applications, spans several interconnected stages—production, conversion, storage, transport, and end use (Figure 20). The hydrogen value chain consists of five interlinked stages: production, conversion, storage, transport, and end use. Each stage involves specific technologies and infrastructure, with cost and performance dynamics that shape hydrogen's role in future energy systems. Understanding this value chain is essential for evaluating hydrogen's potential to support decarbonisation, energy resilience, and economic diversification.

Production

Hydrogen can be produced via:

Electrolysis, which uses electricity to split water into hydrogen and oxygen. When powered by renewable energy, this process yields green hydrogen. While currently more expensive than fossil-based alternatives, green hydrogen production costs are declining due to falling prices for electrolysers and renewable electricity. With optimal conditions, green hydrogen could become cost-competitive in many regions by 2030.

Thermochemical processes, particularly steam methane reforming and coal gasification, which dominate global hydrogen production today. These emit substantial carbon dioxide and are referred to as grey hydrogen when no carbon capture is applied. When combined with carbon capture and storage, they produce blue hydrogen—a lower-emission alternative. However, blue hydrogen still relies on fossil fuels and is subject to upstream methane leakage and incomplete carbon capture.

Hydrogen from electrolysis typically requires around 10 litres of high-purity water per kilogram of hydrogen. In water-scarce regions, desalination is an important cost consideration, but contributes less than US$0.10 per kilogram to total production costs.

Conversion into Derivatives

Hydrogen is often converted into chemical derivatives to enable easier storage, transport, and sectoral integration. Two key conversion products are:

Ammonia, which today is the second-most widely produced chemical commodity globally. Around 85% of ammonia production is used in fertiliser manufacturing, making agriculture its dominant consumer. With the global population projected to rise, fertiliser demand is expected to grow in parallel. In addition, ammonia is gaining attention as a fuel in power generation and maritime shipping. Green ammonia, produced using hydrogen from renewables, offers a major opportunity to decarbonise both traditional and emerging uses. Although currently two to three times more expensive than conventional ammonia, cost projections for 2030—US$500–625 per tonne—would bring it within competitive range, especially compared to recent fossil-driven price spikes.

Methanol, a highly versatile molecule used across the chemicals and transport sectors. In 2019, more than 60% of global methanol production went into chemical synthesis, with another 31% used as fuel or fuel blending agents. Its use as a clean marine fuel is expanding, supported by interest in methanol-fuelled vessels. While green methanol is currently far more expensive than fossil-based production, cost declines to US$250–630 per tonne are anticipated by 2050 as hydrogen and sustainable CO_2 sources become more available.

These derivatives are central to hydrogen's role in cross-sector decarbonisation and global trade.

Storage

Hydrogen can be stored in several forms depending on time horizon, application, and infrastructure availability:

Compressed or liquefied hydrogen tanks are used for short-term storage and mobility applications. Liquefied hydrogen must be cooled to –253°C, requiring specialised cryogenic infrastructure. Compression or liquefaction reduces volume but adds cost and energy losses, with liquefaction consuming 25–35% of the hydrogen's energy content.

Geological storage, especially in salt caverns, provides long-duration, high-volume solutions suitable for balancing seasonal fluctuations in supply and demand. Other formations such as depleted gas reservoirs or aquifers offer larger capacities but require more treatment and validation for hydrogen compatibility.

Solid-state and chemical storage methods—such as metal hydrides—are in earlier stages of development but may enable safe and compact hydrogen storage in future decentralised applications.

Transport

Hydrogen can be transported through pipelines, shipping routes, and road networks, with the most suitable option depending on distance, volume, and end-use requirements.

Pipelines are ideal for short- to medium-distance transport and offer the lowest operating costs once installed. Repurposing existing natural gas pipelines is technically feasible in many cases, though material upgrades may be required. New dedicated hydrogen pipelines involve high upfront costs but are critical for large-scale domestic transmission systems.

1. Shipping is the main option for long-distance and international transport. There are three primary approaches:

- **Liquefied hydrogen**, transported at extremely low temperatures, requires purpose-built cryogenic tankers. Although it delivers high-purity hydrogen directly, it is energy-intensive and costly—shipping over 10,000 km is estimated at US$14–19 per gigajoule.
- **Ammonia**, which is easier and cheaper to ship—US$2–3 per gigajoule over similar distances. As a widely traded chemical with existing infrastructure, ammonia is well suited for near-term hydrogen exports. However, if reconversion to hydrogen is required at destination, additional processing is needed, which introduces energy losses and cost.
- **Liquid organic hydrogen carriers (LOHCs)** bind hydrogen to a stable liquid that can be transported using conventional fuel infrastructure. LOHCs are safer to handle and avoid cryogenic systems, but require chemical conversion both before and after transport, and the carrier liquid must be returned.

2. Trucking plays a key role in regional distribution and early-stage deployments. Trucks are used to transport compressed or liquefied hydrogen, as well as derivatives like ammonia and LOHCs. While trucking is more expensive per unit transported and better suited for short distances, it remains critical for flexible delivery, particularly in areas without pipeline infrastructure.

End-use

Hydrogen finds usage in several end-use technologies and approaches:

Refining: The refining sector accounts for about one-third of global hydrogen demand. Hydrogen is used to remove sulphur and other impurities from fuels, particularly in upgrading heavier crude oils. By 2030, demand in this sector is expected to rise modestly—by around 7%—driven by stricter air quality standards in fuel production. Although future reductions in global oil consumption may limit long-term growth, refineries remain a significant source of baseline hydrogen demand.

Chemicals (Ammonia and Methanol): Hydrogen is an essential input for ammonia and methanol, which are used in fertilisers, industrial chemicals, and fuels. This sector consumes roughly 27% of global hydrogen today. Demand is projected to increase by around 30% by 2030, largely driven by fertiliser production and the growing interest in methanol as a cleaner transport fuel. The scale of hydrogen use in chemical production makes it a key area for the expansion of low-emission hydrogen, particularly in countries with export ambitions.

Steel and High-Temperature Industry: Steel production currently accounts for only 3% of hydrogen use but is expected to see demand double by 2030. This is primarily linked to the gradual shift from coal-based methods toward hydrogen-based processes in ironmaking. In parallel, hydrogen may play a role in industrial sectors that rely on high-temperature heat—such as cement, glass, and ceramics—where electrification is less practical. While hydrogen use in these applications remains limited for now, demand could grow by nearly 10% by 2030, particularly in industrial clusters with pipeline access or shared infrastructure.

Transport: Hydrogen is increasingly considered for transport applications where batteries may not be viable, particularly long-haul and high-load operations. Fuel cell electric vehicles (FCEVs) offer faster refuelling and longer range than battery-electric alternatives, making them suitable for trucks, buses, and regional trains. Hydrogen-derived fuels such as ammonia and synthetic kerosene are also under development for use in maritime and aviation sectors. While hydrogen currently plays a limited role in transport, targeted adoption is expected to expand gradually, especially beyond 2030, as infrastructure improves and vehicle supply chains mature.

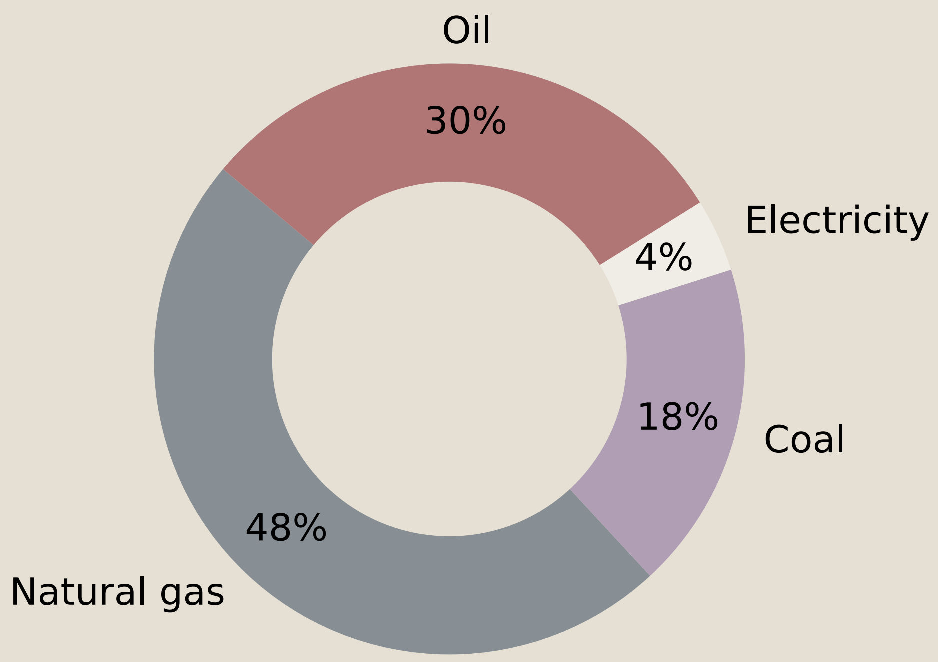
Usage in transport is closely linked to so-called e-fuels, which are synthetic fuels produced using hydrogen and captured carbon dioxide. They could substitute fossil fuels in sectors that are difficult to electrify, such as shipping, aviation, and parts of heavy industry. Because many e-fuels are compatible with existing engines and infrastructure, they offer a transitional pathway to decarbonisation—especially in long-distance and high-energy-demand transport.[6] However, some key technologies still need to mature (Table 25).

Among e-fuels, methanol is particularly advanced in terms of commercial readiness. Global demand reached nearly 100 million tonnes in 2019 and continues to grow, especially as the maritime sector explores low-emission fuel options. Renewable methanol—also known as e-methanol—can be produced from biomass or through synthesis using green hydrogen and captured CO_2.

Current e-methanol production costs range from USD 800 to 1,600 per tonne, depending on the carbon source. In the long term, costs are expected to fall to between USD 250 and 630 per tonne by 2050, particularly in locations with low-cost renewable electricity and hydrogen. Globally, more than 140 renewable methanol projects are under development, with planned capacity expected to exceed 20 million tonnes annually by 2030.

Globally, the e-fuel market was valued at approximately USD 125 billion in 2023 and is projected to reach around USD 646 billion by 2033, with an average growth rate of nearly 18%. This growth reflects increasing interest in low-emission fuels for sectors that are difficult to electrify. While large-scale deployment is still emerging, e-fuels—including methanol, ammonia, and synthetic hydrocarbons—are expected to play an expanding role in future hydrogen-based energy systems and export value chains.

Figure 19: Global hydrogen production by source



Source: Reference 19

Table 24: Classification of hydrogen production methods

Terminology		Technology	Feedstock/ Energy source	Greenhouse gas footprint
Production via electricity	Green hydrogen	Electrolysis	Renewables such as wind, solar, hydro, tidal, geothermal	Minimal
	Pink hydrogen		Nuclear	
	Yellow hydrogen		Mixed-origin grid energy	Medium
Production via fossil fuels	Blue hydrogen	Autothermal reforming, steam methane reforming, or coal gasification + CCS	Natural gas or coal	Low
	Turquoise hydrogen	Pyrolysis	Natural gas	Minimal to low (Solid carbon by-product)
	Grey hydrogen	Autothermal reforming or steam methane reforming		Medium
	Brown hydrogen	Coal gasification	Brown coal (lignite)	High
	Black hydrogen	Coal gasification	Black coal	High
Production via Natural Geological Processes	White hydrogen	Naturally occurring hydrogen extraction	Natural underground hydrogen deposits	Negligible
Production via biomass	Unassigned	Biomass gasification + CCS	Biomass	Potentially negative

Figure 20: The hydrogen economy with sources, applications, and intermediaries

Table 25: Technologies needed to produce e-fuels

Conventional technologies	Key technologies	Critical technologies
Petrochemicals (hydrocracking, separation, distillation, reforming)	Fischer-Tropsch synthesis	Capturing CO_2 from the air
Hydrogen production using PEM or alkaline technologies, with a GW production target	Capturing CO_2 from industrial flue gases, RWGS chemical reactor	High-temperature electrolysis
	Biomass gasification	Co-electrolysis of water and CO_2
	Addition of H_2 to syngas from biomass	System Integration

2.3.2 Hydrogen and e-fuels in Oman

Oman has emerged as a regional frontrunner in establishing a national framework for renewable hydrogen development. Central to this effort is Hydrom, the entity mandated with structuring land allocation, coordinating project auctions, and overseeing governance across the hydrogen value chain. As part of its long-term strategy, Oman has set formal production targets of 1 million tonnes per annum (mtpa) by 2030, 3.75 mtpa by 2040, and 8.5 mtpa by 2050. These targets serve as reference points for sector planning and are intended to guide infrastructure development, renewable deployment, and export engagement (Figure 21).

Hydrogen's multi-sectoral relevance is illustrated in Figure 21, which maps its use across the economy as a feedstock, fuel, and energy carrier:

» **Industry:** Used in both established applications (e.g. ammonia, methanol, refining, and fossil-based DRI) and emerging low-emission processes such as 100% hydrogen-based DRI and high-temperature heating.

» **Transport:** Powers fuel-cell electric vehicles and serves as a base for synthetic fuels in heavy-duty, maritime, and aviation contexts.

» **Power and storage:** Enables seasonal energy storage and, in the near future, could be combusted in gas turbines to generate electricity during peak demand.

» **Heat and distribution:** Can be blended with natural gas for distribution through existing pipeline networks to provide heat for industrial and residential use.

Scaling up exports to this level would necessitate large-scale investments in new storage tanks, deep-water jetties, and supporting marine logistics. The port of Duqm—currently without dedicated ammonia export capacity—is expected to play a major role in the future hydrogen economy due to its geographic location and available land. Infrastructure plans for Duqm include ammonia storage facilities and hydrogen conversion plants with a projected renewable capacity of 1.2 million tonnes of ammonia and 0.87 million tonnes of hydrogen annually. Salalah, which already hosts ammonia and methanol terminals, is expanding its facilities to reach 1 million tonnes of renewable ammonia capacity. A new ammonia export terminal was inaugurated in Salalah in September 2022, adding to the national export infrastructure. Sur and Sohar, which currently handle ammonia, urea, and methanol, remain important to the ammonia supply chain, although no renewable hydrogen-linked expansions have been specified to date. Muscat, which focuses on refining, is not currently part of the hydrogen infrastructure planning.

To enable the export of projected ammonia volumes—estimated at 6 to 7 million tonnes per year by 2030—Oman will require around 400,000 tonnes of ammonia storage capacity across its ports and a dedicated shipping fleet of 12 to 14 large ammonia tankers. The planning and construction of this infrastructure would need to proceed in the immediate term to align with the production and export timelines for 2030 (Figure 22).

In parallel, Oman is exploring investment opportunities in hydrogen-based synthetic fuels, with a particular focus on e-methanol. Oman has already positioned itself as a significant producer of methanol, leveraging its natural gas reserves and industrial infrastructure. Two primary production plants currently dominate the domestic landscape:

» **Salalah Methanol Company LLC,** operational since 2010, with an annual production capacity of 3 million tonnes. Located in Salalah, this facility plays a major role in Oman's export-oriented methanol economy.

» **Sultanate of Oman Methanol Company (SOMC),** based in Sohar and operating since 2007, with an installed capacity of 1 million tonnes per year.

Combined, these facilities generate approximately 6,000 tonnes per day of methanol, with most of the output destined for international markets. Based on average global methanol prices of around USD 349 per tonne, total annual sales are estimated at USD 581 million. Oman's current capacity positions it as a leading methanol supplier in the region.

Several projects are now planned to expand Oman's methanol production while aligning with emerging clean fuel markets. In Duqm, the Sino-Oman Industrial City is expected to host a new methanol plant with an annual capacity of 1.8 million tonnes. The project, part of Phase 1 of the complex near Duqm Port, aims to cater to rising global demand—particularly for low-emission fuels. The Green Energy Oman (GEO) initiative, one of the world's largest proposed clean fuel projects, wants to deploy 25 GW of wind and solar capacity across the Al Wusta and Dhofar governorates to produce hydrogen and its derivatives. Green methanol is among the expected outputs, leveraging Oman's renewable resources and export orientation. In parallel, the BP Oman Green Hydrogen Project expects to develop 3.5 GW of renewable electricity to produce 150,000 tonnes per year of green hydrogen. This hydrogen is intended for conversion into fuels such as ammonia and methanol, supporting Oman's expansion into the renewable fuels market.

Methanol is also being integrated into Oman's national plans for low-carbon industrial development. Regulatory measures are under development to ensure environmental compliance, including air quality and emissions standards for future fuel production and export. With global demand for low-emission fuels increasing—especially in sectors like shipping—Oman's existing infrastructure, growing renewable energy portfolio, and geographic proximity to Europe and Asia position it well to expand methanol production and exports. Its established industrial base and port access provide a practical foundation for scaling up participation in the emerging green methanol economy.

According to Hydrom, eight green hydrogen projects have been announced toward the 2030 target. Together, these projects aim for a combined production capacity of 1.38 mtpa (Figure 23). While sites and project developers have been publicly identified, details regarding timelines, financing, and implementation are at varying stages.

The government has allocated approximately 50,000 km^2 of land as suitable for hydrogen development, and preliminary assessments suggest this could support up to 500 GW of combined solar and wind capacity. Oman benefits from exceptional renewable resources, with onshore wind speeds reaching up to 11 m/s and solar irradiance exceeding 2,400 kWh/m^2 across large parts of the country. Electrolysers used in the announced projects will be powered by renewable electricity to extract hydrogen from desalinated seawater, drawing on Oman's growing experience in large-scale desalination and renewable deployment.

Oman's geographic location also presents an advantage, sitting at the crossroads of Europe and Asia and along key maritime shipping routes. The country's existing fossil fuel infrastructure, particularly in LNG and ammonia handling, can be partially repurposed for hydrogen and hydrogen-based fuels. These operational capabilities reduce barriers to export readiness and contribute to Oman's competitiveness in emerging energy markets. 7

Hydrogen development in Oman may yield several potential benefits over time. It could reduce domestic demand for natural gas, particularly in industry, thereby easing pressure on Oman's reserves and enhancing long-term energy security. It may also contribute to lower national emissions, for example by replacing fossil-based hydrogen in existing applications such as refining. In economic terms, hydrogen and its derivatives could create new export revenues and industrial activity, especially in sectors like ammonia, methanol, and low-emission steel. Associated project development could further support employment generation and contribute to Oman's shift toward more technically specialised industries.

Meeting the 2030 target would require an estimated 50 TWh of electricity—more than double current national output. This implies not only large-scale renewable energy deployment but also major upgrades to supporting infrastructure, including grid extensions, desalination capacity, and export systems. Water availability is a particularly important consideration. Electrolytic hydrogen production requires approximately 10 litres of purified water per kilogram. Based on Oman's production targets, annual water demand could reach 10 million tonnes by 2030, 33–38 million tonnes by 2040, and up to 85 million tonnes by 2050. Given the country's arid conditions, the majority of this water is expected to be sourced from seawater desalination, which contributes only marginally to total hydrogen production costs.

Infrastructure for hydrogen transport and conversion is also a strategic focus. Most of Oman's hydrogen exports are expected to take the form of ammonia, which benefits from an established international supply chain. The country's industrial ports at Salalah, Sohar, and Sur are already equipped with ammonia terminals and supporting logistics, which can be expanded to accommodate future export volumes. Oman's existing experience in LNG and chemical shipping provides an additional operational advantage as it transitions into hydrogen-based exports.

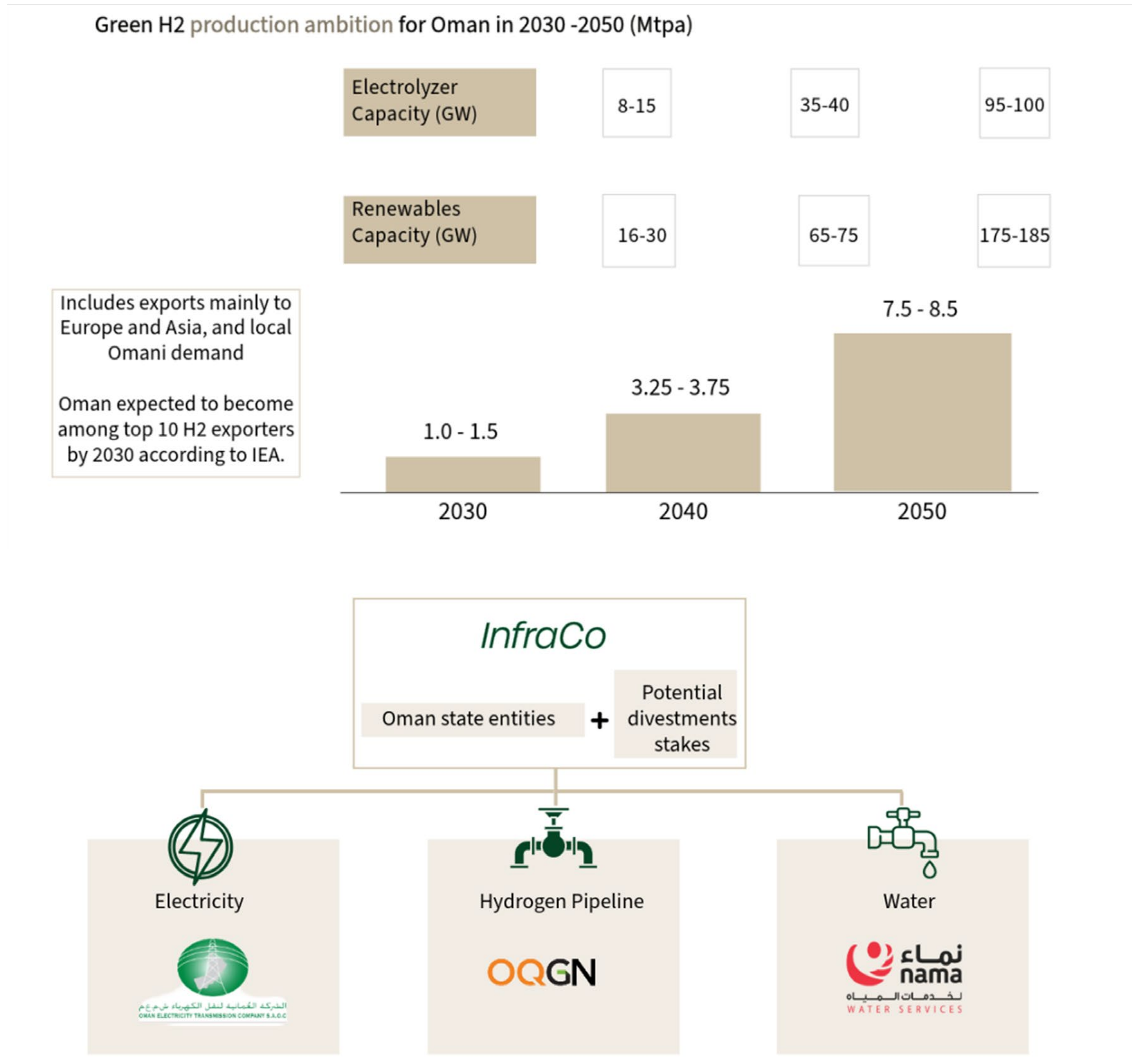
Cost competitiveness remains a central factor in Oman's positioning. The levelised cost of green hydrogen production in Oman is projected to fall to approximately US$1.6/kg by 2030, assuming continued declines in electrolyser system costs and renewable electricity prices.8 Current capital costs for electrolysers range from US$1,400 to 1,770 per kilowatt, including installation. With global deployment expected to expand from 0.5 GW in 2021 to 134 GW by 2030, cost reductions of 68–72% are anticipated, potentially bringing capital costs down to US$440–500/kW. In comparative terms, Oman's projected production costs are expected to be lower than those in Australia (US$1.9/kg), the United States (US$1.7/kg), and most European or Asian demand centres, where production costs could range from US$2.6 to 3.8/kg due to land constraints, higher energy costs, and limited renewable potential.

In terms of end-use, Oman's hydrogen output is expected to be concentrated in derivative products, particularly ammonia, methanol, and green steel. Ammonia is already the world's largest consumer of hydrogen and is being increasingly adopted as a maritime fuel and hydrogen carrier. Methanol is widely used in fuels and chemicals, while green steel—produced via direct reduced iron—offers a route to decarbonise one of the most emissions-intensive industrial sectors. Oman's geography and existing port facilities offer a favourable export profile for these products. Estimates suggest that by 2030, Oman could produce renewable ammonia at a levelised cost of US$400 per tonne, with total delivered costs—after shipping over 10,000 to 20,000 km—ranging from US$440 to 520 per tonne, depending on destination and transport method.

Institutionally, Oman has established a coordinated framework to support the hydrogen sector. Hydrom leads the development process, including land auctions and project coordination. It operates alongside the National Hydrogen Alliance (Hy-Fly), the Oman Net-Zero Center (responsible for monitoring emissions), and InfraCo, created in 2023 to manage shared infrastructure for electricity, water, and hydrogen transport. To facilitate investment, the government has introduced long-duration project licences, reduced land fees, and incentives linked to local employment through Omanisation policies. These measures aim to reduce risk and improve project bankability at an early stage of sector development.

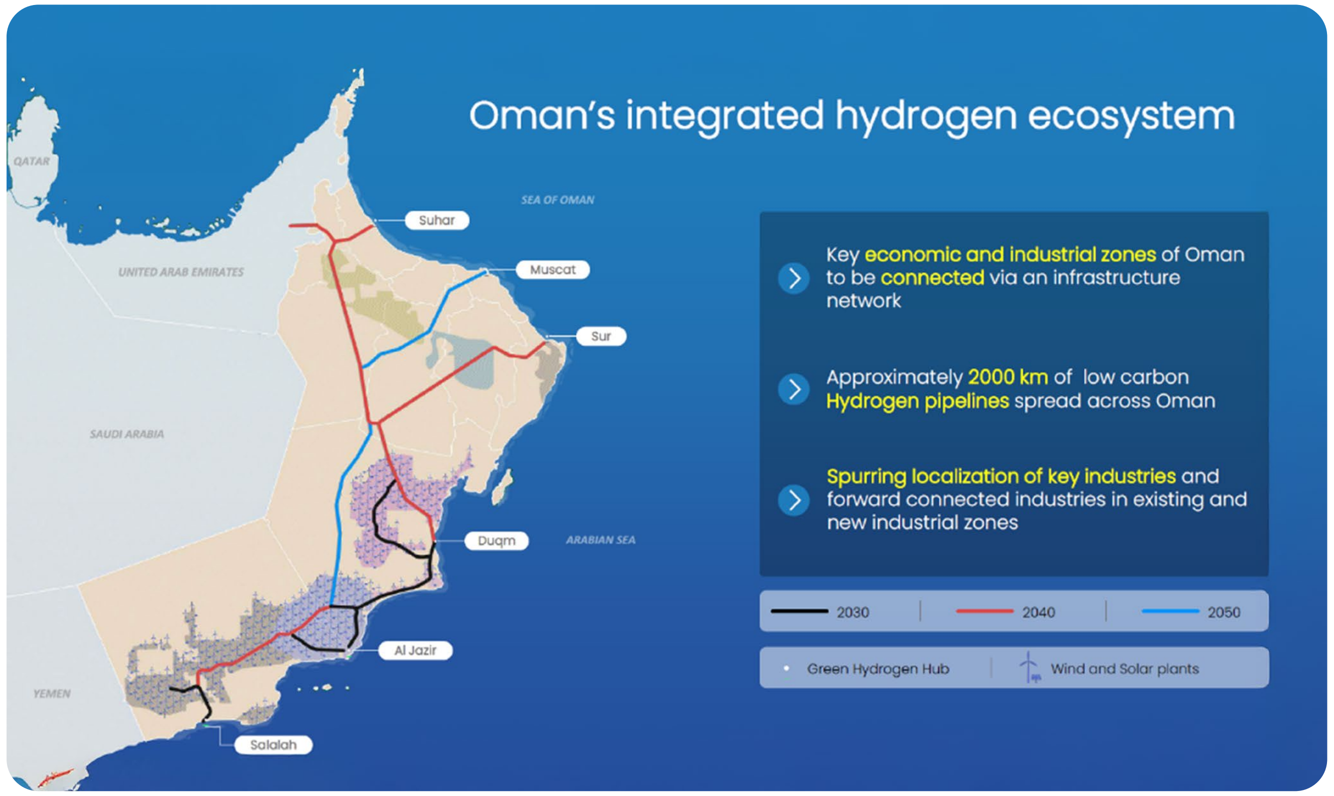
Oman's existing industrial infrastructure provides a foundation for scaling up hydrogen and ammonia exports over the coming decade. Among the country's five main industrial ports—Duqm, Muscat, Salalah, Sohar, and Sur—three (Salalah, Sohar, and Sur) already operate ammonia terminals. These facilities form part of Oman's current ammonia trade, with annual export volumes of approximately 0.2 million tonnes. To meet hydrogen export targets by 2030, this capacity would need to expand significantly. Most of the hydrogen is expected to be exported in the form of ammonia, requiring ammonia export volumes to increase by a factor of 20 to 30.

Figure 21: Green hydrogen production ambitions for Oman, 2030–2050 (in Mtpa), and infrastructure actors



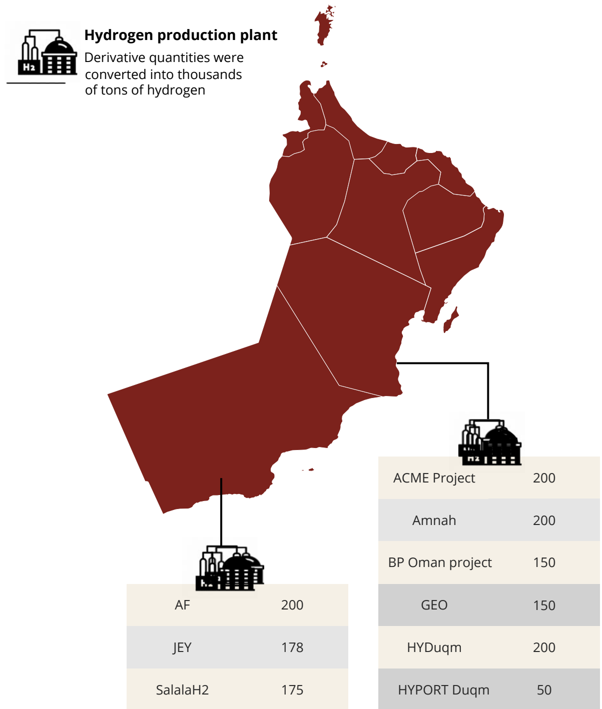
Source: Reference 23

Figure 22: Planned hydrogen pipelines by 2030, 2040, and 2050



Source: Reference 24

Figure 23: Location of planned Hydrom projects for 2030



Source: Majan Council analysis

2.3.3 Hydrogen and e-fuels in the GCC

Hydrogen has emerged as a strategic focus across the Gulf Cooperation Council (GCC) countries, with national governments and leading energy companies increasingly investing in production capacity, technology partnerships, and export infrastructure. The MENA region accounted for nearly 10% of global hydrogen demand, almost entirely for petrochemicals and refining.

The GCC countries possess favourable conditions for both green and blue hydrogen production. Green hydrogen potential is highest in Oman, Saudi Arabia, the UAE, and Kuwait due to their vast land areas and high-quality renewable resources. Blue hydrogen is technically viable in most GCC states—with the exception of Bahrain—given their access to natural gas and potential for carbon capture and storage (CCS). National strategies reflect these differences. Oman has focused on green hydrogen development and has formalised targets through Hydrom. Qatar has emphasised blue hydrogen linked to its LNG sector. Saudi Arabia and the UAE aim to strike a balance between green and blue hydrogen. Kuwait and Bahrain are also advancing mixed approaches, though at earlier stages of policy development.

Further differences appear in strategy and institutionalisation:9 Oman's hydrogen sector has been largely institutionalised around the central orchestrator Hydrom and shaped towards a broad but orderly involvement of international actors, including a system of land auctions and infrastructure planning. Saudi Arabia has publicly declared the goal of becoming the world's largest hydrogen exporter and focusses on selected pilot projects with a strong presence of national champions. The UAE, whose updated Energy Strategy 2050 states its ambition to become a global leader in hydrogen by the 2030s, has furthermore added hydrogen supply investments abroad as a new regional approach to the sector. Qatar refers to hydrogen in its Nationally Determined Contributions (NDCs), while Kuwait and Bahrain have outlined hydrogen-related goals in white papers and sectoral strategies.

At the project level, multiple initiatives are underway or in advanced planning stages across the region. In Saudi Arabia, the NEOM Green Hydrogen Project—developed jointly by ACWA Power, Air Products, and NEOM—is expected to be the world's largest green hydrogen facility. Scheduled to begin operations in 2026, it will produce 600 tonnes of hydrogen per day and up to 1.2 million tonnes of green ammonia annually. Additional projects include a proposed hydrogen hub in Jubail and electrode technology partnerships to support NEOM's expansion.

The UAE has committed to producing up to 1 million tonnes of green hydrogen annually by 2030, led by Masdar and a coalition of national energy entities. Major projects include green ammonia production at Khalifa Industrial Zone Abu Dhabi (KIZAD), a strategic alliance between Masdar and Engie to build a 200 MW green ammonia plant, and the DEWA hydrogen mobility pilot in Dubai. Additional developments are underway in Abu Dhabi's industrial zones, where companies such as Helios Industry and Al Fattan LTechUVC Green Energy plan to build ammonia and hydrogen production plants.

Qatar has historically focused on LNG exports but is now moving toward domestic hydrogen production. It recently announced plans to develop the world's largest blue hydrogen facility, with an expected output of 1.2 million tonnes of ammonia annually by 2026. Ongoing pilot projects, such as HyPEC, also explore green hydrogen pathways using solar-powered wastewater electrolysis.

Kuwait has released a Renewables and Hydrogen Masterplan targeting 17 GW of renewables and 25 GW of green hydrogen capacity by 2050. It has also contracted international advisors to assess large-scale development options. Bahrain, initially more cautious, has now incorporated green and blue hydrogen production goals into its Industrial Strategy 2022–2026 and recently announced a 4 MW green hydrogen pilot plant.

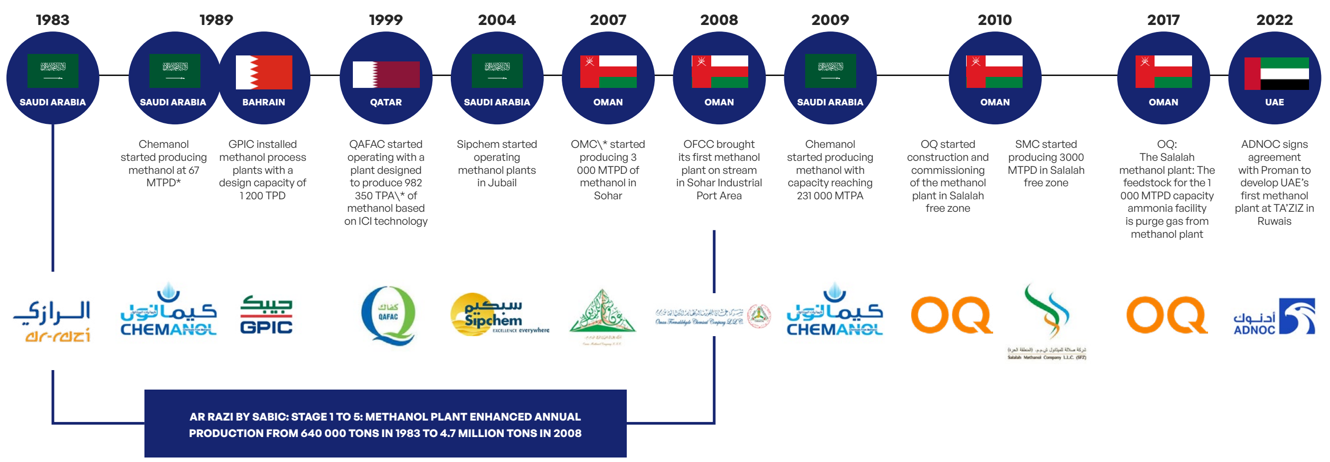
Based on these developments, the methanol sector is gaining in importance as well. GCC countries collectively account for approximately 9.15 million tonnes of annual methanol production capacity, representing 5.7% of the global total (Figure 24). As of 2021, the regional production was led by Saudi Arabia (71%), followed by Qatar and Oman (12% each), and Bahrain (5%). Eight major producers dominate the landscape, including SABIC, Sipchem, Chemanol, QAFAC, GPIC, and Oman's OQ and OMIFCO. The region's strong industrial base, access to natural gas, and existing petrochemical infrastructure have enabled it to develop into a key global supplier.

In Bahrain, the Gulf Petrochemical Company (GPIC) produces 1.5 million tonnes of methanol annually and has implemented a carbon capture system to supply CO_2 for methanol and urea production. In Qatar, QAFAC operates a methanol facility with a capacity of nearly 1 million tonnes per year. Saudi Arabia is home to the Ar-Razi complex, a joint venture between SABIC and Mitsubishi Gas Chemical, which has a total capacity of 5.6 million tonnes across five units. Other key facilities in the Kingdom include Sipchem's International Methanol Company (970,000 tonnes), Chemanol in Jubail (231,000 tonnes), and the Ibn Sina facility, notable for being the first in the region to receive certification for circular methanol production.

Several countries in the region are also pursuing new projects aligned with low-emission fuel production. In the United Arab Emirates, Masdar and TotalEnergies are developing a green hydrogen-to-methanol project in Abu Dhabi, targeting sustainable aviation fuel (SAF) markets. In Saudi Arabia, ENOWA and Aramco are constructing a methanol-to-gasoline plant in NEOM, scheduled to begin operations in 2025. This project will use captured CO_2 to produce up to 12 tonnes of methanol and 35 barrels of gasoline per day.

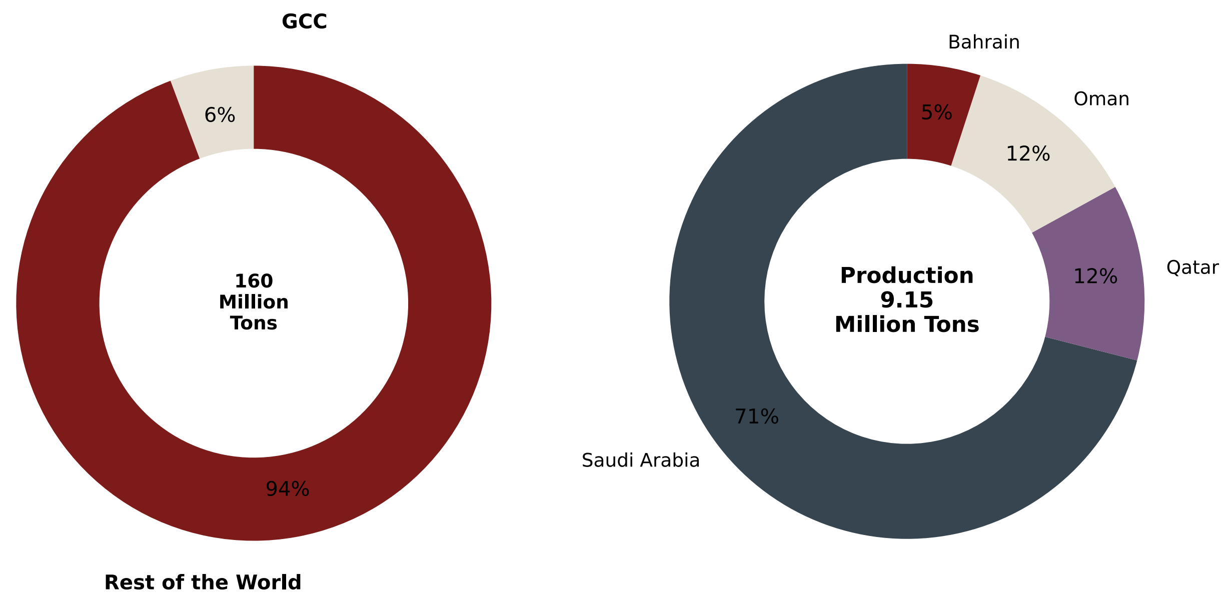
The GCC's methanol sector is expected to grow further as global demand for low-carbon fuels increases. With established industrial capacity, regional ports, and expanding investments in renewable hydrogen, the region is well positioned to scale up green methanol production. Its geographic proximity to European and Asian markets enhances its role as a potential exporter, particularly for applications in shipping, aviation, and petrochemicals where demand for alternatives to fossil fuels is accelerating.

Figure 24: History of methanol production in GCC countries



Source: Gulf Petrochemicals and Chemicals Association

Figure 25: GCC methanol production capacity market share and methanol production capacity by country, 2021



2.3.4 Occupational mapping – Hydrogen Production & Infrastructure Sector

Employment in the hydrogen production and infrastructure sector is expanding steadily as global investment in clean energy increases. Growth is driven by the development of green hydrogen and associated infrastructure such as pipelines, storage systems, and refuelling stations. While the sector remains at an early stage, marked by demonstration projects and ongoing R&D, labour demand is already rising—particularly for engineers, safety specialists, and technically trained professionals. As the industry scales, skillsets are expected to increasingly overlap with those in oil refining, gas processing, and the chemical sector, particularly in areas such as operations, process control, and industrial safety.

Hydrogen project development typically spans multiple stages—from feasibility studies and engineering design to construction, commissioning, and ongoing operation—each requiring a distinct set of skills. A clear understanding of these stages is essential for identifying workforce needs and evaluating the readiness of both sides of the labour market: the supply side, including vocational and higher education institutions, and the demand side, including investors, operators, and project developers. Table 26 provides an overview of key activities across sub-sectors in green hydrogen project development.

Skills and knowledge in hydrogen production often align with those from related industries such as oil and gas, manufacturing, and utilities. Recognising this cross-industry alignment can help reduce training costs and support faster labour transitions. Table 27 outlines the areas of skill and knowledge transferability across sectors, identifying where targeted upskilling is required.

Table 26: Key tasks and activities in the green hydrogen development sector

	Electricity (Solar/ Wind) & Water Supply	Hydrogen Production (Electrolyser Operation & Maintenance)	Hydrogen Storage & conversion (H2 Derivative - e.g., Ammonia or Methanol)	Hydrogen Transport (pipeline and shipping)
Tasks & Activities	• Initial market research to identify demand for electricity and water supply. • Identify location based on solar/ wind resources, and proximity to water sources. • Review solar/wind resources and secure land lease. • Source solar panels, turbines, and water treatment equipment. • Construct solar/ wind farms and water treatment systems. • Install electrical equipment and connect to the grid. • Complete commissioning and verify operational standards. • Maintain and manage solar/ wind farms to ensure agreed daily electricity production levels. • Oversee electricity production, ensuring reliability and efficiency.	• Assess renewable energy availability and water sourcing for electrolysis. • Locate site for hydrogen production near renewable sources. • Assess water supply and access to renewable electricity. • Procure electrolysers, storage tanks, and control systems. • Set up hydrogen production plant infrastructure. • Install electrolysers and connect to grid and water supply. • Conduct testing on electrolyser systems, ensuring quality of produced H_2. • Operate and maintain electrolyser units to achieve consistent hydrogen output. • Manage electrolyser operations, optimising hydrogen output and reducing downtime.	• Study market needs for hydrogen derivatives such as ammonia or methanol. • Choose locations near hydrogen production and demand centres. • Check availability of infrastructure for conversion and storage. • Obtain conversion equipment and storage tanks. • Build conversion facilities and integrate with storage solutions. • Set up connections between production and conversion facilities. • Test storage tanks and conversion facilities, ensuring compliance with safety standards. • Conduct regular maintenance and monitoring for stable production. • Supervise storage and conversion operations to ensure efficiency and safety.	• Evaluate transport demand for hydrogen and derivatives. • Select sites for pipeline terminals and shipping facilities. • Confirm land access for pipeline routes and port terminals. • Acquire equipment for pipelines and loading/unloading terminals. • Construct pipelines, terminal facilities, and ports. • Install pipeline connections and port infrastructure. • Test pipeline integrity and loading/unloading equipment. • Perform routine maintenance to ensure safe and reliable transport. • Manage transportation schedules and logistics for uninterrupted supply.
Required Job Roles	Solar Project Engineer, Solar O&M Manager, PV Engineer, Field Technician, Electrical Engineer, Fleet Manager, SCADA & Automation Engineer, Project Developer, Finance Analyst, Renewable Policy Analyst, Site Assessor, Wind Turbine Engineer, Wind O&M Manager, SCADA Engineer, Electrical Technician, Mechanical Technician, Reliability Engineer, Blade Engineer, Wind Technician, Control Room Technician, Asset Integrity Manager, Health and Safety Specialist, Power Plant Operator, Site Manager.	Automation Specialist, Process Engineer, Control Room Operator, Electrical Engineer, Plant Operator, Mechanical Engineer, Reliability Engineer, Maintenance Planner, Research Engineer, Gas Technician, Power Systems Engineer, Renewable Energy Engineer, Battery Storage Engineer, Assembler, Fabricator, Welder, Piping Engineer, Rotating Equipment Engineer, Civil Engineer, Environmental Engineer, Safety Engineer, Quality Manager, Laboratory Technician, Procurement Specialist, Inventory Manager, Logistics Specialist, Fleet Manager, Site Manager, Project Manager, Production Supervisor, Sales Manager, Regulatory Specialist, HR Manager, IT Support Specialist, Accountant.	Automation Specialist, Process Control Engineer, Electrical Engineer, Plant Operator, Mechanical Engineer, Reliability Engineer, Maintenance Planner, R&D Engineer, Measurement Specialist, Gas Technician, Assembler, Welder, Piping Engineer, Rotating Equipment Engineer, Electromechanical Engineer, Environmental Engineer, Civil Engineer, Structural Engineer, Safety Engineer, Quality Manager, Laboratory Technician, Procurement Specialist, Inventory Manager, Logistics Specialist, Fleet Manager, Site Manager, Project Manager, Production Supervisor, Regulatory Specialist, Contract Manager, Sales Manager, Marketing Manager, HR Manager, IT Support Specialist, Accountant, Administrative Assistant.	Pipeline and Equipment Roles: Automation Specialist, Compression Specialist, Control Engineer, Control Room Operator, Field Operator, Corrosion Engineer, Metering Specialist, Pipeline Integrity Specialist, Pipeline Safety Engineer, Pipeline Technician, Piping Engineer, Rotating Equipment Engineer, Station Operator. Marine and Fleet Roles: Captain, Chief Engineer, Chief Officer, Crewing Manager, Bosun, Able Seaman, Ordinary Seaman, Electro-technical Officer, Fitter, Oiler, Wiper, Fleet Manager, Second Engineer, Third Engineer, Fourth Engineer, Second Mate, Third Mate.

Source: Majan Council analysis

Table 27: Cross-industry skill and knowledge alignment for components in the hydrogen production and infrastructure sector

COMPONENTS	MEMBRANE & BIPOLAR PLATES	POWER ELECTRONICS	GAS ANALYTICS	COMPRESSORS & PUMPS	HEAT EXCHANGERS	PIPES	GAS STORAGE UNIT (EG: TANK)
ELECTROLYSER UNIT							
DESIGN AND PLANNING	Low	Mid	High	Mid	High		
CONSTRUCTION & INSTALLATION	Low	High	High	High	High		
OPERATION AND MAINTENANCE	Low	Mid	Mid	Mid	High		
CONVERSION & COMPRESSION UNIT							
DESIGN AND PLANNING		High	High	Mid	High	Mid	
CONSTRUCTION & INSTALLATION		High	High	High	High	High	
OPERATION AND MAINTENANCE		High	Mid	Mid	High	Mid	
STORAGE UNIT							
DESIGN AND PLANNING		High	High	Mid	High	Mid	Mid
CONSTRUCTION & INSTALLATION		High	High	High	High	High	High
OPERATION AND MAINTENANCE		High	Mid	Mid	High	Mid	Mid
TRANSPORTATION UNIT							
DESIGN AND PLANNING				Mid	Mid	Mid	
CONSTRUCTION & INSTALLATION				High	High	High	
OPERATION AND MAINTENANCE				Mid	Mid	Mid	

Source: Majan Council analysis

Oman currently produces around one million tonnes of hydrogen annually, primarily for conversion into ammonia and methanol at refineries in Sohar and Salalah. This provides a base of industrial experience, but new job roles—particularly those related to electrolysers, hydrogen-specific safety systems, and renewable integration—will require targeted workforce development.

Hydrogen production and infrastructure activities in Oman will span production, storage, conversion into derivatives, and long-distance transport. Key occupational roles—illustrated in Figure 26—cover engineering, operations, safety, and project oversight. Among the most critical roles are:

- **Gas Inspector / Gas Technician**
- **Electrolyser Technician / Hydrogen Electrolyser Technician**
- **Hydrogen Electrolyser Maintenance Operator**
- **Hydrogen Battery Installation Technician**
- **Refuelling Station Operator**
- **Pipe Fitter / Pipeline Contractor / Field Operator – Pipeline**
- **Specialist Hydrogen Process Operator / Station Operator (Compression, Pump)**

These positions are central to the operation and reliability of hydrogen systems—from electrolyser maintenance to refuelling operations and long-distance pipeline management. They also represent key technical entry points into the green hydrogen value chain, and will be essential for building project reliability, industrial safety, and long-term performance.

Table 30 summarises these job roles alongside their associated upskilling and reskilling needs. These findings support the alignment of Oman's labour market with its hydrogen ambitions and help identify where new technical training programmes will be most needed.

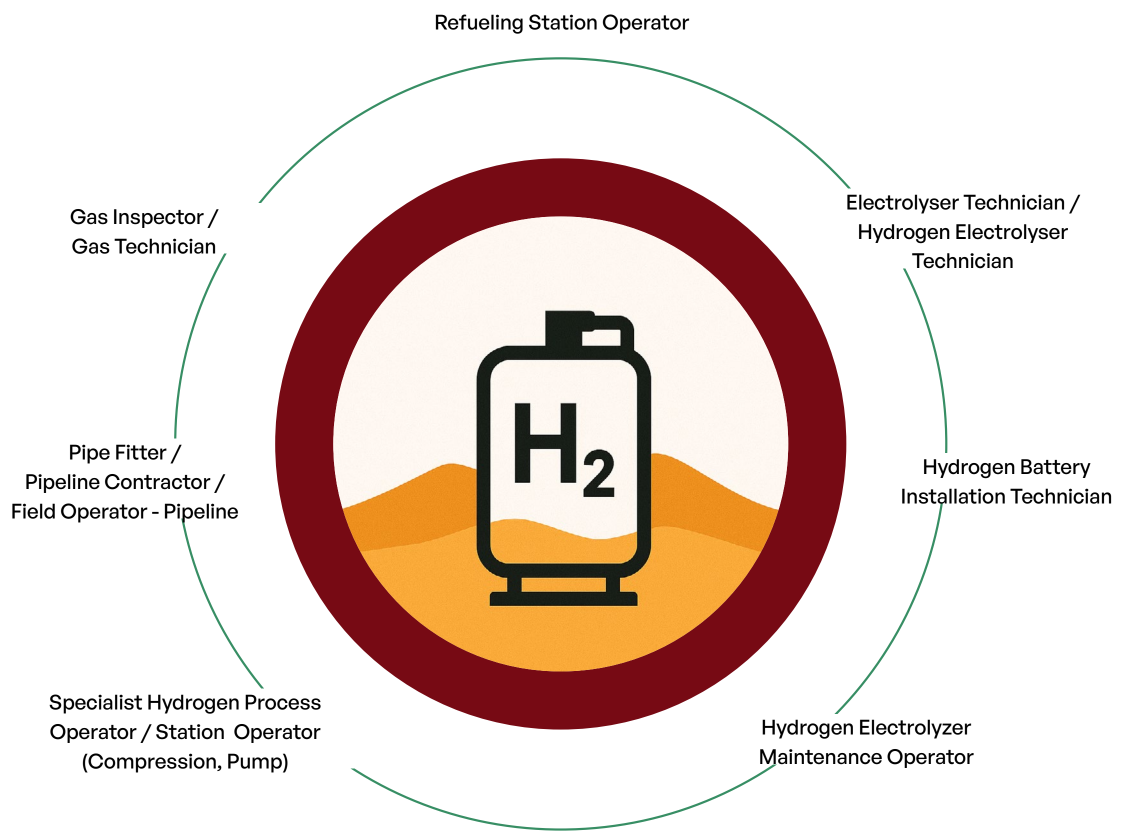


Figure 26: Key roles in the hydrogen sector: engineering and management

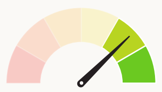
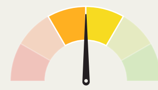
Source: Majan Council analysis

Table 28: Key job roles and upskilling opportunities in the hydrogen production and infrastructure sector

LOW – SKILL GAP
Minimal task changes are required, though some additional domain knowledge may be necessary.

MEDIUM – SKILL GAP
Some new responsibilities are introduced, and upskilling or reskilling is needed to handle these new tasks.

HIGH – SKILL GAP
Significant new responsibilities and unfamiliar areas of expertise are introduced, requiring substantial upskilling or reskilling.

Job Roles	Description	Required Education	Skills	level of skill Gap
Electrolyser Engineer	Designs, tests, and optimises electrolyser systems for hydrogen production, ensuring efficient integration with renewable energy and driving improvements in reliability and sustainability.	PhD/MSc in Economics/ International Economy/ Chemical Engineering/ Electrical Engineering/ Mechanical Engineering	• Designing, operating, and optimising electrolysers for hydrogen production, with knowledge of various types (alkaline, PEM, SOEC) and related auxiliary systems. • Develop and execute testing procedures for design verification, process simulation, and calibration of systems and stacks, ensuring optimal performance, longevity, and cost-efficiency. • Oversee electrolysis projects from design through to commissioning, including writing technical specifications, managing contractors, supervising project phases, and integrating electrolysis units with renewable power sources. • R&D and Continuous Improvement: Competency in advancing technology development, managing R&D activities, and driving continuous improvement in electrolyser technology to align with cost, performance, and environmental goals. • Energy Management and System Optimisation: Understanding of energy management systems, including optimising electrolyser power supply from renewables and assessing reliability and availability for sustained operations. • Supplier and Market Knowledge: Familiarity with global electrolyser suppliers and technology trends, including supplier audits, equipment qualification, and market analysis.	 HIGH
Process Safety Engineer / Technical Safety Engineer	Assesses and mitigates industrial safety risks, conducts risk assessments, and ensures safety standards are integrated into design and operations, especially for hazardous chemicals.	BSc in Process Engineering / Chemical Engineering / Health and Safety Management.	• Risk Assessment & Management: Expertise in conducting and facilitating risk assessments such as HAZOP, What-If, and PHA, and executing risk management strategies. • Safety Hazard Modelling: Proficiency in safety modelling tools like CFD, PHAST, and ALOHA for hazard analysis, scenario modelling, and consequence assessments. • Process Safety Standards & Compliance: Knowledge of process safety standards and hazard mitigation strategies, especially in manufacturing, chemical processing, and energy sectors. • Cross-Disciplinary Coordination: Ability to work with engineering and process teams to integrate safety measures into factory designs. • Chemical Hazard Management: Experience with hazardous chemical safety protocols and safety programmes.	 MEDIUM

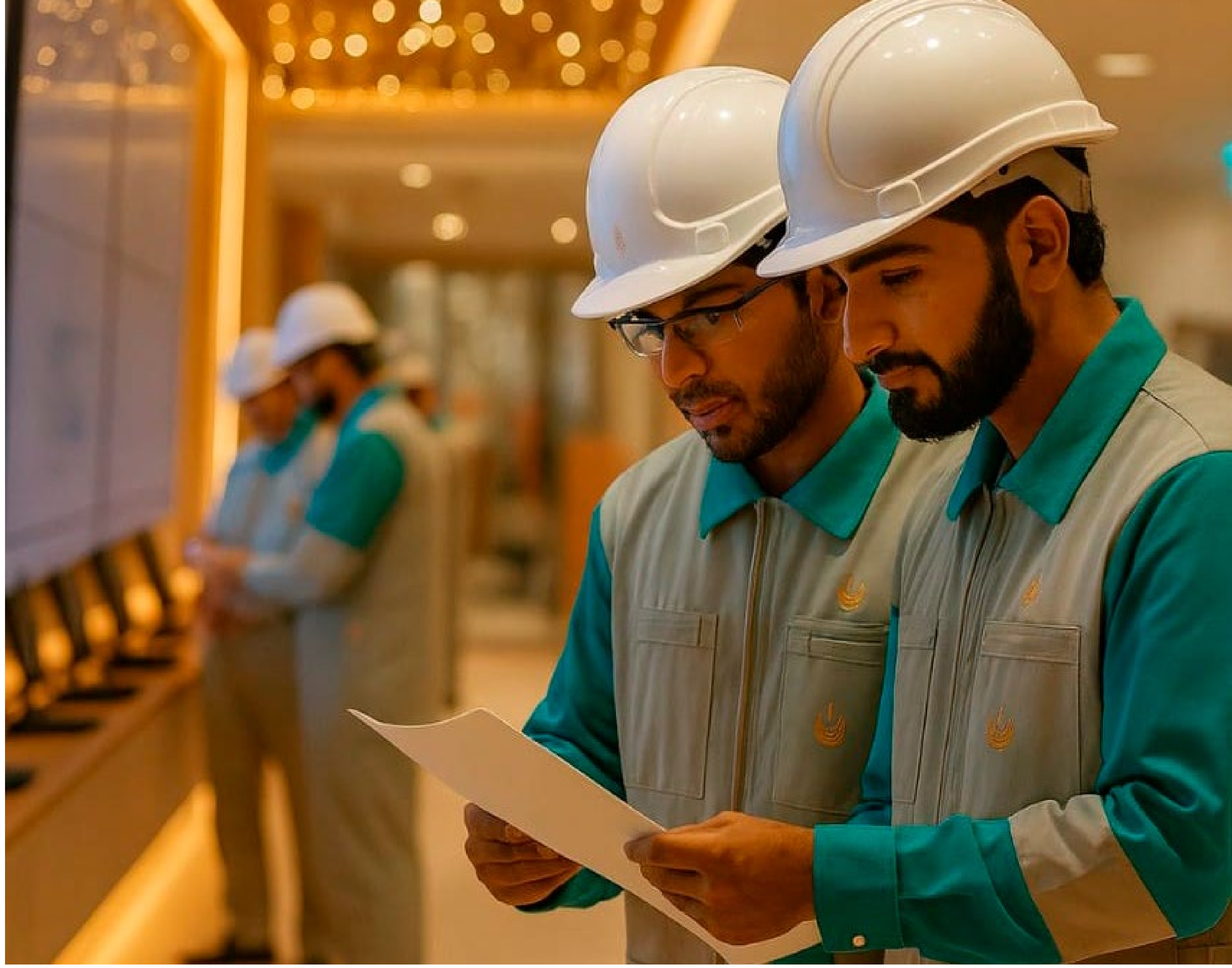
LOW – SKILL GAP
Minimal task changes are required, though some additional domain knowledge may be necessary.

MEDIUM – SKILL GAP
Some new responsibilities are introduced, and upskilling or reskilling is needed to handle these new tasks.

HIGH – SKILL GAP
Significant new responsibilities and unfamiliar areas of expertise are introduced, requiring substantial upskilling or reskilling.

Job Roles	Description	Required Education	Skills	level of skill Gap
Pipeline Hydraulics Engineer	Optimises flow and operations using hydraulic modelling, data analysis, and specialised software to enhance transport efficiency and reliability.	BSc in Mechanical Engineering / Chemical Engineering / Petroleum and natural Gas Engineering	• Hydraulic Modelling & Multi-Phase Flow: Expertise in hydraulic modelling and multi-phase flow dynamics to optimise hydrogen pipeline operations. • Pipeline Operations Optimisation: Skills in enhancing flow efficiency and operational reliability for hydrogen transport. • Data Analysis: Proficiency in analysing and correlating data to inform system performance improvements. • Specialised Software Proficiency: Experience with LSPI proprietary software and Emerson PLO for pipeline analysis and management. • Continuous Improvement: Strong project management skills focused on continuous operational improvements.	LOW
Pipe Fitter / Field Operator – Pipeline	Installs, maintains, and repairs hydrogen piping systems, ensuring they meet safety and operational standards.	Vocational Diploma / Certificate in Welding & Metal Fabrication	• Pipe Installation & Maintenance: Proficient in installing, repairing, and maintaining piping systems, including assembly and disassembly to meet precise tolerances. • Blueprint Reading: Ability to read design specifications and packaging drawings to cut and fit pipes accurately. • Mechanical Aptitude: Skilled in using hand tools, power tools, and precision measuring equipment for pipe fitting. • Testing Knowledge: Experienced in performing hydrostatic and pneumatic testing to ensure pipeline integrity. • Safety Standards Compliance: Familiarity with safety protocols and protective equipment, essential for handling hydrogen-related systems.	MEDIUM

Source: Majan Council analysis



Accredited certifications play a critical role in supporting the development of Oman's hydrogen production and infrastructure sector. They help ensure that workers possess the technical competencies required for safe and efficient project delivery, particularly as hydrogen production shifts toward electrolysis and integrated energy systems. Certifications provide a structured pathway for skills recognition, enhancing employability, supporting career progression, and aligning workforce capabilities with international standards.

For employers and project developers, certified professionals reduce operational risks, improve compliance with regulatory standards, and support higher levels of project reliability and performance. From an investment perspective, certifications signal sector maturity, contributing to greater confidence among financiers and international partners.

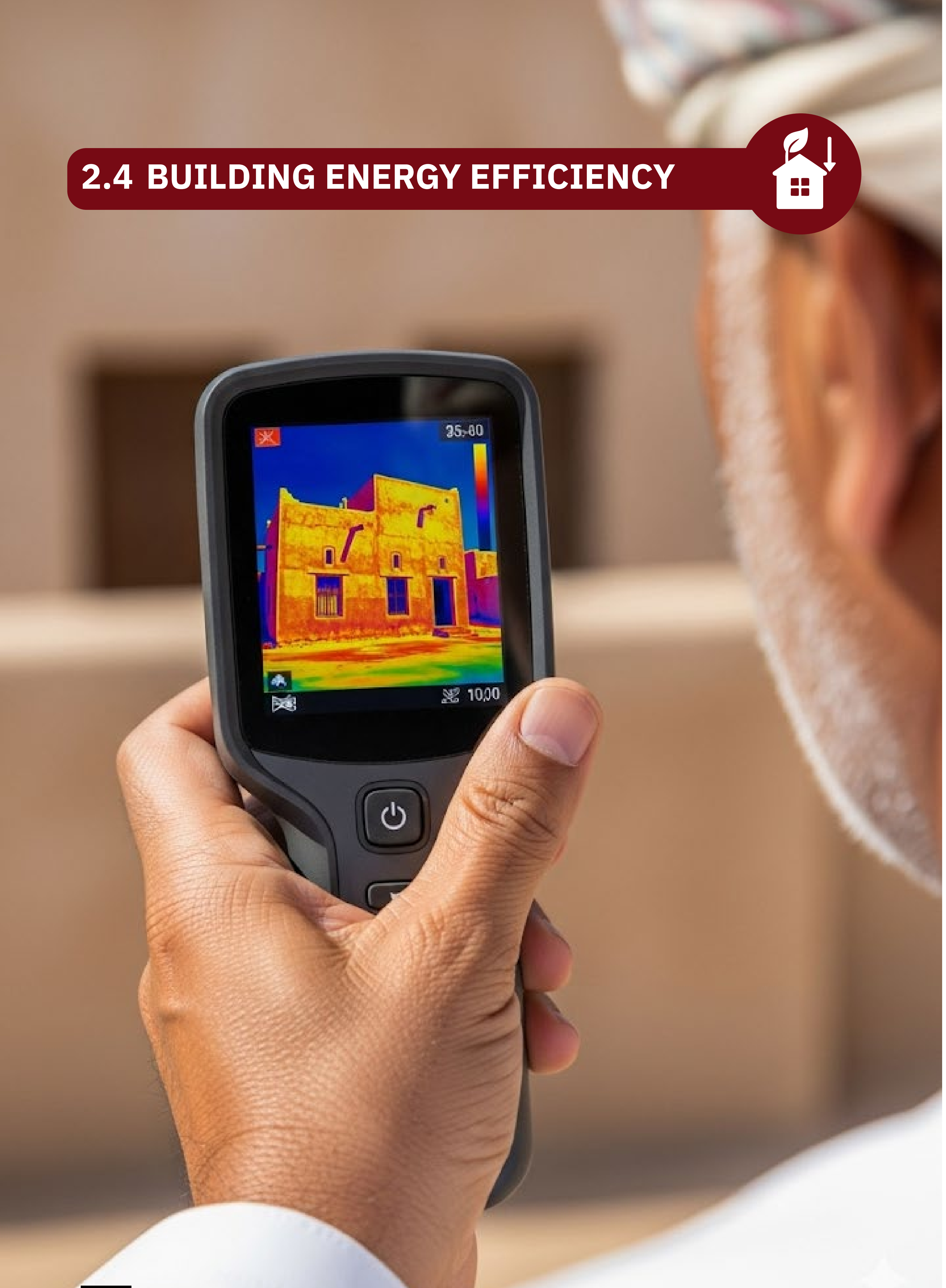
Nationally, the adoption of accredited certification systems can help formalise technical standards, reduce dependence on informal or ad hoc training, and better connect vocational education pathways with emerging labour market needs.

As shown in Table 29, certification frameworks can be mapped to specific occupational roles across key stages of the hydrogen value chain, including engineering design, electrolyser operations, safety compliance, transport systems, and refuelling infrastructure. By expanding access to targeted certifications, Oman can strengthen the talent base needed to support the implementation of large-scale hydrogen projects and ensure long-term sector sustainability.

Table 29: Certifications and relevant job roles across the main stages of the hydrogen sector

	Hydrogen Production - Operations & Maintenance	Hydrogen storage	Transportation
Certificate	Chartered Engineer (CEng)	Chartered Engineer (CEng)	Chartered Professional Engineer (CPEng)
	Lean/Six Sigma Certification	NEC (National Electrical Code) certification	MScs marine certificate of competency (CoC)
	Chartered Professional Engineer (CPEng)	Commercial Driver's License (CDL)	Marine Engine Driver Certificate of Competency (CoC)
	Universal CFC certification	Lean/Six Sigma Certification	Deck Class-II Certificate of Competency
	Supply Chain Management Professional (SCMP)	Mobile Crane Operator certification (MCCCO)	Deck Class-I Certificate of Competency
	Project Management Professional (PMP) Certification	Forklift license (industrial truck, lift truck)	Deck Class-III Certificate of Competency
	NEC (National Electrical Code) certification	Certified Welding Inspector (CWI)	Engine Class - I Certificate
	Commercial Driver's License (CDL)	Certified Welding Engineer (CWE)	First, Second, or Third-Class Motor Engineer Certificate
	Mobile Crane Operator certification (MCCCO)	Chartered Professional Engineer (CPEng)	Engine Class - II Certificate
	Forklift license (industrial truck, lift truck)	Universal CFC certification	Second-Class Motor Engineer Certificate
	Certified Welding Inspector (CWI)	NEBOSH International General Certificate in Occupational Health and Safety	Engine Class - III Certificate
	Certified Welding Engineer (CWE)	NEBOSH certificates	Third-Class Motor Engineer Certificate
	Certified auditor / internal auditor (ISO 45001 / ISO 14001 / ISO 9001)	IOSH Managing safely	Certified ETO under STCW III/6
	Certified Quality Engineer (CQE)	Certified auditor / internal auditor (ISO 45001 / ISO 14001 / ISO 9001)	Qualified electrical practitioner (Electrician)
	Certified Quality Inspector (CQI)	Certified Quality Engineer (CQE)	Dynamic Positioning Maintenance Training Certificate
	NEBOSH International General Certificate in Occupational Health and Safety	Certified Quality Inspector (CQI)	
	NEBOSH certificates	Supply Chain Management Professional (SCMP)	
	IOSH Managing safely	Project Management Professional (PMP) Certification	
	ACCA Chartered Accountant (CA)	ACCA Chartered Accountant (CA)	
	Certified Public Accountant (CPA)	Certified Public Accountant (CPA)	
Target	Process Engineer / Chemical Engineer, Industrial Engineer / Production Engineer / Facility Engineer, Piping Engineer, Electromechanical Engineer, Building Services Engineer, Inventory Managers, Plant Manager / Site Manager, Project Manager, Production Supervisor, Electrician, Plant Operator, Assembler / Fabricator / Assembly Technician, Welder, Quality Manager / Quality Assurance Manager, Quality Engineer / Quality Assurance Engineer, Quality Control Inspector, Health and Safety Expert / Safety and Occupational Health Specialist, Procurement / Sourcing Specialist, Driver, Accountant.	Process Engineer / Chemical Engineer, Electrician, Plant Operator, Industrial Engineer / Production Engineer / Facility Engineer, Assembler / Fabricator / Assembly Technician, Welder, Piping Engineer, Electromechanical Engineer, Building Services Engineer, Health and Safety Expert / Safety and Occupational Health Specialist, Quality Manager / Quality Assurance Manager, Quality Engineer / Quality Assurance Engineer, Quality Control Inspector, Procurement / Sourcing Specialist, Inventory Managers, Driver, Plant Manager / Site Manager, Project Manager, Production Supervisor, Accountant.	Piping Engineer, Electrical and Electronics Engineering Technician, Process Engineer / Chemical Engineer, Control Room Operator, Electrical Engineer, Mechanical Engineer, Reliability Engineer, Mechanical Technician / Mechanical Engineering Technician / Mechanic, Maintenance Planning Specialist, Research Engineer / R&D Engineer / Operations Research Analyst.

Source: Majan Council analysis



2.4 BUILDING ENERGY EFFICIENCY

2.4.1 Value Chain & Sector

Electricity use in buildings has increased sharply over the past 25 years, contributing approximately 60% to global electricity demand growth. Today, buildings account for around one-third of total energy use and half of electricity consumption worldwide. In countries such as China and India, annual growth in building-related electricity demand has exceeded 8% over the last decade. Heating and cooling remain the most energy-intensive services, with buildings and industry together responsible for around 95% of global heating demand and over 40% of energy-related CO_2 emissions. Space heating alone accounts for 34% of electricity consumption in buildings, while cooling, water heating, cooking, and other services contribute 5%, 13%, 8%, and 40% respectively (Figure 27).

In Oman, the issue is particularly pronounced. The building sector accounts for roughly 80% of electricity consumption, with most of this power generated from domestic natural gas (Figure 28). As a result, energy inefficiencies in buildings contribute not only to avoidable emissions, but also to substantial opportunity costs: gas used for electricity generation could otherwise support higher-value industrial or export markets. Enhancing energy efficiency in buildings is therefore strategically important. It reduces emissions, improves fiscal outcomes through energy cost savings, and enables the development of a high-potential economic sector centred on retrofitting, advanced construction materials, digital solutions, and energy services. Building energy efficiency thus presents a triple benefit—supporting climate goals, economic rationality, and sectoral diversification.

Building energy efficiency covers a broad array of technologies and practices. These range from optimising building envelopes and retrofitting existing structures to implementing digital systems and smart controls in new builds. One key set of technologies involves energy management systems, which leverage automation, real-time data, and integrated control to optimise energy use. These systems can contribute average energy savings of around 10% over time. Components include smart thermostats, LED lighting integrated with daylight and occupancy sensors, predictive maintenance algorithms, and submetering. These technologies are increasingly accessible due to the spread of the Internet of Things and smart grid capabilities (Figure 58). Revenues from smart thermostats alone are projected to reach US$4.4 billion by 2025, up from US$1.1 billion in 2016. Smart lighting technologies could reduce global electricity use for lighting in buildings by nearly 20% by 2040.

Despite the technological maturity of many building efficiency solutions, uptake remains uneven. Contributing factors include limited public and institutional awareness of the full benefits, legacy supply chains that do not prioritise high-performance materials, and building codes that are not yet aligned with modern energy standards. Financial incentives are also limited—both in terms of support for efficient construction and the absence of penalties for energy-intensive practices. As a result, investment in energy efficiency for buildings, while rising to over US$250 billion in 2022, remains well below the level needed to transform the sector. Growth has also slowed from 12% in 2021 to just 2% in 2022, affected by macroeconomic pressures and higher costs for materials and financing.

Implementing energy efficiency technologies requires capital investments that vary by building type, system complexity, and functional scope. For example, basic Building Energy Management Systems (BEMS) typically cost between €20 and €30 per square metre—or US$2.30 to US$3.50 per square foot—equating to roughly US$279,000 for a 10,000 m^2 building. Advanced industrial solutions, integrating extensive hardware and analytics, may cost several million dollars. However, small-scale or software-based systems may involve minimal upfront expenditure. Overall, global EMS revenues from the commercial and industrial sectors are projected to rise from US$8.8 billion in 2021 to US$12.7 billion by 2030.

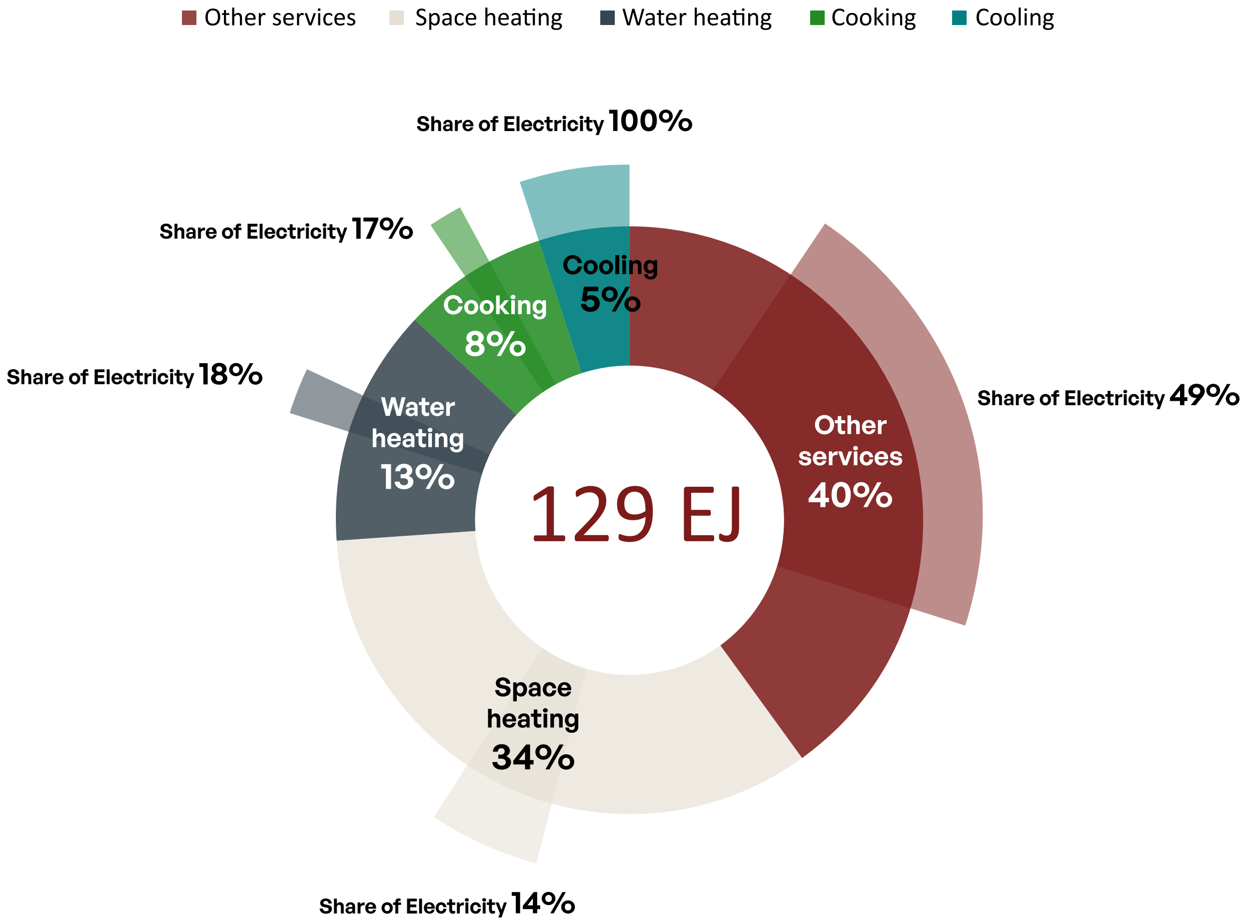
The energy efficiency value chain in buildings comprises several interlinked stages. These stages engage different market actors and require varied skill sets and business models. The main elements of the value chain—especially for setting up a BEMS—are as follows:

- **Planning and project management:** Defining the energy performance goals, budget, and implementation timeline tailored to the specific building or facility.

- **Consulting and auditing:** Conducting detailed energy audits to assess baseline consumption and identify priority efficiency measures.
- **Installation:** Integrating physical systems and digital platforms (e.g. HVAC upgrades, smart metering, LED lighting, control interfaces).
- **Monitoring and verification:** Using software and data analytics to track energy performance and ensure projected savings are realised.
- **Operations and maintenance:** Providing continuous upkeep, troubleshooting, user training, and performance optimisation across the lifecycle.

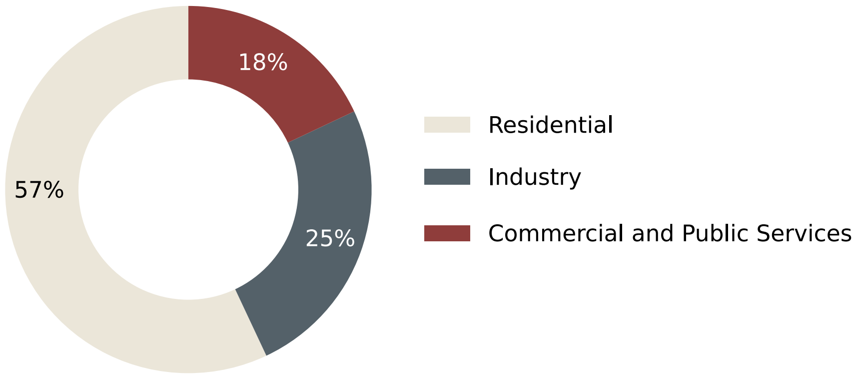
Despite the availability of proven solutions and the promise of long-term cost savings, the implementation of building energy efficiency measures continues to face structural barriers. These include limited awareness of benefits, a lack of regulatory pressure, underdeveloped domestic supply chains, insufficient technician capacity, and high initial costs in the absence of supportive financial mechanisms. In Oman, unlocking the full potential of building energy efficiency will require a coordinated effort across public policy, the private sector, and education providers to scale up both demand and delivery capabilities.

Figure 27: Global share of electricity used in buildings, by service, 2019



Source: Reference 27

Figure 28: Global electricity consumption, by sector, 2023.



Source: IEA

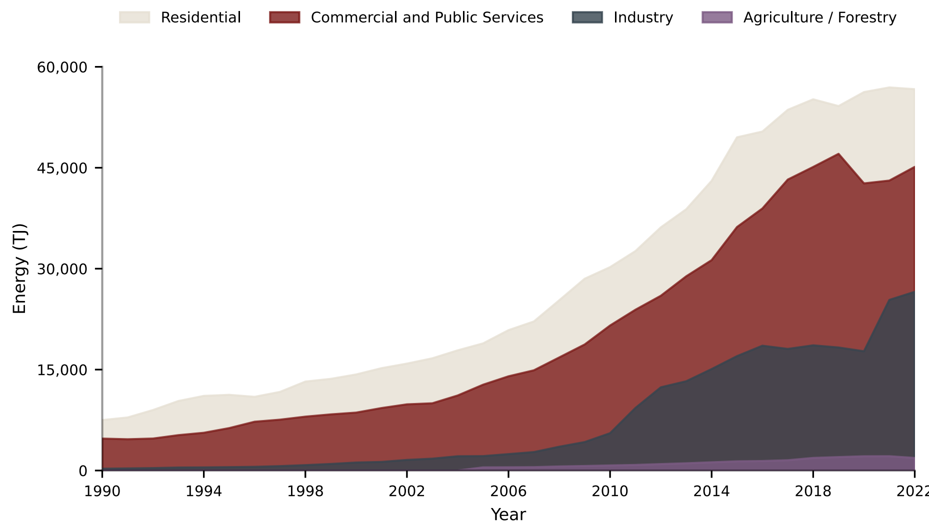
Table 30: Approaches and key elements for building energy efficiency and sustainability

Approach	Key elements
Construction and Design	• Eco-efficient designs • Building orientation • Use of sustainable materials
Behavioural Change	• Proactive energy-saving actions • Providing feedback and information • Promoting social norms
Low carbon energy supply to/in buildings:	• Solar and wind power • Solar thermal systems • Energy storage solutions • Small combined heat and power units
Energy-efficient devices	• High-efficiency air conditioners to reduce energy consumption in cooling • High-efficiency domestic electro-thermal equipment • Heat recovery ventilators that capture and reuse energy from exhaust air • Energy-efficient lighting that complements HVAC systems for reduced heat output
Building Renovations	• Regular maintenance and upgrades • Implementation of high-performance systems • Adoption of smart technologies
Building energy management systems (BEMS)	• Building automation systems using sensors, thermostats, and controls • Integration of smart grids • Optimising energy use for technical systems (heating, cooling, ventilation, hot water, lighting)

Source: Majan Council analysis

2.4.2 Building Energy Efficiency in Oman and the GCC

Figure 29: Electricity consumption by sector, Oman, 1990-2022



Source: IEA

Oman's building sector has expanded rapidly, driven by the country's economic diversification policies and sustained development. According to data from the Authority for Electricity Regulation (AER), buildings account for over three-quarters of annual electricity consumption, with the remainder going to the industrial, tourism, agricultural, and fisheries sectors. Energy efficiency in buildings remains relatively low: most are neither designed nor operated to optimise energy use, and energy performance generally lags behind that of buildings in other countries with similar climatic conditions. Rising living standards and lifestyle patterns—particularly the prevalence of indoor cooling—are further contributing to increased demand. Peak electricity demand in Oman is projected to grow by up to 11% annually, placing additional pressure on the national energy system. Given that electricity generation continues to rely predominantly on domestic fossil fuels, this rising consumption is also associated with increasing greenhouse gas emissions (Figure 39).

Significant energy savings can be achieved through energy efficiency measures adapted to Oman's hot climate. Studies in comparable regions have demonstrated the impact of building energy management techniques in reducing overall consumption. The government has already taken steps to promote energy efficiency. Notable initiatives include a master plan for conservation and the deployment of solar PV systems on rooftops. The Yaseer programme, launched in 2018 by the AER, aims to increase awareness of energy efficiency, reduce electricity subsidies, and encourage the adoption of energy-efficient appliances and building systems. It is supported by cross-agency collaboration and data-driven policymaking, and includes steps such as the implementation of cost-reflective tariffs for high-consumption users.

Broader institutional efforts are also underway. Oman's Net Zero Strategy10 includes energy efficiency as a cross-sectoral priority. In the buildings sector, 27% progress has been reported on a national retrofit programme, and 37% progress on the development of a Green Building Code focusing on system efficiency and technical standards. The Oman Energy Efficiency Centre and the Oman Sustainability Centre have taken lead roles in promoting efficient energy use. The Authority for Public Services Regulation and the Environment Authority have contributed to mainstreaming energy conservation in planning and regulation. In parallel, the Ministry of Energy and Minerals is coordinating the National Programme for Carbon Neutrality, which includes targeted efficiency measures.

To accelerate building energy efficiency in Oman, a combination of regulatory and incentive-based measures will be essential. Building codes are a particularly powerful tool: over 80 countries have implemented mandatory energy codes that improve insulation, building design, and the efficiency of integrated systems. Oman could adopt similar requirements for both new and existing buildings, particularly public and commercial structures. Government buildings and state-owned companies can play a leading role by committing to higher efficiency standards, commissioning energy audits, and integrating building management systems. These actions would demonstrate public-sector leadership while stimulating demand for related services and technologies.

Complementing stronger building codes, minimum energy performance standards (MEPS) for appliances—especially air conditioners and refrigerators—would help eliminate inefficient products from the market. To further encourage efficiency at the household level, targeted financial incentives such as rebates or low-interest loans could be introduced for upgrading appliances and installing high-efficiency air conditioning units. Such measures would lower long-term electricity consumption, reduce pressure on domestic gas supplies, and stimulate growth in the building efficiency sector.

In addition to policy levers such as building codes, minimum efficiency standards, and targeted incentives, addressing labour-related constraints is essential to realising the potential of energy efficiency in buildings. While government mandates and financial incentives can stimulate demand, gaps in workforce capacity and supply chains may undermine implementation. In Oman, targeted interviews with professionals and regulators highlighted specific bottlenecks along the building energy efficiency value chain. These include skills shortages in design and construction, limited training for EMS operation and monitoring, and the absence of specialised oversight mechanisms to ensure quality installation and system performance (see Table 31).

While Oman's efforts in the building sector reflect a set of country-specific constraints and opportunities, many of these challenges are mirrored across the wider Gulf region. The GCC countries share similar climatic conditions, patterns of urban development, and energy system structures—factors that have led to consistently high energy demand in buildings, particularly for cooling. The region continues to record some of the highest per capita energy consumption levels globally, largely due to a reliance on fossil fuels, limited enforcement of energy-efficient design standards, and persistent gaps in maintenance and technology uptake. Between 2000 and 2022, per capita building energy consumption in the GCC rose sharply, with Qatar experiencing a 326% increase, followed by the UAE and Oman at 213%, Saudi Arabia at 171%, and Kuwait at 133%.

Despite recent national pledges to reduce emissions—such as net-zero targets for Saudi Arabia, Bahrain, the UAE, and Oman—progress in the building sector has been limited. This is especially concerning given that buildings account for a substantial share of each country's energy use and are therefore central to achieving any significant decarbonisation. The status of building energy efficiency regulations across the GCC is summarised in Table 32.

The UAE has been among the early adopters of green building policies. In 2010, the Cabinet approved the national implementation of Green Building and Sustainable Building standards. These were initially applied to government buildings, with the aim of reducing electricity consumption and cutting carbon emissions by up to 30% by 2030. Additional initiatives, such as the Emirates Energy Star programme, have been rolled out to retrofit existing buildings with energy-saving control systems, targeting 10–35% reductions in energy use.

In Saudi Arabia, buildings are responsible for 80% of national electricity consumption, prompting significant interest in smart building technologies. These systems integrate energy control and building management functions—such as HVAC, lighting, and security—via digital platforms and Internet of Things (IoT) solutions. Market growth is supported by government programmes like the National Transformation Program 2020 and large-scale smart city developments such as NEOM. These initiatives are complemented by ongoing megaprojects like Qiddiya, Jeddah Tower, and the Red Sea Project, which are driving demand for energy-efficient and digital building technologies. While the market continues to face challenges—particularly high upfront costs and limited public awareness—major firms such as Honeywell, Siemens, Schneider Electric, and ABB are actively investing in the Saudi market, offering building automation technologies that support national energy and sustainability objectives.

As in the UAE and Saudi Arabia, Oman faces several barriers in scaling energy efficiency measures across its building sector. These include regulatory limitations, high upfront costs, low awareness among developers and consumers, and a shortage of qualified professionals in key disciplines such as MEP design and building automation. Although national strategies highlight the importance of decarbonising buildings, implementation remains fragmented. Addressing these challenges will require a mix of updated building codes, targeted incentives, and workforce development.

Table 31: Challenges in implementing energy efficiency measures across buildings in Oman, by development stage

Stage	Supply of Sustainable Building Materials	Design of Building	Construction & Installation	Operation & Monitoring
Challenges	• Absence of Affordable Sustainable Materials: Limited access to cost-effective, sustainable materials essential for Energy Management Systems (EMS) development in buildings.	• Lack of Awareness Among Developers and Owners: Limited understanding of how mechanical, electrical, and plumbing (MEP) designs influence energy consumption and savings.	• Skill Gap in Construction Workers: Insufficient skills among construction workers hinder effective installation of sustainable materials and equipment.	• Lack of Post-Construction Control and Systems: Many buildings lack advanced systems for regulating and monitoring energy use.
	• High-Quality Sustainable Materials Are Expensive: Existing sustainable materials, such as those compliant with LEED standards and designed for low electricity consumption, are high in quality but also high in cost.	• Skill Gaps in MEP Professionals: Shortage of skilled personnel for designing and implementing energy-efficient MEP systems.	• Lack of Qualified EPCs and Developers: Inexperienced Engineering, Procurement, and Construction (EPC) firms can result in poor installation practices.	• Absence of Real-Time Monitoring: Without integrated real-time monitoring, it becomes difficult to track and optimise energy efficiency.
	• Lack of Regulations and Tax Incentives: The absence of supportive regulations or tax incentives discourages investment in sustainable materials.	• Need for Specialised Training: A demand for targeted training in energy-efficient MEP design, such as certified sustainable building designers.	• Absence of Quality Control: Limited oversight during construction increases the risk of incorrect installation.	• Shortage of Skilled Personnel: Limited availability of trained personnel to operate and maintain EMS impacts energy performance.

Source: Majan Council analysis

Table 32: Building energy efficiency regulations in GCC countries

Country	Building EE Regulation	Type of Compliance	Mandatory/ Voluntary
BAHRAIN	Thermal Insulation Requirements (1999). Cabinet Order No. 6-14/2013 and Ministerial Order No. 3/2015, which effectively phased out the use of incandescent lamps.	Prescriptive	Mandatory
KUWAIT	Energy Conservation Code of Practice No. R-6 (2014)	Prescriptive	Mandatory
SAUDI ARABIA	Saudi Energy Efficiency Building Code (2007)	Performance and Prescriptive	Mandatory
UAE	Thermal Insulation requirements (2003)	Prescriptive	Mandatory
	Green Building Regulations and Specifications (2011)	Performance	Voluntary
	The Estidama Pearl Rating System (2023)		
QATAR	Global Building Assessment System (GSAS): - All new Public Buildings (2011) - All new Commercial Buildings (2016) - All new Residential Buildings (2020) New regulations now require improved thermal insulation for walls, roofs, and windows, energy-efficient air conditioning units, energy recovery ventilation systems, the phasing out of outdated window air conditioners, and energy-efficiency labeling on all appliances (2019)	Sustainable Building Label System	Mandatory
OMAN	None	N/A	N/A

Source: References 22 and 23

2.4.3 Occupational mapping – Energy Management/Optimisation Systems in the Building Sector

With clean energy transitions accelerating globally, energy efficiency jobs have expanded steadily across various markets. Building efficiency retrofits—such as upgrades to homes, schools, hospitals, and municipal facilities—are among the most labour-intensive clean energy measures and are expected to generate substantial employment in the coming years. These roles span a wide range of occupations, including engineering, consulting, building automation, and energy auditing, involving tasks such as system design, installation, project management, and long-term monitoring. Energy efficiency has already become one of the largest sources of employment in the energy sector in several countries. According to estimates, around 10 million people globally are currently employed in energy efficiency-related roles, with a significant share in building retrofits, HVAC, and electrical systems. Despite this growth, many markets—including Oman—face shortages in technically trained professionals, especially installation and repair workers such as electricians, plumbers, and HVAC technicians with energy efficiency training. Figure 30 shows global employment growth in the energy efficiency sector between 2019 and 2030.

The energy management and optimisation systems sector comprises several stages: consulting and auditing, planning and management, installation, monitoring and verification, and operation and maintenance. These stages together support the integration of energy-saving technologies and enable buildings to reduce consumption, enhance comfort, and improve cost-efficiency. Each stage relies on specific tasks and functions, from energy audits and feasibility assessments to sensor calibration and system performance verification (see Table 33). The transferability of skills between energy management and other sectors is mixed. While components such as smart meters and automation systems align well with skills in power systems, control engineering, and IT, other roles require dedicated training in energy systems and building dynamics. Table 34 outlines this skill alignment in detail, showing both areas of overlap and specific gaps.

To strengthen the workforce in this area, targeted upskilling programmes are needed to bridge technical gaps and ensure that both engineering graduates and vocational technicians can contribute effectively to energy efficiency goals. Table 35 provides an overview of job roles and corresponding upskilling opportunities in Oman's energy management and optimisation systems sector.

Accredited certifications will play a central role in establishing Oman's capacity to expand its energy efficiency sector. With the building, commercial, and public services sectors consuming approximately 80% of the country's electricity, certification schemes can ensure that professionals involved in system design, installation, operation, and maintenance meet consistent quality and safety standards. Beyond improving workforce readiness, these certifications provide confidence to investors and property developers that systems will be installed and maintained according to international best practices. Standardised credentials also help reduce reliance on informal training pathways and support national decarbonisation objectives by embedding energy efficiency expertise across the building sector. Table 36 highlights the main job roles and relevant certifications at each stage of the energy management and optimisation value chain.

Table 33: Key tasks and activities in building energy efficiency systems

	Consulting & Auditing	Planning & Management	Installation	Monitoring & Verification	Operation & Maintenance
Tasks & Activities	• Energy assessment • Data analysis • Benchmarking • Regulatory compliance review • Energy audits • Report generation	• Develop energy management policies • Create an energy management plan • Allocate resources and budget • Conduct regular performance reviews • Engage stakeholders and communicate plans	• Site assessment (land authorisation, environmental clearance, site investigation) • Equipment selection • System design and layout • Installation of EMS hardware • Documentation of installation process	• Data collection and analysis • Performance tracking against benchmarks • Verification of energy savings • System audits and inspections • Reporting on energy performance • Adjusting strategies based on findings	• Regular system checks and diagnostics • Preventive maintenance scheduling • Troubleshooting and repairs • Software updates and patches • Performance monitoring
Required Job roles	Energy Auditor, Energy Analyst, Sustainability Consultant, MEP Lead, Mechanical Engineer, Software Engineer, IoT Building Specialist, Energy Efficiency Expert, Project Manager, Cyber Security Specialist, Health and Safety Officer, Power Consultant, Environmental Engineer, Technical Support Specialist, Risk Analyst.	Energy Engineer, Planning Engineer, Software Developer, Energy System Architect, Hardware Engineer, Environmental Engineer, BMS Systems Application Engineer, Mechanical Engineer, Project Manager, Energy Manager, Site Supervisor, Energy Efficiency Program Director, Energy Auditor, Cyber Security Specialist, Financial Analyst.	Project Manager, Construction Manager, Health and Safety Officer, Senior SCADA EMS Consultant, Logistics Coordinator, Project Engineer, Building Automation Systems Manager, Building Automation Systems Engineer, Commissioning Specialist, Energy Analyst, Energy Auditor, HVAC Technician, SCADA Engineer, Energy Efficiency Analyst, Control System Engineer.	IT Business Analyst, Software Developer, Energy Analyst, Measurement and Verification Engineer, EMS Modelling Engineer, Project Engineer, Data Collection Specialist, Data Management Analyst, Energy Auditor, Compliance Monitoring Auditor, Energy Performance Analyst, Quality Assurance Engineer, Cyber Security Specialist, Project Coordinator, and Customer Support Specialist.	Network Engineer, Contract Administrator, Procurement Specialist, Energy Efficiency Technician, Instrumentation and Controls Technician, Environmental Technician, Senior Operations Systems Analyst, Energy Auditor, Facilities Maintenance Coordinator, Data Analyst, Operations Specialist, Facilities Manager, Project Manager, EMS Specialist, SCADA Engineer.

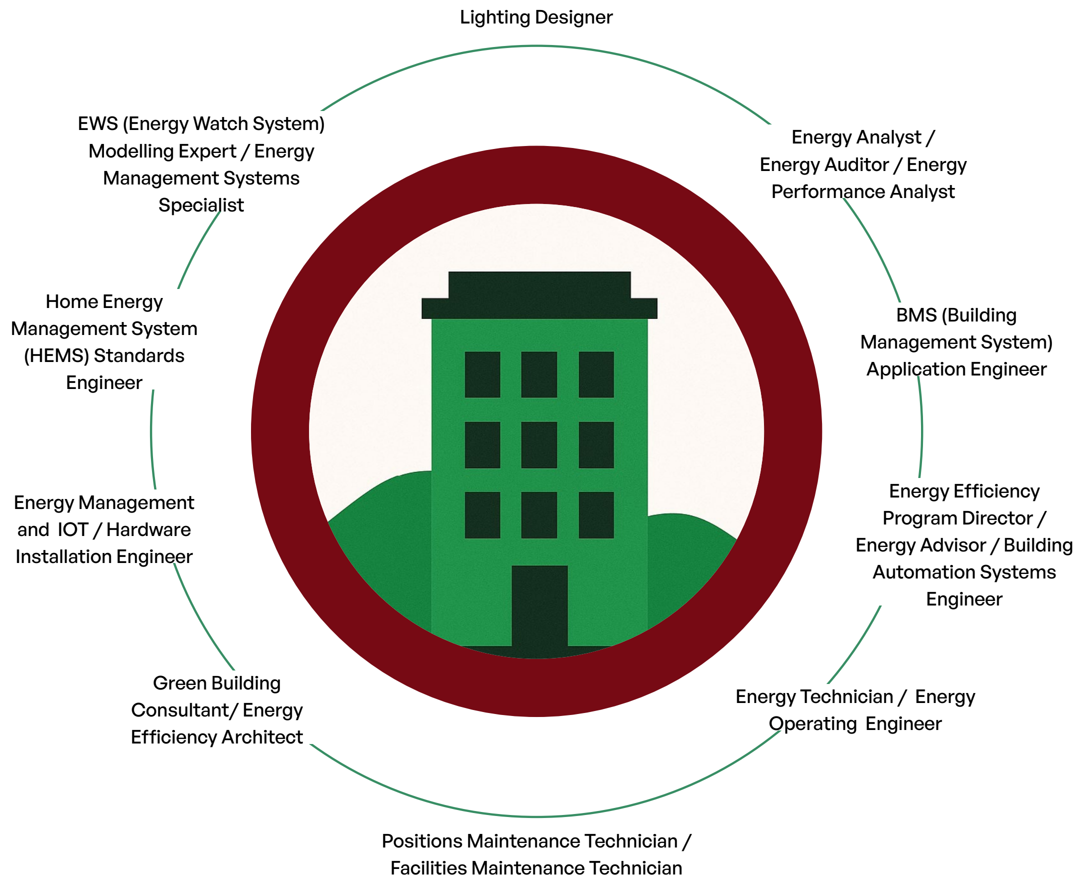
Source: Majan Council analysis

Table 34: Alignment of skills and knowledge for building energy efficiency components with other industries

	Sustainable Materials and Construction Design	Smart Meters & Sensors	Energy-efficient devices & Controllers	Renewable Energy Systems (e.g., solar panels)	Building Renovations	Energy Monitoring Systems
Design & Planning	Low	Low	Medium	Medium	Medium	Low
Monitoring & Verification	Low	Low	High	High	High	High

Source: Majan Council analysis

Figure 30: Key roles in building energy efficiency systems



Source: Majan Council analysis

Table 35: Key job roles and upskilling opportunities in building energy efficiency systems

Job Roles	Description	Required Education	Skills	Level of skill Gap
BMS Systems Application Engineer	Designs, implements, and optimises building management solutions to improve energy efficiency, control, and automation in commercial or industrial facilities.	BSc in Engineering Management / Management System	• Expertise in Building Management Systems (BMS) and Electrical Power Management Systems (EPMS). • Strong understanding of BMS/EPMS for efficient system integration. • System architecture and interfacing: Designs seamless subsystem connections. • Engineering outputs: Produces schedules, control panels, and graphic interfaces. • HVAC and EMS strategies: Optimises control for energy and comfort. • Technical design and integration: Ensures cohesive design and system setup. • Factory Acceptance Testing: Verifies system performance. • Configuration and programming: Configures hardware/software for system needs. • Risk and deliverables management: Balances risk, tracks progress, and maximises profitability.	MEDIUM
EMS Modelling Engineer / Energy Management Systems Specialist	Develops and analyses energy models to optimise energy management systems, promoting efficient energy use and sustainability in buildings.	BSc in Electrical Engineering	• Experience with real-time EMS databases. • Use of EMS display generation software and electric power system display tools. • Knowledge of EMS transmission network analysis, including State Estimation, Security Analysis, and P-V curve analysis. • Coordination of EMS database updates and single-line diagram building. • Tuning the State Estimator during model updates. • Design, implementation, and support of EMS modelling tools and network applications. • Familiarity with EMS Transmission Network Applications (TNA) suite of tools.	HIGH

LOW – SKILL GAP Minimal task changes are required, though some additional domain knowledge may be necessary.

MEDIUM – SKILL GAP Some new responsibilities are introduced, and upskilling or reskilling is needed to handle these new tasks.

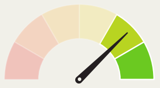
HIGH – SKILL GAP Significant new responsibilities and unfamiliar areas of expertise are introduced, requiring substantial upskilling or reskilling.

Job Roles	Description	Required Education	Skills	Level of skill Gap
Lighting Designer	Creates lighting solutions and designs to optimize energy efficiency and performance in various environments.	BSc in Electrical Engineering	• Knowledge of architectural principles and techniques. • Proficiency in AGi32 and LEED for Building Design and Construction (BD+C). • Understanding of energy conservation strategies. • Experience using physical drafting tools and CAD & simulation tools. • Familiarity with local building codes and industry standards (e.g., NFPA, ANSI, IEEE, MEP).	LOW
Energy Management and IoT Hardware Installation Engineer / IoT Building Specialist	Con Figures and maintains IoT and energy management devices in buildings, ensuring efficient integration for optimised energy monitoring and management.	BSc in Electrical Engineering / Mechanical Engineering / Computer Science	• Installing and configuring energy management and IoT systems. • Performing wiring and connectivity tasks for IoT devices and sensors. • Configuring software for optimal system performance. • Conducting site surveys to identify installation needs. • Documenting installation activities, including diagrams and configurations. • Testing systems for proper operation and compliance. • Troubleshooting technical issues and providing resolutions. • Coordinating with subcontractors and vendors for timely deliveries.	HIGH
Facilities Maintenance Technician	Performs maintenance tasks for facilities housing energy management systems, ensuring equipment and systems remain in good working order.	Vocational Diploma Vocational Certificate/ Certificate in Electrical Engineering / Mechanical Engineering	• Experience in maintenance activities including scheduling, inspections, and preventive programs. • Knowledge of HVAC controls, maintenance, repair, refrigeration, and lighting system design. • Ability to read blueprints, sketches, drawings, manuals, and specifications. • Understanding and application of safety compliance procedures.	LOW

LOW – SKILL GAP
Minimal task changes are required, though some additional domain knowledge may be necessary.

MEDIUM – SKILL GAP
Some new responsibilities are introduced, and upskilling or reskilling is needed to handle these new tasks.

HIGH – SKILL GAP
Significant new responsibilities and unfamiliar areas of expertise are introduced, requiring substantial upskilling or reskilling.

Job Roles	Description	Required Education	Skills	Level of skill Gap
Green Building Consultant	Advises on sustainable practices, green certifications, and energy-efficient design to improve environmental performance and meet green standards.	BSc in Sustainable Systems Engineering / Greenhouses	• Knowledge of LEED, GRIHA, WELL Building Standard, and Net Zero principles. • Accredited professional status from IGBC and GRIHA. • LEED Accredited Professional (LEED AP) preferred.	 HIGH

Source: Majan Council analysis

Table 36: Certifications and relevant job roles across the main stages of building energy efficiency systems

	Consulting & Auditing	Planning & Management	Installation	Operation & Maintenance
Certificate	LEED Green Rater certifications	Leadership in Energy and Environmental Design (LEED) Certified	CSE/M (Confined Space and Monitor and Entry)	Juniper JNCIP Security/ Firewall/Routing Switching
	CEM Certified Energy Manager	LEED AP Certification	Project Management Professional (PMP) Certification	Cisco CCNP Routing Switching Certificates
	Energy Auditing Scheme (EAS) SI426/SI599	Certified Energy Manager (CEM) Certification	Certified Energy Manager (CEM) Certification	BOSIET (Basic Offshore Safety Induction and Emergency Training Certificate)
	Infrastructure Sustainability Accredited Professional (ISAP)	Certification in Project Management (e.g., PMP, Agile Certified Practitioner)	Chartered Professional Engineer (CPEng)	Heating, Ventilation, and Air Conditioning Systems Certification (HVAC)
	Heating, Ventilation, and Air Conditioning Systems Certification (HVAC)	Shainin Red X / Six Sigma Certification	Infrastructure Sustainability Accredited Professional (ISAP)	Certified Facility Manager (CFM)
	Safety Certifications (First Aid, WHMIS, Fall Protection)	ALA Certification	ISO 50001 and Related ISO Energy Management Standards	LEED AP Certification
	SCADA Systems Certificate	NIST Special Publications (FIPS 199, 200, 800-53, 800-37)	Professional Certifications (AEE, CMVP, CEM, CEA)	Infrastructure Sustainability Accredited Professional (ISAP)
	Certification in Project Management (PMP, Agile Certified Practitioner)		Transit Fire/Life Safety Certification	H2S Alive
	Health and Safety Certification (ASP, CSP, CHSP, CIH, CHMM)		Health and Safety Certification (ASP, CSP, CHSP, CIH, CHMM)	Transportation of Dangerous Goods (TDG)
	Energy Auditing Certificate (CEAT, CEEM, CEM, CMVP)		First Aid Certificate	Safety Certifications (First Aid, WHMIS, Fall Protection, Aerial Lift Training)
	LEED - Accredited Engineer		Self-Defense Certificate	Valid Driver's License (VDL)
	LEED - Green Associate			ISO 45001 and Related ISO Occupational Health and Safety Standards
	LEED - AP Building Operation and Maintenance			
	LEED - Control & Design			

	Consulting & Auditing	Planning & Management	Installation	Operation & Maintenance
Target	Sustainability Specialist, Energy Analyst, Sustainability Consultant, Hardware Engineer, Project Controls Engineer, Health and Safety Officer, Project Coordinator, Training and Development Specialist, Risk Analyst, BMS Systems Application Engineer, Building Automation Systems Engineer, EMS Modelling Engineer / Energy Management Systems Specialist, Energy Analyst / Energy Auditor / Energy Performance Analyst, Energy Efficiency Analyst / Energy Efficiency Expert, Facilities Maintenance Technician, Green Building Consultant, Home Energy Management System (HEMS) Standards Engineer.	Energy Engineer, Architectural Engineer, Software Project Manager, Project Manager, Energy Efficiency Program Director, Lighting Designer, Cyber Security Specialist, Energy Efficiency Program Director / BMS Supervisor, Energy Efficiency Technician, Energy Management and IoT Hardware Installation Engineer / IoT Building Specialist, Energy System Architect.	HVAC Technician, Project Engineer, Energy Auditor, Project Manager, Building Automation Systems Manager, Health and Safety Officer, Security Personnel, Measurement and Verification Engineer / Measurement and Verification Specialist / Control System Engineer.	Network Engineer, BMS Supervisor, Maintenance Manager, Senior Operations Manager, Accountant, Operations Specialist, Communication Network Technician.

Source: Majan Council analysis

2.5 MANUFACTURING OF CLEAN ENERGY COMPONENTS

Developing solar PV manufacturing in Oman presents a strategic opportunity to strengthen industrial capabilities and reduce dependence on imported equipment. While manufacturing itself does not reduce emissions—since that depends on how the panels are used—it plays a crucial enabling role in scaling domestic renewable energy deployment. Importantly, Oman's emerging green hydrogen sector is expected to create substantial domestic demand for solar panels, making local manufacturing strategically relevant. In addition to supporting energy infrastructure, the sector offers substantial economic advantages. Solar manufacturing can generate employment across a range of skill levels and help build a more diversified industrial base.

Oman's transition toward renewables and green hydrogen is expected to drive demand for large-scale solar installations. To support this ambition, Oman plans to establish a large-scale solar PV manufacturing facility. This development would contribute directly to the country's In-Country Value (ICV) goals and enable greater control over energy infrastructure inputs. At the same time, it opens the door to economic diversification through industrial participation in global clean energy supply chains.

The manufacturing sector also presents opportunities for new market entrants. Starting with module assembly—a relatively low-cost entry point requiring less than US$50 million in initial investment—could provide a viable path for emerging manufacturers. However, the expansion of solar manufacturing will require targeted workforce development and access to specialised equipment, particularly for upstream processes like ingot and wafer production, which are currently dominated by Chinese suppliers. Addressing these constraints is critical for ensuring supply chain resilience and reducing dependency.

Job creation potential is considerable. Globally, the solar PV manufacturing sector supports approximately 1.38 million jobs, with projections suggesting the workforce could grow to between 500,000 and 2.5 million by 2025. A significant share of these jobs will require specialised training and certification, highlighting the need for coordinated education and skills development programmes.

Oman's clean energy ambitions—spanning solar, wind, and green hydrogen—will require large-scale deployment of core technologies, including solar PV modules, wind turbines, and electrolysers. See the hydrogen chapter for detailed targets and sector context. In support of this trajectory, the Omani government aims to strengthen domestic supply chains by expanding local manufacturing capacities for these components. Localising the production of clean energy components not only strengthens industrial capabilities but also reduces supply chain risks, increases economic value retention, and creates skilled employment across multiple value chain stages.

The projected hydrogen production targets for 2030, 2040, and 2050 imply a rapidly increasing need for component manufacturing. By 2040, Oman aims to reach 3.25 to 3.75 million tonnes of green hydrogen per year, supported by 35 to 40 GW of electrolyser capacity and up to 75 GW of renewable power (see Table 37). To meet these targets, Oman will require millions of PV modules, tens of thousands of wind turbines, and hundreds of large-scale electrolysers. Hydrom has thus begun encouraging the localisation of component manufacturing, with early-stage studies and tenders already initiated.

Table 38 outlines the estimated quantities of each major component needed under two localisation scenarios—50% and 100% domestic supply of components for hydrogen production by 2040. While full localisation may remain ambitious in the near term, partial localisation can already support technology transfer, skills development, and industrial diversification.

Efforts to localise component manufacturing also respond to the rising global competition for clean energy technologies, with major economies ramping up domestic production under industrial policies like the US Inflation Reduction Act and the EU Net-Zero Industry Act. In this context, Oman's industrial policy in clean energy component manufacturing is not just a matter of cost-efficiency, but a strategic move to secure industrial competitiveness and attract downstream investments in clean fuels and energy-intensive green goods.

Table 37: Hydrogen production targets and projected supporting capacities

Year	Hydrogen Production Target (Mtpa)	Electrolyser Capacity (GW)	Renewables Capacity (GW)	PV modules	Wind turbines	Electrolysers
2030	1.0 - 1.5	8 - 15	16 - 30	37,000,000	1,665	1,500
2040	3.25 - 3.75	35 - 40	65 - 75	92,592,593	4,167	4,000
2050	7.5 - 8.5	95 - 100	175 - 185	292,857,143	10,333	10,000

Source: Majan Council analysis and Hydrom

Table 38: Proposed manufacturing capacity to meet future demand for green hydrogen components by 2040

Manufacturing capacity , MW		
PV module	Wind turbine	Electrolyser
4000	2000	3000

Source: Majan Council analysis

2.5.1 Solar PV Panel Manufacturing

Developing solar PV manufacturing in Oman presents a strategic opportunity to strengthen industrial capabilities and reduce dependence on imported equipment. While manufacturing itself does not reduce emissions—since that depends on how the panels are used—it plays a crucial enabling role in scaling domestic renewable energy deployment. Importantly, Oman's emerging green hydrogen sector is expected to create substantial domestic demand for solar panels, making local manufacturing strategically relevant. In addition to supporting energy infrastructure, the sector offers substantial economic advantages. Solar manufacturing can generate employment across a range of skill levels and help build a more diversified industrial base.

Oman is positioning itself as a regional hub for solar PV manufacturing, driven by recent investments and strategic partnerships. Although the country currently lacks a fully integrated solar PV manufacturing ecosystem, several initiatives are underway to build domestic capacity. Sheida Industries LLC operates a solar panel manufacturing facility in Sohar Industrial City with a production capacity of 200 MW. The line was established in collaboration with Ecoprogetti SRL and represents Oman's first commercial-scale solar panel production initiative. In parallel, United Solar Polysilicon (FZC) SPC has begun constructing a large-scale polysilicon facility at Sohar Port and Freezone, with investment exceeding US$1.35 billion. Once operational, the plant will produce 100,000 metric tonnes of high-purity metallurgical silicon per year, intended largely for export.

Further strategic projects are in the pipeline. Bakarat Investment, in partnership with China's Q-SUN Solar, is developing a 10 GW solar PV manufacturing facility in Sohar Freezone. The project includes 8 GW of module capacity and 2 GW of cell capacity, focusing on TOPCon and heterojunction (HJT) technologies, with an estimated investment of US$200 million. Additionally, Drinda New Energy Technology plans to invest nearly US$700 million through its subsidiary JTPV to build a 10 GW TOPCon cell manufacturing plant.

These investments contribute to Oman's broader goals of industrial diversification, job creation, and technology transfer. They also align with national strategies to increase In-Country Value (ICV) and position Oman as a participant in global clean technology supply chains.

Across the GCC region, several countries are following a similar trajectory. Solar panel manufacturing is becoming a core pillar of regional industrial strategy, with several countries initiating large-scale investments and joint ventures to localise production and reduce import dependence (Table 42).

Various wafer and cell technologies are employed within crystalline polysilicon systems. Since 2022, monocrystalline wafers have gained near-universal dominance due to their improved efficiency. Simultaneously, advanced cell designs such as Passivated Emitter and Rear Cell (PERC) technology have secured nearly 60% market share, while emerging high-efficiency technologies—including TOPCon, heterojunction, and back-contact cells—collectively captured around 35% of the market.

The production value chain involves four primary stages, each requiring specialised processes and equipment. First, raw silicon is purified to extremely high standards—over 99.999% purity—through energy-intensive chemical methods. Although polysilicon is also used in the semiconductor industry, the solar sector now accounts for over 90% of global demand. Second, the purified silicon is formed into ingots and then sliced into thin wafers, involving precision cutting, polishing, and shaping technologies. This step can use monocrystalline or polycrystalline structures, depending on efficiency and cost considerations. Third, the wafers are processed into photovoltaic cells. This includes doping the silicon to form a p-n junction and applying top and rear metal contacts, often with additional treatments to enhance cell efficiency. Finally, cells are interconnected and encapsulated within protective glass layers to form modules, which are laminated to ensure durability and performance in field conditions. Key inputs and equipment required for each stage of production are summarised in Table 41.

Solar PV modules have experienced the highest learning rates among renewable energy technologies. Between 2010 and 2022, the levelised cost of electricity (LCOE) from solar PV declined by 89%, falling from US$0.445/kWh to US$0.049/kWh, primarily due to module price reductions. Crystalline silicon module prices dropped by approximately 90% from 2009 to 2022, ranging from US$0.22/W for lower-cost modules to US$0.43–0.44/W for high-efficiency variants.

Several factors have underpinned the surge in solar investment: the technological maturity of PV systems, enhanced system performance, favourable policy environments, reduced technology risks, and growing developer experience. Additionally, expanded manufacturing capacity, innovations in business models, and improved system integration have all strengthened the sector's cost competitiveness.

Nonetheless, supply chain security remains a strategic concern. Manufacturing is highly concentrated, with China accounting for over 80% of production across all stages—from polysilicon to modules. The remainder is largely in other parts of Asia (10%). China also hosts the top 10 global suppliers of PV manufacturing equipment. This concentration poses risks of supply-demand imbalances. In response, countries such as India and the USA have introduced policies to localise production. Investment in solar manufacturing in both countries is projected to reach nearly US$25 billion during 2022–2027—a sevenfold increase compared to the previous five years (Figure 31).

Process innovations across the supply chain have driven improvements in material efficiency, cost reduction, and performance. While solar cell manufacturing capacity globally is estimated at 470 GW, module manufacturing—a lower-skill, more distributed process—totals over 600 GW.

The solar PV manufacturing sector is expected to grow significantly, supported by rising global renewable energy demand. The sector could double its direct manufacturing workforce to 1 million jobs by 2030. Cell and module production are particularly labour-intensive. Current estimates suggest that the sector supports approximately 1.38 million jobs, and could add 75,000 direct jobs annually between 2025 and 2030—with potential for up to 200,000 jobs annually in high-growth scenarios.

Employment intensity varies by value chain segment: polysilicon production (8%), ingot and wafer processing (16%), cell manufacturing (27%), and module assembly and inverter production (27% and 22%, respectively). This underscores the employment relevance of downstream segments such as cell and module manufacturing (see Table 39).

Solar PV module production expanded 38-fold between 2008 and 2022, rising from 7.2 GW to 271 GW. In 2022 alone, output increased from 193 GW to 271 GW. However, capacity utilisation has declined, with less than 50% of capacity operational in recent years—a drop from 83% in 2017 (see Table 40).

In 2022, global production capacity reached 717 GW/year, up from 483 GW/year in 2021. This increase is attributed to both new facilities and improved conversion efficiency. However, much of the nominal capacity includes outdated or idle facilities. Effective capacity is estimated at approximately 500 GW/year. Figure 32 highlights the gap between installed capacity and module production, indicating that many manufacturing facilities are currently underutilised. This suggests that, if necessary, idle facilities could be reactivated to meet increased demand.

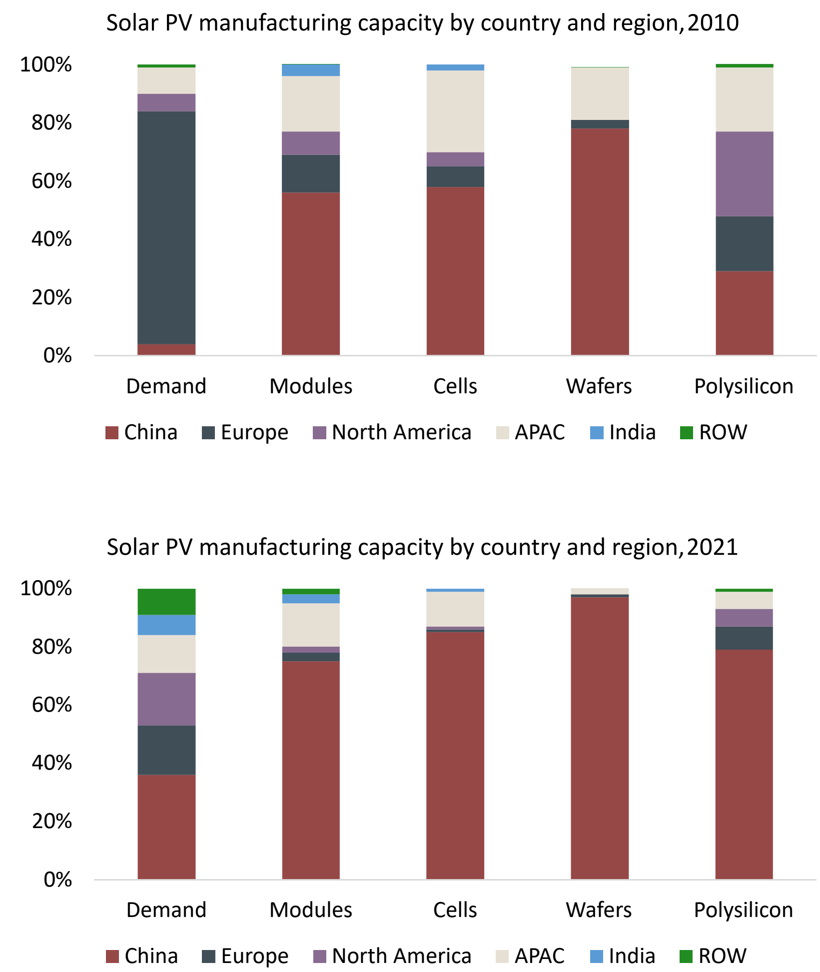
Capital requirements are highest at the upstream end of the value chain: polysilicon production demands around US$300 million, and ingot/wafer production around US$200 million. Cell manufacturing and module assembly require significantly less, at US$50 million and under US$20 million, respectively. This reflects the capital intensity of early-stage production and the relatively lower-cost final assembly process (Figure 33).

To meet growing solar demand, global manufacturing capacity must expand in parallel with the development of diversified, affordable, and resilient supply chains. China's sustained investment in R&D has reduced production costs and entrenched its global dominance. However, this concentration raises risks, including supply disruptions and strategic dependencies.

Policy interventions can help mitigate these risks. Diversifying manufacturing bases, incentivising investment outside China, supporting ongoing innovation, and advancing solar PV recycling systems are essential measures. Together, these strategies can enhance the resilience, sustainability, and inclusiveness of the global solar PV manufacturing landscape.
The solar PV manufacturing value chain encompasses several key components, including polysilicon, wafers, cells, modules, and arrays, as well as supporting elements such as mounting structures, tracking systems, and electrical components. Crystalline polysilicon remains the dominant technology, representing over 97% of the market share for PV modules. Their material composition and associated cost distribution are illustrated in Table 40.

The greatest share of value in solar farms lies in solar panels and silicon cells, followed by steel racking systems. Within the cost structure of a solar cell, silicon cells account for approximately 74%, with glass (10%), ethylene vinyl acetate (7%), and the backsheet (5%) comprising the remainder.[11]

Figure 31: Solar manufacturing capacity in different countries and regions



Source: Reference 33

Table 39: Equipment needed to manufacture solar PV cells & modules

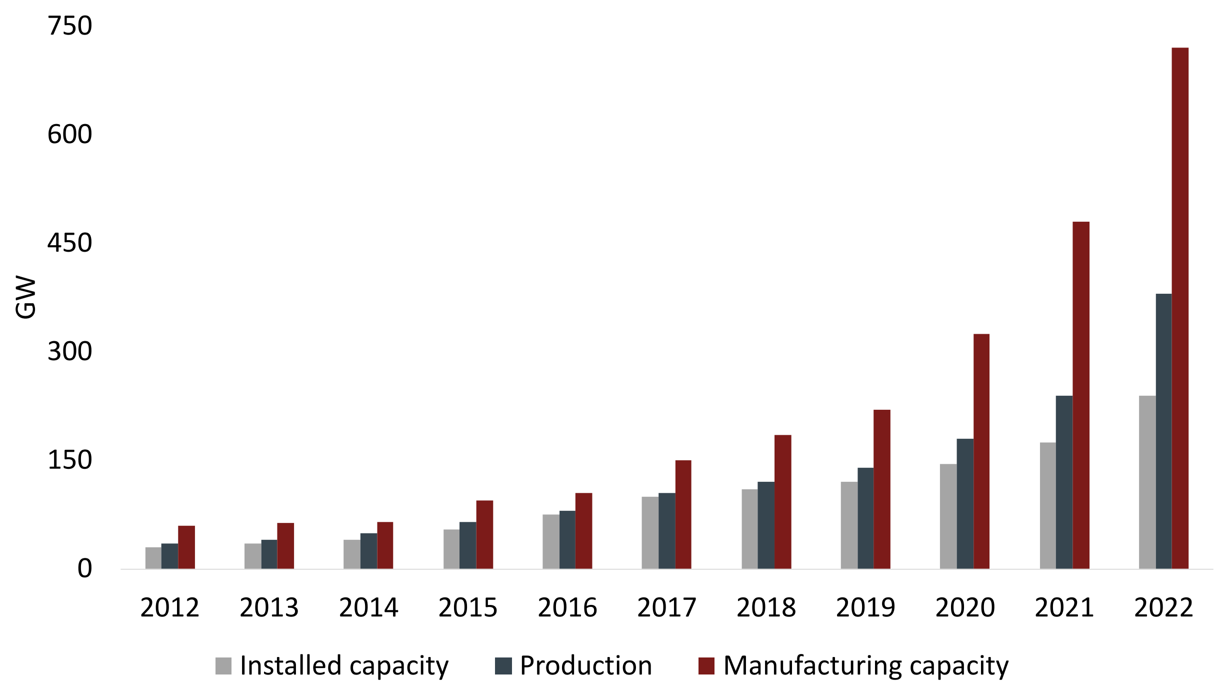
PV Cells	PV Modules
• Crystalline Ingot Growing machine • Diffusion equipment • Deposition machines • Semi-automatic laminator • Full automatic laminator • Solar cell tester • Framing machine • EVA, TPT cutting station • EVA, TPT transfer carrier • Laser cutting machine • Electrical iron • Pneumatic glue gun • Compressor • Quartz recipients, blowing gas machinery	• Systems able to automatically classify cells according to the electric current generated with a voltage: cell select Tables, appearance inspection stations • Washing, joining machines, electric arc furnaces • Cutting machines (circular saw, multi-wire saw) • Serigraphy machinery • Welding equipment • Cell string shelves • Cooling systems • Laser beams • Laying up stations • Module transfer carrier

Table 40: Current and projected production capacities and investment requirements for polysilicon, ingots/wafers, cells, and modules

	Polysilicon	Ingots/Wafers	Cells	Modules
Current Production Capacity (GW)	439	553	568	639
Approximate Future Production Capacity in 2030 (GW)	1504	1046	1377	1262
Total Investment (US$)	12.9 billion	31.82 billion	80 billion	
The required investment (US$/MW)	5,770	1,000,000 - 1,500,000	150,000 -200,000	250,000 - US$350,000
Price	5.77 USUS$/kg	1000 - 1500 US$/ton - 16.7 US$/inch	US$0.15 - US$0.20/ watt	US$0.25 - US$0.35/watt
Electricity intensity	High	High	Medium	Low
Qualified labor	High	High	High	Low
Labor cost	Low	Low	Medium	High

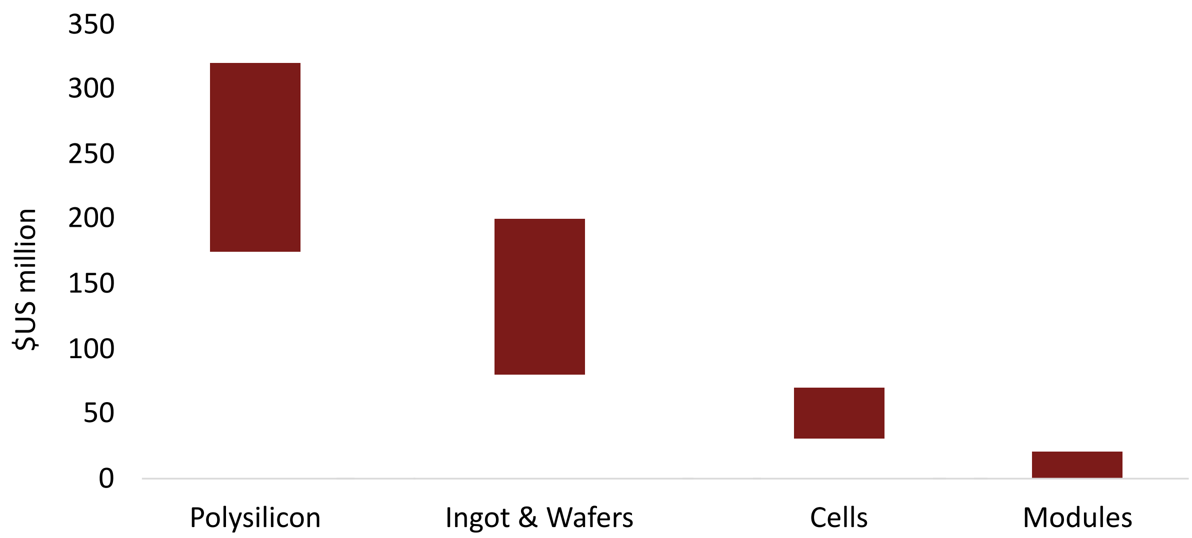
Sources: IEA, Presedence research, Transparency Market Research, Trade Metal, Bloomberg NEF, Bernreuter, ISA, Reference 12

Figure 32: Annual PV installations, module production, and module production capacity, 2012–2022



Sources: Reference 35

Figure 33: Average minimum investment required per value chain step

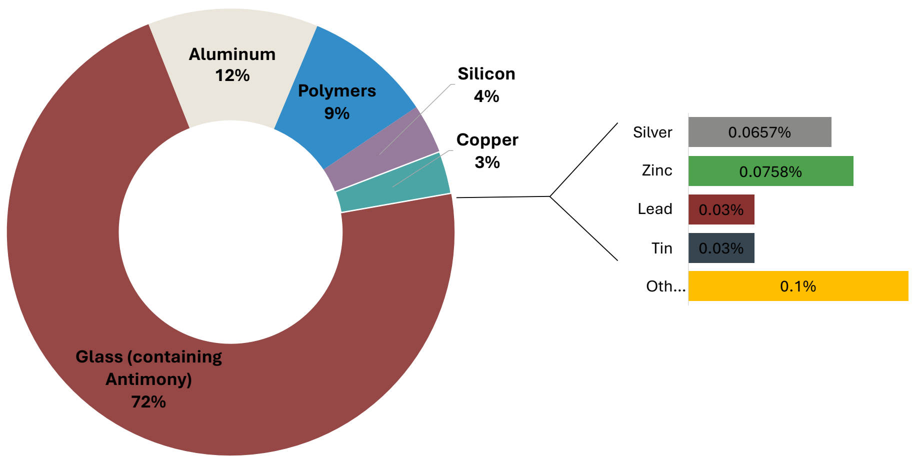


Source: Reference 34 and 36

Table 41: Main equipment and required materials for each stage of solar PV manufacturing

Stage	Main Equipment	Main Consumables	Materials
Solar Grade Polysilicon	• Chemical vapor deposition reactors (not specifically listed in the chart, but typically used in this process)	• Metallurgical silicon	• Met-silicon, Hydrochloric acid, Calcium hydroxide, Amine catalyst, Copper catalyst, Hydrogen
Ingot Pulling	• Single crystal growing furnace	• Doping material	• Silicon quartz, Crucibles, Graphite, Argon, Boron, Vacuum pump oil, Steel wire, Glass beams, Resins + Hardener
Wafer Slicing	• Slicing equipment	• Diamond wire	
Cell Manufacturing	• Texture treatment equipment • Diffusion furnace • Screen printing equipment • Firing furnace	• Chemical precursors • Metallization paste	• Phosphoryl chloride, Nitric acid, Potassium hydroxide, Hydrogen fluoride, Hydrogen chloride, Sulfuric acid, Silane, Ammonium, Liquid nitrogen, O_2 • Silver (Ag) paste, Ag-Al paste, Al paste
Module Assembling	• Laminator • Lay-up equipment • Stringing equipment • Bussing equipment	• Backsheet • Encapsulant • Ribbons • Solar glass • Aluminum frame • Junction box	• Ethyl vinyl acetate, Backsheet (e.g., PET), Glass, Aluminum frame, Copper ribbon, Silicon glue

Figure 34: Material composition shares of c-Si PV modules by weight and by value



Source: Reference 33

Table 42: Current projects and future investments in PV module manufacturing across GCC countries

GCC country	Current Project	Future Projects and Investments
UAE	UAE has made significant progress in establishing a domestic PV module manufacturing industry. Emirates Insolaire, a joint venture between Dubai Investments and SwissINSO, produces innovative coloured solar glass. DuSol Industries, Dubai's first PV module manufacturer, contributes to regional solar advancements.	The UAE aims for 50% solar power generation by 2050. Abu Dhabi targets 5.6 GW of PV capacity by 2026, and Dubai projects 50% renewable electricity by 2050. Investments will expand infrastructure and solar innovation.
SAUDI ARABIA	Saudi Arabia's PV sector includes partnerships like Goldi Solar and Desert Technologies, focused on PV modules, cells, encapsulants, and advanced technologies (TOPCon, HJT). Masdar Solar, with 1,200 MW capacity in Tabuk, localises PV tech under Vision 2030.	Saudi Arabia signed MoUs with TCL Zhonghuan and JinkoSolar to manufacture 20 GW of ingots/wafers and 10 GW of n-type cells/modules, respectively. These initiatives aim to localise 75% of renewable components by 2030.
OMAN	Oman's PV manufacturing industry includes a 200 MW plant by Sheida Industries in Sohar and a 500 MW assembly plant planned in Salalah Free Zone. These projects reduce dependence on imports.	Oman's future includes a US$700 million project by Hainan Drinda to produce 10 GW of TOPCon cells in two phases. United Solar Polysilicon is also building a US$1.35 billion polysilicon facility in Sohar Port to produce 100,000 MT annually, supporting Vision 2040.
QATAR	Qatar Solar Technologies (QSTec) is building an US$1B polysilicon plant producing 8,000 tonnes/year in Ras Laffan. Qatar Solar Energy launched a 300 MW PV module factory in Doha, planning to expand to 2.5 GW and export to Japan and Thailand.	QSTec plans to expand its polysilicon capacity to 50,000 MT and has installed 1.1 MW at its site. It holds strategic investments in SolarWorld AG and Centrotherm, strengthening its global solar technology presence.
BAHRAIN	In 2021, Solartecc Green Energy established a solar module factory in Bahrain International Investment Park with a capacity of 25 MW (expandable to 50 MW), producing high-efficiency panels, including desert-specific modules.	With growing regional demand, Bahrain plans to expand Solartecc's capacity and adopt advanced technologies. Supportive policies are set to attract investment and create green jobs in the sector.

Source: Solarfeeds, DUSOL, Masdar, PV Magazine,PV-Tech, Oman Observer, Zawya, Meed, Renewable Energy Industry

2.5.2 Wind Turbine Manufacturing

The global expansion of green hydrogen has elevated wind energy as a key enabler for low-emissions hydrogen production. Oman's strong wind resources and vast land area create favourable conditions for onshore wind development and domestic manufacturing of turbine components. Oman's hydrogen ambitions—requiring around 10,000 wind turbines—are set to drive substantial local demand. Although no wind turbine manufacturing currently exists in the country, the availability of core raw materials such as steel, iron, concrete, and fibreglass offers a solid basis for localisation. Over 95% of necessary materials are available domestically. Oman could begin near-term production of towers, blades, and balance-of-system components by leveraging its established steel, cable, transformer, and concrete industries.

Transport and logistics are significant constraints. The scale and weight of components—especially towers and blades—make them expensive to import at volume. Local production could reduce costs while enhancing Oman's industrial capacity.

Globally, wind turbine prices outside China declined by 39–55% between 2010 and 2022, driven by falling input costs, competition, and technology improvements. In China, prices fell by nearly two-thirds, though market dynamics differ. Global prices rose slightly in 2022 due to commodity price fluctuations and supply chain bottlenecks, but longer-term trends favour continued cost reductions.17

Larger rotor diameters and higher hub heights have increased energy capture and improved cost efficiency, particularly in moderate-wind locations. These shifts make local production of towers and blades more feasible, especially where heavy industry already exists.
The greatest share of value in solar farms lies in solar panels and silicon cells, followed by steel racking systems. Within the cost structure of a solar cell, silicon cells account for approximately 74%, with glass (10%), ethylene vinyl acetate (7%), and the backsheet (5%) comprising the remainder.31

Wind turbine designs vary significantly, affecting material requirements and localisation potential. Figure 35 presents a breakdown of wind turbine component composition, reinforcing the significance of design choices for localisation potential. One key distinction is between geared and gearless generators. Gearless (direct drive) systems require less maintenance and offer greater reliability but are heavier, unless rare earth elements such as neodymium, praseodymium, dysprosium, and terbium are used to reduce weight. It is estimated that wind turbines require around 200 kg/MW of rare earths. These materials have spurred innovation, especially as lighter nacelles reduce demands on towers and foundations.

In Oman, tower manufacturing presents the most immediate opportunity. Most modern towers are conical tubular steel, fabricated from rolled and welded steel plates, then assembled in sections. These towers can account for 10–15% of wind farm costs—and up to 25% when including shipping (Figure 36). Oman's domestic steel production offers a key advantage, potentially reducing tower manufacturing costs by 7.5–10% compared to non-steel-producing countries. Interest in establishing a local tower facility is growing, but would require investment in a dedicated plant with a production capacity of at least 250 MW annually, ideally scaling to 500 MW. A facility of this size could create 175–200 direct jobs, with up to 2,000 jobs across steel-related industries for 3,000 MW of cumulative output.

In 2022, global manufacturing capacity for nacelles, towers, and blades stood at 110–120 GW, with expected expansion to 120–140 GW over three years. China maintains a dominant position, with 60–80% of global capacity. This concentration underscores the value of regional diversification.

The global wind energy market has developed into a complex supply chain, Figure 37 illustrates projected regional demand and supply imbalances from 2023 to 2030, highlighting global capacity pressures, while with dedicated manufacturing facilities for towers, blades, nacelles, and generators. In 2018, wind turbines accounted for nearly a quarter of the US$50.3 billion wind system equipment market, followed by rotor blades (15%), gearboxes (7%), and generators. 13 By 2023, the global wind turbine market was valued at US$141.4 billion and is projected to grow at over 8% CAGR through 2032, driven by infrastructure upgrades and increasing deployment.

In 2023, 23,833 turbines were installed globally, produced by 30 manufacturers—19 based in Asia-Pacific, 8 in Europe, 2 in the Americas, and 1 in the Middle East. The top 10 OEMs by installed capacity include Vestas, Siemens, GE, Enercon, Goldwind, and Suzlon, among others. Most market growth is still driven by domestic demand in China, the US, and Europe.

China's dominance in wind turbine manufacturing is driven by cost competitiveness, targeted industrial policy, and a coordinated push to build out the full value chain. Government policies—such as feed-in tariffs, local content rules, and subsidies—have supported this expansion, enabling Chinese manufacturers to produce some of the world's largest and most efficient turbines. Europe remains an innovation hub, but much of the manufacturing has shifted to China.14

Competition among manufacturers has intensified, pressuring profit margins. Increased commodity prices in 2021–2022 further affected turbine costs. Competitive procurement practices for renewables and industry consolidation have prompted shifts in production to lower-cost manufacturing hubs.

Steel accounts for roughly 90% of a turbine's total weight and is used primarily in towers and nacelles. Onshore turbines typically require 107–132 tonnes of steel per megawatt (t/MW) and 243–413 t/MW of concrete for foundations. Aluminium, copper, and rare earth elements are critical for nacelles and generators, while blades rely on fibreglass, carbon fibre, epoxy resin, and increasingly sustainable alternatives like PET and pultruded carbon fibre. Table 43 provides a detailed breakdown of the materials and their applications in turbine manufacturing, while Figure 38 illustrates the typical material composition of onshore wind turbines.

Wind turbine manufacturing is a major source of employment. In 2022, Vestas and Siemens Gamesa employed over 28,400 and 27,600 workers respectively, while China's Goldwind employed around 11,200. Labour intensity varies by component: blade and tower manufacturing are the most labour-intensive, followed by nacelles and cables. These areas offer the greatest potential for workforce development in new markets. Figure 39 provides a global overview of the wind energy component supply chain and helps contextualise Oman's potential manufacturing entry points.

Local manufacturing would reduce shipping costs, minimise transport-related damage, and improve delivery timelines. It would also offer opportunities to supply regional markets and related industries, such as hydro pipe fabrication.

Blade manufacturing, which accounts for 20% of capex and 15% of total wind project costs, is considered less feasible in Oman. It requires an advanced composites industry and highly specialised processes. The required scale of production exceeds current domestic market demand.

Assembly of nacelle components presents another potential localisation opportunity. While full nacelle manufacturing is unlikely, assembly functions such as drivetrain, yaw, and electrical integration—accounting for nearly two-thirds of nacelle value—could be developed near ports and industrial zones. Even partial localisation would significantly increase local content.

Barriers to expansion include limited local expertise, nascent market size, and the need for targeted skills development. Supportive procurement policies, government incentives, and industrial coordination would be required to overcome these challenges.

Across the GCC, wind energy potential is concentrated in Oman and Saudi Arabia, with other countries focusing on solar. Both Oman and Saudi Arabia have incorporated wind into their long-term energy strategies. Localising component manufacturing in these countries would enhance energy security, reduce import dependency, and support industrial development.

Saudi Arabia is pursuing domestic wind manufacturing through strategic partnerships. The Public Investment Fund is reportedly negotiating with China's Envision Energy to establish a wind turbine manufacturing plant. Envision, already a major supplier to Saudi Arabia's renewable projects, would be the majority investor. This move supports the country's Vision 2030 goals.

ACWA Power, a leading regional energy developer, would benefit from localised supply chains. With 2,065 MW of wind projects across the Middle East, North Africa, and Central Asia—and a growing presence in Uzbekistan—ACWA Power is well positioned to integrate local manufacturing into its operations.

By investing in wind turbine manufacturing, Oman and Saudi Arabia are positioning themselves as regional leaders in renewable energy and industrial diversification. These developments align with broader goals to reduce dependency on fossil fuels and strengthen national economic resilience.

Figure 35: The component composition of a wind turbine

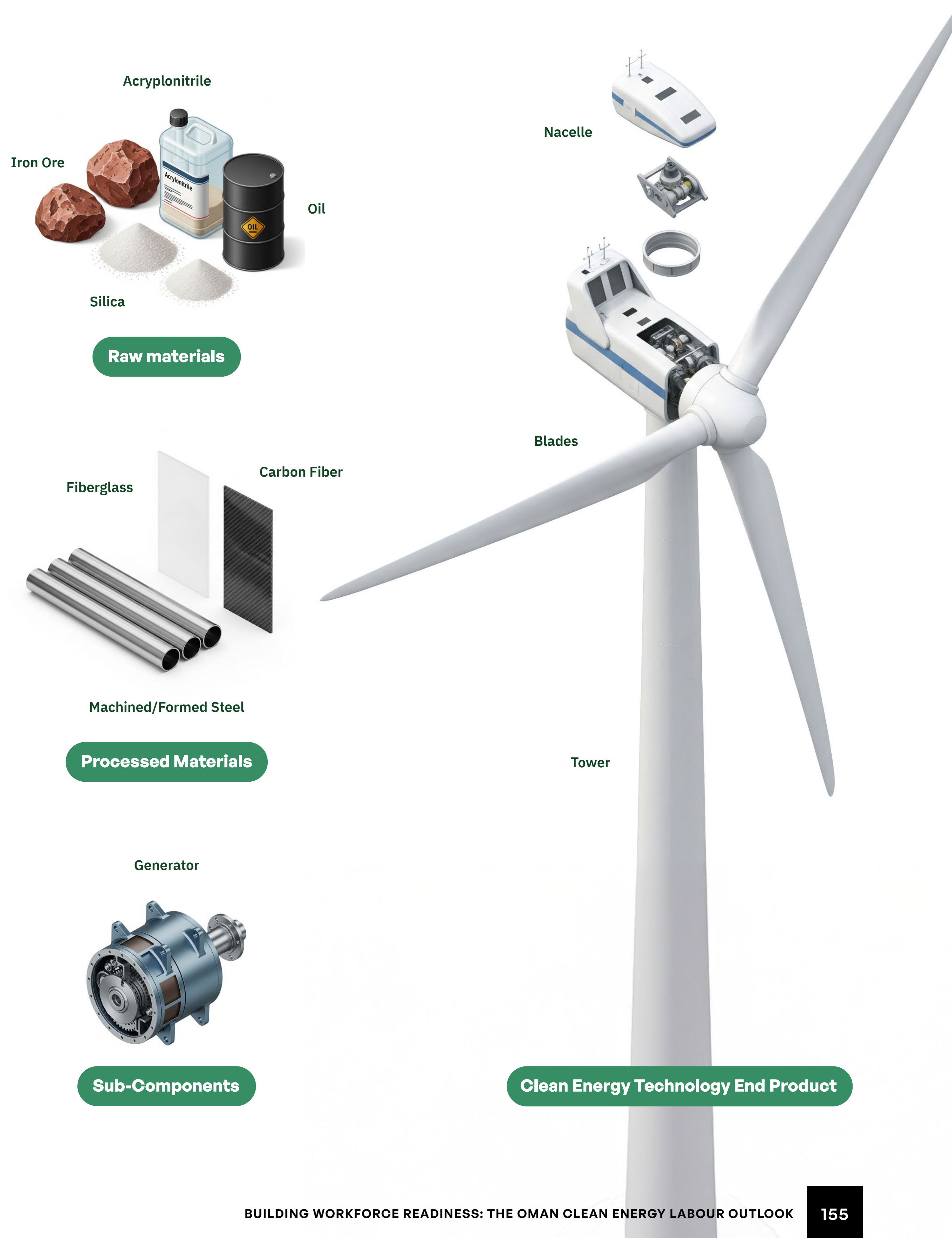
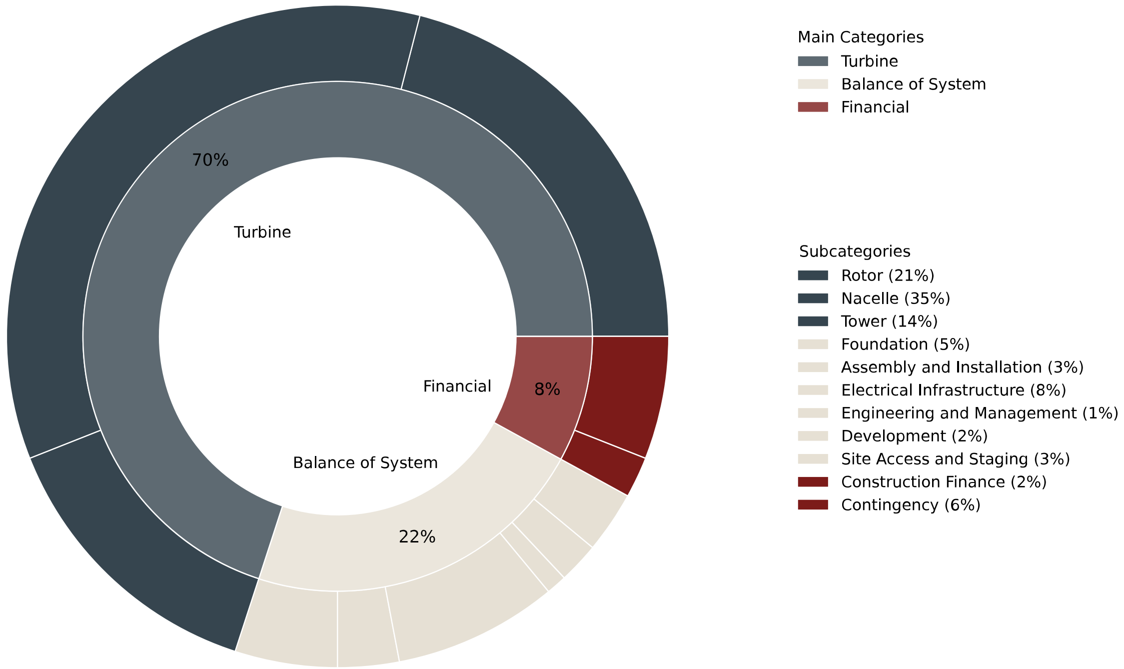
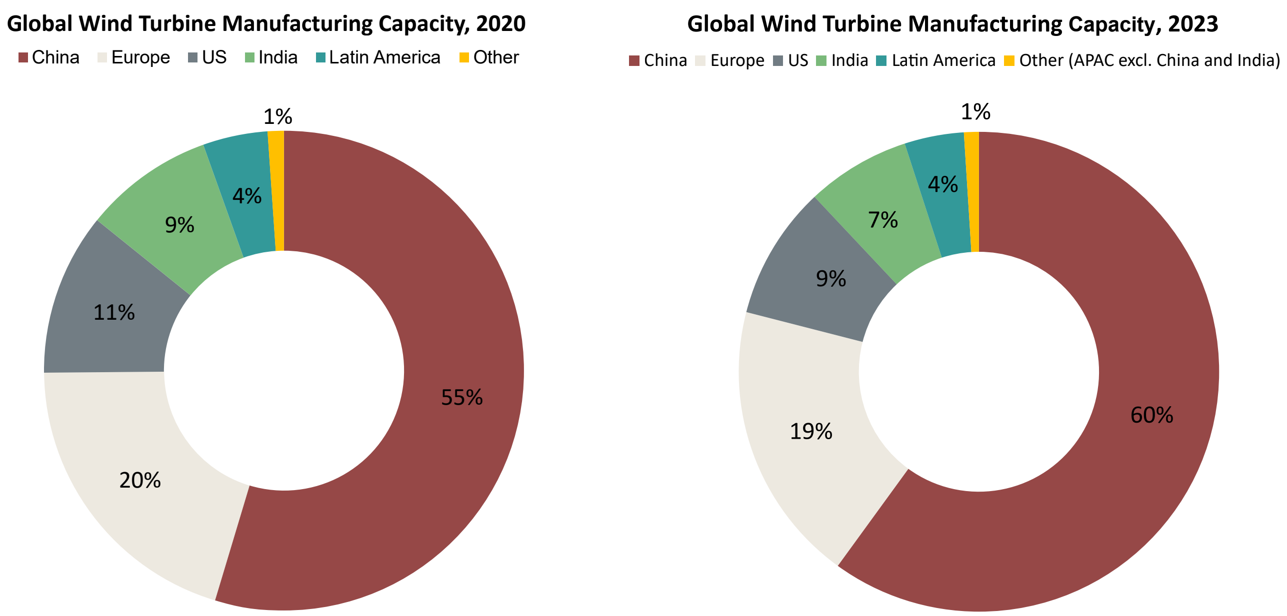


Figure 36: Capital expenditures in the reference wind power plant project



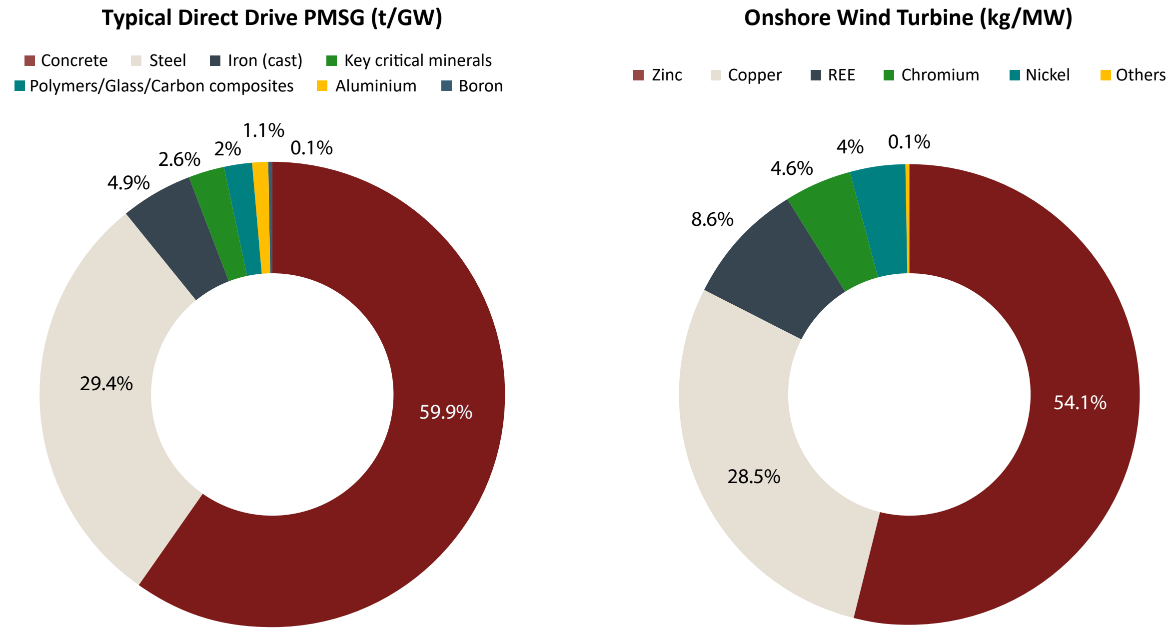
Source: Reference 13

Figure 37: Global wind turbine manufacturing capacity, 2020 and 2023



Source: Reference 69 and 79

Figure 38: Material breakdown of onshore wind turbines



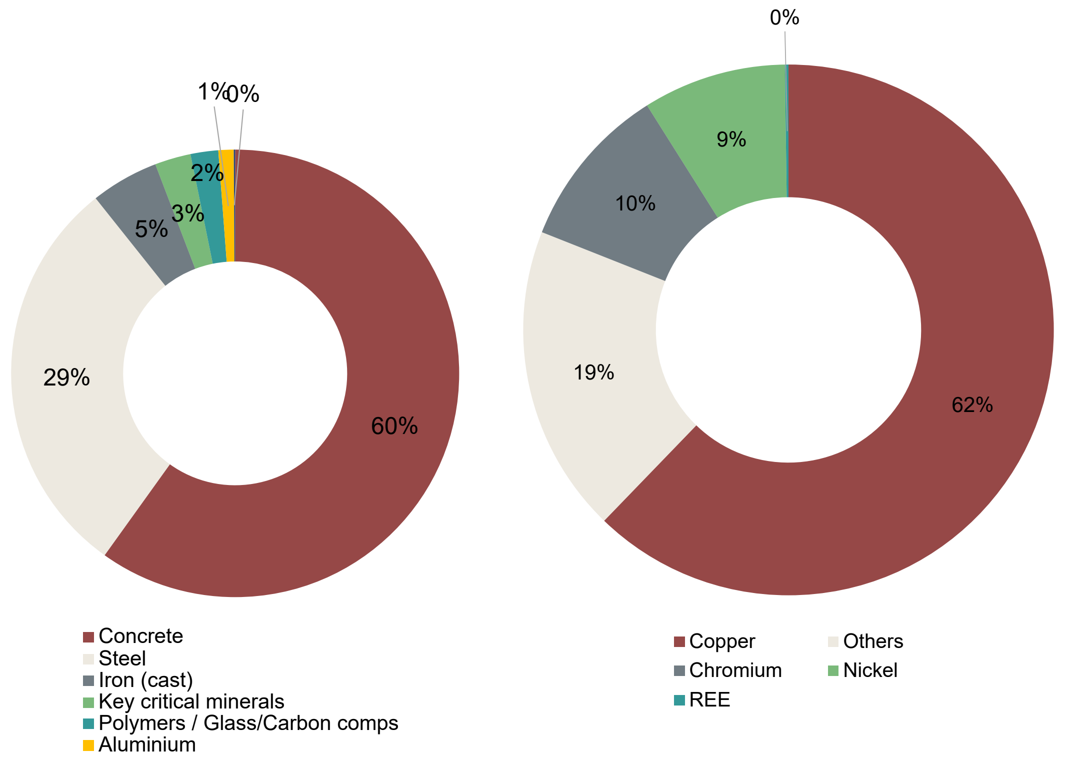
Source: Reference 39

Table 43: Wind turbine materials and components

Component	Key materials	Key minerals	Dependencies	Interdependencies with other sectors
Rotor (Blades, Hub)	Fiberglass, Carbon Fiber, Epoxy Resin	Silica sand (for fibreglass), Carbon, Petroleum (for epoxy)	Composites industry (for blade materials)	Aerospace (for composite materials), Chemical industry
Nacelle (Generator, Gearbox, Housing Main frame, Main shaft, Transformer)	Steel, Aluminium, Copper, Permanent Magnets (NdFeB), Nickel	Iron ore (for steel), Bauxite (for aluminium), Copper ore, Rare Earth Elements (Neodymium, Dysprosium), Nickel ore	Metalworking (for steel and aluminium components), Electronics and electrical engineering, Steel industry	Electronics (for magnets and copper wiring), Heavy machinery (for shafts and bearings), Electrical equipment (motors and generators)
Tower	Steel, Concrete, Aluminium	Iron ore (for steel), Limestone (for concrete), Bauxite (for aluminium)	Construction and metalworking industries	Infrastructure (high-rise buildings, bridges)
Foundation	Concrete, Reinforcement Steel	Limestone (for concrete), Iron ore (for steel)	Construction (for concrete and reinforcement)	Civil engineering (foundations for large structures)

Source: Majan Council Analysis

Figure 39: Overview of key component in the wind power supply chain



Source: Reference 37

2.5.3 Electrolyser Manufacturing

Electrolysers are a central technology for the production of low-emission hydrogen, enabling water to be split into hydrogen and oxygen using electricity—typically sourced from renewable or nuclear energy. While most hydrogen production today depends on fossil fuels, electrolysis is expected to become increasingly important for decarbonising hard-to-abate sectors such as heavy industry and long-distance transport.

Between 2021 and 2022, global electrolyser manufacturing capacity expanded by more than 25%, reaching nearly 11 GW per year. However, only 130 MW of new electrolyser capacity was installed in 2022—a 45% drop from the previous year—reflecting a temporary slowdown in deployment. Despite this dip, industry forecasts suggest a rapid scale-up in manufacturing, with cumulative installed capacity projected to reach between 170 GW and 365 GW by 2030. This anticipated growth is being driven by rising demand for clean hydrogen, greater policy support, and strategic efforts to localise supply chains.[15]

Electrolyser systems rely on the production of key components such as electrod es, membranes, and power electronics (Figure 40). These technologies are critical to enabling cost-effective hydrogen deployment across industrial and energy sectors. Manufacturing capacity is expected to increase significantly as more countries invest in domestic production to strengthen energy security and reduce reliance on imports.

As of 2022, electrolyser manufacturing remains highly concentrated in China and Europe, which together account for approximately two-thirds of global capacity. China leads the sector with 40% of global manufacturing capacity. It is also a major exporter of clean energy technologies and controls a dominant share of related manufacturing in solar PV, wind, and batteries. Its installed electrolyser capacity reached approximately 220 MW in 2022, with an additional 750 MW under construction. In Europe, member states installed 80 MW of capacity in 2022—more than double the previous year. Supportive policy frameworks, such as the EUR 5.4 billion Hy2Tech initiative, are helping to drive local manufacturing and innovation. The United States, through the Inflation Reduction Act (IRA), has introduced incentives that have already triggered new investment in domestic electrolyser production.

Looking ahead to 2030, the global manufacturing landscape is expected to diversify. While China and Europe may each retain around 25% of global capacity, new facilities are emerging in other regions. The Middle East is projected to hold over 1% of global electrolyser manufacturing capacity by 2030, and Australia—with a factory under construction—is expected to account for around 2%.

As global interest in electrolysis rises, the choice of electrolyser technology becomes increasingly strategic. The most commercially mature option, Alkaline Electrolysis (AE), is widely adopted due to its reliability and relatively low cost. Proton Exchange Membrane (PEM) electrolysis offers advantages in flexibility and current density, though it relies on more expensive materials such as iridium and platinum. Anion Exchange Membrane (AEM) electrolysis, a hybrid of AE and PEM, is still emerging but shows potential for improved performance and lower costs. Solid Oxide Electrolysis (SOE), which operates at high temperatures, remains under development but offers potential integration benefits with industrial heat processes. Each technology pathway brings unique manufacturing and deployment requirements, underlining the need for targeted investment in materials, engineering, and workforce development to scale production effectively.

Electrolyser manufacturing involves a sequence of highly specialised stages spanning several industrial sectors. These stages include raw material sourcing, sub-component fabrication, assembly, and final integration into fully functional systems. This value chain intersects with multiple industries, including precision engineering, chemical processing, and power electronics.

The process begins with sourcing critical materials such as iridium, platinum, titanium, stainless steel, and plastics like polypropylene and PE100. These are essential to key system components such as electrodes and gas-handling equipment, with metals like iridium and platinum particularly vital for PEM electrolysers due to their catalytic properties (Figure 40). Supporting electrical and auxiliary components are depicted in Figure 41.

Following material procurement, sub-components are manufactured to precise specifications. This includes stack elements such as anodes, cathodes, electrolytes, and bipolar plates, as well as supporting infrastructure like hydrogen and oxygen separation vessels, pumps, and water purification units. These sub-systems must be engineered to match the demands of different electrolyser types, and often involve complex processes such as membrane fabrication and metal surface treatment (Table 44).

In the assembly phase, these components are combined to create a working electrolyser unit. This step requires interdisciplinary coordination to align mechanical systems, fluid handling infrastructure, cooling systems, and control hardware. A critical focus is placed on ensuring robust and leak-proof integration of hydrogen and oxygen pathways.

The final stage of the value chain involves the full integration of the electrolyser into its operational environment. This includes establishing external connections to power supply units, water sources, and gas distribution systems. High-precision digital control systems are added to regulate temperature, flow rates, and electrical performance, ensuring stable operation across industrial applications. At this point, the electrolyser is fully operational and ready to support hydrogen production at scale.

Each step in this chain is essential to delivering safe, efficient, and durable electrolysers. Building local capacity across these functions will be critical for countries aiming to establish strategic advantages in the hydrogen economy.

Oman is strategically positioned to capitalise on the global growth of green hydrogen, given its abundant renewable resources and national hydrogen strategy. To meet its production target of 1 million tonnes by 2030—scaling up to 8.5 million tonnes by 2050—Oman will need to deploy between 95 and 100 GW of electrolyser capacity, equivalent to more than 5,000 units.

The 2030 target alone will require about 11.5 GW of electrolyser capacity, nearly matching total global manufacturing output in 2022. This creates a compelling opportunity for Oman to localise electrolyser manufacturing, reducing import dependency while building industrial capacity and employment. Early investments could unlock regional spillovers across metals, logistics, and equipment supply chains, while also fostering technology transfer and innovation.

Local manufacturing would support job creation at various skill levels, stimulate demand across adjacent sectors such as steel and electrical components, and enable the development of a broader hydrogen ecosystem. Oman's strategic location also positions it to serve emerging demand in international markets, particularly in Europe and Asia.

The country's first electrolyser manufacturing facility is being developed by Siemens Energy, marking a pivotal step towards industrial localisation. Although still at an early stage, this investment reflects growing institutional and regulatory support for green manufacturing. Establishing a domestic electrolyser industry will require coordinated action across infrastructure, workforce training, and international partnerships. However, it also offers Oman the chance to become a recognised supplier in global hydrogen value chains—aligning economic diversification with long-term energy resilience.

Electrolyser manufacturing in the GCC is still at an early stage, but countries across the region are beginning to explore opportunities aligned with their national hydrogen strategies. The UAE is leading this effort, having announced a 1 GW hydrogen electrolyser plant in partnership with John Cockerill and ADNOC. The facility, developed with Strata Manufacturing, will be the first of its kind in the Gulf and is intended to serve both domestic needs and export markets. This marks a major milestone for the region and demonstrates the UAE's ambition to become a manufacturing hub for hydrogen technologies.

In Saudi Arabia, large-scale green hydrogen initiatives such as the NEOM project point to a likely future need for domestic electrolyser manufacturing. While no current plants have been announced, localisation would align closely with Vision 2030 goals of industrial diversification and energy transformation.

Oman, with its strong hydrogen ambitions under Vision 2040 and abundant renewable resources, is also well placed to build domestic manufacturing capacity. The Siemens Energy project is a first step in this direction. Meanwhile, other GCC countries such as Kuwait, Bahrain, and Qatar have signalled interest in hydrogen but have not yet committed to electrolyser production.

The future market potential for GCC-based manufacturing is substantial. Large-scale hydrogen projects in Saudi Arabia, Oman, and the UAE will create strong domestic demand for electrolysers. In parallel, the region's proximity to key export markets in Europe and Asia offers a strategic advantage for supplying both green hydrogen and electrolyser systems. By developing local manufacturing capabilities, the GCC can reduce reliance on imports, build high-skilled employment opportunities, and secure a foothold in global clean energy value chains.

Cost competitiveness plays a central role not only in the success of Oman's localisation ambitions but also in the global feasibility of hydrogen deployment.

Capital expenditure (Capex) is a decisive factor in scaling up electrolyser manufacturing and hydrogen production worldwide. As of 2023, the cost of electrolysers typically ranges from USD 1,400/kW to USD 1,770/kW, inclusive of gas treatment, plant balancing, and EPC (engineering, procurement, and construction) costs. This cost is projected to decline substantially, reaching USD 440–500/kW by 2030—driven by economies of scale, material innovations, and increasing market competition. Between 2021 and 2030, global installed capacity is expected to rise from 0.5 GW to 134 GW, further accelerating cost reductions.

This downward trend reflects a continuation of earlier developments. Alkaline electrolysis systems saw costs fall by approximately 61% between 2003 and 2020, dropping from USD 1,340–2,190/kW to USD 350–1,660/kW. PEM electrolysers followed a similar trajectory, with costs falling by nearly 68% over the same period. However, the continued reliance on costly materials such as iridium and platinum means that PEM systems remain more expensive on average.

Operational expenditure (Opex) is similarly dominated by electricity prices, as electrolysers require 50–60 kWh of energy per kilogram of hydrogen produced. Regional differences in renewable energy tariffs directly impact competitiveness, making access to low-cost solar and wind resources a critical enabler of hydrogen affordability. Other ongoing costs include routine maintenance and component replacement, particularly for PEM units.

The overall technology outlook is promising. Cost declines are expected to continue through material substitution, design improvements, and policy incentives. Advances in AEM and SOE technologies also offer new pathways for increasing efficiency and reducing system costs. These developments will support broader deployment of green hydrogen and reinforce the need for localised electrolyser production in emerging hydrogen hubs like Oman.

As hydrogen production scales up, the demand for critical minerals will rise accordingly. Electrolysers and fuel cells will require growing quantities of nickel, platinum, iridium, zirconium, and other materials—posing challenges for global supply chains. Alkaline electrolysers rely heavily on nickel and steel, while PEM systems depend on platinum and iridium. SOECs—although less commercially mature—may require smaller volumes of these minerals but still depend on elements like lanthanum and yttrium (Figure 42).

Alkaline electrolysers, due to their low cost and commercial maturity, are widely used for large-scale projects but require over one tonne of nickel per megawatt. A single 1 GW installation could consume up to 1,000 tonnes of nickel, alongside other metals such as zirconium and cobalt. The technology avoids precious metals but remains exposed to nickel market volatility.

PEM electrolysers are compact and offer performance advantages but require around 0.3 kg of platinum and 0.7 kg of iridium per megawatt. Although efforts are underway to reduce these requirements by up to 90% in the coming decade, global supply constraints and competing clean technology demands heighten the risk of shortages.

SOECs present a potentially more resource-efficient option, requiring less nickel per MW and offering integration benefits with high-temperature industrial systems. Currently, each megawatt of SOEC capacity uses approximately 150–200 kg of nickel, 40 kg of zirconium, and 20 kg of lanthanum. These figures could decline significantly with future technological advances, although widespread commercialisation remains limited.

The scalability, cost, and sustainability of hydrogen technologies will increasingly depend on securing reliable access to these critical materials. Diversifying supply chains, improving material efficiency, and investing in recycling and substitution will be essential to ensure that mineral constraints do not impede the growth of the hydrogen economy.

Figure 40: Core components of a hydrogen electrolyser unit.

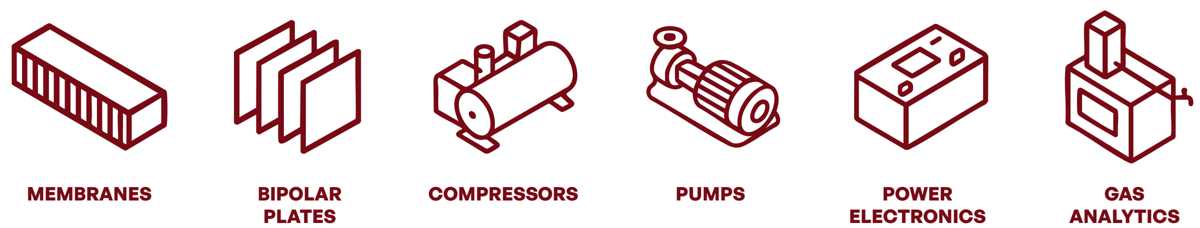


Figure 41: Overview of key equipment and units in hydrogen electrolysis

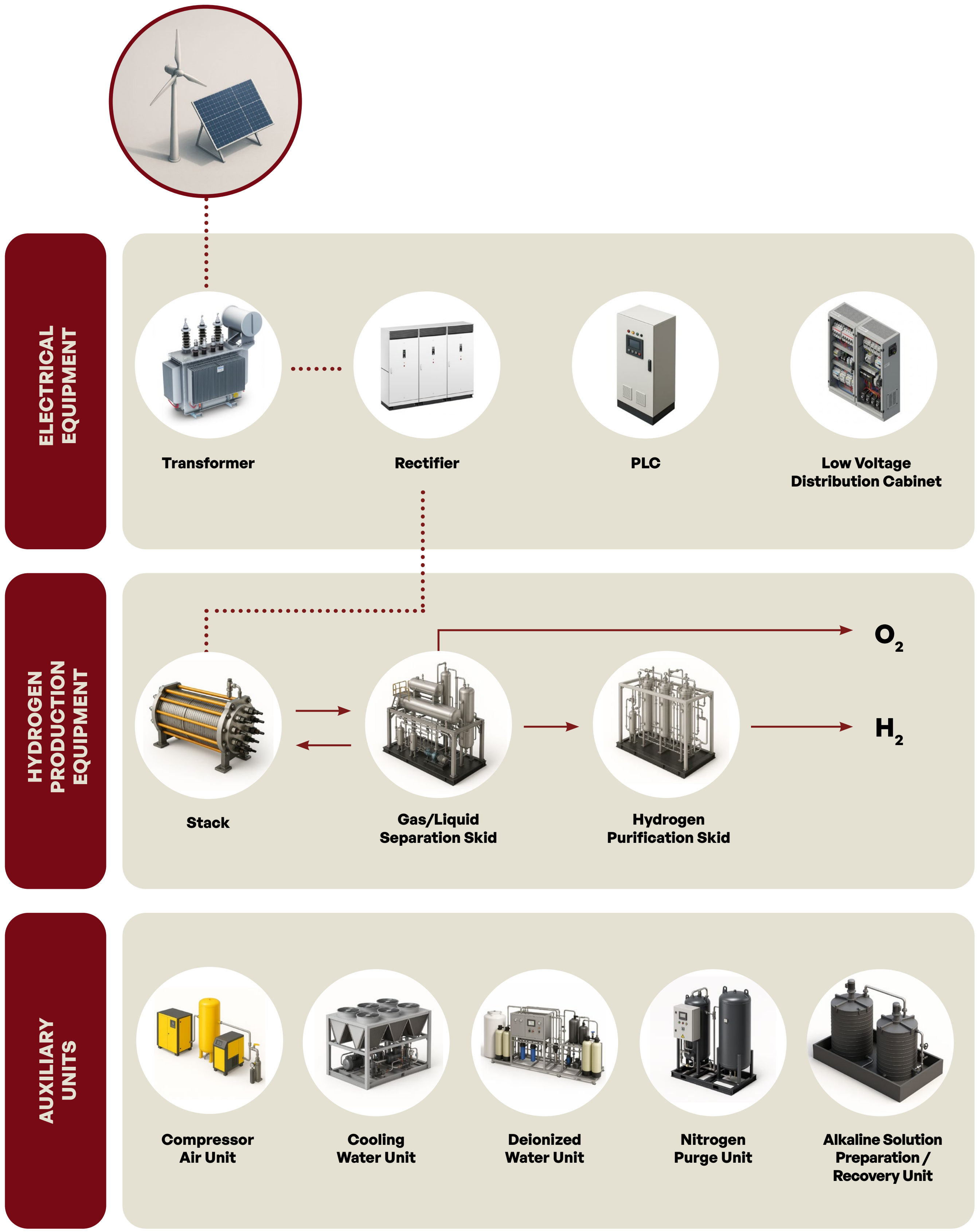


Table 44: Key elements of PEMFC and PEMEC supply chains

Raw Materials	Processed Materials	Subcomponents	End Product
	Perfluorosulfonic acid (PFSA) - Nafion	Electrolyte Membrane	PEM Fuel Cell and PEM Electrolyser cell Stack
	Sulfonated polyether ether ketone (s-PEEK)		
	Polystyrene sulfonic acid (PSSA)		
PGM (Pt)	Pt or Pt alloys	Cathode Catalyst	
PGM (Ir)	Ir or Ir alloys	Anode Catalyst	
Graphite (C)	Carbon metal oxides, carbides, etc. (PEMFC)	Catalyst Support	
Graphite (C)	Graphite composites	Gas Diffusion Layer	
Titanium (Ti)	Ti mesh/foil		
Chromium, Nickel	Stainless steel metallic		
Chromium, Nickel	Stainless steel (Ti-coated for PEMEC)	Bipolar Plates	
Graphite (C)	Carbon fiber		
Chromium, Nickel	Stainless steel	End Plates	
Aluminum	Aluminum		
	Thermoplastic	Seal	
	Elastomer - Silicone, Viton or EPDM		

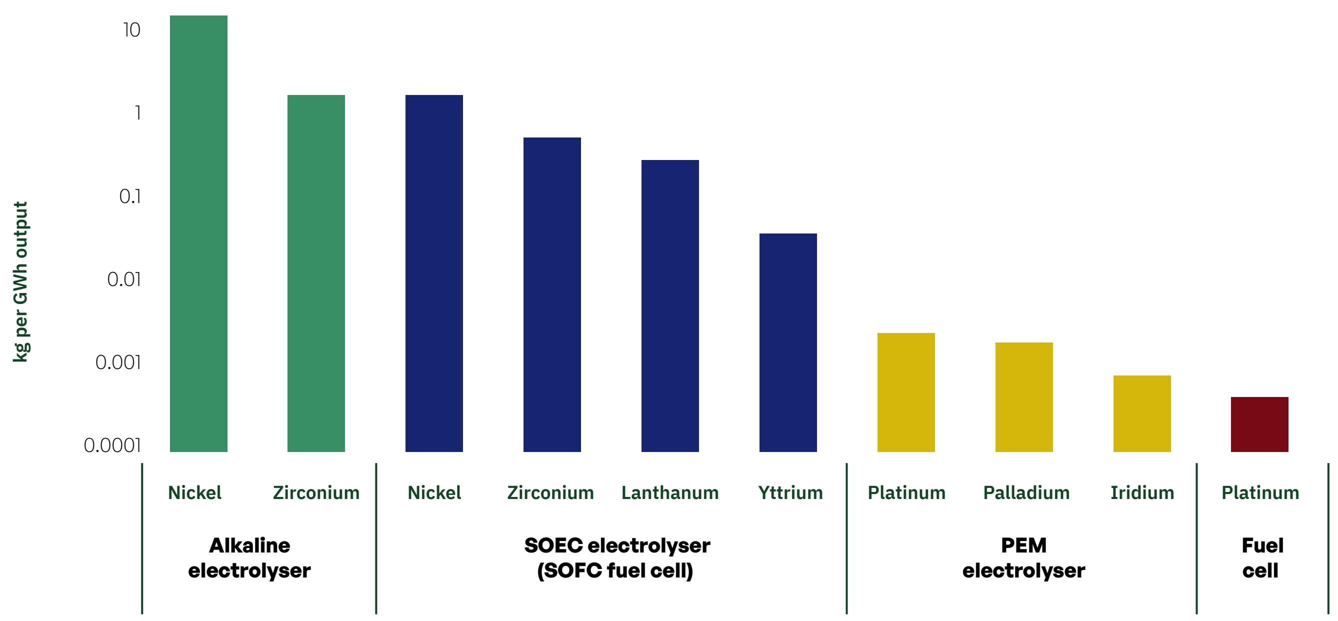
Source: U.S Department of Energy. (2022)

Table 45: Performance indicators for different electrolysers

Year	Technology	Cell Pressure [bara]	Efficiency (system) [kWh/KgH$_2$]	Lifetime [thousand hours]	Capital Costs for Large Stacks (>1MW) [US$/kW$_e$]	Capital Cost for Entire System (>10MW) [US$/kW$_e$]
2020	Alkaline	< 30	50-78	60	270	500-1000
	PEM	< 70	50-83	50-80	400	700-1400
	AEM	< 35	57-69	> 5	-	-
	SOEC	< 10	45-55	< 20	> 2000	-
2050	Alkaline	> 70	< 45	100	< 100	< 200
	PEM	> 70	< 45	100-120	< 100	< 200
	AEM	> 70	< 45	100	< 100	< 200
	SOEC	> 20	< 40	80	< 200	< 300

Source: Reference 20

Figure 42: Estimated levelised demand for selected minerals in Electrolysers and fuel cells today



Notes: PEM = proton exchange membrane; SOEC = solid oxide electrolysis cells; SOFC = solid oxide fuel cell. Normalisation by output accounts for varying efficiencies of different electrolysis technologies. Full load hours of electrolysers assumed to be 5 000 hours per year.

Source: Reference 43

2.6 FINAL PRODUCTS

Essential industries such as steel, aluminium, and cement hold significant potential for industrial development and job creation in Oman. While these sectors are not new, and Oman already has a degree of production capacity and infrastructure in place, they are being given new strategic importance due to the global shift towards decarbonisation. Clean or green variants of these materials—produced using hydrogen, renewable electricity, or carbon capture technologies—are becoming essential for countries aiming to meet climate targets while retaining industrial competitiveness.

The importance of clean industrial goods is growing rapidly, particularly in light of international regulatory developments such as carbon border taxes. Instruments like the EU's Carbon Border Adjustment Mechanism (CBAM) are expected to penalise imports with high embedded emissions, thereby shaping future demand and trade flows in materials like cement, steel, and aluminium. Producers located in energy-efficient economies with access to affordable renewable electricity—such as Oman—may be able to supply these goods more competitively than many of their global peers.

Even if large-scale export markets are not realised immediately, domestic demand within Oman will be significant. Realising the country's hydrogen development targets will require substantial volumes of steel for pipeline networks and wind turbine towers, aluminium for solar panel frames, and cement for foundational infrastructure. In this sense, decarbonising these inputs is not only an export opportunity but also a domestic necessity to support clean energy deployment and meet national net-zero goals.

Table 46 shows how much concrete, steel, and aluminium would be necessary to manufacture the solar PV and wind generation capacities required for Oman's hydrogen development targets. It highlights the substantial raw material demand stemming from projected clean energy deployment and underscores the opportunity to develop specialised supply chains to meet these needs domestically.

Investing in domestic production of these materials not only reduces exposure to global supply chain risks but also offers a pathway to modernise Oman's heavy industry around low-carbon technologies. As clean energy deployment scales up, demand for low-emissions steel, aluminium, and cement will grow—both domestically and internationally. By upgrading existing facilities and aligning them with emerging standards for green production, Oman can position itself at the forefront of low-carbon industrial development in the region.

Table 46: Estimated raw material demand for domestic solar PV and wind turbine production for 2040 hydrogen targets

	Concrete, (m^3/MW)	Steel, (t/MW)	Aluminium, (t/MW)
Solar PV	1,098,900	4,095,900	399,600
Wind	4,745,250	2,997,000	24,975

Source: Majan Council analysis

2.6.1 Clean Cement

Cement is a foundational material for infrastructure development and civil engineering, valued for its affordability, ease of use, and mechanical strength. Its production, however, is energy-intensive and a major source of greenhouse gas emissions. The cement industry accounts for approximately 8% of annual global manmade CO2 emissions due to both the combustion of fossil fuels and the release of carbon dioxide during the clinker process. Global cement production is expected to rise by 12–23% by 2050, intensifying the challenge of decarbonisation.

The cement production process involves several key stages, including quarrying, raw mix grinding, preheating and pre-calcining, clinker production, and cement grinding. Figure 43illustrates these stages. The sector's decarbonisation requires a portfolio of strategies: improving energy efficiency, reducing the clinker-to-cement ratio, shifting to less carbon-intensive fuels, and implementing carbon capture and storage (CCS) technologies.

Three primary decarbonisation routes are currently under consideration:

- **On-site Carbon Capture, Utilisation and Storage (CCUS):** CCS infrastructure is among the most advanced options (TRL 6–9) for reducing cement-related emissions. CO2 is released inherently during the production of clinker, making capture essential. [16]
- **Hydrogen-fuelled kilns:** Kilns are the most energy-intensive components of cement production, with flame temperatures exceeding 1,800ºC.115 Replacing fossil fuels with clean hydrogen could reduce emissions, though most hydrogen kiln projects are still in early stages of development. Clean hydrogen is not yet generally accessible or cost-competitive, and energy storage needs must be taken into account to overcome intermittency. In the near term, increasing the use of biomass in the fuel mix can reduce energy emissions while near-zero technologies advance to commercial scale. [17]
- **Clean power kiln electrification:** Electrification, where feasible, can reduce emissions if powered by clean electricity. While currently limited by technology maturity and cost (TRL 5–6), the shift from coal and gas to renewables for heat and electricity is a critical net-zero pathway. Power-to-heat solutions could reduce chemical sector CO2 emissions by one-fifth.

In terms of market status, global cement production capacity reached 530 million metric tonnes per year in 2024. This is projected to rise to 8.2 billion tonnes by 2030, driven by infrastructure growth worldwide. The World Cement Association projects this to increase significantly. The construction of new cement plants is capital-intensive, with costs ranging from US$100 to US$170 million per million tonnes of annual capacity, depending on location, labour, and environmental requirements. For example, the Sherabad plant in Uzbekistan cost over US$210 million for a 1.5 Mt/year capacity.[18]

Meeting decarbonisation targets will require significant investment. Capital expenditure on CCUS-ready cement plants is projected at US$750–900 billion through 2050, equivalent to approximately US$30 billion annually. Additional infrastructure investments may include up to US$240 billion for CCS integration and US$60 billion for electrified kilns.

The cement value chain consists of six main stages (Figure 43):

1. **Quarrying and raw material preparation:** Limestone, clay, and other materials are extracted, blended, and crushed.
2. **Raw mix grinding:** The materials are milled into fine powder to enhance chemical reactions in subsequent stages.
3. **Preheating and pre-calcining:** Heat from kiln gases removes moisture and initiates decomposition of carbonates.
4. **Clinker production:** The raw mix is processed at high temperatures in rotary kilns, forming clinker nodules.
5. **Cement grinding:** Clinker is combined with gypsum and ground to a fine powder.
6. **Storage and packaging:** The final product is stored in silos and dispatched either in bulk or in bags.

In Oman, the cement industry has played a key role in supporting urban development over the past five decades. The country hosts five operational cement plants: Al Madina Cement Company, Dhofar Cement Company, Oman Cement Company, Sohar Cement Company, and Raysut Cement. Oman Cement operates the largest plant with an annual capacity of 4.2 million metric tonnes. Raysut Cement runs one integrated plant (3.0 Mt/year) and one grinding plant (1.7 Mt/year).

In 2023, Oman Cement reported sales of US$189 million, up 4% from US$181 million in 2022. While green cement is not yet traded domestically, developments are underway. An Omani client has commissioned a Spanish engineering firm to establish a low-carbon cement plant. Further, the Middle East's first low-carbon cement facility is planned in Oman, based on IPIAC's LC3 technology, which aims to reduce carbon emissions by approximately 40%.

Across the GCC, the cement industry continues to grow, supported by infrastructure projects and modernisation efforts. However, overcapacity and cost pressures are driving a shift towards greater efficiency and environmental performance.

In Saudi Arabia, the largest producer in the region, installed capacity stands at 72.4 Mt/year, led by Southern Province Cement's 15.7 Mt/year capacity across three plants. The UAE hosts 17 plants with a total annual capacity of 39.8 Mt, although domestic utilisation remains around 50%, with the rest exported. In Qatar, the industry is led by Qatar National Cement Company with 8.6 Mt/year capacity, while Al Khalij Cement and Al Jabor Cement provide additional capacity of 5.0 Mt/year and 0.9 Mt/year respectively.

Bahrain remains heavily reliant on imports, with a total domestic capacity of just 1.2 Mt/year from Falcon Cement and Star Cement. Kuwait's cement capacity was boosted by the completion of a new clinkerisation unit in 2009, bringing total annual production capacity to 3.8 Mt and operational capacity to more than 5 Mt.

Despite challenges such as overcapacity, fluctuating demand, and rising production costs, the GCC cement sector is expected to develop sustainably. Green cement production and sustainability-focused investments are anticipated to shape the future trajectory of the industry. Table 47 illustrates production levels in 2019 and future projections for key GCC producers.

Decarbonising the cement sector will require both innovation and coordinated investment. The integration of low-carbon technologies into each stage of the value chain—especially in clinker production and kiln operation—will be central to meeting global climate targets while maintaining the sector's critical role in infrastructure development.

Figure 43: Stylised overview of key steps in the cement manufacturing process

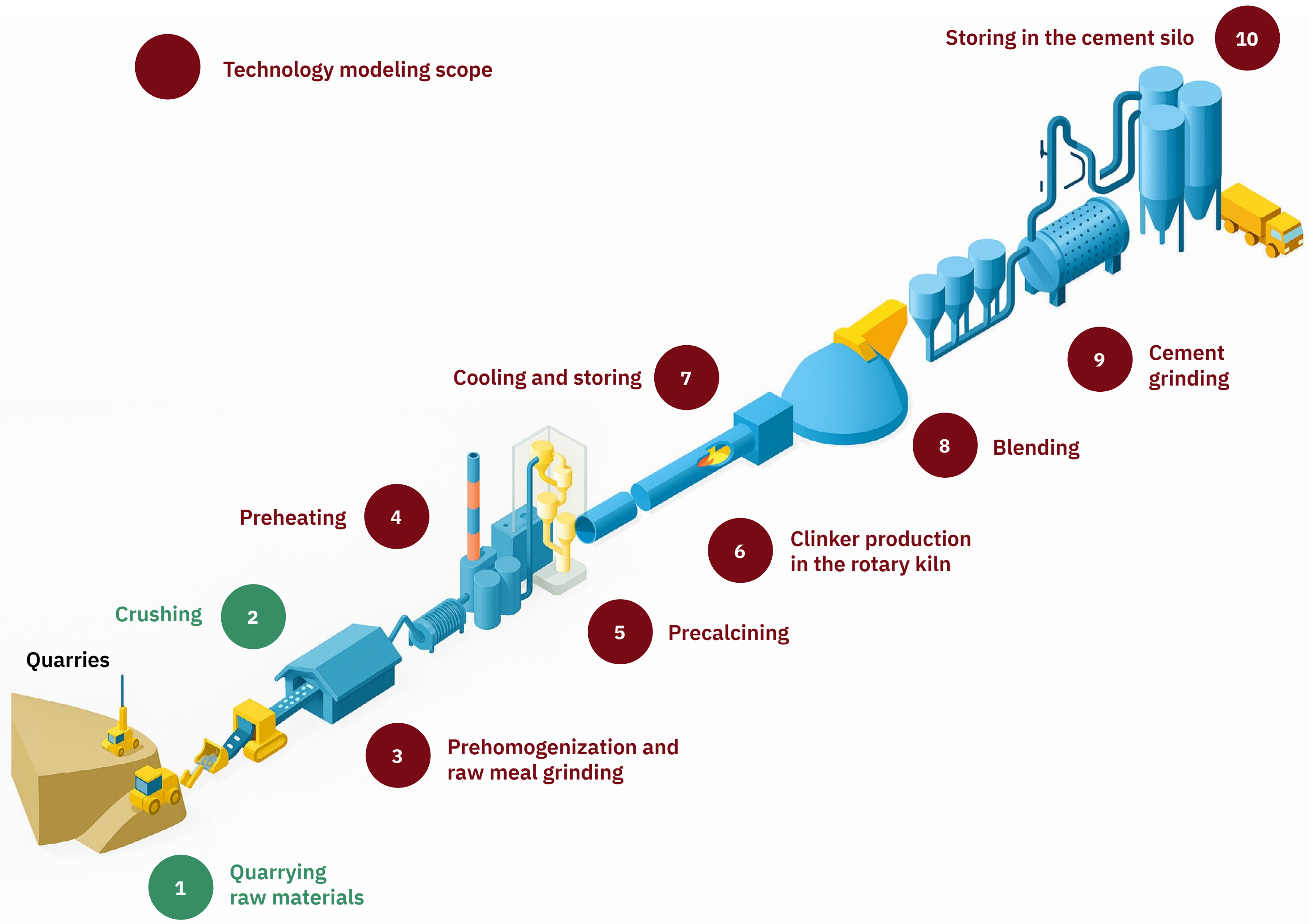


Table 47: Cement capacity in GCC countries in 2019

	Cement capacity (TMT)	Future projections
SAUDI ARABIA	44,341	Projected to reach 88 million tonnes per year by 2028.
OMAN	5,200	Targeting 15,000 tonnes per day in future capacity.
KUWAIT	3,500	Cement production is expected to grow significantly, supported by the development of 250,000 housing units over the next decade.
BAHRAIN	1,760	Projected to grow at an annual rate of 4.4% through 2030.
QATAR	4,500	As of 2023, production stands at approximately 16 million tonnes per year, with increases expected to meet demand from ongoing and upcoming construction projects.
UAE	16,400	Despite being a leading cement producer in the region, oversupply has limited expansion opportunities for smaller producers.

Source: United States Geological Survey

2.6.2 Clean Steel & Aluminium

Steel and aluminium are two of the most emissions-intensive industrial sectors globally, together accounting for a significant share of global energy consumption and carbon dioxide emissions. In 2017, the combined production of steel, aluminium, and cement contributed to around 13% of all direct CO2 emissions and 12% odispensable for applications in power infrastructure, mobility, and buildings. Yet, aluminium production is highly energy-intensive, contributing to about 2% of global man-made emissions, primarily due to its electrochemical production process. The decarbonisation of steel and aluminium is considered both essential and possible.19

In steelmaking, two dominant routes exist: the blast furnace-basic oxygen furnace (BF-BOF) and the electric arc furnace (EAF) (Figure 44). The BF-BOF pathway accounts for about 70% of global steel production and is the more emissions-intensive of the two, as it relies heavily on coal. Iron ore is smelted in a blast furnace to produce pig iron, which is then refined into steel in a basic oxygen furnace. The EAF method, often used for secondary steelmaking, processes recycled scrap metal using electricity.

Given the carbon intensity of the BF-BOF route, a range of mitigation technologies is being explored. These include hydrogen-based direct reduced iron (H2-DRI), electrification, carbon capture, utilisation and storage (CCUS), and waste heat recovery. While some technologies are commercially mature, others remain at pilot or early commercialisation stage.20

Hydrogen-based direct reduced iron (H2-DRI) is among the most promising low-emission options. By using green hydrogen instead of fossil fuels, emissions can be reduced by up to 95% in the DRI-EAF route. In contrast, using hydrogen in the blast furnace route only reduces emissions by about 21%. Additional alternatives, such as e-methane, biochar, or natural gas, can also play a role.

Electrification of steelmaking involves powering key stages of the production process using renewable electricity instead of fossil fuels. Although this approach remains in the early stages of development, it holds considerable promise, particularly when combined with the EAF route and supported by clean power infrastructure.

Carbon capture, utilisation, and storage (CCUS) offers a path to significantly reduce emissions from existing steel facilities (Figure 45). CO2 can be captured from process streams, compressed, and either used in industrial applications or stored in geological formations such as saline aquifers or depleted oil and gas reservoirs. In some cases, CO2 is transported by pipeline, ship, or truck. Captured carbon may also be used to produce building materials, chemicals, and fuels.

Waste heat recovery improves the efficiency of steel production by capturing and reusing excess thermal energy from processes such as smelting and rolling. This not only conserves energy but also reduces emissions by lowering fuel consumption.

Aluminium production follows a multistage process that begins with refining bauxite into alumina through the Bayer process, followed by aluminium smelting via the Hall-Héroult process. This is then followed by casting and fabrication, where semi-finished aluminium products are shaped into sheets, plates, foils, or extrusions (Figure 46).

The aluminium sector has three main pathways for reducing emissions:

» **Clean power for smelting:** Aluminium production is heavily reliant on electricity, especially in the smelting phase. Using renewable energy sources—particularly hydro and geothermal power—can dramatically reduce emissions. Currently, hydropower already accounts for roughly 30–35% of global aluminium output. To accelerate this trend, clean energy integration must be accompanied by carbon capture, utilisation, and storage (CCUS) solutions at scale.

» **Secondary production:** Recycling used aluminium into secondary aluminium consumes far less energy than primary production and can reduce emissions by up to 25% annually by 2050. Enhancements in scrap sorting, purification, and remelting technologies will be crucial to maximising the efficiency and quality of recycled aluminium.

» **Low-emission refining and smelting technologies:** Decarbonising aluminium production in the medium term will depend on advancing low-emission smelting solutions. Inert anode technologies, which eliminate process emissions during smelting, are expected to become commercially viable after 2030. Meanwhile, CCUS applications in aluminium production are still at the demonstration phase and not yet deployed at utility scale.

In terms of market status, global crude steel production reached 165.1 million tonnes in May 2024, while total aluminium production stood at 6.2 million tonnes as of July 2024. In today's world more than half the world's aluminium is produced in China.21

Meeting decarbonisation targets for both sectors will require substantial capital investment. The steel industry is projected to require US$372 billion by 2050, with 60% directed toward upgrading existing assets. The aluminium sector will need over US$200 billion to integrate low-emission technologies such as inert anodes and clean energy-powered smelting.

The steel value chain begins with mining and proceeds through ironmaking, steelmaking, ladle refining, casting, rolling, and finishing (Figure 61). Mining involves extraction of raw materials such as iron ore, limestone, and coke. Iron-making is performed using blast furnaces or direct reduction methods. Steelmaking typically uses either basic oxygen furnaces (BOFs) or electric arc furnaces (EAFs), with ladle refining enabling metallurgical adjustments. Casting then forms semi-finished products, which are shaped into final forms through rolling and finishing processes.

The aluminium value chain encompasses bauxite mining, alumina refining, aluminium smelting, primary casting, and fabrication. The upstream phase covers raw material extraction and processing; the midstream includes smelting and casting; and the downstream includes fabrication and end-use. Table 49 summarises key stages and processes across the aluminium sector.

Oman's steel sector has begun to expand steadily, supported by its contributions to infrastructure, construction, and economic diversification. Jindal Shadeed is the country's sole integrated steel plant, operating since 2010 with a capacity of 1.4 million tonnes per year. Additional iron production facilities include Vale and Sohar Steel. A major new project by Vulcan Green Steel, part of Jindal Group, is set to add 5 million tonnes of green steel production capacity by 2027. Located in Duqm and powered by green hydrogen, the plant is expected to emit 85% less CO2 than current global averages. Figure 47 shows Oman's role among other countries with announced low-carbon DRI capacity by 2030.

In aluminium, Oman's primary producer is Sohar Aluminium, established in 2004 with a capacity of 390,000 tonnes. The company is co-owned by TAQA, Rio Tinto, and OQ Group. In partnership with Oman Aluminium Processing Industries (OAPIL), Sohar Aluminium is exploring low-carbon aluminium production through recycling and renewable energy. Future ambitions include reaching 1 million tonnes of green aluminium annually.

Across the GCC, steel production capacity is expanding, with Saudi Arabia, UAE, and Oman investing in hydrogen-compatible mills. Saudi Arabia plans three new steel plants over the next decade, targeting an additional 6.2 million tonnes of capacity. A MoU between Tasnee and POSCO also outlines plans for a new mill in Saudi Arabia's eastern region. UAE's Emirates Steel Arkan, in collaboration with TAQA and Vale, is developing low-carbon steel at the KEZAD industrial hub. Vale has also signed MoUs with the National Industrial Development Centre (KSA), and Oman's Ministry of Commerce, Industry, and Investment Promotion to explore industrial hubs for low-carbon steel.

In aluminium, GCC production represented 8.9% of global output in 2022. The region houses six major aluminium smelters, including EGA (UAE), Alba (Bahrain), Qatalum (Qatar), Ma'aden (Saudi Arabia), and Sohar Aluminium (Oman). UAE leads in aluminium capacity and innovation, having developed solar-powered aluminium and signed a major supply deal with BMW for low-carbon metal. Table 49 and Table 50 summarise regional steel and aluminium capacities. Table 51 lists the GCC's top five aluminium producers.

The regional aluminium sector also integrates upstream and midstream capabilities. Ma'aden operates a bauxite mine in Saudi Arabia, while EGA runs a mine in Guinea. The region has notable expertise in conductor wire and extrusions. Around 40% of production is consumed regionally, with the remainder exported. Demand is expected to increase in line with infrastructure and manufacturing growth, especially in automotive and clean energy sectors.

China dominates global output for both materials. Over the past two decades, global crude steel production has doubled, with approximately 75% of that growth occurring in China. In the aluminium sector, China's output rose from 7.5 million tonnes in 2005 to 37 million tonnes in 2020, making it the source of more than half of global production.

Steel is the most widely used industrial metal and is considered essential for a green economy due to its recyclability. However, the steel sector alone is responsible for roughly 7% of global CO2 emissions. Aluminium, the second most-used metal worldwide, is prized for its corrosion resistance and low density, making it indispensable for modern infrastructure and low-carbon technologies. However, its energy-intensive production methods remain a key challenge. Advancing low-emission pathways—whether through inert anodes, clean electricity, or expanded recycling—will be crucial for both aluminium and steel to serve as enablers of a decarbonised industrial future.
As Oman and other GCC countries invest in clean manufacturing, these sectors hold potential not only for economic diversification, but also for regional leadership in the emerging global market for green industrial materials.

Figure 44: Steel production processes

Figure 45: Carbon capture, utilisation, and storage process

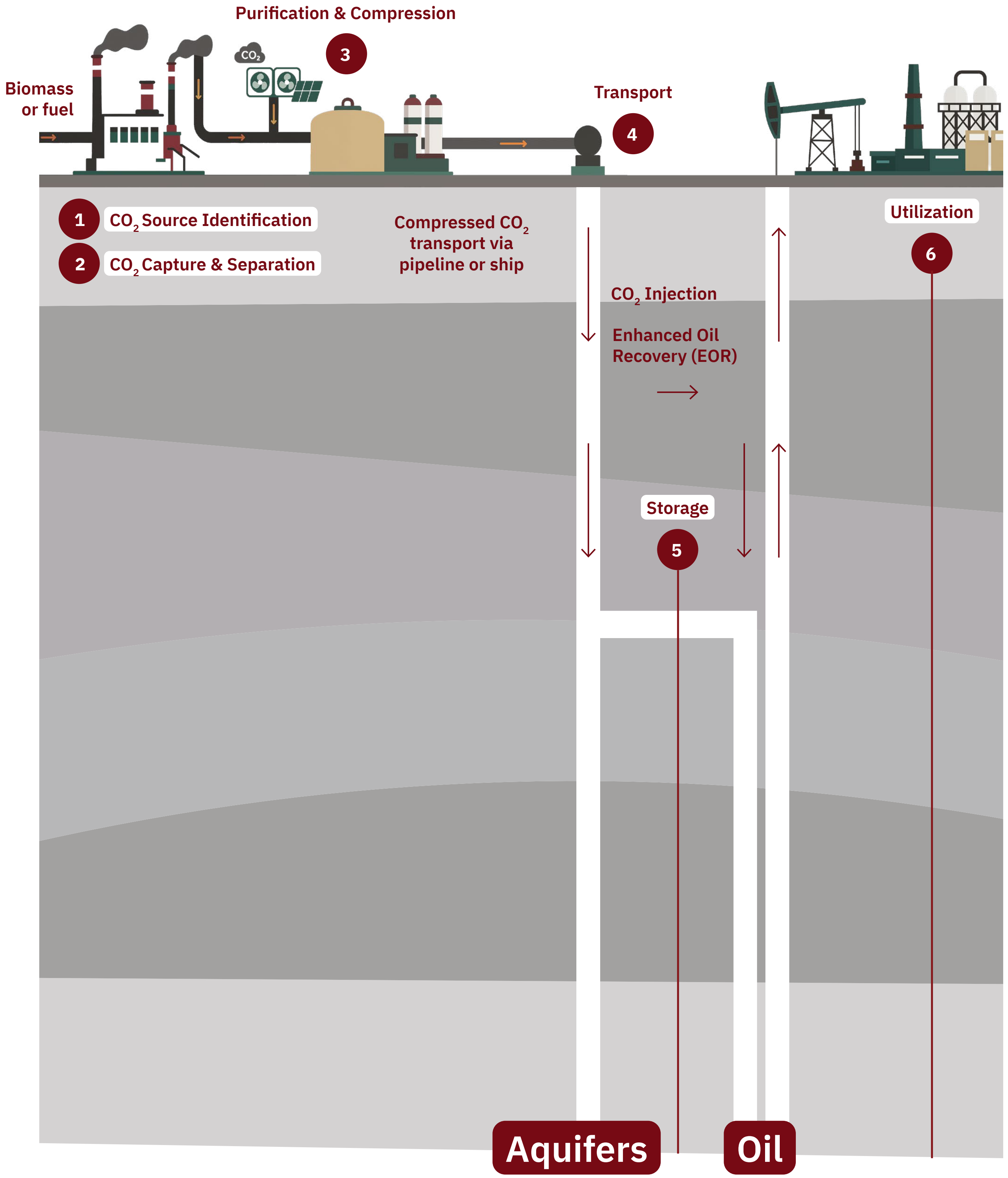


Figure 46: Aluminium production process

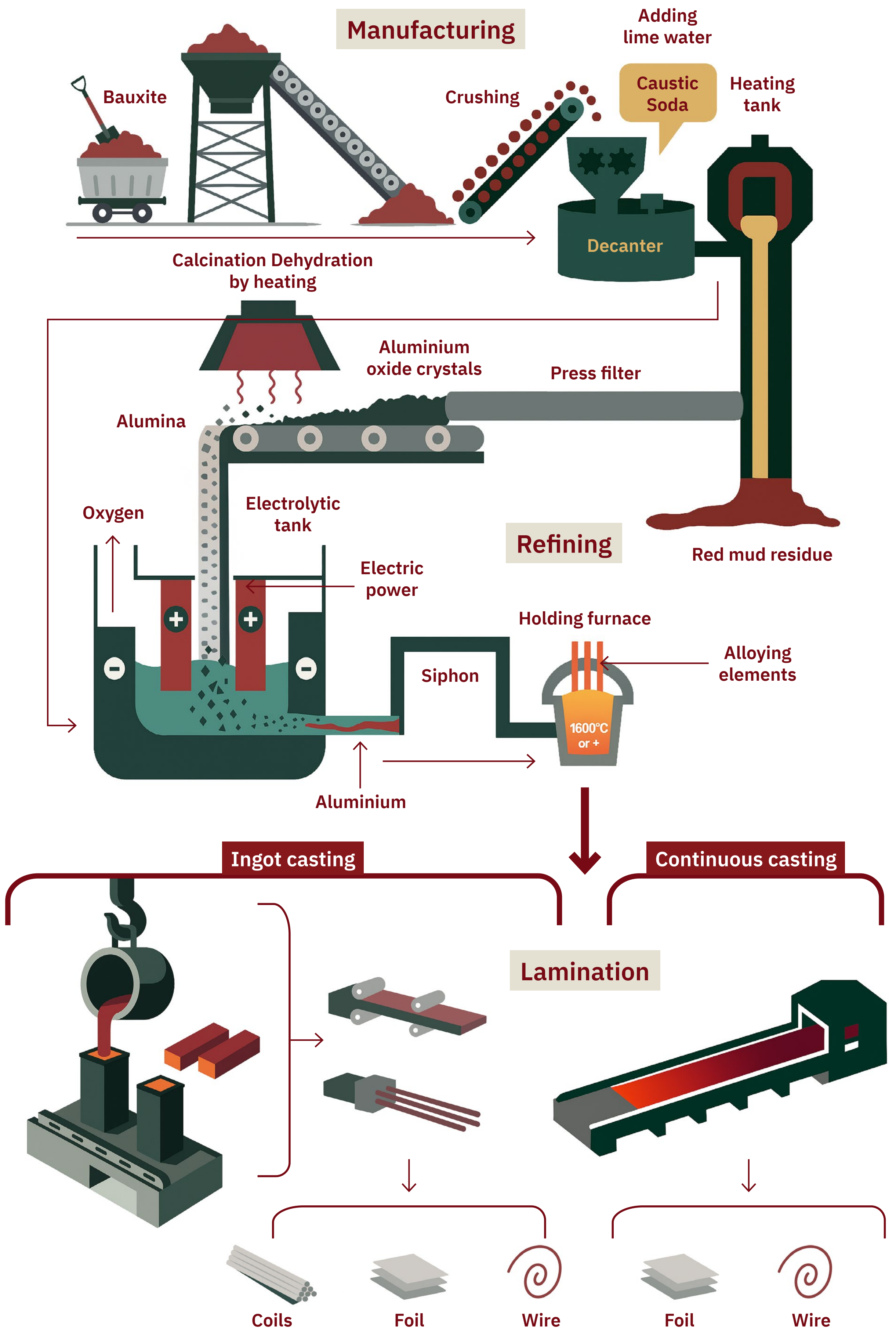
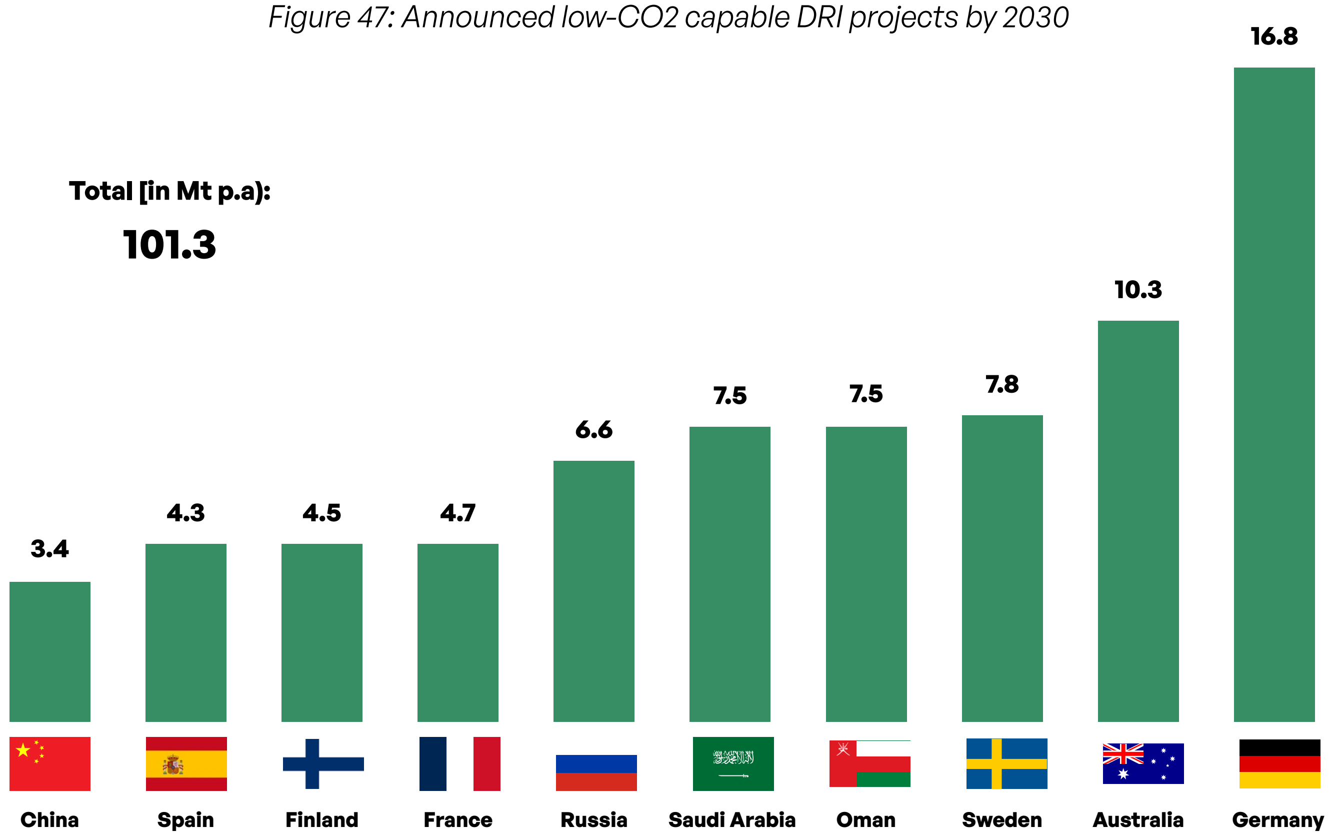


Table 48: Summary of aluminium value chain

Chain	Description
Upstream	Involves mining metallurgical bauxite and refining it into alumina. These two activities are typically integrated; however, in some cases, a refinery may be located adjacent to smelting operations if operational expenditure (OPEX) costs—particularly logistics—are more favourable.
Midstream	Includes the smelting of primary and secondary aluminium. Molten aluminium is fed into an integrated cast house to produce billets, slabs, and/or ingots. Some smelters can supply molten aluminium directly to atomizing plants for granule feedstock used in aluminium powder production. A recent trend involves the use of specialized vehicles to deliver molten aluminium to foundries, reducing energy costs associated with re-melting solid ingots.
Downstream	Involves the production of semi-fabricated aluminium products (semis) and their application in end-use sectors such as transportation, electrical, construction, and packaging industries.

Source: Reference 90

Figure 47: Announced low-CO2 capable DRI projects by 2030



Source: Agora Industry

Table 49: Current steelmaking capacity in GCC countries 2024

Country	Steelmaking capacity 2024 (thousand tonnes per annum)	Future Projects (MTPA)
SAUDI ARABIA	12,330	21.43 (2028)
OMAN	4,300	15.5 (2027)
KUWAIT	1,200	-
BAHRAIN	1,100	-
QATAR	2,575	6.4 (2028)
UAE	4,000	13 (2028)

Source: Global Energy Monitor, Glasgow Research & Consulting, Oman Observer, Arab Iron and Steel Union, Gulf Industry

Table 50: Aluminium capacity in GCC countries by 2019

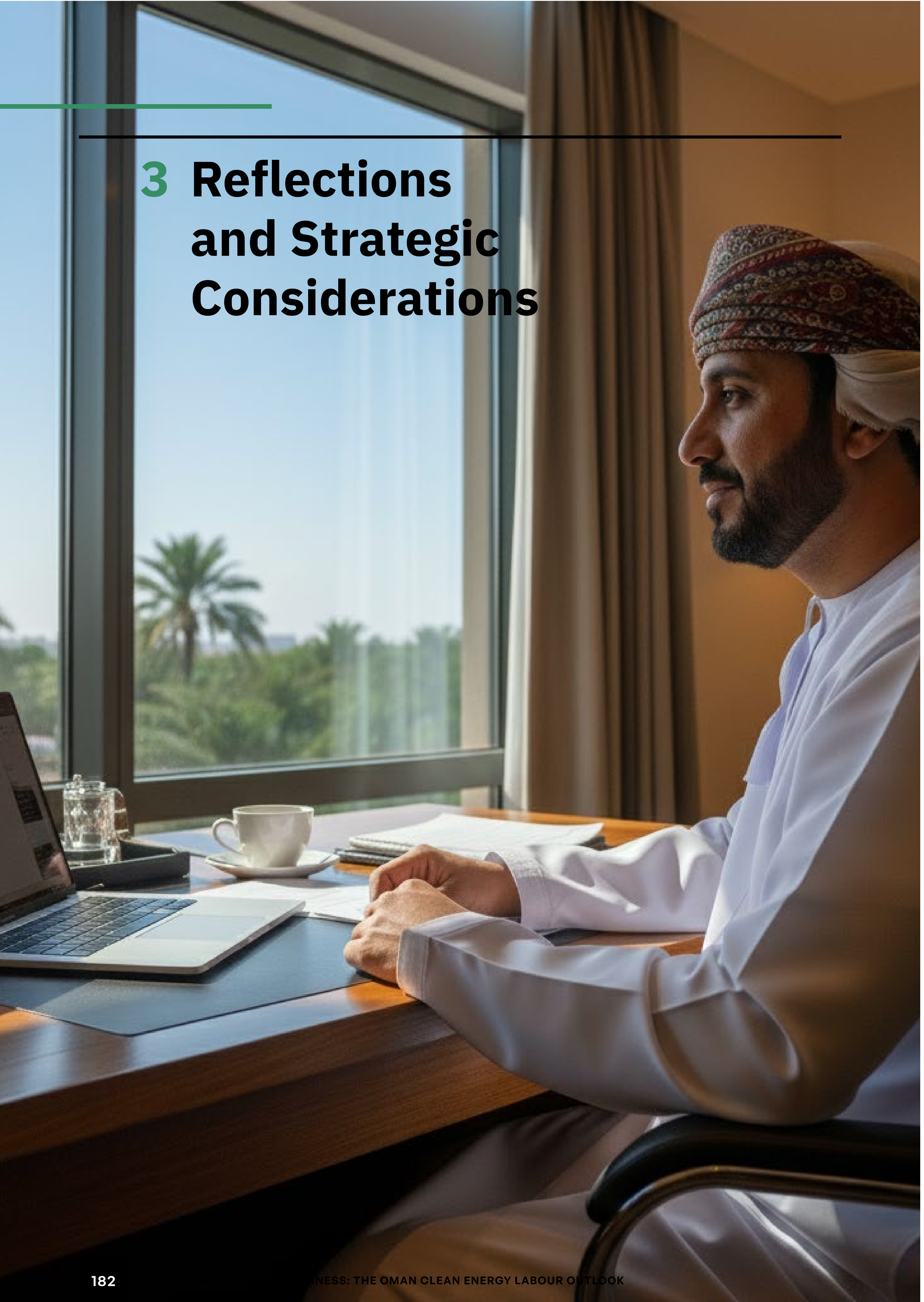
Country	Upstream	Midstream	Downstream	Aluminium capacity 2019 (Thousand metric tons)
SAUDI ARABIA	Al Baitha Mine	Al Baitha Mine	Extrusions, Can Stock, Automotive Sheets	780
OMAN	None	SOHAR Smelter	Foil Stock, Construction Sheet	391
KUWAIT	None	Arabian Light Metals Co. K.S.C	Extrusions, Conductor Wire	15
BAHRAIN	None	ALBA Smelter	Extrusions, Conductor Wire	1,365
QATAR	None	QAMCO Smelter	Extrusions, Conductor Wire	627
UAE	Republic of Guinea	Taweelah Smelter, Jebel Ali Smelter	Extrusions, Conductor Wire	2,570

Source: United States Geological Survey

Table 51: Aluminium projects in GCC countries

Company	Company Overview and Related Data	Country
Alba	Alba began operations in 1971 with annual capacity of just 120,000 mtpa as the first aluminium smelter in the Middle East, and the first non-oil industry established in Bahrain.	BAHRAIN
EGA	Emirates Global Aluminium (EGA) in UAE is the top primary aluminium producer in GCC and it is also among the five largest aluminium producers in the world. EGA's consists of Dubai Aluminium ("DUBAL") and Emirates Aluminium ("EMAL") – whose combined production is 2.4 million tpy. DUBAL's Jebel Ali operation comprises a 1 million tpa smelter, a 2,350 MW power station and other facilities. EMAL's Al Taweelah operation comprises a 1.3 million tpa smelter, a 3,100 MW power station and other facilities – is the world's largest single-site primary aluminium producer.	UAE
Qatalum	Qatalum is a JV between Qatar Petroleum and Hydro Aluminium of Norway and produces about 640,000 tons of high-quality primary aluminium products per annum. Qatalum's complex facilities include a carbon plant, port and storage facilities, as well as a captive power plant.	QATAR
Sohar aluminium	Sohar Aluminium was formed in September 2004 to undertake a landmark Greenfield aluminium smelter project in the Sultanate of Oman and is jointly owned by Oman Oil Company, Abu Dhabi National Energy Company PJSC - TAQA and Rio Tinto Alcan. The smelter has an annual production capacity of 375,000 tonnes of high-quality Aluminium.	OMAN
Maaden	Saudi Arabia houses Ma'aden Aluminium (MA), a joint venture between the Saudi Arabian Mining Company (Ma'aden) and Alcoa that started operations in 2014. The US$10.8b project is expected to be the largest and most efficient integrated aluminium complex in the world once it is completed. MA's facilities include a bauxite mine, an alumina refinery, aluminium smelter, can sheet rolling mill and an automotive mill. The current capacity of aluminium is 740,000 mtpy.	SAUDI ARABIA

Source: United States Geological Survey



3 Reflections and Strategic Considerations

Oman's clean economy presents not only a technological and environmental transition but also a structural economic opportunity—especially in terms of employment, industrial diversification, and skills development. This report has aimed to provide a detailed and data-driven account of the labour market dimensions underpinning this transition. By integrating national employment modelling with sectoral deep dives, the analysis helps to illuminate both the quantitative employment potential and the qualitative transformations required in workforce systems.

The study clearly shows that the green economy holds potential for meaningful employment generation across a range of sectors. However, this potential is more moderate than sometimes anticipated. Clean energy, in particular, is capital intensive and creates relatively fewer long-term jobs than labour-intensive sectors. A large share of employment is concentrated in construction and installation phases, where the Omanisation rate is currently low and likely to remain limited without targeted intervention. Operational roles—though more suitable for long-term localisation—are fewer in number and require specific skill sets.

While the green economy may not independently resolve Oman's employment challenges, it nonetheless represents an important pillar in the country's future economic structure. Even a modest number of high-quality, skilled jobs—if strategically enabled—can have a catalytic effect, especially when embedded in broader industrial development and workforce planning.

To realise this employment potential, however, a carefully orchestrated policy approach is required. Opportunities will not automatically translate into local employment unless decisive steps are taken to ensure both that jobs are created and that Omanis are prepared to take them. This requires action on multiple fronts.

First, clarity and commitment at the strategic level are essential. Investors, developers, and other actors need visibility and certainty regarding the pace and scope of green economy expansion in order to align their planning. Without a clearly signalled commitment—particularly regarding major projects and infrastructure decisions—education institutions and workforce development providers cannot adapt their programmes in time. Experts cannot credibly move forward unless the direction of travel is clear.

Second, timing and sequencing matter. Workforce development needs to be synchronised with project rollouts. If training precedes investment by too long a period, graduates may face delays or mismatches in employment. Conversely, if capacity is added too rapidly, the required workforce may not yet exist. The more evenly distributed and predictably sequenced investment is over time, the greater the chance for building an Omani talent pipeline capable of meeting demand.

These challenges call for more than coordination—they require close, proactive partnership between developers, future operators, educational institutions, and policymakers. Planning must extend beyond general alignment and move toward a shared roadmap that defines when and how specific job categories will emerge, and what qualifications will be required. At the same time, the process for developing and certifying new skills must be rigorous and quality-driven, yet agile enough to avoid bureaucratic bottlenecks. If workforce development becomes bogged down in excessive procedures, the risk of delays and missed Omanisation opportunities rises—prompting firms to source labour internationally.

The way forward lies in transparent, phased investment signals; clearly communicated workforce requirements; and joint responsibility between public and private actors. With such a framework in place, Oman can transform the promise of clean energy into a meaningful source of long-term employment and national economic strength.

Building a skilled, responsive, and inclusive workforce for Oman's clean economy is not a matter of isolated interventions. Rather, it requires a coherent policy environment that links investment certainty, workforce development, and institutional coordination into a shared national effort. This report has shown that while employment potential across clean sectors is real, it is also sector-specific, time-sensitive, and unevenly distributed. The broader implication is that workforce strategies must be designed with these structural dynamics in mind.

Key opportunities lie in sectors with high localisation potential, accessible skills requirements, and clear linkages to industrial policy—most notably clean manufacturing and midstream components of renewable energy systems. Realising this potential depends on timely, credible signals to both the education system and private actors. It also requires reducing institutional fragmentation by establishing mechanisms that can coordinate curricula reform, upskilling programmes, and company training practices around clearly defined industrial needs.

Furthermore, the report highlights the need to address misalignments between higher education outputs and sectoral demand. While some gaps can be addressed through new programmes, much can be achieved by adapting existing qualifications, making curricula more transparent, and enabling modular or short-cycle learning aligned to emerging occupational profiles. This is especially relevant given the oversupply of graduates in certain fields and the parallel shortage of vocational and technical skills in core industries.

Taken together, these findings underscore that employment generation in the clean economy requires careful planning and coordinated action across institutions. No single measure will suffice. Instead, a broad set of policy directions is necessary to align education, workforce development, and investment planning with sectoral trajectories. While detailed recommendations are presented in other sections, this chapter highlights the critical foundations for action: credible long-term investment signals, streamlined and responsive training frameworks, and a tighter coupling between sector development and labour market institutions. (see also the report "Bridging the Clean Sector Gap: Education, Skills, and Workforce in Oman" in this series). In this regard, and despite employment creation needing to be one of the highest national priorities, regulators should strictly refrain from ad hoc regulatory interventions in the labour market and the introduction of additional red tape, particularly with respect to certification requirements, since such measures can easily have unintended consequences, harm the wider economy, and even undermine the intended creation of employment altogether.

List of Abbreviations

Abbreviation	Definition
US$/kW	US-Dollars per kilowatt
US$/kW/year	US-Dollars per kilowatt per year
US$/kWh	US-Dollars per kilowatt-hour
US$/MW	US-Dollars per megawatt
°C	Degree Celsius
3D	Three Dimensional
AC	Air Conditioner
ADNOC	Abu Dhabi National Oil Company
AE	Alkaline Electrolysis
AEE	Association of Energy Engineers
AEM	Anion Exchange Membrane
AER	Authority for Electricity Regulation
Ag	Silver
Ag-Al	Silver Aluminium
ALOHA	Areal Locations of Hazardous Atmospheres
ANSI	American National Standards Institute
AP	Accredited Professional
APAC	Asia–Pacific
ARABRENA	Arab Renewable Energy Academy
ART	Advanced Rescue Training Standard
ARTR	Advanced Rescue Training Refresher Standard
AUS	Australia
BD+C	Building Design and Construction
BEMS	Building energy management system
BESS	Battery Energy Storage System
BF	Blast Furnace
BMS	Building Management Systems
BMW	Bayerische Motoren Werke AG
BOF	Basic Oxygen Furnace
BOSIET	Basic Offshore Safety Induction and Emergency Training
BSc	Bachelor's degree
BST	Basic Safety Training Standard
BST Refresher	Basic Safety Training Refresher Standard
BTU	British Thermal Unit
C	Graphite
C&I	Construction & Installation
CA	Chartered Accountant
CAD	Computer-Aided Design
CAGR	Compound Annual Growth Rate
CapEx	Capital Expenditures

Abbreviation	Definition
CBAM	Carbon Border Adjustment Mechanism
CCNP	Cisco Certified Network Professional
CCS	Carbon Capture and Storage
CCU	Carbon Capture and utilisation
CCUS	Carbon Capture, Utilization, and Storage
CDL	Commercial Driver's License
CEA	Certified Energy Auditor
CEAT	Certified Energy Auditor Technician
CEEM	Certified Energy Efficiency Manager
CEM	Certified Energy Manager
CEng	Chartered Engineer
CFD	Computational Fluid Dynamics
CFM	Certified Facility Manager
CG	Coal Gasification
Chemanol	Methanol Chemicals Co
CHMM	Certified Hazardous Materials Manager
CHSP	Certified Health and Safety Professional
CIH	Certified Industrial Hygienist
CIR	Component Inspection Reports
CMMS	Computerised Maintenance Management Systems
CMS	Condition Monitoring System
CMVP	Certified Measurement and Verification Professional
CO	Carbon monoxide
CO_2	Carbon dioxide
CoC	Certificate of Competency
CoHE	Control of Hazardous Energies Standard
COP28	United Nations Climate Change Conference
CPA	Certified Public Accountant
CPEng	Chartered Professional Engineer
CQE	Certified Quality Engineer
CQI	Certified Quality Inspector
CSE/M	Confined Space and Monitor and Entry
CSP	Certified Safety Professional
CTS	Clean Technology Scenario
CWE	Certified Welding Engineer
CWI	Certified Welding Inspector
DCF	Discounted Cash Flow
DCS	Distributed Control Systems
DEWA	Dubai Electricity and Water Authority
DFMEA	Design failure mode and effect analysis
DNO	Distribution Network Operator
DNP3	Distributed Network Protocol 3

Abbreviation	Definition
DRI	Direct Reduced Iron
DRT	Double Rope Technique
DUBAL	Dubai Aluminium
EAF	Electric Arc Furnace
EAS	Energy Auditing Scheme
EE	Energy Efficiency
EF	Employment Factor
E-fuels	Electrofuels
EGA	Emirates Global Aluminium
EJ	Exajoules
EMAL	Emirates Aluminium
EMS	Energy Management Systems
EPC	Engineering, Procurement, and Construction
EPDM	Ethylene Propylene Diene Monomer
EPMS	Electrical Power Management Systems
Et	Employment
ETO	Electro-Technical Officer
ETS	Emissions Trading System
EU	European Union
EVs	Electric Vehicles
FCEV	Fuel Cell Electric Vehicle
FEA	Finite element method
FID	Final Investment Decision
FIPS 199	Federal Information Processing Standard 199
FLORIS	FLOw Redirection and Induction in Steady-State
FMEA	Failure Mode and Effects Analysis
FTE	Full-Time Equivalent
FZC	United Solar Polysilicon
GCC	Gulf Cooperation Council
GD&T	Geometric Dimensioning and Tolerancing,
GDP	Gross domestic product
GHI	Global Horizontal Irradiation
GIS	Geographic Information System
GPIC	Gulf Petrochemical Company
GRIHA	Green Rating for Integrated Habitat Assessment
GSAS	Global Building Assessment System
GW	Gigawatt
GW/year	Gigawatt per year
GWEC	Global Wind Energy Council
GWO	Global Wind Organisation
H_2	Hydrogen
HAZOP	Hazard and Operability Analysis
HEMS	Home Energy Management System
HJT	Heterojunction
HMI	Human Machine Interface
HR	Human Resources
HSE	Health, Safety, and Environment

Abbreviation	Definition
HT	High Temperature
HV	High Voltage
HVAC	Heating, ventilation, and air conditioning
ICV	In-Country Value
IEA	International Energy Agency
IEEE	Institute of Electrical and Electronics Engineers
IGBC	Indian Green Building Council
IoT	Internet of Things
Ir	Iridium
IRENA	International Renewable Energy Agency
ISAP	Infrastructure Sustainability Accredited Professional
ISO	International Organization for Standardization
IT	Information Technology
JNCIP	Juniper Networks Certified Internet Professional
Jobs/MW	Number of direct jobs created per megawatt (MW) of installed capacity
JV	Joint Venture
k	Parameter calibrated to smoothen the curve's shape and mimic employment dynamics
KEZAD	Khalifa Economic Zone Abu Dhabi
kg/MW	kilograms per Megawatt
KIZAD	Khalifa Industrial Zone Abu Dhabi
km	kilometer
km^2	Square kilometre
KSA	The Kingdom of Saudi Arabia
kV	kilovolt
kWh/m^2	kilowatt-hours per square meter
L	Parameter calibrated to smoothen the curve's shape and mimic employment dynamics
LATAM	Latin America
lbs	Pounds
LC3	Low Carbon Cement
LCOE	Levelised cost of electricity
LED	Light-emitting diode
LEED	Leadership in Energy and Environmental Design
LNG	Liquified Natural Gas
LOHC	Liquid Organic Hydrogen Carrier
LOTO	Lockout/Tagout
LSPI	Liquid Simulation Pipeline Interface
LT	Low Temperature
LV	Low Voltage
m	Meter
m/s	Meter per second
m^2	Square metre
m^3/MW	Cubic meters per megawatt
MCCCO	Mobile Crane Operator certification
MD	Managing Director
MEF	Material Efficiency Variant
MENA	Middle East and North Africa

Abbreviation	Definition
MEP	Mechanical, Electrical, and Plumbing
MEPSs	Minimum Efficiency Performance Standards
MIG	Metal Inert Gas
MOL	Ministry of Labor
MS	Microsoft Office
Msc	Postgraduate degree qualification-Masters degree
MT	Metric ton
Mt	One million metric tons
Mt/year	One million metric tons per year
$MtCO_2$/year	1 million metric tons of CO_2 emitted annually
Mtpa	Million tonnes per annum
MW	Megawatt
N/A	Not Available
NdFeB	Neodymium-Iron-Boron
NEBOSH	National Examination Board in Occupational Safety and Health
NEC	National Electrical Code
NEDC	Nama Electricity Distribution Company
NREL	National Renewable Energy Laboratory
NZE	Net Zero Emissions
O&M	Operations & Maintenance
OAPIL	Oman Aluminium Processing Industries
OEM	Original equipment manufacturer
OMIFCO	Oman India Fertiliser Company SAOC
OpEx	Operating Expenses
P&D	Planning & Development
PE100	Advanced form of high-density polyethylene
PEM	Proton Exchange Membrane
PEMEC	Proton Exchange Membrane Electrolyser Cell
PEMFC	Proton Exchange Membrane Fuel Cell
PET	Polyethylene terephthalate
PFSA	Perfluorosulfonic acid
PHA	Process Hazard Analysis
PHAST	Process Hazard Analysis Software Tool)
PhD	Doctoral degree
PJM	Pennsylvania, New Jersey, and Maryland
PLC	Programmable logic controller
PM	Particulate Matter
PMP	Project Management Professional
Power BI	Power Business Intelligence
PPA	Power purchase agreement
PPE	Personal Protective Equipment
PR	Public Relations
PSCAD	Power Systems Computer Aided Design
PSP	Planning & Scheduling Professional
PSS/E	Power System Simulation for Engineering
PSSA	Polystyrene sulfonic acid

Abbreviation	Definition
Pt	Platinum
PTW	Permit to Work
PV	Photovoltaic
P-V curve	Power-Voltage curve
PWP	Oman's Nama Power & Water Procurement Company
q	Parameter calibrated to smoothen the curve's shape and mimic employment dynamics
QA	Quality Assurance
QAFAC	Qatar Fuel Additives Company Limited
Q-BOP	Quick-quiet Basic Oxygen Process
QC	Quality Control
QNCC	Qatar National Cement Company
QSTec	Qatar Solar Technologies
R&D	Research and Development
RCM	Reliability centered maintenance
RE	Renewable Energy
RFQ	Request for Quote
RWGS	Reverse Water Gas Shift
SAF	Sustainable Aviation Fuel
SATCOM	Satellite Communications
SCADA	Supervisory Control and Data Acquisition
SCMP	Supply Chain Management Professional
Sipchem	Saudi International Petrochemical Company
SMEs	Small and Medium-Sized Enterprises
SOE	Solid Oxide Electrolysis
SOEC	Solid Oxide Electrolyser Cell
SOMC	Sultanate of Oman Methanol Company
SPC	Southern Province Cement
SPC	Special Purpose Corporation
s-PEEK	Sulfonated polyether ether ketone
SRT	Single Rope Technique
STCW	Standards of Training, Certification, and Watchkeeping for Seafarers
STEPS	Stated Policies Scenario
t	Time
t/MW	Tons per Megawatt
TAFE	Technical and Further Education
TDG	Transportation of Dangerous Goods
Ti	Titanium
TMT	Thousand metric tonnes
TNA	Transmission Network Applications
tpa	Tonnes per annum
TPT	Tedlar/Polyester/Tedlar
tpy	Tonnes per year
TRL	Technology Readiness Level
TWh	Terawatt-hours
UAE	United Arab Emirates
USA	United States of America

Abbreviation	Definition
US-CA	USA California
US$	United States dollar
US$/$kW_e$	US dollars per kilowatt of electrical capacity
UTS	University of Technology Sydney
VDL	Valid Driver's License
W	Watt
WACC	Weighted Average Cost of Capital
WAsP	Wind Atlas Analysis and Application Program
WHMIS	Workplace Hazardous Materials Information System
Wind PP	Wind Power Plant
WISDEM	Wind-Plant Integrated System Design and Engineering Model
WRA	Wind Resource Assessment
WTG	Wind turbine generator
WTSR	Wind Turbine Safety Rules

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