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Policy Study

N. 38

PATHWAYS TO A EURO-ARAB GULF GREEN PARTNERSHIP:

How Renewable Energy-Based Manufacturing Value Chains Can Expand EU-GCC Cooperation in Green Transition and Climate Diplomacy

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Content

Executive Summary

This Joint Policy Study explores the Arab Gulf states' significant efforts in energy transition as a means of diversifying their respective economies through decarbonised industrialisation. Through its examination of a variety of projects across the member states (MS) of the Gulf Cooperation Council (GCC), the study finds broad alignment with the energy transition goals of the European Union (EU) and its MS. Due to the unique circumstances of civil war in Yemen, the study confined its examination of GCC MS to the United Arab Emirates (UAE), Saudi Arabia, Oman, Qatar, Kuwait, and Bahrain. The study examines important examples of EU-GCC cooperation and suggests that opportunities for both wider and deeper cooperation exist, particularly since the 2025 announcement of the EU's Clean Industrial Deal (CID) and its associated action plans and initiatives. The study takes the development of renewable energy infrastructure and inter-regional renewable energy-based manufacturing value chains as its primary focus for cooperation between Europe and the Arab Gulf states and secondarily how win-win cooperation in these endeavours can serve as a wider basis for EU-GCC cooperation on carbon management and sustainability. The four chapters of this study examine both the opportunities and challenges from the point of view of production and value chains, regulatory norms and trade, financing, and governance.

The opening chapter by Michael Tanchum lays out the broad themes of the study through an analysis of the green energy ecosystems that are emerging in GCC MS, followed by an assessment of the points of convergence with the CID, its associated Action Plan for Affordable Energy and the European Steel and Metals Action Plan, as well as the CID-associated instrument: the Clean Trade and Investment Partnership (CTIP). The author defines green energy ecosystems and shows how GCC MS are establishing them as means of developing low-carbon, international manufacturing value chains based on renewable energy for the production of intermediate inputs and finished goods within the GCC. With the UAE and Saudi Arabia at the forefront, the author provides an assessment of an array of renewable energy production installations and renewable energy based manufacturing operations across the Arab Gulf region. While demonstrating the positive impact of the EU's Carbon Border Adjustment Mechanism (CBAM) on incentivising the GCC's low-carbon production of materials, the chapter also explores how sustainable industrial diversification for long-term global competitiveness is the principal driver of GCC investments in green production. Concluding that the EU's new orientation toward industrial competitiveness

and economic growth opens common ground for the EU and GCC MS to concretise synergies through joint venture investments, the author points to CTIPs as potentially providing a means for the EU to advance Europe-Arab Gulf states partnerships through Union-level action. He recommends European investment in GCC green ammonia operations and joint EU-GCC investments in green ammonia in the third locations that will service European end markets. He also recommends European investment in metals processing, fertiliser, and sustainable fuel production in the GCC, as well as the opening of European green manufacturing plants in GCC countries to preserve European export share in third countries in Africa and Asia.

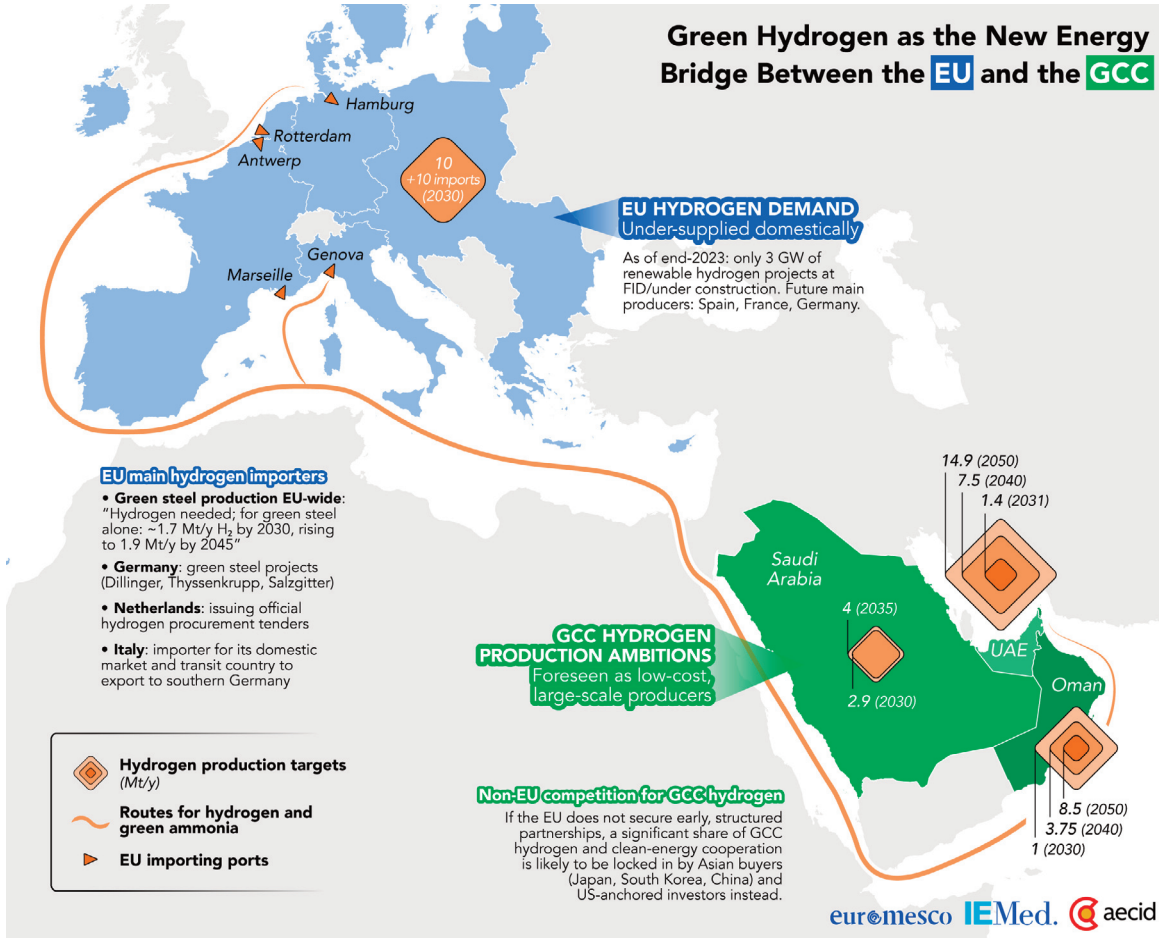
The second chapter by Miriam Salman closely examines the impact of trade dynamics and regulatory norms on renewable energy production and the manufacturing of CBAM-covered and energy transition-critical materials in the Arab Gulf region. With a focus on certification of decarbonised industrial technologies and the scaling of investments, the chapter highlights emerging joint EU-GCC business opportunities. Consistent with the previous chapter, the author finds that in renewables, hydrogen and metals processing, the GCC nations can provide the EU with significant benefits, including secure access to decarbonised imports, the diversification of industrial partnerships, and strengthened climate diplomacy. The chapter concludes that the GCC MS stand out not only as compliance-driven exporters for the EU, but also as partners for the co-creation of a global decarbonised economy leveraging the Arab Gulf's region capital, scale, and implementation capacity. The author recommends that the EU and EU MS should claim early ground in cooperation with GCC MS through cooperation with GCC R&D and funding platforms, co-designing carbon and certification frameworks, and creating joint investment vehicles.

The third chapter by Samir Fakhoury analyses how green financial instruments can accelerate the GCC's transition from hydrocarbons to sustainable growth while enabling deeper EU-GCC cooperation. The author creates a taxonomy of instruments, classifying tools into debt, equity, blended finance, and carbon markets, and then evaluates each by attractiveness, ease of implementation and risk. The author finds that debt instruments and blended finance currently lead due to mature standards and strong investor demand. Although equity and carbon markets are promising, they are constrained by market depth, verification integrity, and policy alignment. In parallel to findings in the first chapter, this chapter finds that the UAE and Saudi Arabia anchor regional momentum with comprehensive frameworks and landmark issuances. While Oman and Qatar show incremental, institution-driven progress, Kuwait and Bahrain are primarily bank-led. Building on the findings of the second chapter, the author suggests that deploying blended finance, building robust Monitoring, Reporting, and Verification (MRV) systems, and establishing mutual cer-

tification for green hydrogen and carbon markets would de-risk capital, enhance credibility, and secure market access. His recommendations call for regional standardisation (especially in the case green sukuk instruments), incentives for sustainability-linked finance (both bonds and loans), phased compliance carbon markets, and a regional accreditation body to scale credible, investable pipelines.

The fourth and final chapter by Johannes Späth takes governance among the GCC MS as its focus, examining the existing governance logics of elite control, state-owned enterprises (SOEs), and sovereign wealth funds (SWFs), and then explores the implications for EU-GCC cooperation. Providing an analytical window into centralised, elite-driven green transition models, the chapter suggests that strategic partnerships, modular cooperation, and early integration into Gulf clean energy value chains will be critical to securing mutual benefits in the new global energy landscape. Consistent with the preceding chapters, the author suggests that the centralised governance models among the Arab Gulf states create space for transactional synergies where EU and GCC strategic interests align. With GCC MS positioning themselves as indispensable nodes in future manufacturing value chains — as suppliers of both green energy and green intermediate inputs –, the author recommends engaging with the right entities early and prioritising transactional partnerships based on joint ventures, offtake agreements, and co-financed R&D rather than focusing first on normative policy alignment.

Taken as a whole, the volume finds significant opportunities for EU-GCC cooperation, in which business synergies can enhance the levels of sustainability and competitive industrial output in both regions by creating robust supply chain resilience for green manufacturing value chains. The common opinion of all authors is that now is the time to act, and to act vigorously. On this basis, it is the sincere hope of those that have contributed to the production of this volume that it will assist in the furtherance of dialogue between Europe and the Arab Gulf states on cooperation in green industrialisation.


Green Hydrogen as the New Energy Bridge Between the EU and the GCC
Hamburg
Rotterdam
Antwerp
10
+10 imports
(2030)
Genova
Marseille
EU HYDROGEN DEMAND
Under-supplied domestically
As of end-2023: only 3 GW of renewable hydrogen projects at FID/under construction. Future main producers: Spain, France, Germany.
EU main hydrogen importers
• Green steel production EU-wide: "Hydrogen needed; for green steel alone: ~1.7 Mt/y H_2 by 2030, rising to 1.9 Mt/y by 2045"
• Germany: green steel projects (Dillinger, Thyssenkrupp, Salzgitter)
• Netherlands: issuing official hydrogen procurement tenders
• Italy: importer for its domestic market and transit country to export to southern Germany
Hydrogen production targets (Mt/y)
Routes for hydrogen and green ammonia
EU importing ports
GCC HYDROGEN PRODUCTION AMBITIONS
Foreseen as low-cost, large-scale producers
Saudi Arabia
14.9 (2050)
7.5 (2040)
1.4 (2031)
4 (2035)
2.9 (2030)
UAE
Oman
8.5 (2050)
3.75 (2040)
1 (2030)
Non-EU competition for GCC hydrogen
If the EU does not secure early, structured partnerships, a significant share of GCC hydrogen and clean-energy cooperation is likely to be locked in by Asian buyers (Japan, South Korea, China) and US-anchored investors instead.
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List of Acronyms and Abbreviations

ACER	EU Agency for the Cooperation of Energy Regulators
ADCB	Abu Dhabi Commercial Bank
ADNOC	Abu Dhabi National Oil Company
ADQ	Abu Dhabi Developmental Holding Company
AED	United Arab Emirates Dirham
AISI	American Iron and Steel Institute
BP	British Petroleum
CBAM	Carbon Border Adjustment Mechanism
CCS	Carbon Capture and Storage
CCUS	Carbon Capture, Utilization, and Storage
CDM	Clean Development Mechanism
CEDA	KSA's Council for Economic and Development Affairs
CID	Clean Industrial Deal
CN	Combined Nomenclature
CO2	Carbon Dioxide
CSP	Concentrated Solar Power
CTIP	Clean Trade and Investment Partnership
DEWA	Dubai Electricity & Water Authority
DFIs	Development Finance Institutions
DRI	Direct Reduced Iron
EAD	Environment Agency – Abu Dhabi
EBIC	Egypt Basic Industries Corporation
EDF	Électricité de France
EDFI	European Development Funds Initiative
EDO	Energy Development Oman
EFSD+	European Fund for Sustainable Development Plus
EGA	Emirates Global Aluminium
EGD	European Green Deal
EHB	European Hydrogen Bank
EIB	European Investment Bank
EPA	Kuwait's Environment Public Authority
EPC	Engineering, Procurement, and Construction
EPD	Environmental Product Declaration
ESG	Environmental, Social, and Governance
ET	Emissions Trading
ETI	Energy Transition Index
ETS	Emissions Trading Scheme
EU	European Union
EVs	Electric Vehicles
EWEC	Emirates Water and Electricity Company
FAB	First Abu Dhabi Bank
FDI	Foreign Direct Investment
FID	Final Investment Decision
GCC	Gulf Cooperation Council
GCC	Gulf Cooperation Countries
GDIP	Green Deal Industrial Plan
GGBS	Ground Granulated Blast-furnace Slag
GHG	Greenhouse Gas

GW	Gigawatt
HYBRIT	Hydrogen Breakthrough Ironmaking Technology
Hydrom	Hydrogen Oman
HS	Harmonised System
ICMA	International Capital Market Association
ISO	International Organisation for Standardisation
IPOs	Initial Public Offerings
JI	Joint Implementation
KPIs	Key Performance Indicators
KSA	Kingdom of Saudi Arabia
LC3	Limestone Calcined Clay Cement
LCOE	Levelized Cost of Electricity
LHV	Lower Heating Value
LNG	Liquified Natural Gas
LTS	Long-Term Strategy
MBR	Mohammed bin Rashid Al Maktoum
MBS	Mohammed bin Salman
MBZ	Muhammad bin Zayed Al Nahyan
MDBs	Multilateral Development Banks
MENA	Middle East and North Africa
MEWA	KSA's Ministry of Environment, Water and Agriculture
MME	Qatar's Ministry of Municipality and Environment
MMR	Market Monitoring Report
MOCCAE	UAE's Ministry of Climate Change and Environment
MOCI	Qatar's Ministry of Commerce and Industry
MOECC	Qatar's Ministry of Environment and Climate Change
MOEI	UAE's Ministry of Energy and Infrastructure
MoU	Memorandum of Understanding
MRV	Measurement, Reporting, and Verification
MS	Member States
MSV	Monitoring, Reporting, and Verification
MW	Megawatt
NBB	National Bank of Bahrein
NBD	National Bank of Dubai
NBK	National Bank of Kuwait
NDCs	Nationally Determined Contributions
NGHC	NEOM Green Hydrogen Company
NOCs	National Oil Companies
NREP	National Renewable Energy Program
OEMs	Original Equipment Manufacturer
OIA	Oman Investment Authority
OPAZ	Oman Public Authority for Special Economic Zones and Free Zones
OSINT	Open-Source Intelligence
PDO	Petroleum Development Oman
PIF	Public Investment Fund
PPA	Power Purchase Agreement
PPPs	Public-Private Partnerships
PV	Photovoltaic

QWEC	Qatar Water and Electricity Company
QIA	Qatar Investment Authority
QF	Qatar Fundation
RAECO	Rural Areas Electricity Company
REDPO	Saudi Arabia's Renewable Energy Project Development Office
R&D	Research and Development
SAF	Sustainable Aviation Fuel
SAPCO	Saudi Aramco Power Company
SAR	Specific Absorption Rate
SBTI	Science Based Targets Initiative
SCE	Bahrain's Supreme Council for Environment
SCZONE	Suez Canal Economic Zone
SEC	Saudi Electricity Company
SEFE	Securing Energy for Europe
SEZs	Special Economic Zones
SLB	Sustainability-Linked Bonds
SLL	Sustainability-Linked Loans
SMEs	Small and Medium-sized Enterprises
SNOC	UAE's Sharjah National Oil Company
SOEs	State-Owned Enterprises
SPPC	Saudi Power Procurement Company
STEP	Strategic Technologies for Europe Platform
SWFs	Sovereign Wealth Funds
TAQA	Abu Dhabi National Energy Company PJSC
TRL	Technology Readiness Level
UAE	United Arab Emirates
UK	United Kingdom
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
VCMs	Voluntary Carbon Markets
WRI GHG	World Resources Institute Greenhouse Gas

Advancing Green Industrialisation in the Arab Gulf LNG States

Opportunities for EU Partnerships in the Emerging Renewable Energy-Based Manufacturing Value Chains in the GCC

Michael Tanchum
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Introduction

Several Arab Gulf states have embraced energy transition as an opportunity to diversify their respective economies through decarbonised industrialisation. With economies built primarily upon hydrocarbon fuel exports for almost one hundred years, member states (MS) of the Gulf Cooperation Council (GCC) are attempting to leapfrog into industrial diversification by developing 21st-century, climate-friendly manufacturing based on renewable energy. A development of geopolitical consequence, this chapter opens the present volume with a survey examination of this pivotal transformation and an exploration of the opportunities it provides for cooperation between the Arab Gulf states and the European Union (EU) and its MS.

The chapter's analysis focuses on key renewable energy and green manufacturing initiatives among the Arab Gulf states that are forming the basis of new international value chains. From this vantage point, the chapter will explore how EU-GCC relations can move beyond the coercive aspects of the EU's Carbon Border Adjustment Mechanism (CBAM) to a form of EU-GCC cooperation on carbon management and sustainability conducted on a win-win basis with mutual benefit and dignity. Following its examination of initiatives in various GCC MS, the chapter suggests that a greater alignment exists now between the Union and GCC MS since the recent announcement of the EU's Clean Industrial Deal (CID) framework, which, taking its direction from the 2024 Draghi Report on EU Competitiveness and the European Commission's 2025 Competitiveness Compass for the EU, places a new priority on industrial competitiveness and economic growth alongside the effort to achieve carbon neutrality by 2050. The action plans associated with the CID such as the Action Plan for Affordable Energy and the European Steel and Metals Action Plan, and the CID-associated instrument the Clean Trade and Investment Partnership collectively, could serve as a platform to formalise cooperation between the EU and GCC MS in establishing mutually beneficial renewable energy-based manufacturing value chains.

As part of its examination, the chapter describes current partnerships with firms from EU MS as well as with firms from some non-European countries to highlight the potential for EU MS to establish interregional, green manufacturing value chains with their GCC counterparts. Joint partnerships in new, renewable energy-based value chains can also reset the terms of EU-GCC interactions on global climate diplomacy.

The emergence of the GCC's green energy ecosystems and renewable energy-based value chains

The Arabian Peninsula possesses some of the world's richest solar energy resources. During the previous decade, GCC nations adopted "Vision 2030 plans" with ambitious initiatives to build industrial-scale renewable power generation capacity. These plans and their associated national energy strategies include targets for increasing renewable energy's share of the power supply mix up to 50%. To meet these targets, many of the proposed projects across the region are scheduled for completion during the current decade. The United Arab Emirates (UAE) and Saudi Arabia are regional leaders in developing renewable energy-based value

chains, followed by Oman and Qatar. These countries are achieving their success through the establishment of green energy ecosystems, defined by the development of utility-scale renewable energy infrastructure in coordination with the development of robust offtake markets and the establishment of commercially viable storage and transportation mechanisms to service those markets. As this chapter shows, low-carbon, international manufacturing value chains based on renewable energy are emerging from these green energy ecosystems.

While electricity interconnection will play a role in the future export of renewable energy, interconnection alone is an insufficient offtake mechanism to establish robust value chains. Low-carbon, international value chains anchored in the Arab Gulf are arising primarily due to the seaborne export of green hydrogen in the form of green ammonia as well as the export of green hydrogen-derived fuels and fertilisers, green metals, and green manufactured intermediate products and finished consumer goods. CBAM's carbon tariffs on the six targeted sectors of hydrogen, fertilisers, iron/steel, aluminium, cement, and electricity provide an important and immediate economic impetus for the development of the GCC's production of green hydrogen, green fertilisers, and green metals. However, it is the internal economic logic of sustainable industrial diversification over the long term that is the principal driver of the development of green energy ecosystems among GCC MS and their efforts to establish renewable energy-based manufacturing value chains as part of those ecosystems, including the higher value-added green manufacturing of intermediate products and finished consumer goods, such as electric vehicles (EVs). To assist in the furtherance of EU-GCC partnerships, EU frameworks beyond CBAM – particularly the CID framework, its action plans, and the CTIP – should be leveraged wherever synergies exist with GCC efforts to achieve sustainable industrial diversification, as reflected in initiatives to establish renewable energy-based manufacturing value chains.

Green hydrogen is a key catalyst

Green hydrogen production, particularly the production of its derivative green ammonia, is playing an important role as a catalyst for the development of green energy ecosystems and renewable energy-based manufacturing value chains. Conventional hydrogen is produced from natural gas in a process that releases considerable quantities of carbon dioxide (CO2), thought to be a main contributor to climate change. In contrast to this "grey" hydrogen, green hydrogen is produced by using electricity generated from renewable sources to split water into its hydrogen and oxygen components, creating a versatile, carbon-free (hence, "green") energy carrier. Green ammonia, which is a green hydrogen derivative, can be easily transported by ship and is presently the most cost-effective way to store and transport green hydrogen. In the form of green ammonia, green hydrogen becomes a versatile energy carrier for renewable energy, enabling renewable energy to be transported and traded internationally like cargoes of oil or liquified natural gas (LNG).

Being able to transport renewable energy on demand as green ammonia greatly expands the scope of opportunities for developing a diverse array of manufacturing value chains based on renewable energy. By recombining green hydrogen and oxygen back into water in a fuel cell, electric current is generated, providing

Low-carbon, international value chains anchored in the Arab Gulf are arising primarily due to the seaborne export of green hydrogen in the form of green ammonia, as well as the export of green hydrogen-derived fuels and fertilisers, green metals, and green manufactured intermediate products and finished consumer goods.

on-demand, climate-smart power. Thus, green ammonia serves as an alternative technology to utility scale batteries, without the toxic and difficult to obtain minerals that current battery technology requires.

The attraction of green ammonia initially stemmed from the fact that ammonia, a nitrogen-hydrogen compound, forms the basic component of most synthetic fertilisers upon which modern agri-food production depends. Fertiliser manufacturing accounts for about 70% of global ammonia consumption (IEA, 2021). While the nitrogen is sourced from the air, the hydrogen used for ammonia production is primarily from natural gas-derived grey ammonia. Fertiliser industries are incentivising the development of green ammonia production capacity, as fertiliser producers attempt to ensure the resilience and cost-effectiveness of fertiliser production by phasing out natural gas-derived ammonia in favour of climate-friendly, supply shock-resistant green hydrogen-derived ammonia produced from renewable energy. Trailblazing GCC members, the UAE and Saudi Arabia are already significant exporters of fertilisers or fertiliser inputs. With a nearly guaranteed offtake option for fertiliser production, green ammonia has emerged as a preferred end-product of green hydrogen production.

Green ammonia is also emerging as a preferred energy carrier for the greening of industrial manufacturing processes in the EU as well as the GCC. Beyond fertiliser production, green hydrogen will also increasingly serve as a feedstock fuel in industrial manufacturing, particularly steel production (known as “green steel”) and other green metals processing – with green metals understood as metals whose processing is not powered by fossil fuels (Ellerbeck, 2022). The transition to renewable energy will require additional production of massive quantities of other key metals, especially copper and aluminium. The Energy Transitions Commission has estimated that the energy transition needed to meet 2050 climate targets could require the production of 6.5 billion tons of end use materials – 95% of which would be steel, copper, and aluminium (Energy Transitions Commission, 2023). Green metals production is critical for energy transition. For example, the worldwide steel sector accounts for about 7% of global CO2 emissions (European Commission, 2022b). The use of green hydrogen means that renewable energy can power the additional, energy-intensive metals processing required for the construction of new renewable energy production infrastructure.

In 2023, Europe’s first green steel production plant fuelled by green hydrogen, Sweden’s H2 Green Steel plant, began operations (Jones, 2023). A second green steel manufacturing facility in Sweden, the EU-funded HYBRIT (Hydrogen Breakthrough Ironmaking Technology) project, is scheduled to be fully operational in 2026 (DG CLIMA, 2023). In 2025, Germany’s Putzmeister, a global giant in the manufacture of construction equipment, entered into an agreement to purchase HYBRIT’s fossil-free steel for use in products such as concrete pump trucks and concrete mixers (FCW, 2025). Beyond Sweden, major green steel production projects based on green hydrogen are underway across Europe – including in Spain, France, and Germany (Savage, 2023). – as well as in South Korea and Japan (Yermolenko, 2023; Suga, 2023). European and Asian green steel production and other green metals processing will expand the exports markets of GCC-produced green hydrogen, encouraging increased foreign investment in renewable energy infrastructure in the region. Concurrently, increased metals demand is already spurring the expansion of metals

production in the Arab Gulf region itself where the green energy is locally produced.

As discussed below, the UAE has already pioneered the production of green aluminium from solar power. The UAE, Saudi Arabia, and Oman already have significant mining and metal processing sectors, which are in the process of expansion.

Green metals production powered by renewable energy also comprises a vital part of the green energy ecosystem through its intimate relationship with green mobility – the transition to the production and widespread use of electric vehicles (EVs). According to a Bloomberg forecast of EV metals and minerals, aluminium and nickel demand will experience a fourteen-fold increase by 2030, while phosphorous and iron demand will increase ten times in the same period (Richter & Yue Li, 2020). A ten-fold demand increase is expected for copper and graphite, while lithium demand will increase nine-fold (Richter & Yue Li, 2020). Each of the manufacturing processes associated with green mobility could be powered by renewable energy creating green circular production.

Green mobility is increasingly becoming an important component of Gulf State green energy ecosystems. In 2023, both the UAE and Saudi Arabia initiated an EV manufacturing sector. The UAE has also opened a recycling facility for end-of-life EV batteries. GCC renewable energy will power the metals and materials manufacturing, both locally or outside the region, for the components of climate-smart cars, trucks, buses, and aircraft. With their already existing infrastructure for fossil fuels and petrochemical production, Gulf States, such as the UAE, are also at the forefront of developing sustainable aviation fuel (SAF) from green hydrogen.

European nations are not the only partners interested in the green hydrogen potential of the GCC MS. Asian markets for Arab Gulf green ammonia may rapidly develop as the coal-burning regions of Asia move toward "co-firing," using both ammonia and coal as fuel in hitherto coal-fired power plants (Tanchum, 2023). Japan has been pioneering the development of co-firing technology, and, in 2023, successfully tested the operation of one its major coal plants using a fuel mix of 20% ammonia and 80% coal (Take, 2023). Tokyo aims to achieve 50-50 fuel during the 2030s and then phase out coal entirely in favour of 100% ammonia-fired plants by the 2050s (Watanabe, 2022). To meet their own commitments to achieve carbon-neutrality, Japan and other Asian nations using co-firing as an intermediate step will likely seek to import Arab Gulf-produced green ammonia, creating an additional dimension to GCC-centred renewable energy supply chains and their green energy ecosystems.

Among GCC MS, the UAE has been at the forefront in developing a green energy ecosystem with Saudi Arabia quickly adopting many aspects of the Emirati approach in a manner appropriate to its own needs and often on a grander scale. Oman aspires to use the opportunity to similarly expand its international footprint. Global LNG giant Qatar is charting its own course that is focused on lowering the carbon footprint of its natural gas operations. Kuwait and Bahrain are late adopters, with Kuwait having only restarted its renewable energy development in 2024 (Chandak, 2024) and Bahrain issuing a tender for its first utility-scale solar power plant in the same year (Bellini, 2024). Neither Kuwait nor Bahrain have a clear path to participating in renewable energy supply chains beyond investing in, and integrating with, the green energy ecosystems of their larger neighbours.

Green metals production powered by renewable energy also comprises a vital part of the green energy ecosystem through its intimate relationship with green mobility, which is increasingly becoming an important component of Gulf State green energy ecosystems.

The UAE is home to the most developed green energy ecosystems among the GCC states.

The UAE and Saudi Arabia are using their capital and experience in managing international hydrocarbon trade flows to become an engine driving the development of renewable energy infrastructure and green energy ecosystems in Europe, Asia, and Africa as well as in their own countries. These efforts are placing the Arabian Peninsula at the centre of an emerging pattern of renewable energy-based manufacturing value chains.

GCC green energy ecosystems: Arab gulf-state approaches to de-carbonised industrialisation and renewable energy-based value chains

The UAE's advancing green energy ecosystem: toward becoming a hub for renewable energy-based value chains

The UAE is home to the most developed green energy ecosystems among the GCC states, starting with its energy transition investments from the time of Abu Dhabi's ratification of Kyoto Protocol in 2005. A 2015 Paris Climate Accord signatory and committed to achieving net zero by 2050, the UAE's cumulative investment in clean energy projects from 2005 to 2023 totals over $40 billion (UAE Government Portal, 2023). Aspiring to a leading role in global efforts toward sustainability, the UAE has invested in renewable energy projects across 70 countries whose cumulative worth is $16.8 billion (UAE Government Portal, 2023). The UAE's extensive foreign investments reflect the Emirati approach that regards its own green energy ecosystem as a hub for inter-regional, renewable energy supply chains.

The UAE's forward-leaning policies have succeeded in making the UAE home to the largest renewable energy power generation capacity in the Arab Middle East. In 2023, the UAE announced its Updated National Energy Strategy to achieve in 2050 an energy mix of 44% renewable energy, 38% natural gas, 12% "clean coal", and 6% nuclear energy (UAE Government Portal, n.d.). The UAE is embarking on $54.5 billion of investments to quadruple its renewable energy power generation capacity by 2030 (Gulf Business, 2023b; Economist Intelligence, 2023; DEWA, 2024) [1].

Emirati efforts to develop its green energy ecosystem have benefited from the skilful leveraging of the country's experience in oil, natural gas, and petrochemicals production and export, encouraging collaboration between its national oil companies, the country's various power authorities, and companies engaged in renewable energy development, most notably Masdar (Abu Dhabi Future Energy Company). This collaboration has been facilitated by the bureaucratic integration of state-owned enterprises across the country's seven emirates, with a crucial coordinating role played by the UAE's various sovereign wealth funds such as the state-owned holding companies the Abu Dhabi De-

[1] Most of the 14.2 GW will come from the expansion of the UAE's solar energy capacity, with a combined 470 MW coming from waste-to-energy and pumped-storage hydropower. A 220 MW waste-to-energy plant at Dubai's Warsan landfill and a 250-MW pumped-storage hydro-electric power project under construction at the Hatta Dam in the Dubai area.

velopmental Holding Company (ADQ) and Mubadala Investment Company (known simply as Mubadala).

ADQ, one of the UAE's primary long-term investors in the country's non-fossil fuel economy, wholly owns the Emirates Water and Electricity Company (EWEC), which is the sole procurer of water and power within the Emirate of Abu Dhabi and in other emirates through partnering with plants across the UAE. In February 2023, for example, EWEC met 80% of its power demand using renewable and clean energy from its solar and nuclear plants, equivalent to 6.2 GW (Forbes Middle East, n.d.b). Similarly, Mubadala plays a central role in Masdar, now a global leader in clean energy and green hydrogen development. Active in the UAE and over 40 countries, Masdar's cumulative global investments exceed $30 billion (Forbes Middle East, n.d.a). Mubadala owns Masdar in partnership with ADNOC (the Abu Dhabi National Oil Company) (TAQA, 2022). ADNOC, through its fertiliser subsidiary Fertiglobe, is a sizable player in green ammonia production through its operations across the Middle East and North Africa (See discussion below).

Among the UAE's seven emirates, Dubai and Abu Dhabi account for at least 90% of the country's renewable energy capacity (ITA, 2021), Dubai's massive $13.6 billion Mohammed bin Rashid Al Maktoum (MBR) solar complex is the UAE's flagship renewable energy project (Casey, 2023). Touted as the "largest single-site solar park in the world," MBR is slated to have an installed capacity of 5 GW by 2030 (Masdar, 2023a). The participation of Saudi Arabia's ACWA Power and the Kuwaiti Gulf Investment Corporation in MBR's development serves to develop GCC stakeholder interest in the UAE's green energy ecosystem. Abu Dhabi's two major solar power mega-projects have focused on developing partnerships in Europe and Asia. The major project in the Emirate of Abu Dhabi is the 1.5 GW Al Dhafra solar complex currently under construction. Touted as the world's largest single-site PV solar facility, Al Dhafra's leading stakeholder is TAQA (40%) with Masdar, while France's EDF Renewables and China's JinkoPower each hold 20%. EWEC's major renewable energy facility is the Noor Abu Dhabi solar power complex in the Al Ain region, with TAQA owning a 60% share and JinkoPower and Japan's Marubeni each holding 20%.

The UAE's Updated National Energy Strategy has adopted a green energy ecosystems approach with a National Hydrogen Strategy that calls for the UAE to become a leading producer and exporter of low-carbon hydrogen, with the target of producing 1.4 million tons per year by 2031 and 15 million tons by 2050 (Gulf Business, 2023b). The UAE's strategy aspires to a 25% market share of the major hydrogen markets in Europe and Asia (Gulf Business, 2022). The UAE's domestic green hydrogen production will account for approximately 50% half of the green hydrogen produced by Emirati green hydrogen investments globally. Masdar is the entity responsible for spearheading most of the UAE's green hydrogen development. By 2030, Masdar aims to produce a total 1 million tons of green hydrogen and derivatives from its various operations across the Middle East and North Africa (MENA) region (Masdar, 2023b). Since Emirati domestic green hydrogen demand is forecast to be 200,000 tons annually (Masdar, 2023c), the remaining 300,000 tons produced locally and the 500,000 tons produced by Emirati operations abroad will be exported internationally (Masdar, 2023c). Leveraging ADNOC's experience and export infrastructure in the petrochemicals industry, Masdar seeks to make the UAE an international hub in the nexus of green hydrogen production and trade flows.

With its focus on low-carbon hydrogen, the UAE is developing both green hydrogen and blue hydrogen production capacity in tandem. In 2021, Masdar signed a "strategic alliance agreement" with France's multinational utility giant ENGIE to explore the co-development of a "UAE-based green hydrogen hub" (Engie, 2021). As the core of the hub, the two companies are eyeing a $5 billion investment to develop a minimum capacity of 2 GW by 2023 (UAE Government Portal, 2024). The UAE's National Hydrogen Strategy calls for the establishment of two "hydrogen oases" by 2031 and five by 2050 (UAE Government Portal, 2024). The development of these loci green hydrogen production has been incentivised through the UAE's chemicals and fertilisers industry.

Masdar via ADNOC and its fertiliser subsidiary Fertiglobe already operate ammonia production in Egypt and is involved in developing green ammonia production in Egypt along with a massive production complex in Mauritania. The Norwegian renewable energy company Scatec and Fertiglobe, in partnership with the Sovereign Fund of Egypt, are building a green hydrogen facility in the industrial zone of the Red Sea port of Ain Sokhna, near Fertiglobe's subsidiary Egypt Basic Industries Corporation (EBIC) (Scatec, 2021a). Scatec will operate the Ain Sokhna facility with Fertiglobe enjoying a long-term offtake agreement for the plant's green hydrogen output as a feedstock for EBIC's green ammonia production (Scatec, 2021b). The plant is the anchor project in the effort to turn Egypt's Suez Canal Economic Zone (SCZONE) into a hub for green hydrogen production and export (Scatec, 2024).

Masdar, as co-owner of the Emirati-Egyptian joint venture Infinity Power Holding, partnered with Germany's Conjuncta to construct a $34 billion green hydrogen complex in Mauritania that will produce 8 million tons of green hydrogen or its green ammonia equivalent (Tanchum, 2023). The investment reflects Masdar's desire to position itself in seaborne green ammonia trade flows from Atlantic Africa to western Europe. Mauritania's high level of solar and wind resources is similar to the level of its northern neighbour Morocco, a rising green hydrogen producer. With a population of about 5 million, 7 times smaller than Morocco's, sparsely inhabited Mauritania can more easily serve export markets while making affordable electricity and desalinated water available to its own population. Masdar is looking to Morocco as a "key geography" because the combined export volumes of green ammonia from Morocco and Mauritania transported via Morocco's already existing export infrastructure would provide commercial advantages that would advance an Atlantic Africa green hydrogen supply chain (even more so, when combined with future exports from Namibia's production facilities currently development). Besides Morocco and Egypt, Masdar is looking at other "key geographies", such as Saudi Arabia and Oman, which can easily serve as regional hubs for Asian markets (green hydrogen production in Saudi Arabia and Oman are discussed below). Masdar already enjoys a partnership with Saudi Arabia through ACWA Power's role in constructing the UAE's solar power infrastructure (Masdar, 2025). Masdar built Oman's Dhofar wind farm, whose output can meet 7% of the Dhofar Governate's electricity demand (Masdar, 2025).

The Emirati aviation industry is also becoming a component of the UAE's green energy ecosystem, creating another value chain through sustainable aviation fuel from green hydrogen. A global leader in air travel, the UAE's aviation sector is an important pillar of the Emirati economy, earning about $47 billion (Business Traveller, 2023) and accounting for about 13% of GDP (Kamel, 2021). Masdar is

spearheading an initiative to produce green hydrogen-based SAF in partnership with French energy giant TotalEnergies, Germany's Siemens Energy, and Japan's Marubeni (Masdnar, 2023). The UAE's Etihad Airways and Germany's Lufthansa are also partners in the collaboration. In early 2023, Masdar, ADNOC, and Etihad Airways, along with Tadweer (Abu Dabi Water management Company), partnered with BP to explore the development of SAF using municipal solid waste and green hydrogen (Gulf Business, 2023a).

The ambition of the UAE's National Hydrogen Strategy to become a low-carbon, hydrogen hub achieved a milestone in 2022 when Fertiglobe shipped its first consignment of Emirati-produced blue hydrogen for industrial use to Germany (Arubis, n.d.). So-called blue hydrogen is natural gas-derived hydrogen with a lower carbon footprint, hence "blue" instead of grey, due to the use of a carbon capture mechanism in the production process. The consignment was delivered in the form of blue ammonia produced at Fertiglobe's plant in the Ruwais industrial complex in Abu Dhabi (ADNOC, 2022). Although produced by the UAE's fertiliser sector, the blue ammonia exported to Germany served as a proof-of-concept for the use of hydrogen in industrial manufacturing, with the demonstration cargo being delivered to Aurubis, a European leader in the production of non-ferrous metals (Arubis, n.d.). The Hamburg-headquartered company utilised the Emirati blue ammonia in its copper wire rod plant (Arubis, n.d.), paving the way for the eventual use of green ammonia in the energy-intensive manufacturing processes used in multi-metal production. Aurubis is one of the world's largest copper recyclers. Beyond copper, Aurubis also produces a variety of battery metals. The company's use of low-carbon hydrogen also increases the prospects for the circular production of new green energy infrastructure, in which the metal and other inputs are supplied from recycling processes fuelled by green hydrogen produced from renewable energy.

The circular production of green energy infrastructure has also begun with the UAE's aluminium industry, the world's fifth largest aluminium producer (Pistilli, 2025). In 2021, the UAE inaugurated the world's first green aluminium production, with the transmission of solar power from the MBR solar complex to the state-owned aluminium manufacturer Emirates Global Aluminium (EGA) (Hall, 2021). Jointly owned by Mubadala and the Investment Corporation of Dubai, EGA is the UAE's largest manufacturing company outside the oil and gas sector and a world leader in premium aluminium production (Hall, 2021). The first consignment of aluminium produced with solar power, marketed under the brand name CelestiAL solar aluminium, was sold to German automaker BMW (Hall, 2021). Subsequently, EGA purchased Clean Energy Certificates for 1.1 million MWh of electricity from EWEC supplied by the Noor Abu Dhabi solar power plant for the production of about 80,000 tons of CelestiAL solar aluminium (EGA, 2022a). In 2022, EGA began supplying CelestiAL solar aluminium to Austrian-headquartered Hammerer Aluminium Industries for their manufacture of aluminium automotive components for automotive plants in central and eastern Europe (EGA, 2022b). In 2024, EGA acquired full ownership of Germany's Leichtmetall, which produces high-strength recycled aluminium using renewable energy (EGA, n.d.). While the renewable energy used by Leichtmetall is produced in Germany, EGA Leichtmetall could be fuelled in the future by Emirati-produced green ammonia. Most significantly, EGA's acquisition of Leichtmetall opens the possibility that green aluminium produced in the UAE could supply the Emirate's nascent EV manufacturing industry, which

is emerging as an important component of the UAE's green energy ecosystem.

The UAE's Updated National Energy Strategy calls for hybrid and electric cars to constitute 53% of passenger vehicles by 2050, and electric and hybrid buses to constitute 60% of all Emirati buses in service. In October 2022, the UAE's M Glory holding company opened the Al Damani Electric Vehicle Factory, the country's first electric car manufacturing plant. The $408 million facility will have an initial production capacity of 10,000 EVs per year (Oxborrow, 2022). With capacity expansion, the Al Damani plant is expected to produce 55,000 EVs annually for sale in the UAE as well as for export to GCC and African markets (Oxborrow, 2022). Electric vehicles are currently composed of 25-27% more aluminium than their internal combustion engine counterparts (MT, n.d.), and this is likely to greatly increase as manufacturers seek reduce EV weight and production times (Metals Warehouse, 2022). Domestically produced green aluminium such as CelestiAL solar aluminium could provide a significant advantage for the further development of EV manufacturing in the UAE.

While the Emirates' embryonic EV manufacturing industry currently does not warrant the creation of an EV battery manufacturing sector, it could emerge through EV battery recycling. In 2023, Beeah Recycling, a subsidiary of the Sharjah-based Beeah Group focused on waste recycling, signed an agreement with the Ministry of Energy and Infrastructure to open the UAE's first recycling plant for end-of-life EV batteries (BEEAH Group, 2023). Beeah Group jointly runs a waste-to-power facility with Masdar. With the UAE EV market expected to grow at 30% compounded annual growth rate through 2028 (BEEAH Group, 2023), domestic EV battery recycling will form a significant part of the UAE green energy ecosystem if the recycling process is powered by renewable energy. The availability of affordable renewable energy could also see the UAE become a regional hub for battery recycling.

Saudi Arabia: poised to become a rising power in renewable-energy based value chains

As the Middle Eastern country that generates most electric power, Saudi Arabia is central to the region's decarbonisation. For comparison, Saudi Arabia's electricity production was twice that of Egypt, whose population is three times the size of Saudi Arabia and 2.6 times that of its neighbouring oil and natural gas producer, the UAE (Energy Institute, 2023). The Kingdom relies on oil and natural gas for 99.8% of power generation, with oil making up 32.7% of the fuel supply mix (Our World in Data, n.d.). Untenable for further industrial development, energy transition forms a fundamental requirement for Saudi Arabia's ambitions to develop a 21st-century diversified economy. Saudi Arabia's Vision 2030 plan called for the Kingdom to generate 50% of its power from renewable energy sources by 2030 (Kingdom of Saudi Arabia, n.d.). To achieve the renewable energy targets of Vision 2030 and the King Salman Renewable Energy Initiative (launched in 2016), Riyadh established the National Renewable Energy Program (NREP) in 2017 to "maximize the potential of renewable energy in Saudi Arabia" (Ministry of Energy, n.d.). Riyadh aims for a 2030 installed capacity of 58.7 GW from renewable energy sources – 40 GW from PV solar power, 16 GW from wind power, and 2.7 GW from CSP (Gnana, 2023). Representing an 800% increase over its 2024 renewable power generation capacity, the Kingdom's ability to reach its ambitious targets

by 2030 remains uncertain. While the Kingdom is slated to double its renewable capacity by the end of 2025 with an impressive acceleration of its renewable energy capacity in absolute terms (Ingram, 2025), Saudi Arabia's longer-term prospects to achieve energy transition are strong due to Riyadh's adoption of a green energy ecosystem approach.

Saudi Arabia's largest project is the 2.06 GW solar power complex in Al Shuaibah, expected to be operational in Q4 2025 (ACWA Power, 2022). In November 2022, ACWA Power and Badeel, the Water and Electricity Holding Company subsidiary of Saudi Arabia's Public Investment Fund (PIF), agreed to develop the $2.2 billion solar power facility as a 50-50 joint venture that signed a 35-year power purchase agreement with the Saudi Power Procurement Company (SPPC) (ACWA Power, 2022), nationalised by the Saudi Ministry of Finance and Ministry of Energy in 2022 (Arab News, 2022). A key measure in the Kingdom's effort to reform and restructure the electricity sector to coordinate the rapid deployment of renewable power generation, SPPC is responsible for planning electric power generation infrastructure, concluding wholesale and electric power purchase agreements, and developing energy trading markets. In May 2023, Badeel and ACWA Power (of which, PIF is a 44% stakeholder) signed 35-year power purchase agreements connected to the development of three additional jointly developed PV solar power plants with a combined installed capacity of 4.55 GW (ACWA Power, 2023).

The strength of the current Saudi approach to renewable energy development is Riyadh's focus on creating renewable energy value chains through the development of a diversified green energy ecosystem, with green hydrogen as a renewable energy carrier playing a prominent role. Like the UAE, Saudi Arabia is looking to supply European and Asian markets with low-carbon ammonia for use in industrial manufacturing and as fuel ammonia in co-firing plants. Riyadh is leading with blue ammonia while eyeing the longer-term development of green ammonia markets. In October 2023, Saudi Aramco signed a letter of intent with Korea Electric Power Corporation, Korean steelmaker POSCO Holdings, and Korea's Lotte Chemical for investments and purchases related to the development of $15 billion blue ammonia production plant in the Kingdom (Suratman, 2023).

Saudi Arabia's efforts to develop a robust green hydrogen industry are anchored in the futuristic NEOM mega-city project. The $500 billion city is slated to be powered entirely by renewable energy based on solar and wind power (ENOWA.NEOM, n.d.) to create a carbon-free urban ecosystem (NEOM, n.d.). NEOM will also feature an $8.4 billion green hydrogen plant, touted to become the world's largest when operational (NEOM, 2023). Construction and operation of the plant is being managed by the NEOM Green Hydrogen Company (NGHC), an equal joint venture among NEOM, ACWA Power, and Air Products (the US-headquartered industrial chemicals and gases giant with significant subsidiaries across Europe, Asia, and the Middle East). The NGHC plant's initial production capacity will be 1.2 million tons of green ammonia per year (NEOM, 2023). NGHC's 30-year offtake agreement with Air Products for all the green ammonia produced at the plant will make Saudi Arabia a player in global green hydrogen value chains (NEOM, 2023).

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Mining and the processing of minerals and metals is central to Saudi Arabia's emerging green energy ecosystem. A key

pillar of the Kingdom's economic diversification agenda under the Vision 2030 plan, the development of the sector has been spearheaded by Ma'aden, whose meteoric rise over the past decade has seen it become one of the world's top multi-commodity, mining and metals companies by market capitalisation (Brand Finance, 2022). Ma'aden has committed to achieving carbon neutrality by 2050, while Riyadh aims to utilise steeply rising global demand for minerals to advance low carbon metals processing and thereby enhance its role in renewable energy-based value chains (SPA, 2023). Speaking in 2023, Saudi Arabia's Vice Minister of Industry and Mineral Resources for Mining Affairs, who oversaw the creation of the Kingdom's mining and mineral industries strategy as part of the Vision 2030 plan, affirmed that the strategy reflects Saudi Arabia's Vision 2030 commitments to green energy transition (SPA, 2023). With Saudi Arabia's ample mineral deposits and Ma'aden's focus on the production of copper, aluminium, and phosphates, the company has already experienced increased demand for its products driven by the global growth in renewable energy infrastructure construction, EV manufacturing, and fertiliser production (Brand Finance, 2022).

Saudi Arabia's mineral and metals processing sector also functions as a springboard for the Kingdom to realise its potential to play a broader role in the green manufacturing of intermediate products and finished goods.

The Indian conglomerate Essar is building a 4 million ton per year green steel facility in Saudi Arabia's Ras al Khair Industrial City (ESSAR, 2023). Concurrently, Brazilian metals giant Vale is creating a "Mega Hub" in Ras al Khair Industrial City to produce 12 million tons of low-carbon, cold-briquetted iron ore annually to feed the production of green steel (VALE, 2025; VALE, 2023). In 2024, Ma'aden acquired a 10% stake in the Brazilian company's subsidiary Vale Base Metals, via Manara Minerals, which Ma'aden jointly owns with PIF (Arab News, 2024). Ma'aden is also looking at the low carbon production of other metals and minerals, and is developing aluminium and phosphogypsum recycling plants at its Ras al Khair site. Phosphogypsum is a by-product of phosphoric acid production, a key input for phosphorus nitrogen fertilisers and for lithium iron phosphate EV batteries, which are fast becoming the new industry standard. Ma'aden is developing the phosphogypsum recycling plant in partnership with Germany's Thyssenkrupp (Thyssenkrupp, 2024) and will use a recycling process that can be fuelled by green hydrogen. The process has an important carbon reduction benefit as it converts phosphogypsum into quicklime (calcium oxide), which then can be used to bind CO2 through the formation of limestone, forming a carbon sink that can be used directly in construction or cement production.

Saudi Arabia's mineral and metals processing sector also functions as a springboard for the Kingdom to realise its potential to play a broader role in the green manufacturing of intermediate products and finished goods. Like the UAE, green mobility is playing a central role, as part of Riyadh's motivation to develop green metals is to support the development of a domestic EV manufacturing sector (Reuters, 2022b). In September 2023, the PIF-majority owned EV maker Lucid Group opened its first Saudi factory at the Red Sea port of Jeddah (Reuters, 2023). With an initial phase capacity to assemble 5,000 vehicles a year from semi-knock down kits manufactured by the company in the United States, Lucid plans to transition its Jeddah plant to manufacture a total of 155,000 EVs annually (Lucid, 2023). In 2025, Korean automaker Hyundai, in a 70-30 joint venture with PIF, began construction of manufacturing plant in the Kingdom with an annual production of 50,000 vehicles, both EVs and intern combustion engine vehicles (Techinasia, 2025). EV manufac-

turing in Saudi Arabia with both component manufacturing and assembly powered by renewable energy could possibly become an important driver of green circular production in the Kingdom.

Oman: fast-tracking large-scale green hydrogen production to position itself in international, renewable energy-based value chains

Although the UAE and Saudi Arabia are at the leading edge of the development of green energy ecosystems and renewable energy supply chains, Oman is seeking to fast-track the development of its own green energy ecosystem through rapidly developing a hydrogen-centric economy built on both blue and green hydrogen. Starting with large-scale green hydrogen production, Muscat plans over $45 billion of green hydrogen and green ammonia projects, including a 14 GW green hydrogen facility to be powered by 25 GW solar and wind energy resources (ITA, 2024). Separate from green hydrogen, Oman is scheduled to bring 4.04 GW of renewable online by 2029 – 3 GW from solar power, 0.9 GW from wind power, and 140 MW from waste-to-energy (Vassileva, 2023) – accounting for about 30% of the Sultanate's projected 2029 power production. (Bhambhani, 2023).

The development of Oman's renewable energy sector is part of a larger restructuring of the Omani economy under the Oman 2040 Vision plan promulgated in 2020 (Oman Vision 2040, n.d.). Under the plan, Muscat established the company Energy Development Oman (EDO) to facilitate investments to create a sustainable energy sector in Oman (EDO, n.d.). In 2022, EDO established Hydrogen Oman (Hydrom), regulated by the Ministry of Energy and Minerals, to implement the country's ambitious green hydrogen programme (Hydrom, n.d.). In a June 2023 report, the International Energy Agency published a programme outlining how Oman can produce over 1 million tons of green hydrogen by 2030 and 3.75 million tons by 2040 on the way to producing 8.5 million tons by 2050 (IEA, 2023). The 2050 target is modest when considering that the 50,000 sq km of land designated by the Omani government for green hydrogen production – a territory the size of the country of Slovakia – is sufficient to produce 25 million tons of green hydrogen (Chandak, 2023). If Oman succeeds in achieving these targets, it would become the largest producer of green hydrogen in the Middle East as early as 2030.

Oman's hydrogen transformation would require an aggregate investment of at least $33 billion, with $20 billion for the construction of renewable power generation dedicated to green hydrogen production, and $13 billion for green hydrogen production and its conversion to green ammonia (IEA, 2023). Oman's Duqm Port, located at the heart of the Arabian Sea's western shore, is geographically well-suited to serve as a green ammonia hub for trade flows to both Asian and European markets. However, Oman does not have a large conventional ammonia industry and thus lacks pre-existing ammonia offtake mechanisms to leverage in the transition to green ammonia. Despite its natural gas production, Oman exports only 0.2 million tons of grey ammonia per year (IEA, 2023). To export a significant portion of its slated 2030 green hydrogen output, Oman would need a 20-fold increase in the capacity of its ammonia export infrastructure (IEA, 2023).

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Given Oman's need for foreign investment for infrastructure development and offtake

distribution development, Muscat may be able to exploit synergies with the UAE, Saudi Arabia, and Qatar to develop win-win partnerships. A potentially critical node for international renewable energy-based manufacturing value chains, Oman's green hydrogen industry could be widely appealing for investment from European and Asian companies, as illustrated by Vulcan Green Steel's project to construct a green steel plant in Duqm. The company is ultimately part of India's Jindal group, which also acquired Vitkovice Steel, a leading Czech steel mill, which has agreed to purchase 1 million tons per year of Vulcan's 5 million green steel output when production begins in 2027 (Prabhu, 2024).

Qatar: lowering the carbon footprint of natural gas and trusting in blue hydrogen

Qatar announced it was constructing the world's largest blue ammonia production plant, slated to be operational in 2026. Unlike the UAE and Saudi Arabia, Qatar has not made any significant investments in developing green hydrogen.

Qatar's renewable energy strategy, based on its National Vision Plan 2030 (State of Qatar, n.d.), was focused on reaching an original intermediate 2030 target of 20% of power to be generated from renewable energy sources on the way to achieving net zero by 2050. Doha is now seeking to achieve an increased intermediate target of 30% of the country's power mix to be produced from solar power (Ataullah, 2023). In October 2022, Qatar inaugurated the 800 MW Al Kharsaah Solar PV Power Plant, its first large-scale solar power facility, capable of generating about 10% of the country's peak demand (Qatar Energy, 2022). Doha is presently engaged in the construction of two additional solar power plants with a combined installed capacity of 880 MW (The Peninsula, 2023), while also exploring the development of utility scale wind power as well as waste-to-energy power generation options.

As the world's third largest exporter of LNG (Statista, 2024), Qatar is focused on using renewable energy to lower the carbon footprint of its LNG production to enhance LNG's status as bridge fuel in energy transition (The Peninsula, 2023). Like the UAE and Saudi Arabia, Qatar is seeking to capture a share of the global hydrogen market through production of blue ammonia. In August 2022, Qatar announced it was constructing the world's largest blue ammonia production plant, slated to be operational in 2026, with an initial production capacity of 1.2 million tons of blue ammonia per year (Reuters, 2022a). Establishing market share and offtake mechanisms through the export of blue ammonia, Qatar could theoretically develop a green ammonia export sector in the future. Unlike the UAE and Saudi Arabia, Qatar has not made any significant investments in developing green hydrogen.

The EU's Clean Industrial Deal as a potential reset opportunity for EU-GCC partnerships in establishing renewable energy-based value chains

Although the EU's CID builds upon the European Commission's 2019 European Green Deal (EGD) (European Commission, n.d.d) and its 2023 Green Deal Industrial Plan (GDIP) (European Commission, 2023b), the tone and substance of the CID reflect the priorities put forth in the 2024 "Draghi Report on EU Competitiveness" (European Commission, 2024) and especially in the European Commission's subsequent January 2025

"Competitiveness Compass for the EU", which provides a vision for how Europe "must act now to regain its competitiveness and secure its prosperity" (European Commission, 2025b). Whereas the CID's predecessors emphasised achieving climate neutrality by 2050 with a single-minded exuberance that led to inadequate consideration of energy costs, industrial competitiveness, and economic growth, the CID presents itself as a "transformational business plan" to make Europe "a decarbonised economy by 2050" while promoting the Union's global industrial competitiveness and overall economic growth (European Commission, 2025d). The CID's orientation more closely resembles the orientation of various GCC efforts described above, and elsewhere in this volume, to develop a renewable energy-powered industrial base. The greater alignment between European and the Arab Gulf States' approaches to establishing decarbonised industrial value chains provides greater common ground to explore synergistic partnerships between the two regions.

To support the realisation of the CID's goal, the Commission issued its Action Plan for Affordable Energy in February 2025 to decrease energy cost across the Union. Among its regulatory and administrative reforms, the plan calls for the establishment of more efficient natural gas markets and the use of EU joint purchasing power to obtain better long-term contractual engagement for the procurement of LNG imports. The plan further suggests that "the EU and/or MS could also accompany EU importers in investing directly in export infrastructure abroad, providing preferential loans to private investors" (European Commission, 2025c). Stating that "Alternatives to natural gas imports should be explored when possible" (European Commission, 2025c), the plan opens the possibility of taking the same investment approach to investing in green ammonia and other renewable power export infrastructure in the Arab Gulf region.

Leaving aside governance issues, the CID's main challenges are identifying the financing mechanisms for the complex transformation of value chains that the CID seeks to achieve, and defining the parameters and mechanisms of the EU's international partnerships that will support this transformation. The CID estimates that achieving its goals will require an annual investment of €480 billion (European Commission, 2025d). For perspective, the Commission estimates that the necessary investments in electricity grids alone through 2030 will total €584 billion (European Commission, 2023a; Thomassen et al., 2024). Taking this €480 billion per year as a baseline minimum, revenues from existing EU tools such as the Emissions Trading System (European Commission, n.d.a) and the reallocation of finances from the Union's existing funds, such as the various cohesion policy funds among other (European Commission, n.d.b), would be insufficient to finance the transformation that the CID seeks to achieve.

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Furthermore, the Commission would need unanimous MS approval to inject new funding into the Union's long-term budget. The fate of the Strategic Technologies for Europe Platform (STEP), a predecessor to the CID that sought to promote European competitiveness through investments in cleantech, biotech, deep tech, and digital sectors, revealed the high degree of MS resistance to creating new large funds at the Union-level to finance the Commission's industrial policy. In 2024, the STEP received less than 10% of the additional funding requested, all of which was allocated to the European Defence Fund (Greenacre, 2024), reflecting a shift toward defence spending that is unlikely

to abate amidst escalating threats to the Union from the spillover of the ongoing Russia-Ukraine war. As with the Action Plan for Affordable Energy, the implementation of the CID as a whole will mean that the Commission will need to unlock private investment. EU-GCC joint venture investments in both regions could be utilised to establish mutually beneficial decarbonised industrial value chains between the Union and the GCC or between the Union and individual Arab Gulf States.

A particularly promising area for cooperation is green metals production as envisioned under the framework of the European Steel and Metals Action Plan. Promulgated by the Commission in March 2025 as "a comprehensive work programme for the short to medium term" that complements the CID and the Action Plan for Affordable Energy, the European Steel and Metals Action Plan seeks "to ensure a stable and resilient supply chain" for these materials, which the plan considers "critical to strengthening the European Defence Technological and Industrial Base, ensuring the EU's preparedness and internal security, meeting EU defence and aerospace needs, and ensuring tech sovereignty" (European Commission, 2025a). The plan builds upon 2024 Critical Raw Materials Act primarily focused on expanding the Union's domestic capacities to extract, process, and recycle raw materials (European Commission, n.d.c).

The Commission's 2020 Hydrogen Strategy requires fundamental reform to serve the Union's needs for industrial competitiveness and economic growth emphasised in the Draghi Report and the Competitive Compass.

In addition to its objectives to protect European industrial capacities and quality industrial jobs in Europe, the European Steel and Metals Action Plan seeks to facilitate the ample supply of affordable clean energy for metals processing and promote circularity. Recognising that "Energy costs remain the key driver of the metals industries' competitiveness," the plan prioritises "accelerating grid connections and the uptake of renewable and low-carbon hydrogen" (European Commission, 2025a). The plan also acknowledges that "Since direct electrification is not always possible or cost-effective, hydrogen is a key enabler of decarbonisation in the steel and metals industries" (European Commission, 2025a). The plan further identifies hydrogen as "the most promising option to decarbonise primary steel production" and the main contender to replace natural gas in the processing of other metals.

Again, investments with international partners in supplying green energy to Europe-based metals processing and joint venture investments in metals processing in both regions form essential components of realising the CID's goals. In the case of steel production, the European Steel and Metals Action Plan itself notes that "a strategic approach" to strengthening supply chain resilience "could involve investing in partner countries and redefining industrial collaborations to create a more sustainable and resilient steel production ecosystem" (European Commission, 2025a). As seen from the previous sections overview of green hydrogen and green metals production among GCC MS, the Arab Gulf States are primary candidates for EU partnership.

It is widely recognised that the Commission's 2020 Hydrogen Strategy for a climate-neutral Europe (European Commission, 2020) requires fundamental reform to serve the Union's needs for industrial competitiveness and economic growth emphasised in the Draghi Report and the Competitive Compass. The 2024 Market Monitoring Report (MMR) on European hydrogen markets published by the EU Agency for the Cooperation of Energy Regulators (ACER) outlined many of the demand and production challenges within

Europe and has inspired a vigorous discussion about how to remedy them (ACER, 2024). The ACER MMR's analysis includes the Commission's 2022 REPowerEU Plan, announced in the wake of the 2022 Russian invasion of Ukraine. Declaring that "renewable hydrogen will be key to replace natural gas, coal and oil in hard-to-decarbonise industries and transport," REPowerEU set a target of 10 million tons of domestic renewable hydrogen production and 10 million tons of renewable hydrogen imports by 2030 (European Commission, 2022a). As with the previous initiatives discussed, a coherent vision and platform for coordinated action at the Union level to implement the REPowerEU's foreign dimension has yet to materialise.

A central coordinating investment platform at the Union level to facilitate joint ventures that would establish renewable energy-based value chains is necessary and would require the institutional revamping the Global Gateway initiative to serve CID objectives. Although announced on 15 September 2021, the Global Gateway initiative has yet to develop into a transformative force that offers European-led partnerships for connectivity that are attractive amidst global alternatives. One basic problem consists of the fundamental contradictions existing among the institutions tasked with implementing the Global Gateway strategy, specifically between the various EU institutions operating within a development aid framework and those that could be involved in facilitating joint venture investments for value-added manufacturing infrastructure in line with the CID's objectives for industrial competitiveness and economic growth. While an analysis of the problem is beyond the scope of the present chapter, the issues have been raised elsewhere (Tanchum, 2022). The problem ultimately rests with the Global Gateway's Commissioners-only steering committee including the Commission President and High Representative. The Global Gateway Steering Committee so far has not mobilised the Union's institutions with sufficiently compelling and coherent action to inspire confidence among the private sector business communities in EU MS nor potential partner countries (Benaglia & Ergenc, 2025).

The Commission's announcement of a new trade instrument, the Clean Trade and Investment Partnership (CTIP), to implement the CID's international partnership aspirations could potentially remedy the lacuna. First proposed in the Competitiveness Compass, the CTIP is considered by the Commission as an "alternative form of engagement" that is tantamount to a "mini trade deal" that can be concluded without the conventions of a free trade agreement (Jütten, 2025). As such, CTIP can be used to create comprehensive, cross-sectoral partnerships that are customised to each particular partner country. CTIPs offer the possibility of being legally binding, with clearly defined outcomes and a specific timeline for their realisation. Investments could be encouraged through provisions for withdrawal if the required progress specified in the partnership timeline is not achieved or an appropriate solution is not found through negotiation. Such measures would promote oversight and transparency and inspire confidence that the Commission can deliver tangible results. CTIPs would be compatible with a variety of financing instruments analysed elsewhere in this volume. The CTIP, as a mini trade deal, also provides the Commission with the opportunity to act as a coordinating platform to facilitate effective cooperation across the relevant industrial sectors in Europe as well as across MS national boundaries.

The Global Gateway Steering Committee so far has not mobilised the Union's institutions with sufficiently compelling and coherent action to inspire confidence among the private sector business communities in EU MS nor potential partner countries. The Clean Trade and Investment Partnership could potentially remedy the lacuna.

Conclusions and policy recommendations

The efforts by leading Arab Gulf states to develop green energy ecosystems are placing the Arabian Peninsula at the centre of an emerging pattern of renewable energy-based manufacturing value chains as well as renewable energy supply chains. While CBAM's carbon tariffs provide a short-term economic incentive for the GCC's low carbon production of the six targeted sectors of hydrogen, fertilisers, iron/steel, aluminium, cement, and electricity, the internal economic logic of sustainable industrial diversification for global competitiveness over the long term is the principal driver of the development of green energy ecosystems among GCC MS, particularly the UAE, Saudi Arabia, and Oman. While the production of green inputs such as green ammonia and green aluminium have catalysed the emergence of green energy ecosystems, the GCC MS are also working toward the establishment of renewable energy-based manufacturing value chains that include higher value-added green manufacturing of intermediate products and finished consumer goods on the Arabian Peninsula.

Despite Europe's increasing reliance on Arab Gulf-produced green hydrogen and green metals, European firms are relatively absent as joint venture partners and investors in production facilities on the Arabian Peninsula. The Union's new orientation toward industrial competitiveness and economic growth opens common ground for the EU and GCC MS to concretise synergies through joint venture investments. With the growth of green energy and green input production on the Arabian Peninsula, the leading GCC states are witnessing a concomitant growth in the green manufacturing of intermediate products and finished consumer goods. European firms are likewise underrepresented as joint venture partners and investors in GCC manufacturing plants, particularly as compared to their Asian counterparts. This absence is a strategic lacuna for the EU and individual EU MS.

Through its relative lack of business-to-business engagement with the Arab Gulf states, facilitated by effective public private partnerships, Europe is relinquishing its ability to influence the nature and configuration of renewable energy-based value chains. Win-win joint venture investments in green manufacturing that create jobs and contribute to GDP in both regions align with CID objectives, and would reverse Europe's eroding influence over the emerging green energy supply chains and value chains that the Union will depend upon in the future. CTIPs potentially provide a means for the EU to advance Europe-Arab Gulf state partnerships through Union-level action. Such mutually beneficial investments would powerfully facilitate EU-GCC cooperation in global climate diplomacy to achieve carbon management, sustainability, and the implementation of the green transition.

- **European investment green hydrogen operations in the GCC:** The EU and its MS should facilitate European business investments in the production, storage, and transport of green hydrogen and green ammonia. Win-win opportunities should be sought in the upstream, mid-stream, and downstream operations. European firms likely provide value added for the latter two aspects. The most promising opportunities may be in Oman, given its lack of sufficient offtake infrastructure for ammonia. An EU-Oman CTIP on green hydrogen and derivatives could serve as a starting point for CTIPs with other GCC MS.

- **Joint EU-GCC investments in green hydrogen production in third locations that will service European End markets:** The EU and its MS should facilitate European business investments in the production, storage, and transport of green hydrogen and green ammonia that GCC firms are developing in third countries that would be part of supply lines to Europe. The joint venture between Emirati and German firms in Mauritania's green ammonia production serves as a model. The EU should engage the UAE and Saudi Arabia, in particular, in this regard.

- **European investment in metals processing, fertiliser and fuel production in the GCC:** Beyond green hydrogen, the EU and its MS should facilitate European business investments in metals processing, fertiliser and fuel production in the GCC to ensure the optimal configuration of supply chains and value chains that serve European interests. Otherwise, the absence of European investments relative to investments by firms from other regions will result in the erosion of Europe's influence on trade flows of these inputs. CTIPs and other mechanisms to realise the foreign component of the CID and its associated actions plans need to clarify the Union's position on the intermediate green imports.

- **European green manufacturing plants in GCC countries to preserve European export share in third locations in Africa and Asia:** To ensure continued export market share outside of Europe, the EU and its MS should facilitate European business investments in GCC manufacturing of finished consumer products intended for export to other Asian and African markets. Otherwise, cost-efficient, green manufacturing on the Arabian Peninsula by Asian firms will likely result in the loss of market share for European exports, and absent European production facilities in or near the African or Asian markets themselves.

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Bridging the Carbon Economy: Unlocking EU-GCC Cooperation in an Era of Industrial Decarbonisation

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Introduction

Analytical framework and sources

This chapter implements a policy options analysis perspective to examine how European Union (EU)-Gulf Cooperation Countries (GCC) trade and investment relations are being reshaped by the EU's Carbon Border Adjustment Mechanism (CBAM) and related regulatory frameworks. Framing the EU's evolving industrial and climate policy frameworks as both industrial policy instruments and a vehicle of climate diplomacy, the analysis assesses pathways for GCC producers to align with EU decarbonisation norms while safeguarding competitiveness, fostering industrial transformation, and creating new opportunities for cross-regional cooperation.

To support this analysis, this chapter draws on a combination of open-source intelligence (OSINT), media reports, corporate announcements, and public statements, complemented by data from trade organisations, industry filings, and EU and GCC databases. Analysis synthesises these sources to provide a comprehensive, evidence-based assessment of regulatory, financial and industrial decarbonisation trends, ensuring both reliability and relevance for policy and strategic insights. A full reference list is provided at the end of the chapter.

The EU's increasingly assertive carbon regulations are reshaping the global trade landscape, with far-reaching implications for industrial exporters worldwide. Central to this shift are the Clean Industrial Deal,[2] REPowerEU,[3] the Net Zero Industry Act,[4] the Industrial Decarbonisation Accelerator Act,[5] and sectoral initiatives like the Steel and Metals Action Plan.[6] The cumulative effect of these initiatives is the emergence of a more comprehensive industrial architecture within the EU, one that fuses climate ambition with competitiveness. The Clean Industrial Deal (which includes the Steel and Metals Action Plan) and the Net Zero Industry Act seek to build strategic capacity in decarbonised manufacturing, while REPowerEU accelerates the deployment of renewable energy and energy efficiency to underpin that transition.

In parallel, the Industrial Decarbonisation Accelerator Act reinforces sectoral obligations and financing pathways to speed the uptake of clean technologies in hard-to-abate industries. Taken together, these frameworks are less about piecemeal regulation and more about consolidating a long-term trajectory for Europe's industrial base, ensuring that climate policy does not

weaken but rather redefines the EU's competitive advantage. These developments amplify the external effects of the EU's internal market rules, creating regulatory gravity that trading partners will find difficult to ignore.

Yet, it is the CBAM, a flagship initiative under the 'Fit for 55' package of the European Green Deal[7] that represents the most consequential intervention for the EU's external trade relations, embedding carbon costs directly into cross-border commerce. CBAM introduces a dual requirement for importers of emissions-intensive goods: comprehensive emissions reporting, and, ultimately, a carbon levy at the EU border. This mechanism is designed to reduce global emissions and protect the competitiveness of European industries subject to the EU's own carbon pricing regime. By assigning a carbon cost to imported goods, CBAM aims to mitigate carbon leakage, i.e., the displacement of emissions to jurisdictions with less stringent climate policies, while incentivising global partners to align with higher environmental standards. As such, the EU is not only internalising its climate commitments but also externalising climate ambition through trade policy.

For the GCC, a region deeply integrated into EU supply chains for products such as aluminium, steel, cement and fertilisers, the CBAM presents both a policy challenge and a strategic opportunity. Preserving market access and economic competitiveness will require accelerated progress toward credible domestic – or ideally regional – carbon pricing frameworks. Without such measures, GCC exports may become increasingly exposed to EU tariffs, and potentially to similar mechanisms adopted by other trading partners or linked to the EU's Emissions Trading Scheme (ETS). Inaction could erode the region's position in global value chains, especially in a world moving rapidly toward climate-aligned trade norms.

This report explores the policy and business implications of shifting trade dynamics, as industrial transformation efforts in the GCC respond to the EU's emerging climate-aligned trade and regulatory norms. It analyses strategic shifts in manufacturing of CBAM-covered and energy transition-critical materials in the region, and explores practical first-mover strategies for alignment, such as adopting certification schemes and scaling investment in industrial decarbonisation technologies, with a focus on renewables and hydrogen. The final sections highlight emerging joint EU-GCC business opportunities in these areas – initiatives that not only align with the GCC's strategic vision, but also offer the EU significant benefits, including secure access to decarbonised imports, diversification of industrial partnerships, and strengthened climate diplomacy. The report concludes with targeted recommendations for EU-GCC collaboration that can support the GCC's transition from reactive compliance to proactive leadership in the emerging global carbon economy.

For the GCC, a region deeply integrated into EU supply chains for products such as aluminium, steel, cement and fertilisers, the CBAM presents both a policy challenge and a strategic opportunity.

The GCC is strategically positioning itself for decarbonised industrialisation

So far under the CBAM, not every product from high-emitting industries is liable to the carbon tax

Only products classified by Combined Nomenclature (CN) and Harmonised System (HS) codes of the Annexes of the EU CBAM Implementing Regulations are covered by the CBAM. For instance, while components like aluminium ingots, sheets, and processed aluminium in a car door are CBAM-covered, the final product (the car door itself) is not, as it is not classified under CN or HS codes. Exempted final products are typically "simple goods" (Carbon Chain, n.d.).

CN and HS classifications are generally reserved for raw materials, ingots, agricultural products, and their derivatives used in manufacturing simple goods. For example, ammonia, derived from hydrogen, has a CN code and is subject to the CBAM, as is hydrogen itself (Greenberg-Traurig, 2024). This also applies to crude oil and natural gas, which will be subject to the CBAM once included in its scope.

This distinction can yield new opportunities for GCC countries by:

- **Encouraging innovations that lower emissions** in the high carbon-emitting parts of their value chain, and/or convert that part of the value chain into a product that does not require such a classification;
- **Diversifying lower-carbon footprint product lines** or expanding lower-carbon product ranges;
- **Retaining the entire value chain** of their product at home, instead of exporting CN and HS-classified goods to Europe, where they will then get converted into a final good; and
- By extension, **establishing new manufacturing facilities for export-ready final goods,** such as automotives, vehicle parts, pipes, electrolysers, turbines, solar panels, and a wide gamut of other products.

Such a distinction may already have informed new strategic shifts in industrial products' manufacturing

For example, it may have partly informed Emirates Global Aluminium's[8] 100% acquisition of Leichtmetall Holding GmbH – a German specialty foundry utilising renewable energy and secondary aluminium – in 2024 to develop a green aluminium business close to EGA's customers in Europe, primarily Germany, Italy, and France (Gulf News, 2024).

By producing ingots and sheets within the EU, the United Arab Emirates (UAE) can bypass CBAM taxation which it otherwise would be exposed to if exported from the UAE. Although EGA does produce about 66 kt/y of solar aluminium – CelestiAL – in the UAE, it may consider converting it into a final good for export to the EU and other markets as a more competitive endeavour.

As noted in the previous chapter, since 2023 EGA has been producing CelestiAL-R, which is the world's first blend of aluminium made with solar power and recycled metal, with BMW being one of the major offtakers for it (WAM, 2024). The Leichtmetall plant will also produce the same, mainly using secondary aluminium – i.e., high-quality pre- and post-consumer scrap such as sheet metal or profiles – alloyed with zinc, magnesium, copper, manganese or tin, requiring 95% less energy than making primary aluminium,

keeping costs low. The plant has been using electricity from 100% renewable energy sources in Germany since 2022, and despite high costs of electricity there, pays about a fraction (€68.60/t) of the electricity cost for producing primary aluminium (~€1,372/t in Germany).[9]

With the acquisition of Leichtmetall, EGA can produce much higher volumes of CelestiAL-R closer to its customer base, thereby reducing transportation costs and lead times, and allowing for easier compliance with European regulations, which include not just carbon taxes but also quality standards and environmental certifications. Meanwhile, it can continue utilising the CelestiAL-R produced at home to further its manufacturing capabilities for export-ready final goods.

Similar to the Leichtmetall deal, EGA also completed the acquisition of an 80% majority stake in US aluminium recycling firm Spectro Alloys in September 2024 to supply the US market with secondary alloys (EGA, 2024).

Similar examples exist in other GCC countries, but at a less developed level

Saudi Arabia mining company Ma'aden has approved plans for a new 400 kt/y aluminium recycling plant in Ras al-Khair, in addition to an existing recycling facility, and has also partnered with Finnish industrial machinery developer Metso and Germany's Thyssenkrupp to develop phosphogypsum[10] recycling (Enterprise, 2024). The endeavour will recycle phosphogypsum into quicklime through a calcination process that will capture CO2 emissions, thereby promoting a circular economy by converting waste into valuable resources. Although green aluminium has not been identified as a strategic mandate yet, Ma'aden has routinely collaborated with EGA on expansion of green technology for aluminium smelting (The National, 2022).

Green steel is also receiving growing attention, with Brazilian mining giant Vale signing a land reservation agreement with the Royal Jubail and Yanbu Commission in January 2025 to build a 12 Mt/y green steel facility in Ras Al-Khair to supply high-quality iron ore and contribute to the development of the regional green steelmaking ecosystem (Steel Radar, 2025). The project will supply iron ore agglomerates (primarily briquettes) for Indian steel group Essar's US$ 4.5 B, 4/Mt/y integrated steel plant also in Ras Al-Khair (VALE, 2023). Essar will develop renewable energy generation and storage solutions along with solar PV firm Desert Technologies for use at its project which is set to start production in 2027 (Outlook Business, 2023). Produced green steel will be used domestically as well as exported, helping meet CBAM requirements if sent to the EU.

An environmentally "friendlier" cement produced by local company Al Jouf Cement with 30% lower CO2 emissions (thanks to locally sourced alternative ma-

terials (reducing the need for imported components like Ground Granulated Blast-furnace Slag (GGBS) and fly ash) low heat of hydration, and the signing of a power purchase agreement (PPA) with Engie to develop a 22 MW solar PV plant at its facility in Turaif) (Global Cement, 2024) has also been approved for use in NEOM City (Global Cement, 2025) to meet its sustainability goals, but does not appear to be earmarked for export.

GCC nations appear to be pursuing a more constructive path – preparing to comply with CBAM requirements through strong monitoring and reporting practices, while also exploring the possibility of establishing domestic or regional carbon markets that could eventually support their case for an exemption from the EU's carbon levy.

Oman, similarly, is planning the Middle East's first low-carbon cement plant with Madrid-headquartered IPIAC contracted to supply its LC3 cement plant based on innovative low-carbon cement technology. Unlike traditional cement, which relies heavily on a material called clinker (made by heating limestone at very high temperatures and responsible for most of the carbon emissions in cement production), LC3 replaces much of the clinker with a more environmentally friendly ingredient: calcined clay. This change dramatically reduces the energy needed and the CO2 released during production, cutting emissions by about 40% (Prabhu, 2024a). Produced cement will be used domestically and for export.

Vulcan Green Steel, sister company of Jindal Shadeed Iron and Steel under the Vulcan International Holding Company (which is part of India's Jindal Group) (Moggridge, 2023), meanwhile, is constructing its 5 Mt/y green steel mill at Oman's Arabian Sea Port of Duqm, and has signed a binding agreement with Czech company Vitkovice Steel for 1 Mt/y of green steel supply from the project when it comes into operation in 2027 (Prabhu, 2024b). This produced steel could meet CBAM requirements even if relying solely on operational efficiency gains, renewable power, and technology expansion to reduce emissions (Martin, 2023).

Clearly, these GCC countries have taken a pragmatic approach to evolving carbon regulations

While many of the EU's trading partners like the UK, Australia, and Türkiye are creating their own CBAM-style policies, some nations such as China, India, and South Africa have criticised the EU's move as protectionist. In contrast, the GCC nations appear to be pursuing a more constructive path – preparing to comply with CBAM requirements through strong monitoring and reporting practices, while also exploring the possibility of establishing domestic or regional carbon markets that could eventually support their case for an exemption from the EU's carbon levy.

Table 1. Trade Statistics of CBAM-Covered Products Exported to the EU Chiefly Include the UAE, Saudi Arabia, and Oman, among Other MENA Countries

Product	Trade Statistic (as of 2024)
Aluminium	• 85% of EU imports come from 10 exporters, which include the **UAE** and Bahrain, each representing 8% and 3% of such imports • **Saudi Arabia, Oman,** and Qatar all appear on the list of the top 30 exporters to the EU (19th, 24th, and 28th positions respectively)

Fertilisers	• 85% of imports are accounted for by five countries, which include Morocco, Egypt and Algeria, each representing 22%, 21% and 20% of such imports, respectively • Libya, **Oman, Saudi Arabia,** Tunisia, and Qatar appear on the list of the top 30 exporters to the EU (16th, 17th, 18th, 21st, and 28th positions respectively)
Cement	• Algeria (6%), Morocco (5%), and Tunisia (3%) are among the top exporters that account for about 80% of the total imports to the EU • **Saudi Arabia,** Kuwait, Jordan, and the **UAE** occupy the 12th, 25th, 28th, and 29th place on the list of top 30 exporters to the EU, respectively
Steel	• Tunisia, Egypt, the UAE, and Saudi Arabia occupy the 17th, 21st, 23rd, 25th, and 30th place on the list of the top 30 exporters to the EU, respectively

Note. Elaborated by author, sourced from Ghoneim (2024), World Bank (2023) and Van Bael & Bellis (2021).

This approach is particularly important given the GCC's significant export exposure to CBAM-covered products such as aluminium, fertilisers, cement, and steel. For example, the UAE and Bahrain together account for over 10% of the EU's aluminium imports, and countries like Saudi Arabia, Oman, and Qatar rank among the top 30 exporters of several CBAM-regulated products (Table 1). Until a carbon pricing system is formalised in the region, initiatives such as carbon tax compliance and emissions tracking – with support from experts like Verofax (Verofax, n.d.), for example – will be critical for maintaining market access and competitiveness in the EU.

Role of carbon regulation in decarbonised industrialisation

Unlike many other regions where pluralist regulatory models and private-sector coordination play a central role, the GCC's highly centralised, state-led governance structure has enabled rapid decision-making and resource mobilisation in the transition. Political commitment at the highest levels has translated into swift execution of megaprojects and the channelling of sovereign wealth, public utilities, and state-linked enterprises toward industrial decarbonisation initiatives.

This governance model underpins the "high credibility" often associated with GCC hydrogen and renewable projects: announcements are typically backed by state resources, long-term offtake guarantees, and vertically integrated industrial strategies, reducing the risk of fragmented or stalled implementation that can often be a challenge in pluralist regulatory environments.

Nevertheless, these centralised governance models also bring political economy dynamics such as regional rivalries and competition for foreign investment that can lead to duplicative green industry projects, potentially impacting cross-border coordination and economies of scale. Recognising these dynamics is essential to appreciating why GCC states can advance

industrial decarbonisation faster than many peers, but also why the trajectory is uneven across the region and not without structural risks.

GCC states have advanced significantly in green energy and decarbonisation over the past 5 years

The GCC countries have already made considerable strides in green energy investments and decarbonisation efforts over the last half decade. All except Qatar have committed to net zero emissions. While sector-specific measures, such as renewable energy investments, electric vehicle incentives, and infrastructure optimisation are already underway, the focus is increasingly on market-based policies like carbon pricing, green procurement, and green certifications.

These market-specific policies are designed to drive both green energy adoption and sectoral decarbonisation, offering subsidies, land provisions, and other support mechanisms to foster green growth. In the GCC, emerging industries such as green hydrogen, green ammonia, and industrial green products are central to this strategy. While these products often carry a green premium compared to conventional alternatives, they present substantial opportunities for long-term sustainability, provided that investments and robust industrial policies are in place to support their development and market integration.

A domestic cap-and-trade scheme could be linked to a local CBAM

One such policy being explored for implementation in the GCC currently is a local cap-and-trade scheme. Figure 1 depicts a schematic of how a cap-and-trade system could work in a GCC country. So far this has been the purview of only the UAE, but may expand to the others in the future. In any case, the most benefit would be realised by linking such a scheme to a domestic CBAM, as it would allow these countries to:

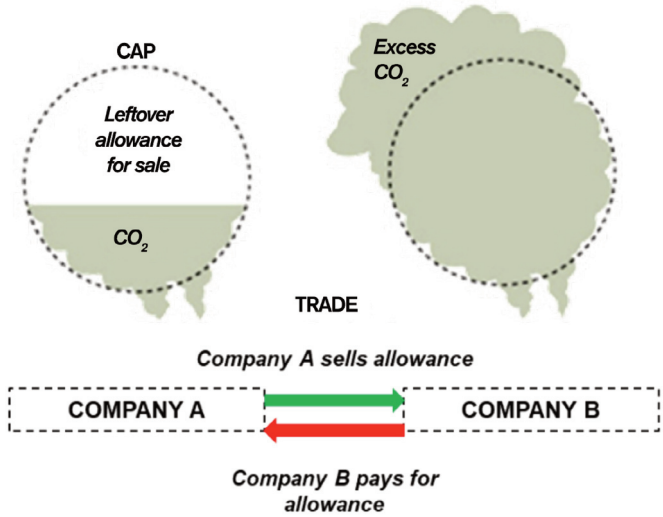
1. **Argue for a reduction or exemption for their industrial exports from the EU CBAM,** since these exports already paid a carbon price at the time of production
2. **Argue for lower CBAM rates** if the rate paid at the time of production of their goods is lower than the average weekly EU ETS price, thus reducing the cost burden on their producers

In the UAE, an international standard carbon Measurement, Reporting, and Verification (MRV) programme by the Environment Agency – Abu Dhabi (EAD) has been launched to lay the groundwork for a successful carbon pricing mechanism, with preliminary assessments estimating a future UAE carbon price of US$ 21/tCO2 in 2026, against current EU ETS prices of US$ 90.7/tCO2 (Sandbag, 2025). The programme will require large carbon emitting facilities to monitor, report, and verify by third parties their emissions on an annual basis with first reports due by 2026. Data generated will meet guidelines defined by the United Nations Framework Convention on Climate Change (UNFCCC) in alignment with the Enhanced Transparency Framework of the Paris Agreement and international collaborations for climate mitigation initiatives.

The programme is also linked to the development of a mandatory cap-and-trade system to incentivise industries to reduce emissions while allowing them to choose between decarbonisation measures to

achieve reductions where they are most feasible and cheapest. In its first Long-Term Strategy (LTS): Demonstrating Commitment to Net Zero by 2050, the UAE states that implementing a cap-and-trade system is also intended to smooth trade with other countries that are putting in place carbon border taxes and other adjustment mechanisms (UAE Ministry of Climate Change & Environment, 2023), a direct nod to the perceived impact of the EU CBAM on the UAE's exports if it does not develop relevant carbon regulation of its own.

Figure 1. Schematic of How a Cap-and-Trade System could Work in a GCC Country



Note. Elaborated by author.

Green standards and procurement policies will aid in developing carbon benchmarks

Mandating green standards for CBAM-covered industries is another option GCC producers can explore for establishing benchmarks that account for the lower carbon content of their products. For example, in the steel sector, standards such as Responsible Steel, World Resources Institute Greenhouse Gas (WRI GHG) Protocol, Climate Bonds Standard, World Steel Association Protocol, International Organisation for Standardisation (ISO) 14404, ISO 14025 (Environmental Product Declaration [EPD]), American Iron and Steel Institute (AISI) standard, and Science Based Targets Initiative (SBTI) Steel Sector Guidance can all be applied relatively straightforwardly to steel operations to make them more environmentally friendly.

Key criteria under these standards include accounting for CO2 and other GHG emissions per tonne (for example, divided between the direct reduced iron (DRI)/furnace and electric arc furnace); having environmentally friendly operating practices (such as having a CCUS capture rate of >70%, low-carbon hydrogen in DRI, scrap usage of >70%); mitigating other pollution; and pursuing other relevant ESG criteria (such as community, labour rights, safety, community engagement, R&D, etc.).

By incentivising emissions reductions, green certifications are also accelerating innovation in cleaner technologies and sustainable industrial practices.

Green procurement policies on the other hand will set a rising procurement standard for green industrial products (green steel, green aluminium, green cement, etc.), for example rising from 10% today to 100% by 2035. These could have a price ceiling calculated as the maximum premium over non-green material, and can be linked to local content programmes, encouraging in-country production of green materials.

Green certifications can allow industries to move beyond compliance to drive business growth

Green certification practices are being used as a powerful tool to demonstrate GCC industries' commitment to climate action and carbon control, and establish their market credibility as stewards of sustainability. Certifications like ISO 14001 (Environmental Management Systems), ISO 14040 (Life Cycle Assessment: Principles and Framework), ISO 14044 (Life Cycle Assessment: Requirements and Guidelines), ISO 14067 (Carbon Footprint of Products), ISO 27915 (Carbon Neutrality), ISO 17029 (Validation and Verification of Sustainability Claims), Cradle to Cradle (Certification Framework for Products designed with a Circular Economy mindset), and others are being explored by industrial players as proof that their products are sustainability produced and have a lower carbon footprint. Because these certifications include rigorous audits and third-party verification, they act as a reliable, standardised way to report emissions, ensuring compliance with carbon regulations like the CBAM.

By incentivising emissions reductions, green certifications are also accelerating innovation in cleaner technologies and sustainable industrial practices. In striving to meet certification standards and avoid carbon-related penalties, industries are increasingly investing in R&D, energy efficiency, and circular economy solutions – such as captive renewable energy systems in power-intensive sectors like aluminium and cement, or carbon capture solutions in large gas-based industrial sectors like direct reduced iron (DRI) and fertilisers.

Fact Box 1. Green Certifications for Low-Carbon Hydrogen Products in the GCC

In 2022 Saudi Aramco and state-owned fertiliser company SABIC Agri-Nutrients acquired the world's first independent certification of lower-carbon natural gas with CCUS-based ammonia (or "blue" ammonia)[1] and hydrogen production from TÜV Rheinland, one of the first third-party testing and certification organisations to focus on the low-carbon sector (Saudi Aramco, 2022). In 2024 a similar shipment of natural gas with CCUS-based ammonia to Mitsui in Japan for use in power generation became the world's first certified bulk commercial shipment by TÜV SÜD (Martin, 2024), which introduced its standard for natural gas with CCUS-based hydrogen and its derivatives in late 2023.

[1] Blue ammonia is ammonia (NH3) produced using hydrogen derived from natural gas, where the resulting CO2 emissions are captured and stored using carbon capture and storage (CCS) technology. This makes it a lower-carbon alternative to conventional "grey" ammonia, though not as emissions-free as "green" ammonia produced from renewable hydrogen.

Fact Box 2. Certifying Hydrogen Products as Low-Carbon via the TÜV SÜD Certification Standard

The TÜV SÜD certification standard requires the production process to emit 70% fewer GHGs compared to a benchmark of 94 kgCO2e/MJ at lower heating value (LHV), a measure of the energy content of hydrogen or its derivatives. This corresponds to 3.4 kgCO2e/kgH2, also meeting the EU Renewable Energy Directive's standards for low-carbon hydrogen and its derivatives.

Note. Elaborated by author.

As GCC industries embrace green certifications to remain competitive and credible in a carbon-conscious global market, these efforts are also laying the foundation for broader shifts in industrial strategy. Among the most pivotal of these shifts is the integration of **low-carbon hydrogen,** both as a means to reduce emissions across hard-to-abate sectors and as a vehicle for long-term economic diversification and global competitiveness. The next section examines this strategic role in greater depth.

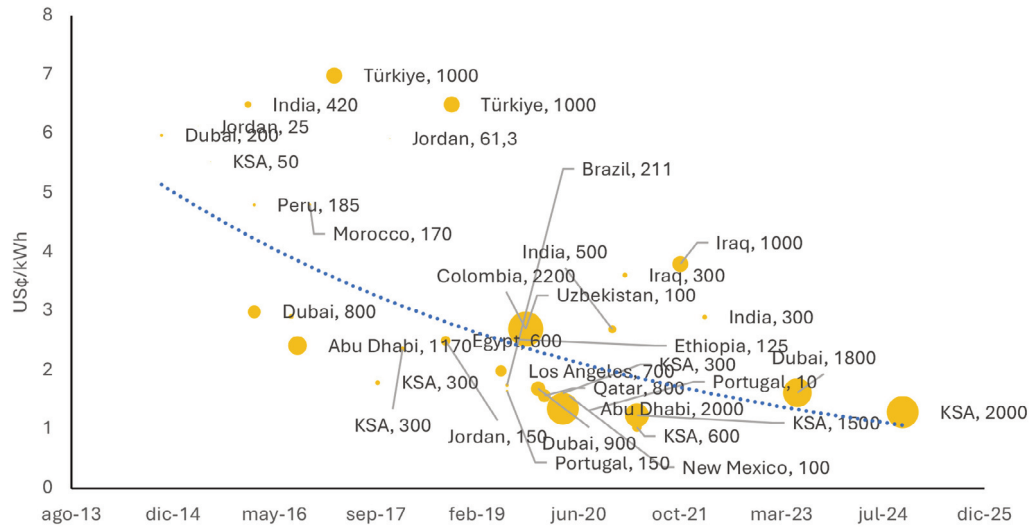
Low-carbon hydrogen is a strategic pillar for GCC industrial policy

The GCC countries have navigated the often complex and evolving energy landscape of the last decade quite successfully by increasingly embracing renewable energy technologies, as seen in the extremely low levelised cost of electricity (LCOE) bids achieved for renewable energy (Figure 2).

This is based on high levels of solar irradiation; the availability of large, contiguous plots of relatively flat and unused land; straightforward permitting processes with little prospect for legal or social opposition; increasing experience in managing large renewable installation projects; the selective use of up-to-date technology (for example, bifacial panels); giant scale, thus spreading "soft" costs such as legal and project management over a large base; and, a low cost of capital, facilitated by political stability and the commitment to offtake power from these projects by state-controlled utilities or power purchase agencies.

To illustrate, Saudi Arabia's 600 MW Shuaibah solar PV project was awarded in April 2021 at US$¢ 1.04/kWh, then a world record (Cockayne, 2024), while the most recent round, in October 2024, attracted a bid of US$¢ 1.29/kWh for the 2 GW Al Sadawi PV project (Saudi Gulf Projects, 2024). In the UAE Masdar reached financial close on the 1.8 GW Phase 6 of the Mohammed bin Rashid Al Maktoum Solar Park – the largest single-site solar project in the world – at a bid price of US$¢ 1.6/kWh in February 2024 (Jowett, 2024). A team led by EDF Renewables and Korea Western Power for the 1.5 GW Al Ajban Solar PV in Abu Dhabi submitted a winning bid of US$¢ 1.41/kWh in July 2023, and was awarded the project in February 2024 (Aguinaldo, 2024). Wind resources are less evenly distributed, but parts of the GCC have good wind conditions. The 416 MW Dumat Al Jandal wind farm in Saudi Arabia was awarded in 2019 for US$¢ 1.99/kWh (Power Saudi Arabia, 2019).

Figure 2. Historical Solar PV Bid Costs, Project Sizes in MM



Note. Elaborated by author, sourced from international and national news outlets, open-source intelligence (OSINT) data, official government communications, and announcements from relevant project developers.

The massive scale-up of renewable energy in the last few years is also a strategic consideration for these countries, as it is intended to help them transition from their status as fossil energy exporters to low-carbon energy exporters.

The massive scale-up of renewable energy in the last few years is also a strategic consideration for these countries, as it is intended to help them transition from their status as fossil energy exporters to low-carbon energy exporters, mainly hydrogen. The region is prioritising the accelerated development of large-scale renewables-based "green" hydrogen, for which ambitious renewable energy targets are being pursued.

For example, Saudi Arabia is targeting 130 GW of renewable energy capacity by 2030 from 4.7 GW today (IRENA, 2025), while the UAE is better than on-track to surpass 19.8 GW of clean energy capacity by 2030, with forecasts pegging a long-term renewable capacity of nearly 200 GW by 2050. Oman's targeted 8.5 Mt/y of renewables-based hydrogen capacity by 2050 (IEA, 2023) suggests a hydrogen-dedicated renewables capacity of nearly 119 GW.

Despite its low-carbon intensity, natural gas will be exposed to carbon pricing, especially for the 10% of emissions not captured by the carbon capture (at a capture rate of 90%) when producing natural gas with CCUS-based "blue" hydrogen, which could incur high costs. This in turn would require regulation to ensure that the produced hydrogen is utilised domestically, or to enable revenues from the carbon costs to be recycled to fund further decarbonisation technologies, including green hydrogen.

Green hydrogen is therefore the more focussed-on hydrogen type in terms of planned and under development hydrogen projects in the GCC.

The GCC countries have large ambitions for future renewables-based hydrogen production

Most of them have robust national hydrogen strategies, explicitly outlining

targets for 2030, 2040, and 2050. The UAE has the most developed strategy so far, targeting 1.4 Mt/y of low-carbon hydrogen (both blue and green) by 2031, 7.5 Mt/y by 2040, and 14.9 Mt/y by 2050, split equally between blue and green hydrogen, with a minor share for nuclear-based hydrogen, or "pink" hydrogen. Interestingly, its hydrogen strategy targets a domestic demand potential of 2.7 Mt/y by 2031, estimated as the "full potential" of the UAE hydrogen market, but recognises can happen only if the right market conditions (appropriate technology being available as well as the market mechanisms to catalyse both production and uptake of low-carbon hydrogen) are realised, with a disclaimer that continuous assessments and monitoring of industry forecasts will adjust the target in future iterations of the strategy (UAE Ministry of Energy & Infrastructure, 2023).

There is also an expectation that the 2031 production target will include 0.5 Mt/y of green hydrogen produced "abroad", with another 0.5 Mt/y produced domestically, and 0.4 Mt/y produced as blue hydrogen (UAE Ministry of Energy & Infrastructure, 2023). While there is no explicit reference to where the "abroad" location will be for the 0.5 Mt/y of green hydrogen production, it likely refers to Masdar's overseas investments in green hydrogen technology, mainly in Europe, Central Asia, Africa, and other Middle East and North Africa.

For example, the company has signed several agreements with European renewable hydrogen pioneers to co-develop large-scale green hydrogen production projects in Europe, including with Lhyfe in January 2025 (Lhyfe, 2025), and Hy24 – a French private equity asset investor in hydrogen – in December 2023 (Masdar, 2023). Developing projects overseas will help the UAE meet its ambition of supplying major demand markets directly, while working towards development of export networks and infrastructure domestically.

Saudi Arabia meanwhile is targeting 2.9 Mt/y of low-carbon hydrogen by 2030, including 1.93 Mt/y from blue hydrogen for blue ammonia exports, with the remainder from green hydrogen. No official figures have been announced for a longer-term 2050 target, but a 2035 target includes 4 Mt/y of low-carbon hydrogen (EIC, 2024). The 2030 target is ambitious given that only one large-scale hydrogen project – NEOM Helios – has taken FID so far, but the project pipeline continues developing, with nearly 2.1 Mt/y (excluding NEOM) of projects announced to 2030.

Oman too has ambitious hydrogen production targets, focussing exclusively on green. The country is targeting 1 Mt/y of green hydrogen by 2030, 3.75 Mt/y by 2040, and 8.5 Mt/y by 2050, and expects only 0.61 Mt/y of domestic demand by 2050, with the rest to be exported in the form of green ammonia (IEA, 2023). Still, there is an expectation that local demand could grow substantially on the back of increasing investments in low-carbon steel, derivative products such as polyolefins, and potential applications in glass and cement.

Securing firm offtake has been identified as a key issue for most hydrogen projects to proceed

In a new sector like hydrogen, it is natural to have an attrition rate where the business case simply isn't strong enough, but this is not the case for the GCC countries, where hydrogen projects are some of

Strong government backing, lower costs of capital and risk, large-scale FIDs and the availability of funding options make the GCC region a standout in terms of large-scale, effectively-planned green hydrogen projects.

the highest credibility ones, thanks to the low-cost and low-carbon resource base they are based on. This makes them best placed to meet emissions standards in Europe, Japan, China, and elsewhere at the least possible cost.

These projects also have strong government backing, while European projects have struggled to secure large-scale FIDs despite the availability of funding options like IPCEI support. The US, focussing on blue hydrogen, further complicates the global landscape for green hydrogen, keeping it in the backseat there. This makes the GCC region a standout in terms of large-scale, effectively-planned green hydrogen projects, since they have the advantage of being snapped-up for domestic use if export commitments do not materialise soon enough or not at all, thus helping these countries meet their ambitious national decarbonisation goals.

Domestic offtake will drive the era of green manufacturing in the GCC

The focus on industrial applications for low-carbon hydrogen will reduce costs for green hydrogen integration into core sectors of these countries' economies like steel, aluminium, cement and fertilisers, making industrial decarbonisation more viable and expanding hydrogen's role in hard-to-abate sectors more generally.

Such efforts will also facilitate a more integrated hydrogen market, creating stronger supply chains and improving market liquidity, by, for example, establishing reliable supply lines, introducing higher competition and easier cross-border transactions, boosting collaboration and standardisation, and increased capital flows.

By deepening its investment in low-carbon hydrogen across its industrial sectors, the GCC has opened the door for a new phase of strategic engagement with the EU, where complementary strengths in technology, capital, and policy ambition can be harnessed to mutual advantage. The following section explores how green hydrogen could serve as a cornerstone for a renewed EU-GCC industrial partnership, grounded in shared decarbonisation goals and long-term economic resilience.

Green hydrogen can link the EU and GCC in a new industrial chapter

Major industrial sectors such as steel and aluminium will require increasingly large volumes of hydrogen to abate their emissions and affix a green premium to low-carbon hydrogen-embedded products. For example, green steel could require 19% of the total EU policy target for domestic renewable hydrogen production, i.e., 1.7 Mt/y by 2030, increasing to 1.9 Mt/y by 2045 (Hydrogen Central, 2024). However, with only 3 GW of renewable hydrogen production projects having started construction or reached FID at the end of 2023, the EU is majorly behind its 10 Mt/y of domestic production capacity by 2030 (Martin, 2024). This increases the focus on imports, especially in the near- to medium-term as the bloc ups its own production, which still won't be sufficient to meet all local demand.

Countries like Germany, the Netherlands, and Belgium will rely heavily on hydrogen imports (Reuters, 2024; Hellis, 2023), with Germany being able to cover only 30% of its forecasted demand from do-

mestic sources by 2045 (Carr, 2024). The Netherlands and Belgium meanwhile are estimated to collectively import 6.2 Mt/y of the EU's 10 Mt/y by 2030 renewable hydrogen import target (Hydrogen Europe, 2023). While pipelines (either existing natural gas pipelines retrofit to carry hydrogen, or new hydrogen-dedicated pipelines) are considered by some recent studies to be a promising source of hydrogen imports in the North Sea region, shipping is still slated to be a significant source of imports to southern Europe, and/or pipelines connecting the GCC states to southern Europe via Egypt and Greece, a study for which conducted in 2023 suggests the feasibility of a cost-effective pipeline originating in the GCC before crossing Saudi Arabia and Egypt to enter Europe via the Mediterranean and then scatter across Central European countries (AFRY & RINA, 2023).

Germany has already announced three tenders for green hydrogen to support its low-carbon steel production projects, such as the Dillinger Steel Mill in Saarland (FCW, 2024), Thyssenkrupp Steel Europe's site at Duisburg (although this has been put on hold due to "significantly higher prices" (of hydrogen in Germany) than expected" (Eurometal, 2025) and Salzgitter's new direct-reduced iron (DRI) plant in Salzgitter (Parkers, 2024), while the Netherlands has issued a tender for the procurement and transport of hydrogen to meet national energy needs (Dokso, 2024). Other EU states are more mixed in their import needs, with Spain largely being an exporter – 2.5 Mt/y of production by 2030 compared to 1 Mt/y of domestic demand (Lombardi, 2024) – and Italy also largely expected to import but send some supplies to the southern German state of Bavaria (Landini & Amante, 2023).

These requirements are increasingly pushing EU countries to collaborate with Middle East and North African states, particularly the GCC countries who are the more preferred partner due to their lower costs of capital and risk. Still, the GCC's cooperation agreements are not just western-bound; they extend also to Asian countries, in particular Japan and South Korea, and more recently China to facilitate joint solutions that support these countries' future hydrogen import needs.

For example, Japan's JERA and the UAE's ADNOC signed a strategic collaboration agreement to work together in clean hydrogen and ammonia (JERA, 2023), while Japan and Saudi Arabia signed the Lighthouse Initiative that aims to develop clean energy projects in areas such as hydrogen and ammonia, e-fuels, carbon recycling, direct air capture, and critical minerals (Arab News, 2023). Sumitomo Corporation also signed an initial agreement with the UAE's Sharjah National Oil Company (SNOC) to conduct a joint feasibility study for CCS projects, including techno-economic analysis into the adaptability of both countries' technologies relevant to carbon capture, transport, and storage (Argus Media, 2023).

Deals with China, meanwhile, are more clean energy and technology-based, with associated benefits for hydrogen projects. For example, Saudi Arabia's ACWA Power has signed several agreements with the state-owned China Southern Power Grid International Company and clean energy integrated solution provider MingYang Smart Energy Group to spur innovation in clean energy technologies which can also be applied to hydrogen (ACWA Power, 2023).

Other similar deals include a JV created between the Saudi Public Investment Fund and China's LONGi Solar to supply solar PV modules (Petrova, 2022), and an agreement with Human Horizons to

build an electric vehicle assembly plant in Saudi Arabia (Reuters, 2023). At a smaller scale but still significant, China's Three Gorges company bought the UAE's Alcazar Energy Partners, a small renewables developer (Darasha, 2021).

Current stakeholders in GCC hydrogen projects are mostly from Europe, Asia, and North America

EPC companies, technology providers, and OEMs currently working on large-scale hydrogen projects in the region include leading global firms like Snamprogetti, Invensys, Maire Tecnimont, Tenova HYL, Denieli & C, Chinook Sciences, Wood, Fluor, Kent, Axens, Thyssenkrupp, Siemens, Air Liquide, Air Products, Haldor Topsoe, Enertech, DUTCO, Tecnicas Reunidas, Johson Matthey, and KBR.

Jointly investing along the GCC hydrogen value chain unlocks a host of benefits, not just for the receiving GCC countries, but also for these companies, as they are involved in different segments of the value chain. They gain access to competitive energy resources, an early mover advantage in shaping government support and policy frameworks, a strategic market position of exports and future energy security, supply chain integration and localisation, a dynamic innovation ecosystem, and the opportunity to set up manufacturing hubs and service networks within the GCC.

This not only reduces their own operational costs but also helps them align with the region's focus on economic diversification and job creation, providing a pathway for international companies to build a long-term presence in a key growth market. Moreover, collaborating with national energy giants offers them access to capital, infrastructure, and expertise, while also providing a reliable customer base for advanced hydrogen solutions, since the GCC's energy players are already some of the world's largest oil and gas exporters.

Joint EU-GCC opportunities can occur across lesser-explored segments of the hydrogen value chain

Both the production and end-use segments of the hydrogen value chain are widely discussed in hydrogen literature and business development strategies, but joint opportunities can occur across other segments, such as storage and distribution, and transportation. In the production and processing stage, the GCC has several dedicated hydrogen production projects (a handful being natural gas with CCUS-based, while all others renewables-based,), while in the end-use stage, it has low-carbon methanol (natural gas with CCUS) projects, SAF from renewable hydrogen projects, a flurry of pilots and demonstrations around hydrogen in transport, and continues to plan for renewables-based and natural gas with CCUS-based hydrogen use in core sectors, such as steel, aluminium, and cement to meet aggressive decarbonisation targets.

The storage and distribution segment has been relatively lesser explored but is receiving fast-growing attention for unique opportunities that can speak to the interests and capabilities of European companies within hydrogen value chains. One such sub-segment is for supply chain optimisation. The GCC's hydrogen targets

will require supply chains that extend beyond the manufacture of electrolysers and their components to system integration, system and ancillary services, pressure vessels for transportation, essential and/or critical materials substitution, end-of-life material recovery or recycling, storage solutions (such as self-contained storage pods), and circularity within storage and distribution systems.

While electrolyser manufacture might be the more commonly pursued opportunity, major GCC players like the UAE and Saudi Arabia are intending to build out local capabilities for more carbon-efficient, low-risk profile electrolyser subcomponents that contribute to overall lower-cost, higher-efficiency, and low lifecycle carbon-intensity electrolysers. These can set them apart from competitors in the region who are also strongly pursing electrolysis-based hydrogen.

For example, the UAE is pursuing a pressurised alkaline electrolyser manufacturing facility with Belgian manufacturer John Cockerill (ADNOC, 2023), which will rely on nickel and nickel alloy for the end-product, now a volatile commodity prone to price spikes and bottlenecks following Russia's invasion of Ukraine. Suppliers of subcomponents that rely on lesser volatile, more environmentally friendly, and low-cost essential / critical materials can also enhance the electrolyser manufacturing capability of the UAE in a way that drives down costs more impactfully. Similarly Saudi Arabia has taken proactive steps by signing an MoU with India to ensure reliable and resilient supply chains for materials utilised in low-carbon hydrogen, including for electrolysers.

European companies specialising in project development, EPC services, and electrolyser technologies (including OEMs) might face competition from existing players in the GCC hydrogen value chain but can take advantage of a relatively unsaturated landscape in the midstream, i.e. transport, storage, and distribution segment of the value chain. Ecosystem and sector integration, digitalisation and automation, logistics (from compression and liquefaction to storage and distribution) are areas where European companies can take a dominant share, thanks to their already existing, well-established and mature businesses.

European companies specialising in project development, EPC services, and electrolyser technologies might face competition from existing players in the GCC hydrogen value chain but can take advantage of a relatively unsaturated landscape in the midstream segment of the value chain.

Innovation activity is an important consideration for novel R&D opportunities

Apart from the hydrogen value chain, hydrogen innovation activity is an important, overarching consideration that can offer R&D opportunities at different stages of technology development. This spans the innovation cycle from basic research, applied research and demonstration, to deployment at scale. In the GCC, hydrogen innovation opportunities range from basic research to patent activity, with basic and applied research typically relating to technologies that globally have a lower TRL but can be pursued as niche specializations in the GCC due to strong support for R&D endeavours, funding opportunities, and existing connections with technology specialists, such as Masdar in the UAE. These are often next generation technologies, with a longer-term commercialisation outlook.

Under patent activity, cutting-edge technologies occurring at a higher TRL that have potential for demonstration, scale-up and commercialisation in the short- to medium-term are equally supported, with the focus now mainly on the storage and distribution segment of the hydrogen value chain which has been relatively

underexplored so far in the GCC. For European R&D companies, engaging with the right stakeholders (such as counterpart R&D institutions, technology providers and developers, academia, media institutions, etc.) can give an indication of commercial implementation and scale-up focus areas.

It should be noted that technologies used on domestic projects in the GCC may have to be developed domestically or obtained from overseas technology providers, including European. The GCC is equally amenable to both, despite its push for localisation of the value chain. In either case, project activity can also speak to the potential for collaboration and knowledge sharing in skills, trades and implementation "know-how", even for GCC stakeholders seeking opportunities in the European hydrogen space.

GCC sovereign wealth funds are also increasingly partnering with European tech firms in other hydrogen-relevant areas, such as AI and big data, while looking to Europe's innovations in smart city development and digital infrastructure efforts to develop their own urbanisation projects, such as Saudi Arabia's NEOM. Additionally, Europe's leadership in AI-driven industrial automation and the growing adoption of the digital clean energy applications create unique opportunities in under-the-radar areas with high growth potential but less market attention. For the GCC countries this is particularly advantageous, as they gain exposure to sectors that align with long-term global trends, such as sustainability and technological innovation, while benefiting from access to Europe's green economy.

For Europe, joint investments with the GCC aligns with its aims of diversifying investment partnerships, making the GCC a strategic ally in renewable energy and green hydrogen partnerships. Europe's expertise and the GCC's ambition for sustainable development align closely, extending into technology as well, and any partnerships in this space can become emblematic of a broader trend toward North-South cooperation, where emerging economies, if strategically aligned, can bypass traditional fossil-dominated energy systems and create new growth opportunities.

Conclusions and policy recommendations

From compliance to competitiveness – a joint imperative

As the EU positions itself at the forefront of climate-driven trade policy through mechanisms like the CBAM, its success will hinge not only on internal alignment but on securing robust partnerships beyond its borders. The GCC stands out as a critical partner in this regard – not simply as a compliance-driven exporter, but as a region undergoing a profound transformation toward clean industry, innovation, and energy diversification.

The GCC's rapid progress in renewable and low-carbon hydrogen, decarbonised materials, and smart infrastructure presents the EU with a rare opportunity: to co-create the next phase of the global carbon economy with a region rich in capital, scale, and implementation capacity. More than that, it offers the EU a chance to anchor its climate diplomacy, secure strategic clean energy imports, and extend the global relevance of its standards.

Yet this window will not remain open indefinitely. Other global powers are also

vying for influence in the GCC's energy transition, from Asia to the US, through trade agreements, technology partnerships, and clean infrastructure investment. Without timely and strategic engagement, the EU may miss the opportunity to deepen its presence in a region with the potential to become a key pillar of its own green industrial strategy. To avoid this, and to secure both economic and geopolitical advantage in a rapidly decarbonising world, the EU should prioritise structured, forward-leaning engagement with the GCC through the following action-driven recommendations.

1. **Claim early ground in underexplored hydrogen segments:** Engage the GCC in co-developing under-invested parts of the hydrogen value chain – **storage, distribution, and transport** – where EU expertise can shape early standards and long-term trade flows
2. **Tap into GCC innovation ecosystems to scale EU technologies:** Leverage **GCC R&D and funding platforms** to demonstrate and scale EU-born clean technologies, especially in hydrogen, industrial decarbonisation, and AI-powered energy systems, creating demand for EU innovation outside its borders
3. **Co-design carbon and certification frameworks:** Support the GCC in building interoperable **carbon markets and certification systems,** which not only help with CBAM compliance, but embed **EU environmental norms globally,** extending the EU's regulatory reach
4. **Strengthen strategic investment channels:** Facilitate **joint investment vehicles** between EU cleantech firms and GCC sovereign wealth funds to accelerate industrial decarbonisation and technology transfer before competitors establish deeper ties
5. **Institutionalise EU-GCC industrial cooperation:** Launch a structured **EU-GCC Green Industrial Dialogue** to coordinate strategy, address trade alignment, and future-proof supply chains, ensuring that the EU, not its rivals, is the partner of choice in the GCC's clean industrial future

At this pivotal juncture, the EU has a unique opportunity to help shape a new phase of North–South green industrial cooperation. As the GCC positions itself as an emerging hub for low-carbon production and innovation, deeper engagement could allow the EU to play a formative role in this transformation. Proactive collaboration would not only advance mutual climate and industrial goals, but also help ensure that the evolving global low-carbon economy reflects shared values and standards.

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Green Financial Instruments in the GCC: Trends, Deployment, and Collaboration Pathways

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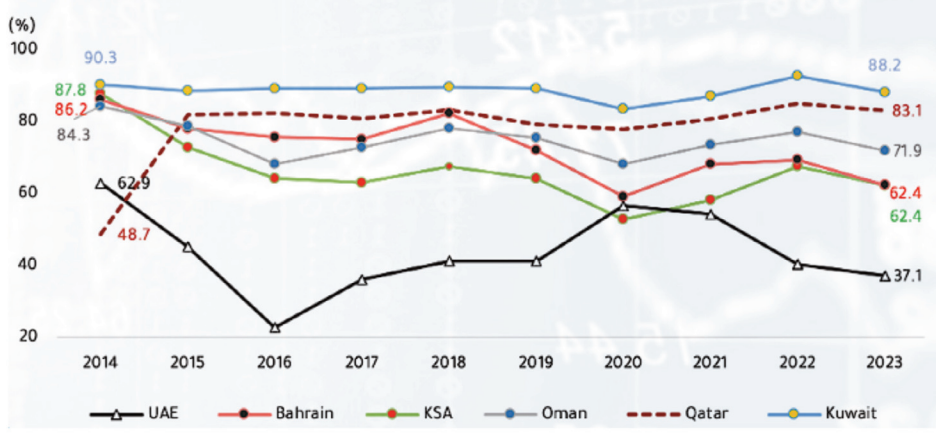
Introduction

Achieving net-zero emissions by 2050 will require an estimated annual investment of approximately $4 trillion, with the energy sector covering electricity generation, transport, manufacturing, and buildings being responsible for around 75% of global emissions (IEA, 2021; Ge, M. et al., 2024). This investment imperative is particularly critical in hydrocarbon-dependent economies, such as the GCC states, where public finances remain closely tied to oil and gas revenues.

As shown in the figure below, in 2023, Kuwait exhibited the highest dependency, with oil revenues constituting approximately 88.2% of its total government revenues. Qatar followed at 83.1%, while Oman recorded 71.9%. Bahrain and Saudi Arabia (KSA) each had oil revenue contributions of 62.4%. In contrast, the United Arab Emirates (UAE) demonstrated greater diversification, with oil revenues accounting for only 37.1% of total government revenues.

Additionally, oil and natural gas have accounted for almost all of the GCC's energy consumption, with industry, centred on energy-intensive sectors such as steel, aluminium, and petrochemicals, representing around a third of final energy demand, followed by transport and non-energy uses (IRENA, 2023). This underscores the region's heavy reliance on fossil fuels not only for exports but also for domestic economic activities, including electricity generation (IRENA, 2023).

Figure 3. Contribution of Oil Revenues to Total Government Revenues in the GCC Countries (2014-2023)



Note. Figure adapted and sourced from GCC-STAT (2024).

As a result, most of the GCC countries are intensifying efforts toward economic diversification, investing heavily in renewable energy, energy efficiency, and the development of green hydrogen for the decarbonisation of industrial, energy, and agricultural sectors. Building on its relatively lower dependence on oil revenues, the UAE has emerged as a leading example of advancing renewable energy initiatives and sustainable economic diversification. A report by Strategy& (Part of PwC) estimates that green investments could contribute up to a cumulative $2 trillion to the GCC economy by 2030 (Camarate, et al., 2022). Given the scale of trans-

formation required, mobilising green financial resources at an unprecedented scale is imperative.

Green finance has thus emerged as a critical enabler of sustainable economic transition and climate action. For the GCC, it is essential not only to support decarbonisation efforts but also to accelerate broader economic diversification strategies beyond hydrocarbons. These ambitions are grounded in national strategies such as Saudi Arabia's Vision 2030 and the UAE's Energy Strategy 2050, which provide the overarching policy frameworks for advancing sustainability and attracting climate-aligned investments. Increasingly, governments across the region are embedding green finance within their national agendas, recognising its role in fostering investment, resilience, and long-term competitiveness.

Within the region, United Arab Emirates (UAE) and the Kingdom of Saudi Arabia (KSA) anchor regional momentum with comprehensive frameworks and landmark issuances; Oman and Qatar show incremental, institution-driven progress; Kuwait and Bahrain are primarily bank-led. Sovereign Wealth Funds and Public-Private-Partnerships function as capital and delivery anchors for large-scale projects.

As green finance becomes more embedded in the GCC, two key dynamics are emerging. First, the region is positioning itself as an emerging hub for sustainable capital flows, driven by the alignment of policy priorities and growing investor interest. Second, the evolution of green finance in the GCC opens strategic opportunities for deeper collaboration with the EU, particularly through co-financing platforms and the harmonisation of green finance standards (EEAS, 2024).

This chapter examines how green financial instruments are currently being utilised in the GCC to advance the green transition, and what role they can play in strengthening EU-GCC investment and collaboration. It applies a typology-based framework that categorises instruments into debt-based, equity-based, blended finance, and carbon markets, and evaluates each through three criteria: attractiveness, ease of implementation, and risk exposure, as seen in Table 1 below. This framing provides the basis for assessing the viability, scalability, and comparative potential of different instruments in supporting sustainable investment flows and EU-GCC cooperation.

Green finance has thus emerged as a critical enabler of sustainable economic transition and climate action.

The GCC region is positioning itself as an emerging hub for sustainable capital flows, driven by the alignment of policy priorities and growing investor interest. It also opens strategic opportunities for deeper collaboration with the EU, particularly through co-financing platforms and the harmonisation of green finance standards.

Table 2. An Overview of the Major Green Financial Instruments

Green Financial Instruments	
Type	**Instrument**
Debt-Based Instruments	Green Bonds Green Sukuk Sustainability-Linked Finance Green Loans
Equity-Based Instruments	Green Venture Capital Private Equity Funds Green IPOs
Blended Finance	Blended Finance Structures (mix of debt/ equity/grants, guarantees)

Carbon Markets	Emissions Trading Clean Development Mechanism Joint Implementation

Note. Elaborated by author.

This study relies on secondary research through a comprehensive desk review. Sources include governmental reports and policy documents, international, regional and national institutional publications, and corporate sustainability reports from private companies and financial institutions mainly national banks. The analysis draws primarily on GCC data and examples, supplemented by EU-GCC collaborative initiatives, to ensure claims are grounded in verifiable, open-source material.

The first section explores the various financing mechanisms available to support the GCC's decarbonisation efforts, analysing their advantages, limitations, and potential for fostering stronger EU-GCC collaboration. It categorises green financial instruments into debt-based, equity-based, blended finance, and carbon market mechanisms, and evaluates them against the criteria of attractiveness, ease of implementation, and risk exposure. The following segment then examines how these instruments are being deployed across GCC countries, focusing on national frameworks, institutional roles, and project-level applications that shape the region's green finance landscape. The final section builds on these analyses to present targeted recommendations aimed at strengthening the region's financial ecosystem and accelerating the green transition.

Green financial instruments taxonomy

Green financial instruments

Green finance relies on a variety of financial instruments, broadly classified as debt-based and equity-based mechanisms, to mobilise capital for sustainable projects. Debt financing refers to raising capital through instruments such as bank loans or bonds, with the obligation to repay the borrowed funds with interest (CFI, 2022). Equity financing, in contrast, refers to raising capital through the sale of company shares, giving investors ownership rights and returns tied to the performance of the venture (CFI, 2025). A key consideration in evaluating green financial instruments is whether they impose long-term financial burdens (such as the direct financial obligations of green bonds or loans) or provide more flexible, risk-sharing alternatives.

In assessing different financial instruments, this study uses three key criteria: attractiveness, ease of implementation, and risk exposure. Attractiveness reflects investor confidence, market demand, and credibility, often strengthened by adherence to recognised standards and guidelines. Ease of implementation considers regulatory clarity, market infrastructure, and standardisation, including the presence of national or international frameworks that facilitate issuance, verification, and reporting processes, which determine how seamlessly an instrument can be introduced and scaled. Risk exposure accounts for potential challenges, including greenwashing, regulatory inconsistencies, and market volatility, which may affect the stability and impact of these instruments.

Cross-cutting mechanisms such as blended finance and carbon markets do not fit strictly within the debt-equity classification but play a vital role in mobilising capital and providing market-based in-

centives for sustainable development. These are also assessed in comparative analysis to capture the dynamics of the broader ecosystem of green financial instruments.

a. Debt-based instruments

Several debt instruments offer structured approaches to financing green initiatives. Among the most prominent, green bonds have gained traction due to their defined use-of-proceeds, clear sustainability objectives, and broad issuer base, including sovereigns, municipalities, and corporations (ICMA, 2021). For instance, Saudi Arabia's Public Investment Fund (PIF) issued $8.5 billion in green bonds between 2022 and 2024 to finance projects like NEOM's Green Hydrogen Company and Red Sea Global's green buildings (Public Investment Fund, 2024). Their attractiveness is supported by established frameworks such as the Green Bond Principles, growing investor demand, and regulatory alignment. However, risks persist, particularly around the scepticism of the bond's "greenness", with concerns over limited environmental impact and the adequacy of reporting and verification mechanisms (Pfaff, et al., 2023; ICMA, 2021).

Green sukuk, the Shariah-compliant counterpart to green bonds, finances environmental projects while adhering to Islamic finance principles (Utermarck, et al., 2024). They offer diversification potential and have seen notable growth in the GCC (LSEG, 2023). Their appeal stems from rising demand in Islamic markets and their ability to provide access to a different investor base, supporting portfolio diversification. For example, UAE's Majid Al Futtaim, a leading private real estate and retail conglomerate, pioneered the region's first green sukuk in 2019 (Majid al Futtaim, 2019). By targeting Shariah-compliant investors, green sukuk expands the capital pool beyond conventional green bond markets, enhancing both geographic and thematic diversification for sustainable investment portfolios. However, the small yet growing market faces challenges: the absence of a clear regulatory framework complicates implementation, while limited secondary market liquidity raises concerns over investment risks (Shalhoob, 2023).

Sustainability-linked finance (SLF), including both bonds and loans, is performance-based rather than project-specific, with financial terms linked to the achievement of predefined sustainability targets (De La Orden & De Calonje, 2022). These instruments are attractive due to their flexibility and the support of established international principles. However, by relying on issuer-set targets, with limited independent verification, SLF faces risks of weak ambition and greenwashing that undermine transparency and investor trust (ICMA, 2023).

Green loans are used to raise capital for environmental projects and are typically smaller in volume than bonds, with lower transaction costs (World Bank, 2021). They are often privately issued and follow the Green Loan Principles, ensuring proceeds are used for green activities. (For example, Saudi Arabia's green loans to finance Red Sea Global, 2021) Their flexibility and accessibility make them appealing in emerging markets and for issuers with smaller portfolios. However, market visibility and standardisation remain limited, which may affect scalability and transparency.

Green sukuk, the Shariah-compliant counterpart to green bonds, finances environmental projects while adhering to Islamic finance principles and have seen notable growth in the GCC.

b. Equity-based instruments

Green equity-based finance can involve either private funding through direct equity investments or public funding via stock exchanges. On one hand, the direct equity

investments include green venture capital, which provides early-stage financing for high-growth green startups, and green private equity, which targets more mature companies or projects (UNEP, 2019). Such instruments are attractive because they offer the potential for high returns and strong innovation outcomes, but they also carry a high risk of failure, particularly in early-stage ventures. In addition, their performance is highly sensitive to regulatory and policy shifts that could alter investment viability or returns (Sabbi & Karampini, 2019).

On the other hand, public equity is raised through green Initial Public Offerings (IPOs), which allow companies working on green projects to list shares on stock exchanges (UNEP, 2019). Compared to private equity, IPOs offer the advantage of liquidity, as shares can be traded in secondary markets, allowing investors greater flexibility to enter or exit their positions. At the same time, IPOs impose additional disclosure requirements, which can expose sensitive information to competitors and increase compliance costs, making them less attractive for some firms relative to private equity (Stulz, R. M., 2019).

Overall, direct equity investments, particularly venture capital, have demonstrated stronger market activity in the latter half of the decade compared to public equity (The CityUK, 2022).

c. Blended finance

Blended finance refers to the strategic use of public or philanthropic capital to mobilise additional private sector investment for sustainable development (OECD, 2018; Randall, 2022). These structures typically mix debt and equity instruments, grants and risk-mitigation tools such as guarantees, concessional tranches, or equity-debt layering to reduce risk and improve project bankability. Their attractiveness lies in the ability to mobilise commercial investment at scale for sustainable development by using public support, while also improving the risk-return profile of projects in developing countries to help attract private investors (OECD, 2018). Development banks and Development Finance Institutions (DFIs) are central to blended finance, designing instruments that reduce risks and attract private investors. Multilateral Development Banks (MDBs) provide the largest share of private sector mobilisation through their dedicated operations. In the EU, initiatives like the Global Gateway, EFSD+, and the European Investment Bank (EIB) have mainstreamed blended mechanisms, underscoring their policy importance. Blended finance benefits from adaptability, as the wide range of financial instruments available allows it to be applied across diverse contexts (OECD & World Economic Forum, 2015). However, one concern regarding blended finance is limited additionality, where public funds risk subsidising investments that might have occurred regardless, raising doubts about the real value added and the potential diversion of resources from more impactful aid (OECD, 2018).

One of the key mechanisms of blended finance is Public-Private Partnerships (PPPs), which represent an institutionalised form of collaboration between governments and private partners. In PPPs, risks, returns, and financing are negotiated, allowing the public sector to contribute regulatory oversight and policy support while the private sector brings financial resources and technical expertise (OECD, 2018). This arrangement enables large-scale infrastructure investments, particularly in energy, water, and transport that would otherwise be difficult to finance. In the GCC, PPPs are increasingly adopted in

renewable energy projects, often in cooperation with international investors and development finance institutions, making them a critical tool for mobilising green finance and de-risking investment.

d. Carbon markets

Carbon markets, either compliance-based or voluntary, are market mechanisms that allow entities to buy or sell carbon credits,

each representing one ton of CO_2 or its equivalent in other greenhouse gases (UNDP, 2022). They operate through two main approaches: cap-and-trade systems, where a limit is set on total emissions, and allowances are allocated or auctioned; and baseline-and-credit mechanisms, where emissions reduction or removal projects generate tradable credits (Carbon Market Watch, 2020). The core purpose of carbon markets is to incentivise emission reductions and facilitate the transition to a low-carbon economy, while also mobilising finance for climate adaptation and resilience.

Carbon markets typically operate under three mechanisms: Emissions Trading (ET), the Clean Development Mechanism (CDM), and Joint Implementation (JI) (UNFCCC, 2025). ET, such as the EU Emission Trading System (ETS), imposes a decreasing cap on national emissions and allows trading of allowances (European Commission, 2025). CDM enables developed countries to invest in emission-reducing projects in developing countries, earning credits toward their targets whereas JI applies to projects between developed countries, with credits issued separately from the CDM (Carbon Market Watch, 2020). In addition to these three mechanisms, the EU's Carbon Border Adjustment Mechanism (CBAM) serves as a crucial policy tool. CBAM, a tariff-like measure applying a carbon price on imports of emission-intensive goods, reinforces the ETS by extending its pricing influence internationally, making it a key driver of global alignment with EU carbon market standards (European Commission, 2025).

Which instruments are attractive?

Green financial instruments vary based on their relative attractiveness to investors, impacting their viability. Market demand, investor confidence, and the maturity of frameworks supporting each instrument must be taken into account when assessing the attractiveness and therefore viability of various instruments. Additionally, the ease of implementation and key risks also inform strategic prioritisation in green finance planning. The following summary presents a structured breakdown of the instruments accordingly.

a. Highly Attractive Instruments

Green bonds, green loans, and green sukuk are among the most attractive instruments for mobilising green finance. Bonds and loans benefit from clear international frameworks, strong investor demand, and regulatory familiarity, while sukuk add diversification by tapping Shariah-compliant markets. Implementation is generally straightforward for bonds and loans, whereas sukuk, despite ICMA guidance, still face regulatory gaps in the GCC. Risks across all three are moderate, mainly linked to greenwashing, execution, and limited sukuk market liquidity, but with stronger regulation, sukuk in particular could see accelerated growth and consolidation as a leading regional instrument.

Green bonds, green loans, and green sukuk are among the most attractive instruments for mobilising green finance.

Blended finance is highly attractive due to its strong mobilisation potential, institutional support from DFIs/MDBs, and adaptability across sectors. Implementation can be complex, given the need for layered structures and coordination among multiple stakeholders, but risks of limited additionality are generally outweighed by its ability to

de-risk projects and attract large-scale private capital.

b. Moderately Attractive Instruments

Sustainability-linked finance and green equity instruments (venture capital, private equity, and Green IPOs) offer promising opportunities but are moderately attractive due to key challenges. Their appeal lies in flexibility and potential high returns, yet credibility issues such as setting robust KPIs, risks of greenwashing, and fragmented standards reduce confidence. Implementation is feasible where investor appetite and regulatory capacity are stronger, but market limitations still restrict growth. Risk exposure varies; for example, venture capital carries the highest uncertainty with early-stage projects, and private equity is somewhat less risky given more mature investments, while IPOs depend heavily on market depth and investor confidence.

Carbon markets hold moderate attractiveness: they benefit from international and rising GCC interest, but fragmented standards and limited regional liquidity reduce their appeal. Implementation remains challenging due to verification, monitoring, and compliance costs. Risks include volatility in credit prices, potential greenwashing, and reliance on evolving regulatory environments

Table 3. Categorisation of Green Financial Tools Based on Their Attractiveness

Attractiveness	Debt-Based Instruments	Equity-Based Instruments	Hybrid Instruments
High Attractiveness	Green Bonds Green Loans Green Sukuk	-	Blended Finance
Moderate Attractiveness	Sustainability-Linked Finance (Bonds and Loans)	Green Venture Private Equity Funds Green IPOs	Carbon Markets

Note. Elaborated by author.

In the next section, the financial instruments being utilised or proposed across the GCC are discussed, examining the local financial frameworks, institutional roles, and project-level applications examples in each country in order to bring the regional dynamics shaping the current practice of green finance into sharper focus.

Understanding green finance in the GCC

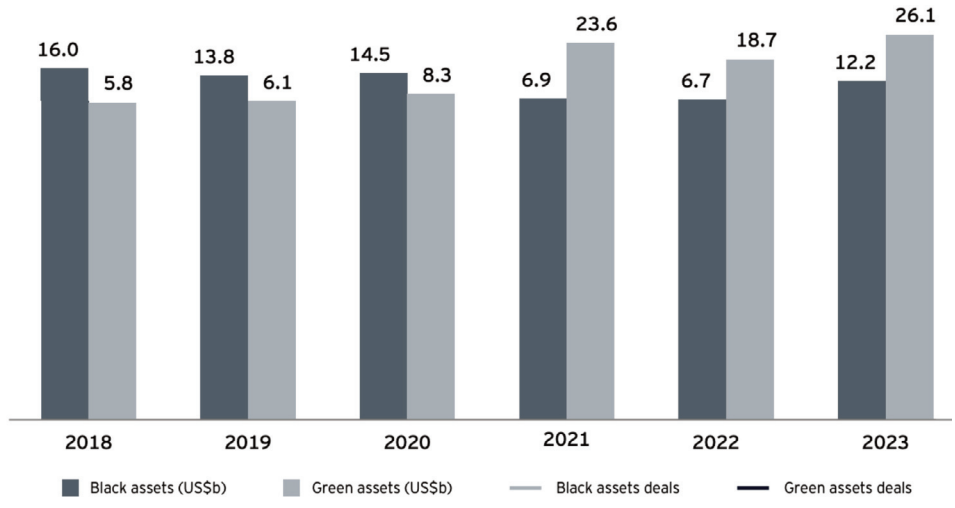
Following the overview of green financial instruments in Section 2, this section examines how GCC countries are applying them through national frameworks, sovereign investments, and private initiatives. It explores the use of debt-based instruments like green bonds, sukuk, and sustainability-linked finance, as well as equity investments, blended finance, and emerging carbon markets. Together, these mechanisms are shaping the region's approach to sustainable economic development and climate transition.

Sovereign Wealth Funds

In the GCC, Sovereign Wealth Funds (SWFs) such as Saudi Arabia's PIF and the UAE's Mubadala are pivotal state-led

investment vehicles with substantial resources (Alfarhan & Alsudairi, 2024). Traditionally tasked with promoting long-term financial sustainability, stabilising local capital markets, and attracting foreign investment, these funds have also become central to the region's green transition (Alhajraf, 2025). By directing capital toward renewable energy, clean technologies, and sustainable infrastructure, SWFs serve as catalytic vehicles in the GCC's green finance landscape, anchoring private participation and accelerating the region's energy transition. Figure 2 illustrates this shift, showing how sovereign investors have increasingly redirected portfolios from conventional assets toward green over the past years.

Figure 4. Investment by Sovereign Investors in Black vs. Green Assets



Note. Sourced from EY (2025).

GCC green finance frameworks

Green finance is increasingly seen as the backbone of decarbonisation strategies and sustainable economic transitions. In recognition of this, GCC governments are progressively embedding green finance into their national agendas, viewing it not only as a tool for climate action but also as a catalyst for economic diversification. Dedicated green finance frameworks have begun to emerge, outlining how financial instruments such as green bonds, sukuk, and loans will be mobilised to achieve national sustainability goals (with further discussion of these instruments in the following sections). Understanding the current green finance landscape across the region is key to assessing both the status quo and future opportunities for climate-aligned investment.

The UAE has positioned itself as a regional frontrunner in advancing sustainable finance, publishing its national "Sustainable Finance Framework" (2021-2031) and introducing comprehensive regulations for green and sustainability-linked bonds and sukuk in 2023. This framework operates through three pillars: mainstreaming sustainability in financial decision-making, enhancing the supply and demand for green financial products, and strengthening the enabling environment through cross-sector collaboration. Together, these measures are designed to embed sustainability into institutional practices, expand investment opportunities, and foster

GCC governments are progressively embedding green finance into their national agendas, viewing it not only as a tool for climate action but also as a catalyst for economic diversification.

the development of a resilient and competitive green finance ecosystem, as outlined in the UAE's Sustainable Finance Framework (UAE Ministry of Climate Change and Environment, 2021).

Saudi Arabia followed with its "Green Finance Framework" in 2024, aligned with its Vision 2030 and the Saudi Green Initiative, which offers structured guidance on green and low-carbon investments. Developed in compliance with the International Capital Market Association (ICMA) Green Bond Principles and Green Loan Principles, KSA's framework identifies key sectors such as renewable energy, energy efficiency, clean transportation, green buildings, and sustainable water management as priority areas for green financing. The framework emphasises transparency through regular allocation and impact reporting, and robust governance mechanisms for project selection and fund management. By embedding international best practices, Saudi Arabia aims to attract a broader base of domestic and international investors to support its decarbonisation agenda (Ministry of Finance of the Kingdom of Saudi Arabia, 2024).

In a broader context, similar to how fiscal and regulatory frameworks coordinate regional borrowing and risk management (Wheeler et al., 2025), national green financial frameworks provide the necessary structure to align private financial institutions toward sustainable development goals and avoid market fragmentation.

While the UAE and KSA have established comprehensive, state-led national strategies to embed green finance within their broader economic visions, other GCC countries are progressing through more incremental and fragmented approaches. In Oman, for instance, the government published its inaugural "Sustainability Finance Framework" in 2023 to enable the issuance of green, social, and sustainability bonds, loans, or sukuk, primarily supporting clean energy and water infrastructure under Vision 2040 and linked to national climate strategies (Ministry of Finance of the Sultanate of Oman, 2024). However, unlike the UAE and KSA, Oman's framework is designed to allocate financing to eligible green and social projects, rather than positioning green finance as a systemic pillar of its broader economic transformation agenda (Vora & Dutta, 2024).

Qatar, although lacking a consolidated national green finance policy, is advancing through institutional initiatives: the Qatar Financial Centre launched a sustainable sukuk and bond framework in 2022, and the Qatar Central Bank introduced its own Sustainable Finance Strategy in 2024 (Qatar Financial Center, 2022; Qatar Central Bank, 2024). However, Qatar's progress remains sectoral and institution-driven rather than coordinated at a sovereign level.

Similarly, Bahrain and Kuwait are advancing primarily through financial institutions. In Kuwait, banks such as NBK, Warba, and Kuwait Finance House have launched green bond frameworks, while the Central Bank has issued guidelines for sustainable financing (Kuwait Central Bank, 2022). Bahrain's National Bank and Gulf International Bank have also adopted sustainability financing strategies aligned with green lending principles, though national-level coordination remains limited (National Bank of Bahrein, 2024). This divergence between state-led and institution-led approaches reflects varying levels of ambition, capacity, and integration of green finance into broader national economic planning across the GCC. Table 3 provides an overview of the Green Financial Landscape in the GCC.

Table 3. GCC Green Finance Landscape

Country	Green Finance Approach	Green Finance Landscape Status
UAE	State-led	Systemic pillar of economic transformation
KSA	State-led	Comprehensive & central to diversification
Oman	State-led (Incremental)	Project-level focus, not systemic
Qatar	Institution-driven	Fragmented, sectoral initiatives
Kuwait	Institution-driven	Bank-led, limited sovereign coordination
Bahrain	Institution-driven	Bank-led, limited sovereign coordination

Note. Elaborated by author.

Collectively, these efforts reflect a regional pivot toward sustainable finance, although progress remains uneven. Countries with formal frameworks are gaining traction in green capital markets, while others rely on bank-led initiatives in the absence of state direction. The region's growing alignment with international standards, such as the ICMA Principles, signals an evolving regulatory landscape and a shift toward mainstreaming green finance as a core component of economic and environmental policy.

Green bonds and sukuk in the GCC

Green bonds and sukuk have emerged as the most widely adopted green financial instruments in the GCC, particularly in the UAE and KSA, where government-related entities have leveraged them to fund major low-carbon infrastructure. Typically structured as project-specific debt instruments aligned with international standards, these tools have proven effective in financing renewable energy, green buildings, smart grids, and infrastructure. Issuance has been led by quasi-sovereign and corporate actors, with increasing international investor participation reflecting both credibility and demand.

The UAE was the first country in the region to enter the green bond market in 2017, with government-linked entities raising $587 million for renewable energy, energy efficiency, and wastewater treatment projects (UAE Ministry of Climate Change and Environment, 2021). Since then, the market has expanded significantly. Masdar, the UAE's flagship clean energy company jointly owned by TAQA (a majority state-owned utility), ADNOC (the national oil company), and Mubadala (Abu Dhabi's sovereign wealth fund), issued two green bonds in 2023 and 2024, raising $750 million and $1 billion respectively to finance equity contributions in global renewable ventures (Masdar, 2024). Masdar's second issuance was oversubscribed 4.6 times, with 70% of allocations going to international investors, among which were Crédit Agricole CIB, Natixis, and Mitsubishi UFJ Financial Group (Masdar, 2024). TAQA and Mubadala have also advanced Abu Dhabi's green agenda through sizable green debt offerings. On the sukuk front, Majid Al Futtaim, a leading private real estate and retail conglomerate, issued the region's first corporate green sukuk, raising $600 million

Green bonds and sukuk have emerged as the most widely adopted green financial instruments in the GCC, particularly in the UAE and KSA, where government-related entities have leveraged them to fund major low-carbon infrastructure.

to finance and refinance eligible green projects, including LEED-certified green buildings, renewable energy, sustainable water management, and energy efficiency initiatives (Majid al Futtaim, 2024). For example, green sukuk proceeds were allocated for Aloft Hotel, a green building, where GHG emissions were reduced by 2% compared to the 2019 baseline, and annual energy consumption decreased by 18% between 2022 and 2023 (Majid al Futtaim, 2024).

In Saudi Arabia, the PIF, Saudi's sovereign wealth fund, issued $8.5 billion in green bonds between 2022 and 2024 to fund flagship projects, and allocated $5.2 billion in projects such as wind and solar PV, green buildings, clean transport and sustainable water management, most notably NEOM's Green Hydrogen Company and Red Sea Global-Green Buildings (Public Investment Fund, 2024). One of its 2023 issuances was oversubscribed more than six times, with orders surpassing $33 billion. Similarly, the Saudi Electricity Company (SEC) issued a $1.3 billion green sukuk to support the installation of 3.5 million smart meters and expand renewable-ready grid infrastructure (Sustainability Excellence, 2023).

Elsewhere in the region, green bond adoption is still in early stages. Qatar issued its inaugural green bond in May 2024 for $2.5 billion, which was oversubscribed 5.6 times (Qatar News Agency, 2022). In Kuwait, the National Bank of Kuwait (NBK) issued a $500 million green bond, which was oversubscribed 3 times, solidifying its position as the country's leader in sustainable finance (NBK, 2024). The bond funds projects focusing on green buildings, renewable energy and clean transportation.

The increasing deployment of green bonds and sukuk across the GCC has translated into tangible infrastructure outcomes, enabling national climate goals and advancing renewable energy, clean transportation, and sustainable urban development. Beyond direct project financing, these instruments have catalysed blended financing models, with sovereign and quasi-sovereign issuers partnering with global investors, multilateral institutions, and private developers. This growing alignment between public policy priorities and investor appetite has strengthened the region's climate finance ecosystem, positioning the GCC as an emerging hub for sustainable capital flows. It also underscores the potential for deeper EU-GCC collaboration through co-financing platforms and the harmonisation of green finance standards.

Sustainability-linked bonds and loans (SLBs and SLLs)

Sustainability-linked finance is still nascent in the GCC, but the UAE has led early adoption through high-profile corporate deals. Other states, including Saudi Arabia and Qatar, are beginning to integrate performance-based structures into their financing strategies, laying the groundwork for wider adoption.

In the UAE, corporations have led regional innovation. In 2018, UAE's global port operator and logistics company DP World converted a $2 billion revolving credit facility into the region's first Sustainability Linked Loan, linking loan margins to carbon intensity (Reuters, 2018). Majid Al Futtaim followed with two SLLs totalling $2.75 billion, tied to emissions reduction, green building certifications, and gender diversity in leadership (Majid al Futtaim, 2023). Etihad Airways issued the world's first sustainability-linked sukuk in 2020 ($600 million), targeting a 20% reduction in carbon intensity by 2025 (Etihad Airways, 2019). In 2024, Emirates NBD, a Dubai government-owned banking group

and one of the largest banks in the Middle East, issued a $500 million bond backed by an SLL, marking a global first and reflecting strong regulatory and institutional support for performance-linked finance in the UAE (Emirates NBD, 2024). Qatar recorded its first SLL in 2024, a deal between UAE's Mashreq Bank, a leading private-sector bank, and UAE-based Landmark Retail, supporting renewable energy adoption and sustainable materials in Qatar (Mashreq, 2024). While most sustainable finance activity in Qatar remains centred on green bonds and loans, the deal sets a precedent for the broader use of SLLs among corporates. Qatari banks have also introduced sustainability frameworks in anticipation of further market growth.

In Saudi Arabia, Kuwait, and Bahrain, no formal SLBs or SLLs have yet been issued. However, institutions like the National Bank of Kuwait (NBK), Kuwait's largest commercial bank, and the National Bank of Bahrain (NBB), a leading commercial bank in Bahrain, have developed ESG-aligned lending frameworks. In Oman, Bank Nizwa, the country's first Islamic bank, has taken a pioneering step by issuing a SLL to support a large-scale mangrove plantation project, indicating institutional readiness.

SLBs and SLLs offer a flexible alternative to use-of-proceeds instruments like green bonds, especially suited to large corporates and diversified energy players in the GCC. Their ability to link financial terms to ESG outcomes allows companies to align transition strategies with access to capital, without the need for green project ring-fencing, the practice of restricting funds exclusively to pre-approved environmental projects, as required in traditional green bonds. Although sovereign engagement is absent and adoption remains limited, national frameworks, private-sector momentum, and global investor interest position SLBs and SLLs as promising tools for driving corporate decarbonisation and EU-GCC green finance partnerships.

Green loans

Green loans have played a modest but growing role in GCC climate finance, primarily supporting large-scale energy and infrastructure projects. Their structure makes them attractive for public utilities and corporations seeking targeted funding for decarbonisation without the scale or complexity of bond issuance.

In the UAE, Emirates Global Aluminium (EGA), the world's largest premium aluminium producer, acquired an 80% stake in US-based Spectro Alloys through a green loan facility (EGA, 2024). Recycling aluminium at Spectro Alloys requires approximately 95% less energy than producing primary aluminium and avoids around

390,000 tons of CO_2 emissions annually (The Opus Group, 2025). Abu Dhabi National Oil Company's $3 billion green loan in 2024, financed by Japan Bank for International Cooperation (JBIC) and co-lenders, marked a turning point as the national oil company committed capital to carbon capture, hydrogen, and renewables (ADNOC, 2021). Another recent example is the Barakah Nuclear Energy Plant, which secured $2.42 billion in green financing through two UAE banks, Abu Dhabi Commercial Bank (ADCB) and First Abu Dhabi Bank (FAB) (ENEC, 2024). Once fully operational, the plant is expected to generate 40 terawatt-hours of electricity per year while preventing the release of approximately 22.4 million tons of carbon emissions annually (ENEC, 2024).

Saudi Arabia has used green loans to finance renewable energy and sustainable infrastructure development, most notably through a SAR 14.1 billion ($3.76 billion) facility for Red Sea Global, supporting

Although sovereign engagement is absent and adoption remains limited, national frameworks, private-sector momentum, and global investor interest position SLBs and SLLs as promising tools for driving corporate decarbonisation and EU-GCC green finance partnerships.

the construction of a fully off-grid energy system powered by solar and wind. It will be integrated with one of the world's largest battery energy storage systems 1,300 MWh, along with renewable-powered water, waste, and cooling infrastructure (Red Sea Global, 2021; JBIC, 2022).

Other GCC states are taking early steps. Qatar's Al Kharsaah 800 MW solar plant was backed by a green loan funded by JBIC, while Bahrain's Alba, one of the world's largest aluminium smelters, secured a green loan to establish a solar farm project with a capacity of more than 6 MW across a total area of 37,000 square metres (Alba, 2023). Kuwaiti and Omani banks have introduced green lending frameworks and supported public utility upgrades, often with support from international partners.

Green loans in the GCC follow a consistent pattern: project-specific, infrastructure-focused, and often backed by international lenders. While there is limited variation in structure, their growing use by national champions, especially in the UAE and Saudi Arabia, suggests increasing comfort with green lending as a tool for transition. Their flexibility and eligibility for blended finance make them well-suited to scaling up private-sector climate investment across the region.

The previous instruments all showcase great potential and provide financial resources to finance green projects, including renewable energy, energy efficiency, and green building. Debt remains the backbone of GCC green finance with green bonds, sukuk, and green loans being attractive due to their scale, clear standards, and strong investor demand. By design, however, they create fixed repayment obligations and, where sovereign guarantees are involved, contingent liabilities. For example, Dubai has made big financial promises to support green projects like solar energy and waste management. By the end of 2024, Dubai's public debt was AED 112.4 billion, but it also had AED 34.9 billion still outstanding from guarantees linked to environmental projects under the Dubai Clean Energy Strategy 2050 (Ministry of Finance of the Government of Dubai, 2025). These guarantees, covering initiatives by DEWA and Dubai Municipality, illustrate the importance of careful structuring by ensuring that debt is backed by reliable cash flows, transparent guarantees, and sound governance. The issue is not debt itself, but how it is managed. Equity and blended finance therefore serve as complementary tools, absorbing early-stage or revenue risk and helping preserve fiscal space, while debt instruments continue to anchor the region's green finance landscape.

a. Equity-based instruments in the GCC

The UAE has emerged as a leader in green equity through Masdar, which has taken direct stakes in international renewable projects, including the two recent agreements totalling $15 billion with the Philippines to support the development of solar, wind and battery energy storage systems, providing it with up to 1 GW of clean power by 2030 and an acquisition of a solar portfolio in Spain consisting of a 234 MW photovoltaic plant, with the potential to add the hybridisation of Battery Energy Storage Systems of 259 MW (Masdar, 2025a; Masdar, 2025b). These investments reflect a strategy of leveraging sovereign capital for global returns while reinforcing the UAE's position as a green energy hub. Saudi Arabia, Qatar, and Kuwait have followed similar paths, with equity deployed through state-linked entities. Saudi Arabia's Public Investment Fund has supported domestic clean

energy manufacturing via three joint ventures and equity stakes in solar and wind supply chains through Saudi Firm Vision Industries (Public Investment Fund of the Government of Saudi Arabia, 2024). The first joint venture with Envision Energy aims to manufacture and assemble wind turbine components, with output capacity designed to support 4 GW of wind power annually. The second, established with Jinko Solar, will produce high-efficiency photovoltaic (PV) cells and modules capable of generating up to 10 GW. The third venture, with LUMETECH S.A. PTE. LTD, focuses on producing solar ingots and wafers to supply the equivalent of 20 GW of solar power generation per year Industries (Public Investment Fund of the Government of Saudi Arabia, 2024).

In 2024, Qatar's Investment Authority (QIA) partnered with Enel Green Power to jointly develop three wind farms in South Africa's Eastern Cape, with a combined capacity of 330 MW and expected annual generation exceeding 1,100 GWh (QIA, 2024). Oman, like its neighbours, has pursued equity-backed partnerships to advance its domestic energy transition. The HyDuqm project between Oman's Hydrom and the consortium of French-based Engie and Korean POSCO, aims to install 5.25 GW of solar and wind capacity, and will provide approximately 200 kilotons per year of clean hydrogen that feeds into ammonia production of 1.2 million tons by 2030 annually (OECD et al., 2024). Another joint venture between Belgium-based DEME and Oman's OQ with British BP equity aims to produce green hydrogen to green ammonia powered by solar and wind energy of a combined capacity of 4 GW in two phases. These projects reflect international co-investment to finance and de-risk infrastructure, rather than sole state ownership (Čučuk, 2024).

Green equity in the GCC is predominantly sovereign-driven and international in scope, aimed at securing returns and global positioning (Deloitte Middle East, 2025). While domestic deployment exists, particularly through joint ventures, there remains a gap in localised private equity and venture capital participation (Deloitte Middle East, 2025). The growth of private equity assets in the region has been slow due to strong competition from state-owned enterprises, which dominate economic activity with deep capital reserves, regional expertise, and extensive networks. Additionally, limited transparency, weak corporate governance, and the prevalence of family-owned businesses further constrain deal-making opportunities. Strengthening homegrown equity channels, especially for small and medium-sized enterprises (SMEs) and green startups, could broaden the investment base, diversify risk, and enhance regional readiness for EU co-investment opportunities.

Green equity in the GCC is predominantly sovereign-driven and international in scope, aimed at securing returns and global positioning.

In the GCC, equity and blended finance mainly come through sovereign-led joint ventures with international partners, which helps bring in know-how without adding government debt. To keep equity practical, secure the buyer first where a long-term purchase contract with a utility or large industrial is locked so revenues are visible from day one and bring one reputable public lender as a small co-investor or guarantor. Ideally, a potential for an EU partner opens an EU-GCC collaboration channel, adds partial guarantees and longer tenors, helps align reporting with EU standards, and can unlock European tie-ups. Framed this way, equity sits well beside debt: it takes the early risk, builds local capability, and prepares projects that can later scale with loans and green bonds.

Carbon markets in the GCC

Under the Paris Agreement, all GCC countries have committed to emission

reduction targets, while several major companies across the region have also announced similarly ambitious voluntary climate goals. Given the region's dominance by carbon-intensive industries, particularly oil, gas, and petrochemicals, GCC countries are well positioned to become both suppliers and buyers of carbon credits, presenting significant opportunities for carbon credit generation and trading.

The carbon market landscape across the GCC is still evolving and is primarily shaped by VCMs, where the private sector plays a central role. Although no country in the region has implemented a government-regulated carbon market mechanism to date, all six have expressed interest in international carbon market cooperation through their latest nationally determined contributions (NDCs) (Luomi et al., 2023). Some have also initiated the development of national frameworks or platforms to support carbon trading.

Qatar has opted for a unique position regarding carbon markets, by launching the Global Carbon Council as the first independent voluntary carbon offsetting programme in the region. It aims to serve as a bridge between the Global South and international carbon markets, particularly in supporting project developers from developing countries.

Saudi Arabia has emerged as a regional frontrunner. In 2022, it launched the Voluntary Carbon Market (VCM) Company, a platform facilitating carbon credit trading. Its first auction sold credits equivalent to

1.4 million metric tons of CO_2, followed by a second auction in Kenya with over 2.2 million metric tons of credits (Miriri, 2023). Major purchasers included Aramco, the Saudi Electricity Company, and ENOWA, NEOM's Energy and Water company, acting as a service provider within NEOM.

The UAE has also made major strides in 2024 by establishing a national carbon registry and trading system to manage VCM transactions (UAE Ministry of Climate Change and Environment, 2024). In 2023, it pledged to invest and purchase carbon credits worth $450 million from African countries by 2030, reinforcing both regional climate commitments and global south cooperation (Emirates News Agency, 2025). Qatar has opted for a unique position by launching the Global Carbon Council as the first independent voluntary carbon offsetting programme in the region (Al-Sarihi, 2024). Through this platform, Qatar aims to serve as a bridge between the Global South and international carbon markets, particularly in supporting project developers from developing countries.

Bahrain has also established a voluntary carbon offsetting platform, with a focus on credits for emissions in aviation, shipping, and logistics (Al-Sarihi, 2024). Meanwhile, Kuwait remains in the early stages of setting up its first national platform for voluntary offsets (Al-Sarihi, 2024).

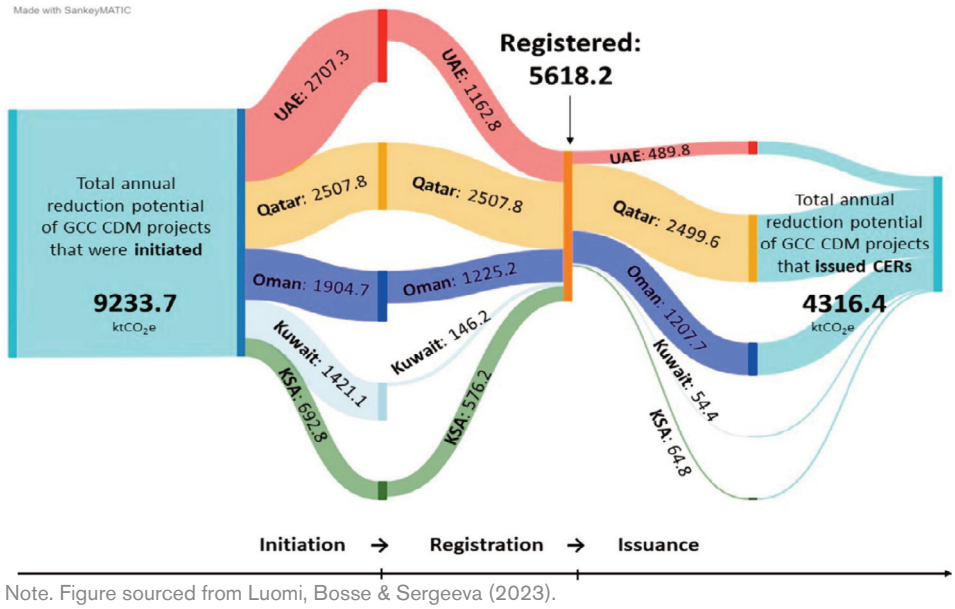
Oman has not yet implemented a formal carbon market, but in 2023-2024, it established a "Green Alliance" initiative, a collaboration between the Environment Authority and the Oman Energy Association, to promote afforestation-based carbon credit generation and develop foundational carbon market policies (Environment Authority & Rafraf, 2025). One flagship effort is the Oman Blue Carbon project, aiming to plant 100 million mangroves across the country (Haddad, 2024). This restoration is projected to remove about

14 million tonnes of CO_2 and could generate as much as $150 million in carbon credits (Haddad, 2024). The initiative is tied to Oman's broader National Net Zero Strategy, aiming to position carbon credits as a tool for climate finance and sustainable development (Environment Authority & Rafraf, 2025).

The GCC countries have also engaged with international carbon markets through their participation in the Clean Development Mechanism (CDM) under the

Kyoto Protocol. As of 2023, the region hosts 29 registered CDM projects, with the UAE and Saudi Arabia accounting for 22, while Bahrain has not participated (Luomi et al., 2023). At the project level, the average annual emission reduction potential of CDM projects in the GCC (201 $ktCO_2e$/year) exceeds the global average (129 $ktCO_2e$/year) (Luomi et al., 2023). Figure 3 showcases an overview of GCC CDM projects' reduction potential from initiation through issuances.

Figure 5. Overview of GCC CDM Projects' Reduction Potential from Initiation through Issuances.



Note. Figure sourced from Luomi, Bosse & Sergeeva (2023).

Interestingly, unlike other developing regions where renewable energy dominated CDM portfolios, the GCC's projects have primarily focused on methane reduction and energy efficiency. This reflects a policy preference for energy efficiency as the initial mitigation strategy, rather than shifting directly to renewable energy, a decision likely influenced by the region's deep integration with fossil fuel production and subsidised energy pricing.

The GCC faces shared opportunities and challenges in developing carbon markets. Global climate policies, particularly the EU's CBAM, could impact regional trade, especially in carbon-intensive sectors such as energy. While this presents a potential risk, it also creates strategic openings for the GCC to supply carbon credits to companies striving to meet their net-zero commitments. The region's growing momentum in adopting carbon markets is not only strengthening regulatory infrastructure but also building technical expertise in carbon accounting, verification, and trading. This evolving capacity is crucial for responding to international policy shifts and for laying the groundwork for future carbon pricing initiatives. These tools can drive emission reductions while opening new sources of revenue.

In this context, the GCC's strong financial position leveraged through green bonds, sukuk and sustainability-linked loans is

The region's growing momentum in adopting carbon markets is not only strengthening regulatory infrastructure but also building technical expertise in carbon accounting, verification, and trading; crucial for responding to international policy shifts and for laying the groundwork for future carbon pricing initiatives.

fueling a pipeline of green projects across renewables, industrial decarbonisation, and nature-based solutions. If these projects incorporate credible monitoring and verification standards, they can generate internationally recognised carbon credits. EU companies, facing regulatory pressures from CBAM and corporate net-zero goals, are increasingly seeking high-quality offsets. GCC-generated credits could fill this gap, creating a foundation for EU-GCC joint ventures and co-development initiatives. Through such partnerships, European expertise in carbon governance can complement Gulf-based project implementation and financing, advancing shared sustainability goals.

Green investments in the GCC

Intra-GCC investment efforts supporting the green transition are increasingly driven by cross-border collaboration that leverages public-private partnerships and the vast capital of Gulf sovereign wealth funds. The GCC states have aligned their national development strategies with climate goals. For example, Saudi Arabia's Vision 2030 and the UAE's Energy Strategy 2050 set ambitious renewable energy targets and are jointly seeking to attract private investment into clean energy projects. Major renewable infrastructure initiatives are now frequently structured as PPPs to mobilise private capital and expertise, with project consortia often spanning multiple member countries. For instance, Dubai's 5 GW Mohammed bin Rashid Al Maktoum Solar Park, the world's largest single-site solar farm, has been realised through a multi-phase PPP model led by the Dubai Electricity and Water Authority (DEWA) in collaboration with regional partners from across the GCC. Intra-GCC cooperation has been central to the project's development: Saudi Arabia's ACWA Power, KSA's leading developer, investor, and operator of power generation, served as lead developer for multiple phases, including Phase 2, which inaugurated 200 MW, Phase 4, part of a hybrid 950 MW development, and Phase 5, which inaugurated 900 MW, in partnership with Kuwait's Gulf Investment Corporation. Abu Dhabi's Masdar was a key partner in Phase 3 and co-developer of Phase 6 (Government of Dubai, 2021). Another example is KSA's 400 MW Dumat Al Jandal wind farm, which was co-developed by Abu Dhabi's Masdar in partnership with a European firm (EDF renewables) under a similar model (Masdar, 2019). Moreover, other examples can be seen across the GCC: Oman's Harweel Wind farm is being jointly developed by Oman state owned Rural Areas Electricity Company (RAECO) and Masdar with a capacity of 50MW, while Masdar also signed an agreement with Bahrain's Bapco Energies, with the purpose of jointly seeking opportunities for the development and investment in wind projects in the Kingdom with a capacity of up to 2 GW (Masdar, 2017; Masdar, 2024).

At the same time, GCC SWFs are channelling an increasing share of their portfolios into green ventures across the region. The state investment funds play a pivotal role in financing renewable energy and clean technology projects in line with economic diversification agendas, exemplified by joint vehicles like the Gulf Investment Corporation, owned by all six GCC states, which has taken equity stakes in major solar and desalination projects in Saudi Arabia, Oman and the UAE. To complement such equity investments, Gulf governments and their financial institutions are also scaling up sustainable finance instruments; green bond and sukuk issuances in the GCC surged from about $605 million in 2021 to over $8.5 billion in 2022, reflecting a collective commitment to fund the green transition and meet the mid-century net-zero

emissions targets now pledged by five of the six GCC countries (Marmore MENA Intelligence, 2024).

In the current geopolitical context, the EU is accelerating its decarbonisation agenda while also reshaping its energy partnerships after 2022 (European Commission, 2022). With instruments such as the EU ETS and CBAM, Europe is extending carbon pricing beyond its borders to prevent leakage, directly affecting exporters to the European market (Dechezlepretre et al., 2025). At the same time, the EU has underscored the strategic importance of engaging the Gulf in its Joint Communication on a Strategic Partnership with the Gulf, framing GCC states as both reliable energy suppliers and emerging partners in renewable energy, hydrogen, and sustainable finance (European Commission & High Representative of the Union for Foreign Affairs and Security Policy, 2022). Initiatives under the Global Gateway strategy and the EFSD+ guarantee facility are expanding EU support for cross-border renewable and hydrogen projects, reinforcing its external climate diplomacy. For the GCC, aligning with these frameworks not only secures long-term market access but also enhances the bankability of green projects by reducing exposure to future carbon costs, while opening channels to co-financing from European institutions such as the EIB and European Development Funds Initiative (EDFI).

The green transition has therefore emerged as a strategic area of cooperation between the EU and the GCC. Europe's search for diversified clean energy partnerships converges with the Gulf's financial capacity and natural endowments, positioning the GCC as a future leader in supplying renewable electricity and hydrogen. This cooperation will increasingly depend on hydrogen infrastructure, storage, and port facilities, which serve as critical enablers of trade. EU-GCC joint ventures in such green infrastructure are often structured as public-private partnerships that blend government-backed capital with private-sector expertise. These models not only channel foreign investment but also distribute risk and align sustainability goals across regions.

In addition to intra-GCC collaboration, Dubai's Mohammed bin Rashid Al Maktoum Solar Park has attracted significant European participation through its PPP model. In Phase 2, Spain's TSK Group served as the main engineering, procurement, and construction (EPC) contractor alongside the project developer (Government of Dubai, 2021). In Phase 3, the UAE's Masdar partnered with France's EDF Group, enhancing technical expertise and project execution through the Shuaa Energy 2 company (Government of Dubai, 2021). European financial institutions have also supported project financing, with banks such as Natixis (France) and Standard Chartered (UK) contributing to funding structures.

Another leading example is the Memorandum of Understanding (MoU) between Saudi Arabia's ACWA Power and Germany's state-owned energy company Securing Energy for Europe (SEFE). The agreement, signed in 2025, outlines a plan to supply 200,000 tons of green hydrogen annually to Germany by 2030 (ACWA Power, 2025). Under this partnership, ACWA Power will lead the development and operation of hydrogen and green ammonia production facilities in Saudi Arabia, while SEFE will serve as both co-investor and offtaker, distributing the hydrogen to industrial clients across Germany and Europe. This PPP illustrates how strategic investment and cross-border collaboration can align climate goals and energy security objectives.

Europe's search for diversified clean energy partnerships converges with the Gulf's financial capacity and natural endowments, positioning the GCC as a future leader in supplying renewable electricity and hydrogen.

Beyond project-level cooperation, the EU has institutional financing mechanisms that can reinforce EU-GCC partnerships. The EIB and the EDFI have increasingly deployed blended finance tools that combine concessional public capital with private sector investment, reducing risk and catalysing large-scale renewable infrastructure (IFC et al., 2021). Instruments such as the EFSD+ guarantee under the EU's Global Gateway strategy explicitly support cross-border energy and green transition projects, including hydrogen and renewable energy corridors. These mechanisms are particularly relevant for GCC partnerships, where sovereign wealth funds can provide anchor capital, while EU DFIs and venture investors can channel expertise and risk-sharing finance for SMEs and technology transfer. Together, these arrangements strengthen bankability and deepen the pipeline of investable projects beyond state-linked ventures.

While EU-GCC PPPs for the green transition face non-trivial risks and coordination challenges, they also offer a framework to pool capital, share risk, and align standards in ways that can accelerate sustainable investment.

Another illustrative example is the Masdar-Port of Amsterdam partnership, which aims to establish a dedicated green hydrogen supply chain from the UAE to the Netherlands. The UAE government-backed clean energy company Masdar has signed a Joint Study Agreement with Dutch entities, including the Port of Amsterdam, SkyNRG, and Zenith Energy Terminals. The agreement supports the development of green hydrogen production in Abu Dhabi and its export to the Netherlands, where it will serve key sectors such as aviation, shipping, and heavy industry (Masdar, 2023). The Port of Amsterdam, partially state-owned, is developing an industrial hub for hydrogen imports, showcasing how EU-GCC PPPs can link production, logistics, and end-use markets in a cohesive green energy corridor.

Building on earlier examples, PPP-based EU-GCC green initiatives reveal both formidable financing challenges and novel opportunities. On the one hand, massive capital mobilisation is required for such sustainable infrastructure, far exceeding the capacity of any single public or private actor, necessitating joint investment efforts. Strategic PPP arrangements enable risk-sharing, as public incentives and guarantees combine with private capital to distribute risks and rewards, thereby attracting investors to these long-term projects. Regulatory alignment emerges as a critical hurdle: divergent EU-GCC regulatory regimes and the lack of common certification frameworks (for instance, to certify green hydrogen or other renewable outputs) can undermine investor confidence and impede cross-border project viability.

Conversely, harmonising regulations and establishing mutually recognised sustainability certification schemes is an opportunity to secure market access and credibility, ensuring projects meet both EU and GCC criteria. With clear rules and robust risk allocation in place, such cross-regional ventures become more bankable, evidenced by greater lender confidence and even reduced reliance on sovereign guarantees in well-structured deals. This financing perspective underscores that while EU-GCC PPPs for the green transition face non-trivial risks and coordination challenges, they also offer a framework to pool capital, share risk, and align standards in ways that can accelerate sustainable investment.

In conclusion, green finance has rapidly evolved into a cornerstone of the GCC's sustainable economic transition, with several green financial instruments, such as green bonds, sukuk, green loans, and equity investments, which can be mobilised to fund decarbonisation and diversification efforts that can serve different purposes and attract different investors. Advancement of green finance in the GCC varies; while the UAE and Saudi Arabia have es-

tablished comprehensive national frameworks and lead the region, other states are progressing more incrementally through financial institutions. Intra-GCC collaboration and growing European partnerships through PPPs are accelerating infrastructure development, yet scaling green finance will require stronger regulatory alignment, deeper private-sector engagement, and cross-border co-investment platforms. This paves the way for new opportunities for collaboration, particularly as the GCC positions itself as a leader in decarbonised energy and the EU seeks to enhance its energy security.

Conclusions and policy recommendations

1. **Develop a regional green financial framework:** While most GCC countries have developed or are developing national green finance strategies, creating a unified regional green financial framework would harmonise standards, laws, and regulatory approaches. This coordination would boost investor confidence, unlock cross-border capital flows, and facilitate joint green initiatives across the Gulf. It would also ensure consistency in achieving national and regional net-zero targets.
2. **Standardise green sukuk structures across the region:** Green sukuk holds major potential as Shariah-compliant green investment tools. However, inconsistency in definitions, structures, and reporting standards limits scalability. A standardised green sukuk framework, endorsed across GCC countries, would attract broader investor participation, particularly from international Islamic finance markets, and enhance the region's credibility as a sustainable finance hub.
3. **Incentivise sustainability-linked bonds and loans:** Sustainability-linked instruments are key to expanding private sector participation in the green transition. Policy-makers should incentivise SLBs and SLLs through tax breaks, preferential regulatory treatment, or co-financing schemes. These performance-based tools can help corporations integrate ESG targets into financing structures and align their operations with national and EU decarbonisation priorities.
4. **Create robust national MRV systems to support market integrity:** Credible carbon markets and effective emission management in the GCC will depend on the establishment of comprehensive MRV systems. Building standardised MRV platforms would enhance transparency, support both voluntary and compliance carbon markets, and strengthen confidence in the region's emissions data and green finance metrics. Drawing on its experience with the EU ETS, the EU could assist by providing technical expertise and capacity-building to help GCC countries develop robust, internationally recognised MRV frameworks.
5. **Establish compliance-based carbon markets:** Building compliance-based carbon markets would allow the GCC to achieve more verifiable emission reductions and create carbon credits to provide new revenue streams for green investments. The GCC region can build upon current existing voluntary market initiatives across different countries by phasing in compliance mechanisms, starting with high-emitting sectors, while ensuring compatibility with international carbon trading systems. The experience gained through the operation of the EU ETS could provide regulatory expertise in the GCC in establishing a compliance market as well as facilitate technical

exchanges and assist in designing market frameworks aligned with global trading standards.

6. **Establish a regional accreditation body for EU compatibility:** Given ongoing efforts by GCC exporters to reduce emissions, a regional sustainability accreditation body would help translate these actions into internationally recognised standards. This is critical in the context of the EU's CBAM. The body would ensure conformity with EU regulations, protect trade flows, and boost the export competitiveness of GCC-produced green goods and services.
7. **Develop a mutual green hydrogen certification framework:** Green hydrogen is a strategic pillar of both the EU and GCC climate goals. A mutually recognised certification framework for green hydrogen would provide regulatory certainty, reduce transaction risks, and facilitate long-term energy partnerships. This step is crucial and would enable hydrogen trade corridors and ensure GCC hydrogen production qualifies under EU climate regulations. Drawing from its CertifHy initiative, the EU could support the development of a mutual certification scheme, ensuring that hydrogen produced in the GCC meets the sustainability and emissions standards required for access to European markets.
8. **Leverage EU instruments:** Align green bonds and loans with the EU Taxonomy to enhance credibility and attract European investors. Partnering with EFSD+, EIB, and EDFI can mobilise blended finance for renewable energy, hydrogen, and other green transition projects. Embedding such cooperation within Global Gateway corridors would reinforce EU-GCC climate diplomacy, reduce investment risks, and secure long-term access to European markets.

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Green Nobility: The GCC Reinvention through Renewable Power

Strategic Implications for EU-GCC Energy Cooperation

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Introduction

The Gulf Cooperation Council (GCC) states, long defined by their hydrocarbon wealth and global energy influence, are entering a critical juncture in their political economies. Pressures from climate change, decarbonisation policies, and volatile fossil fuel markets are pushing Gulf monarchies to diversify their economies and position themselves as central actors in the emerging clean energy order.

This chapter addresses the following core research question: How does Gulf energy governance shape the green transition in the region, and what are the implications for European Union (EU) engagement? In answering this question, the chapter argues that the GCC's renewable energy push is less a departure from the hydrocarbon era than a reinvention of it: rather than dismantling the oil-based political economy, Gulf monarchies are embedding renewables within existing governance logics of elite control, state-owned enterprises (SOEs), and sovereign wealth funds (SWFs).

The analysis applies a governance-centred lens, emphasising how elite-driven institutional frameworks, characterised by overlapping ruling-family control of ministries, SOEs, SWFs, and special economic zones (SEZs), enable rapid project execution and coherent national strategies. By examining domestic governance structures, regional "coopetition" in clean energy, and international partnerships in green and emerging technologies, the chapter demonstrates how these governance models both facilitate large-scale renewable deployment and constrain broader systemic change.

For external actors, engagement will require understanding and navigating this centralised, elite-driven green transition model. Strategic partnerships, modular cooperation, and early integration into Gulf clean energy value chains will be critical to securing mutual benefits in the new global energy landscape. The analysis further shows that while Europe and the Gulf approach climate policy from different starting points, the Gulf's centralised governance model creates space for transactional synergies where strategic interests align.

Domestic governance structures

Across the GCC, governance structures underpinning the energy transition share notable similarities but also reflect country-specific variations. Common to all is the elite-driven, top-down nature of policy-making, where ruling families and their close confidants directly control key ministries, SOEs and SWFs. This allows for rapid mobilisation of capital, alignment of political and economic priorities, and swift execution of mega-projects. Yet important differences remain among the GCC member states as the following country-by-country analysis will show. Understanding these convergences and divergences is essential for external partners, as they shape the speed, scope, and reliability of Gulf green energy strategies.

United Arab Emirates

The United Arab Emirates (UAE)'s federal-local governance system divides climate policy between the 2016 created Ministry of Climate Change and Environment (MOCCAE) and emirate-level initiatives. MOCCAE works closely with the Ministry of Energy and Infrastructure and engages private and non-governmental

actors through cross-sectoral committees. The UAE Council on Climate Change and Environment, also established in 2016 under the UAE Green Agenda 2030, serves as the key coordinating platform, promoting vertical and horizontal integration of previously fragmented policies (MOCCAE, 2017).

However, the most influential governmental body in green energy production is the Ministry of Energy and Infrastructure (MOEI). Due to its extensive portfolio that has frequently been expanded over the last decades — spanning energy (oil, gas, renewables, nuclear), electricity and water policy, infrastructure and housing, as well as transport — it can be regarded as a super ministry. The integration of the UAE's four power authorities, covering all seven emirates, into MOEI has streamlined strategic planning and decision-making by centralising state-owned energy companies under a national framework (Tanchum, 2024).

On the implementation level, SOEs are central to the UAE's green energy transition, acting as key instruments of state policy. Closely tied to the ruling elite, these entities are often led by royals or trusted confidants who hold overlapping government and corporate roles, ensuring policy alignment (Cahill, 2021).

Masdar, the UAE's flagship renewable energy company, exemplifies this structure. Jointly owned by three major UAE energy players — Abu Dhabi National Oil Company (ADNOC), Mubadala Investment Company, and Abu Dhabi National Energy Company PJSC (TAQA) — Masdar operates in over 40 countries with projects worth $20 billion and aims to reach 100 GW of renewable capacity by 2030, including producing 1 million tons of green hydrogen (Enerdata, 2022).

Leadership across Masdar, ADNOC, Mubadala, and TAQA is highly interwoven, with at least a dozen figures linked to the Al Nahyan-ruling family holding multiple top roles simultaneously. Notably, ADNOC alumni such as ADNOC and Masdar CEO al-Jaber and Minister of Energy al-Mazrouei have risen to senior leadership roles under the reign of Muhammad bin Zayed Al Nahyan (MBZ), highlighting their close ties to the ruler. These technocrats have built strong working relationships, with al-Mazrouei previously serving as al-Jaber's deputy at Mubadala (Hegdes, 2022). Likewise, the current Mubadala CEO Khaldoon Khalifa Al Mubarak, another close confidant of MBZ, sits on the board of ADNOC.

The UAE's Hydrogen Alliance exemplifies how these interwoven governance structures enable state-backed entities to form comprehensive joint ventures to tackle the energy transition. ADNOC leverages its natural gas resources, infrastructure, and global partnerships to expand blue hydrogen production, while Mubadala, through Masdar, contributes renewable energy expertise and international investment networks. ADQ, another key player, integrates its energy and transport assets — including TAQA, Etihad Rail, and Abu Dhabi Ports — ensuring a full-spectrum hydrogen value chain (Mubadala, 2021). This coordinated, all-in-one approach enables the UAE to advance its energy transition holistically and at scale.

Another Mubadala asset, Emirates Global Aluminum (EGA), is at the forefront of sustainable industrial production. EGA pioneered the production of "CelestiAL" solar-powered aluminium, utilising solar energy from the UAE's Noor Abu Dhabi solar plant. In 2023, EGA produced approximately 66,000 tons of CelestiAL aluminium (EGA, 2024b). The recently announced Masdar-EGA alliance (April 2024) further strengthens this decarbonisation effort. With Sultan Al Jaber also

sitting on EGA's board and hence facilitating the deal, Masdar's clean energy expertise will play a crucial role in ensuring EGA's aluminium production is increasingly powered by renewables (Masdar, 2024).

Saudi Arabia

Saudi Arabia's green energy transition is being driven by a tight nexus of elite-led state institutions and SOEs – mirroring the UAE's model, but with even greater centralisation.

Following the UAE's early leadership in renewable energy, Saudi Arabia has increasingly adopted a similar top-down model of green governance; one that integrates environmental objectives into a broader strategy of state-led economic transformation. Under King Salman and Crown Prince Mohammed bin Salman (MBS), the Kingdom has undergone extensive institutional restructuring to consolidate control and fast-track Vision 2030, Saudi Arabia's flagship diversification initiative.

With the 2015 establishment of the Ministry of Environment, Water and Agriculture (MEWA), King Salman merged previously fragmented environmental portfolios. However, in practice, MEWA plays a secondary role to the Ministry of Energy, which coordinates both domestic and international energy policy and is traditionally helmed by senior royals, currently Prince Abdulaziz bin Salman, MBS's half-brother.

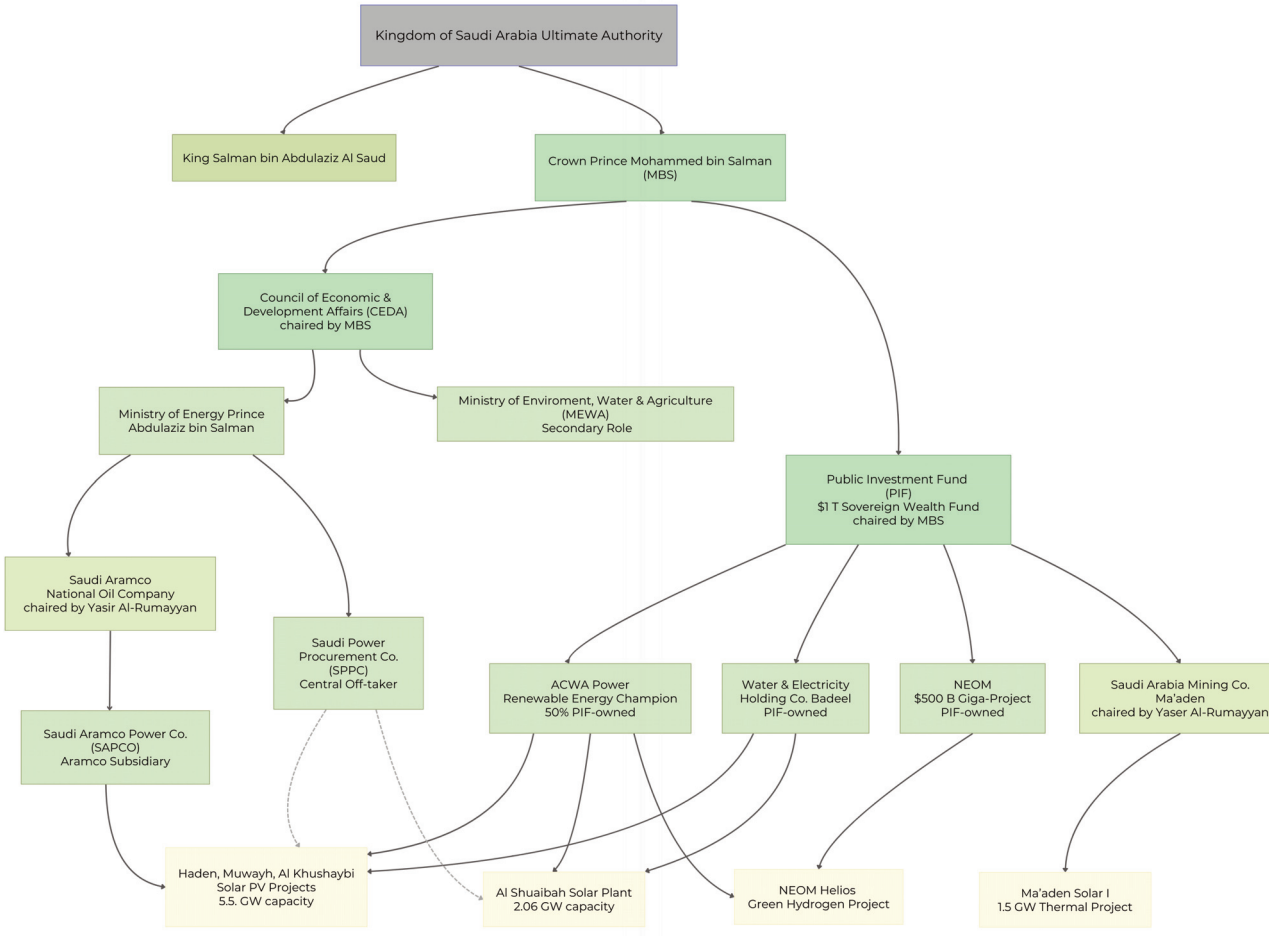
Also in 2015, King Salman established the Council for Economic and Development Affairs (CEDA) to centralise domestic policy-making. Chaired by MBS, CEDA brings together critical institutions, including MEWA and the Public Investment Fund (PIF), under one authoritative umbrella (House, 2019; PIF, 2025). PIF, Saudi Arabia's $1 trillion sovereign wealth fund, is the Kingdom's financial engine for Vision 2030 and central to implementing its clean energy transition. MBS's personal chairmanship of both CEDA and PIF has concentrated strategic control at the top, facilitating rapid decision-making and alignment across sectors. At least six of the nine PIF board members are also CEDA members, including PIF Governor Yasir Othman Al-Rumayyan, Minister of State Mohammad Abdul Malek Al-Shaikh, and Minister of Finance Mohammed Al-Jadaan — all trusted allies of MBS.

Saudi Arabia's green energy transition is being driven by a tight nexus of elite-led state institutions and SOEs — mirroring the UAE's model, but with even greater centralisation. At its core is Saudi Aramco, the national oil company, which remains focused on hydrocarbons but is expanding into hydrogen, carbon capture, and renewables under Vision 2030 (Tanchum, 2024; George, 2025). The appointment of PIF governor Yasir Al-Rumayyan as Aramco's chairman underscores the deepening integration of energy and finance under MBS's oversight. This convergence is further exemplified by ACWA Power, a PIF-owned company that plays a strategic role in advancing renewable energy initiatives.

ACWA Power has access to non-interest-bearing loans from the PIF, which holds a 50% stake in it (The Saudi Boom, 2024). The workings of this private-public nexus in Saudi's energy governance are exemplified by the Haden, Muwayh, and Al Khushaybi solar photovoltaic (PV) projects, which have a total investment value of $3.2 billion and aim to generate a combined capacity of 5.5 GW. The projects are a joint venture of ACWA Power, the also PIF-owned Water and Electricity Holding Company (Badeel), and Saudi Aramco Power Company (SAPCO), a wholly-owned subsidiary of Aramco. The government-owned Saudi Power Procurement Company (SPPC) is the procurer and the offtaker for the projects (ACWA Power, 2024). All parties involved are hence directly controlled by MBS and his closest trustees. Badeel and ACWA Power also develop the single

largest solar energy plant in the Middle East with a capacity of 2.06 GW solar facility in Al Shuaibah (Ghantous, 2022). The private public nexus is also evident in the $500 billion Vision 2030 flagship project, NEOM, which is envisioned as a special economic zone to cover an area of 26,000 square kilometres in Saudi Arabia's North West as well as parts of Egypt and Jordan. Spearheaded by MBS, who serves as Chairman of the NEOM Board of Directors, as well as that of its financial arm, the PIF, NEOM is the cornerstone of the Kingdom's economic diversification efforts, especially in the sectors of tourism, attraction of foreign direct investment (FDI), and green energy production. In 2020, ACWA Power signed a $5 billion agreement with US Air Products to develop Neom Helios — the world's largest green hydrogen-to-ammonia project — powered by wind and solar (Khan & Al-Ghamdi, 2023). Furthermore, Neom Green Hydrogen (a joint venture between ACWA Power, state-backed Neom, and US-based Air Products & Chemicals Inc.) is part of Riyadh's broader

Figure 6. Overview of KSA Domestic Governance Structure in the Realm of Green Energy, Including Selected Analysed Mega-Projects



Note. Elaborated by author, sourced from international and national news outlets, open-source intelligence (OSINT) data, official government communications, and announcements from relevant project developers.

strategy to expand into clean-tech industries as it prepares for a future beyond fossil fuels. The larger component of the venture, an $8.4 billion project designed to produce 600 tons of hydrogen per day using wind and solar power, is slated to begin exporting green ammonia by 2026 under a 30-year supply agreement with Air Products, which has been pivotal in securing the project's financing (Di Paola, 2023). Another PIF asset, Saudi Arabia's mining champion Ma'aden, has, under the chairmanship of Al-Rumayyan, partnered with the American company GlassPoint to develop Ma'aden Solar I, a 1.5 GW thermal solar process heat plant in Ras al Khair (Glasspoint, 2025). Both companies have also signed a Memorandum of Understanding (MoU) to develop the first solar steam project in the Kingdom to decarbonise Maaden's aluminium refinery, thereby aiming to reduce carbon emissions by approximately 600,000 tons annually (Ma'aden, 2022).

The EU implemented general measures to keep essential goods moving during COVID-19, which saw EU agri-food imports from Morocco actually increase by 8.4% year-on-year.

Qatar

Qatar, alongside the UAE, leads GCC climate change policy, highlighted in the Qatar National Vision 2030, which integrated environmental policy as a key development pillar. In 2008, Qatar established its first Ministry of Environment, later merged into the Ministry of Municipality and Environment (MME). However, in 2021, the Ministry of Environment and Climate Change (MOECC) was re-established. Despite these efforts, frequent restructuring may have hindered its progress toward sustainability targets (Al-Hababi, 2022).

As in other GCC countries, the true power to drive economic diversification and green policies in Qatar lies within the energy sector. In 2021, Qatar's national oil and gas company, Qatar Petroleum, rebranded as Qatar Energy to reflect its expanded focus on low-carbon and renewable energy (Ugal, 2023). Previously, Qatar Energy operated under the Ministry of Energy and Industry, which no longer exists as a standalone entity. Today, Qatar Energy is directly overseen by the Supreme Council for Economic Affairs and Investment, chaired by Emir Tamim bin Hamad Al Thani (Qatar Energy, 2025). His trustee, Saad Sherida Al-Kaabi, holds dual roles as Minister of State for Energy Affairs and Deputy Chairman and President and CEO of Qatar Energy, while the company is chaired by Abdullah bin Hamad Al Thani, the Deputy Emir of Qatar and the Emir's half-brother. Meanwhile, the portfolio of industry has shifted to the Ministry of Commerce, now being the Ministry of Commerce and Industry (MOCI) under the leadership of Sheikh Faisal bin Thani bin Faisal Al-Thani.

The close-knit structure of green governance, primarily anchored in the Emir's immediate family, is further exemplified by the Qatar Foundation (QF). Founded and chaired by Sheikha Moza, the Emir's mother, QF plays a critical role in advancing research, innovation, and sustainable solutions across sectors. Additionally, QF established Qatar Solar Technologies, a solar manufacturing company. Initially a joint venture, QF held a 70% stake, with Qatar National Bank owning 1% and SolarWorld holding 29%. Following SolarWorld's insolvency, QF's fully owned holding company, Qatar Solar, appears to have acquired SolarWorld's shares (Zumbraegel, 2022, 156).

The Qatari "family first" governance approach is mirrored in the board of the country's SWF, the Qatar Investment Authority (QIA). Three of the seven board members belong to Qatar's ruling family, the Al-Thanis, including chair and vice-chair. The presence of Qatar Energy president Al-Kaabi, MOCI head Faisal Al-Thani, and Minister of Finance Ali bin Ahmed Al-Kuwari serves to align the $450 Billion

fund with Qatar's low-carbon energy ambitions. For example, Qatar Holding, a wholly-owned subsidiary of the QIA, formed a joint venture with the Qatar Water and Electricity Company (QEWC) to establish Nebras Power. Over the years, Nebras Power has expanded its presence across four continents, with 22 operational power-generating assets in nine countries and an ambition to exceed 9 GW in renewable energy production by 2032 (Nebras Power, 2022). Given that Al-Kaabi also serves as the chairman of QEWC, his influence played a key role in the formation of this joint venture, making it natural that Nebras Power frequently collaborates with Qatar Energy.

Oman

Oman can be seen as a regional outlier, having pursued a more sustainability-oriented development approach than its neighbours, during Sultan Qaboos bin Said's nearly 50-year rule. It was the first Middle Eastern country to enact a comprehensive environmental policy in 1982 and to establish an environmental ministry in 1984 (Bodetti, 2018). With the passing of Sultan Qaboos in 2020 and the ascension of Sultan Haitham bin Tariq, Oman underwent a significant governance reshuffle. As part of these changes, the Ministry of Environment was downgraded to an agency within the Civil Aviation Authority, removing climate affairs from representation at the Council of Ministers. This shift signals a prioritisation toward revitalising Oman's struggling economy, potentially at the expense of climate and sustainability priorities. Furthermore, the restructuring risks policy fragmentation, as environmental, climate, and energy policies now fall under separate entities. While the environment agency operates within civil aviation, renewable energy remains under the Ministry of Energy and Minerals (Al-Sarihi, 2020). As in other GCC states, the Omani Ministry of Oil and Gas has been rebranded and expanded to also include the portfolio of energy.

Omani leadership sees green hydrogen as key to balancing its net-zero goal by 2050 with economic diversification and growth. For this reason, Sultan Haitham set up a new state-owned energy firm, the Energy Development Oman (EDO). EDO's task is to fund the expansions of Oman's NOC, Petroleum Development Oman (PDO), including into renewable energy. EDO owns the Sultanate's share in PDO (60%) and has created a new subsidiary, Hydrom, which leads the hydrogen sector initiatives across Oman (EDO, 2024). This represents a streamlined governance structure, in which fossil fuel production and sale is managed in lockstep with the continuous development of renewable energy sources. Minister of Energy, Salim bin Nasser Al Aufi, serves as chairman of EDO, PDO and Hydrom, while his undersecretary, Mohsin bin Hamed Al-Hadhrami, serves on the boards of EDO and PDO. In addition, the Sultanate's SWF, the Oman Investment Authority (OIA) and the Ministry of Finance are represented on EDO's board, while PDO's board is stacked with senior EDO staff. Hydrom functions as an all-in-one governance entity for Oman's green hydrogen sector, overseeing its development from planning to execution. Its responsibilities include master planning the sector, allocating government land for projects, coordinating infrastructure, and facilitating ecosystem industries.

Finally, SEZs are key governance actors in Oman's green energy sector, integrating hydrogen projects into industrial and export frameworks. Overseen by the Public Authority for Special Economic Zones and Free Zones (OPAZ), SEZs in the port cities Sohar, Duqm, and Salalah provide regulatory coordination, investment incentives

and export facilities. OPAZ ensures tight coordination between commerce, energy, and state finance. Its board is chaired by the former and current commerce ministers, with Energy Undersecretary Al-Hadhrami and representatives from the OIA and Ministry of Finance also serving.

Kuwait and Bahrain

Kuwait and Bahrain lag behind other GCC countries in energy transition. Environmental governance in Bahrain and Kuwait remains largely unchanged, with key institutions lacking ministerial status and direct executive power, which has slowed the pace of their energy transition.

Kuwait and Bahrain lag behind other GCC countries in energy transition, as shown in the World Economic Forum's Energy Transition Index (ETI). While most GCC countries rank around the global average, Kuwait and Bahrain find themselves near the bottom (World Economic Forum, 2024).

The reason for this discrepancy lies primarily in political and structural factors that hinder large-scale green initiatives. In contrast to other GCC countries which saw major political restructuring over the last decades, environmental governance in Bahrain and Kuwait remains largely unchanged, with key institutions — Bahrain's Supreme Council for Environment (SCE) and Kuwait's Environment Public Authority (EPA) — lacking ministerial status and direct executive power. Both bodies report to higher authorities: Kuwait's EPA operates under a Supreme Council of Environment, which typically approves its decisions before forwarding them to the Council of Ministers, while Bahrain's SCE, despite having regulatory oversight on paper, must coordinate with ministries for policy implementation (Zumbraegel, 2022, p. 84f.). This structural limitation weakens their ability to drive ambitious climate policies, as final decision-making authority rests elsewhere. Unlike other GCC countries, Kuwait and Bahrain have not integrated renewable energy into their powerful Ministries of Oil. Instead, the portfolio remains under the Ministry of Electricity and Water in Kuwait and the Electricity and Water Authority in Bahrain, which has slowed the pace of their energy transition.

Kuwait's energy transition ambitions have further been stifled by a long-lasting gridlock between the cabinet and the relatively powerful parliament, which impedes a streamlined, top-down governance on energy transition as seen in the other GCC countries (Thafer, 2024). Without unambiguous political directive from the top, the heavily oil-dependent "extreme rentier" (Herb 2014, 14) state structure of Kuwait has little internal incentive to diversify and innovate, rather than preserve the status quo. Bahrain's diversification efforts are further impeded by its small size and predominantly urban structure, which makes large scale solar and wind farms less viable, a comparative lack of financial power and policy implementation being slowed by an overarching bureaucratic apparatus (Al-Ubaydli 2024).

Emerging patterns

The recent evolution of GCC governance underscores three interlinked insights with direct bearing on EU-Gulf green-energy collaboration. First, the creation of supra-ministerial bodies and the elevation of environmental portfolios have compressed decision-making cycles, enabling gigawatt-scale renewable projects to move from concept to execution in record time. The alignment of NOCs, SOEs, SEZs, and SWFs into a cohesive bureaucratic framework with streamlined decision-making processes, led by technocratic individuals with overlapping portfolios and direct access to top leadership, facilitates the swift implementation of large-scale projects through an all-in-one

governance approach. This structure ensures seamless coordination between political priorities and economic execution, rendering long-term planning both constant and predictable.

Second, GCC SEZs function as testing grounds for integrated energy solutions, offering streamlined permitting, fiscal incentives, and export-oriented infrastructure. Their governance structures, often directly tied to ruling elites, allow for rapid iteration of technologies like green hydrogen/ammonia production or solar-powered industrial processes.

Third, embedding clean-energy mandates within hydrocarbon ministries has engineered a "dual-track" transition, which leverages existing energy infrastructure and expertise to maintain fiscal stability while systematically unlocking new markets in blue/green hydrogen and ammonia. For EU stakeholders, these insights imply that successful engagement will depend on direct alignment with the Gulf's governance nodes to align with decision-making velocity, utilise SEZs as regulatory sandboxes for piloting interoperable technologies and standards, as well as engage dual-track ministries and NOCs as bridges between hydrocarbon legacies and green industrialisation.

The EU's Carbon Border Adjustment Mechanism (CBAM) provides a critical, if indirect, leverage point in this context. By pricing the carbon content of imports, CBAM creates a powerful economic incentive for Gulf exporters to decarbonise their industrial and energy production to maintain access to the EU market. In practice, this external policy driver amplifies the internal logic of the Gulf's dual-track transition, making partnerships with European technology providers on decarbonisation projects not only strategic but increasingly economically attractive for Gulf SOEs.

Regional and bilateral governance

The shifting alliances and complex interplay of diverging and converging interests among GCC member states have often stalled progress in climate policy within the regional organisation. At the same time, these dynamics have spurred a wave of bilateral collaborations in the clean energy sector. One example is UAE's Masdar, which has delivered the first large-scale wind farm in the GCC region in Dhofar, Oman, with an expected capacity of 50 MW (Masdar, 2025a).

Oman is making significant strides in the region's green hydrogen race, with a $20 billion development programme attracting major regional and international partners. In December 2023, a Japanese-Omani-Korean consortium, including OQ (Oman's state-owned energy investment company) and Dutco (a Dubai-based developer), signed agreements with Hydrom to develop a green ammonia project in Oman. The deal grants the consortium 47-year usufruct and development rights, allowing for in-depth feasibility studies and supply chain integration (Marubeni, 2023). A separate Omani-UAE-Japanese-Irish consortium, featuring OQ, Dutco, Marubeni, and Linde, is spearheading the SalalaH2 project in the Salalah SEZ, targeting a production of 1,000 tons of green ammonia per day. This project integrates a 400 MW electrolysis facility powered by 1 GW of solar and wind energy, leveraging OQ's existing ammonia plant (ONA, 2021). Kuwait's EnerTech is involved in another consortium in Oman aiming to produce up to 150,000 tons of green hydrogen annually, supported by 4 GW of renewable energy (Foreign Ministry of Oman, 2023).

Saudi-UAE cooperation in sustainability is also intensifying. In January 2024, a regional consortium led by Abu Dhabi's TAQA an-

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Cross-border clean energy projects led by GCC SOEs reveal that, despite being friendly competitors in the climate governance space, Gulf countries adopt a pragmatic, results-oriented approach, prioritising joint value creation over full political or strategic alignment.

nounced plans to develop a strategic water reserve in Al-Juranah, Saudi Arabia, partially powered by on-site solar energy (SWPC, 2024). In parallel, Saudi Arabia's ACWA Power has been selected by the Dubai Electricity and Water Authority (DEWA) to construct and operate a solar-powered desalination project in Hassyan, Dubai (Enterprise, 2024). The Saudi green energy champion has also been instrumental together with Spain's TSK in multiple phases of the construction of the Mohammed bin Rashid Al Maktoum Solar Park in Dubai, which is among the largest single-site solar parks globally, with a planned capacity of 5 GW by 2030 (MBRSIC, 2025). Additionally, ACWA Power has signed MoUs with Tunisia and Egypt to explore projects aimed at producing and exporting green hydrogen to Europe via the SoutH2 Corridor.

UAE's Masdar continues to expand its regional footprint, including its investment in the 1,100 MW Al-Henkiyah solar plant, where it has partnered with Saudi Arabia's Nesma and France's EDF (Masdar, 2025b). The same constellation also secured the 300MW Jeddah solar project after submitting the most cost-competitive bid in a tender run by Saudi Arabia's Renewable Energy Project Development Office (REPDO). Following the award, the group signed a 25-year Power Purchase Agreement with the Saudi Power Procurement Company (SPPC) to design, finance, build, and operate the plant (Masdar, 2023).

Cross-border clean energy projects led by GCC SOEs reveal that, despite being friendly competitors in the climate governance space, Gulf countries adopt a pragmatic, results-oriented approach, prioritising joint value creation over full political or strategic alignment. Their ability to co-invest, co-develop, and co-own major clean energy projects across borders shows that strategic cooperation can thrive even amid diverging ambitions. This regional logic of "coopetition" offers an important lesson for Europe: engagement with the Gulf need not hinge on full political consensus or shared ideology. Instead, Europe can, and should, embrace a similarly outcome-driven mindset, seizing mutually beneficial opportunities in green hydrogen, renewable infrastructure, and decarbonised supply chains to accelerate its own and the GCC states' energy transition. The contrast between the stagnant climate agenda at the supranational GCC level and the dynamism of bilateral and trilateral green energy ventures among GCC states also suggests that Gulf states intentionally opt for flexible, interest-based cooperation models that preserve national autonomy while allowing them to pursue shared objectives, especially when there is tangible mutual benefit, economic upside, and reputational gain. For Europe, this offers a lesson: engagement with the GCC should not aim to "multilateralise" or institutionalise too quickly, but rather build trust and momentum through modular cooperation, flagship projects, and adaptable governance frameworks that match the Gulf's preference for outcome-driven, ad-hoc partnerships. This in turn can form the basis for enhanced EU-GCC coordination and cooperation in climate diplomacy.

International and multilateral frameworks

Beyond the GCC, Gulf states are positioning themselves as indispensable players in the global energy transition. As seen with partnerships involving Korea, Japan, the US, and Europe, their ambitions extend beyond domestic decarbonisation to securing a long-term role in a post-fossil fuel world. The sheer scale of investment, integrated governance frame-

works, and reliable project execution have made the Gulf an attractive hub for global energy players. Companies and governments worldwide are eager to establish a foothold, while Gulf expertise in large-scale renewables is increasingly in demand. A growing number of MoUs reflect this trend. Without a unified regional hydrogen market, individual GCC states have signed separate agreements with European and Asian buyers such as Siemens Energy, the Port of Amsterdam, Lhyfe, Linde, and Marubeni. Notably, Masdar partnered with Spain's Iberdrola to develop the 476 MW Baltic Eagle offshore wind farm in the German Baltic Sea, demonstrating a shift from mere technology transfer to deep, equity-based co-investment (Iberdrola, 2025). This collaboration provides Masdar with crucial operational experience in European offshore wind while supplying the EU with renewable energy, showcasing a partnership model that could be replicated and scaled under the EU's Global Gateway investment framework. Moreover, Germany's Uniper is developing a 1.3 GW solar plant aimed at producing clean hydrogen via electrolysis by 2026 (Chandak, 2023) and Siemens Energy has collaborated with DEWA to inaugurate the first industrial scale green hydrogen project in the Middle East, connected to the Al Maktoum Solar Park (Siemens Energy, 2021).

A significant milestone in Saudi-German energy cooperation was marked in February 2025 with the signing of an MoU between ACWA Power and SEFE (Securing Energy for Europe), the German government-owned energy company. The agreement was formalised in the presence of Saudi Arabia's Minister of Energy, Prince Abdulaziz bin Salman bin Abdulaziz, and German Minister of Finance, Jörg Kukies. Under the deal, SEFE will act as both co-investor and primary offtaker, marketing green hydrogen to its German and European customers. The partnership aims to establish a hydrogen bridge between Saudi Arabia and Germany, beginning with the supply of 200,000 tons of green hydrogen annually by 2030 (ACWA Power, 2025; SEFE, 2025). Together with the aforementioned joint ventures between French government-owned EDF and UAE's Masdar, these are prime examples of how SOEs can effectively collaborate to drive forward the green energy agenda.

The potential of Gulf-European cooperation extends well beyond the confines of green energy generation alone. It increasingly encompasses the decarbonisation of hard-to-abate sectors, such as fertiliser, cement, and industrial manufacturing, indicating an integrated value chain in the making. ADNOC-owned Fertiglobe's breakthrough renewable ammonia deal with Europe (supply 19,500 tons of renewable ammonia in 2027, with volumes potentially rising to 397,000 tons by 2033) signals the Gulf's growing role as a green input supplier for European agriculture and chemicals, while Spanish IPIAC's upcoming low-carbon cement (LC3) plant in Oman, the first of its kind in the Middle East, exemplifies how European construction companies could access a cleaner, cost-competitive supply of critical building materials by leveraging the Gulf's expertise in sustainable infrastructure and abundant local resources (H2 Global, 2024; Prabhu, 2024). EGA's recent acquisition of German alloy producer Leichtmetall further exemplifies this trend. It positions the UAE not just as a green materials exporter, but as a stakeholder in Europe's advanced manufacturing base (EGA, 2024a).

These projects highlight more than isolated successes. They point to the potential for deeply integrated green manufacturing supply chains. Gulf states can

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supply Europe with clean hydrogen and derived products (ammonia, methanol, SAF), while Europe can supply electrolysis technology, engineering services, and regulatory frameworks. These inputs could feed into decarbonised steel and fertiliser production, green automotive manufacturing (e.g., car frames, batteries, lightweight components), and sustainable aviation fuel, which are all sectors where Europe's industrial base is looking for scalable green inputs.

To capitalise on this, European companies and governments must engage with the particular governance features of the Gulf: the preference for bundled mega-projects, long-term investment horizons, and a limited circle of decision-makers capable of aligning infrastructure, regulation, and financing with unusual speed. Success will depend on structuring B2B partnerships and public-private mechanisms that match this governance style — such as joint ventures in SEZs, co-financed R&D hubs, and guaranteed offtake agreements underwritten by export credit agencies.

These developments also highlight a clear trend: the Gulf states are not merely adapting to the energy transition — they are actively shaping its trajectory, securing strategic partnerships, and positioning themselves as indispensable nodes in the future global energy network.

The EU's toolbox for strategic gulf engagement

The EU is not a passive observer but is actively developing a suite of instruments to foster the green transition in partner countries.

The EU is not a passive observer but is actively developing a suite of instruments to foster the green transition in partner countries, with significant potential application in the GCC. The Global Gateway strategy, Europe's offer for sustainable infrastructure investment, provides an overarching framework for strategic engagement. Its principles align well with Gulf megaprojects, focusing on sustainable investments in energy and digitalisation.

Concretely, financial de-risking tools are crucial. The European Fund for Sustainable Development Plus (EFSD+), under the NDICI-Global Europe instrument, can provide guarantees, blended finance, and technical assistance to mobilise private investment. This mechanism is ideally suited to de-risk European corporate participation in large-scale GCC hydrogen and renewable projects, mitigating perceived political and financial risks for European small and medium-sized enterprises (SMEs) and investors. Furthermore, the European Hydrogen Bank (EHB) is a pivotal vehicle for bridging the demand-supply gap, especially once its international pillar is fully developed. Its pilot auction for renewable hydrogen production internationally (expected September 2025) could provide a vital offtake guarantee and a fixed premium to cost-competitive Gulf hydrogen producers, effectively subsidising the initial price gap with fossil alternatives and accelerating project Final Investment Decisions (FIDs). This creates a direct channel for Gulf SOEs like Masdar, ACWA Power, or NEOM to more readily access the EU market.

Finally, Team Europe initiatives, combining resources from the European Commission, the European Investment Bank (EIB), and member states' development finance institutions, can offer a one-stop-shop for Gulf partners. The EIB's evolving mandate for outside-the-EU investments could provide critical long-term, low-cost financing for projects that meet strict environmental standards. By presenting a coordinated European offer that mirrors the Gulf's integrated, top-down project approach, the

EU can position itself as a more streamlined and reliable partner.

Conclusions and policy recommendations

The study of the GCC state's governance structures revealed that the Gulf decision-makers perceive the green energy transition as an opportunity to diversify their countries' economies, while safeguarding existing political models for the post-oil era. Streamlined decision-making processes via SOEs, SWFs and SEZs directly connected to ruling circles, leveraged existing energy experience through dual-track NOCs, and the GCC countries' preference of ad-hoc win-win constellations over legalised multilateral climate governance all carry important implications for European stakeholders and the potential for enhanced cooperation.

While EU policy frameworks often treat decarbonisation as a balancing act between ecological responsibility and industrial competitiveness, Gulf states are recasting green energy as a core engine of growth, not a constraint on it. Yet rather than clashing, these differing paradigms are increasingly meeting in the middle through joint ventures, offtake agreements, and green supply chains that are rooted in business. It is in these transactional spaces that a new form of climate alignment can take shape. One that is not driven by summit communiqués or treaty harmonisation, but by mutual self-interest and operational trust.

Gulf investments in cost-competitive hydrogen, solar-driven industries, and mineral processing infrastructure are rapidly positioning the region as a lynchpin in global clean energy value chains. Europe's industrial competitiveness and supply chain resilience stand to gain from securing early-mover access to GCC renewables expertise, low-carbon exports, and strategic logistics hubs. However, delay risks losing ground in an increasingly competitive landscape. The GCC's project execution speed and long-term planning certainty offers European industries a critical edge, if Brussels and member states manage to align incentives, streamline joint ventures, and prioritise GCC markets with the same vigour applied to internal decarbonisation. In this recalibration of energy geopolitics, economic foresight, not just climate idealism, will dictate who shapes and profits from the new energy order.

- **Engage early in GCC value chains:** Position EU actors as first movers in Gulf clean energy projects by building modular partnerships in hydrogen, renewables, and decarbonised industrial supply chains. Early integration increases leverage and reduces the risk of being overtaken by competitors. To this end, a task force comprising technical and financial experts could act as a single point of contact and a "deal factory" to Gulf countries to bundle EU offerings (financing, technology and offtake) and accelerate decision-making. This would cut through internal EU silos and possibly create the necessary speed for early integration.
- **Recognise SOEs, SWFs and SEZs as central governance nodes:** Tailor EU engagement to the Gulf's elite-driven model, where SOEs and SEZs operate as both policy executors and investment vehicles. Acknowledge these as legitimate climate governance actors and structure cooperation accordingly. In this regard, a recurring "EU-GCC Sovereign Investment Forum" focused solely on green transition co-investment could be advantageous. The goal would

be to build personal relationships and trust between the technocrats running the PIF, Mubadala, QIA, OIA, and their counterparts at the EIB and member state development banks, creating a direct channel that bypasses slower diplomatic circuits.

- **Adapt EU financial instruments to Gulf megaproject logic:** Calibrate EFSD+, EIB financing, and blended finance schemes to match the Gulf's preference for large, bundled, state-backed projects with long-term horizons. Flexible de-risking mechanisms should align with GCC project lifecycles rather than EU bureaucratic timetables.
- **Leverage the European Hydrogen Bank's international pillar:** Ensure the design of the upcoming EHB auctions accommodates both green and low-carbon hydrogen (where compatible with EU emissions thresholds), creating realistic entry points for Gulf producers. Clear rules and transparent eligibility will strengthen EU credibility as an off-take partner.
- **Anchor cooperation in outcomes, not values alignment:** Prioritise tangible results, such as co-financed plants, off-take agreements, and joint R&D hubs, over normative convergence on climate governance. Outcome-driven, ad-hoc partnerships reflect Gulf preferences and build operational trust, without diluting EU environmental standards.
- **Use CBAM strategically as a pull factor:** Frame the EU's CBAM not only as a compliance hurdle, but as a driver for Gulf industries to decarbonise in partnership with European technology providers. This demand-driven rationale transforms the mechanism from a potential point of friction into a foundation for deeper industrial cooperation and shared supply chain decarbonisation.

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