Mapping Sand Supply Chains in the Gulf Region

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Responsible business for people and planet

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Newcastle University

Table of Contents

Executive Summary

In the 21st century, sand has emerged as the second most extracted mineral resource globally at approximately 50 billion tonnes every year, surpassed only by water. As a fundamental requirement for modern industrialisation, it is utilised extensively in the production of concrete, as well as in glass manufacturing, infrastructure infill, water purification and as strategic inputs for high-technology sectors, including solar energy and semiconductor manufacturing.

Demand for the material is particularly high in areas of the world experiencing periods of growth and development, including across the Gulf Cooperation Council (GCC) countries. In this region, the construction supply chain operates within a uniquely complex risk environment shaped by geopolitics, complex labour structures, and governance gaps. Given how resource intensive GCC countries' economic diversification plans are - and how much sand is required to propel these projects forward - there is an urgent need for more visibility of and accountability for the social risks that exist within sand and silicate supply chains, including forced labour and unsafe working conditions.

Gulf Sustain strives to promote worker welfare in GCC countries' economic diversification and green transition processes through research, capacity building, and collaboration. Part of Gulf Sustain's ongoing engagements with key sectors across the Gulf region - including oil and gas, construction, renewable energy and transport/logistics - centres around assessing worker welfare and labour challenges in supply chains and engaging with businesses to advance responsible practices.

Newcastle University has been commissioned by Gulf Sustain in partnership with Design for Freedom by Grace Farms to examine the sand supply chains in relation to key Gulf countries (the UAE, Saudi Arabia, Oman and Qatar) with a focus on how it is sourced, processed, transported and used. This work builds on the OECD (2026) Due Diligence for Responsible Sand and Silicate Supply Chains report with a practical, implementation-focused view of supply chains across the GCC region.

The report aims to identify key bottlenecks and pertinent social risks within the sand supply chain, while providing recommendations for implementing more sustainable practices. The findings of the report will form the basis of ongoing discussion and engagements with businesses directly and indirectly associated with sand and silicate supply chains to advance responsible business practices in this space.

Key Findings

Risks to workers and communities linked to sand and silicate supply chains are not isolated at single points but are embedded across four stages of extraction, processing, transport, and construction, often intensifying as materials move through opaque, multi-tiered systems.

The report identified three primary labor and social risks companies operating in this sector face:

- There is a significant disparity between direct employment and the total labour footprint. In some markets, the construction sector carries a footprint nearly three times its direct employment, indicating that the highest risks for labour exploitation are embedded in poorly monitored subcontracted tiers.
- Workers in the processing and transport stages face extreme vulnerabilities. These include exposure to silica dust during crushing and grading, which can lead to adverse health related impacts (silicosis risk) , as well as extreme heat stress, and exploitative conditions for long-haul drivers in the logistics network.
- Unlike high-value minerals, sand lacks a cohesive international regulatory framework. This allows the rise of illicit trade and "sand mafias" who capitalize on weak local governance and the difficulty of verifying material provenance once it enters regional processing hubs.

These risks are compounded by the sheer scale and observed growth in the region's demand for sand and aggregates, which have frequently outpaced regulatory oversight, creating a complex ecosystem where rapid economic growth intersects with significant human rights and occupational safety vulnerabilities. Additionally, since the sand market varies significantly across the GCC countries this research assessed, the identified risks may present different challenges across contexts.

In particular, the report identifies four distinct roles within the regional trade network:

- Saudi Arabia dominates regional volume, with domestic consumption peaking at approximately 600 million tonnes annually. The Kingdom's massive requirements for major projects are primarily met through internal extraction, maintaining a trade balance near equilibrium.
- The United Arab Emirates (UAE) is a dominant exporter, with roughly 45% of its domestic extraction destined for international markets. It simultaneously serves as a global leader in high-quality quartz and silica sand imports (holding a 15% global share) required for specialized industrial applications.
- Oman has recorded significant steady growth in aggregate exports, peaking at 25 million tonnes annually. In 2019, it captured nearly 20% of the global share of aggregate exports, serving as a vital raw material supplier for its neighbours.

- Qatar is structurally dependent on imports, sourcing over 50% of its consumption from external supply chains during the height of World Cup preparations. It has consistently accounted for 9–12% of all global sand and gravel imports.

Recommendations for government and business

Governments in the Gulf region occupy a key regulatory and enforcement role in mitigating social risks across sand and aggregate supply chains. The rapid growth in the extraction and construction industries and labour-intensive construction demand have potentially outpaced oversight capacity, particularly in contexts reliant on low-skilled migrant labour. To address risks of forced labour, child labour, and corruption, governments must transition from fragmented regulatory approaches to integrated, risk-based governance frameworks aligned with international standards such as the International Labour Organisation conventions (ILO, 2019) and the OECD Due Diligence Guidance (OECD, 2026).

Key actions include strengthening labour inspection regimes across all supply chain stages, particularly in extraction and transport where oversight is weakest. Governments should mandate human rights due diligence (HRDD) for all large-scale construction and quarrying operations, with legal liability extending to subcontracting tiers.

As established by the UN Guiding Principles on Business and Human Rights, businesses too have the responsibility to address negative human rights impacts they cause, contribute to, or are directly linked to through their business relationships, including with suppliers and subcontractors across the supply chain.

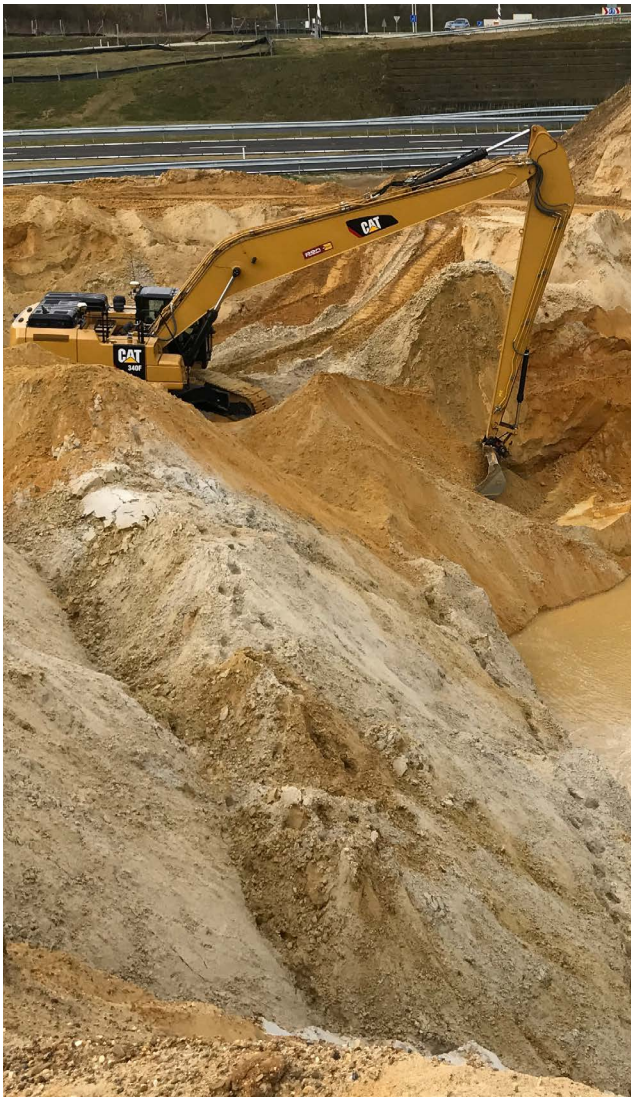
Companies, in particular developers, contractors, and multinational firms, play a central role in shaping labour conditions through procurement, contracting, and operational practices. The construction sectors in the Gulf exhibit disproportionately large labour footprints relative to direct employment, indicating that the highest risks are embedded in subcontracted supply chains. As such, companies must move beyond compliance-based approaches toward proactive supply-chain governance aligned with the United Nations Guiding Principles on Business and Human Rights.

A primary action is the implementation of robust human rights due diligence systems that map supply chains down to extraction and logistics levels. This includes identifying high-risk suppliers, conducting regular audits, and integrating traceability tools such as digital product passports. Contractual mechanisms should require suppliers to meet minimum labour standards, prohibit recruitment fees, and ensure safe working conditions, with clear penalties for non-compliance.

Companies must also address systemic risks linked to subcontracting. This can be achieved by rationalising supply chains (reducing excessive layers and consolidating outsourcing), ensuring direct payment mechanisms to workers, and mandating transparent wage systems. In addition, worker voice mechanisms, such as grievance

channels, trade union access, and anonymous reporting systems, should be implemented and made accessible.

From an anti-corruption perspective, firms should implement strict controls over procurement and licensing interactions, particularly in extraction and transport stages where illicit practices are prevalent. ESG-linked procurement, especially in state-backed projects, offers a powerful tool to incentivise responsible sourcing. Ultimately, companies must recognise that reputational, financial, and legal risks increasingly extend beyond direct operations to the full lifecycle of materials used in construction.

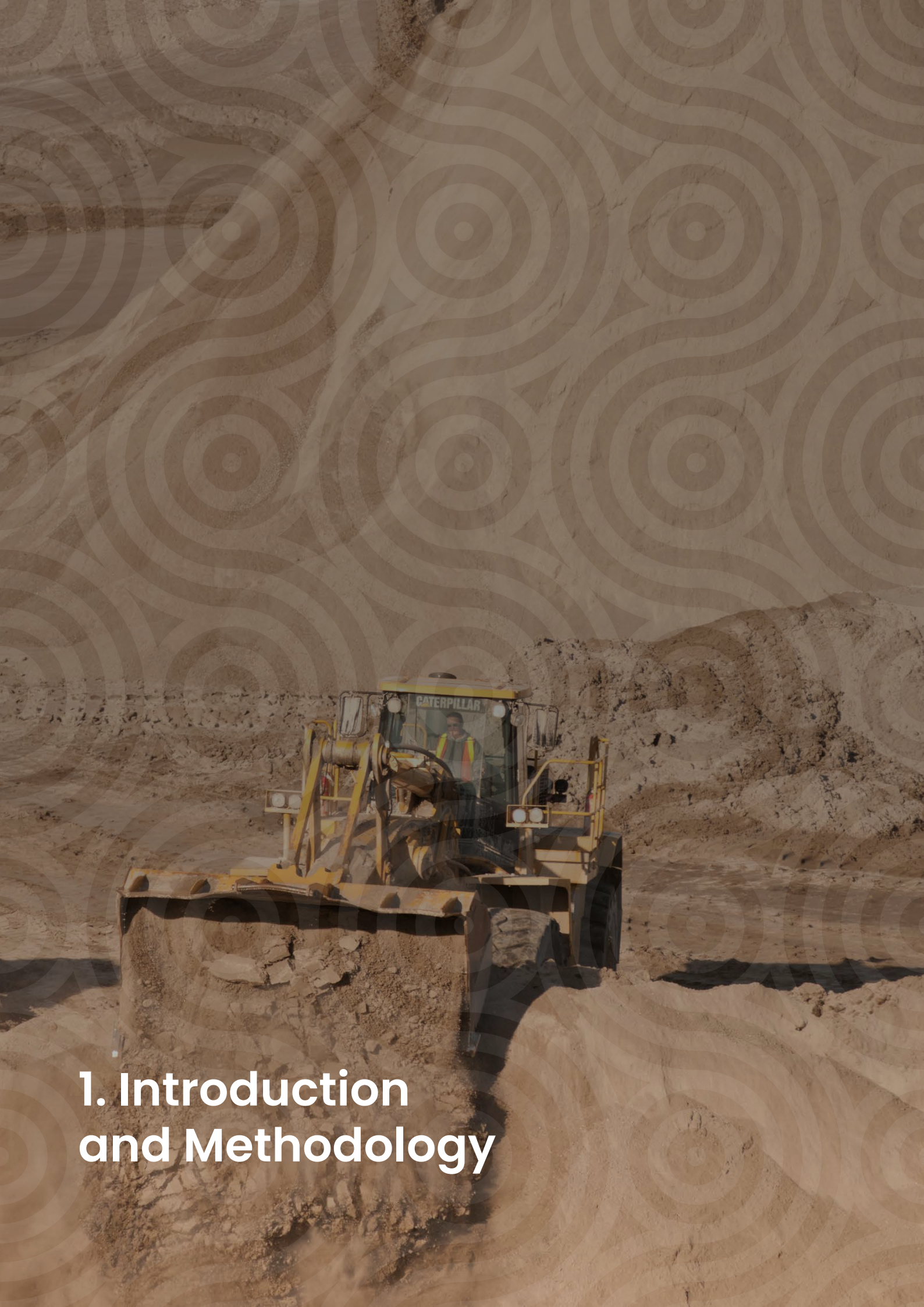


Conclusion

The report highlights that the scale of sand and silicate extraction—estimated to be roughly 70,000 times the combined volume of high-value minerals like cobalt, lithium, and gold—creates a unique risk landscape where even a small percentage of international trade can mask significant adverse impacts. In the context of the GCC - where the execution of economic diversification plans require major construction projects that rely heavily on materials including sand - there is a high level of exposure to supply chain risks, including forced labour and poor worker welfare conditions.

Although GCC countries are not full members of the OECD, there exist numerous cooperation agreements leading to regulatory alignment with OECD standards. Consequently, there is an urgent call for importers of all scale, from the nation state to private enterprises, to move beyond traditional compliance-based models and systematically identify and mitigate labour risks, environmental degradation, and financial crimes that are currently embedded within these decentralised and often opaque global networks. Alignment with OECD recommendations on issues of sustainable and just supply chains in the sand and silicate industries is, therefore, important.

Building on the findings of this report, Gulf Sustain will continue to engage stakeholders including businesses and governments across the region to advance more responsible and sustainable practices throughout the sand supply chain and beyond.



1. Introduction and Methodology

1.1 The importance of sand and aggregates

In the 21st century, sand has emerged as the second most extracted mineral resource globally, surpassed only by water, with annual extraction estimated at approximately 50 billion tonnes (UNEP, 2014; 2022). As a fundamental prerequisite for modern industrialisation, it is utilised extensively in the production of concrete, which constitutes nearly half (549 Gt) of all anthropogenic mass on the planet (Elhacham et al., 2020) - as well as in glass manufacturing, infrastructure infill, and water purification. At a global level, the vast majority of sand and aggregate consumption occurs within the borders of the extracting nation-state. In 2023, global domestic consumption of construction-dominated non-metallic minerals reached 49 billion tonnes, while international trade accounted for only 520 million tonnes, representing approximately 1% of national consumption totals (UNEP IRP, 2024). Despite these comprehensive datasets, the transparency of supply chains remains significantly obscured due to the absence of a cohesive international regulatory framework (Torres et al., 2021; OECD, 2026; UNEP, 2026a). Unlike other extracted commodities such as gold, oil, or gas, sand is governed by a decentralised tapestry of national regulations that vary drastically in their efficacy regarding labour standards, environmental protection, and worker welfare (Bendixen et al., 2021). This has led to a range of conflicts and synergies with the UN Sustainable Development Goals (Figure 1), where the extraction of sand and aggregates can be seen as helping achieve, and also hinder progress towards, global sustainability targets (Bendixen et al., 2021).

Figure 1: The relationship between sand and gravel extraction and the UN Sustainable Development Goals. Adapted from Bendixen et al. (2021)

This regulatory vacuum has facilitated the rise of "sand mafias" who dominate supply chains in numerous regions, often engaging in unauthorised extraction from beaches and rivers through the use of force (Hoffman, 2021). Whilst mining is critical to many economies, illegal extraction creates opportunities for the exploitation of people through corruption, conflict, forced labour and human trafficking (Interpol, 2022). The manufacturing sector (encompassing agriculture, forestry, fishing, mining and quarrying) accounts for almost one fifth (~3 million) of forced labour of adults (ILO, 2022). The illegal sand trade is currently valued as the third-largest illicit trade globally, with annual revenues estimated between US$199.88 billion and US$349.98 billion (Ramadon, 2020). This sector frequently exploits poorly regulated labour markets, leading to high incidences of forced and child labour (Da and Le Billon, 2022; Bari and Haque, 2022). Evidence of forced labour has been documented in the supply chains of India, Morocco, and Sierra Leone (Bari and Haque, 2022; ILO, 2019; US Department of Labour, 2020), suggesting that improving national-level regulatory mechanisms is the primary lever for securing worker rights within these networks.

Torres et al. (2021, p. 645) offer a conceptualisation of the sand-supply network but emphasise the urgent requirement for a more "robust qualitative understanding and quantification of the physical system," including comprehensive mapping of supply chains and the identification of stakeholders at every echelon. Such research is vital for building resilience against illicit actors who capitalise on high global demand and weak local governance, particularly in regions experiencing rapid urbanisation where alternative materials are not financially viable. Consequently, there is a pressing scientific and humanitarian need to bridge the knowledge gap regarding labour markets and illicit networks to ensure the global sand economy becomes sustainable, equitable, and just.

To further address these regulatory and transparency deficits, the OECD (2026) emphasises the critical necessity of implementing risk-based due diligence frameworks specifically tailored to sand and silicate supply chains. While such materials have historically been overlooked in critical mineral initiatives, they are increasingly recognised as strategic inputs for high-technology sectors, including solar energy and semiconductor manufacturing (OECD, 2026). The report highlights that the scale of sand and silicate extraction—estimated to be roughly 70,000 times the combined volume of high-value minerals like cobalt, lithium, and gold—creates a unique risk landscape where even a small percentage of international trade can mask significant adverse impacts. Although no GCC countries are full members of the OECD, there exist numerous cooperation agreements between many GCC countries (e.g. UAE) and the OECD, leading to regulatory alignment with OECD standards. Consequently, there is an urgent call importers of all scale, from the nation state to private enterprises to move beyond traditional compliance-based models and systematically identify and mitigate human rights abuses, environmental degradation, and financial crimes that are currently embedded within these decentralised and often

opaque global networks. Alignment with OECD recommendations on issues of sustainable and just supply chains in the sand and silicate industries is, therefore, important. This report builds on the OECD (202) *Due Diligence for Responsible Sand and Silicate Supply Chains* report with a practical, implementation-focused view of supply chains across the GCC region.

1.2 Purpose and Scope

Despite the regional abundance of sand across the GCC in the form of desert dunes, the aeolian (wind-blown) sand of the Arabian Desert is structurally unsuitable for high-strength concrete due to its rounded grain geometry (UNEP 2022). Consequently, the construction sectors of the Gulf region are reliant on a complex, and often unclear provenance, global supply chain for sand, sourced from marine, fluvial, and manufactured (crushed rock) origins. The rapid urban transformation across the Gulf Cooperation Council (GCC) region represents one of the most resource-intensive periods of capital accumulation in modern history. Across the Kingdom of Saudi Arabia (KSA), the United Arab Emirates (UAE), Qatar, and Oman, the transition towards hyper-urbanised, diversified economies has been predicated on the continuous consumption of mineral aggregates (Arfi and Aldosary, 2023) increasing demand for construction grade aggregates.

In 2023, global domestic consumption of construction-dominated non-metallic minerals - those primarily comprised of sand and aggregates, but also including clays and limestones - reached an unprecedented 49 billion tonnes (UNEP IRP Global Material Flows Database, 2024). Globally, the vast majority of this demand is met within national borders, with international trade of these minerals recorded at 520 million tonnes - approximately 1% of total global consumption values (UNEP IRP Global Material Flows Database, 2024). Despite these massive volumes, the supply chains associated with extraction remain opaque. This is, in part, a consequence of the absence of a cohesive international regulatory framework. Unlike high-value commodities such as gold, oil, and gas - which are governed by rigorous global transparency standards and multilateral oversight - sand and aggregate regulation is devolved to the national level. This has resulted in a spectrum of regulatory efficacy and stringency regarding labour welfare, environmental impact, and extraction ethics. Forced labour has been exposed across sand supply chains across India, Morocco and Sierra Leone (Bari and Haque, 2022; ILO, 2019; US Department of Labour, 2020) and is likely prevalent more widely where inefficient regulation exists. Therefore, greater transparency and accountability across sand supply chains is necessary to reduce injustice and exploitation of workers.

The necessity for a granular understanding of these supply chains is driven by an unprecedented wave of infrastructure development across the GCC. Under Saudi Arabia's Vision 2030, projects such as NEOM, the Diriyah Gate, and the Qiddiya entertainment City demand volumes of aggregate that challenge existing regional capacities. Similarly, the UAE is planning major infrastructure upgrades to rail, air and energy infrastructure, whilst Qatar's National Vision 2030 emphasise advanced manufacturing and logistics hubs. All of these projects will require

increasing quantities of aggregates, in addition to high-specification industrial sands, and associated labour. These "Giga-projects" function as nodes in a cross-border GCC trade network where sand is frequently re-exported between countries, with one country acting as an intermediatory. This onward trade adds layers of complexity to traceability, as the point of origin becomes blurred through regional processing hubs.

This report will identify key drivers of sand demand, bottlenecks and pertinent social risks within the international sand supply chains of four GCC focus countries; Oman, KSA, Qatar, and the UAE over the period of 2015 -2024. Where subnational data are limited, four key international-scale commodity trade databases are interrogated. In doing so it will (1) identify the key regional players leading demand for construction aggregates, (2) highlight evolving trade patterns both regionally and internationally and (3) identify pertinent human rights risks within these sand supply chains, including those related to sourcing, processing, transporting, and being used in construction. Finally, it will provide recommendations for implementing more sustainable practices across the GCC region in terms of sand sourcing, supply and trade and the need for greater cooperation and alignment with existing global organisations such as the OECD and Coalition for Responsible Sand and Silicates.

1.3 Methodology

Global annual trade statistics for specific construction-based commodities and industries across are compiled across four main databases: Comtrade, Resource Trade Earth, SCP-HAT and Material Flows. Each database compiles a different range of national and international trade accounts to examine different facets of construction-related resources. For an overview of construction-based commodities examined, refer to Appendix Table A. These findings are examined within the available wider literature, reports and media.

Comtrade

The United Nations Comtrade database aggregates detailed global annual trade statistics by product and trading partner, including import, net export, re-export and domestic export for 1991-2024. Data compiled by the UN Statistics Division covers approximately 200 countries and represents more than 99% of the world's merchandise trade. Data are submitted directly by national statistical authorities. Here, construction-based commodities include sands of all kinds (HS-2505), quartz sands and quartzite (HS-2506), monumental and building stone (including granite, porphyry, basalt and sandstone; HS-2516), pebbles, gravel and crushed stone (HS-2517), bitumen and asphalt (HS-2714) and ceramic constructional goods (including bricks, blocks, tiles; HS-6902 and HS-6905).

Resource Trade Earth

The Chatham House Resource Trade Database (CHRTD) is a repository of bilateral trade in natural resources between more than 200 countries and territories. The database includes monetary values, masses of trade and percentage share of global trade across over 1,350 different types of natural resources and resource products. This directly aligns with the Comtrade database of construction-based commodities.

SCP-HAT

SCP-HAT is a tool to identify hotspot areas of industrial commodity consumption and production in over 164 countries and regions – covering the period 1990-2024 (UNEP, 2026b). It is underpinned by the Global Resource Input-Output Assessment (GLORIA, v059) database built for the UN International Resources Panel, forming part of the UN IRP Material Flows database (see below). Both data from domestic territorial accounts and trade information (with data sources including the UN IRP and FAOSTAT) are aggregated to define footprints and impact indicators for different sectors – making the database different to that of Comtrade. Here, four construction-related sectors examined include construction material quarrying, construction, ceramics and coal, oil and gas mining.

The tool differentiates employment in construction-related sectors by skill level and gender. Persons in employment are defined as all those of working age who, during a short reference period, were engaged in any activity to produce goods or provide services for pay (UNEP, 2026b).

Material Flows

The Global Material Flows database aggregates more than 300 different materials into 13 categories of material flows, covering more than 200 countries between 1970 and 2024. However, the

years 2022 to 2024 are estimated based on economic proxies. For construction-dominant materials, data sources are multiple and include UN Comtrade (UN 2026), UNSD, UNGS, AND IEA (UNEP IRP, 2024). Here, two Material Flows databases are included: MFA4 and MFA13.

Based on known volumes of domestic extraction and physical imports and exports, the direct material input, domestic material consumption, and the physical trade balance of a given country are calculated (Eurostat, 2018). The domestic material input of a given country is calculated as the sum of domestic extraction and physical imports. Domestic material consumption is defined as the total amount of materials directly used in a national economy, calculated as the direct material input minus physical exports. The physical trade balance is calculated as physical imports minus physical exports – estimating the physical trade surplus or deficit of a given country.

In particular, the domestic extraction of non-metallic minerals (MFA4) records material flows from the environment to the economy related to mining and quarrying of mineral material, including stone, sand, clay, salt, etc., but excluding metals and fossil energy carriers (Eurostat, 2018). Non-metallic minerals are used most notably in construction (i.e. sands, gravels, stones), the manufacture of mineral products (i.e. glass, cement) or manufacture of chemicals (i.e. mineral fertilisers). Comparatively, MFA13 allows further disaggregation of sectors, and includes the construction dominant portion of non-metallic minerals.

2. Sand Supply Chains in the Gulf: Regional Overview

2.1 Global setting of Gulf region aggregate trade

The scale of the Gulf's aggregate usage is dominated by Saudi Arabia, which exhibits a domestically dominated supply chain (Figure 2). Saudi Arabia's domestic extraction (DE) and domestic consumption (DC) have mirrored each other since the early 2000s, reaching a peak of approximately 600 million tonnes annually. This indicates that the Kingdom's massive infrastructure requirements are predominantly met through internal extraction, maintaining a trade balance that remains close to equilibrium.

In contrast, the UAE and Oman have more export focussed sectors (Figure 2). The UAE's export volume surged after 2010, plateauing at roughly 80 million tonnes, while Oman has seen a steady trajectory of export growth since 2015, peaking at ~25 million tonnes. These two nations provide the raw materials necessary to facilitate the import requirements of Qatar, whose imports of non-metallic minerals spiked significantly around 2015 - aligning with World Cup-preparations - reaching volumes between 20-30 million tonnes.

The regional supply chain structure plays a significant role in the broader pattern of global trade of sand and aggregates, as is shown in Resource Trade Earth Databases (Figures 2 and 3). Whilst imports of sand and gravel are typically low (< 3% of global trade), Qatar has accounted for 8-10% of global sand and gravel imports consistently since 2010, peaking at ~12% in 2015 around the time of the FIFA World Cup (Figure 3). Imports of high-quality grade quartz and silica sands have risen considerably over the past decade across the region, rising from <5% of global imports pre-2010, to the UAE representing 10 –15% of global imports in 2018, before a recent decline back to levels of ~5%.

Extraction in the Gulf region is split between the mining of natural sands (aeolian or marine) and the production of manufactured sand (M-sand) from crushed rock (gabbro and limestone; Al-Ansary et al., 2012). Oman and the UAE dominate the export of aggregates (Figure 2). Oman has captured a significant percentage of the global share of a range of sub-categories of aggregate exports, peaking at nearly 20% around 2019 (Figure 3). Similarly, the UAE accounts for 10% of global sand and gravel exports, peaking at 15% in 2016.

While the region is largely self-sufficient in bulk aggregates (Figure 2), it remains a major importer of aggregates. The UAE has emerged as a global leader in high-quality quartz and silica sand imports, holding a global share of roughly 15% in 2020 (Figure 3). These imports, often sourced from outside the region (see Section 3.1 for further breakdown and details), are essential for specialised industrial applications, including glass manufacturing and hydraulic fracturing.

In Saudi Arabia, the stability of the trade balance suggests that domestic consumption is the primary driver of extraction, with materials being immediately absorbed into completed and ongoing Giga-projects. In Qatar, the positive trade balance (indicating net imports) reflects a structural dependency on external supply chains to maintain its construction momentum.

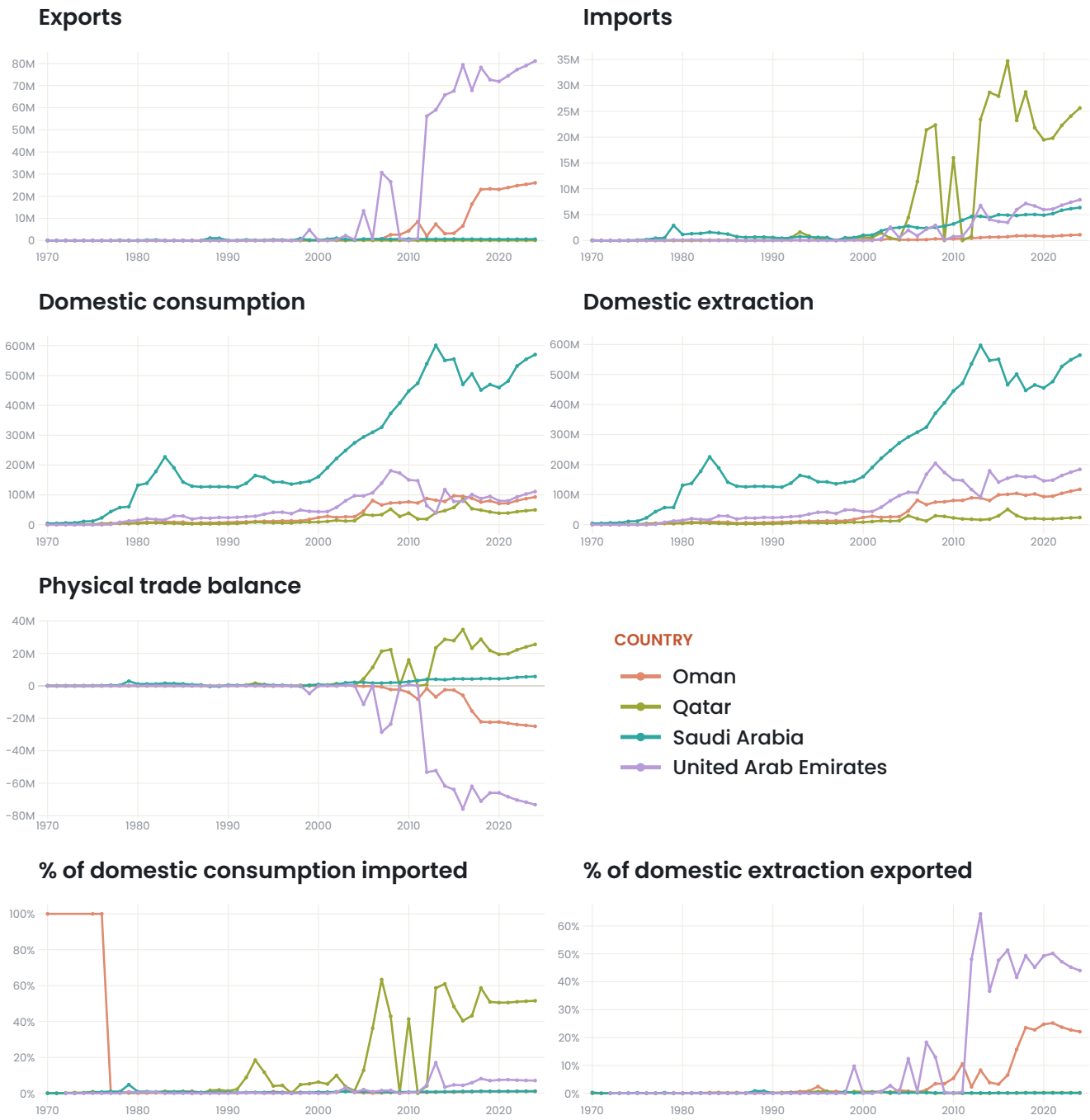


Figure 2. Non-metallic mineral (construction dominant) export, import, domestic consumption, domestic extraction and physical trade balance (difference between imports and exports) for Oman, Qatar, Saudi Arabia and the United Arab Emirates. Data retrieved from the Global Material Flows Database (UNEP IRP 2026).

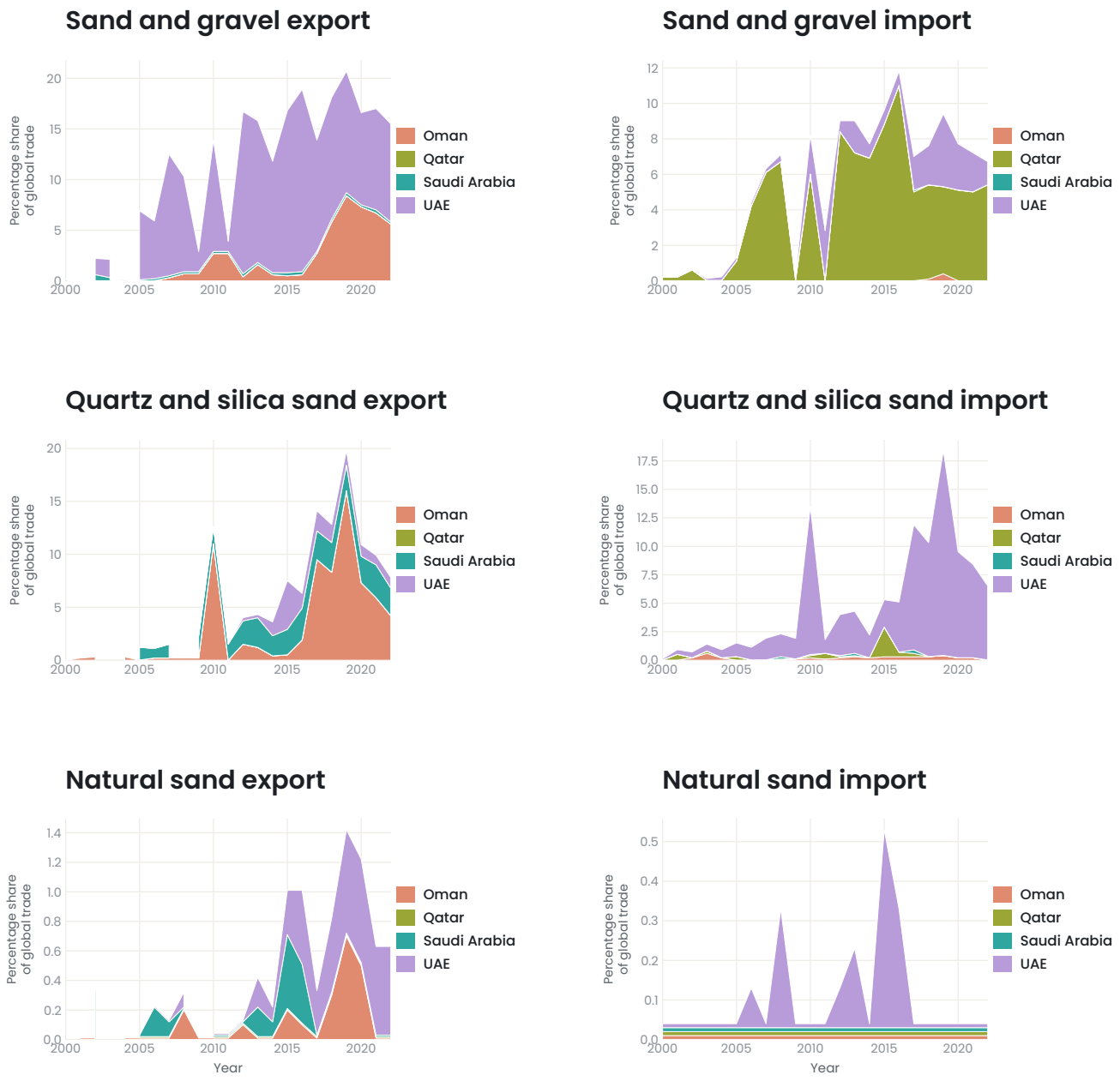


Figure 3. Global percentage share of exports and imports for sand and gravel (aggregated commodity containing 6 sub-commodities), quartz and silica sand, and natural sand. Data retrieved from the Resource Trade Earth Database (Chatham House, 2026).

3. Country Profiles: Sand Supply Chains and Risks

3.1 United Arab Emirates

a) Supply Chain Structure

The UAE's non-metallic mineral sector (MFA4) is characterised by high domestic self-sufficiency and regional dominance of the export market (Figure 2). Since 2012, approximately 45% (fluctuating by ±10% over 1–2 year periods) of the UAE's domestic extraction of non-metallic construction dominant minerals (MFA13) has been destined for export, with exports distributed globally (Figure 4). This reflects a substantial reliance on internal reserves, contributing to a consistently negative trade balance (a significant trade surplus).

Since 2017, the UAE has maintained a stable hierarchy of sourcing for construction-based commodities (HS 2505; HS2506; HS2516; HS2517; HS2714; HS6902; HS6905; see Appendix Table A). From 2017-2020 and 2021-2024, the top three suppliers, in descending order of volume, were Oman, Saudi Arabia, and Iran. The primary destination for UAE sand exports since 2013 has been Bahrain. Other major regional partners across construction-based commodities include Kuwait, Bangladesh, Iraq and Qatar, all of which have been the top four secondary importers since 2017 to 2024.

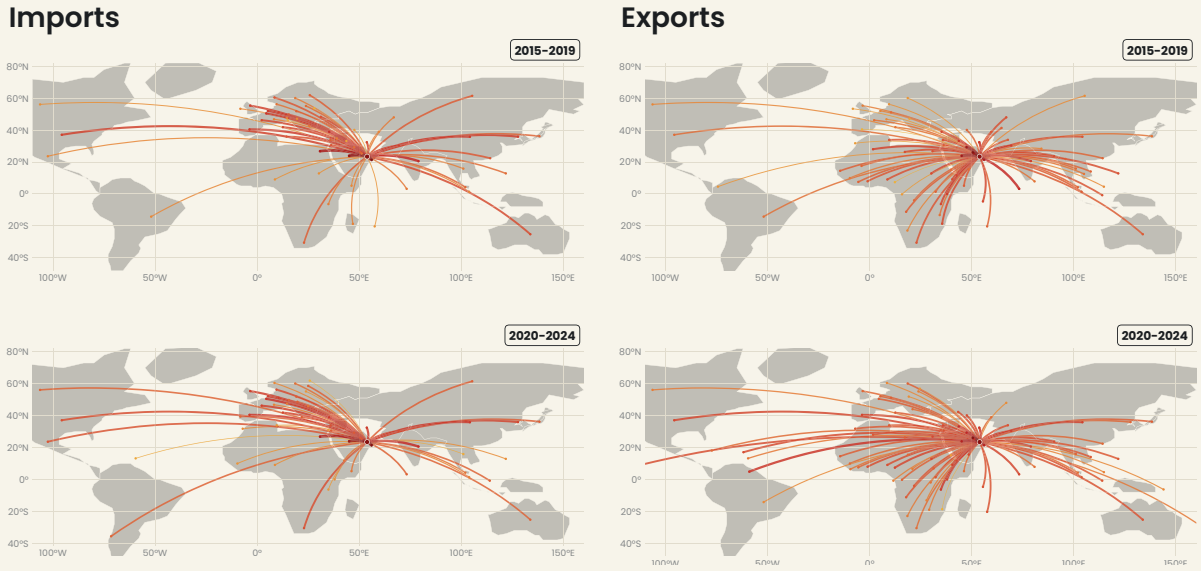


Figure 4: Global import (left) and export (right) trade maps showing the international trade to and from the UAE in all construction-based commodities (HS2505; HS2506; HS2516; HS2517; HS2714; HS6902 and HS6905), across two time periods, 2017 – 2020 (top) and 2021 – 2024 (bottom).

b) Demand Drivers (2015–2025)

While the Coal, Oil & Gas mining sector accounts for the largest share of domestic material use with the UAE (54.5%), the primary driver of the national material footprint is the construction sector, which accounts for 32.6% of total material consumption (UNEP, 2024d). This demand is underscored by the explosive growth of the Ceramics sector, where domestic raw material extraction increased by 441.2% (from 1.1 million tonnes in 1990 to 5.8 million tonnes in 2024; UNEP 2024d). The rapid increase seen in HS-2506 (quartz and silica sand) could also be an indication of the UAEs rapid build out of their digital infrastructure, including data centres and other non-construction based uses. This highlights the need for greater scrutiny of this sector in terms of silicate supply chains in the coming decade.

This growth reflects a decade-long demand cycle fuelled by massive infrastructure projects and the legacy of Expo 2020. The industry is largely "pull-driven" by final demand for infrastructure and real estate, with the construction sector contributing 11.7% to overall final demand in the economy.

c) Employment and labour

Labour dynamics in the UAE reveal a large workforce within extraction and construction (Figure 5). Employment in the construction and mineral quarrying (CMQ) sector has increased from 120,000 in 2020 to 138,000 in 2024, employing ~2% of the workforce in the UAE. Economically, this sector contributed ~1.8% of the overall monetary output produced in the economy of the UAE. By comparison, the energy sector (Coal, Oil & Gas) remains the largest employer in the UAE, increasing from 550,000 to 600,000 over the same period. Despite the recent boom, the ceramics sector only employed 0.8 % of the overall work force in United Arab Emirates despite contributing 13.1 % to the overall monetary output produced in the economy of United Arab Emirates.

The UAE's CMQ sector employs the highest number of workers across the four Gulf countries studied here, gradually increasing from 120,000 in 2020 to 138,000 people in 2024. The industry is dominated by low-skilled workers. Whilst the proportion of low-skilled workers has remained relatively the same from 2020-2024 (~54%) employment numbers at this skill level have increased from 97,000 to 127,000 in the same period. The number of high skilled workers has also increased from 27,000 to 34,000 from 2020-2024, but at a much slower rate than low-skilled workers. Proportionally, the number of women employed in the sector decreased from 12% in 2020 to 10.7% in 2024.

The broader supply chain associated with the construction sector is evident in the UAE, where the sector itself employs 6.0% of the workforce but carries a

16.5% labour footprint. This disparity suggests that the supply chains feeding UAE construction are highly labour-intensive, indicating that for every direct construction worker, there are nearly three times as many people working along the supply chain to support that sector's consumption, often in subcontracted or international roles where oversight is more difficult.

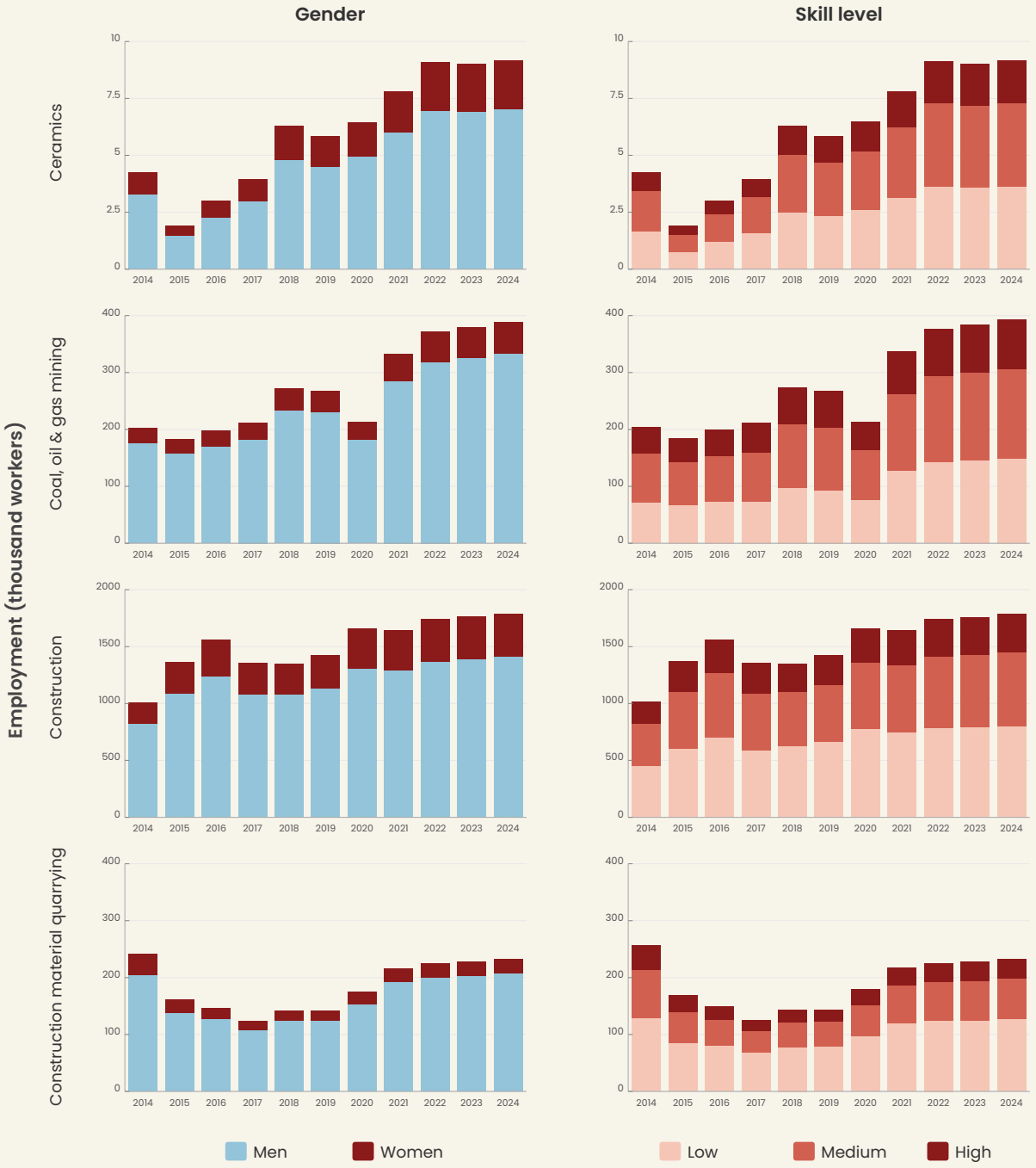


Figure 5. Employment in the (1) ceramics, (2) coal, oil and gas, (3) construction and (4) construction material quarrying industries in the United Arab Emirates split by gender and skill level (low, medium and high). Data retrieved from the SCP-HAT database (UNEP, 2026b).

3.2 The Kingdom of Saudi Arabia (KSA)

a) Supply Chain Structure

KSA's non-metallic mineral sector (MFA4; UNEP IRP 2024) is characterised by the highest levels of domestic consumption in the region, increasing from 125 million tonnes in the 1990s to ~500 million tonnes in the period since 2015, peaking at 600 million tonnes in in 2013, before declining to 579 million tonnes in 2024. There has been a recent increase in domestic consumption over the past four-year period, indicating domestic self-sufficiency and regional dominance of the export market (Figure 2). The scale of domestic operations has increased substantially, with raw material extraction for the quarrying sector increasing by 353.1% between 1990 and 2024, rising from 123.4 million tonnes to 559.0 million tonnes.

Imports and exports have remained relatively low, though the past decade has seen a gradual and continual increase in imports from ~5 million tonnes in 2015 to ~6.4 million tonnes in 2024 (Figure 2). The KSA have frequently changed the countries they import the most construction-based commodities from over time – with a wide geographical reach (Figure 6). From 2017-2020, the five highest countries (in descending order) included China, the UAE, Spain, Italy and Greece. Contrastingly, from 2021-2024, the five highest countries (in order from high to low) were China, Spain, the UAE, India and Italy. The UAE have always imported the highest quantities of construction-

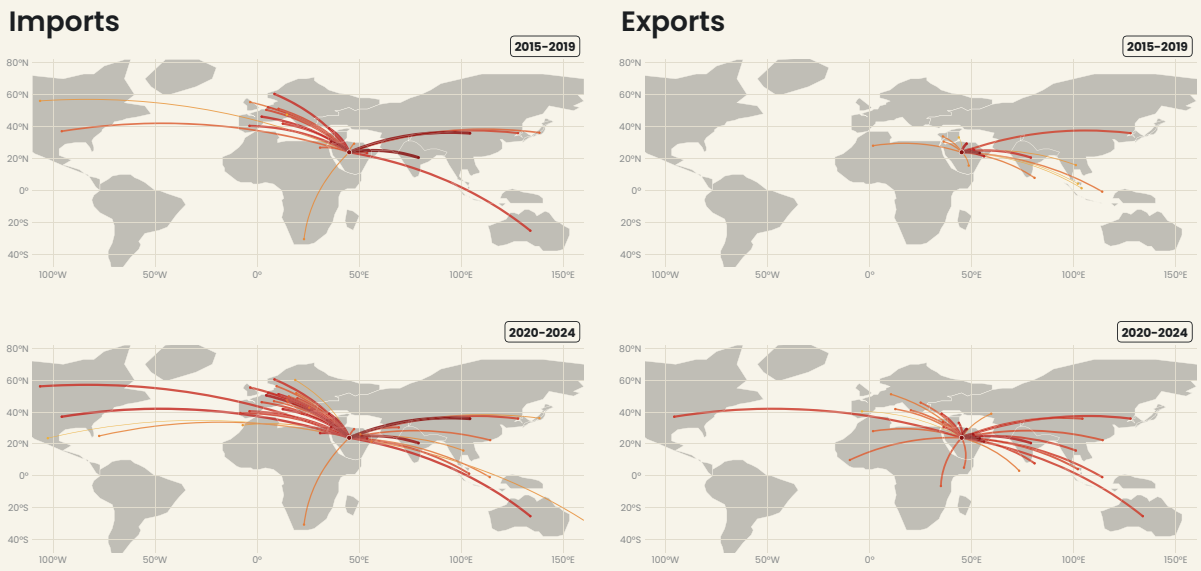


Figure 6. Global import (left) and export (right) trade maps showing the international trade to and from Saudi Arabia in all construction-based commodities (HS2505; HS2506; HS2516; HS-2517; HS2714; HS6902 and HS6905), across two time periods, 2017 – 2020 (top) and 2021 – 2024 (bottom).

based commodities from China from 2017 to 2024. The remaining same four countries have fluctuated their imports from KSA from 2017-2020 and 2021-2024 – these countries are UAE, Kuwait, Bahrain, Oman and India.

b) Demand Drivers

Current material demand in the KSA is overwhelmingly driven by the built environment. From a domestic production perspective, Coal, Oil & Gas mining accounts for 50.0% of material use (UNEP, 2024c). However, from a consumption footprint perspective, the Construction sector accounts for 54.2% of the total national material footprint). This indicates that more than half of all materials "consumed" in the KSA - regardless of where they were extracted - are destined for final demand in construction (UNEP, 2024c). Similar to the UAE, the rapid increase seen in HS-2506 (quartz and silica sands) may be indicative of a rapid upscaling in digital infrastructure, evidenced through rapid data centre growth. As such, non-construction sectors require oversight and observation in the coming years to ensure their supply chains remain responsible and sustainable.

The dramatic 353.1% increase in quarrying extraction over the last three decades highlights a long-term strategic pivot toward infrastructure and giga-projects including NEOM, the Red Sea Project and other infrastructure projects associated with Vision 2030.

c) Employment and labour

Employment trends in the KSA reveal a rapidly growing workforce with significant differences between direct employment and supply chain "footprints" (Figure 7). Direct employment in construction has climbed steadily from 825,000 in 2018 to approximately 1.05 million in 2024. This sector directly accounts for 5.9% of the workforce directly but is responsible for 17.2% of the country's labour footprint, suggesting for every directly employed worker in the construction sector, there are an additional three people employed in supporting supply chain roles. This indicates the majority of the labour required to satisfy Saudi Arabian construction demand is embedded in the supply chain - often through complex subcontracting layers that carry higher risks for migrant labour oversight.

Interestingly, while domestic extraction of construction facing materials has increased, the CMQ sector is highly automated and employs relative low levels of labour compared to others, with only 40,000 people (0.2% of the workforce) in 2024 and contributing 0.0% to the national labour footprint (UNEP, 2026b).

Figure 7. Employment in the (1) ceramics, (2) coal, oil and gas, (3) construction and (4) construction material quarrying industries in Saudi Arabia split by gender and skill level (low, medium and high). Data retrieved from the SCP-HAT database (UNEP, 2026).

3.3 Qatar

a) Supply Chain Structure

Qatar's supply chain is fundamentally distinct from its regional neighbours. While KSA, and to an extent the UAE, leverage domestic reserves for export, Qatar dominates the region in non-metallic mineral imports (MFA4). Since 2019, over 50% of Qatar's domestic consumption in the construction-dominant mineral sector (MFA13) has been imported. This reliance has resulted in a consistently negative trade balance (Figure 2).

Qatar maintains a broader geographical range for construction-based commodities compared to other focus countries (Figure 8). From 2017-2020 and 2021-2024, the same top five suppliers in both periods were Oman, the UAE, Iraq, Iran, and India. Yet, Qatar's supply chain is highly responsive - between 2014 and 2023, China was a top-tier supplier (ranking between 2nd and 4th), but trade volumes with China have decreased significantly since 2023. In contrast to imports, Qatar exports negligible quantities of sand, focusing almost exclusively on internalising resources to meet domestic demand.

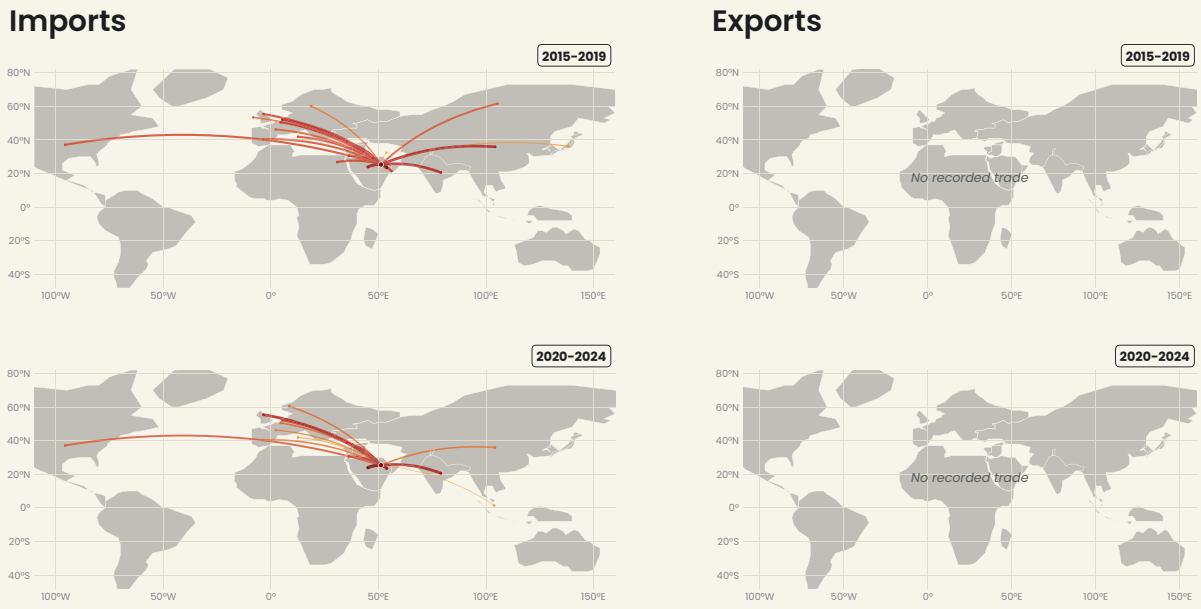


Figure 8. Global import trade maps showing the international trade to and from Qatar in all construction-based commodities (HS2505; HS2506; HS2516; HS-2517; HS2714; HS6902 and HS6905), across two time periods, 2017 – 2020 (top) and 2021 – 2024 (bottom).

b) Demand Drivers

While Qatar's domestic production is dominated by the energy sector - with Coal, Oil & Gas mining accounting for 88.1% of material use - the consumption footprint is almost entirely driven by the construction sector, which accounted for 83.1% of the national material footprint in 2024 (UNEP, 2024b). The material footprint of Qatar's construction sector is 55.20 tonnes per capita. This is 1,412% higher than the Middle East & North Africa (MENA) average of 3.65 tonnes. Growth has been evident across a range of sectors, including the Ceramics sector, with raw material extraction increasing by 1,580.4% since 1990 (from 0.1 million to 2.5 million tonnes).

The infrastructural acceleration associated with the 2022 FIFA World Cup constituted a significant driver to Qatar's economy, amplifying pre-existing structural trends in both aggregate demand and labour market composition. Expenditure estimated between US$200 – 300 billion in the decade leading to the 2022 FIFA World Cup (Bibolov et al., 2024), particularly on stadium construction, transport networks, and urban development, formed a substantial component of Qatari aggregate demand. This expansion was further reinforced by increased private sector participation, especially in real estate and hospitality, as firms anticipated elevated tourist inflows and long-term returns on capital investments. From a labour market perspective, the tournament intensified demand for low- and semi-skilled migrant labour, predominantly within the construction and services sectors. Employment levels rose markedly between 2015 and 2022 (see below), with foreign workers constituting the majority of new labour market entrants.

c) Employment and labour

Qatar's labour market shows a unique skill profile and significant supply chain labour risks, particularly within the built environment (Figure 9). All major industrial sectors have seen steady employment growth. The Energy sector employed between 150,000–200,000 workers, while the Construction sector grew to 140,000 and CMQ to 48,000 by 2024. The construction sector directly employed 6.1% of the workforce, but carried a 26.0% labour footprint in 2024, suggesting wide-spread and disperse supply chains. For every direct worker in Qatar, there are roughly four more workers providing materials and services upstream, often in jurisdictions with varying labour protections.

The Construction Material Quarrying (CMQ) sector is a significant contributor to GDP relative to its size. While in 2024 it employed only 2.0% of the workforce, it contributed 21.2% ($46.6 bn) to the Qatar's GDP. Within the quarrying sector subset (stone, sand, and clay), extraction has surged by 547.2% since 1990, reaching 21.6 million tonnes by 2024. However, compared to other Gulf region

countries, Qatar displays a prevalence of "medium skill level" workers as a fraction of the total number employed in the CMQ (46 – 43% from 2020 – 2024), which is relatively higher than in Saudi Arabia (56 – 57% from 2020 – 2024) across all three primary industries.

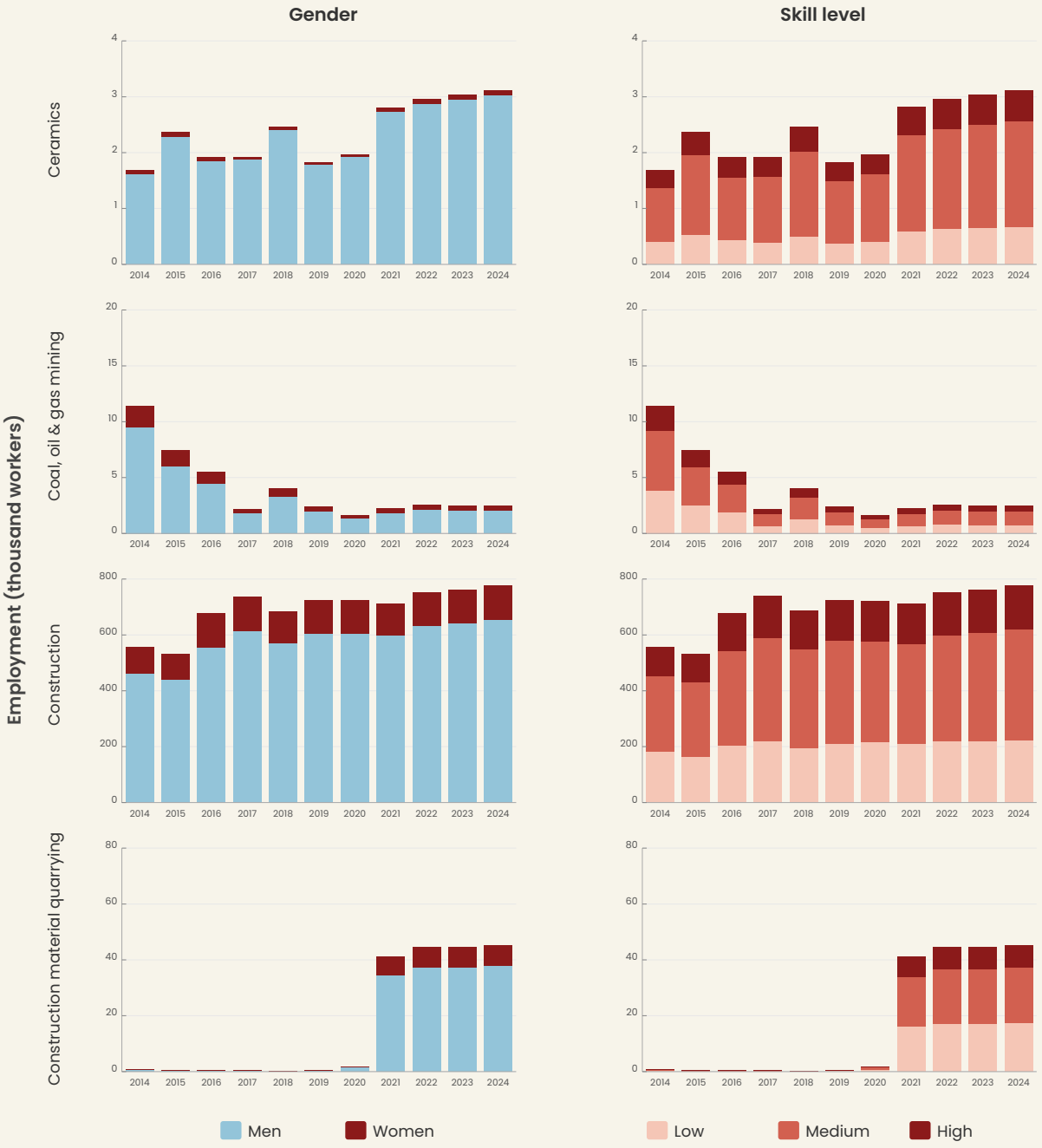


Figure 9. Employment in the (1) ceramics, (2) coal, oil and gas, (3) construction and (4) construction material quarrying industries in Qatar split by gender and skill level (low, medium and high). Data retrieved from the SCP-HAT database (UNEP, 2026b).

3.4 Oman

a) Supply Chain Structure

Oman's supply chain is defined by its role as a primary extractor and exporter with a broad geographical reach (Figures 2 and 10). Following a rapid increase in exports since 2015, Oman now exports ~25 million tonnes of sands of all kinds (HS-2505). This has been coupled with a 1,078.3% increase in domestic material extraction within the CMQ sector since 1990 - rising from 9.7 million tonnes to 114.4 million tonnes in 2024.

For construction-based commodities more broadly, Oman has shifted its sources through time; from 2017-2020 the top five countries included the UAE, Iran, Saudi Arabia, India and China, whereas from 2021-2024 this included the UAE, Saudi Arabia, India, Iraq and China. Contrastingly – the same three countries have imported the highest quantities of construction-based commodities from 2017-2020 and 2021-2024: the UAE, Bahrain and India. This confirms Oman's transition into a regional supplier of construction materials. Indeed, both Oman's CMQ and Ceramics sectors report zero reliance on raw material imports to deliver to final consumption. The entirety of the 114.4 million tonnes of non-metallic minerals used by these sectors originates from domestic extraction.

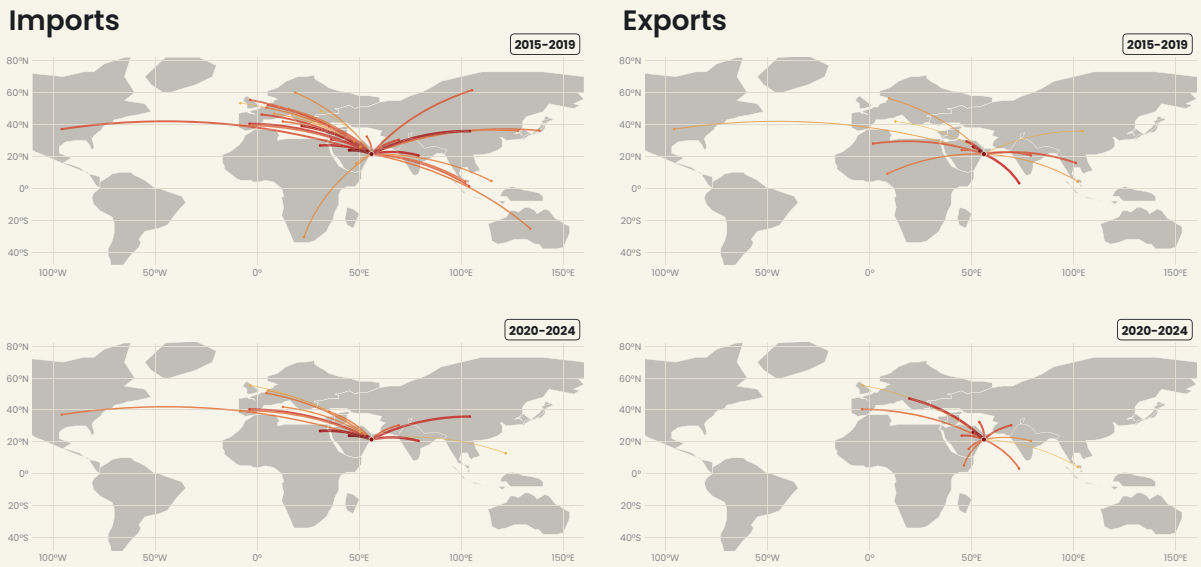


Figure 10. Global import (left) and export (right) trade maps showing the international trade to and from Oman in all construction-based commodities (HS2505; HS2506; HS2516; HS-2517; HS2714; HS6902 and HS6905), across two time periods, 2017 – 2020 (top) and 2021 – 2024 (bottom).

b) Demand Drivers

While quarrying leads resource material production, the construction sector remains the ultimate driver of Oman's material footprint from a consumption perspective, accounting for 62.9% (UNEP, 2024a). Oman's construction sector contributed 21.48 tonnes per capita to its material footprint in 2024 (UNEP, 2024a). This is 489% higher than the Middle East & North Africa (MENA) average of 3.65 tonnes, indicating an extremely high intensity of building and infrastructure activity relative to the population (UNEP 2026b). Yet, whilst the CMQ sector produces 56.9% of materials, it only accounts for 2.7% of the national material footprint. This gap suggests that a vast majority of Oman's extracted materials are being consumed by the domestic construction sector or exported to neighbouring markets, rather than being embodied in the final demand of the quarrying sector itself.

c) Employment and labour

Oman's labour market reflects the heavy physical demands of its extraction and building sectors, with a notable disparity between direct employment and supply chain labour. The Construction sector employs 6.0% of the overall workforce, yet has a labour footprint of 17.4%, nearly tripling the direct employment. This indicates that Oman's construction activity relies heavily on labour embedded in supply chains. In contrast, the CMQ sector has a labour footprint of 0.9%, which is lower than its direct employment of 1.1%, suggesting its supply chains are less labour-intensive than the final construction phase.

In 2024, the construction sector in Oman employed ~76,000 Omani nationals, compared to ~442,000 workers, suggesting a heavy reliance on expatriate workers to deliver construction projects (Figure 11; UNEP, 2026b). Of this workforce, 64% are classed as low-skilled, with expatriate workers comprising the largest proportion of this workforce. By comparison, the CMQ sector comprises a 70% Omani workforce, employing ~31,000 workers (UNEP, 2026b).

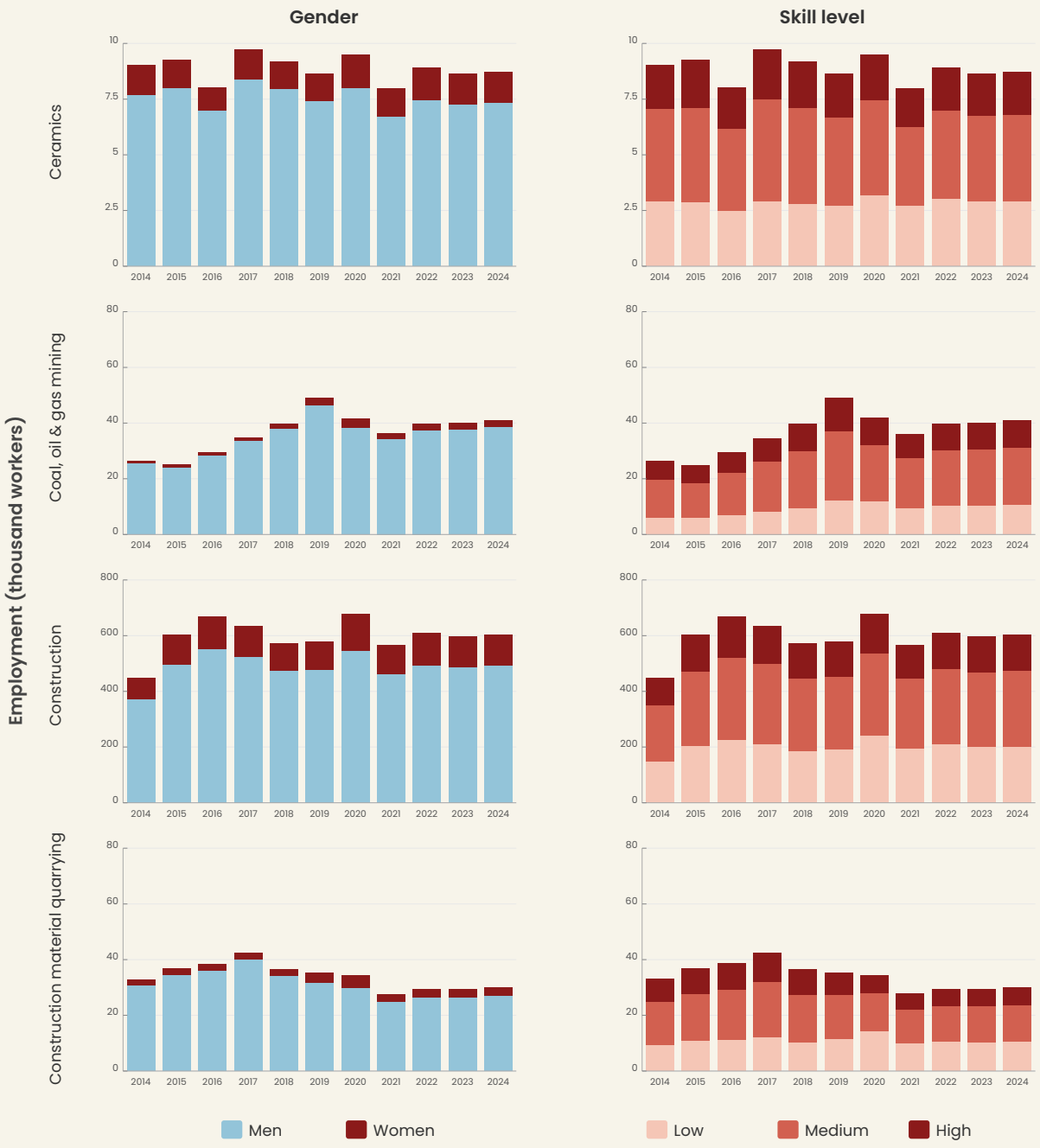


Figure 11. Employment in the (1) ceramics, (2) coal, oil and gas, (3) construction and (4) construction material quarrying industries in Oman split by gender and skill level (low, medium and high). Data retrieved from the SCP-HAT database (UNEP, 2026b).

4. Human Rights Risks Across the Sand Supply Chain

4.1 Risk Mapping by Supply Chain Stage

The sheer scale and observed growth in the regions' demand for sand and aggregates have frequently outpaced regulatory oversight, creating a complex ecosystem where rapid economic growth intersects with significant human rights and occupational safety vulnerabilities. To ensure the ethical integrity of these developments, it is necessary to adopt a stage-gated analysis of the supply chain. By segmenting the supply chain of sand and aggregate flows into four distinct stages - Extraction, Processing, Transport, and Construction (Figure 12) - stakeholders can systematically identify and mitigate specific risks that are otherwise obscured within decentralised and often opaque networks. This granular approach is essential for establishing a robust due diligence framework, enabling a precise understanding of how vulnerabilities manifest at different aspects of the supply chain and ensuring that the Gulf's future infrastructure is built upon fair and sustainable labour practices.

Stage 1: Extraction

The extraction phase is the primary point of entry for mineral aggregates into the regional economy, and it is characterised by massive scaling to meet the demands of rapid urbanisation. In the Gulf, this stage involves the mining of natural marine or terrestrial sands and the production of manufactured sand (M-sand) from crushed rock like gabbro and limestone. The most severe human rights risks at this stage include forced labour of adults and children, unsafe working conditions, and land dispossession. Further, child labour and underemployment are common in many informal quarry sites (OECD, 2026). These risks are likely to be particularly acute in jurisdictions where the sector's rapid growth has outpaced regulatory oversight.

Oman and the UAE serve as the region's primary extraction hubs. Oman has undergone a 1,078.3% increase in domestic material extraction within its construction material quarrying (CMQ) sector since 1990, reaching 114.4 million tonnes by

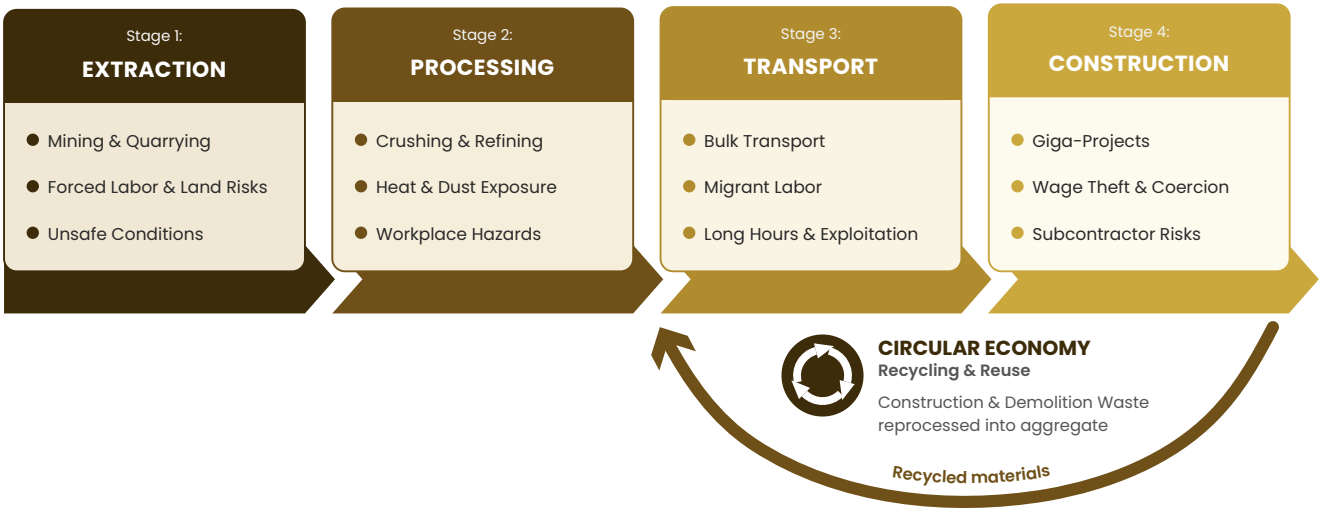


Figure 12: Supply chain stages in the construction industries of Qatar, Saudi Arabia, the United Arab Emirates, and Oman.

2024. While the Omani CMQ sector is notable for having a high proportion of national workers (70% Omani), the sheer volume of extraction increases the pressure on site safety and environmental management. In contrast, the UAE's extraction sector is heavily reliant on low-skilled migrant labour, which grew from 97,000 to 127,000 workers between 2020 and 2024. This reliance on a growing, low-skilled expatriate workforce creates a significant vulnerability to exploitative recruitment and poor site-level welfare standards. Within the KSA, extraction is driven by domestic demand, with quarrying extraction increasing by 353.1% since 1990 to reach 559 million tonnes. Qatar also demonstrates high extraction intensity; while its CMQ sector employs only 2% of the workforce, it contributes a disproportionate 21.2% to the national monetary output, suggesting a high-pressure environment for the 48,000 workers involved.

Stage 2: Processing

The processing stage involves the refinement of raw aggregates into specialised materials, such as industrial silica for glass or ceramic construction goods like tiles and bricks. The majority of material passing through this stage of the supply chain by volume is aggregates for construction. The primary risks identified at this stage are health hazards, including heat exposure and dust inhalation (silicosis), and general physical hazard workplace accidents. These hazards are profoundly amplified by the Gulf's extreme climate, where rising temperatures pose a life-threatening risk to workers in industrial processing facilities.

The ceramics sector provides a clear example of the risks associated with rapid industrial intensification. Qatar has seen the most dramatic surge, with raw material extraction for ceramics increasing by 1,580.4% since 1990. Similarly, the UAE's ceramics sector domestic extraction grew by 441.2% over the same period. While these sectors contribute significantly to national GDP- for instance, the UAE ceramics sector accounts for 13.1% of the country's monetary output - they often employ a small, highly concentrated workforce (only 0.8% of the UAE total). This concentration indicates a high-output industrial environment where workers are subjected to prolonged shifts in high-heat and dust-intensive conditions. Furthermore, the technical requirements for high-strength concrete necessitate the use of manufactured sand, which involves energy-intensive crushing and grading of rock. Workers in these specialised facilities are often expatriates operating under subcontracted arrangements where the enforcement of occupational health and safety (OHS) standards may be inconsistent.

Stage 3: Transport

The transport and logistics stage is the critical link between remote extraction sites, regional processing hubs, and urban construction zones. The key human rights risks at this stage are migrant exploitation, physical injury, operational dangers, and excessively long working hours. The transport of bulk commodities like sand is uniquely vulnerable to these risks because it relies on a vast network of truck drivers and logistics personnel who may have historically operated under the "Kafala" system or similar structures that can limit their labour mobility.

Regional trade patterns reveal the scale of this logistics challenge. Qatar is a net importer of aggregates, sourcing over 50% of its domestic consumption from external suppliers, primarily from KSA and the UAE. This dependency requires constant cross-border movement of material. The UAE serves as a major regional pivot, with approximately 45% of its domestic extraction destined for export to countries like Bahrain, Kuwait, and KSA. This onward trade model significantly blurs the point of origin, making it nearly impossible for contractors to verify the labour conditions under which the sand and aggregates were originally extracted. In Oman, the logistics of exporting 25 million tonnes of sand relies on an expatriate workforce that accounts for a large portion of the 442,000 non-national workers in the broader construction-related pool. Drivers likely face gruelling schedules to deliver bulk loads over long desert corridors, leading to fatigue-related safety risks and potential coercion.

Stage 4: Construction

The construction stage is the final sink for the region's sand and aggregate consumption, where materials are embodied in massive Giga-projects. The primary risks at this juncture are poor working conditions, wage theft, coercion, and illegal recruitment fees. A defining feature of this stage is the disparity between direct employment and the broader labour footprint which describes the total number of workers across the entire supply chain required to support construction activities.

The construction sector in the Gulf relies on complex, multi-tiered subcontracting layers that obscure oversight. In Qatar, the sector directly employs 6.1% of the workforce but is responsible for a 26% labour footprint—the highest in the region. This means that for every worker directly employed on a site, there are approximately four more workers upstream in the supply chain providing materials and services. Similarly, in Saudi Arabia, the sector's labour footprint is 17.2%, nearly triple its direct employment rate of 5.9%. This oversight gap is where the most significant human rights vulnerabilities emerge. Low-skilled migrant workers, who dominate the construction labour force in all four countries, are often the furthest removed from the end-client's compliance policies. In Oman, for instance, 64% of the construction workforce is classed as low-skilled. These workers are frequently the victims of withheld wages or coercive contract terms, especially when working for small, lower-tier subcontractors who face extreme financial pressure to deliver on large-scale infrastructure projects.

4.2 Gulf-Specific Risk Factors

The Gulf's construction supply chain operates within a uniquely complex risk environment shaped by geopolitics, labour structures, and governance gaps. These risks are not isolated at single points but are embedded across the four stages of extraction, processing, transport, and construction (Figure 12), often intensifying as materials move through opaque, multi-tiered systems.

A key emerging factor is the potential implication of geopolitical instability, particularly in relation to recent tensions with Iran. Any escalation in conflict could disrupt critical maritime routes such as the Strait of Hormuz, through which a significant proportion of regional trade

flows. For supply chains dependent on the steady movement of bulk materials, especially aggregates transported between Oman, the UAE, and Qatar, this presents immediate logistical risks, including delays, cost inflation, and supply shortages. At the same time, conflict scenarios often generate a paradoxical surge in demand. Post-conflict reconstruction would likely require vast quantities of aggregates, intensifying extraction and processing pressures across the region. This could exacerbate already strained regulatory systems, increasing the likelihood that human rights and environmental safeguards are sidelined in favour of rapid output. Moreover, Qatar's reliance on imported aggregates and the UAE's role as a regional re-export hub mean that disruptions in one jurisdiction can cascade across the entire supply chain, further obscuring traceability and accountability.

Overlaying these geopolitical risks is the Gulf's structural dependence on migrant labour. Across all four supply chain stages, low-skilled expatriate workers form the backbone of operations, from quarry sites in Oman to processing facilities in the UAE and construction sites in Saudi Arabia and Qatar. This dependency creates systemic vulnerabilities. Migrant workers often operate under restrictive sponsorship systems that limit job mobility and tie legal residency to employers. In practice, this can reduce workers' ability to refuse unsafe conditions or report abuses. The concentration of migrant labour in high-risk roles- such as long-haul trucking in the transport stage or physically demanding construction work - means that any breakdown in labour protections

has widespread implications for safety and wellbeing.

Recruitment fees further compound these vulnerabilities. Many migrant workers enter the Gulf through complex recruitment corridors, often incurring substantial debts to secure employment. These fees, although formally prohibited in several Gulf countries, persist in practice through informal or offshore recruitment channels. Indebted workers are more likely to accept exploitative conditions, excessive overtime, or withheld wages in order to repay loans. Within the supply chain, this dynamic is particularly pronounced in lower-tier subcontracting arrangements, where oversight is weakest. Workers in extraction or processing facilities, who are often employed indirectly, may be several steps removed from the principal contractor's compliance systems, making it difficult to enforce ethical recruitment standards consistently.

A further critical gap are weak grievance mechanisms. While many Gulf states have introduced labour reforms and formal complaint channels, their effectiveness remains uneven, particularly for workers at the margins of the supply chain. Barriers such as language differences, fear of retaliation, limited legal awareness, and restricted mobility can deter workers from reporting abuses. In decentralised supply chains, where multiple subcontractors operate across jurisdictions, responsibility for addressing grievances is often unclear. For example, a transport worker facing exploitative conditions while moving aggregates across borders may have limited recourse if their employer is a subcontractor operating in a different legal context than the project owner. Similarly, workers in small-scale extraction sites or processing plants may lack access to formal mechanisms altogether.

Taken together, these factors create a risk landscape in which vulnerabilities are mutually reinforcing. Geopolitical instability can intensify demand and strain oversight; migrant labour dependency increases exposure to exploitation; recruitment fees deepen worker precarity; and weak grievance systems limit avenues for redress. Addressing these challenges requires a shift from project-level compliance to supply chain-wide due diligence. This includes greater transparency in sourcing, stronger enforcement of ethical recruitment standards, and the development of accessible, trusted grievance mechanisms that extend to all workers, regardless of their position within the supply chain.

5. Traceability, Transparency and Technology

5.1 Why Traceability Is Difficult for Sand

Traceability challenges in the sand and aggregate supply chain stem primarily from three structural features: its nature as a bulk commodity, the widespread practice of mixing and blending, and a high degree of operational informality. Materials are traded in large volumes with limited differentiation, frequently combined to meet engineering specifications, and often pass through fragmented networks of subcontractors, particularly in extraction and transport. In the context of the GCC, these characteristics are amplified by cross-border trade (e.g., exports from Oman and the UAE to Qatar and Saudi Arabia) and the speed of construction demand, which can outpace documentation and oversight systems. However, rather than insurmountable barriers, these challenges point to the need for targeted, technology-enabled and policy-driven solutions tailored to the region's logistical and governance realities.

5.2 Tools and Solutions

A combination of digital, scientific, and governance-based tools offers a practical pathway to improving traceability in GCC sand supply chains. Their effectiveness depends on how well they are adapted to regional trade patterns, labour structures, and regulatory capacity.

Digital Product Passports and Smart Sensors

Digital product passports (DPPs) involve assigning a unique, trackable identity to materials, linked to a database containing information on origin, processing, and handling. In the context of aggregates, DPPs could be applied at the batch level rather than the individual unit level, making them more compatible with bulk materials. When combined with internet-of-things (IoT) enabled smart sensors such as GPS trackers on trucks or RFID tags at processing plants, these systems can provide real-time visibility over material flows.

In the GCC, this approach is particularly suited to formalised nodes of the supply chain, such as large-scale quarries in Oman or industrial processing facilities in the UAE. Governments in the region have already invested heavily in digital infrastructure, which creates a strong foundation for integration. However, uptake may be uneven in smaller subcontracting tiers, especially in transport, where informal operators dominate. To be effective, DPP systems would likely need to be mandated through public procurement requirements tied to major Giga-projects.

Geochemical Fingerprinting

Geochemical fingerprinting uses the unique mineral composition of sand to trace it back to a specific geological source (Melcher et al. 2008; Sickmann et al. 2023). This method is particularly valuable in contexts where documentation is unreliable or where materials have been mixed. In the GCC, where distinct geological formations (e.g., gabbro from Oman versus sand from Saudi Arabia) are already well understood, fingerprinting could serve as a verification tool rather than a primary tracking system.

Its most practical application would be in high-risk or high-value projects, where developers or regulators conduct periodic audits to validate supplier claims. However, the method can be costly and requires specialised expertise, which may limit its scalability. It is best viewed as a complementary enforcement mechanism, especially useful in cases of suspected non-compliance or disputes over sourcing. Sickmann et al. (2023) showed that major element and optical petrography fingerprints are preserved throughout the construction sand processing and transport aspects of the supply chain, indicating sand can be tied back to its original mining source even at the final, construction, stage. Furthermore, it has been shown that with the aid of machine learning techniques, image analysis models can be up to ~90% effective at determining the original mining source of sand (Sickmann et al., 2023), suggesting they may offer a lower cost alternative to geochemical fingerprinting of sand material origin.

Certification Schemes

Certification schemes establish standards for responsible sourcing and require independent verification of compliance. While widely used in sectors like timber or minerals, they are less developed for aggregates. In the GCC, there is an opportunity to develop region-specific certification frameworks aligned with existing national visions (e.g., sustainability goals embedded in large infrastructure programs).

The main challenge is that certification often struggles to penetrate lower-tier suppliers, where risks are highest. For certification to be effective in the Gulf, it would need to be tied directly to contract eligibility for major projects, ensuring that even subcontractors are incentivised, or required, to comply. Without this linkage, certification risks remaining a top-tier exercise with limited impact on actual working conditions.

Satellite Monitoring and Remote Sensing

Satellite imagery and remote sensing technologies can monitor quarry expansion, detect unauthorised extraction, and assess environmental

impacts. In the GCC, where extraction sites are often located in remote desert or coastal areas, these tools are highly applicable. Governments and large developers could use satellite data to cross-check licensed extraction volumes against actual activity, identifying discrepancies that may signal illegal or unregulated operations.

This approach is particularly valuable for regulatory oversight at scale, but it does not directly address labour conditions. Its strength lies in increasing transparency at the extraction stage, which can then be linked to other due diligence measures. As satellite data becomes more accessible and cost-effective, it offers a scalable solution for regional monitoring bodies.

ESG-Linked Procurement

Perhaps the most powerful lever in the GCC context is Environmental, Social and Governance (ESG)-linked procurement. Given that large-scale construction is driven by state-backed or state-linked projects, procurement policies can directly shape market behaviour. By embedding traceability requirements, such as mandatory disclosure of sourcing, use of digital tracking systems, or compliance with certification standards, developers can push transparency requirements down the supply chain.

In practice, this could involve contractual clauses requiring suppliers to demonstrate origin tracking, disclose recruitment practices, or participate in approved monitoring systems. As contractors compete for access to major projects, ESG-linked procurement creates a strong commercial incentive to adopt traceability tools. In the Gulf, where a relatively small number of mega-developers dominate demand, this approach is both feasible and potentially transformative.

A combined approach

No single tool can fully resolve traceability challenges in the sand supply chain. However, a layered approach - combining digital tracking, scientific verification, remote monitoring, and procurement-driven enforcement - offers a realistic pathway forward. In the GCC, the centralized nature of development planning and the scale of public investment provide a unique opportunity to implement such systems effectively. The key will be ensuring that these tools extend beyond top-tier suppliers and meaningfully address risks embedded in the lower tiers of the supply chain, where visibility remains weakest.

6. Stakeholder Roles and Responsibility

6.1 Governments

Governments in the Gulf region occupy a key regulatory and enforcement role in mitigating human rights abuses across sand and aggregate supply chains. The rapid growth in the extraction and construction industries and labour-intensive construction demand have potentially outpaced oversight capacity, particularly in contexts reliant on low-skilled migrant labour (see Section 3). To address risks of forced labour, child labour, and corruption, governments must transition from fragmented regulatory approaches to integrated, risk-based governance frameworks aligned with international standards such as the International Labour Organisation conventions (ILO, 2019) and the OECD Due Diligence Guidance (OECD, 2026).

Key actions include strengthening labour inspection regimes across all supply chain stages, particularly in extraction and transport where oversight is weakest. Governments should mandate human rights due diligence (HRDD) for all large-scale construction and quarrying operations, with legal liability extending to subcontracting tiers. Reform of labour systems, building on moves away from kafala-type sponsorship as seen in KSA, must ensure full worker mobility, prohibition of recruitment fees, and enforceable wage protection systems to prevent wage theft. Furthermore, governments must ensure the timely and appropriate payment of contractors and workers to reduce contributing to wage theft or pushing workforces into poverty or debt (HRW, 2025).

Environmental Impact Assessments (EIAs) should be expanded to include social risk criteria, incorporating labour conditions and community impacts as well as being enhanced in an effort to ensure minimal environmental impact across all stages of the supply chain. Digitalisation of permitting and licensing systems can reduce opportunities for bribery and illicit extraction, particularly when combined with satellite monitoring and public registries of licensed operators. Here, public procurement is a critical lever as embedding ESG and traceability requirements into state-backed giga-projects can cascade compliance across markets. Finally, cross-border regulatory cooperation within the GCC is essential to harmonise standards, improve traceability, and prevent regulatory arbitrage between jurisdictions.

6.2 Companies

Companies, in particularly developers, contractors, and multinational firms, play a central role in shaping labour conditions through procurement, contracting, and operational practices. The construction sectors in the Gulf exhibit disproportionately large labour footprints relative to direct employment, indicating that the highest risks are embedded in subcontracted supply chains (see Section 3). As such, companies must move beyond compliance-based approaches toward proactive supply chain governance aligned with the United Nations Guiding Principles on Business and Human Rights (UNHR, 2011).

A primary action is the implementation of robust human rights due diligence systems that map supply chains down to extraction and logistics levels. This includes identifying high-risk suppliers, conducting regular audits, and integrating traceability tools such as

digital product passports. Contractual mechanisms should require suppliers to meet minimum labour standards, prohibit recruitment fees, and ensure safe working conditions, with clear penalties for non-compliance.

Companies must also address systemic risks linked to subcontracting. This can be achieved by rationalising supply chains (reducing excessive layers and consolidating outsourcing), ensuring direct payment mechanisms to workers, and mandating transparent wage systems. In addition, worker voice mechanisms, such as grievance channels, trade union access, and anonymous reporting systems, should be implemented and made accessible.

From an anti-corruption perspective, firms should implement strict controls over procurement and licensing interactions, particularly in extraction and transport stages where illicit practices are prevalent. ESG-linked procurement, especially in state-backed projects, offers a powerful tool to incentivise responsible sourcing. Ultimately, companies must recognise that reputational, financial, and legal risks increasingly extend beyond direct operations to the full lifecycle of materials used in construction.

6.3 Suppliers and Logistics

Suppliers and logistics actors, including quarry operators, processors, transport companies, and intermediaries, represent the most operationally complex and risk-prone segments of the sand supply chain. These tiers are often characterised by informality, migrant labour dependency, and weak oversight, particularly in transport and extraction stages (see Section 3). Consequently, they are critical intervention points for addressing forced labour, unsafe working conditions, and corruption.

At the extraction and processing levels, suppliers must implement occupational health and safety (OHS) standards that address risks such as dust exposure (and silicosis risk), heat stress, and hazardous machinery. Alignment with international frameworks from the International Labour Organisation is essential, including provision of protective equipment, regulated working hours, and independent safety inspections. Suppliers should also formalise employment relationships, eliminating informal hiring practices that facilitate exploitation and child labour.

In logistics, particular attention must be given to driver welfare. Long-haul transport systems in the Gulf often rely on migrant workers exposed to excessive hours and coercive conditions. Companies should enforce maximum driving hours, ensure rest provisions, and adopt digital tracking systems to monitor routes and working conditions. Here, traceability is a core responsibility at this level. Suppliers should adopt batch-level tracking, maintain verifiable documentation of material origin, and participate in certification schemes where available. Collaboration with up-chain and down-chain actors is essential to ensure continuity of information flows.

Anti-corruption measures are equally critical. Transparent contracting, digital payment systems, and third-party audits can reduce bribery risks associated with licensing, transport permits, and cross-border trade. Strengthening governance at this tier is essential, as failures here

undermine all higher-level compliance efforts.

6.4 International Actors

International organisations, financial institutions, and multilateral frameworks play a crucial enabling and standard-setting role in improving governance across Gulf aggregates supply chains. Given the absence of a cohesive global regulatory framework for aggregates, actors such as the International Labour Organization, World Bank, International Monetary Fund, and European Union (amongst others) can provide critical guidance, financing, and enforcement incentives.

Such organisations will likely play a key role in the development and promotion of international standards, including due diligence frameworks, labour conventions, and anti-corruption guidelines. These should be tailored to bulk commodities like sand, where traceability challenges differ from high-value minerals. International actors can also support capacity-building initiatives, helping Gulf governments strengthen labour inspection systems, judicial enforcement, and digital monitoring capabilities. They may also be able to represent "best practice" examples from countries such as the United Kingdom, where sand supply chains are held up as exemplary (UNEP, 2022).

Development finance institutions such as the World Bank can embed strict ESG and human rights conditionalities into infrastructure financing. This is particularly relevant given the scale of regional giga-projects, where access to international capital can be leveraged to enforce compliance across supply chains. Similarly, trade agreements and investment frameworks, especially those involving the EU, can include binding provisions on labour rights and transparency.

Accordingly, data and transparency initiatives are another critical area where international organisations can play a leading role. Leveraging their global reach, international organisations can support the transparency and continued improvement of global databases on aggregate flows, labour conditions, and risk indicators, addressing current information gaps.

Finally, international actors should facilitate cross-border cooperation, particularly within the GCC, to harmonise standards and prevent regulatory arbitrage. By aligning incentives across governments, companies, and financiers, they can help transition the sector toward a more transparent, accountable, and rights-respecting model.

7. Recommendations

A) Better disaggregation and transparency of sub-national supply chains, including identifying key companies, production and construction sites

GCC Governments should require disclosure of extraction, processing, and export activities at site level, particularly in high-volume hubs such as Oman and the UAE where re-exporting obscures the origin of primary material, potentially masking labour and human rights infringements. Public registries of licensed operators and production volumes would enable more effective oversight and compliance. Companies must map supply chains beyond first-tier suppliers, identifying subcontractors in transport and processing where risks are concentrated. Applying risk-based due diligence aligned with the OECD (REF) will allow targeted interventions. Greater sub-national transparency is essential to reduce illicit extraction, improve traceability, and strengthen accountability across complex regional trade flows.

B) More transparent reporting and data in production and usage statistics covering mineral production and use and associated employment and labour

Governments should integrate production, trade, and labour datasets to better reflect the imbalances identified in Section 3, such as high material consumption alongside relatively low direct employment in extraction but large supply chain labour footprints. Reporting should include workforce composition, wage compliance, and occupational safety indicators across all stages of the aggregates supply chain. Companies should standardise ESG disclosures and align them with International Labour Organization conventions to ensure consistency. Improved data transparency will enable policymakers and investors to identify where high-volume flows coincide with elevated risks of forced labour, supporting more targeted and evidence-based interventions.

C) Environmental and socially responsible diversification of aggregate supply chains, nationally and internationally, and development of circular economies

Supply chains should be diversified to reduce over-reliance on concentrated regional flows. Section 3 shows that Qatar depends on imports for over 50% of its supply, largely from regional partners, while Oman and the UAE dominate exports and Saudi Arabia remains domestically focused but increasingly import-diverse. Importing countries should broaden sourcing beyond current suppliers to include international partners with stronger labour and environmental governance. At the same time, GCC governments should engage bilaterally with key source countries for sand to support improved and more responsible sand governance. This can be achieved in by collaborating with, and adhering to, established guidance from the OECD. In parallel, governments and companies should scale investment in recycled aggregates and manufactured sand to reduce pressure on high-intensity extraction hubs. Support from international organisations and institutions can facilitate this transition. Diversification enhances resilience, reduces systemic risk concentration, and creates market incentives for higher standards.

D) Increase engagement and collaboration with key international organisations to develop shared governance standards for the sand supply chain

GCC governments should engage closely with the GCC secretariate and other key international organisations, such as the OECD, UNEP, ILO, the Coalition for Responsible Sand and Silicates (and others) and establish a regional dialogue on just and sustainable sand supply chains. This dialogue should bring together not only GCC governments, but also source country counterparts, construction companies and civil society to develop a shared governance framework and standards that ensure responsible sand and aggregates supply chains within the GCC region, and across its trading partners. The OECD (20206) Due diligence report for responsible sand and silicate supply chains offers a first entry point for these discussions and fora to coalesce around.

E) Increase uptake of digital technologies to help track and trace aggregate supply chains and identify potential overlaps with forced labour

Governments should mandate the use of digital traceability tools, such as digital passports, sedimentary fingerprinting, GPS tracking of transport and logistical components of the supply chain, and electronic permitting, across key trade corridors linking major exporters and importers in the region. Companies should integrate these tools into procurement systems to monitor supplier compliance and identify high-risk flows associated with labour exploitation. Satellite monitoring, combined with rapidly developing AI tools can complement these systems by verifying extraction activity in high-output areas. Alignment with emerging global frameworks on labour standards, environmental protection, and material sourcing will support interoperability of data generated using these tools. A layered digital approach is essential to improve visibility in bulk commodity supply chains and strengthen due diligence.

F) Shift to contract and rights-based employment laws and regulations and reduce reliance on undocumented migrant labour force

GCC governments should accelerate the shift toward enforceable, contract-based labour systems that guarantee wages, worker mobility, and access to grievance mechanisms. This is critical given the large supply chain labour footprints identified in Section 3, where risks are concentrated among low-skilled migrant workers in subcontracted roles. In line with OECD guidance, GCC labour regulators should introduce and enforce mandatory dust suppression, ventilation and health monitoring requirement for workers engaged across sand supply chains. Such standards should explicitly be included in inspection protocols of national labour authorities. Recruitment fees must be eliminated through stricter regulation and international cooperation. Companies should implement ethical recruitment policies and ensure direct, transparent wage payments across all tiers. Alignment with International Labour Organization standards is essential. Strengthening formal labour systems will reduce exploitation and address structural drivers of forced labour.

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9. Appendix

Table A. Comtrade (UN 2026) HS commodity codes related to the construction industry.

Commodity name	HS code	Sub-commodity	Sub-commodity name	Uses
Natural sands of all kinds (whether or not coloured; other than metal-bearing sands)	2505	250510	Natural, silica and quartz sands (whether or not coloured)	• Glass manufacturing • Rubber • Construction • Paints and coatings • Metal pre-casting (foundry sand) • Sports and leisure (i.e. golf courses, volleyball courts)
		250590	Natural sands (other than silica and quartz sands, whether or not coloured)	• Concrete production • Asphalt and road construction • Metal pre-casting and masonry • Land reclamation and fill material
Quartz and quartzite	2506	250610	Quartz, other than natural sands	• Glass manufacturing • Ceramics • Metal pre-casting • Rubber • Paints and coatings • Refractory bricks • Cement production • Photovoltaic cells • Electronics and communications
		250620	Quartzite (whether or not trimmed our cut)	• Glass manufacturing • Cement production • Flooring and floor coatings • Ornamental stone
		260621	Quartzite (crude or roughly trimmed)	
		250629	Quartzite, slabs, etc.	

Granite, porphyry, basalt, sandstone, other monumental and building stone	2516	251611	Granite (crude or roughly trimmed into rectangular blocks)	• Breakwaters or jetties • Reservoirs • Bridges • Submerged foundations • Flooring • Building blocks • Tiles • Ornamental stone • Cladding and facades • Monuments
		251612	Granite (merely cut into blocks or slabs)	
		251620	Sandstone (whether or not roughly trimmed or cut into rectangular shape)	• Cladding • Building blocks (i.e. bricks) • Structural walls • Landscaping • Cladding and facades • Refractory • Aggregate (concrete, mortar, road base, railway ballast) • Monuments
		251621	Sandstone (crude or roughly trimmed)	
		251622	Sandstone (merely cut into blocks)	
		251690	Monumental or building stone (whether or not roughly trimmed or cut into rectangular shape)	• Cladding • Building blocks • Facades • Foundational and structural stonework • Monuments • Landscaping
Pebbles, gravel, crushed stone for concrete aggregates	2517	251710	Pebbles, gravel, broken or crushed stone	• Aggregate (concrete) • Cement • Brick • Monumental building stone (i.e. paving slab)
		251720	Macadam of slag, dross or similar industrial waste	• Road metalling – for construction, resurfacing and road maintenance • Railway ballast • Coarse aggregate (building foundations, structures and pavement) • Industrial fill material
		251730	Tarred macadam	• Road metalling – for construction, resurfacing and road maintenance • Railway ballast • Coarse aggregate (building foundations, structures and pavement)
		251741	Stones of marbles, in: granules, chippings and powder	• Concrete • Flooring • Decorative road surface • Decorative chipping • Industrial filler (paint, plastic, paper, cement) • Terrazzo flooring
		251749	Stones of (1) marble and travertine or (2) granite, porphyry, basalt, sandstone or other building stone	• Concrete • Railway ballast • Road construction (road metalling) • Terrazzo flooring • Decorative chipping • Industrial filler • Road surface treatment

Bitumen and asphalt, bituminous or oil shale and tar sands, asphaltites and asphaltic rocks	2714	271410	Bitumen and asphalt, natural or oil shale and tar sands	• Road construction and surfacing • Paving • Waterproofing material (sealants and coatings)
		251790	Bitumen and asphalt, asphaltites and asphaltic rock	• Road construction and surfacing • Paving • Waterproofing material (sealants and coatings) • Roofing material • Insulation
Refractory bricks, blocks, tiles and similar refractory ceramic construction goods	6902	690210	Refractory bricks, blocks, tiles and similar refractory ceramic constructional goods (containing more than 50% of MgO, CaO or Cr^2O^3	• Lining of furnaces and kilns • Steelmaking • Cement manufacturing • Glass manufacturing • Material for heat containment processes
		690220	Refractory bricks, blocks, tiles and similar refractory constructional goods (containing more than 50% of alumina, silica or a mixture compound of these)	• Lining of furnaces and kilns • Alumina-silica components • Material for heat containment processes
		690290	Refractory bricks, blocks, tiles and similar refractory ceramic constructional goods not elsewhere classified	• Lining of furnaces and kilns • Material for heat containment processes
Roofing tiles, chimney pots, cowls, chimney liners, architectural ornaments and other ceramic constructional goods	6905	690510	Ceramic roofing tiles	• Roofing
		690590	Ceramic chimney pots, cowls, chimney liners, architectural ornaments, and other constructional goods	• Roofing • Chimney components • Ceramic fittings (including decorative)

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