Leveraging Fossil Fuel Capabilities for Clean Energy Transitions

Assessment of opportunities in Oman

International Energy Agency

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Abstract

As the global energy transition accelerates, all energy sectors will experience significant transformations, affecting how energy is produced and consumed. This implies a changing role of hydrocarbon fuels such as oil and natural gas. While these fuels will continue to play a role in energy systems, notably in large energy demand centres, all scenarios point to a gradual decline in demand for both oil and gas. As a result, producer economies such as Oman, whose economic development has been to a significant part enabled by a thriving oil and gas industry, have been exploring opportunities to adapt their economic model to the emerging energy economy we are observing.

Nevertheless, it remains important to appreciate the role producer economies play in the global energy transition. While this transformation involves a wide range of challenges to secure future revenues and employment opportunities for citizens, the energy transition also holds with it a range of opportunities. Oman's assets, infrastructure, and skills were once developed in the service of an omnipresent oil and gas industry. Today, the objective of this study is to lay out the opportunities of repurposing these advantages in the services in developing clean energy supply chains in Oman, led by solar PV, wind and low-emission hydrogen where significant economic value is expected to lie as the global economy decarbonises.

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Acknowledgements, contributors and credits

This study was designed and co-authored by Abdullah Al-Abri and Nadim Abillama. Other IEA colleagues who contributed to this work include Simon Bennett, Jose Miguel Bermudez Menendez, Christophe McGlade, Elisa Asmelash and Yasmina Abdelilah. Also, a special thank you goes to Gaia D'Alfonso, Angelina Flora Gutierrez and Gaia Guadagnini for their support in drafting and editing.

Ali Al-Saffar, Amir Lebdioui and Pavel Bilek (consultants) co-authored the study and contributed to this work as independent industrial analysts.

This publication was produced with the support of the Japanese Ministry of Foreign Affairs (MOFA) under the IEA's Clean Energy Transitions Programme.

The IEA would also like to thank the following senior government official and experts who reviewed and provided feedback to the report:

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Thanks also to the IEA Communications and Digital Office (CDO) for their help in producing the publication, especially to Jethro Mullen, Astrid Dumond, Clara Vallois, Poeli Bojorquez and Aya Abu-Shaqra.

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Executive summary

Oman's oil and gas industry holds significant advantages as the country accelerates its economic diversification in which clean energy can play a central role

Oman, a prominent producer economy heavily reliant on fossil fuels for export earnings and government revenue, is embarking on a bold and strategic mission: a dual transformation towards energy diversification and economic resilience. The overarching goal is to reduce dependence on fossil fuels and chart a course towards a sustainable and dynamic future. This endeavour extends beyond energy alone, but certainly resting on the bedrock of a well-functioning and sustainable energy ecosystem.

Oman possesses a unique opportunity to harness its wealth of expertise and productive capabilities in fossil fuels as a launchpad into the promising world of new energies and innovative energy partnerships. A strategy that builds on these potential advantages could help mitigate the inherent risks and attract the investment needed for transition while positioning Oman as a competitive frontrunner in the realm of new energy solutions. This strategic shift could also enable the country to strategically weave clean energy supply chains into its economic fabric, capitalising on a spectrum of diversification opportunities spanning upstream, where local goods and services can fuel clean energy technology, midstream and downstream industries, where low-emission manufacturing thrives.

Repurposing a wide spectrum of oil and gas infrastructure and skills is pivotal to this transformation. Oman can leverage its strengths in energy project design, chemical and thermodynamic engineering, and site preparation to construct a distinctive portfolio encompassing both fossil fuel and emerging energy sectors. Key assets with high transversality potential include gas pipelines (suitable for hydrogen transport) and refinery and storage facilities, followed by reservoirs for carbon storage and associated infrastructure. Challenges remain, especially in adapting existing gas pipelines for hydrogen transport, requiring technical finesse.

To guide workforce redeployment and skilling for low-emission industries and operations, Oman can draw on global and local best practices. While re-skilling and talent migration are feasible across the oil and gas value chain, particular

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disciplines, including geosciences, supply chain logistics, refining, and chemical engineering, demonstrate high redeployment potential.

A comprehensive policy toolkit is indispensable to bolster linkage development, encompassing four critical domains: a long-term vision with sectoral targets, innovative policies supporting clean energy supply chain evolution, incentives and supportive mechanisms, and an institutional framework facilitating seamless policy coordination. We refer to linkages here as the overlap between existing infrastructure, assets and skills that can be transferred to support clean energy development. The effectiveness of this policy toolkit will be the linchpin for the success of linkage development, necessitating cohesive and resolute policy coordination.

Fostering linkage development and orchestrating a comprehensive shift from fossil fuels to clean energy supply chains demand proactive coordination across energy, industrial, fiscal, skills development, and labour market policies. This strategic policy coordination holds the potential to catalyse the emergence of robust clean energy industries characterised by substantial forward and backward linkages. In turn, this aligns with Oman's national objective of achieving net zero emissions by 2050, providing a buffer against potential fluctuations or declines in oil and gas exports and tax revenues while simultaneously generating sustainable employment opportunities in the short and long term.

Oman must incorporate a regular feedback and review mechanism into its strategy, in the face of rapid technological and market shifts. This approach ensures agility and adaptability, positioning the nation to seize evolving opportunities in its journey toward energy diversification.

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Introduction

The twin agenda of economic diversification and energy transition for producer economies

Producer economies are those in which fossil fuels make up a substantial proportion of both export earnings and government fiscal revenues. Producer economies are characterised as pro-cyclical in economic terms. This means that such economies are vulnerable to price fluctuations and market volatilities such as those seen in the 2015 downturn and during the Covid-19 pandemic. In addition, producer economies are also subject to two more fundamental pressures: the need to reduce domestic emissions and climate vulnerabilities as well as to navigate their economies in a world that may be characterised quite soon by lower demand for fossil fuels (and fossil fuel infrastructure).

Several producer economies have therefore started to look into the twin agenda of energy transition and economic diversification to boost their macroeconomic resilience to sectoral shocks and disruptions, to reduce their domestic emissions, to diversify their investments and partnerships, and to open up new corridors for employment.

However, producer economies do not have to start from scratch, and though they have received little policy attention, opportunities exist to steer existing value chains in the oil and gas sector towards energy transition. Taking that perspective into consideration, several key questions arise regarding the ways in which producer economies can strategically embark on a low-emission energy and clean energy economy agenda:

- What are the opportunities and challenges for fossil fuel exporters in the production of clean energy including low-emission hydrogen?
- What kind of infrastructure, skills, and industrial processes can be repurposed from fossil fuel extraction operations to the clean energy supply chain?
- How can clean energy sectors support the much-needed process of economic diversification and local value addition?
- What policy tools are needed to facilitate the process of repurposing of energy capabilities?

By generating key insights into how the leading businesses in the oil and gas sector are repurposing in-house capabilities towards clean energies, this study aims to provide the first extensive mapping of the different types of linkages between fossil fuels and clean energy supply chains, with Oman's ecosystem in mind. This study also analyses policy implications for the context of Oman.

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Oman is a particularly relevant case in the context of the twin challenge of economic diversification and energy transition. Oman remains dependent on oil and natural gas as a source of exports, foreign exchange revenues, public revenues, and as source of domestic power generation. This multifaceted dependency on fossil fuels poses several challenges, not the least of which is that Oman has already a smaller share of fossil fuel resources relative to other Gulf Cooperation Council (GCC) countries, especially in terms of natural gas reserves, making the prospect of lower revenues over the mid to longer term a more realistic predicament.

Oman has embarked on an ambitious economic diversification agenda as part of the Oman Vision 2040. The design of this agenda is evidently much broader than just energy, but it rests on a well-functioning energy sector. Clean energy, and especially low-emission fuels such as hydrogen, represent a key opportunity to reduce Oman's reliance on fossil fuels as a domestic energy source for local industry, to develop new export and fiscal revenues in the medium to long-term, and to create new job opportunities.

This study explores linkages and repurposing capabilities between fossil fuels and clean energies that can have considerable business and policy implications for Oman. Fostering linkage development and a socially inclusive repurposing of capabilities from fossil fuels to clean energy supply chains development requires a multi-dimensional and proactive policy approach, along with carefully coordinated energy, fiscal, industrial, skills as well as labour market policies.

Producer economies in the face of global energy and economic paradigm shifts

The global energy (and associated economic) trade flows are undergoing major shifts wherein countries and regions prioritise domestic resources where possible in an attempt to ensure reliable supplies of energy and to limit exposure to volatile international markets. Overall, energy security concerns reinforce the rise of renewables and nuclear. In the IEA's Announced Pledges Scenario (APS), in which governments achieve all of their national energy and climate targets in full and on time, renewables increase more than four-fold in 2050 compared with 2022 levels, making up 51% of the total energy supplies worldwide. This increase is even more prominent in the Net Zero by 2050 Scenario (NZE) where renewables make up over two-thirds of the total energy supplies worldwide in 2050. These trends are shown in Figure 1.

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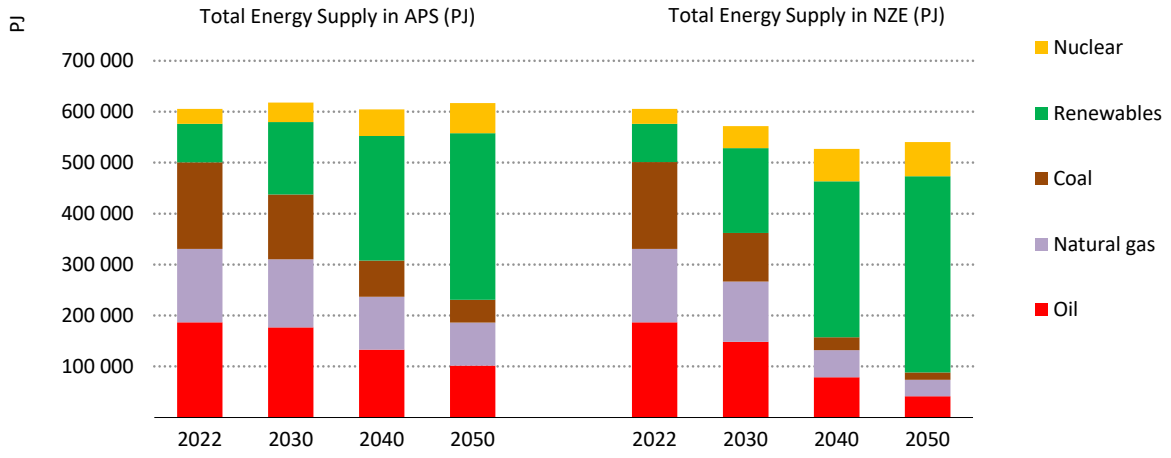
Figure 1 Total global energy supply in the APS and NZE Scenarios



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Source: IEA analysis, 2023 WEO data.

This growth in renewables and to a lesser extent in nuclear will translate in (much) lower global demand for oil, natural gas, and coal in the mid to longer terms. This lower demand can strand assets and severely impact the fiscal status of producer economies through lower incomes as a result of lower export volumes and lower commodity prices as well as greater burdens from the domestic subsidies.

In addition to the direct implications of the fuels trade, industries (such as steel) in producer economies can also be impacted by climate-related legislations and proposals in key consumer markets such as those in the United States and the European Union (for example the Carbon Border Adjustment Mechanism), which imply a change in regulations and market demand towards sustainable products. Because the ability to export is a critical feature of a country's economic development and prosperity, fossil fuel economies (such as Oman) thus need to anticipate – and adapt to – low-emission trade regulations and the implementation of sustainability standards.

These collective reasons indicate that economic diversification strategies should entail the promotion of a structural transformation towards more sustainable production models in the longer run, thereby reducing vulnerability to the effects of climate change as well as macroeconomic transition risks. In the context of a sustainable diversification strategy, clean energies and low-emission fuels such as low-emission hydrogen will be key to achieving the decarbonisation of many hard-to-abate sectors, and these features prominently in all future energy transitions projections.

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The value of repurposing capabilities for producer economies

The process of linkage development often underpins successful diversification strategies. Indeed, throughout history, nations, firms and clusters have maintained their competitive edge by repurposing their existing capabilities towards new activities. As shown by global experiences, the ability to repurpose transversal capabilities from one sector to another generates considerable benefits, including macroeconomic resilience to sectoral shocks and disruptions, diversified political partnerships, and new avenues of employment opportunities. For instance, Equinor is capitalising on its resource and expertise to (1) continue producing oil and gas but in a differentiated way (i.e., through carbon capture, utilisation and storage or CCUS as in the case of the Sleipner and Snøhvit fields in the North Sea), (2) increase operational excellence through efficiency and electrification, and (3) expand to the world of new energies. Another example is Ørsted, previously known as Danish Oil and Natural Gas (DONG) Energy, which is aggressively pushing towards the development of renewable energy sources – and, ultimately, divesting away from oil and gas operations.

Understanding how to leverage productive capabilities in the fossil fuel sector bears considerable implications for producer economies, which are highly vulnerable to transition risks. For those countries, the repurposing agenda is essentially a pathway to catch-up in sectors central to the green economy, thereby seizing emerging green windows of opportunity[1].

At the corporate level, several oil and gas companies have already started to re-evaluate their strategic responses to the global decarbonisation agenda, both to improve their financial resilience and to reposition to take advantage of new opportunities arising out of the low-emission economy. A number of those companies are reorganising as integrated energy players, which an impact on revenue streams, capital and resource allocation while their current dividend streams and market valuations still rely on their oil and gas businesses. However, there is a clear division between European and US-based companies with regards to their approach to renewable energy. The large European companies are generally expanding beyond production of fossil fuels, investing in renewable

[1] Mathews, 2018; Lee, 2019; Yap and Truffer, 2019; Lema et al. 2021.

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technologies, and moving as a result into new business areas such as electricity. US-based companies are largely maintaining a profile as providers of liquids and gases, incorporating a rising share of low-emission fuels. The expansion of clean energy operations by oil and gas companies also stems from an identification that they are best suited to compete in some segments of low-emission energy supply chains[2]. Oil and gas companies have capabilities that may be valuable for parts of a new low-emission energy system, which can also offer interesting returns in comparison with their conventional businesses.[3] For instance, for many oil and gas companies operating, CCUS when applicable and scalable, represents a natural extension of core capabilities such as managing reservoirs and pipelines.

At the country level, a repurposing agenda also entails adopting a different approach towards energy transition, not only based on clean energy deployment but also on linking energy transition with local industrial development. This holistic approach will help countries integrate low-emission value chains into the broader economic diversification agenda. For instance, with the right policy tools, the creation of a robust low-emission hydrogen production capacity can generate significant forward and backward linkages, improved cost environmental competitiveness in downstream sectors, reduced domestic gas consumption (thereby freeing up those resources for exports in international markets with a higher profit margin at current prices), and opportunities for industrial development more broadly. Such strategies are highly context specific and should be tailored to the national economic, social and political context, while taking into account pre-existing capabilities.

However, despite companies initiating internal strategies to transition and repurpose their operations, there is a lack of comprehensive studies across multiple firms that investigate the interrelationships between the fossil fuel and clean energy industries. This knowledge gap extends to the national level as well, despite the substantial macroeconomic implications for long-term sustainability. Producer economies need to embrace a more holistic approach to fostering linkages that goes beyond merely repurposing capital. It should encompass a wider array of productive capabilities, including infrastructure, expertise, skills, technology, and industrial processes.

[2] More details on this can be found further on in the surveys underpinning this study, wherein the surveyed oil and gas majors identified significant linkages with various low emission energy sources.
[3] Ibid.

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Overview of the case of Oman

Trade and energy landscapes: Multifaceted dependencies and ambitions

Oman is dependent on oil and natural gas as a source of exports, foreign exchange revenues, public revenues, and as source of domestic power generation. This multilayered dependency on fossil fuels poses several challenges, but Oman has embarked on an ambitious energy transition agenda as part of the Oman Vision 2040. Although oil and natural gas still make up the majority share of total energy supplies, plans are underway to increase the roll-out of renewable technologies. While Oman still does not exhibit a significant manufacturing sector for renewable energy value chains (solar photovoltaic, solar concentrating solar power or wind), plans and initiatives do exist to increase the share of localisation. The following section covers the Omani economy and trade, the country's energy profile as well as the current state of the manufacturing sector.

Economic, trade, and energy profile

Oman is a major oil and gas producer and exporter. In 2020, it was the 19th largest producer of oil by daily barrel production (1.1% of global production) and the 20th largest producer of natural gas by cubic feet (1.0% of global production), with further exploration work ongoing to find new reserves. Oman's government currently derives roughly 70% of its annual revenue from the oil and gas sector, exposing the government to significant volatility due to commodity price swings.

Oil and natural gas make up the majority share of Oman's total energy supplies (TES), as shown in Figure 2, with renewables contributing less than 1% in 2020. Oil products, natural gas and electricity make up the total final consumption (TFC) totalling 22 Mtoe in 2020. Industry, transport, commercial and public services account for 66% of the TFC.

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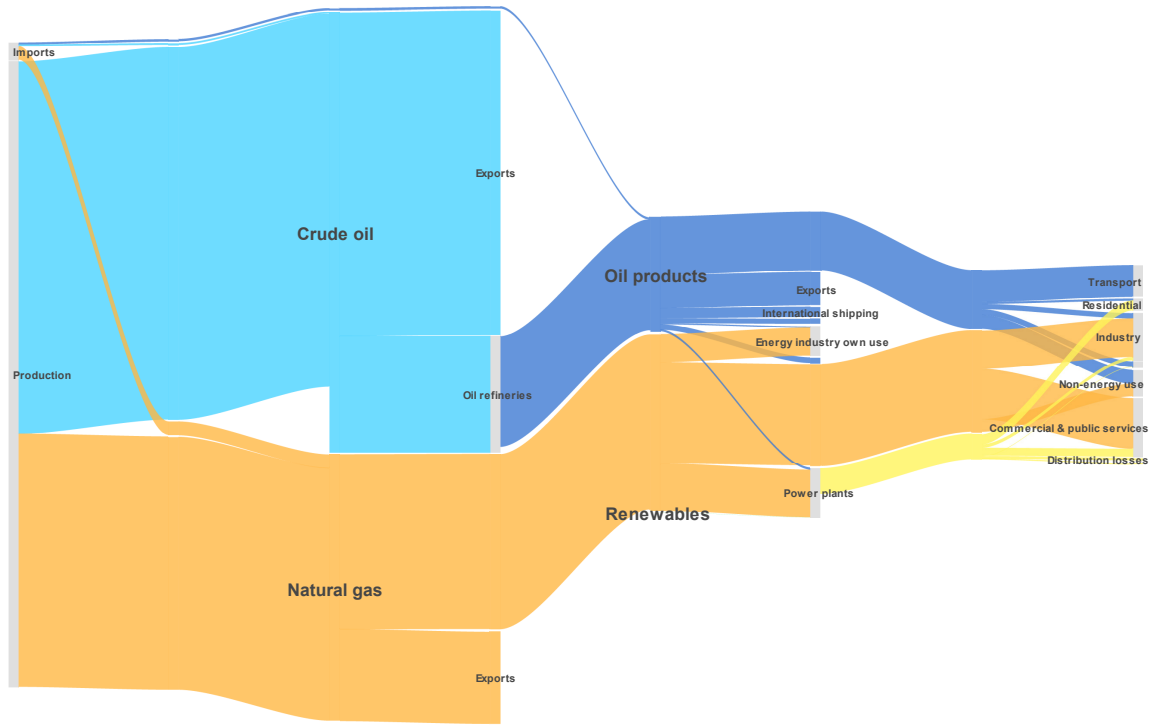
Figure 2 Oman's energy balance, 2019



Source: IEA analysis and data (2022)

The oil and gas, chemical and metal industries accounted for almost 90% of all export revenues in 2019. While revenues from fossil fuel and extractive sector product exports have increased in absolute value in the last two decades, there has been some initial diversification into other sectors, including manufactured products which contributed to increasing the relative non-hydrocarbon share of exports.

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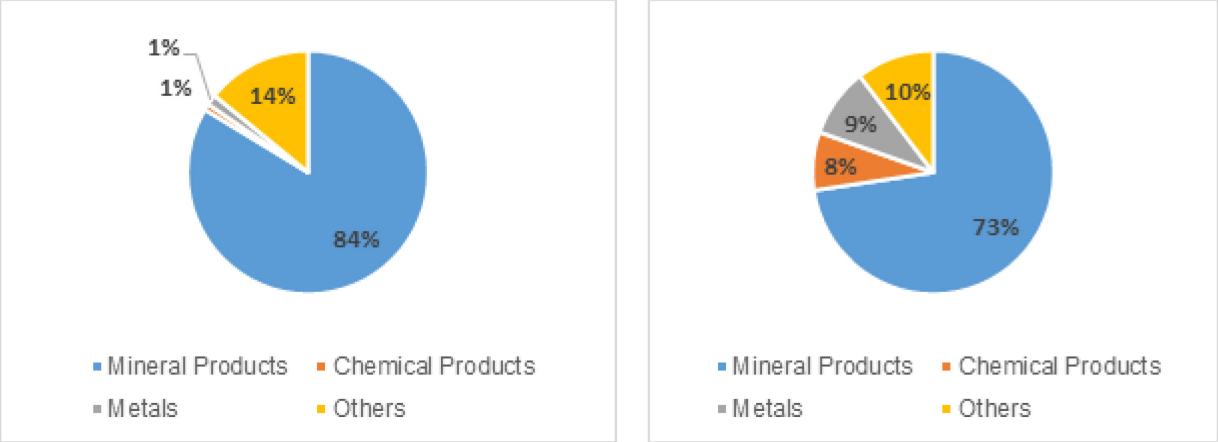
Figure 3 Composition of exports in 2000 (left) versus 2019 (right)



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Source: Observatory of Economic Complexity (OEC), https://oec.world/en/profile/country/omn.

While in 2000 Oman mostly exported crude oil, the proportion of value-added products and refined petroleum increased substantially, owing to the addition of refining capacity and actual throughput quantities in the past two decades. Nevertheless, the export basket is still very heavily dependent on the production of three key sectors (minerals, chemicals and metal products) which have nevertheless boosted export revenues substantially from only roughly USD 10 billion in 2000 to closer to USD 40 billion in 2019.

Domestic energy sector

The total final energy consumption of Oman has grown rapidly since the early 1990s as the country industrialised and the economy grew. Industry accounted for the largest share of energy consumption between 1990 and 2019, followed by the transportation sector. The largest increase in the share of total consumption was however interestingly found in the commercial and public services sector, which became the largest consumer by 2019.

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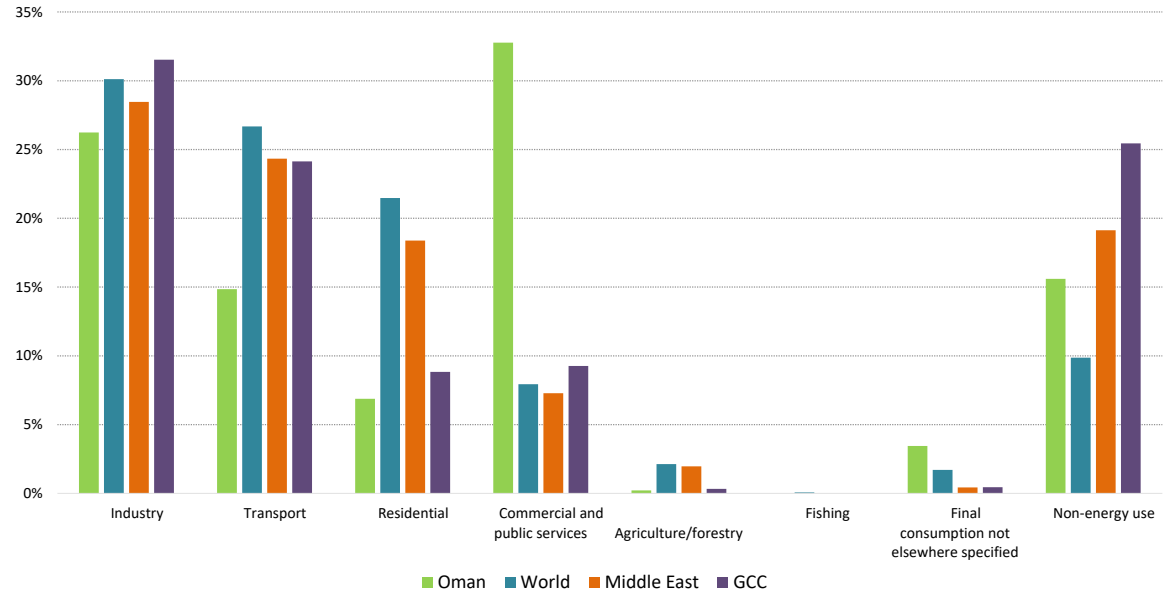
Figure 4 Total final consumption by sector in Oman and other regions, 2021



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Comparing this to global, Middle East and GCC benchmarks, Oman's total final consumption is slightly lower in industry, and considerably lower both in the transport and residential sectors. Interestingly, the commercial and public services sector is roughly four times higher than for all other benchmarked regions.

While oil products accounted for over 75% of total final consumption in 1995, this number dropped to roughly 32% by 2019. At the same time, electricity accounted for only 12%, with natural gas representing over 50% of TFC between 2010 and 2019. Further electrification plans are to some extent driven by the plans to rollout larger variable renewable energy capacity.

When comparing this with global, Middle East and GCC benchmarks, Oman's TFC is highly dependent on natural gas, with oil products accounting for a much lower share than in other regions.

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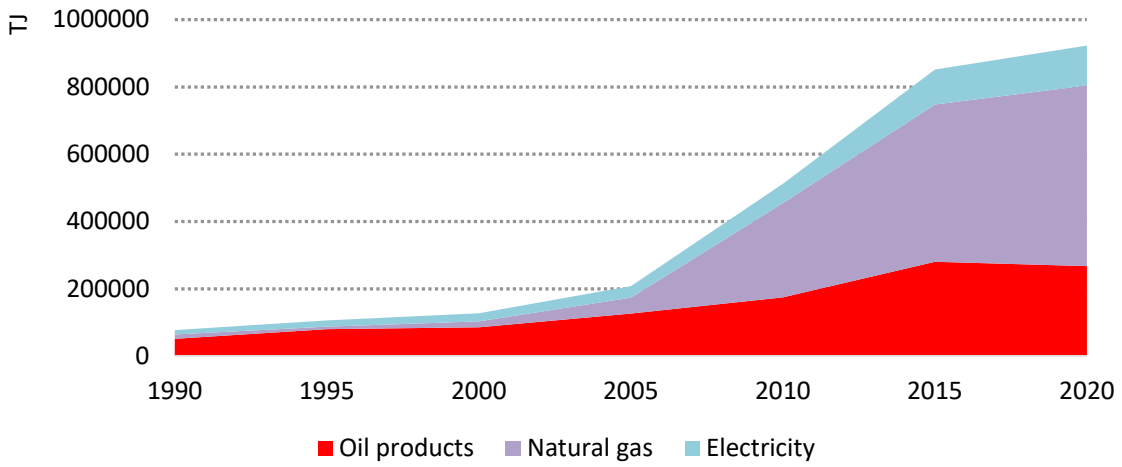
Figure 5 Total final consumption by source in Oman, 2021



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Assessment of existing industrial capabilities in the energy sector in Oman

In order to identify relevant opportunities and challenges in the relation with the development of domestic manufacturing capacities for low-emission industries, it is imperative to further assess the current state of the manufacturing sector and relevant activities in the country; it is also important to take into account the broader context in which those manufacturing activities take place.

Petroleum sector

As shown in the trade and energy sections, a large part of existing manufacturing capabilities is found in the petroleum sector. Activities are tightly linked to downstream petrochemicals, which account for the largest share among manufacturing sub-sectors when the contribution to total manufacturing value added (MVA) is considered. This is shown in Figure 6.

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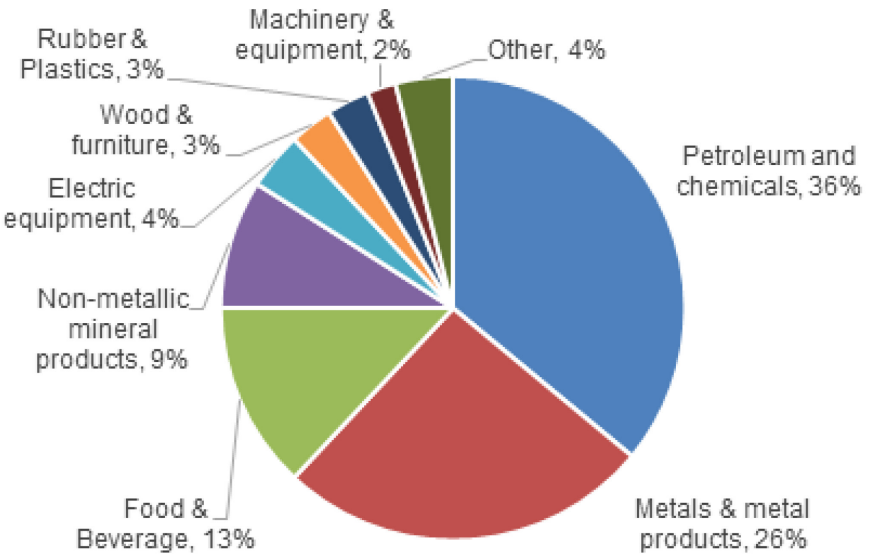
Figure 6 Composition of Oman's manufacturing sector, as of 2016 (% MVA)



Source: Oman Ministry of Commerce and Investment (MOCI), Industrial Statistical Survey (2016).

Several oil and gas companies are present in the upstream segments of the Omani oil and gas space, with the state-owned Petroleum Development Oman (PDO) being the most significant, followed by the US Occidental Petroleum. Several of the other oil majors are also present with varying levels of operations in the country. The downstream refining and petrochemical sectors are still being developed, with several significant investments in at various stages of development. These include the recently completed Sohar Refinery Improvement Project and the USD$ 7 billion OQ8, the largest investment project in the history of Oman.

Oman's oil and gas sector is serviced by a variety of domestic, regional, and international suppliers across the entire value chain of operations. While the total number of suppliers across the various categories is difficult to assess, a large number of companies relies on the oil and gas sector to develop their business, including:

- Oilfield services & equipment companies (OFSE)
- Oilfield equipment suppliers
- Drilling contractors
- Valve and pipe companies (and equipment manufacturers or importers more broadly)
- Engineering design companies
- Projects and construction companies
- Operations and maintenance companies

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- Transport and logistics companies
- Health, safety, and environment companies
- Services companies (including catering, uniforms etc)

The size of the sector, coupled with the traditional focus almost solely on the dominant fossil fuel industry, makes the assessment of possible linkages and repurposing ever more timely.

Other manufacturing sectors

Despite the dominance of the fossil fuel sector in the economy, other non-petroleum manufacturing activities do exist. Given very low energy costs, Oman boasts the important Sohar aluminium smelter, with a significant capacity of 375 000 tonnes per year. Crucially, Oman already produces steel and fertiliser, both of which have high potential for repurposing to use low-emission hydrogen as an input. In December 2022, announcements were made for the construction of a green steel production facility in one of the country's special economic zones. Nonetheless, production facilities also already exist for products with higher added-value products, such as cables and wires, used for both domestic and export markets.

Additionally, several additional downstream metal and steel products are manufactured, although the level of sophistication can still be improved. Several facilities also exist in the country and specialise in the production of various types of fertilisers, with several of the announced low-emission hydrogen plans also emphasising the utilisation of hydrogen to make by-products (e.g., ammonia).

Renewable energy sector

Oman has a high potential for large-scale deployment of renewable energy capacity, notably in terms of onshore solar and offshore wind. While renewables currently account for a negligible fraction of total energy supply, plans are in place to rapidly scale up capacity to ensure that renewable energy sources (RES) contribute to at least 20% of total electricity generation by 2027. It is however worth noting that given the dominance of natural gas and oil products within consumption compared to electricity, this would still only account for a relatively minor share of total energy supply. The currently planned and approved projects are listed in Table 1 below.

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Table 1 Recent and projected renewable energy projects in Oman

Name of project	System	Technology	Capacity	Status
Miraah Solar Thermal Project	-	Solar thermal for EOR	330 MW_t	Online in 2018
Dhofar I Wind Project	DPS	Wind	50 MW	Online in 2019
Amin Solar	MIS	Solar	125 MW	Online in 2020
Ibri II Solar	MIS	Solar	500 MW	Inaugurated in January 2022
Liwa Solar project	MIS	Solar	100 MW	Estimated operation in 2023
Manah I Solar	MIS	Solar	500 MW	Estimated operation in Q1 2025
Manah II Solar	MIS	Solar	500 MW	Estimated operation in Q2 2025
MIS Solar IPP 2025	MIS	Solar	500 MW	Estimated operation in Q1 2026
Jalaan Bani Bu Ali	MIS	Wind	100 MW	Estimated operation in Q1 2026
Duqm I Wind IPP	Ad Duqm Power System (Rural Areas Electricity Company)	Wind	200 MW	Estimated operation in Q1 2026
Dhofar II Wind Project	DPS	Wind	100 MW	Estimated operation in 2026
Ras Madrakah Wind IPP	Ad Duqm Power System (Rural Areas Electricity Company)	Wind	200 MW	Estimated operation in 2027
MIS Solar IPP 2027	Al Wusta Governorate	Solar	500 MW	Estimated operation in 2027

Note: EOR = enhanced oil recovery; MWt = megawatt thermal; MW = megawatt; MIS = Main Interconnected System; DPS = Dhofar Power System.
Source: IEA (2023), Renewable Hydrogen from Oman.

All of these projects are expected to contribute 3 956 MW of installed RES capacity by 2027. Given that non-RES installed capacity in 2020 was 12 189 MW and assuming this capacity remained unchanged, RES would constitute roughly 32% of the installed capacity. At the same time, there is potential to achieve efficiency gains in a number of current installations. There is awareness of that and the Omani government made energy efficiency a key priority for the coming decade.

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Hydrogen sector

The development of a global low-emission hydrogen market can represent a key opportunity for fossil fuel exporters. The IEA estimates that low-emission hydrogen production from water electrolysis or fossil fuels with CCUS could rise from less than 1 Mt in 2021 to 37 Mt by 2030 and exports are expected to reach 16 Mt per year by 2030.

Oman has already taken steps towards low-emission hydrogen development, notably with the establishment of the National Hydrogen Alliance (Hy-Fly) and Hydrogen Oman (HYDROM). Hy-Fly is a national alliance aiming to support the development of a hydrogen ecosystem and supply chain that brings together 15 institutions from the public and private sectors, including government agencies, oil and gas operators, educational and research institutions, as well as ports. HYDROM is a central and independent entity with a mandate to orchestrate the hydrogen sector, delineating government-owned land areas, structuring associated large-scale renewable hydrogen projects, managing the process for their allocation to developers, overseeing their execution and facilitating the development of shared infrastructure as part of a connected ecosystem.

Oman has recently announced the signing of three agreements for the production of renewable hydrogen from around 960 km^2 of land in Al Wusta and Dofar governorates. These agreements will have around 7 to 9 years for project development and construction and 40 years for operation. These projects are expected to produce an excess of 11 GW of renewable power and are expected to generate around USD 20 billion of total investments in 9 years. The announcement also incorporated information on the project developers' countries of origin that include Denmark, Kuwait, Singapore, France, South Korea, and Belgium.

Besides exports, opportunities should be assessed for using low-emission Omani hydrogen in a variety of hard-to-abate industries, including the steel and fertilisers sectors, where technological retrofitting and adaptation could be used to allow for hydrogen as an input.

Local content policy landscape

Oman adopted a local content policy to foster the domestic workforce's capability and stimulate private-sector development. The "in-country value" (ICV) is defined as the "total value spent in-country that can benefit business development, contribute to the human capacity development and stimulate productivity in the Omani economy"[4]. The concept of ICV and the related strategy for the oil and gas

[4] Al Shezawi, H. & Khan, F. (2018). In-country value (Icv) – entrepreneurial opportunities in the companies of Oman. International Journal of Management, Innovation & Entrepreneurial Research, 4, 1, 25–41; Ministry of Oil and Gas (2018).

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industry were introduced in 2013 to reduce imports and to create jobs. Significant efforts were also made to spur the involvement of Omanis in the private sector through several programmes and initiatives.

While non-petroleum activities in the country now account for around 60 per cent of GDP, many of these remain closely tied to the oil and gas sector, with a myriad of non-petroleum service providers still mainly servicing the oil and gas sector. A key challenge moving forward will be to ensure adequate support for the repurposing of some of these activities towards supporting broader, non-petroleum based economic and energy mix diversification.

While Oman has set ambitious goals for the deployment of renewable energy and low-emission hydrogen, the value chain focuses mostly on the installation, operations and maintenance stages, with very little manufacturing taking place in the country. Oman is currently an importer of all key technologies needed for its low-emission ambitions which includes photovoltaic cells and wind turbines.

The solar sector, which is more developed given its significant potential and outlook, features a variety of domestic involvement including service provision. Most local firms are active in the installation (e.g., mounting structures, inverters, switchgears) and the provision of cables which companies such as Oman Cables and NUHAS Oman active on the market. Other companies are also integrating more than one services which, on top of installation, include operation and maintenance. Companies such as EIREC, Nafath, Tandeedh, Hussam Technology Company are active on this market. Previous surveys demonstrate that many of the companies operating in the solar sector are present in more than one segment, including energy performance contracting (EPC), site preparation and installation, construction, as well as commissioning and operations, but very few manufacture or assemble solar equipment. While the sector is still at an early stage and a relatively small number of players is present in the space, opportunities can exist for companies to import and supply specific components and products if growth in the sector is maintained.

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Analysis of linkages between fossil fuels and clean energy supply chains

Market positioning and repurposing plans for international oil and gas majors and service providers, and operators and service providers in Oman

Structured surveys at the firm level were used to acquire insights into the market positioning and repurposing plans in relation with for the productive capabilities for the international oil and gas majors and service providers' provider productive capabilities. The same approach was adopted for operators and service providers in Oman. These surveys were conducted in two consecutive phases: phase 1 targeted the international players, followed by phase 2 which targeted the local players in Oman. In total, 16 firms responded to the survey.

The quality of the data received from the questionnaires sent to companies varied in terms of quality, relevance and the level of detail provided, but allows for interesting insights into how the oil and gas sector conceptualises transition pathways to a greener economy as well as the different stages and maturity of the process.

International oil and gas majors and services providers

Five responses were received from the target oil and gas companies. While the sample is small and statistical analysis cannot be applied, significant diversity exists across the companies surveyed.

These differences mainly lie in the positioning of these companies along the oil and gas value chain reveal slightly divergent plans with regards to the development of their low-emission divisions. All five surveyed companies are already transitioning or are looking to move into the low-emission space, albeit to differing extents and with differing goals. All five companies have announced their low-emission strategies within the last six years, with all five either updating or substantially increasing ambitions between 2020 and 2022. Some companies have been engaged in lower-emission sources for decades but have only recently formalised their strategies.

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Table 2 below provides a summary of the key areas that the five companies are prioritising in their low-emission strategies.

Table 2 General survey results summary table: International oil and gas firms

Proportion of investment in low-emissions technologies by 2030	Ranging between 30% to 40%	
Low emissions industries with business involvement		% of respondents
	Low emissions hydrogen	100%
	Solar	60%
	Wind	60%
	Bioenergy	60%
	CCUS	60%
	Electric Vehicle (EV) charging	40%
	Geoenergy & Geothermal	20%
	Battery storage	20%

Activities with high level of transversality	Activities with low levels of transversality
Refining capacity	Wind power appraisal
Gas pipelines	Drilling engineering
Offshore engineering	
Project design & engineering services	
Reservoirs for carbon storage	

Source: IEA-led survey (2022).

Each of the oil and gas majors listed their existing capabilities, experience, and assets as a primary reason for their interest in entering and becoming market leaders in the hydrogen segment. All of them also identified hydrogen as a major area of focus, albeit with varying levels of readiness. While two firms are looking to push ahead in the renewable hydrogen segment, three others envision developing their fossil-based hydrogen in the mid-to-long term, while some noted that they would like to move into low-emission hydrogen in the long term as well, although some smaller projects already exist.

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Out of the surveyed companies, only two have established new company structures for their low-emission divisions, with the remaining three setting up separate divisions within the original company structures.

Table 3 General survey results summary table: Key low-emission areas of focus

Energy Company 1	Energy Company 2	Energy Company 3	Energy Company 4	Energy Company 5
Low-emission & renewable H_2	Low-emission H_2	Low-emission H_2	Low-emission & renewable H_2	Low-emission & renewable H_2
Wind	Wind	Wind		
Solar	Solar	Solar		
				Battery storage
				Geoenergy and geothermal
Bioenergy (biofuels & biogas)	Bioenergy (biofuels & biogas)		Bioenergy	
EV Charging	EV Charging			
		CCUS	CCUS	CCUS

Source: IEA-led survey (2022).

In terms of expected capital expenditure (CAPEX) on low-emission divisions, there is a wide range of results. Some companies have high goals, with figures as high as 50% by 2030. Additional information provided by one of the respondents highlighted that currently the revenue split between their oil and gas and low-emission divisions is roughly 95%-5% and the current investment split is 90%-10% but this is due to ramp up rapidly in favour of clean energy investments. These developments are shown in Table 4.

Table 4 Capital Expenditure (CAPEX) on low-emission investment

Investment Horizon	Company 1	Company 2	Company 3	Company 4	Company 5
2025	40%	25-30% (25% for RES and electricity & 5% for new molecules: biofuels, H_2)	30%		N/A
2030	50%		50%	15% (By 2027)	N/A

Source: IEA-led survey (2022).

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Local oil and gas operators

A total of five responses from companies working in Oman were received, covering a broad range of segments and sectors.

Of the five companies surveyed, and despite differences in their stage in the value chain, operations and core business models, four noted some sort of focus on renewable energy technologies. One operator mentioned that their strategy was still under board discussion, but that certain low-emission energies would feature in future projects.

Two companies disclosed the share of spend on renewable technologies, albeit at low levels (5-15% and 3-4% by 2023 respectively) although there is expectation of variance. Across firms, solar energy is a key target sector. However, some firms have also outlined other key focus sectors, such as wind energy, CCUS, and hydrogen production. These findings are summarised in Table 5.

Table 5 General survey results summary table: Operators in Oman

Proportion of investment in low-emissions technologies	**Ranging between 3% to 15%**		**Activities with high level of transversality**	**Activities with low levels of transversality**
Low emissions industries with business involvement		% of respondents	Gas pipeline networks	*Unable to identify*
	Hydrogen	80%	Water treatment facilities	
	Solar	80%	Reservoirs, well and fields for CCUS towards low-emission H2 production	
	Energy efficiency	60%		
	Wind	20%		
	CCUS	20%		

Source: IEA-led survey (2022).

Hydrogen featured in the strategies of four of the five surveyed companies. This took the form of either becoming hydrogen producers or utilising hydrogen in their processes. For one operator currently producing fossil-based hydrogen, plans exist to switch a part of this to low-emission hydrogen, when market conditions are right, and costs decrease. All organisations however said that they were

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considering only fossil-based hydrogen, with renewables-based hydrogen only envisaged in the long-term. One organisation mentioned it was well positioned to produce renewable hydrogen and hydrogen with CCUS, capitalising on its experience and track record of renewable projects.

Out of the respondents, only one noted that they created a new subsidiary separate from the group's oil and gas business, but this was done at the corporate and not at business levels. Other operators noted the need for separate business units to cover new projects.

Local oil and gas service providers

A total of six responses were received from local Omani suppliers servicing the oil and gas industry, with wide variance across the services they provide.

The breadth of focus and expertise across the supply chain yielded valuable results, with a relatively high quality of responses. Additional responses would be useful for further research, especially from the local engineering consultancies and OFSE companies.

All respondents mentioned that the scope of their services such as training, consulting or operations, had been widened to include clean energy projects, with only one company mentioning it had not received requests for new services in Oman – though it still they mentioned it worked on these projects in other geographical locations. Five out of six respondents had some operations or projects outside of Oman, with most also performing services in the wider Gulf Cooperation Council (GCC) region. Two respondents specifically mentioned seeking international partnerships and trying to utilise international expertise and best practices, with one emphasising that the Omani government could do more to foster these international alliances. A summary of these results is presented in Table 6.

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Table 6 General survey results summary table – Suppliers in Oman

Proportion of business in Oil and Gas	From 10% to 95%		Activities with high level of transversality	Activities with low levels of transversality
Low carbon industries with business involvement		% of respondents	General engineering	Enhanced oil recovery
	Hydrogen (Low emission & renewable H2)	83%	Electrical engineering	Drilling & subsurface engineering
	Solar	50%	High pressure engineering	Chemical-based services
	Wind	50%	High temperature fluids and gases	
	Waste to energy	33%	Overhead transmission lines	
	CCUS	33%		

Source: IEA-led survey (2022).

The oil and gas sector still dominates the business portfolio of most companies. For four out of the six respondents, oil and gas make up between 85%-95% of revenues, with a vision of increasing the share of renewable and hydrogen in the immediate future. Out of these, three respondents mentioned they would be providing services that target renewable hydrogen, although other types of hydrogen were also mentioned. One respondent also mentioned they were working on a project aiming to localise solar PV panel production.

In terms of business segmentation, some respondents mentioned they had recently created new divisions or segments for renewable energies and hydrogen, or at least that they were planning on having a separate taskforce for new projects in the clean energy space. Concurrently, none had created new legal subsidiaries.

Overall analysis of transversal linkages

Overall, this study was able to identify some of the important transversal linkages that exist between the oil and gas industry and clean energy industries. These

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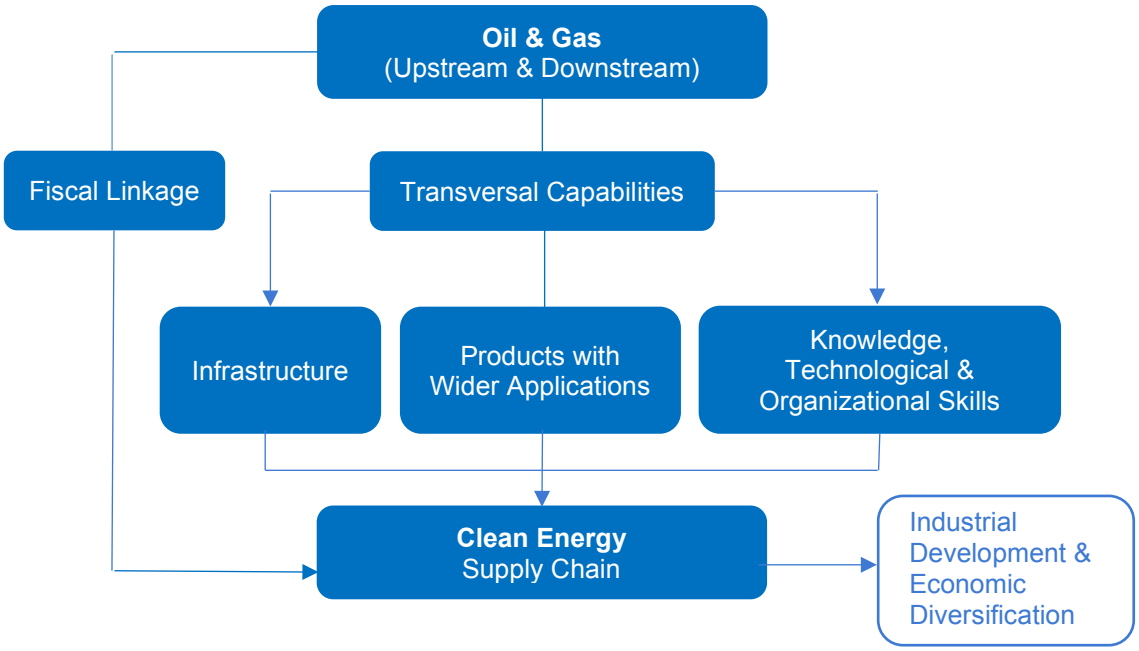
linkages indicate that producer economies could draw on a range of pre-existing transversal capabilities to jump ahead in the development of local clean energy supply chains. Those capabilities can take the form of infrastructure, products, services, and skills at the including technical, managerial and organisational levels.

Figure 7 Conceptual framework of linkages from fossil fuels to clean energy industries



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Low-emission hydrogen, as one of technologies for clean energy, can for instance feature a significant breadth and depth of linkages towards a range of industries through both forward linkages (e.g., towards low-emission steel production) and backward linkages (e.g., the production of equipment such as electrolysers). This implies that the transition towards hydrogen, if carefully designed, can help open the way for a variety of lower-emission industrial pathways and support broader critical objectives such as economic and export diversification.

The analysis also details the linkages that exist across the productive and infrastructural fields, with significant possible complementarities found in service providers and in the skills required by both sectors. Most respondents in Oman are at least to some extent thinking about and implementing changes to their organisations to prepare for the increased demand stemming from renewable energy segments. Hydrogen production with CCUS is also seen as a priority for many organisations given very strong linkages to fossil-based hydrogen production, but organisations also see complementarities with renewable

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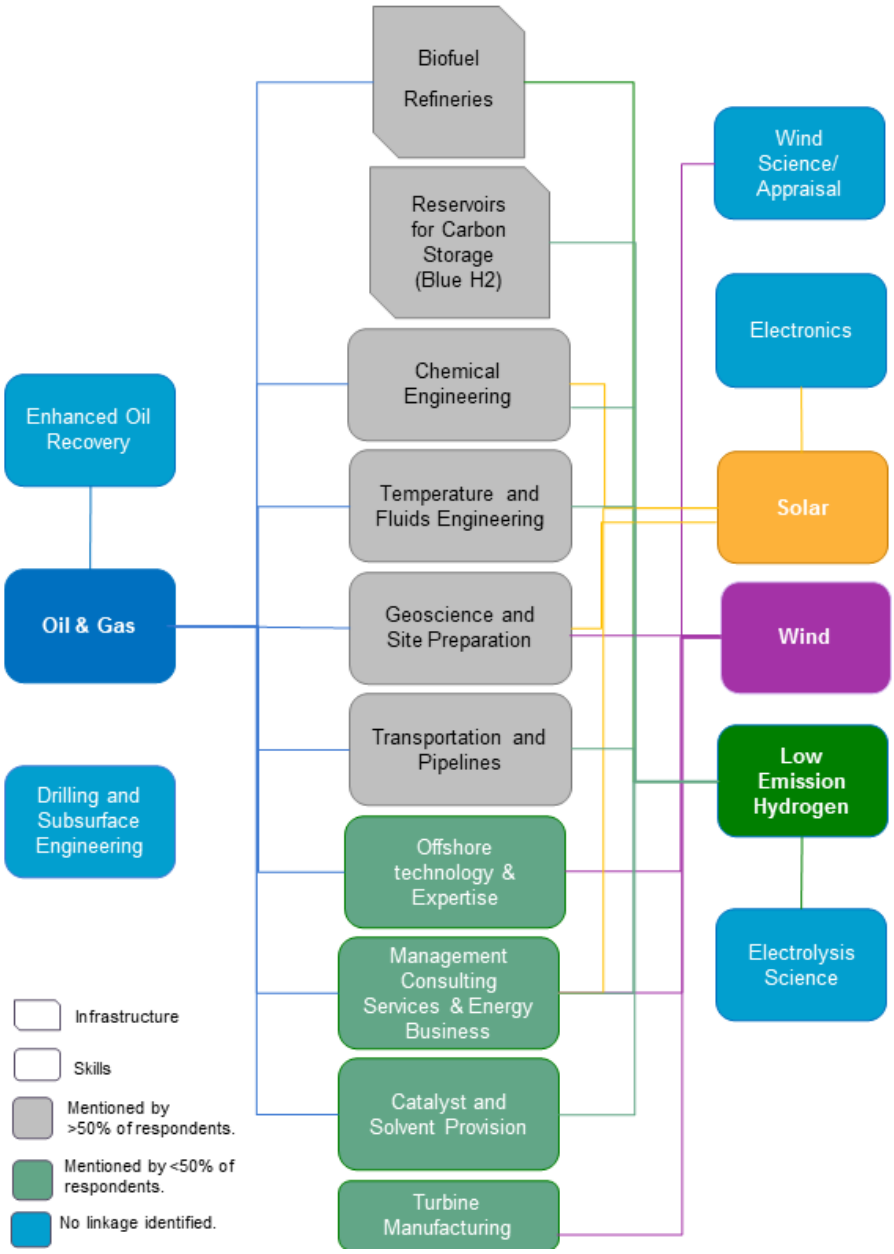
hydrogen production. While back-office positions and skills can be easily repurposed for new, low-emission divisions and operations, even technical and engineering skills can find useful applications. Concurrently, some challenging areas remain. These include the repurposing of existing gas pipelines for hydrogen transport, as well as some skills that may not find wide-scale applications, especially in the renewable hydrogen segment. Figure 8 shows these interrelations and enable a better understanding of where overlap can or might exist and the different stakeholders' perceptions in that regard.

Figure 8 Mapping results of the transversal capabilities between fossil fuels and clean energy industries



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The next three sub-sections review the analysis of the specific types of linkages identified and used to build our mapping (whether skills, infrastructure, or transversal suppliers which have been able to repurpose their capabilities).

Transversal suppliers

Results at the international level

The study also identified a large list of transversal suppliers which are currently servicing both the oil and gas sector and clean energy operations, including low-emission hydrogen. These suppliers operate across many areas and disciplines, including:

- Project design and engineering services
- Engineering, procurement, and construction
- Management consulting services
- Site preparation (including offshore construction)
- Equipment providers
- Chemical providers

All four of the surveyed oil majors noted that many of their suppliers currently supply and service both their oil and gas and low-emission divisions, across many areas and disciplines. Several respondents also noted that several of their suppliers across the entire oil and gas value chain had built up renewable and low-emission capabilities, including project design and engineering; engineering, procurement and construction; technology licensing, and in equipment, chemical and product manufacturing. Table 7 below presents a brief list of some of the suppliers identified by their location on the value chain. It is worth noting that all of these are large traditional players supply the oil and gas space, showing that the industry has quickly re-adapted to lower-emission technology solutions.

Table 7 Categorising oil and gas and low-emission technology transversal suppliers

Project design and engineering	**Hydrogen** Technip, SAIPEM, KBR, Wood, JGC, Chiyoda, Worley, McDermott	**Offshore wind** Doris, Worley, Technip, SAIPEM, Ramboll, Wood.
	Solar Wood, JGC, Worley	**Others** Aker, Worley, DNV, Atkins
EPC Contractors	SAIPEM, Technip, SBM, McDermott, Ponticelli, Wood, KBR, Worley, JGC, Chiyoda, Petrofac, Bouygues, Colas	
Technology licensers	UOP, Axens, Haldro Topsoe	

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Site preparation and construction	Geotech, development & consenting suppliers RPS, Gardline, Xodus, Fugro Installation vessel suppliers Heerema, Subsea7, Chouest, SAIPEM Marine services Bourbon, Louis Dreyfus	Historical dredging contractors DEME, Van Oord, Jan de Nul and Fred Olsen Drilling contractors Transocean Cranes for offshore wind Huisman, Mammoet and Sarens
	Environmental survey and consulting suppliers AECOM, ERM, Ramboll, Wood	
Equipment and product manufacturing	Substations Schneider Electric, Siemens, ABB Floating wind technology suppliers NOV, SBM, Technip FMC	Cables Nexans, Prysmian, NKT Turbine/Rotating equipment GE, Siemens
	Also, ABB, Emerson, Rockwell, Schneider Electric, Yokogawa	

The Omani context: operators and suppliers

In contrast with the international respondents, and perhaps given the early stages of low-emission industrial activities in Oman, operators in Oman could not effectively identify potential transversal suppliers, with some firms noting that suppliers in their renewable energy businesses had not yet been identified, as strategies had not yet been finalised.

Nonetheless, all respondents amongst the supplier firms in Oman noted their ability to provide services and goods to the renewable and hydrogen sectors to some extent. Three suppliers noted that many of their engineering services could be repurposed, with the ability to handle hydrogen and renewable technologies as many of the engineers “have a background in process plants handling high pressure, high temperature fluids and gases.” Some respondents also noted that the electrical departments’ skill sets were the same for the oil and gas and clean energy sectors. Some companies on the engineering side noted that years of EPC knowledge allowed them to build resilient and diversified supply chains which include many services that could be transferred across industries (e.g., engineering, power stations, power plants, overhead transmission lines). For the research or training institutes, the core expertise came from product knowledge (i.e., training) and the ability to repurpose this for the renewables sector. Much of the expertise in training/education institutes came from new hires (discussed further in the Skills & Training section).

Nonetheless, some of the core areas of some of the companies surveyed were noted as being more difficult or impossible to repurpose, including a range of services such as enhanced oil recovery, drilling and subsurface engineering, and some chemical-based services.

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Infrasctruture

International oil and gas companies

In terms of the actual parts of the value chain and existing infrastructure that can be repurposed, companies answered largely based on their corporate low-emission goals. This yielded interesting and varied insights. Figure 9 and Table 8 summarise the results.

Figure 9 Infrastructure assets with potential for repurposing based on survey results

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Source: IEA-led survey (2022).

Table 8 Possible repurposing of existing assets

Energy company 1	Energy company 2	Energy company 3	Energy company 4	Energy company 5
Gas pipelines for hydrogen		Gas pipelines for hydrogen	Gas pipelines and storage for hydrogen and CO_2	
Biofuel refineries	Biofuel refineries		Biofuel refineries (incl. storage and transport)	
	Electrification	Electrification of installations		

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Energy company 1	Energy company 2	Energy company 3	Energy company 4	Energy company 5
		(offshore production and onshore gas terminals)		
Offshore facilities (Low-emission H_2 with CCS)	Offshore facilities to wind power		Reservoirs for carbon storage	Reservoir performance
			Hydrogen as input for refining and chemical processes	
EV Charging in retail operations	EV Charging in retail operations			Production systems
				Well construction
				Digital & integration

Source: IEA-led survey (2022).

The business mix of these companies and their asset portfolios determine the range of possibilities in terms of infrastructure repurposing. For instance, energy company 2 mostly focused on the already planned and ongoing repurposing of its biofuel refinery but did note the possible integration of solar and other renewable energy sources (RES) to power existing oil and gas infrastructure, or even turning offshore oil and gas installations into wind power. The integration of RES into existing oil and gas operations was also mentioned by the other energy companies, but to varying extents.

According to energy company 3, the electrification of current operations and the repurposing of pipeline infrastructure to accommodate hydrogen transportation was a key area of focus. It also noted that a significant degree of electrification already occurred. Energy companies 1 and 4 which provided the most comprehensive answers both listed pipeline infrastructure as key assets to repurpose but also added a variety of other assets which they would be looking to repurpose. Two respondents elaborated on their plans for biofuels. Energy company 1 was looking to invest in at least five biofuel projects, three of which would be adjacent to existing refineries and two of which would be converted from existing refinery capacity. Most hydrogen projects would likely be greenfield. For energy company 2, two refineries were mentioned, with an investment requirement of EUR 500 million to convert one of them into a biofuels refinery by 2024. Energy company 4 was also planning the repurposing of its pipeline and storage infrastructure to accommodate biofuels, hydrogen and CO_2. Energy

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company 5 highlighted the conversion of one of their factories to electrolysers but declined to mention the investment required for this.

Both energy companies 1 & 2, who have significant retail operations, highlighted a push to increase EV charging capabilities. One was focusing on the fitting of 300 road service stations and 600 urban service stations with high power chargers by 2030, in order to support e-mobility. The other was also looking to install high speed charging capabilities at its service stations.

Some mention was made of retrofitting existing downstream capabilities to accommodate the acceptance of cleaner inputs in the manufacturing process. One respondent (energy company 4) specifically mentioned this regarding their refining and chemical processes.

The conclusion from the supplier and repurposing component of the survey is that oil and gas majors are currently actively thinking about the repurposing of existing infrastructure across the value chain for low-emission technologies. While some are heavily considering the electrification of existing oil and gas production facilities (assumptions can be made that all of the players are doing this, even if they haven't listed it here), others are already actively thinking about transportation and pipeline adaptations for hydrogen.

Challenges however remain. Energy company 3 mentioned that the repurposing of pipelines for hydrogen would be very challenging, especially under current market conditions. Energy company 1's survey responses noted that the majority of both off- and onshore oil and gas installations would be difficult to repurpose (although some would support carbon capture and storage – CCS). Liquefied Natural Gas (LNG) liquefication and regasification facilities will also be difficult to adequately repurpose, although some export infrastructure might support the development of the transport element of the hydrogen supply chain.

Challenges and uncertainty might persist as the status of the global hydrogen market, including costs and demand were still to be fully defined. This is a key barrier which has so far prevented some of the survey respondents from engaging more deeply with the hydrogen sector.

Oman operators and suppliers

Respondents operating in the oil and gas sector in Oman were not able to provide sufficient information on the infrastructure and investment needs for two key reasons:

- Lack of applicability
- Strategy currently being formulated or not yet clearly defined

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One respondent noted a willingness to repurpose assets "based on opportunities", noting only that the fuel gas pipeline network could be under consideration for repurposing. Some of the infrastructure and power generation could also be repurposed. Another respondent noted that some infrastructure, including reservoirs, well and fields could be repurposed for CCUS supporting low-emission hydrogen. Some facilities, including power grids and water treatment facilities could also be used in the new segments. Another respondent noted that they were exploring the usage of hydrogen as an input, although they mentioned that some LNG processing assets could not be repurposed.

Overall, even though clear opportunities exist for the repurposing of oil and gas infrastructure towards hydrogen production, some challenges and concerns persist, in particular in relation to the adaptation of pipelines for hydrogen under current market conditions as well as LNG liquefication and regasification facilities, reservoirs for carbon storage, and the reconversion of refineries for biofuels.

Skills and training

The level of transversality of skills can be reflected by the rate and type of redeployment of labour from oil and gas to low-emission operations. Overall, survey results reveal that the rate of internal redeployment of labour versus external hiring for low-emission operations ranges widely from 36% to 89% (as of 2020). Though there is a general consensus that re-skilling and moving talent into low-emission divisions is possible across the value chain (general agreement), specific areas of redeployment include:

- Geoscience
- Engineering
- Research, supply chain and logistics,
- Refining, biofuels and chemicals manufacturing.

In contrast, some very specific roles will require external hiring (e.g., wind energy appraisal and wind science)

International Oil Companies (IOC)

Three of the respondent firms provided in-depth information including concrete figures related to their skills and training outlook.

One respondent noted that so far, mostly internal talent had been leveraged and redeployed across its low-emission divisions, but only an estimate of a "few hundred workers" was given. Nonetheless areas of redeployment were listed, including, but not limited to geoscience, commercial, engineering, research, supply chain and logistics, and refining, biofuels and chemicals manufacturing. Other respondents provided much more detail but agreed that re-skilling and

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moving talent into low-emission divisions was possible across the value chain. Table 9 provides a summary of these findings.

Table 9 Full-Time Equivalent (FTE) in companies' clean energy divisions

	Energy Company 1		Energy Company 2	Energy company 5
	Low-emission	EV		
Since 2020	- 90 external FTEs - 50 internal FTEs moved. - 80 FTEs seconded from technical disciplines	- 50 external FTEs - 50 internal FTEs moved.	-Roughly 2500 FTEs for Integrated Gas, RES and Power (GRP) -800 FTEs moved into renewable fuels	- 200 FTEs In the H_2 production facility more specifically: - 5 external FTEs - 40 internal FTEs
2022	250-300 FTEs expected to be recruited to H_2 and offshore wind	250 FTEs	1500 FTEs will be available in GRP. 350 young FTEs	
2030	2000-3000 FTEs (mixed hiring)	1750-2000 FTEs (mixed hiring)		

Source: IEA-led survey (2022).

In terms of skills that have already been repurposed in-house, there was broad agreement that project management and engineering and design skills were transferrable, and office jobs had also converted easily, especially functions such as finance, procurement, business development, human resources, marketing, sales, legal etc. One respondent noted that the requirements for project management and engineering design would grow, but that the digital function had already seen high growth since 2020 (470 external FTEs and 180 internal FTEs)

Three respondents noted that while some new skills would be needed many can still be sourced in-house (digital, technical etc.), and could often be strategically sourced through joint ventures (JV) or partnerships and not exclusively by recruiting. Nonetheless some very specific roles would require external hiring (e.g., wind scientists etc.), largely in areas where the company had no prior experience.

All three companies were also heavily reliant on an internal pipeline and interest to shift employees into the cleaner energy divisions. For energy company 1 this had been 170 FTEs so far, for energy company 5 it was about 80% of the division, while energy company 2 noted that several hundred clean energy jobs were primarily advertised through the company's internal talent portal.

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Oman operators

Four out of five companies hired external experts or created small new teams looking at the decarbonisation of their operations. While these experts had so far mostly focused on operational aspects, three companies highlighted that in the future they would primarily require more process engineering capacity with experience in the renewables sector and CCUS, along with other engineers (electrical, chemical etc). While there has been some internal re-skilling, external hires, especially those with renewable engineering backgrounds were envisioned in the future. Concurrently, some respondents also mentioned the need to bring on board further administrative, legal, financial and economic experts at a later stage to support a more energy-transition led vision and strategy.

Omani suppliers

A variety of responses were recorded with regard to the perception of existing versus future skills and qualifications needed. The research and training institutions all hired new experts focusing on clean energy segments, with a view of expanding operations in the field and therefore increasing intake.

One university mentioned that some Omani engineering graduates were being placed in clean energy divisions. All engineering companies also hired or were looking to hire new experts, with a view of expanding recruitment as more clean energy projects arose. There seemed to be an understanding that many of the engineers previously hired could perform tasks in the clean energy divisions, with respondents noting that there were little expectations that skills requirements would dramatically change, with traditional oil and gas skills still in demand, although some new more specific hires would need to be made.

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Policy implications: Putting capabilities repurposing at the heart of policy action in Oman

Aligning local content policies towards transversal capabilities and industrial diversification

The findings of this study bear considerable relevance for policy making in Oman. The study identified various types of linkages (e.g., infrastructural, industrial, or skills-related) between fossil fuels and clean energy industries. However, by comparing the results from the surveys of international and Omani firms, it becomes evident that the oil majors have made the first move towards releasing their strategies regarding repurposing capabilities. As Oman pursues its transition efforts, we can expect domestic operators and suppliers to share their vision on the matter. Emerging opportunities in clean energy technologies and higher risks of lock-in are factors that will likely accelerate existing trends within the Omani oil and gas supply chains. However, considering the highly heterogenous levels of transversality embedded in productive capabilities around the fossil fuel sector, the level of readiness for repurposing amongst Omani firms operating in oil and gas supply chains remains unclear, mainly due to insufficient research dedicated to the topic as well as the lack of clear and unified corporate strategic direction.

From that perspective, local content policies in the energy sector are needed, but not sufficient to ensure that the type of local capabilities corresponds to transversal capabilities that can be easily repurposed. Indeed, Oman has already implemented a local content policy to foster its domestic workforce's capability and to stimulate private-sector development and employment. However, given the different scope for repurposing, and Oman's policy direction in favour of energy sector decarbonisation, priority should be given to local content activities that provide higher prospects for linkages with other sectors that can support national economic and energy diversification objectives. Attention should also be given to linkages that drive the highest value to the Omani economy, to offset potential revenue losses induced by the transition.

Oman's ambitions and plans for the production of low-emission hydrogen, especially hydrogen electrolysed from renewable-based electricity, will help to develop relevant local economic sectors for both solar PV and wind power. While

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numerous local providers and installation companies already exist in Oman, the expected rapid increase in renewable capacity deployment will help create higher demand for the localisation of larger parts of the renewable technology value chain within the country. Furthermore, as the global road to decarbonisation progresses, further electrification of all key end-sectors and sector coupling will be increasingly necessary, and Oman's hydrogen production plans could accelerate the push towards low-emission electrification. This may lead to the creation of cleaner downstream segments. As such, regardless of how hydrogen markets evolve in the medium to long term, the increase of renewable electricity generation capacity can already bring significant economic benefits and importantly help with reducing the domestic consumption of other fossil fuel resources, notably natural gas, which are less abundant than for other Gulf exporters.

As the global hydrogen (and especially low-emission hydrogen) market develops, sufficient foresight and holistic planning must be in place to ensure that hydrogen does not follow the price-volatile and resource-dependent path that key producers have experienced their oil and gas sector. It may be necessary to consider diversification upstream or downstream into hydrogen-based products to counteract the impacts of market volatilities. Furthermore, the utilisation of low-emission hydrogen in Oman's hard to abate sectors and industrial clusters must be assessed for feasibility. Within the metals and fertiliser sector, the use of low-emission hydrogen could be possible (given the appropriate technical and economic feasibility modelling), with the opportunity to not only decarbonise industrial production, reduce natural gas consumption and decrease emissions, but also to promote high value manufacturing in compliance with future standards set by key export destinations. The production of low-emission steel, aluminium or fertiliser could also help Oman's products find new markets and increase bilateral trade and economic relations, especially with the EU and the US. The decarbonisation of existing industry and hard-to-abate sectors, as well as the creation of new downstream green segments will require significant involvement from the government and financing institutions to provide the right incentives and guarantees for companies and producers to invest in switching their technologies to accommodate for hydrogen.

Multilevel policy action to promote local integration in clean energy supply chains

Policy actions to foster the repurposing of capabilities from the oil and gas supply chains to the clean energy supply chain hinges on four core enablers:

- Long-term vision with clear sectoral targets.
- New policies to support clean energy supply chain development.
- Development incentives and supportive instruments.
- Institutional setup and integrated policy coordination.

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Long-term vision with clear sectoral targets

Despite the economic and industrial benefits of local integration in the clean energy sector, repurposing skills at company level remains a complex endeavour, and one which involves risks, costs as well as dependency on a broader energy policy. To accompany this transition, it is necessary to have a long-term vision for both domestic and international industry stakeholders (e.g., investors, state-owned companies, IOCs, contractors and suppliers) to plan their resources and costs accordingly. Oman's renewable hydrogen strategy adopted in 2022, for instance, already provides production targets for 2030 at 1 Mt/yr, and by 2050, to reach 7.5-8.5 Mt/yr by 2050. In addition, the government shared the amount of investments needed to achieve these targets, which it estimates to be USD 140 billion by 2050.

While this vision provides a clear direction to industry stakeholders, adequate mechanisms need to be put in place in order for the vision to translate into concrete projects and the achievement of production targets. More specifically, each sector involved in the hydrogen supply chain needs to understand how they might contribute to the development of the industry domestically. This could be facilitated by the establishment of clear targets for each sector and by sharing best practices among stakeholders with similar features and interests.

New policies to support clean energy supply chain development

To support the vision and sectoral targets, new policies or policy upgrades will be necessary to ensure the maximum leverage of the existing advanced capabilities in the oil and gas industry towards the development of new energies in Oman. Beyond energy, Figure 10 shows an integrative toolbox to support a comprehensive, structured, and competitive clean energy supply chain development.

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Figure 10 Policy toolbox to support clean energy supply chain development

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The domestic private banking sector can be risk-averse and can be reluctant to provide long term seed funding, while venture capital tends to be attracted to opportunities where an exit can be achieved within a reasonably short time. Consequently, domestic development banks such as the Oman Development Bank can help overcome such limitations, notably by reducing risk levels through blended finance.

Governments can engage their central banks and other domestic development institutions to provide incentives—including special facilities and financing options—to induce financial markets to lend for energy transition projects. This includes asset-based reserve requirements to allocate resources to preferred sectors (e.g., in relation with hydrogen production) or the provision of capital to development institutions, such as the National Development Bank, to provide lending to priority sectors[5]. The creation of these new instruments can be formulated in close coordination with the relevant stakeholders, including private sector actors from identified priority industries, to ensure access to credit and lower the cost of capital.

Targeted skills development and adapted labour market policies will also be essential. Governments can have a key role as a catalyst of targeted human capital accumulation necessary for the development of the clean energy and hydrogen supply chain, which require the widespread acquisition of different types of skills. Policymakers in Oman can provide a clear direction and coordination for such skills development and training activities in which higher education institutions. These include both public and private universities and training centres,

[5] Dikau, S., & Volz, U. (2021). Central bank mandates, sustainability objectives and the promotion of green finance. Ecological Economics, 184, 107022.

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such as Sultan Qaboos University and Gutech which could play a leading role. Skills needed to adapt and develop products, services, and processes for clean energy need to be integrated into the wider training and skills development policy rather than being seen as additional or separate from other forms of skills development. The successful redeployment and repurposing of skills from the fossil fuel to the clean energy industries will also only be possible by ensuring that workers can adapt and transfer from traditional areas of employment to clean energy activities (especially those with higher prospects for repurposing) such as the production of low emissions hydrogen.

In conjunction with an adapted skills development policy, labour market policies will also be needed to ensure readiness to seize green job opportunities and to avoid potential misalignments across time, space, and educational abilities. Re-skilling programmes can be developed and implemented in coordination with government, industry, and educational institutions in a way that the workforce is aligned with clean energy industries' needs.

Develop incentives and supportive instruments

Once the vision with sectoral targets is developed and the related supportive policies are in place, incentives and support instruments can be considered to stimulate interest in developing new energies for both the domestic and international markets.

Oil and gas development bids could be adapted to incentivise technologies that would contribute to the emerging hydrogen supply chain. For example, oil and gas power supply agreement (PSA) extensions can be linked to investments in technologies such as CCUS or Solar PV to support the government's renewable hydrogen strategy. Other incentives to contractors and suppliers can take the form of tax breaks, attractive land concessions or subsidised energy cost for operating assets such as electrolysers.

Institutional setup and integrated policy coordination

Policy coordination between policymakers, regulators, and other government stakeholders during both strategy implementation and evaluation is a key requirement for the successful performance of industrial, energy, fiscal, economic, labour and educational policies. This coordination is fundamental for local suppliers to access critical information on quality standards, product and services needs, as well as skills requirements in the clean energy supply chain in order to facilitate their integration.

Institutional coordination for the case of Oman can be further strengthened to avoid the risk of stakeholder misalignment as the project pipeline develops. Some institutional recommendations:

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- Set up an inter-industry platform for suppliers in the oil and gas sectors and key clean energy and renewable hydrogen actors specifically to share information on supplying needs, quality standards and engineering requirements to help inform the strategic adoption of Oman's in-country value (ICV) strategy to prioritise transversal capabilities in the energy sectors rather than activities and services at higher risks of being locked within the oil and gas sector.
- Create a national agency with a skills repurposing mission and retraining capacity to help workers (including those with little scope for repurposing in the fossil fuel sector) to acquire the skills and know-how required for local integration in the hydrogen industry. Chile and Germany took similar initiatives. Establish a national readiness framework in the context of the energy transition, leveraging PDO's existing analysis and data in this area.

Considering the multilevel degree of optimal policy support for repurposing capabilities from fossil fuels to clean energy, this agenda requires policy coordination between a wide range of actors, including:

- **The Ministry of Energy and Minerals**: to set credible targets, ensure coordination, and policy coherence with Oman's energy policy.
- **The Ministry of Finance Central Bank of Oman**: to prioritise capital allocation to repurposing as part of a broader transition towards an allocative role and a green central banking mandate.
- The Oman Development Bank and the Oman Investment Authority: to deploy long term capital towards priority areas.
- **The Ministry of Industry Commerce and Industry**: to design and implement a far sight industrial policy incentivise hydrogen supply chain local integration.
- **The Ministry of Higher Education, Scientific Research and Innovation**: to align human capital accumulation with the skills needs of a local supply chains development around hydrogen production.
- **Universities**: to expand graduate programmes in areas that offer the highest degree of transversality within the energy sector.
- **The business sector**: especially hydrogen firms, oil and gas operations, and their local suppliers to allow for information sharing and capacity building.

These recommendations are summarised in Table 10.

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Table 10 Multilevel policy action to leverage local capabilities and foster local value added around clean energy production in Oman

	Policy Tools	Examples
VISION SETTING	Adoption of clear industrial goals and roadmap	- *Consolidation of Oman's 2040 vision with the adoption of clear objectives for local value addition in clean energy supply chains, and industry-specific roadmaps for firms currently operating in the oil and gas sector*
CAPACITY BUILDING	Information sharing and intra-industry linkages Consideration of local content incentives and capacity development programmes to foster learning-by-doing for local suppliers	- *National survey for the supply of goods and services around clean energy* - *Establishment of a platform for knowledge sharing regarding requirements, etc.* - *Inclusion of local content considerations as part of tenders for clean energy projects* - *Strategic international partnerships allowing to share best practices*
FISCAL INCENTIVES & FINANCIAL SUPPORT	Investment promotion in the clean energy supply chains, including associated infrastructure Financial support for investment in the clean energy supply chains and allocative role of the Central bank	- *Fiscal incentives for investments in solar and wind energy plants* - *Subsidised credits (through the national development bank or the Central bank) for investments in the clean energy supply chains.* - *Tax breaks for operations within clean energy supply chains for firms whose business is normally in the oil and gas sector to encourage repurposing*
DEMAND-SIDE	Incentives and adoption of sustainability standards to generate the demand for clean energy	- *Government regulations to phase-in clean energy industrial activities*

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	Collaboration with potential domestic adopters and incentives to fuel switch to clean energy in their production	- *Tax breaks, subsidies or preferential loans for industrial adopters looking to repurpose their existing production process to clean energy*
TECHNOLOGICAL RESILIENCE	Technological foresight capabilities	- *Setting up of centre for technological foresight to keep track of advances around hydrogen and foster the localisation of activities with the highest capacity for repurposing and lower risks of technological disruption, offer incubation and support for technology transfer & diffusion*
SKILLS ACCUMULATION	Establish national competency frameworks for the repurposing of skills from 'dirty' to 'clean' energies Expansion of education and training programmes for skilled human capital accumulation related to green industries	- *Retraining programmes for jobs at risks from the global energy transition (similarly to Chile Valora for instance)* - *Expansion of training programmes to provide skills required for the localisation of activities related to renewables* - *Inter-university collaborations and strategic international partnerships*

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Conclusions

A key aspect of energy and economic diversification in fossil fuel exporting economies such as Oman lies in the domestic ability to repurpose existing productive capabilities towards clean energy value chains. In that sense, this study contributes to identifying some of the productive capabilities (technologies, skills and infrastructure) that can be repurposed from fossil fuel production in order to promote local integration in clean energy chains, as well as addressing the challenges that persist.

Not all activities have the same scope for repurposing, and the panorama for repurposing is indeed extremely heterogeneous. While chemical and temperature engineering capabilities can be easily repurposed, other capabilities (such as drilling expertise and equipment) do not offer great scope for transversality towards clean energy operations, implying that workers might require considerable retraining as part of a low-emission energy future if producer economies look to accelerate the development of clean energy production, making the role of policy interventions particularly important.

In Oman, those findings have considerable policy implications in order to support the government's long term energy transition and hydrogen strategy. Proactive policy interventions, based on a multistakeholder approach and careful institutional coordination, will be of paramount importance for the success of this agenda.

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Annex

Survey methodology

To generate a mix of quantitative and qualitative insights on the repurposing of productive capabilities from oil and gas to hydrogen, the methodology used in this study relied on firm-level surveys, at the global level as well as national (Oman) level, where both oil and operators and local suppliers were surveyed. Such methods offer a superior, and highly granular level of qualitative understanding of repurposing plans compared to the quantitative analysis of trade data given the limited export of low-emission hydrogen to date or conducting similarity tests between the supply chains in question.

In total, 16 respondents were included in the analysis of the surveys (five oil and gas majors, five operators in Oman, and six local suppliers). The quality of the data received from the questionnaires sent to the companies varied in terms of quality, relevance and the level of detail provided, but does allow for interesting insights on how the oil and gas sectors conceptualise the transition pathways to a greener economy and the different stages and maturity of the process. The analysis provides a summary of the findings on the linkages that exist between the O&G operations and hydrogen operations, which helps advance the understanding of the nature of dual decarbonisation-diversification pathways in fossil fuel producing countries.

- Respondents' profile: Oil and gas majors

In total, five responses were received from the target oil and gas companies. While the sample is small and statistical analysis cannot be applied, significant diversity exists across the companies surveyed in terms of the way they are integrated and which business segments they prioritise.

This differentiates them with regards to the development of their revenue streams along the value chain and the relative importance of their low-emission divisions. All five surveyed companies are already transitioning or are looking to move into the low-emission space, albeit to differing extents and with differing goals. All five companies have announced their low-emission strategies within the last six years, with all five either updating or substantially increasing ambitions between 2020 and 2022. Some companies have been engaged in lower-emission sources for decades but had only recently formalised their strategy.

- Respondents' profile: Operators in Oman

A total of five responses from operators working in Oman were received, covering a broad range of segments and sectors:

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Of the five companies surveyed, and despite differences in their stage in the value chain, operations and core business models, four noted some focus on renewable energy technologies. One operator mentioned that their strategy was still under board discussion, but that certain low-emission energies will feature in future strategies.

Two companies disclosed the share of spend on renewable technologies, albeit at low levels (5-15% and 3-4% by 2023 respectively) although there is an expectation of variance. Across firms, solar energy is a key target sector. However, some firms have also outlined other key focus sectors, such as wind energy, CCUS, and hydrogen production.

- Respondents' profile: Suppliers in Oman

A total of six responses were received and from local Omani suppliers servicing the oil and gas industry, with wide variance across the services they provide:

The breadth of focus and expertise across the supply chain yielded valuable results, with a relatively high quality of responses (though additional responses would be useful for further research, especially from the local engineering consultancies/OFSE companies).

All of the respondents mentioned that their services (e.g., training, consulting or operations) have been broadened to include renewable energy or hydrogen projects, with only one actor mentioning they had not had requests for new services in Oman (although they mentioned they do work on these projects in other geographies). Five out of six respondents had some operations or projects outside of Oman, with most of them also performing services in the wider GCC region. Two respondents specifically mentioned seeking international partnerships and trying to integrate international expertise and best practices, with one highlighting the fact that the Omani government could do more to foster these international alliances.

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Abbreviations and acronyms

APS	Announced Pledges Scenarios
CAPEX	Capital Expenditure
CBAM	Carbon Border Adjustment Mechanism
CO_2	Carbon Dioxide
CCS	Carbon Capture and Storage
CCUS	Carbon Capture, Utilisation and Storage
DONG	Danish Oil and Natural Gas
DPS	Dhofar Power System
EOR	Enhanced Oil Recovery
EPC	Energy Performance Contracting
EV	Electric Vehicle
FTE	Full-Time Equivalent
GCC	Gulf Cooperation Council
GDP	Gross Domestic Product
GRP	Gas, RES and Power
Gutech	German University of Technology
H_2	Hydrogen
ICV	In-Country Value
IOC	International Oil Company
JV	Joint Venture
LNG	Liquefied Natural Gas
MEC	Muscat Engineering Consultancy
MENA	Middle East and North Africa
MIS	Main Interconnected System
MVA	Manufacturing Value Added
NZE	Net Zero by 2050 Scenario
OFSE	Oilfield Services & Equipment
OLNG	Oman Liquefied Natural Gas
PDO	Petroleum Development Oman
PSA	Power Supply Agreement
PV	Photovoltaics
RES	Renewable Energy Source
SPFZ	Sohar Port and Freezone
TES	Total Energy Supplies
TFC	Total Final Consumption
US	United States

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Units of measure

GW	Gigawatt
Km2	Square kilometre
Mt	Million tonnes
Mt/yr	Million tonnes per year
Mtoe	Million tonnes of oil equivalent
MW	Megawatt
MWt	Megawatt Thermal
TJ	Terajoule

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Typeset in France by IEA - November 2023
Cover design: IEA
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