DEVELOPING CLEAN ENERGY INDUSTRIES AND WORKFORCE

CASE STUDY INSIGHTS

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Content

Executive Summary

INSIGHTS FROM INTERNATIONAL CASE STUDIES ON DEVELOPING NEW ENERGY SECTORS—IN OMAN AND BEYOND

This report presents four distinct case studies illustrating opportunities, approaches, and challenges in developing new sectors adjacent to clean energy and the green economy. It focuses on sector trajectories, government action, and workforce empowerment. The case studies are:

GERMANY'S SOLAR INDUSTRY

Germany's solar industry initially experienced rapid growth (driven by policies supporting domestic demand), but **solar PV manufacturers later faced a wave of bankruptcies** due to the 2008 financial crisis, Chinese competition, and policy changes. While the employment and economic footprint of solar energy project development and maintenance have steadily increased over time, manufacturing has never recovered. The case highlights **the intricacies of stimulating the market**, the importance of **anticipatory and targeted industrial policy**, and the crucial role of **apprenticeships, vocational training, and strengthening general university programmes** to equip the workforce.

SAUDI ARABIA'S EV SECTOR

Saudi Arabia is making **significant public investments** to develop a homegrown battery electric vehicle (EV) industry. Manufacturing investments are complemented by infrastructure expansion and strategic partnerships, **aiming to create substantial employment** opportunities while positioning itself as a sustainability leader. The approach **subsidises both supply and demand** to establish manufacturing and offtake simultaneously, while importing knowhow through strategic investments and targeted expertise acquisition. The case illustrates the **strength of a top-down**, sovereign-wealth-fund-led approach, alongside the significant, **possibly long-term costs** it entails.

THE NETHERLANDS' WIND POWER INDUSTRY

The Netherlands has, **despite its limited size** and exposure to economically strong neighbours, **successfully developed a domestic wind power industry** encompassing manufacturing, project development, and research capacities. A mix of **supportive agreements and industrial policy** has helped expand and sustain the sector, despite emerging **technical and social challenges**. The case study highlights the importance of identifying **viable and sustainable niche sectors**, the role of leveraging knowledge and **skills from other parts of the energy industry**, and the fact that public preferences for a technology do not always translate into **social feasibility**.

MOROCCO'S EV SECTOR

Morocco's **strong automotive industry**—to a large extent, direct investments by European car producers—is rapidly **advancing towards EV production**, driven by the private sector and supported by national plans, international assistance, and Morocco's **free trade agreements**. Challenges remain regarding supply chain vulnerabilities, local demand, and the need for continuous education and training. The case study highlights the potential for a **balanced approach involving foreign direct investment, international development funds, and government coordination**; the role of favourable international agreements; and the importance of creating a **sectoral ecosystem rather than fragmented supply chain elements**.

CENTRAL LEARNINGS FOR OMAN INCLUDE:

BALANCE AMBITION WITH REALISM IN SECTOR SELECTION AND DEVELOPMENT
Carefully select sectors that have stable, intrinsic demand—both domestically and internationally—rather than relying on excessive subsidies to artificially generate markets. Sectors should ideally leverage Oman's strategic competitive edges, including its strategic geography, and historical relationships with East Africa and South Asia. Investment and industrial policy measures, including prudent use of local content requirements, should emphasise the creation of complete sectoral ecosystems rather than isolated market segments, thus generating sustainable in-country value.

ALIGN EDUCATION AND LABOUR POLICIES CLOSELY WITH INDUSTRIAL STRATEGY
Education and workforce strategies must be timed and aligned precisely with the development of new sectors. Clear anticipation of when and how sectors will emerge is necessary to effectively structure labour-market measures. A coordination platform involving government, private-sector representatives, investors, and education providers can provide central strategic guidance, while still encouraging broad participation and flexibility.

ENHANCE EDUCATIONAL PROGRAMMES THROUGH FLEXIBILITY AND RESPONSIVENESS
Universities should have the autonomy to regularly update curricula, reflecting technological and industrial developments. While accreditation and quality-assurance mechanisms remain essential, excessive rigidity can hinder timely curricular updates. A dynamic regulatory approach allows institutions to swiftly adapt curricula to emerging sectoral demands, ensuring graduates have the relevant and up-to-date skills required by industry.

PRIORITISE VOCATIONAL TRAINING AND PRACTICAL WORKFORCE DEVELOPMENT
Vocational training should be emphasised strongly, especially given the significant need for skilled technicians in clean energy and green economy sectors. Vocational programmes must combine classroom education with on-the-job apprenticeships. Initially, temporary engagement of foreign experts can help bridge skills gaps, provided their roles are clearly limited to enabling the rapid and effective development of a domestic workforce.

ENABLE RAPID WORKFORCE TRANSITIONS THROUGH REGULATORY FLEXIBILITY
Labour regulations should facilitate workforce transitions into new sectors by focusing on upskilling and reskilling. Formal qualification barriers should remain minimal, given the significant overlap in skills across various engineering, technical, and administrative roles. International examples (e.g., Germany, the Netherlands) demonstrate clearly that such flexibility can be achieved without compromising quality standards.

EMPLOY PROACTIVE RISK MANAGEMENT AND STRATEGIC FORESIGHT
Regular and proactive assessments of sectoral competitiveness and external market risks, particularly in export-focused sectors such as hydrogen, are crucial. Long-term contracts may stabilise sectors in the medium term but do not provide sufficient guarantees for short-term shocks or long-term shifts. Proactive risk management strategies and anticipatory policymaking are thus essential to maintain sectoral resilience and sustained competitiveness.

1 Introduction

Economic landscapes worldwide are undergoing significant change. Demographic shifts, technological progress, and evolving market conditions are prompting countries to reassess traditional economic models. For energy-exporting economies, there is growing recognition of the need to explore new sectors to create sustainable employment and long-term prosperity. The energy sector itself is a natural candidate for expansion, as it allows these countries to complement existing structures and leverage their expertise.

The Sultanate of Oman is actively working to expand its conventional energy industry with clean energy and green sectors. Yet, whether in developing these industries, sustaining their growth, or ensuring job creation for the domestic workforce, significant challenges arise. While initial conditions differ across countries, the core challenges remain strikingly similar. This opens the door to valuable lessons from how different nations have approached the development of clean energy and related industries.

This report, developed as part of the Oman Labour Market Intelligence Analysis project, examines the economic and employment potential of these emerging sectors within the energy industry. It provides insights drawn from both local experience and international examples, making it a resource not only for Omani policymakers but also for academics and decision-makers in other contexts.

The report is structured as an edited volume of four case studies, each offering a detailed look at how different countries have navigated the challenges of developing new energy-related sectors:

International benchmarking provides insights into how kickstart and maintain sector and workface development.

Saudi Arabia's Battery Electric Vehicle Industry: An examination of how strategic investments by the sovereign wealth fund have driven the creation of new value chains in battery and electric vehicle technology.

Morocco's Electric Vehicle Assembly Industry: A study of how Morocco has leveraged foreign direct investment and existing industrial infrastructure to successfully enter the electric vehicle assembly market.

Germany's Solar PV Industry: A review of the rapid expansion of the solar photovoltaic manufacturing sector in the early 2000s, followed by a decline in manufacturing jobs, and an eventual recovery in the downstream sector—illustrating the cyclical dynamics of industrial development.

The Netherlands' Wind Energy Industry: An analysis of the resilience of the wind energy sector, which has maintained strong business performance and stable employment despite fierce competition.

The conclusions drawn from these case studies address key questions for Oman:

- **How does a government-led (top-down) approach compare to a private-sector-led (bottom-up) approach when establishing new sectors?**
- **Which government policies or interventions are crucial for building and sustaining both industries and employment?**
- **How can skills development and education be integrated into the local workforce to support these emerging sectors?**

Using these four case studies as benchmarks for international policy action, this report derives key lessons and provides targeted policy recommendations for decision-makers in Oman. These insights align closely with Oman's Vision 2040, highlighting pathways for sustainable economic growth and sectoral expansion. While tailored to Oman, these findings offer relevant perspectives for similar contexts, contributing to the broader discourse on energy sector development and employment creation..

2 Rise, Fall... and Rise Again? The Case of Germany’s Solar (Manufacturing) Industry

SUMMARY

RAPID GROWTH AND LEGISLATIVE SUPPORT
The German solar manufacturing industry grew rapidly in the early 2000s due to favourable policies, technological innovation, existing engineering expertise, and rising public awareness. Feed-in tariffs—a component of the Renewable Energy Sources Act (EEG) of 2000—provided crucial financial incentives, stimulating demand for solar technology.

TECHNOLOGICAL ADVANCEMENTS AND MARKET BOOM
Investments in research and development enhanced solar module efficiency and reduced production costs, leading to a boom from 2005 to 2011, making Germany the largest market for solar photovoltaic (PV) systems.

IMPACT OF THE 2008 FINANCIAL CRISIS
The 2008 financial crisis, especially its effect on the Spanish solar sector, led to cancelled projects and affected German manufacturers, causing a first wave of bankruptcies and market consolidation.

CHINESE COMPETITION AND MARKET OVERSUPPLY
China’s massive subsidies and economies of scale drove down solar PV costs, leading to a global market oversupply starting in 2009. German feed-in tariffs implicitly favoured Chinese producers.

CURRENT MARKET STATUS
Despite the domestic upstream crisis, Germany leads the EU solar PV market with significant installations. In 2023, Germany’s market share was 25% of the EU total, generating substantial sales, though domestic production remains low. Only 0.6% of global solar PV module production was in Europe in 2022.

EMPLOYMENT TRENDS
Employment peaked in 2011 but declined sharply due to the industry’s collapse. Since 2018, employment has increased, particularly in the downstream sector (installation and planning), though the workforce is still smaller than in 2011.

RECENT DEVELOPMENTS
The war in Ukraine has renewed focus on the solar PV industry, leading to the 2023 Photovoltaik-Strategie and Solarpaket I, aiming to boost (again) feed-in tariffs, streamline permitting and enhance financial incentives. However, these measures may repeat past mistakes by focusing on demand-side rather than supply-side subsidies.

LESSONS LEARNED
Key lessons from the industry’s crises include minimizing policy changes, gradually adjusting subsidies and tariffs, investing in grid infrastructure and storage technologies, monitoring and diversifying supply chains, engaging in strategic industrial policy, and forming partnerships and alliances.

FUTURE OUTLOOK
The mid-term outlook for sector growth is optimistic regarding installed capacity and job creation in the downstream sector. However, despite promising technological innovations, a limited production landscape and a lack of targeted industrial policy may hinder a significant rebirth in the upstream sector.

2.1 CONTEXT AND STRUCTURAL DYNAMICS

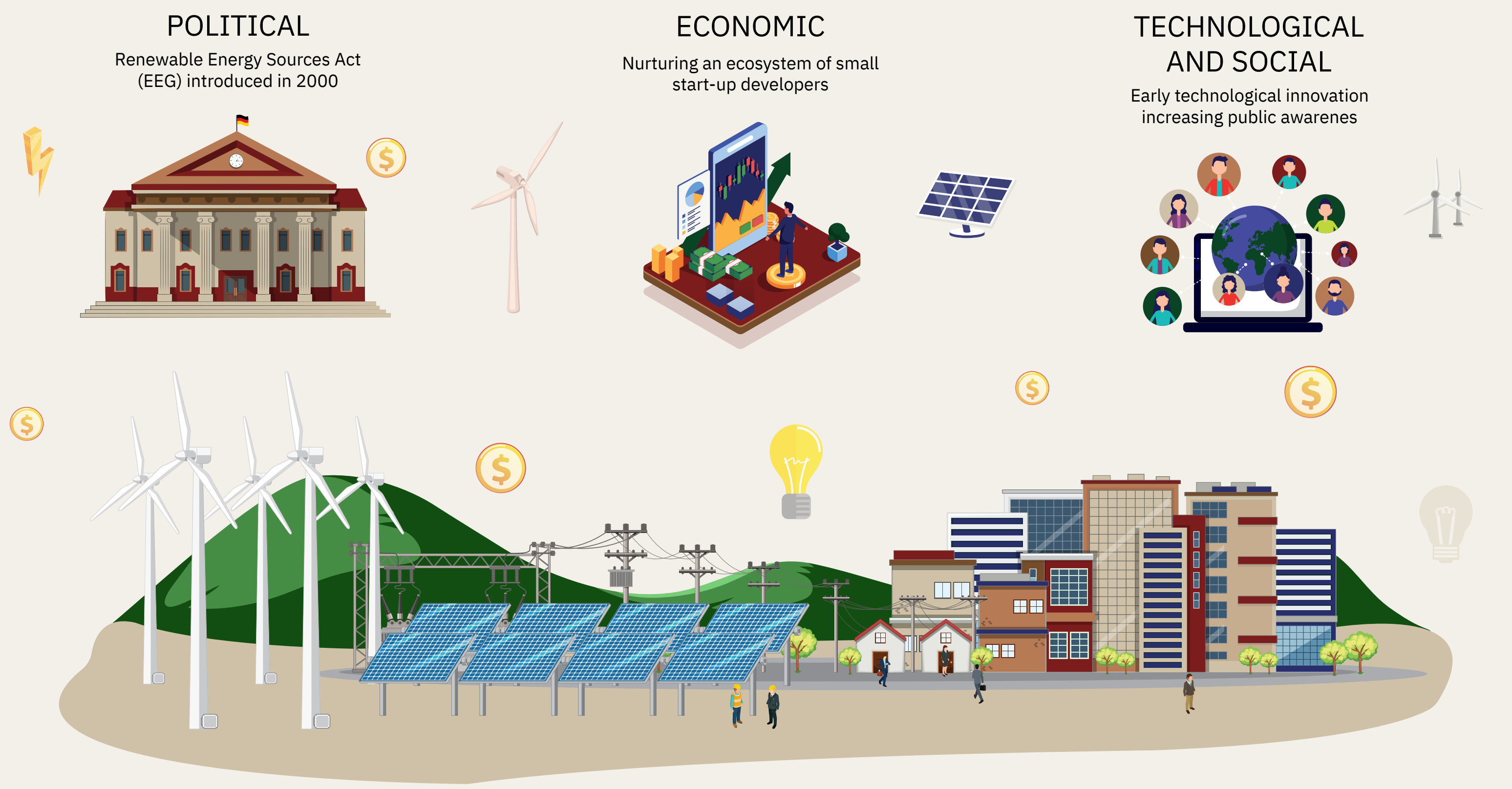
Germany, the world's third-largest economy and Europe's largest, with a GDP of US$4.27 trillion in 2023, plays a significant role in the global economic landscape[1]. Known for its robust industrial base and technological innovation, Germany focuses heavily on exports. It is committed to ambitious national decarbonisation goals, aiming for at least 80% renewable energy in the power sector by 2030, achieving a 65% emission reduction by 2035 and net-zero emissions by 2045.

The end of Russian gas supplies has caused industrial disruptions and a surge in energy prices, with it an even stronger focus on decarbonisation and renewables expansion. Competing with lower-cost Asian industries, Germany also recognises the need to (re)gain a technological edge in green technologies, like solar. Ambitions and reality still diverge, though: in 2023, 54% of Germany's electricity came from renewables, up from 46% in 2022. However, only 19% of primary energy consumption was from renewables, with oil at 36% and gas at 25%[2]. The industrial sector (28% of total final energy consumption), transport (30%), and households (29%) rely heavily on fossil fuels[3]. Plans are in place to replace these with green hydrogen and renewables[4].

Against this backdrop, there is new momentum and significant potential for further expansion of renewable energy demand, particularly for solar energy. Germany already leads the EU solar market, with 14.1 GW annual and 82.1 GW cumulative installations in 2023, accounting for 25% of the EU total. Plans for annual and cumulative installed capacity are ambitious through 2030, with an annual addition of 22 GW starting in 2026.

Despite this growth, solar PV contributed only 62.3 billion kWh to the electricity mix in 2023, compared to wind energy's 132.3 billion kWh, lignite's 86.6 billion kWh, and natural gas's 77.9 billion kWh[5]. From 2020 to 2022, the EU's solar capacity grew from 139 GW to 208 GW (22% CAGR), while Germany's grew from 54 GW to 66 GW (10% CAGR). While the German solar industry has yet to fully recover from the crisis of the early 2010s, employment in the sector has risen steadily over the past five years, in line with a steady increase in installed capacity. However, most of this employment growth has occurred in the downstream sector, highlighting a structural loss in manufacturing capacity that remains unresolved since the decline from 2008 to 2013.

The key factors and conditions that have influenced the development of clean energy in Germany fall broadly into political, economic, technological, and social aspects. Politically, the Renewable Energy Sources Act (EEG) introduced in 2000 provided financial incentives for renewable energy production through feed-in tariffs, ensuring fixed payments to renewable energy producers. With the support of favourable policies, early technological innovation, existing engineering expertise, and increasing public awareness, the German solar industry experienced rapid growth in the early 2000s, nurturing an ecosystem of small start-up developers. Furthermore, high domestic energy prices made solar energy an attractive alternative for both residential and commercial consumers—for whom not just financial incentives but also climate action were crucial. Strong public support for environmental conservation and clean energy initiatives provided a mandate for the government to pursue aggressive renewable energy policies and pushed for sustainable energy solutions and stricter environmental regulations. The number of installations and the total installed capacity of solar PV systems surged, making Germany one of the global leaders in solar energy.



2.2 SECTORAL DEVELOPMENT AND GOVERNMENT ACTION

By 2008, Germany had rapidly emerged as a leader in the solar panels manufacturing industry with significant investments in crystalline silicon photovoltaics and thin-film technologies. However, the 2008 Global Financial Crisis and European debt crisis led to reduced feed-in tariffs in key markets, causing market oversupply and bankruptcies among German solar companies. Notably, Spain's abrupt tariff cuts led to project cancellations, forcing German manufacturers to sell solar PV modules at a loss, resulting in significant job losses.

Simultaneously, China subsidized its solar panels manufacturing industry with direct supply-side subsidies, massively increasing production between 2009 and 2011. Chinese companies produced cost-effective manufacturing equipment, leading to a global oversupply and inexpensive Chinese solar PV modules flooding the (German) market[6]. This competition led many German companies to bankruptcy, closure, or acquisition. Notable bankruptcies included Solon, Solar Millennium, Scheuten Solar, Solarhybrid, Odersun, and Q-Cells.

In the 2010s, political changes in Germany further reduced feed-in tariffs (2013), pressuring the struggling sector. Foreign firms acquired companies like Q-Cells and Conergy. Despite EU tariffs on Chinese imports (imposed in 2013 but revoked in 2018), domestic production and employment in the upstream sector inexorably declined.

After a decade of scarce legislative activity regarding the solar industry, in 2022, the Ukraine war and a renewed focus on renewable energy sparked renewed interest in Germany's solar industry. However, the US Inflation Reduction Act's massive tariffs led to an influx of Chinese solar PV modules to Europe and Germany. The influx of Chinese modules and the following global price fall thwarted hopes for a revival of domestic production despite increased German demand for rooftop solar panels. Almost all German producers limited operations, shut down, or moved abroad; examples include Solarwatt planning to relocate to Asia and Meyer Burger producing in the US[7].

Summing up, by 2013, a mix of global circumstances, national policy failures, and ignored external factors sealed the fate of Germany's solar PV manufacturing industry. Germany's policies focused on subsidizing domestic demand rather than production. This effectively supported the growth of manufacturing capacities in China, which, in contrast, subsidized production and exports and came to dominate the global market. When Germany reduced subsidies in 2013, it misjudged China's impact, leading to a decline in the domestic solar PV manufacturing industry—a mistake driven by a lack of strategic industrial policy, overconfidence in technological superiority, and the unforeseen scale-up of Chinese production.

Government action played a crucial role in these developments. In 1990, federal and state governments launched the 1,000 Roofs Program, the first subsidy for private photovoltaic systems, followed by the 100,000 Roofs program in 1999. The Renewable Energy Sources Act (EEG) of 2000 promoted electricity generation from biomass, solar, water, and wind, using a feed-in tariff to guarantee a state-fixed fee for renewable electricity. Until 2010, this tariff remained around 50 cents per kilowatt hour for small photovoltaic systems, making solar PV energy competitive. In 2013, the feed-in scheme was drastically reduced at the national level. Simultaneously, the EU introduced protective tariffs against cheap solar modules from the Far East, limiting duty-free Chinese exports to the EU to 7 GW annually if priced above US$0.58 per watt.[8] No significant German solar legislation followed in these years, since wind energy gained more traction.

In the second half of the 2010s, Germany's legislation set new goals for renewable expansion, but no specific initiative to revive domestic solar PV manufacturing. The 2016 Climate Action Plan 2050 set long-term goals for greenhouse gas reduction and renewable energy expansion, aiming for 65% renewable energy in the power sector by 2030. The EEG 2017 introduced competitive bidding for renewable projects, refined in 2021 to enhance market integration and transparency. The 2018 Energy Collection Act (*Energiesammelgesetz*) adjusted regulations to meet 2030 climate targets, introducing special solar and wind energy tenders before the revised Renewable Energy Law corrected sectoral targets upwards to at least 80% renewable energy in the power sector by 2030.[9] Meanwhile, in 2018, the EU ended anti-subsidy and anti-dumping tariffs on Chinese solar PV products as import prices aligned with world market prices, and the European industry saw no benefit from reduced Chinese imports. In fact, Chinese market dominance in the years leading up to 2013 had already wiped out a large part of European and German solar production. The 2022 REPowerEU plan aimed for over 320 GW of solar PV by 2025 and nearly 600 GW by 2030.[10]

However, until the 2023 Net Zero Industry Act, there had not been an actual EU-level initiative targeting solar PV manufacturing. The Act sets a target for domestic manufacturing capacities of net-zero technologies to meet at least 40% of the EU's annual deployment needs by 2030, prioritizing solar PV projects.[11] However, the act lacks funds and financial support schemes.

For its part, Germany's 2023 ***Photovoltaik-Strategie*** aims to expand solar deployment capacity through financial incentives, better grid integration, and R&D investment. The 2024 *Solarpaket I* targets 215 GW of solar capacity by 2030 with VAT exemptions, increased feed-in tariffs, and streamlined permitting.[12,13] However, no measures to support domestic production have been introduced. Feed-in tariffs remain strongly demand-oriented.

2.3 MARKET DYNAMICS AND EMPLOYMENT IMPACT

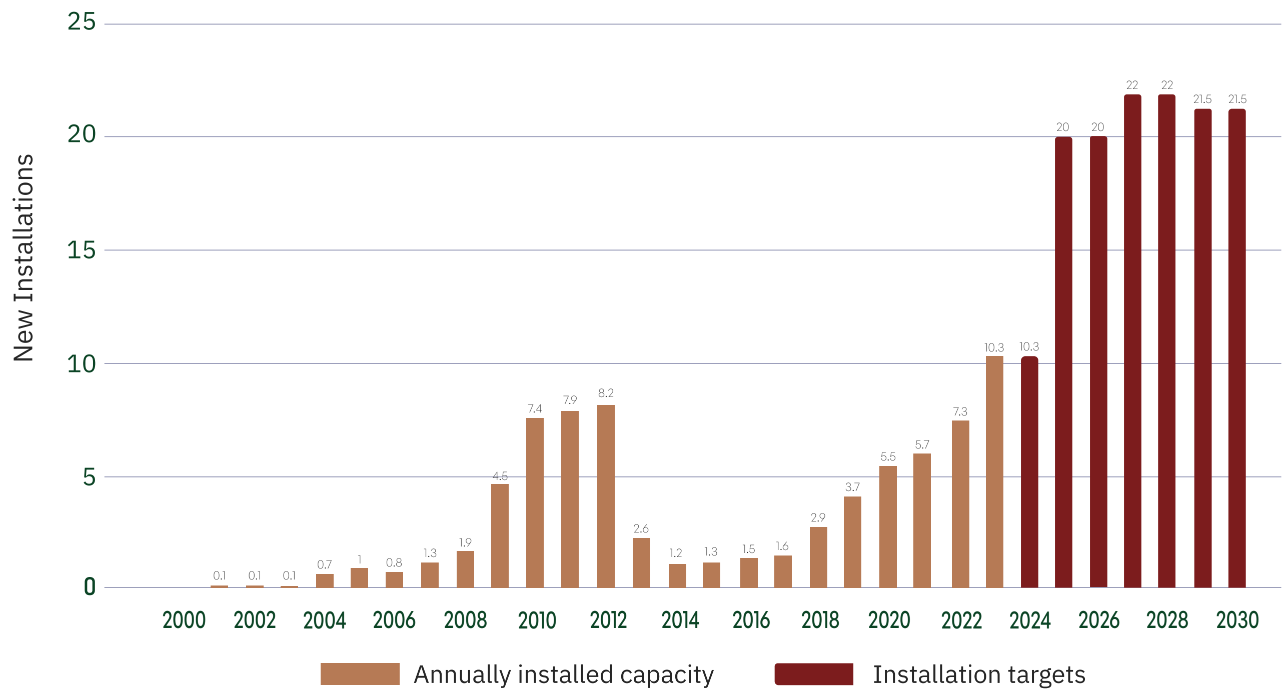


Figure 2.1: German solar PV capacity installation 2000-2022 and annualised 2030 targets[13,14]

The German solar PV market, which dropped from over 8 GW in 2012 to 1.19 GW in 2014, has been rising steadily since. In 2023, Germany added 14.1 GW of new solar installations—almost double the 2022 figure—exceeding the target of 9 GW (Figure 1). The CAGR is projected to be 18% from 2023 to 2027.[14] In 2023, the photovoltaic industry generated around US$33 billion, selling over one million solar and half a million storage systems.[15] Sales are expected to reach US$ 48 billion by 2030, a 45% increase.

Germany remains the most significant contributor to the EU solar PV fleet, with 82 GW out of 263 GW in 2023, and ranks fourth globally in PV additions, with around 15 GW added.[16] It ranks fifth worldwide in accumulated PV capacity, with about 83 GW.

In the upstream sector, although Germany's solar PV industry is prominent in a few segments of the value chain, it is fragmented and lacks scale. SMA Solar Technology leads in inverters, and Wacker Chemie is the only EU polysilicon producer with a capacity of around 60,000 metric tons. Meyer Burger is the EU's largest EU solar cell manufacturer, with "merely" 1.4 GW capacity in Germany. Domestic manufacturing, conversely, is mostly concentrated in solar PV modules, primarily in the eastern regions. However, production is scattered across producers with small to medium factory sizes (Figure 2.2).

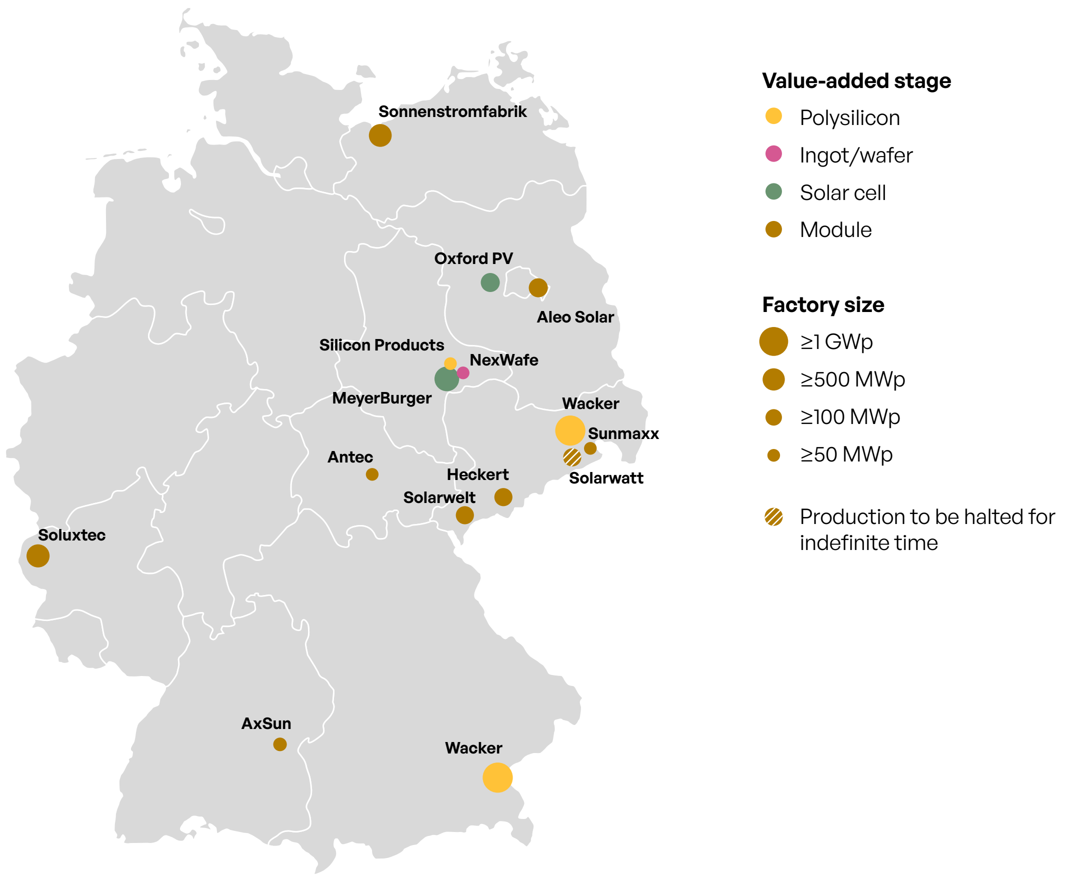


Figure 2.2: Solar PV manufacturing landscape in Germany. Based on the author's data

In Germany, solar PV employment peaked in 2011 with around 160,000 jobs but dropped to about 40,000 by 2017. Since then, it has risen steadily. Between 2018 and 2021, the total number of jobs created annually in Germany was slightly less than 5,000 on average.

In 2022, the sector experienced unprecedented growth, with 35,600 new jobs added, bringing the workforce to 84,100. In 2023, the increase was even more remarkable: around 118,000 employees were working in solar-related jobs, with 103,000 in the PV sector (Figure 2.3).

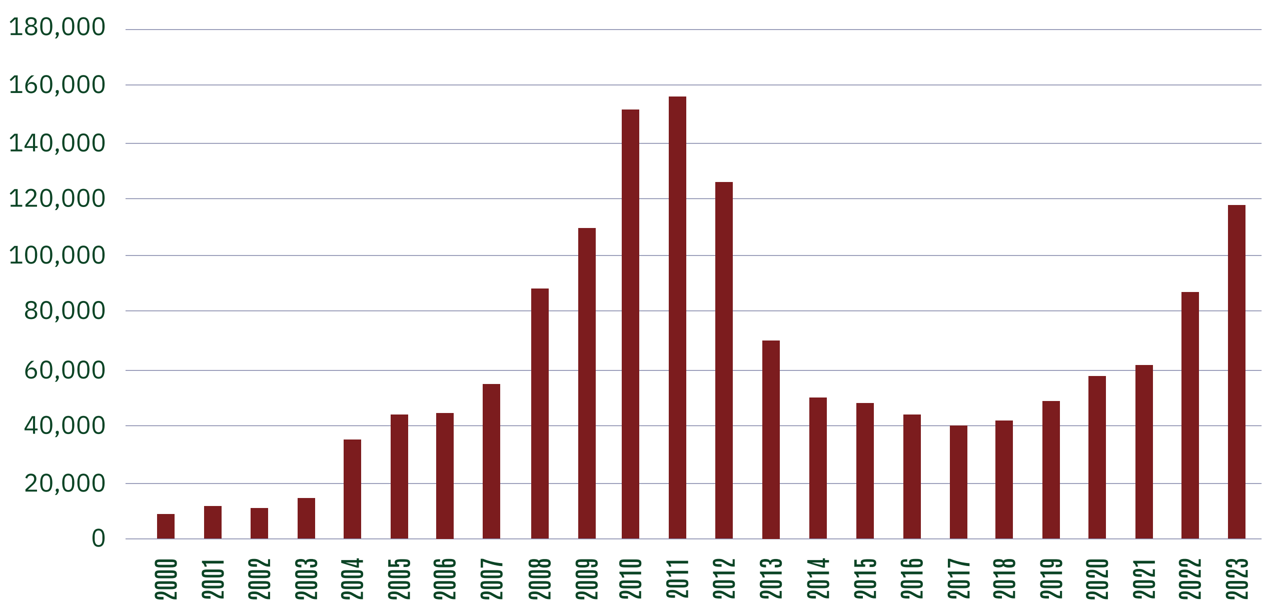


Figure 2.3: Employment in the German solar PV sector 2000-2023, in FTEs.[17]

Nevertheless, these figures combine all PV-related employment: it is mixed between the solar PV manufacturing and solar panel rooftop installation, as there is no available breakdown of employment figures at the national level. In fact, the jobs created so far have been mainly in the downstream sector rather than upstream. For instance, job demand remains low, due to the scarce domestic production capacity—even in solar modules, the strongest manufacturing sub-sector.[17]

In Germany, jobs were created in trade, planning, project management, managerial positions, and, most prominently, installation. In 2022, according to BSW estimates, there were 25,000 solar craftsmen in around 5,000 electrical trade companies in the photovoltaic industry, accounting for about 30% of all the jobs in the sector in the same year. While the portion of utility-scale projects within annual solar installations has been growing at the European level, including in Germany, job growth remains significantly skewed toward rooftop PV systems limited to on the installation of rooftaops. The rapid increase in rooftop installations in response to the ongoing Ukrainian conflict was a major reason for this development.[18]

Ambitious annual installed capacity goals drive the demand for skilled workers in the downstream sector, especially in installations. However, a mismatch between the ever-growing demand and the scarce supply of skilled workers has led to a growing shortage. Between 2019 and 2022, demand for advertisements related explicitly to solar energy quadrupled. In 2022, there were more than 10,000 job postings for overseeing corporate organisation and strategy, while roofing specialists were increasingly sought to install solar systems on roofs. In addition to specialists in electrical operating technology and supervision of electrical engineering, sales and administrative specialists are increasingly in demand in the solar energy sector.[19] Conversely, a combined shortage of 200,000 skilled workers for the solar and wind industry was also recorded in 2022. Among the professions relevant to expanding solar and wind energy, the shortage of skilled labour is currently most significant in construction electrics.[20]

The workers mostly originated from conventional energy industries such as coal and nuclear, automotive, electronics, utility companies, and construction and from fields like mechanical and electrical engineering, mining, manufacturing, quality control, and grid management. The workforce from abroad is also being attracted. For instance, the German Solar Industry Association and the Indian Skill Council for Green Jobs signed an agreement on integrating Indian skilled workers into the German solar industry during the Chancellor's visit to Delhi in 2023.[21]

2.4 SKILL DEVELOPMENT

According to the EU Solar Jobs Report 2023, the solar workforce in Europe increased by 39% in 2022, with Germany being a major contributor to this growth[22]. The industry's rapid expansion necessitates diverse skills, particularly in construction and electrical work, prompting workers from other sectors to transition into solar jobs. In the EU, workers transitioning from fossil fuel industries filled approximately 25% of new jobs in the renewable energy sector.

Germany offers various training and education programs to support the solar industry's workforce. These programs intend to address the skills gap and ensure that workers are adequately prepared for roles in solar energy. With regards to formal education, many universities in Germany offer bachelor's and master's degrees in fields such as renewable energy, environmental engineering, electrical engineering, and solar energy. Institutions like the University of Freiburg and the Munich Institute of Technology offer specialized study programs focused on solar technology and renewable energy systems.

The core of Germany's skill development for the solar sector is its robust and renowned VET system (Vocational Training and Apprenticeships), which includes apprenticeships and vocational schools offering specialized training in solar technology and installation. Germany's dual education system allows individuals to combine classroom-based education with practical training in a company. Apprenticeships in fields such as electrical engineering, energy technology, and installation technology are particularly relevant to the solar industry.

Technician training programs provide advanced technical training, such as those for becoming a Staatlich geprüfter Techniker (State-Certified Technician) in renewable energy. Meanwhile, specialized training programs offer targeted instruction for various trades and technical skills required in the solar industry, such as photovoltaic system installation and maintenance.

Additionally, various retraining programs are available for workers transitioning from other sectors, focusing on solar installation and maintenance skills. Government incentives and the private sector often support these programs collaboratively.

As part of continuous professional development, organisations such as the German Solar Industry Association (BSW-Solar) and the Chamber of Commerce and Industry (IHK) offer certification programs for solar installers, engineers, and project managers.

The solar industry is evolving rapidly, with solar PV modules continuously improving, inverters becoming increasingly digitalized, and new opportunities emerging from integrating electric vehicles and heat pumps at the building level. Electricians and installers must have access to appropriate upskilling programs to keep up with these technological developments.

2.5 SECTORAL RESILIENCE AND KEY CHALLENGES

Job stability in the solar PV manufacturing industry has remained volatile since the early 2010s, marked by a major crisis that led to widespread layoffs and bankruptcies. While recovery followed in the late 2010s, recent geopolitical events, notably the war in Ukraine, have reshaped investment patterns. More recently, the Inflation Reduction Act and the influx of low-cost Chinese modules have disrupted manufacturing, contributing to renewed insolvencies and job losses despite policy interventions such as the PV strategy. In contrast, the downstream sector, particularly installation, has seen sustained job growth, driven by rising demand, technological advancements, and supportive policy measures.

Specific year-to-year data on job retention in the solar industry are not available—there are no public records of such data—making it challenging to provide a detailed analysis of employment trends. Nevertheless, observable trends suggest that while certain sectors within the industry experience significant volatility, others, such as installation, continue to provide steady job opportunities.

The solar sector itself—from its take-off—has roughly spanned 25 years so far. Even though installed PV capacities are experiencing unprecedented growth in Europe, capacity additions do not translate into domestic production. With Chinese competition outpacing German companies, many were forced to shut down or relocate outside Germany—and have never returned. Consequently, the future of the domestic industry remains unclear. Without targeted (and potentially expensive) policy support, companies have little incentive to produce domestically.

As previously described, the decline of Germany's solar PV manufacturing industry can be attributed to a few noticeable factors. Firstly, German policy focused on technological development and demand-side subsidies, neglecting the scaling-up of manufacturing and protecting its national industry. This reliance on market mechanisms failed to account for the changing geopolitical and economic environment. The reduction in feed-in tariffs since 2013 responded to decreasing solar technology costs driven by Chinese manufacturers, making new projects less economically viable and overlooking the impact of increased competition from China. Chinese manufacturers

have been able to produce low-cost solar modules due to economies of scale, government subsidies, and cheaper labour, flooding the market and making it difficult for German companies to compete. This resulted in bankruptcies and industry consolidation. Policy uncertainty further contributed to the decline, as frequent changes in renewable energy policies created an unstable investment environment.

However, the broader solar sector has experienced a persistent employment boom, with a shift from upstream to downstream. This shift has been driven by the combined effects of the war in Ukraine (primarily increased prices) and climate commitments, which have led to even more ambitious decarbonisation goals and higher annual and cumulative installed capacity targets in solar PV energy. By 2027, Germany may ascend to the forefront of solar job creation in Europe.

In line with an EU-wide trend, anticipated changes in the distribution between rooftop and utility-scale annual capacities—primarily characterized by an increasing share of utility-scale PV power plants—will result in a corresponding shift in the division of jobs. In Germany, the rise of large-scale installations will reduce the dominance of rooftop-related jobs from roughly 70% in 2022 to slightly more than 50% in 2027.

Nonetheless, the German solar industry (in its broadest terms) faces significant challenges that must be addressed for continued growth and competitiveness. One major issue is supply-chain dependency on Asia, making the industry vulnerable to disruptions. This resulted in a push for reshoring and increasing local manufacturing. However, the central issue remains Chinese competition. One strategy is to focus on next-generation solar modules, where Chinese competition is less advanced. Technological advancements in solar module efficiency, durability, and performance are essential.

Additionally, integrating solar energy into the national grid requires substantial infrastructure investments to ensure sufficient capacity and stability. Germany's grid connection procedures are complex and fragmented, with varying requirements from operators. Simplifying, digitalizing, and unifying these procedures is necessary to streamline the process and improve efficiency. Incentivising private investments is crucial, especially with high interest rates. Financial incentives are needed to foster investment and secure jobs in the solar power value chain.

The EU's Net Zero Industry Act (NZIA) aims to address these challenges by promising a tougher approach to Chinese imports and providing national support measures. Germany's Photovoltaik-Strategie and Solarpaket I aim to support local solar industries with financial incentives, simplified regulatory procedures, and promotion of research and development (R&D). However, they focus heavily on demand-side subsidies rather than direct manufacturing support. Finally, accelerating and expanding training programs and skilled worker migration is necessary to address the job shortage in the sector, particularly in installation.

2.6 LESSONS LEARNED

KEY LESSONS

GRADUAL POLICY ADJUSTMENTS
Careful and gradual adjustments to subsidies and tariffs can prevent market destabilisation and ensure a smooth transition.

STABLE POLICY ENVIRONMENT
A stable policy environment builds investor confidence and facilitates long-term planning.

STRATEGIC INDUSTRIAL POLICY
Prioritizing national manufacturing capacity and job creation to strengthen resilience against global competition, particularly from China, is crucial.

INVESTMENT IN R&D
Continuous investment in research and development is essential to maintain technological leadership and competitiveness.

GRID AND STORAGE INVESTMENTS
Adequate investment in grid infrastructure and storage technologies is necessary to accommodate a high share of renewable energy.

SUPPLY CHAIN MONITORING
Diversifying supply chains reduces vulnerability to disruptions, requiring a global perspective on geopolitics, industrial policies, and market development.

STRATEGIC PARTNERSHIPS
Forming strategic partnerships and alliances, both domestically and internationally, can help share risks and resources, strengthening the industry and improving its resilience to future challenges.

GENERAL

STRONG INNOVATIVE POTENTIAL AS A SUCCESS FACTOR
One of the early critical success factors for the German solar industry was its strong innovation potential. Continuous advancements in solar PV technology, including higher efficiency of solar PV modules and improved manufacturing processes, have allowed the industry to maintain competitiveness and reduce costs for almost a decade.

INTENSE COMPETITION FROM LOW-COST PRODUCER
However, the industry has faced intense competition from low-cost producers, particularly from China, which has not been addressed rightly by politics, leading to a steep decline in domestic industrial production. For instance, those German companies that survived the crisis now focus on high-quality, next-generation solar technologies. However, strategic industrial policies, such as those outlined in the EU's Net Zero Industry Act (NZIA), aim to support local manufacturing and reduce dependency on Chinese imports but still struggle to be translated into national initiatives.

REDUCTION IN FEED-IN TARIFFS AND POLICY CHANGES
The German example shows that the reduction in feed-in tariffs and frequent changes in government policies pose significant challenges. These reductions have made new solar projects less economically viable, leading to declining installations. Policy stability is crucial for maintaining investor confidence and supporting long-term industry growth.

IDENTIFYING INDUSTRIAL POLICY PRIORITIES TO MAINTAIN A STRONG INDUSTRIAL BASE
Maintaining a strong industrial base and leveraging existing manufacturing and engineering capabilities is essential for the industry's growth. This includes ensuring that the workforce is skilled and that the necessary infrastructure is in place. However, it is essential to identify which industries to preserve and support through strategic policies. If maintaining or building up a robust solar industry is considered critical for energy security, job and value creation, and achieving climate goals, then supporting high-value industries, such as advanced solar technology manufacturing, can help maintain or achieve a competitive edge and drive economic growth. In the case of Germany, however, it is questionable whether a more active industrial policy will help "bring manufacturing back home."

EFFECTIVE GOVERNMENT STRATEGIES

IMPLEMENTING THE RENEWABLE ENERGY SOURCES ACT (EEG)

The Renewable Energy Sources Act (EEG) has been pivotal in promoting the expansion of renewable energy in Germany. It provided feed-in tariffs and financial incentives that made investments in solar energy attractive and economically viable.

STRONG GOVERNMENT COMMITMENT

A strong government commitment to transitioning to renewable energy has been essential, while erratic policies have been detrimental to investments. Policies and strategies, such as the Climate Action Plan 2050, have set ambitious targets for increasing the share of renewables in the energy mix, providing a clear roadmap for industry growth.

HIGH PUBLIC AWARENESS AND ACCEPTANCE

High public awareness and acceptance of clean energy solutions have supported the adoption of solar energy. Public support is crucial for successfully implementing renewable energy policies and projects.

CONTINUOUS INNOVATION AND INVESTMENT

Continuous innovation and investment in solar technology are critical for competitiveness. In the case of Germany, in the early stage and until the first sector crisis (2008), investment in research and development (R&D) has led to technological advancements that improved efficiency and reduced costs.

EDUCATION AND SECTOR COORDINATION

FOCUS ON (RE-)TRAINING PROGRAMS

Aligning education with sector needs involves focusing on retraining programs based on industry requirements and attracting a skilled workforce from abroad. Certification programs for installers and technicians specializing in solar PV are essential for maintaining high standards and ensuring quality installations.

FLEXIBILISATION AND MODERNISATION OF GENERAL PROGRAMS

While specialised degrees such as “Renewable Energy Engineering” have been utilized and become a pillar of the workforce development for solar PV, the lion share workforce development is stemming from updated generalised programs such as “Electrical Engineering” which were updated to include sufficient coursework about renewable energy and, most importantly, lecturers with experience in this field.

GOVERNMENT-BACKED INITIATIVES

Implementing government-backed initiatives to support education and training in renewable energy and digitalisation is crucial. These initiatives can help build a skilled workforce capable of supporting the industry’s growth and technological advancements.

SUSTAINABILITY MEASURES

ESTABLISH A LONG-TERM POLICY FRAMEWORK

Establishing a long-term, stable policy framework provides certainty for investors and businesses. Encouraging public-private partnerships can drive sector growth and ensure sustainable development.

CONTINUED INVESTMENT IN R&D

Continued investment in R&D is necessary to promote the development of high-efficiency modules and smart grid solutions. Innovation is key to maintaining competitiveness and meeting future energy needs.

INTERNATIONAL COLLABORATIONS AND EXPORT MARKETS

Engaging in international collaborations and entering export markets can leverage Germany’s expertise and create new opportunities. This can help diversify the market and reduce dependency on domestic demand.

SUSTAINABLE MANUFACTURING PRACTICES

Focusing on sustainable manufacturing practices and developing strategies for recycling and disposal of solar panels are crucial for the industry’s long-term sustainability. Environmental considerations must be integrated into all aspects of the industry.

TARGETED INDUSTRIAL POLICY

Implementing targeted industrial policies to support capacity scale-up is essential. This may include supply-side subsidies and other measures to ensure the industry can compete globally.

3 State-Powered Acceleration: How Saudi Arabia is Driving Its EV Future

SUMMARY

GOVERNMENT-LED SECTOR ADVANCEMENT
Saudi Arabia is rapidly advancing its electric vehicle (EV) sector as part of its Vision 2030 and the Saudi Green Initiative (SGI), setting the foundation for a transformative shift in its economy and energy landscape.

ECONOMIC DIVERSIFICATION AND LEADERSHIP GOALS
Through Vision 2030 and the SGI, Saudi Arabia aims not only to diversify its economy but also to position itself as a leader in advanced technologies.

STRATEGIC ROLE OF GOVERNMENT
The Saudi government plays a central role through substantial incentives, infrastructure investments, and strategic partnerships with global automotive leaders. These efforts focus on building local manufacturing capabilities and fostering technological innovation in the EV sector.

SUBSIDIZED ECOSYSTEM FOR GROWTH
The government implicitly and explicitly supports both supply and demand in the EV sector. This dual approach is essential for fostering competitive production while simultaneously driving consumer offtake. The strategy ensures balanced sectoral growth, albeit at a significant cost.

SIGNIFICANT INFRASTRUCTURE INVESTMENT
Significant infrastructure investments guide the sector, including the establishment of the Electric Vehicle Infrastructure Company, which plans to deploy over 5,000 fast chargers across more than 1,000 locations by 2030. However, infrastructure challenges remain elsewhere, including grid stability and heat-resilient technologies.

EMPLOYMENT GROWTH AND WORKFORCE DEVELOPMENT
The EV sector is projected to create approximately 30,000 direct jobs by 2034. The establishment of CEER's Electric Vehicle Manufacturing Complex in King Abdullah Economic City is a central component of these plans. The Human Capability Development Program (HCDP) ensures alignment between education actors and labour market needs through specialized training and practical experience programs.

RESILIENCE-BUILDING AND RESOURCES
Sectoral development is accompanied by investments in renewable energy and securing critical materials for battery production. These initiatives seek to reduce carbon emissions, ensure long-term competitiveness, and increase sectoral resilience.

POLICY STABILITY AND STRATEGIC VISION
Establishing a stable and coherent policy framework is critical to sustaining investor confidence and driving long-term sector growth. While Saudi Arabia's Vision 2030 provides a clear long-term framework, its implementation must prioritise consistency to ensure private sector engagement.

3.1 CONTEXT AND STRUCTURAL DYNAMICS

Saudi Arabia's economic model has traditionally revolved around oil. Under Vision 2030, the country is pivoting towards renewable energy and sustainable industries. The EV sector is a critical component of this strategy, aiming for significant market penetration and local manufacturing capabilities. The Kingdom accounts for over half of the total vehicle sales in the GCC, placing it among the top 20 global markets.[23] SUVs and sedans dominate the market, with Japanese automaker Toyota holding a 30% market share, followed by the Hyundai group (including Kia) at 22%. European, American, and Chinese manufacturers, including Changan and SAIC Motors, are also active in Saudi Arabia.

Initially, Saudi Arabia had minimal local EV manufacturing capabilities but a robust market for internal combustion engine (ICE) vehicles. The Kingdom's economic diversification plans required substantial investments in renewable energy and technological innovations. The substantial capital costs of EVs and the significant replacement cost of EV batteries are significant barriers to adoption. In addition, the insufficient number of public charging points is among the top five barriers preventing the adoption of EVs on a large scale.[24]

The automotive industry in Saudi Arabia is seeing rapid growth with significant investments. The Public Investment Fund (PIF) has invested in companies like Lucid Motors, which is establishing a production facility with an annual capacity of 150,000 vehicles.[25] CEER Motors, a joint venture between PIF and Foxconn, aims to produce 170,000 cars annually in 2025.[26] However, there are four heavy-truck assembly plants operating in the Kingdom, albeit with relatively small volumes. Volvo, Mercedes-Benz, and MAN have their facilities in the Western region, and Isuzu in the Eastern region. Despite the limited vehicle manufacturing space, Saudi Arabia has several companies that supply parts and materials to OEMs globally, such as SABIC, which supplies plastic raw materials worldwide, and Ma'aden, which provides aluminium to several notable OEMs. Other suppliers, like AC Delco, Saudi Filters, Denso, and Sadara, also contribute to the automotive sector to varying degrees. The EV market in Saudi Arabia is projected to grow at a compound annual growth rate (CAGR) of 42.5% from 2021 to 2027, with substantial investments expected to reach US$50 billion over the next decade.[27]

3.2 SECTORAL DEVELOPMENT AND GOVERNMENT ACTION

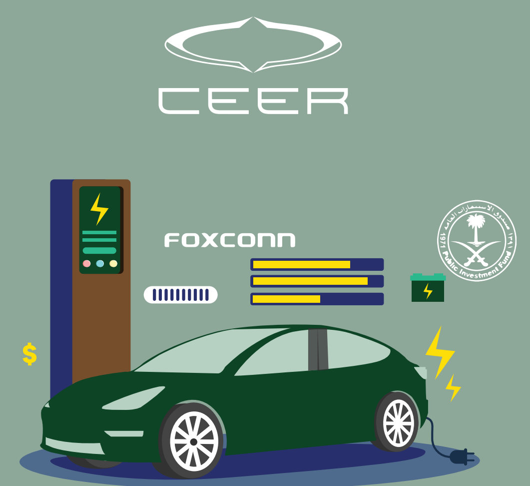
There were over 15 million vehicles in Saudi Arabia in 2020, 45% of these being (private) cars and other light vehicles. The Middle Eastern EV market, including Saudi Arabia, was valued at US$40.25 million in 2021 and is expected to reach US$93.10 million by 2027, registering a CAGR of more than 15%. Although buses operate between cities and to and from neighbouring countries, and trains run between (and, in one case, within) major cities, such as Riyadh, Jeddah, and Dammam, public transport is still developing. Most people commute with private vehicles, as missing public transport provision is compensated for by subsidized fuel, making cars affordable, even for low-income residents.[28] For example, in Riyadh, the capital city, private vehicle ownership almost doubled between 1996 and 2008, accounting for 85% of 8 million daily trips taken, against only 2% in buses.[29] According to the study conducted by Saudi Energy Efficiency Center, transportation currently consumes around 21% of total energy in the KSA, at around one million barrels of oil equivalent per day, and 52% of the sector is light duty vehicles. As transportation energy consumption is expected to double by 2030, the widespread adoption of EVs could have a significant impact in reducing CO_2 emissions; however, the findings of the survey conducted for this study indicate that there are almost no EVs on the KSA's roads at the moment. Only one participant out of 698 stated that they currently drove an EV, with nearly 3.5% owning hybrid vehicles, but more than 96% of respondents drive conventional vehicles.[29]

Domestic fuel prices have been gradually aligned with international levels. In the first round of energy price reforms in December 2015, retail prices rose significantly, with further increases in 2018 and a cap introduced in July 2021 following global crude oil price spikes. As of mid-2021, 95-octane and 91-octane gasoline were capped at US$0.62 and US$0.58 per litre, respectively.[30] Electricity tariffs were adjusted in January 2018 to US$0.048/kWh for residential and US$0.053/kWh for commercial consumers. As fuel costs rise, consumer interest in electric alternatives is increasing.

The Saudi government acts on promoting the context of Saudi Vision 2030, and some policies supporting their adoption have already been developed. However, adoption initiatives, such as the agreement with Lucid Motors, are in their early stages and are just beginning to be implemented in the country.[31] This is reflective of the general approach to EVs of the petroleum-producing states within the GCC, with the notable exception of the UAE. Despite Saudi Arabia being one of the world's largest oil producers, many of these studies indicate that a key challenge to EV adoption is the massive additional demand EVs will place on an already overloaded electrical network, especially during the summer, and steps are now being taken to design systems to evaluate the impact of EVs on the grid.

Saudi Arabia officially allowed the import and use of EVs in 2018, following regulations set by the Saudi Standards, Metrology, and Quality Organisation (SASO).[32] The target is to replace 30% of Riyadh's 4.8 million gasoline-powered vehicles with EVs by 2030. The recently initiated Electric Vehicle Infrastructure Company aims to establish over 5,000 fast chargers across more than 1,000 locations by 2030 to enable this transition.[33] The EV sector in Saudi Arabia has rapidly developed, marked by the establishment of significant manufacturing facilities:

Lucid Motors: Backed by substantial investments from the Public Investment Fund (PIF), the company has established a production facility in King Abdullah Economic City (KAEC) with an annual capacity of 155,000 vehicles.



CEER: Saudi Arabia's first homegrown EV brand, a joint venture between PIF and Foxconn, aims to produce multiple EV models by 2025 using BMW's component technology.

Under the National Industrial Development and Logistics Program (NIDLP), four initiatives have been identified:

1 **Manufacturing of light vehicles (EV and ICE)**
2 **Manufacturing of heavy commercial fuel-cell vehicles**
3 **Manufacturing and assembly of automotive components**
4 **Manufacturing of lithium-ion batteries**

The total expected investment in the sector is US$10.93 billion, anticipated to create 57,000 direct and indirect jobs. While Saudi Arabia does not have a history in ICE manufacturing, it is strategically looking at EV production. PIF announced Lucid's plans to set up an EV production facility in KAEC, with an annual capacity of 155,000 vehicles. The plant is expected to produce four premium EV models. Additionally, in November 2022, HRH Crown Prince announced the creation of CEER, the first Saudi Automotive Brand. CEER, a joint venture between PIF and Taiwanese FOXCONN, will develop, build, and sell several EV models, including sedans and SUVs, in the Kingdom by 2025.

With an annual production capacity exceeding 150,000 vehicles, CEER will utilize BMW technology for EVs and play a pivotal role in developing the automotive industry ecosystem in the Kingdom. Another project, focusing on ICE/EV assembly with an annual capacity of 50,000 units, is also planned. By 2030, the Kingdom's total installed capacity is expected to reach 310,000 vehicles per year, with 10 models introduced gradually by 2027. These factories are expected to position Saudi Arabia as a key player in the automotive sector.

The increase in supply is coupled with growing demand for EVs in the Kingdom. The Electric Vehicle Infrastructure Company, a joint initiative by PIF and the Saudi Electricity Company, plans to establish over 5,000 fast chargers at more than 1,000 locations by 2030.[35] EVs could achieve a 10% market share of the total automotive market by 2030, but this will require significant expansion of EV charging infrastructure, greater consumer awareness of GHG emissions reduction, and substantial EV purchases by Saudi government entities.

Key government bodies such as the Ministry of Energy, the Ministry of Industry and Mineral Resources, and PIF have been pivotal in driving the sector's growth. Significant subsidies are provided for R&D in battery technology and EV infrastructure to establish a robust local manufacturing ecosystem. A further cornerstone is regulatory support: initiatives like SASO regulations ensure the conformity and safety of EVs and charging infrastructure.

The Saudi government furthermore offers substantial subsidies for research and development in battery technology and infrastructure development. These subsidies foster innovation and ensure the Kingdom remains competitive in the global EV market. Saudi Arabia aims to invest an annual equivalent of 2.5% of GDP in R&D by 2040, contributing an additional 60 billion Saudi Riyals (US$16 billion) to the economy. This reflects the country's growing focus on research and innovation, which directly supports advancements in battery technology and EV infrastructure.[34] In February 2022, Lucid Motors entered into agreements with the Ministry of Investment, Saudi Industrial Development Fund (SIDF), KAEC (Emaar-The Economic City), and Gulf International Bank (GIB) to establish a manufacturing facility. Lucid Motors is set to benefit from financial support and investment incentives totalling as much as US$3.4 billion over the next 15 years.[37]

An integrated set of legislative, regulatory, and technical frameworks has been established to organise the electric vehicle charging market in Saudi Arabia. The effort has been coordinated by the Infrastructure Team for Electric Vehicle Charging Stations, under the leadership of the Ministry of Energy. Key milestones include the issuance of a regulatory framework by the Water and Electricity Regulatory Authority, the development of technical standards by the Ministry of Municipal and Rural Affairs and Housing, and the definition of charger specifications and certification processes by the Saudi Standards, Metrology and Quality Organization. In addition, an electronic platform—the Electric Vehicle Charging Gateway—has been launched to streamline procedures for businesses interested in operating or investing in charging stations, while ensuring safety and compliance with national standards.

Institutional responsibilities are clearly defined. The Ministry of Commerce issues commercial licences for charging activities, while the Ministry of Municipal and Rural Affairs and Housing sets site-specific technical and regulatory requirements. The Water and Electricity Regulatory Authority oversees the overall regulatory framework, and the Saudi Electricity Company manages the Electric Vehicle Charging Gateway and facilitates safe installation and grid connection. The Saudi Standards, Metrology and Quality Organization provides conformity certificates and defines technical specifications for chargers. These coordinated measures aim to ensure a safe, reliable, and efficient charging infrastructure across the country.

3.3 EMPLOYMENT IMPACT, SKILL DEVELOPMENT, AND RESILIENCE

The development of the EV sector is projected to create approximately 57,000 direct and indirect jobs by 2030. This growth is supported by the Human Capability Development Program (HCDP), which aims to align educational outcomes with labour market needs through initiatives like mandatory internships and apprenticeship programs, ensuring graduates acquire practical experience and are prepared for the workforce. Additionally, the establishment of the Electric Vehicle Infrastructure Company and partnerships with major global brands like Lucid Motors and Foxconn are expected to further drive both job creation and economic growth in Saudi Arabia.

Workers transitioning into the EV sector often have backgrounds in traditional automotive and related industries. Specialized training programs, along with partnerships between educational institutions and industry leaders, such as agreements with Lucid Motors and the Saudi Industrial Development Fund, help workers acquire skills in EV technologies. These initiatives are crucial for developing a skilled workforce to support the growing EV industry.

Leading universities in the country, such as King Abdulaziz University, King Fahd University of Petroleum and Minerals, and King Saud University, provide foundational engineering education that is essential for the EV sector. These institutions are updating their curricula to include specialized training in EV and renewable energy technologies, with support from partnerships with industry leaders.

Programs like the Power and Water Academy and initiatives by the Saudi Council of Engineers provide specialized courses in new energy topics, ensuring the workforce has the skills needed for the evolving industry. HCDP focuses on developing the skills and values needed for future labour markets through strategic initiatives, such as updating curricula to focus on modern skills, promoting innovative teaching methods, and providing specialized training programs for educators. These initiatives aim to create a flexible and dynamic learning workforce that supports lifelong learning and continuous upskilling, which are essential for the growing EV sector.[35] The rise of EVs is expected to bring about a shift in talent requirements within the automotive industry. New opportunities will emerge for professionals in Information Technology, AI, and data analytics as the industry becomes more software-driven.

Sectorial resilience is a major concern. Authorities focus on long-term job retention through continuous skill development and adaptation to technological advancements. There are plans for continuous R&D investment and the development of a local supply chain for EV components to reduce dependency on imports. Increased efforts by the kingdom in its mining sector feed into this strategy. Integrating EVs with renewable energy sources will further help achieve long-term sustainability by ensuring better utilisation of electricity generation from renewable sources.

KEY MATERIALS AND COMPONENTS IN THE AUTOMOTIVE INDUSTRY

Steel and Aluminium
For tires.

Plastic
For injection moulding of parts like bumpers, interior panels, and cockpit assemblies.

Glass
For windshields and windowpanes.

Rubber
For tires.

Copper
For electrical components.

Electronics and Software
Essential for modern vehicle functionalities.

Vehicle manufacturing relies on a value chain where major auto Original Equipment Manufacturers (OEMs) serve as architects and assemblers rather than manufacturers. The automotive industry supply chain consists of three main tiers of suppliers:

- **Tier 1 suppliers:** Sell directly to OEM plants.
- **Tier 2 suppliers:** Sell to Tier 1 suppliers.
- **Tier 3 suppliers:** Sell to Tier 2 suppliers.

The development of the EV industry in the Kingdom requires establishing an entire ecosystem for the automotive industry. EV-specific components represent a strong opportunity to supply the domestic and export markets. Furthermore, as the current automotive value chain in the Kingdom is virtually non-existent, onshoring other parts of the value chain is necessary for both synergy effects and supply chain resilience. These include:

- **Steel and Aluminium**: For casting, stamping, and machining.
- **Plastic**: For injection moulding of parts like bumpers, interior panels, and cockpit assemblies.
- **Glass**: For windshields and windowpanes.
- **Rubber**: For tires.
- **Copper**: For electrical components.
- **Electronics and Software**: Essential for modern vehicle functionalities.

- The vehicle assembly plant encompasses various processes and components:
- **Chassis Components**: Manufactured through casting, stamping, and machining.
- **Seats Assembly**: Involving stamping and welding.
- **Cockpit Assembly**: Integrating electronics and plastic components.
- **Bumper Injection and Painting**: Utilizing plastic injection techniques.
- **Interior Panels and Console Injection**: Made from plastic.
- **Windshields and Door Glasses**: Manufactured from glass.
- **Wires and Electronics**: Critical for vehicle functionalities, using copper.
- **Tires and Rims**: Made from rubber and aluminium.
- **EV-Specific Components**: Such as batteries and e-motor inverter converters, made from chemicals, plastic, copper, and steel/aluminium.
- **ICE-Specific Components**: Like exhaust systems, fuel tanks, and engine gearboxes.

Some of these components will also find further opportunities in the aftersales market. Potential opportunities exist for global suppliers to be attracted directly or establish local joint ventures to supply future Saudi automotive plants and potentially the export market. The sustainability of the EV sector in Saudi Arabia is further supported by initiatives such HCDP.

3.4 LESSONS LEARNED

KEY LESSONS

GOVERNMENT SUPPORT AS THE MAIN DRIVER
Comprehensive subsidies, tax incentives, regulatory frameworks, and state-led demand have proven essential for initiating the EV sector. However, the sustainability of such measures requires aligning them with long-term goals and ensuring efficient resource allocation—including the use of local firms and

STRATEGIC PUBLIC-PRIVATE PARTNERSHIPS
Effective collaboration between government and private enterprises has potential in bridging infrastructure and skill gaps. These partnerships must focus on actionable outcomes to ensure progress beyond planning stages.

LOCALIZED SUPPLY CHAINS FOR RESILIENCE
Dependence on imports for critical EV components poses risks to long-term sustainability and autonomy. Developing a localized supply chain and building synergies with other sectors, such as mining, is therefore imperative. It strengthens resilience to global disruptions and ensures consistent progress in addition to strengthening economic structures overall.

R&D INVESTMENT AS A DRIVER OF INNOVATION
Continuous investment in research and development fosters technological innovation, supports local expertise, and enables the sector to stay competitive in a rapidly evolving global market. However, ensuring long-term in-country value might require more emphasis on the role of local SMEs.

SKILLED WORKFORCE AS A CORNERSTONE
Aligning education and training programs with market demands is crucial to addressing skill shortages and creating a pipeline of competent workers for the EV sector. Partnerships with industry can enhance this alignment.

INFRASTRUCTURE AND TECHNOLOGY

CHARGING INFRASTRUCTURE

Charging infrastructure is a critical issue for EV adoption. Developing a comprehensive, nationwide charging network must precede the widespread introduction of EVs. This is particularly important in Saudi Arabia and other GCC countries with vast empty lands. The long distances between cities and the heavy use of air conditioning drain batteries more quickly, leading to 'range anxiety' among drivers. Charging stations on all main roads are essential; they could be run using isolated microgrids powered by renewable energy with diesel backup.[36]

EV REPAIR CENTRES

The absence of repair centres and workshops specifically for EVs, in contrast to those for Internal Combustion Engine Vehicles (ICEVs), has frustrated current EV owners. As EV technology is still relatively new, few workers are trained to repair EVs, resulting in costly repairs and longer wait times for complex issues. Establishing a network of specialized repair centres and implementing technician training programs are critical to addressing this gap.[37]

POWER NETWORK STABILITY

EVs consume a high amount of real power in a short period of time due to the non-linear nature of their loads, which can cause instability in power networks.[38] Overloading of charging may also affect aspects of the grid and distribution network, depending on driving and charging behaviour, significantly impacting the power network's load curve. EVs will therefore place additional burdens on overstretched grids.

ENERGY STORAGE AND V2G TECHNOLOGY

Storage of energy is also an issue for EV adoption. However, the increasing global uptake of EVs, facilitated by technological advances such as cheaper batteries, has initiated new business models to exploit the potential of EVs for electric storage.[39] Vehicle-to-Grid (V2G) technology is one such development, enabling EVs to be charged and to return stored electricity to the grid through a connection to a domestic, commercial, or public charging station.[40] Such systems do, however, need ample planning and organisation.

BATTERY PERFORMANCE IN EXTREME HEAT

Lithium-ion batteries' performance and lifespan are significantly affected by high temperatures, such as those present in the GCC. The heat could reduce battery efficiency and lifespan, posing a challenge for EV adoption[41]

MARKET AND WORKFORCE

PUBLIC ENGAGEMENT AND OFFTAKE

Public engagement and interest in low-carbon solutions remain low, compounded by the GCC's strong preference for large vehicles. This significantly affects private consumer interest in purchasing EVs without substantial financial incentives or support.

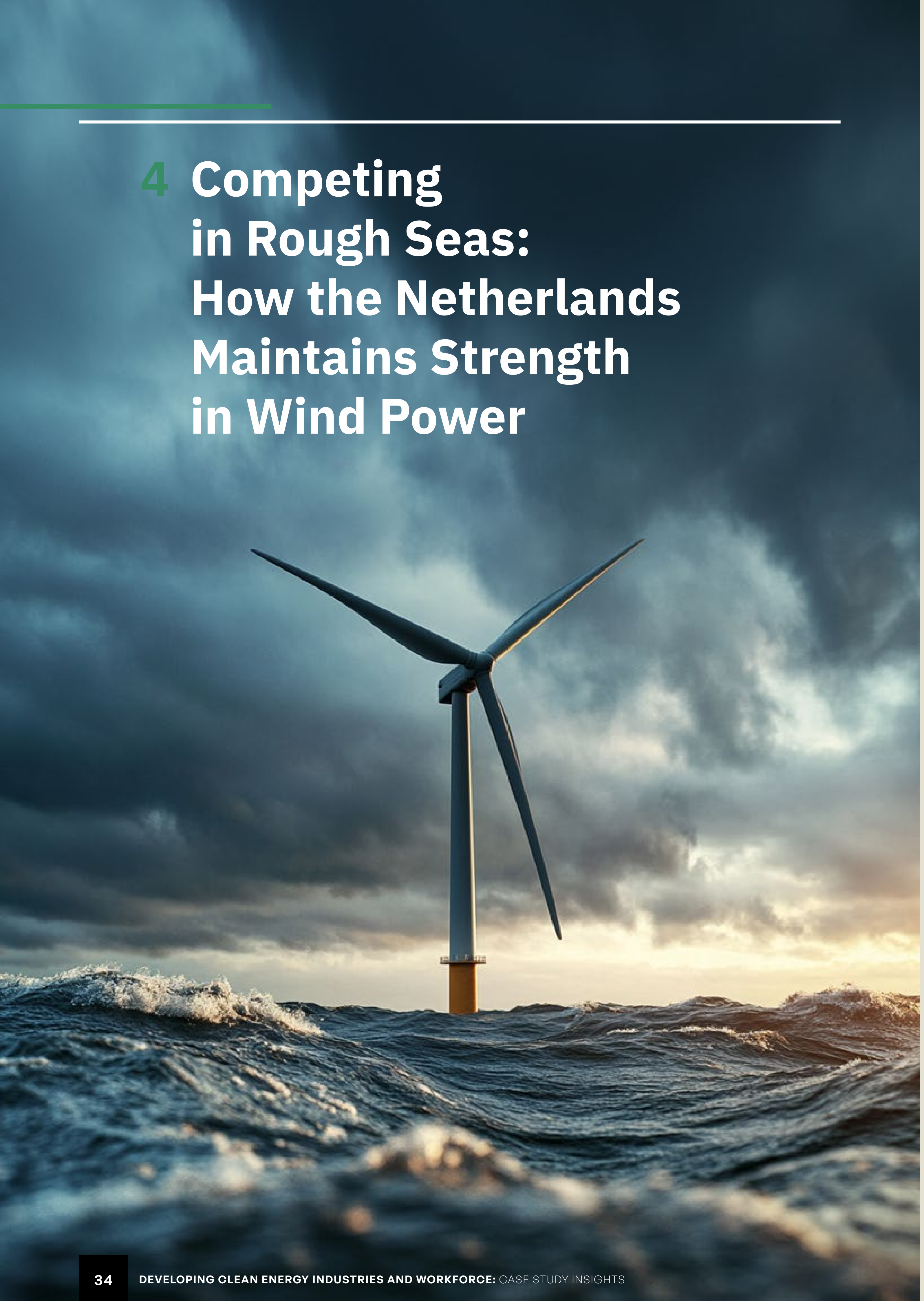
INTEGRATED MANUFACTURING AND INFRASTRUCTURE APPROACH

Saudi Arabia's significant investments in domestic EV manufacturing, such as PIF's support for Lucid Motors and the establishment of CEER, emphasize the importance of aligning infrastructure expansion with local production capabilities to support long-term sector growth.

LESSONS ON EDUCATION AND SUSTAINABILITY

Aligning educational initiatives with industry demands through specialized university programs and industry partnerships ensures the workforce is equipped with relevant skills. However, drawing from general resources and degrees is equally important. Additionally, developing localized EV supply chains and prioritizing R&D investments are critical for reducing import dependency and fostering long-term sector grow.

4 Competing in Rough Seas: How the Netherlands Maintains Strength in Wind Power



SUMMARY

PIONEER IN WIND ENERGY
The Dutch wind power industry has evolved into a global frontrunner, boasting significant achievements in both onshore and offshore wind development since the 1980s.

KEY MILESTONES AND EARLY INVESTMENTS
Foundational projects like Windpark Eemmeerdijk (established in 1996) laid the groundwork for large-scale offshore ventures, such as Hollandse Kust (zuid).

BROADER TARGETS AND LOCAL MARKET DRIVING PROGRESS
Ambitious targets within the Energy Agreement for Sustainable Growth and the Climate Agreement as well as the availability of a local market have proven pivotal in guiding the sector's expansion.

MARKET GROWTH TRAJECTORY
The Dutch wind power sector climbed to a market volume of about US$5 billion by 2022.

OFFSHORE INVESTMENT SURGE
Capital investments in offshore wind power reached 8% in 2020, underscoring the importance of robust infrastructure upgrades and stable policy incentives to sustain further growth.

EMPLOYMENT PEAKS AND DOWNTURNS
The sector employed 42,100 workers in 2020; however, this figure dropped to 11,400 by 2022 due to grid constraints, project costs, environmental considerations, and technology gaps.

EMERGING CHALLENGES
Grid connectivity, social acceptance (NIMBYism), environmental impact, and the rising complexity of project costs all demand continuous innovation and stakeholder engagement.

MEASURES FOR LONG-TERM STABILITY
Upgrading grid infrastructure, preserving stable policies, fostering community support, boosting R&D, and diversifying energy sources are all essential strategies to safeguard the Netherlands' leading position in renewable energy.

4.1 CONTEXT AND STRUCTURAL DYNAMICS

The Netherlands' engagement with wind energy dates to the era of traditional windmills. Today, the country stands among the leading nations in the deployment of modern wind turbines. Interest in alternative energy sources began during the 1970s.[42] Significant milestones include the initial construction of wind farms in the early 1990s and the expansion into offshore wind power during the last decade of the 2000s. The Dutch wind power sector has experienced consistent growth due to the availability of advanced technology, a consistent government strategy, and collaborative efforts between the private and public sectors.

Driven by energy diversification and environmental sustainability, the Netherlands—which is, moreover, one of Europe's larger natural gas producers—has prioritized the adoption of renewable energy sources. Wind energy, in particular, plays a significant role in the country's energy transition strategy. Benefiting from favourable wind conditions along its extensive coastline, the Netherlands has developed onshore and offshore wind energy applications, leveraging this natural resource to meet its renewable energy goals.

The Dutch wind power sector has experienced significant growth over the past few decades. While early efforts focused primarily on onshore wind energy, increasing land constraints led to a strategic shift toward offshore wind power. The sector now spans the entire wind energy value chain, encompassing the manufacturing of wind turbines, the development and construction of wind projects, operations and maintenance (O&M), and grid interconnection.

While wind energy development in the Netherlands has been both endorsed and led by the public sector, public support remains a critical determinant in its advancement. Public opinion in the country often places significant emphasis on environmental issues and sustainability, reinforcing the societal acceptance of such initiatives. Technology has played a role too. Advancements in wind turbine technology have facilitated the use of larger-scale turbines, improving the sector's efficiency and capacity, and have been connected to (public) research initiatives.

4.2 SECTORAL DEVELOPMENT AND GOVERNMENT ACTION

The wind energy industry has experienced substantial economic expansion in the Netherlands, becoming a pillar of the nation's energy sector (Figure 4). This evolution can be segmented into distinct phases. Prior to the 1990s, wind energy was in its infancy, with only limited installations of small-scale onshore wind turbines and a focus on research and development to assess its viability and potential. During this stage, the foundations for the sector were laid.

The sector emerged in the 1990s, and the Electricity Act of 1998 accelerated developments for the 2000s through the introduction of feed-in tariffs.[43] This policy stimulus expedited the development of onshore wind farms and significantly increased installed capacity. Concurrently, advancements in turbine technology enabled the installation of larger and more efficient wind turbines.

Recognising the constraint of land availability in the Netherlands, the focus shifted toward offshore wind in the 2000s. The commissioning of the "Offshore Windpark Egmond aan Zee" in 2007[44] marked a tipping point. Subsequent enhancements in governmental subsidies and streamlined permit processes facilitated the financing of offshore wind projects. Additionally, efforts were directed toward the development of advanced turbine technologies, integration into the electricity grid, cost reduction, and international collaboration.

Wind power has become an integral part of the electricity mix in the Netherlands, emerging as the second-largest source of electricity generation in the country by 2022.[45] The Dutch government has set ambitious targets, aiming for 50 GW of offshore wind power capacity by 2040 and 70 GW by 2050, reflecting the country's commitment to the continued expansion of wind energy.[46]

1970	**Research and small-scale trials by government and academia.**
1980	**First wind farm.**
1990	**First onshore wind farms built; Dutch Wind Energy Association (NWEA) formed to promote wind power.**
1991	**First offshore wind farm.**
2007	**Egmond aan Zee, the first offshore wind farm, commissioned.**
2015	**Borssele Wind Farm Zone becomes one of the largest offshore wind zones globally. The Offshore Wind Energy Act an act passed on 1 July 2015**
2020	**Total wind energy capacity exceeds 6 GW.**
2023	**Construction of Hollandse Kust (zuid), one of the world's largest offshore wind farms, underway.**
2024	**Target of 11.5 GW offshore wind capacity by 2030.**

Figure 4.1: Timeline of major milestones in the Dutch wind power sector.

These developments were supported by key legislation, financial incentives, and the active role of state-owned entities. Notable initiatives include the 2013 Energy for Sustainable Growth Agreement and the 2019 Climate Agreement. These frameworks outlined clear renewable energy targets, including achieving 16% of energy from renewable sources by 2023 and reduction in greenhouse gas emissions by 2030 to 49% compared to 1990 levels.[47]

Project subsidies, such as the Sustainable Energy Production Subsidy Scheme (SDE+ and SDE++)47, play a vital role in bridging the cost gap between renewable energy production and market prices, ensuring the economic viability of wind projects. Dutch institutions like the Netherlands Enterprise Agency (RVO), the Ministry of Economic Affairs and Climate Policy, and TenneT have been key in implementing policies and managing infrastructure.

Efforts to support sector growth include revising the permitting regime under the Offshore Wind Energy Act, upgrading grid connections to accommodate increased capacity, and investing in research to drive technological advancements. Additionally, engaging local communities and stakeholders, along with conducting environmental impact assessments, has addressed social and environmental concerns, fostering favourable conditions for the development and stability of wind energy in the Netherlands.

4.3 MARKET DYNAMIC, WORKFORCE, AND SKILL DEVELOPMENT

The installed capacity of wind energy doubled between to 2018 and 2022 thanks to strong policies, technological advancements, and major investments in infrastructure[48]. Figure 4.2 shows that both onshore and offshore wind have steadily grown over the years, starting from below 500 MW in 2000 and reaching 7,251 and 3,764 MW, respectively, by 2023. The progress in offshore wind has been particularly striking since 2020, with large-scale projects and partnerships between the government and private sector playing a big role.[49]

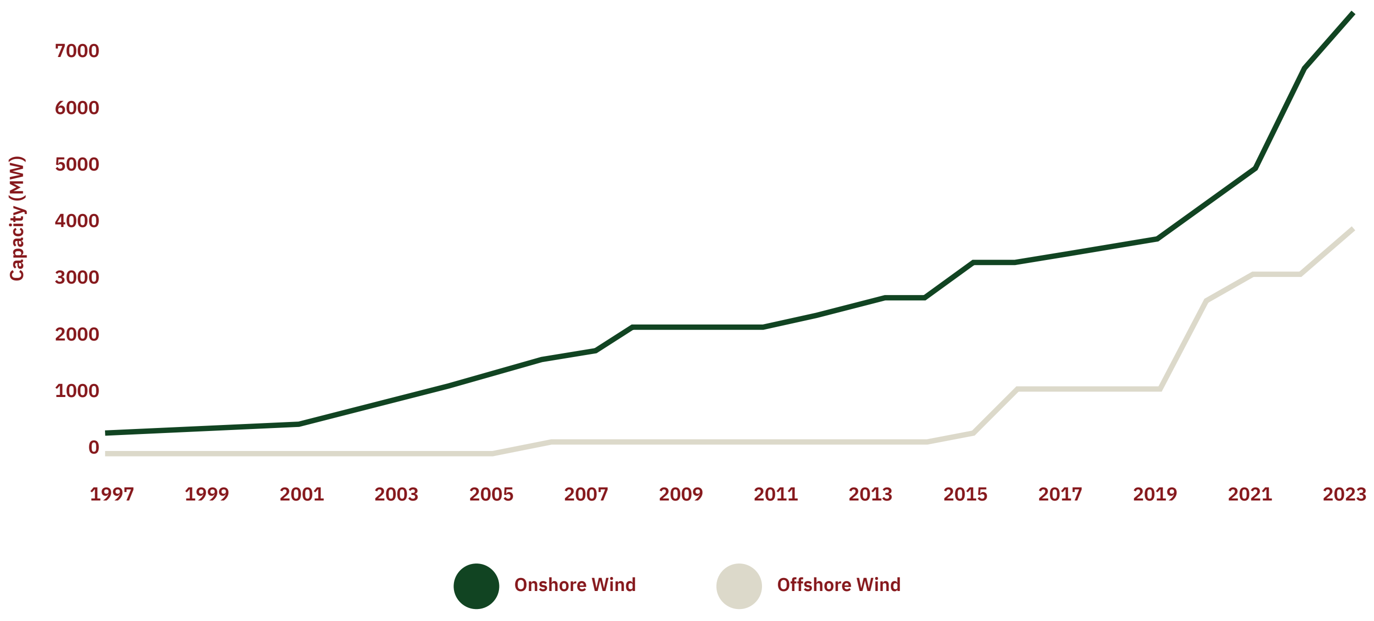


Figure 4.2 Growth in onshore and offshore wind power capacity in the Netherlands 1997–2023.[50]

The Netherlands illustrates the employment potential of the wind energy sector, with 11,400 direct and indirect jobs recorded in 2022 (Figure 4.3). Employment peaked at approximately 42,100 in early 2020, an increase of 39,000 from 2019. This spike, the highest during the review period, highlights the sector's capacity to generate job opportunities under favorable conditions. However, such fluctuations underscore the sector's sensitivity to project cycles, investment flows, and broader economic factors, warranting further examination to ensure long-term employment stability.

The wind energy sector relies on a range of critical roles. Project managers oversee the entire lifecycle of wind projects, from site selection to construction and operations, while Operations and Maintenance Managers handle daily wind farm activities, including maintenance and performance optimisation. Engineers in electrical, mechanical, and civil fields are vital for designing, building, and maintaining turbines and farms. Finance and legal professionals secure funding, manage contracts, and ensure compliance. Emerging roles like data analysts optimize turbine performance, and offshore wind specialists address the unique demands of marine engineering and logistics for offshore projects.

The increasing demand for specialists, technicians, and engineers has prompted workforce transitions from industries like construction, electrical engineering, and shipbuilding. Additionally, the sector has attracted professionals from mechanical engineering, project management, and logistics. As the industry has matured, the need for specialized expertise, including wind turbine technicians and grid integration specialists, has increased, driving the development of targeted training programs and educational initiatives.

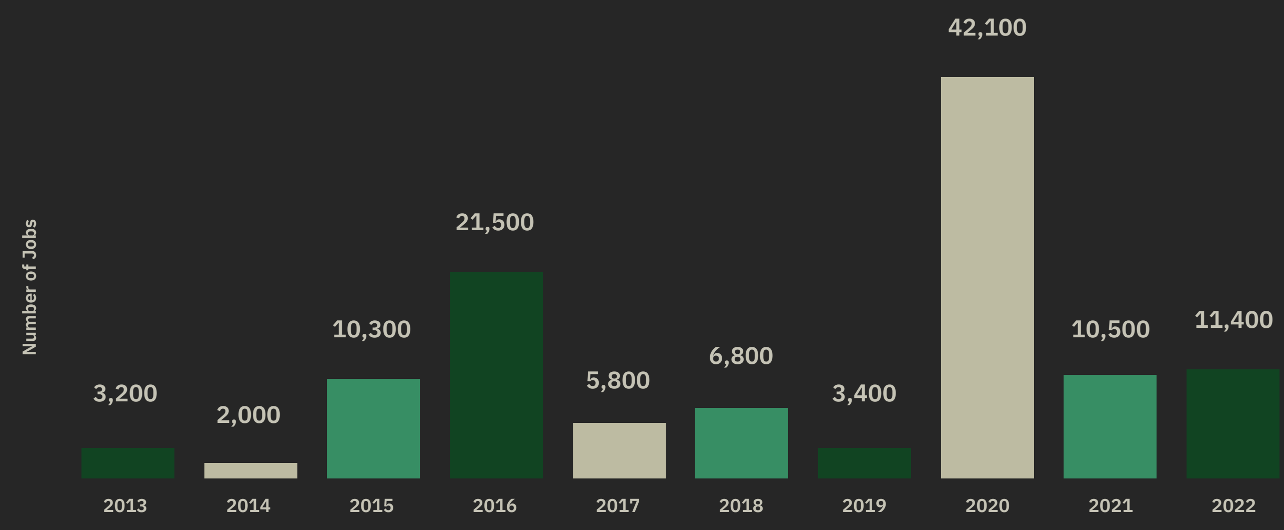


Figure 4.3 Number of jobs in the Dutch wind power sector 2013 to 2022 [51]

It is estimated that 20–25% of the workforce in the Dutch wind energy sector has transitioned from traditional energy industries such as oil and gas, manufacturing, and construction. These individuals bring valuable expertise, particularly in engineering, project management, and technical roles, which are highly transferable to wind energy, and account for approximately 2500 workers in 2022. Training and reskilling initiatives have played a significant role in facilitating these transitions, equipping workers with the industry-specific knowledge for wind energy industry. For example, government- and industry-funded programs offer instruction in turbine technology, renewable energy systems, and environmental impact assessments.

Although comprehensive national data on participation and completion rates for training programs is unavailable, the breadth of available options highlights the emphasis placed on workforce development in the Netherlands' wind energy sector. This focus ensures a skilled and adaptable workforce to support the industry's continued growth and innovation.

The type of training required depends on the specific role within the sector. For instance, manufacturers provide on-the-job training related to wind turbine operation, ensuring workers gain practical, hands-on skills in addition to theoretical instruction. Training programs also focus on wind farm management and maintenance activities.

Furthermore, vocational schools and colleges across the Netherlands offer programs in wind energy technology, maintenance, and installation, equipping students with the practical skills needed to enter the workforce. A key initiative in this regard is the "Internship Guarantee Agreement for Wind Netherlands," which establishes partnerships between vocational schools and wind energy companies. This program ensures that students gain practical experience while providing companies with access to a pipeline of skilled workers.

Universities play a vital role in advancing the skills of professionals and engineers. Among them, the European Wind Energy Master's program at TU Delft is particularly notable, emphasizing offshore engineering, rotor design, electrical power systems, wind farms, and atmospheric physics. The program also connects participants with industry partners, providing valuable opportunities for practical experience. [52] Another prominent program is the Wind Energy Project Management course offered by HAN University of Applied Sciences, which develops expertise in effectively managing wind energy projects.[53] Specialized academies furthermore contribute to workforce readiness through intensive training programs. These initiatives target incoming professionals to the wind energy sector, equipping them with essential knowledge about the offshore wind energy industry.

Additionally, standard training programs necessary for daily operations are widely available through accredited institutes affiliated with the Global Wind Organisation.[54] These include mandatory courses on working at heights and rescue procedures, which are prerequisites for climbing turbines and must be renewed annually. Such programs, offered at various training centers across the Netherlands, foster safety and preparedness in the sector.

4.4 SECTORAL RESILIENCE AND KEY CHALLENGES

The Dutch wind energy sector is qualified as mature, characterised by well-established infrastructure, significant installed capacity, and ongoing technological innovation. The industry's maturity results from several key drivers, including the provision of strong government support in the form of clear and ambitious policies, substantial financial incentives, and effective coordination between various relevant stakeholders. Policies such as the Energy Agreement for Sustainable Growth and the Climate Agreement have provided certainty and encouraged long-term investments in wind energy. The presence of advanced grid infrastructure, managed by TenneT, and the undertaking of continuous research and development (R&D) presented by TNO, innovative energy of the Netherlands, efforts have also played a pivotal role in sustaining growth and efficiency in the sector.

Despite the maturity, the Dutch wind energy sector faces several challenges that could influence its future. These include constraints on grid capacity, environmental considerations, and the need for ongoing technological advancements to remain competitive. Addressing these issues will require investments in smart grid technologies, efforts to engage local communities, and sustained innovation.

As installed wind energy capacity continues to grow, accommodating fluctuations in wind power has become increasingly important. These variations present challenges for grid integration, necessitating upgrades to grid infrastructure and the adoption of smart grid technologies. Strengthening interconnections with neighboring countries will also play a role in balancing supply and demand effectively.

Despite the Netherlands' pro-environmental approach, NIMBYism ("Not In My Backyard") remains a significant challenge in the development of wind farms. While a significant share of the Dutch population endorses renewable energy and sustainability as policy priorities, concerns about the local impact of wind farms—such as visual intrusion, noise, and effects on property values—can lead to resistance at the community level.

Another important area is the sustainability of financial support and investment. Shifts in policy, market conditions, and financing availability introduce risks that could impact long-term growth. Maintaining stable policies and clear regulatory frameworks will be essential to attract ongoing investment. This includes retaining financial mechanisms such as feed-in tariffs, subsidies, and tax incentives. Engaging communities and addressing public concerns will also be vital to ensure local support for wind energy projects.

Innovation remains a key driver for the sector's progress including Enhancing turbine efficiency, durability, and maintenance solutions will require continued funding for research and development. Collaboration between industry, academia, and government can support technological progress and foster the development of innovation hubs.

4.5 LESSONS LEARNT

KEY LESSONS

STABLE POLICY ENVIRONMENT AS A DRIVER
Clear and ambitious targets in the Energy Agreement for Sustainable Growth and the Climate Agreement have helped create a predictable investment landscape, reducing risk for investors and ensuring long-term expansion of wind power.

FINANCIAL INCENTIVES TO BRIDGE COST GAPS
Subsidy schemes (SDE+, SDE++) have been crucial in making wind energy projects financially viable, encouraging both domestic and foreign investment.

STRATEGIC R&D FOR TECHNOLOGICAL INNOVATION
Sustained investment in research and development is integral for improving turbine efficiency, reducing costs, and maintaining the sector's competitiveness on a global scale.

INFRASTRUCTURE AND TECHNOLOGY

OFFSHORE WIND EXPANSION
The Netherlands' focus on offshore wind, supported by streamlined permitting (Offshore Wind Energy Act), accelerates installation timelines and facilitates large-scale generation to meet ambitious 2030 targets.

SMART GRID DEVELOPMENT
Investments by TenneT and other stakeholders in onshore and offshore transmission ensure efficient integration of wind power. Employing real-time data analytics and smart grid technologies can further balance supply and demand.

COST REDUCTION THROUGH INNOVATION
Advances in turbine design, materials, and digital monitoring tools continue to drive down production and maintenance costs, strengthening the sector's economic viability.

EDUCATION AND WORKFORCE

EQUAL EMPHASIS ON VOCATIONAL, UNIVERSITY, AND APPRENTICESHIP PATHWAYS

A robust workforce strategy balances vocational training, university-level programs, and structured apprenticeships. This ensures that entry-level technicians through to advanced researchers are equipped with industry-relevant skills.

INDUSTRY-ACADEMIA-GOVERNMENT COLLABORATION

Frequent dialogue among employers, educational institutions, and public authorities shapes curricula to meet evolving market needs. Specialized courses (e.g., at Delft University of Technology) are complemented by government-supported apprenticeship schemes for hands-on learning.

CONTINUOUS PROFESSIONAL DEVELOPMENT

Ongoing reskilling initiatives allow workers to stay current with rapidly advancing technologies. This approach also helps individuals from traditional energy sectors transition smoothly into wind-specific roles, ensuring a stable talent pipeline.

GOVERNMENT SUPPORT FOR TRAINING

Public funding and tax incentives encourage companies to invest in employee training. This comprehensive approach not only sustains a qualified workforce but also fosters innovation and adaptability.

SUSTAINABILITY AND SOCIAL ASPECTS

LONG-TERM COMMITMENT TO R&D

Ongoing research in areas like offshore engineering, storage solutions, and environmental impact assessment keeps the Netherlands at the forefront of wind energy innovation while boosting local job creation.

COMMUNITY ENGAGEMENT & NIMBY CONCERNS

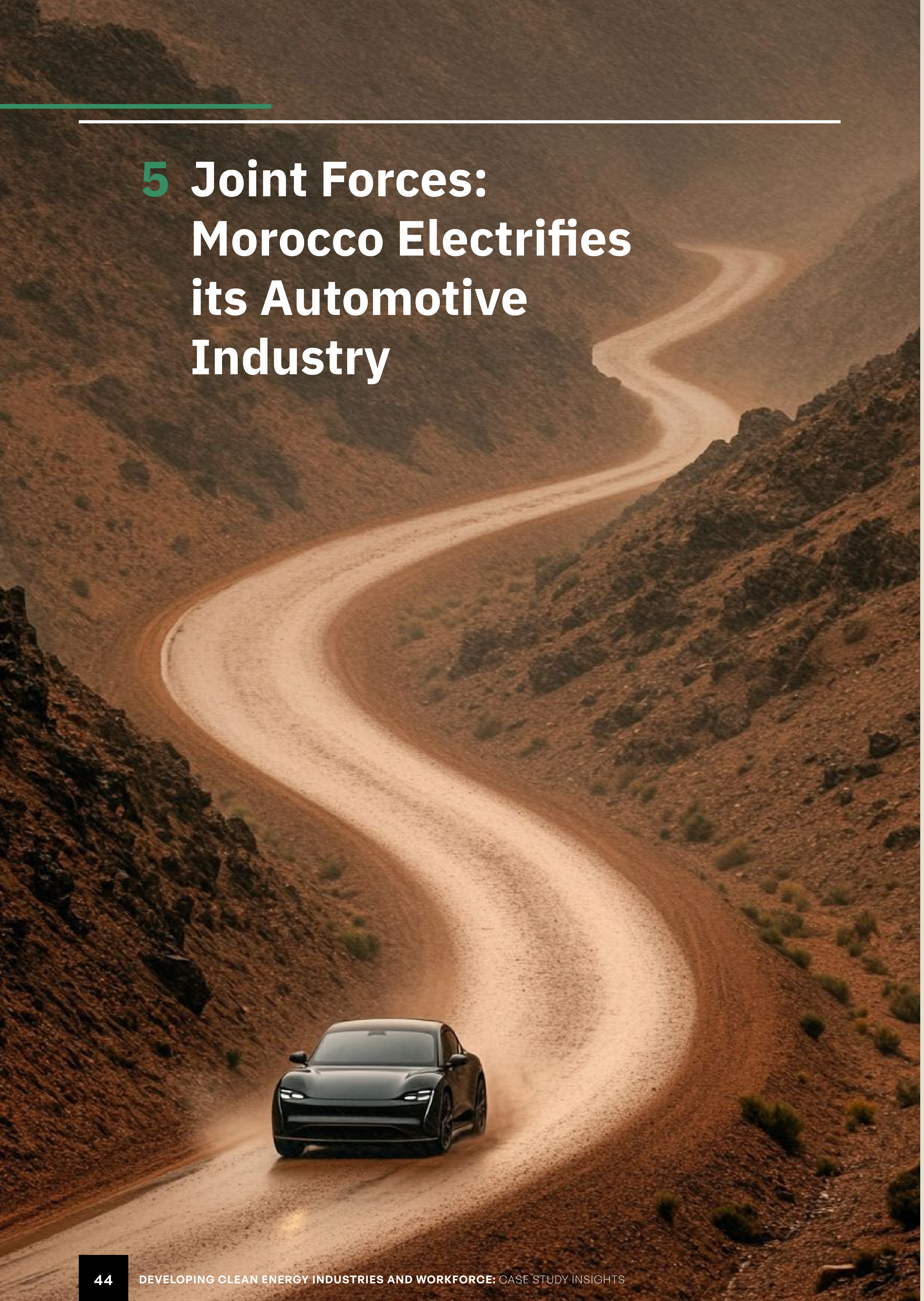
Despite strong pro-environmental sentiment in the Netherlands, local resistance can arise when wind farms are proposed. Early engagement with communities, transparent dialogues about noise and visual impact, and demonstrating tangible benefits (e.g., local job opportunities, revenue sharing) are vital to securing public support.

DIVERSIFICATION & SYSTEM RESILIENCE

While wind is a cornerstone of Dutch renewable energy, combining it with other sources—like solar and hydro—provides stability during periods of low wind and strengthens overall energy security.

ENVIRONMENTAL PROTECTION & PERMITTING

Rigorous impact assessments and mitigation strategies (addressing wildlife, noise, and visual concerns) ensure that wind projects align with ecological protection goals, reinforcing both community buy-in and environmental stewardship.



5 Joint Forces: Morocco Electrifies its Automotive Industry

SUMMARY

STRATEGIC FOUNDATIONS AND FDI

Strategic policy frameworks established by the government, coupled with significant foreign direct investments (FDIs), have underpinned the development of Morocco's electric vehicle (EV) sector. Public initiatives have laid a supportive foundation, complemented by private-sector investments from international companies such as Renault, Stellantis, and Gotion High-Tech, facilitating rapid growth in the industry.

COLLABORATIVE WORKFORCE DEVELOPMENT

Collaborative Workforce Development: Morocco has effectively aligned workforce capabilities with the electric vehicle (EV) sector through coordinated efforts between the government and industry stakeholders. Strategic initiatives have ensured workforce skills closely match sectoral requirements, securing sustained growth and industry competitiveness.

EMPLOYMENT GROWTH

While Morocco's conventional automotive sector has generated over 220,000 jobs, new EV-related positions—especially in battery manufacturing and renewable energy integration—are expected to augment this figure further.

DOMESTIC DEMAND CHALLENGES

Despite these job gains, domestic EV demand remains low. This is largely due to infrastructural deficiencies, including an underdeveloped charging network and limited grid readiness, which restrict widespread EV adoption.

SUPPLY CHAIN AND ENVIRONMENTAL CONSIDERATIONS

Morocco's reserves of cobalt and phosphorite strengthen its role in the global EV supply chain. However, reliance on imported technologies and environmental concerns linked to mining present ongoing challenges.

GLOBAL COMPETITIVENESS AND TRADE ADVANTAGES

The country's strategic location between Europe and Africa, as well as the free trade agreements with the EU and the US, facilitate access to global markets and attract foreign investment.

RESEARCH, DEVELOPMENT, AND GLOBAL TRENDS

Collaborative research initiatives in battery technology, renewable energy integration, and sustainable manufacturing are critical for enhancing global competitiveness and stimulating local demand.

5.1 CONTEXT AND STRUCTURAL DYNAMICS

The shift to electric mobility is gaining rapid momentum, including in Africa, the Middle East, and the Mediterranean. The EU has scheduled the implementation of its Carbon Border Adjustment Mechanism (CBAM) for 2026, which will place border tariffs on carbon-intensive materials—such as steel, cement, and aluminium. This policy aims to harmonise competition between EU and non-EU producers by factoring in the carbon emissions linked to imported goods. Decarbonising such goods is, therefore, imperative to maintain exports to the EU.

In this context, Morocco seeks to upgrade its conventional automotive industry towards electric vehicles. The development is fuelled by government initiatives and foreign investments alike, while building on the country's established automotive industry.

Morocco's industrial landscape has substantially transformed in recent years, driven by strategic government initiatives designed to foster economic growth and enhance global competitiveness. The Industrial Acceleration Plan (PAI) 2014-2020 played a pivotal role, focusing on establishing a robust manufacturing base and diversifying the economy.[55] This plan sought to increase industrial output and position Morocco as a player in global supply chains.[56] Building on this foundation, the Moroccan government introduced the 2021-2025 Industrial Acceleration Plan (IAP 2021-2025), which prioritises innovation, sustainable practices, and an increased role of the sector in Morocco's economy.[57] The New Development Model (NDM), launched in 2021, further expands on this idea and presents a comprehensive vision for economic and social development toward 2035, emphasizing sustainability and economic inclusion.[58] These plans are supported and co-financed by the African Development Bank.

5.2 SECTORAL DEVELOPMENT AND MARKET DYNAMICS

The conventional automotive industry has become a cornerstone of Morocco's economy, rapidly evolving into one of the country's leading sectors. The PAI 2014-2020 was pivotal in this transformation and led to the establishment of key automotive hubs, such as Tangier, hosting the Renault plant, and Kenitra, where the Peugeot-Citroën factory is located.[59] The significant FDIs have contributed to Morocco becoming Africa's largest automotive manufacturer and exporter.[60] The assembly of vehicles has been accompanied by the onshoring of a dense network of Tier 1 and 2 suppliers (see also Section 3.3), many of which link African suppliers to European ones.

With an annual production capacity of 700,000 vehicles, the automotive sector is Morocco's leading export sector, generating a turnover exceeding US$8 billion annually, and it accounts for 22% of GDP. The sector has created over 220,000, exceeding its initial target of 90,000 jobs projected in the Industrial Acceleration Plan.[61] By 2023, the manufacturing capacity for EVs reached 40,000 units and is projected to grow to 100,000 by 2025 and 600,000 by 2030.[62,63]

Current plans foresee using electric vehicles not just for export but also domestically. This requires significant infrastructure enhancement, expanded manufacturing capabilities, and, more importantly, a robust charging infrastructure. Currently, the country counts roughly 1,500 charging stations and plans to deploy another 250 by 2026. This initiative is spearheaded by APIME, the Intersectoral Professional Association for Electric Mobility. The new charging stations will be installed in cities like Tangier, Rabat, and Casablanca. However, the Moroccan EV market remains in its early stages—currently, only about 500 electric vehicles are in use. As of 2024, the Moroccan EV market is valued at approximately US$51 million, but projections consider a CAGR of 8.97% from 2024 to 2029.

These developments are linked to other economic and political goals of the Moroccan government as well as diverse strategic factors. Renewable energy targets for 2030 aim to supply 52% of Morocco's electricity capacity.[64] Overall, the country as opted for a model of "green diplomacy", which seeks to expand Rabat's strategic capacities through the adotion of green industries and energy.[65] Morocco's location between Africa and Europe allows it to utilise low-cost networks within Africa while easily accessing European markets and investments.[62]

Arguably most relevant is the construction of a sectoral ecosystem that includes battery production and cobalt mining. In 2024, the Moroccan government signed an investment agreement with Gotion High-Tech, a Chinese-German battery manufacturer, to establish a gigafactory in Kenitra. The initial phase of the factory is planned to have a capacity of 20 gigawatt-hours (GWh), with expansion plans to reach 100 GWh. This project represents a total investment of approximately US$6.8 billion and is expected to generate 17,000 jobs, including 2,300 high-skilled positions.

Additionally, LG Chem, in collaboration with Huayou Cobalt, has announced plans to construct a lithium conversion plant in Morocco. The plans foresee a production capacity of 50,000 metric tons of lithium-phosphate-iron cathode materials per year, sufficient to power up to half a million electric vehicles annually. Scheduled to begin operations in 2026, the plant will primarily serve the U.S. market, leveraging Morocco's free trade agreements with the United States to facilitate competitive market access—although plans were made prior to the re-emergence of US protectionism under the current administration.

Furthermore, CNGR Advanced Material, a Chinese manufacturer of battery components, has partnered with the Moroccan holding company Al Mada to invest US$2 billion in a cathode materials plant in Jorf Lasfar. This facility will capitalize on Morocco's abundant phosphorite resources and its proximity to European markets, producing key components for EV batteries.[66] Volkswagen has identified Morocco as a strategic hub for EV battery production, with plans to commence production of battery materials by 2025.[67]

Table 2: EV Battery Factories in Morocco.

Project	Location	Capacity	Investment	Job creation	Operational Date	Primary Market
Gotion High-Tech Gigafactory	Kenitra	20 GWh (initial), expanding to 100 GWh	US$6.4 billion	17,000 (2,300 high-skilled)	June 2026	Global
LG Chem and Huayou Cobalt Plant	Undisclosed	50,000 tonnes/year of lithium-phosphate-iron cathode materials	Undisclosed	Undisclosed	2026	U.S.
CNGR Advanced Material Plant	Jorf Lasfar	Cathode materials for EV batteries	US$2 billion	Undisclosed	2025	Europe, U.S.
Volkswagen's Strategic Hub	Undisclosed	Battery materials production	Undisclosed	Undisclosed	2025	Europe

5.3 EMPLOYMENT IMPACT AND SKILL DEVELOPMENT

Morocco's conventional automotive sector's development has significantly impacted employment, creating over 220,000 jobs between 2014 and 2021. The sector's ability to attract and retain talent has been crucial for this development.[68] Further job creation from rising EV production, alongside battery manufacturing, is expected. For example, Gotion High-Tech's gigafactory in Kenitra is expected to create 17,000 jobs, including 2,300 highly skilled positions.[69] Similarly, initiatives like LG Chem and Huayou's lithium-phosphate-iron (LFP) cathode material plant are projected to generate significant employment opportunities.[70] The Moroccan government has supported this workforce transition through targeted training programs and educational initiatives, equipping workers with the skills needed to thrive in this evolving industry.

The development of skills and training programs in Morocco's EV sector is a multi-faceted effort involving government initiatives, private sector contributions, and international collaborations. This comprehensive approach is aimed at ensuring that the workforce is adequately prepared. The National Pact for Industrial Emergence has significantly expanded the availability of training courses, leading, for instance, to the establishment of centres of the Institut de Formation de l'Industrie Automobile (IFMIA). This development preceded the EV sector expansion, taking place between 2011 and 2017. The centres aimed at aligning educational programs with industry needs by offering specialized training in EV technology, battery systems, and sustainable manufacturing practices. The Office of Vocational Training and Employment Promotion (OFPPT), Morocco's primary public vocational training operator with 368 institutions, has implemented initiatives to address the skills gap in the EV sector.[71,72] A key initiative is the creation of "Cities of Professions and Skills" (Cités des Métiers et des Compétences - CMC), which provide state-of-the-art infrastructure and training facilities. Located in regions such as Tamesna, these centres deliver comprehensive training programs with technical and soft skills.

The private sector contributes to the skill-formation efforts. Leading automotive companies have partnered with educational institutions to create tailored training programs that meet industry-specific requirements through collaborations. The Renault Group collabourates with local universities and vocational training centres to offer students internships, apprenticeships, and hands-on training opportunities. These programs emphasize EV technology, battery management systems, and sustainable manufacturing practices, ensuring that trainees gain practical experience and are prepared to contribute effectively to the growing EV sector. Similarly, the PSA Group has established an "OpenLab" initiative dedicated to research on sustainable mobility. The project is a collaboration with five Moroccan universities, two American universities with campuses in Morocco, and other local educational institutions. OpenLab focuses on electric mobility, renewable energy, and future logistics, offering students hands-on experience and access to advanced research and development facilities. A key objective of the initiative is to develop electric powertrains tailored to the African market, while supporting the advancement of ecological and economical energy solutions.[73]

Universities are another central actor. Key initiatives include the Batteries Center of Excellence at the Private University of Fez, led by Moroccan scientist Rachid Yazami, focusing on battery innovation critical to electric mobility. The International University of Rabat's School of Aerospace and Automotive Engineering emphasizes R&D in EV technologies and sustainable mobility, collabourating with global institutions. Additionally, Hassan II University in Casablanca, in partnership with CENNTRO Morocco, is working on EV technology development to strengthen Morocco's capabilities in sustainable transportation. Further research addresses behavioural, political, and social challenges related to EV adoption.[74,75] IRESEN (the Research Institute for Solar Energy and New Energies), another relevant actor, leads research on infrastructure needs and smart grids.[76]

5.4 KEY CHALLENGES

Despite significant progress in Morocco's EV sector, growth and competitiveness are contingent on addressing several challenges. One of the most pressing concerns is the country's dependence on FDIs and technology transfers. While partnerships with European and Chinese manufacturers have accelerated sectoral establishment, they also leave the industry vulnerable to external economic fluctuations and shifting geopolitical dynamics. A homegrown innovation ecosystem and enhanced domestic know-how can help mitigate some of these risks; however, the dominance of foreign ownership constrains local decision-making authority and strategic autonomy.

These issues are further exacerbated by the limited domestic demand for EVs, as offtake remains primarily export-driven and therefore vulnerable to external market developments. For many Moroccan consumers, EVs are perceived as impractical compared to conventional vehicles, with their appeal largely geared toward export markets in wealthier regions with stricter environmental regulations. High upfront costs, insufficient charging infrastructure, and concerns over reliability continue to deter local uptake. Addressing this disconnect between domestic market conditions and policy ambitions—such as through targeted measures to improve affordability—could stimulate local demand, but would likely entail significant fiscal and institutional costs. Aside from behavioural and socioeconomic factors, infrastructure readiness remains a constraint for domestic EV adoption. Geographic disparities in the availability of charging stations, coupled with challenges in grid integration, further compound the issue.

Global supply chain vulnerabilities add another layer of complexity. The COVID-19 pandemic and geopolitical tensions have exposed the fragility of international supply networks, making it more difficult to secure critical components for EV production. Morocco also faces increasing competition from emerging producers, particularly China, alongside protectionist policies in key export markets. Given the limited domestic offtake, effective hedging strategies will be essential to ensure long-term sectoral resilience.

5.5 LESSONS LEARNED

KEY LESSONS

GOVERNMENT SUPPORT AS A DRIVER OF GROWTH
Robust governmental programs like the Industrial Acceleration Plan (PAI) and the New Development Model (NDM) have been instrumental in shaping Morocco's EV sector. These frameworks have attracted foreign investment, strengthened local manufacturing capabilities, and provided the regulatory and financial infrastructure for growth.

STRATEGIC ASSETS AND FOREIGN INVESTMENT
Morocco's strategic use of its free trade agreement with the US, its geographic position, and its success in attracting foreign investments highlight the role of focussing on favourable international partnership setups and strategic assets.

LOCALISED PRODUCTION AND SUPPLY CHAIN RESILIENCE
Building a sectoral ecosystem, e.g., simultaneously expanding into batteries and mining, has decreased (though not nullified) supply-chain risks and boosted sectoral resilience. Nonetheless, reliance on critical components, FDIs, and overseas offtake limits resilience vis-à-vis external factors.

WORKFORCE DEVELOPMENT AS A PILLAR
The establishment of specialized training centres, such as the IFMIA, and broad partnerships with universities and private companies have contributed to workforce readiness. Programs targeting EV-specific skills are essential to keep pace with sectoral demands. Further investment in advanced technical training and re-skilling initiatives will remain critical.

DOMESTIC OFFTAKE NEEDS INFRASTRUCTURE—AND SUPPORT
Domestic manufacturing does not automatically translate into domestic offtake. Infrastructure upgrades—such as the expansion of charging stations currently underway in Morocco—are essential. However, demand for high-cost products like EVs remains limited if socioeconomic conditions and consumer preferences do not evolve in parallel. While both infrastructure and demand-side barriers can be addressed, doing so may involve substantial expenditure.

INFRASTRUCTURE AND TECHNOLOGY

EV CHARGING INFRASTRUCTURE
The ongoing expansion of charging stations across Morocco demonstrates the government's commitment to supporting EV adoption. However, gaps remain in ensuring a fully integrated and renewable energy-powered infrastructure that meets projected demand.

TECHNOLOGICAL INNOVATION IN BATTERY MANUFACTURING
Morocco's growing EV battery sector, supported by projects like Gotion High-Tech's gigafactory, reflects the importance of continuous investment in R&D. Advances in battery efficiency and recycling methods will be critical to enhancing sustainability and competitiveness.

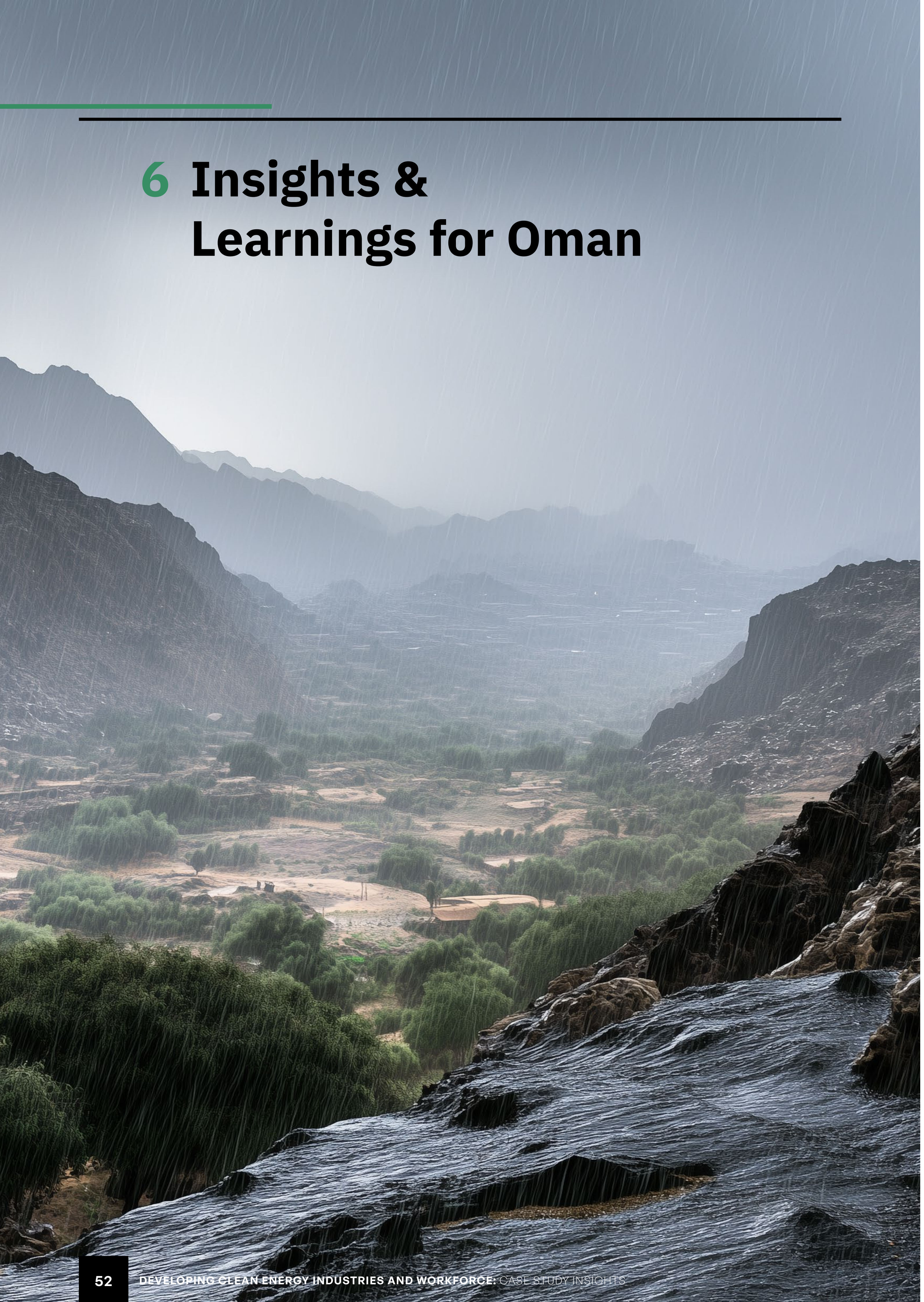
MARKET AND WORKFORCE

OVERCOMING CONSUMER HESITANCY
Consumer demand for EVs in Morocco remains limited due to high costs, insufficient incentives, and cultural preferences for conventional vehicles. Policies aimed at affordability, coupled with public awareness campaigns, will be vital in encouraging adoption.

WORKFORCE TRANSITION AND SKILLS ALIGNMENT
The Moroccan EV sector has benefited from robust vocational training programs and partnerships with private companies. However, scaling these initiatives to meet future industry needs will require a stronger focus on advanced manufacturing, grid integration, and battery technology skills.

CIRCULAR ECONOMY IN BATTERY PRODUCTION
Addressing the environmental challenges of battery production and disposal is essential for Morocco's EV sector. Developing battery recycling facilities and sustainable manufacturing practices will mitigate ecological impacts.

NON-FINANCIAL IMPACTS
For Morocco, establishing green industries is not solely an economic endeavour; it also supports green diplomacy and broader strategic objectives. These strategic gains can outweigh financial costs and represent a key source of value for the development of green sectors.



6 Insights & Learnings for Oman

6.1 CASE STUDY SAUDI ARABIA

1 Large parallels allow Oman to draw strategic lessons from Saudi Arabia

Given the similarities in both countries' economic contexts as producer economies, Saudi Arabia's case presents the most relevant comparison to Oman. Like Oman, Saudi Arabia has historically not prioritised the development of sectoral ecosystems and instead focussed on fragmented parts of value chains and rent generation. However, recent shifts in focus towards establishing these chains, particularly with an emphasis on employment and socioeconomic development, align closely with Oman's own strategic goals. This parallel makes Saudi Arabia a valuable case study from which Oman can draw insights.

2 Relying on top-down governance in sector development—and on existing networks

Both Saudi Arabia and Oman share a tendency for top-down, government-led approaches in sector development. This method has been prominent in Saudi Arabia's efforts to construct sectors and is also the dominant narrative in current undertakings to broaden the country's economic structure. In this case, the sector's domestic success is less a question of external factors and more one of the intense government support behind the sector.

While EV and battery production are relatively new sectors, the broader automotive industry in Saudi Arabia is not entirely new. The sector is being developed with partial integration into existing industrial structures, though know-how and supply chain integration remain limited. Oman can consider this gradual approach as a potential model, recognising that entirely new sectors may face greater challenges in the absence of foundational industry support.

3 Government support in Saudi Arabia highlights the need for careful financial planning in Oman

Saudi Arabia's government has played a central role in subsidising the manufacturing sector, forming joint ventures, and making substantial investments. These efforts extend beyond battery electric vehicle production to cover the broader value chain, including research and development. However, one of the main challenges lies on the demand side, where significant direct or indirect subsidies are likely to be required to stimulate uptake.

For Oman, the key lesson is to approach such a model with caution. While establishing new sectors is possible, it can become prohibitively expensive if both supply and demand require sustained subsidisation. Oman should prioritise sectors characterised by stable, intrinsic, and secure demand to enhance cost-efficiency and reduce reliance on public expenditure. In particular, the often-tempting strategy of using publicly owned companies to artificially generate demand is economically questionable and should not serve as the primary driver. While sectoral targets might be achieved, they would come at a high hidden cost. Long-term financial sustainability must remain a core consideration. Focusing on sectors with inherent demand stability can reduce the need for extensive demand-side support and lead to more economically viable sector development.

4 Enhancing existing education programs more important than creating new ones

Saudi Arabia anticipates a notable, though not exceptional—given the size of the country—increase in labour demand from the new sector. The workforce required is being developed through existing educational programs at prominent Saudi universities, where batteries and electric vehicles are already integrated into general curricula. Additionally, specialised training is provided by academies and professional associations.

Notably, Saudi Arabia's approach to workforce development focusses less on creating entirely new educational streams but rather enhancing existing ones with targeted additional training. While, in the case of Saudi Arabia, skilling the workforce is an issue that is not entirely resolved, Oman should adopt a similar approach by relying on existing educational capacities and augmenting them with specialized training as needed. This method is cost-effective and shows there is no need to "reinvent the wheel" in education and workforce development.

5 Strategic foreign investments unlock critical knowledge and resources

A critical component of Saudi Arabia's strategy has been acquiring knowledge and expertise through strategic investments in foreign companies and knowledge transfer from a limited number of foreign experts. This approach has been instrumental in integrating the sector into existing supply chains, including the automotive industry and raw materials.

For Oman and its investment bodies, targeted and strategic investments in foreign companies can unlock essential know-how, access to supply chains, and other critical resources. This strategy, which was also successfully employed by China during its period of intense growth, can contribute to Oman's efforts to develop new sectors without relying solely on domestic expertise or domestically available supply chains.

6 Conclusions: Weigh sector success against the costs of government intervention

The success of Saudi Arabia's new sectors appears likely, albeit potentially at a high cost. Oman should carefully assess the financial sustainability of similar efforts and weigh anticipated benefits against the associated expenditure. The key takeaway is the importance of selecting sectors with stable demand and ensuring efficient resource allocation.

Oman can also draw lessons from Saudi Arabia's approach to education and workforce development by enhancing existing programmes rather than creating new ones. Similarly, targeted investments in foreign companies can provide access to essential knowledge and supply chains, supporting the development of new sectors.

In summary, Oman should prioritise sectors with secure demand, avoid reliance on extensive subsidies, build on existing educational and industrial capacities, and pursue strategic foreign partnerships to address critical capability gaps.

6.2 CASE STUDY GERMANY

1 Solar Energy is a Key Industry with Risks

Germany's experience with solar energy is particularly relevant for Oman, which is currently considering the establishment of solar module manufacturing. While solar energy presents a promising opportunity, Germany's case also highlights potential risks. The German solar industry initially expanded through demand-side policies such as feed-in tariffs. However, these measures did not prevent the decline of domestic manufacturing, as foreign competitors—particularly from China—capitalised on the subsidies to enter the market.

For Oman, this underscores the importance of designing support mechanisms carefully. While solar module manufacturing may appear attractive, there is a risk that subsidies could inadvertently benefit foreign suppliers rather than strengthening domestic industry. Any support provided should aim not only to stimulate market growth but also to build competitive domestic capabilities.

2 Dependence on foreign markets requires foresight and monitoring

Germany's solar manufacturing industry suffered significantly when subsidies in key export markets were reduced. Its reliance on foreign markets for growth left the industry vulnerable to external policy changes. Dependence on foreign markets is a double-edged sword: while it can drive growth, it also introduces considerable risks that must be carefully managed. For Oman, understanding and mitigating these risks is essential.

To avoid similar pitfalls, Oman should: (i) proactively assess the risks associated with export dependence; (ii) continuously monitor foreign policies, subsidies, and market access conditions; and (iii) develop strategies to respond to shifting global dynamics, including contingency plans for changes in policy, subsidies, or competitive pressures. Such preparedness will be critical to maintaining long-term stability in the industry.

3 Competitor strategies must be monitored

In addition to domestic policy shifts, the decline of Germany's solar manufacturing sector was compounded by increased subsidisation among competing producers, particularly in China. As domestic support mechanisms were phased out, China expanded its subsidies for solar module production, contributing to a significant shift in global market shares. This combination of reduced domestic incentives and intensified external competition created a challenging environment for Germany's industry.

For Oman, the experience underscores the importance of monitoring not only developments in import markets but also the policy and industrial strategies of key competitors. Sustained competitiveness will require close tracking of global market dynamics, including changes in cost structures, trade policies, and production incentives. A comprehensive understanding of both external risks and strategic responses by other producers will be essential to inform effective industrial policy design.

4 Identify Niches Instead of Competing Head-on

Germany's struggle against China's dominance in solar module manufacturing underscores the importance of finding strategic niches rather than competing directly with larger, more powerful economies. Despite being an economic powerhouse, Germany could not compete with China's sheer scale and capacity in this sector. This dynamic is particularly relevant for Oman, a smaller market compared to its GCC neighbours and other regional players.

Oman should focus on identifying and occupying niches where it can excel without facing overwhelming competition. This requires closely monitoring the competitive landscape and understanding where Oman's strengths lie. By strategically positioning itself in sectors where it can leverage its unique advantages, Oman can carve out a space for itself in the regional and global markets without trying to outcompete economically stronger countries.

5 Repositioning within the value chain is possible, but requires existing capacities

In Germany, employment in the solar sector gradually shifted from manufacturing to development, illustrating the potential for repositioning within a value chain. This transition enabled Germany to retain a strong role in the sector, despite the decline of domestic manufacturing. However, this shift was facilitated by Germany's pre-existing industrial and technological infrastructure—an advantage that Oman may not currently possess.

For Oman, repositioning within the solar value chain remains a potential strategy but may be more difficult to implement in the absence of comparable foundational capacities. Solar project development may be more feasible to sustain than manufacturing, particularly from a regulatory perspective. Nevertheless, regional competition—such as from Saudi Arabia's ACWA Power—underscores the need for Oman to define clear strategic advantages and consider how best to safeguard its role in the sector.

6 Vocational training is more important than specialised programs

Germany's solar energy transition relied primarily on its well-established vocational training and apprenticeship system, rather than on specialised university programmes. This underscores the importance of practical, hands-on training over purely theoretical education. Vocational training equipped the workforce with the skills needed to adapt to and thrive in the evolving solar industry, highlighting the value of a strong vocational education system.

While some specialised university degrees do exist, the majority of engineers in the sector come from generalised programmes—such as electrical, industrial, or energy engineering. Notably, Germany's generalised university system is characterised by a high degree of internal selection and specialisation within programmes. This suggests that flexibility and quality within general programmes matter more than the proliferation of narrowly specialised degrees.

For Oman, two key implications emerge: (i) Vocational training institutions may be more critical than universities in supporting the renewable energy sector. Many jobs in this field do not require university degrees but rather vocational skills. Enhancing vocational training—potentially by integrating classroom instruction with practical apprenticeship models, as in Germany—should be a priority. (ii) Specialised university programmes can add value, but greater impact is likely to come from improving, modernising, and increasing the flexibility of generalised engineering curricula.

7 Proactive supply chain monitoring is essential

Germany's growing dependence on Asian suppliers—particularly China—for raw materials and solar modules introduced both economic and geopolitical risks. These vulnerabilities were not addressed early enough, making mitigation more difficult at a later stage. Germany's experience highlights the importance of managing supply chain dependencies proactively to avoid exposure to external pressures.

For Oman, this underscores the need to take early action in identifying and monitoring supply chain dependencies. By mapping potential risks and vulnerabilities, Oman can implement preventive measures to mitigate disruptions and reduce long-term exposure. Such measures will be essential to ensure the resilience of Oman's renewable energy sector amid global market volatility and geopolitical uncertainty.

8 Strategic Partnerships Can Share Risks and Resources

To mitigate risks and share resources, strategic partnerships and alliances are essential. Germany's experience shows that collaboration can be key to navigating complex markets. For Oman, forming partnerships both within the GCC and internationally (e.g. piggybacking on historical lines, such as Pakistan or East African nations) can provide the support needed to thrive in the renewable energy sector.

6.3 CASE STUDY NETHERLANDS

1 Leveraging niche markets in a competitive region and aligning sector development with goals

The Netherlands, despite being surrounded by larger economies, successfully identified and developed niches where it could compete effectively. This ability to find and capitalise on niches demonstrates the importance of strategic positioning in sectors where Oman can excel, without needing to directly challenge larger neighbours in the GCC.

Furthermore, the Netherlands' development of the wind energy sector was driven by a national commitment to sustainability and reducing reliance on fossil fuels. This alignment with broader national goals provided the sector with strong backing and contributed to its success. Oman can draw a parallel by ensuring that the sectors it chooses to develop are closely tied to its own national objectives, particularly Vision 2040. By aligning sector development with its broader national goals, Oman can ensure these industries receive consistent support, making it easier to secure resources and drive long-term growth.

2 Comprehensive job creation along the value chain

The Dutch wind energy sector is a strong example of how a well-developed industry can generate jobs across the entire value chain. From manufacturing to maintenance, the sector offers employment opportunities at every level, demonstrating that a holistic approach to job creation is both possible and beneficial. For Oman, this model suggests that building capacity across the entire value chain, rather than focusing on just one part, can be a viable strategy for ensuring employment opportunities.

3 Building on existing engineering expertise and tacit knowledge

The Netherlands began developing its wind energy sector by leveraging more conventional engineering fields, such as mechanical engineering. As the sector grew, more specialized personnel were trained in areas like grid connection and turbine maintenance. This gradual approach allowed the industry to grow without the need for an entirely new workforce from the start.

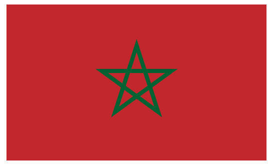
A significant portion of the workforce in the Dutch wind power sector transitioned from the oil and gas industry, showing that tacit knowledge can be effectively transferred across sectors. This demonstrates that Oman's existing workforce in conventional energy could be a key asset in building its renewable energy sectors.

While there are renowned specialised programs in the Netherlands, the majority of the workforce in the wind energy sector was developed through broad general programs and standard training. This highlights the importance of maintaining a strong foundation of generalized education, with specialized programs serving as a complement rather than the core.

For Oman, this means that existing engineering talent, particularly from the oil and gas sectors, can be a valuable resource as the country expands renewable energy. By gradually introducing specialized training, Oman can ensure a smooth process without overwhelming its educational systems. While formal training remains important, Oman should also focus on harnessing tacit knowledge within its existing industries. Strengthening broad-based education and training that can support multiple sectors, while using specialized programs as targeted enhancements is a preferrable option.

4 Flexibility in certification and industry involvement

In the Netherlands, non-state actors, such as industry associations, played a crucial role in bridging skills gaps by offering certifications and training programs. Flexibility in certification, particularly in the early stages of sector development, allowed the wind energy industry to grow more rapidly. For Oman, encouraging industry associations to take an active role in workforce development and allowing for flexible certification processes can help ensure that emerging industries have the agility needed to establish themselves quickly and effectively.



6.4 CASE STUDY MOROCCO

1 Morocco's financial model is a strategic approach Oman can investigate

Morocco's industrial expansion, particularly in the automotive sector, is a result of a balanced financial model that combines targeted industrial policies, foreign direct investment (FDI), and international development funding. FDIs did not take place in a vacuum but were carefully groomed through strategic policies, including tax incentives, sector-specific clusters, and financing from institutions like the African Development Bank.

The Moroccan case therefore differs from the Saudi model insofar that the has been largely driven by foreign direct investment (FDI) instead of public money, making it primarily a private sector initiative. This approach offers advantages, including reducing the financial burden on the Moroccan government, and ensuring that the products developed are market-relevant, as evidenced by the export success of car manufacturing in Morocco.

However, it is important to recognise that this success was not solely a bottom-up phenomenon. Morocco also implemented targeted industrial policies, such as loans from the African Development Bank, tax incentives, and the creation of sector-specific clusters, which played a crucial role in attracting FDI.

Oman could investigate the benefits of adopting a similar approach of balancing own public investment, development funding, and foreign direct investment to develop new sectors without overburdening government finances. Nonetheless, it is important for Oman to ensure that the economic benefits are balanced and that profits remain within the country. Oman can explore this model, focusing on attracting FDI to drive job creation and economic growth. Yet, overall, ensuring sufficient participation of private actors ensure that the sector is developed in a way that is relevant to the market and offers long-term financial sustainability.

2 Anticipating strategic geographic positions in climate policy can attract investment

Morocco's proactive stance in aligning with the European Union's Carbon Border Adjustment Mechanism (CBAM) highlights the importance of anticipating global policy shifts. By strategically positioning itself, Morocco has attracted significant investment in energy-intensive industries. Oman can similarly leverage its geographical and industrial advantages, preparing for future global climate policies and enhancing its competitiveness in sectors like clean steel and aluminium.

3 Growing vertically along the value chain strengthens industries

Morocco's success in integrating industries vertically, particularly in the automotive sector, where battery production and potential lithium conversion are part of the value chain, has strengthened its industrial base. This vertical growth enhances both integration into the national economy and external economies of scale. Oman can benefit from a similar approach by ensuring that new sectors are connected to and grow along their value chains, enhancing both resilience and economic impact.

Morocco's expansion into electric vehicles and battery production builds on its existing automotive industry, demonstrating the advantages of enhancing established sectors and building integrated ecosystems. Oman can apply this lesson by focusing on expanding its strong sectors, particularly in renewable energy and advanced manufacturing, rather than starting new sectors from scratch

4 Leveraging free trade agreements can boost economic growth

The strategic use of free trade agreements, as seen in Morocco's automotive and battery industries, is a key lesson for Oman. Morocco has successfully used its free trade agreement with the United States to enhance its global market position. Although recent moves by the U.S. government have complicated global trade, Oman should leveraging existing agreements and explore competitive edges in trade.

5 A mixed approach to training ensures the inclusion of all actors

A significant aspect of Morocco's approach has been the emphasis on vocational training and workforce development tailored to the automotive sector's needs. This initiative has involved collaboration between the government and private sector, ensuring that the workforce is equipped with the necessary skills to meet industry demands. The success of these efforts highlights the importance of targeted education and training programmes in supporting industrial growth. For Oman, adopting a similar strategy by focusing on vocational training and creating industry-specific education programmes could be beneficial in developing a skilled workforce that supports emerging sectors.

6 Balancing workforce development with private sector needs ensures readiness

The Moroccan case illustrates the effectiveness of balancing vocational training with R&D initiatives, supported by both public and private sector partnerships. Oman can benefit from this approach by fostering collaborations that align workforce development with industry needs, ensuring that its workforce is well-prepared for both current and future demands.

6.5 OVERARCHING CONCLUSIONS: INDUSTRIAL, LABOUR, AND EDUCATION POLICY FOR ENABLING SUSTAINABLE SECTORS

The various insights presented in this report feed into two distinct policy tracks. The first concerns industrial and economic policy, particularly regarding the establishment and support of new sectors. The second relates to labour market and education policy.

Opportunities and Risks in Sector Development

With respect to economic and industrial policy, the joint benchmarking overview reveals both opportunities and potential pitfalls in creating new sectors. All case studies demonstrate substantial potential—not only for economic and financial gains but also for job creation and enhanced strategic positioning. However, although any sector can technically be developed with sufficient financial backing, a financially and economically sustainable approach requires careful consideration of which sectors to prioritise and how to integrate them effectively.

A key consideration is the development of value and supply chains in a holistic manner, rather than focusing on isolated market segments. This approach ensures supply chain security and maximises efficiency gains from a broader ecosystem. At the same time, sectoral growth should be guided by genuine demand. Permanently subsidising both supply and demand is financially unsustainable, yet industrial policy is often essential for directing existing domestic demand toward emerging sectors.

For instance, Oman's growing need for solar energy should be met through local photovoltaic (PV) development companies, with an eye toward integrating domestic solar panel manufacturing into the supply chain. Hydrogen could likewise complement Oman's existing energy-related industries. However, if hydrogen production remains narrowly focused on export markets, it may be vulnerable to shifting foreign demand—even though long-term offtake agreements can provide some stability in the mid-run, they do not necessarily guarantee resilience in the short or long term. Exploring domestic hydrogen applications could strengthen overall sustainability, but this depends on a clear assessment of immediate and lasting local needs.

Energy efficiency provides another illustrative case. Enhanced measures can remain competitive if policymakers require that energy efficiency audits and related services be undertaken by local firms. Oman's high electricity consumption—alongside rapid building expansion and urbanisation—creates a degree of inherent demand for such solutions, making this a viable sector for sustainable development.

Long-Term Competitiveness and Strategic Positioning

Long-term competitiveness is another critical factor. A sector that appears advantageous in the short term may not remain so over time, as shown by the decline of Germany's solar manufacturing industry. Industrial policy should therefore anticipate future competitiveness and integrate measures such as local content requirements or structured demand policies to secure resilience. However, these measures must be carefully designed to avoid creating artificial, unsustainable demand.

Beyond economic considerations, Oman's competitive positioning can also be shaped by non-economic factors. The country's free trade agreement with the U.S., its strategic geography, and its historical ties to East Africa and South Asia may provide unique advantages that warrant further exploration.

Ultimately, economic policy and public investment strategies must align with broader economic goals and anticipatory policymaking to ensure long-term sectoral resilience. A narrow focus on short-term financial gains risks overlooking potential disruptions to existing industries and investments, particularly in the face of major domestic or international shifts. Identifying priority sectors should therefore be a highly coordinated effort, focused on establishing robust ecosystems and securing substantial portions of supply and value chains, while ensuring sustainable demand both domestically and in key export markets.

Ensuring Workforce Readiness

The realisation of broader economic goals is contingent on a carefully coordinated alignment between economic policymaking and labour and education policy. The case studies have demonstrated that, beyond the necessity of strong partnerships between government, the private sector, and education providers, there are also clear lessons regarding how education and workforce development should be structured. While specialised programmes tailored to new sectors—such as hydrogen or solar energy—can be valuable additions to existing strategies, two fundamental pillars remain central to equipping the next generation with the right qualifications: the modernisation and continuous updating of general education programmes, and a stronger emphasis on vocational training.

Successful examples from Germany and the Netherlands highlight how updating existing university programmes to reflect new technologies, rather than creating entirely separate degrees, can be highly effective. For instance, disciplines such as electrical engineering, chemical engineering, or mechanical engineering can integrate modern technologies like photovoltaics or hydrogen applications. This requires both sufficient incentives for universities to update curricula continuously and a regulatory framework that permits greater flexibility. Accreditation processes and regulatory requirements are essential for quality assurance and standardisation; however, if overly rigid, they risk becoming barriers to keeping educational programmes aligned with technological and industrial developments. A more dynamic approach—where universities can update curricula and integrate emerging technologies without excessive procedural hurdles—would not only maintain academic standards but also ensure that graduates acquire relevant, up-to-date skills.

Strengthening Vocational Training and Workforce Transitions

Vocational training is also vital, since many new jobs in clean energy and the green economy will be for skilled technicians rather than university-trained engineers. Germany and the Netherlands both show that vocational training should not be limited to classrooms but must involve in-field and on-the-job components, such as apprenticeships. Two key challenges arise here. First, training opportunities must be expanded through close collaboration with companies that require future workers and can also provide practical learning. Second, there is a workforce bottleneck in the early stages: skilled technicians are needed to build up the sector, yet the sector is needed to produce skilled technicians. One potential solution is to introduce time-limited contracts for foreign skilled workers whose primary role is to train local staff, rather than filling long-term positions. Ensuring that this remains a temporary measure is crucial so that a domestic workforce can take over as soon as possible.

Although education and labour policies must be well-prepared, they play a subsequent role to industrial policy. In practical terms, workforce development strategies can only be implemented effectively once there is clarity on when and how new sectors will emerge. This points to the need for a structured yet flexible coordination mechanism that brings together investors, private sector actors, and policymakers, alongside labour and education representatives. Even if public financing—from sources such as Oman's investment authority—plays a central role, broad participation of domestic and international private actors is crucial. The challenge is to balance central coordination and strategic incentive-setting with an openness that neither over-regulates nor assumes too much about private-sector engagement.

Ensuring Flexibility in Workforce Policies

Establishing new sectors often requires a balanced mix of foreign direct investment and government-led public investment. These industries tend to be capital-intensive, but the economic, financial, and social dividends can be significant. The Dutch example, in particular, shows that new sectors are capable of absorbing existing jobseekers—provided that workforce transitions are managed flexibly and do not create excessive barriers to job-shifting. This underscores the importance of regulatory flexibility in workforce development. Labour and education policies should focus on upskilling and reskilling job shifters rather than relying on rigid qualification frameworks. Many roles in both engineering and administrative fields share overlapping skills, so avoiding bureaucratic entry barriers is essential. Instead, emphasis should be placed on practical, applied training and on-the-job experience. Concerns over diminished quality due to greater flexibility have largely proven unfounded, as seen in both Germany and the Netherlands. In fact, such flexibility is often a prerequisite for a smooth transition into emerging industries.

All of this points to the need for joint action, anticipatory foresight, and a realistic yet ambitious approach. Labour and education policy must be aligned with industrial strategy in a way that promotes workforce readiness, regulatory flexibility, and resilience in the face of sectoral change. Learning from international best practices, while carefully tailoring policies to Oman's specific requirements, can lay the groundwork for new economic opportunities—ensuring both sustainability and long-term competitiveness.

Abbreviation Table

Abbreviation	Definition
US$	US Dollar
AI	Artificial Intelligence
BSW	German Solar Industry Association
CAGR	Compound Annual Growth Rate
CBAM	Carbon Border Adjustment Mechanism
CMC	Cities of Professions and Skills *(Cités des Métiers et des Compétences)*
CO_2	Carbon Dioxide
COVID-19	Coronavirus Disease 2019
EEG	Renewable Energy Sources Act *(Erneuerbare-Energien-Gesetz)*
EU	European Union
EV	Electric Vehicle
FDI	Foreign Direct Investment
FIT	Feed-in tariff
GCC	Gulf Cooperation Council
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIB	Gulf International Bank
GSBP	The Green & Smart Building Park
GW	Gigawatt
GWh	Gigawatt-hours
GWO	Global Wind Organisation
HCDP	Human Capability Development Program
ICE	Internal Combustion Engine
ICEV	Internal Combustion Engine Vehicle
IEA	International Energy Agency
IFMIA	Institut de Formation de l'Industrie Automobile
IHK	The German Chambers of Industry and Commerce
IRA	Inflation Reduction Act
IRESEN	Research Institute for Solar Energy and New Energies
KAEC	King Abdullah Economic City
KOICA	Korea International Cooperation Agency
KSA	The Kingdom of Saudi Arabia

Abbreviation	Definition
kW	Kilowatt
kWh	Kilowatt-hour
LFP	Lithium-phosphate-iron
Li-ion	Lithium-ion
MENA	Middle East and North Africa
MW	Megawatt
NDM	The New Development Model
NIDLP	National Industrial Development and Logistics Program
NZIA	Net Zero Industry Act
O&M	Operations and Maintenance
OEM	Original Equipment Manufacturer
OFPPT	The Office of Vocational Training and Employment Promotion
PAI	Industrial Acceleration Plan
PIF	Public Investment Fund
PV	Solar Photovoltaic
R&D	Research & Development
REPowerEU	Renewable Energy Power European Union
RVO	The Netherlands Enterprise Agency
SABIC	Saudi Basic Industries Corporation
SASO	Saudi Standards, Metrology, and Quality Organisation
SDE++	Stimulation of Sustainable Energy Production and Climate Transition Incentive Scheme *(Stimulering Duurzame Energieproductie en Klimaattransitie)*
SGI	Saudi Green Initiative
SUV	Sports Utility Vehicle
TU Delft	Delft University of Technology
TWh	Terawatt-hours
UAE	United Arab Emirates
UIR	The International University of Rabat
UM6P	Mohammed VI Polytechnic University
US	United States
V2G	Vehicle-to-Grid
VAT	Value-Added Tax
VET	Vocational Education and Training

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