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Green Steel Opportunity in the Middle East and North Africa

Region Can Lead Green Hydrogen Use in Steel Sector

Executive Summary

The global steel industry is eyeing a switch to direct reduced iron (DRI) using green hydrogen to reduce emissions.

Unlike the blast furnace-basic oxygen furnace (BF-BOF) process that uses coal to make iron, the direct reduced iron-electric arc furnace (DRI-EAF) route predominantly uses natural gas, which produces lower carbon emissions.

The direct reduction of iron ore is the process of oxygen removal from ore without melting, usually using a mixture of carbon monoxide and hydrogen derived from natural gas.

About 55% of the current reduction gases in DR facilities (i.e., Midrex shafts) is hydrogen. By using pure green hydrogen, it is possible to produce carbon-neutral steel.

The Middle East and North Africa (MENA) region is potentially in a good position to begin producing carbon-neutral or green steel, as it has particular advantages over other areas in the world.

The MENA region is potentially in a good position to begin producing carbon-neutral or green steel.

Its steel sector is already dominated by DRI with an established supply of DR-grade iron ore. Technical barriers may make it difficult to ramp up DR-grade iron ore production to supply other regions.

The region produced just 3% of global crude steel in 2021 but it accounted for nearly 46% (55 Mt) of the world's DRI production. Further, some of the largest iron ore pelletising plants in the world are in MENA and supply of DR-grade pellets is not a hurdle, in contrast with other areas.

The International Energy Agency (IEA) in its Net Zero Emissions scenario models the global share of hydrogen-based (H_2) DRI-EAF production reaching 29% of primary steelmaking by 2050. BloombergNEF estimates that 56% (840 Mt) of primary steel production will come from H_2DRI-EAF by 2050 in a net zero emissions scenario.

MENA's transition to H_2DRI-EAF could commence immediately due to the region having more DRI plants than anywhere else globally.

Initially, it would be possible to replace 30% of natural gas with hydrogen in the incumbent fleet of DR plants without any major equipment modifications. The region could then move towards 100% green hydrogen to produce carbon-free steel.

MENA has excellent solar resources to aid in the production of green hydrogen via renewable electricity. The World Bank found MENA has the highest photovoltaic power potential capacity globally and could theoretically produce more than 5.8 kilowatt hours (kWh) per square metre daily.

[MENA's] access to rich solar energy resources will allow for production of green hydrogen at a competitive price.

IHS Markit forecasts that the region will add 83 gigawatts (GW) of wind and 334GW of solar by 2050, which will increase the respective share of power generation from the current 1% and 2% to 9% and 24%.

Access to such rich solar energy resources will allow for production of green hydrogen at a competitive price.

The cost of hydrogen production via electrolysis is currently lower than that for blue hydrogen in Middle Eastern countries.

As of July 2022, the cost of alkaline electrolysis in Qatar was US$2.59/kg, Saudi Arabia US$3.20, Oman US$3.55 and United Arab Emirates US$5.14. The cost of polymer electrolyte membrane (PEM) electrolysis is generally around US$1/kg higher than alkaline technology. The price of blue hydrogen, produced by the combination of steam methane reforming (SMR) and carbon capture and storage (CCS), is about US$7/kg in the Middle East.

According to IEA, with MENA's available capacity, producing green hydrogen below US$1/kg is achievable by 2050.

The process of switching MENA's DRI capacity to use green hydrogen instead of natural gas is simpler and cheaper when compared to switching from BF-BOF to DRI-EAF in other regions. Challenges for those areas include new investment costs in shifting from BF-BOF to DRI-EAF, management of the value chain including producing DR-grade iron ore pellets, and procurement of green hydrogen.

Demand for green steel is rising globally, led by European car manufacturers. With the European Union soon establishing a Carbon Border Adjustment Mechanism, MENA steel exports would have an advantage if they were zero carbon.

By 2026, EU importers of steel from outside the EU must purchase Carbon Border Adjustment Mechanism certificates, a regulatory framework that includes reporting of direct and indirect embedded emissions in final products.

As the DRI-EAF route has lower emissions than BF-BOF, MENA's producers are ahead in terms of their market positioning and will remain so if they accelerate the transition to carbon-free steel using the H_2DRI-EAF route.

If it acts fast, MENA has the potential to lead the world in green steel production.

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Acronyms

BF-BOF	Blast furnace-basic oxygen furnace
CBAM	Carbon Border Adjustment Mechanism
CCS	Carbon capture and storage
DEWA	Dubai Electricity and Water Authority
DRI	Direct reduced iron
DRI-EAF	Direct reduced iron-electric arc furnace
EAF	Electric arc furnace
EU	European Union
GCC	Cooperation Council for the Arab States of the Gulf, known as the Gulf Cooperation Council
GW	Gigawatt
H_2DRI-EAF	Hydrogen-based direct reduced iron-electric arc furnace
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
kWh	Kilowatt hour
LCOE	Levelised cost of electricity
LCOH	Levelised cost of hydrogen
LCOS	Levelised cost of steel
MENA	Middle East and North Africa
Mt	Million tonnes
MW	Megawatt
MWh	Megawatt hour
PEM	Polymer electrolyte membrane electrolysis
PV	Photovoltaic
SMR	Steam methane reforming
Syngas	Synthesis gas
T	Tonne

Introduction

The steel industry is responsible for 7% of total CO_2 emissions.[1] If global steel production were a country, it would be the third-biggest emitter in the world after China and the U.S.[2]

The likely game changer is using green hydrogen in steelmaking, a subject at the top of all recent steel decarbonisation studies.

So-called "green" steel is made possible by applying green hydrogen in the direct reduced iron (DRI) production process using electric arc furnaces (EAF)—powered by renewable energies—to melt it.

Some steel producers are still planning to move towards the DRI-EAF route as a promising solution to meet zero-emission ambitions. Middle East and North Africa (MENA)[3] steel producers have been using this technology for a long time. As production in these countries is already gas-based direct reduction, there are huge opportunities for decarbonising the process by shifting towards a green hydrogen-based (H_2) DRI-EAF to deliver green steel on a large scale.

MENA has a competitive position in the steel decarbonisation race.

MENA has a competitive position in the steel decarbonisation race from a technology viewpoint, being at least one step ahead of other steelmakers. However, new investment in renewables and consequently green hydrogen is essential to enable the transition.

Overview of Steelmaking Technologies

Steel is currently produced from three main processes. The most widespread is BF-BOF, in which iron oxide is reduced to iron inside a blast furnace with coke (derived from coking coal) as a reducing agent. The resulting pig iron is then processed into steel in a basic oxygen furnace, where oxygen is blown through the

[1] IEA. Iron and Steel Technology Roadmap. October 2020.
[2] Global Efficiency Intelligence. Global Steel Production Costs. January 2022.
[3] According to the World Bank classification, the MENA countries include: Algeria, Bahrain, Djibouti, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Qatar, Saudi Arabia, Syria, Tunisia, United Arab Emirates, West Bank and Gaza, and Yemen. The focus of this report is on the countries with active direct reduction or downstream facilities in the steel value chain.

molten, carbon-rich pig iron to reduce its carbon content. In 2021, 71% of global crude steel production was made via the BF-BOF process.[4]

Another primary steelmaking pathway is processing DRI into steel in an EAF. DRI is produced by the direct reduction of iron ore without melting, usually using a mixture of carbon monoxide and hydrogen derived from natural gas, although these can also be derived from gasified coal. Increasingly, steel companies are seeking to develop technology that uses 100% hydrogen in the DRI-EAF process. This potentially can be zero-carbon green hydrogen, produced via renewable energy-powered electrolysis once this technology becomes cost competitive.

As an alternative to primary steel manufacture, scrap steel can be used in EAFs to recycle and produce new steel. The scrap-EAF route (also called secondary steelmaking) is a technology that does not involve iron ore or coking coal. An EAF is charged with steel scrap where it is heated and melted to form new steel. The electricity powering EAFs can come from renewable sources, reducing carbon emissions for the scrap-EAF process to almost zero.

In 2021, steel produced from EAFs amounted to 29% of total global crude steel production. Some of this was produced via the DRI-EAF route in countries such as India and Iran but the majority came from the secondary scrap-EAF process.

Overview of MENA's Steel Industry

Production

In 2021, MENA accounted for nearly half of the world's DRI production. The region produced only 3% of global crude steel output, of which about 95% was based on EAF production, predominantly from DRI-EAF.[5] This is explained by the abundance of natural gas in the region as well as the lack of high-quality coking coal reserves.

Figure 1 illustrates DRI production around the world. MENA with more than 55 million tonnes (Mt) was highest followed by Asia and Oceania (including India) with about 39Mt.[6] India is the world's largest producer of DRI utilising gasified thermal coal, a more carbon-intensive process compared to gas-based technology.[7] Mexico, Russia and the U.S. are other significant producers.

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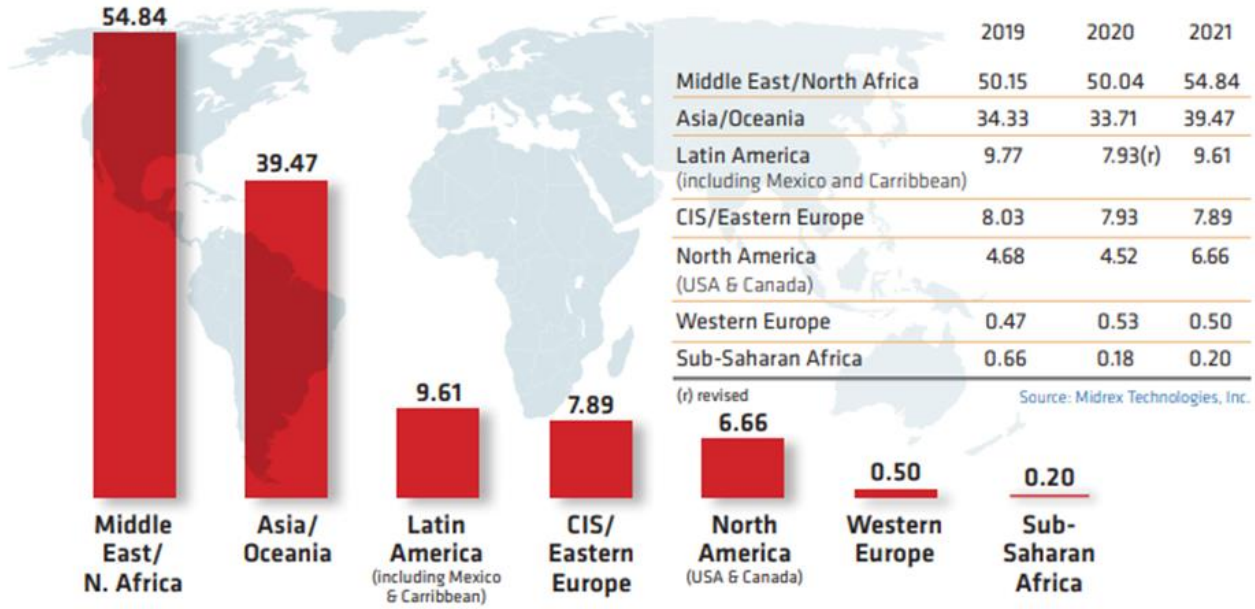
[4] World Steel Association. 2022 World Steel in Figures. 2022.
[5] World Steel Association. 2022 World Steel in Figures. 2022.
[6] Midrex. 2021 World Direct Reduction Statistics. 2022.
[7] IEEFA. India's technology path key to global steel decarbonisation. 14 February 2022.

Figure 1: World DRI Production by Region (million tonnes), 2021



Source: Midrex, 2021 World Direct Reduction Statistics, 2022.

Iran, Saudi Arabia and Egypt are the leading steel players in the MENA region, producing more than 80% of the region total. Table 1 shows MENA's production of crude steel and DRI in 2021.

The EAFs can also take DRI, scrap or even pig iron as a feedstock. In some countries, all steel production comes from the secondary process, scrap-EAF.

Producing one tonne of crude steel takes 1.11–1.17 tonnes of DRI. Steel producers generally use a combination of DRI and scrap in the steelmaking process. The conversion rate between DRI and crude steel and also a percentage of scrap charge define the feedstock mix and explains the gap between DRI production and crude steel production. In the Middle East, due to scrap insufficiency, the proportion of scrap charge is about 10% and the rest is DR-grade pellet.[8]

[8] Midrex. Maximizing Iron Unit Yield from Ore to Liquid Steel (Part 3) – Melting Practice. June 2020.

Table 1: MENA Crude Steel and DRI Production in 2021 (million tonnes)

Country	Crude Steel Production	Share of Electric Furnace (%)	Share of Basic Oxygen Furnace (%)	DRI Production*
Iran	28.5	90.3	9.7	31.85
Saudi Arabia	8.7	100	-	6.13
Egypt	10.3	100	-	5.23
UAE	3.0	100	-	3.66
Algeria	3.5	87.5 (2020)	12.5 (2020)	3.08
Oman	2.0	100	-	1.70
Bahrain	0.7	100	-	1.51
Libya	0.5	100	-	0.88
Qatar	1.2	100	-	0.79

*Source: World Steel Association and Midrex**
Note: At the time of writing, 2021 crude steel production figures for Bahrain, Libya and Qatar were not published and 2020 figures were applied.
Table excludes countries in the region that produce steel from scrap-EAF: Morocco, Tunisia, Kuwait, Jordan and Israel.

In 2021, the Middle East produced more than 45Mt of crude steel, with 94% produced from the EAF route and the rest from the BF-BOF route. Iran is the only country in the area that used BF-BOF with just 2.8Mt produced via this technology in 2021.[9] For North Africa, the proportions are almost similar.

Capacity Expansion

The International Energy Agency (IEA) modelled in its 2021 Net Zero Emissions scenario that H_2DRI-EAF's share of global primary steel production would reach 29% by 2050.[10] Under its own net zero by 2050 scenario, BloombergNEF models 56% of primary steel production would come from H_2DRI-EAF by 2050, equivalent to 840Mt annually.[11]

The current global share of the DRI-EAF route is less than 5%, yet the future appears bright for this technology and MENA is likely to be one of the leading players due to the region's competitive advantages.

In 2020, steelmaking capacity in the Middle East increased by 7.2Mt. It will rise further in the coming decades mainly due to the expansion of Iran's steel sector. Iran, the largest steelmaker in MENA, is targeting an increase in steelmaking capacity and crude steel production from the current 29Mt to 55Mt by 2025.[12] Almost all new capacities under development are gas-based DRI-EAF.

[9] World Steel Association. 2022 World Steel in Figures. 2022.
[10] IEA. Net Zero by 2050 Scenario. May 2021.
[11] BloombergNEF. Decarbonising Steel. A Net-Zero Pathway. 1 December 2021.
[12] OECD. Latest Development in Steelmaking Capacity. 2021.

In Northern Africa, most of the expansion projects are based on EAF and, due to the pandemic causing delays in commissioning, capacity in this part of MENA is growing more slowly.

Emissions

MENA's steel industry is relatively low carbon compared to the rest of the world, where steel production is dominated by blast furnaces using coal, both as a source of energy and iron ore reduction.

According to IEA, direct and indirect carbon emission of BF-BOF is 2.2 tonnes per tonne (t/t) of crude steel while the DRI-EAF emits 1.4 t/t.[13]

MENA's steel industry is relatively low carbon compared to the rest of the world

As natural gas has more hydrogen molecules than coal, reduction of iron ore in the gas-based DRI-EAF is primarily achieved via hydrogen, with water as a by-product. In blast furnaces, the reduction gas is carbon monoxide, which after reacting with oxygen in the iron ore produces carbon dioxide as a by-product. Hydrogen accounts for about 55% of the current reducing gases (or syngas) produced from natural gas in the Midrex DR facilities. By substituting syngas with "green" hydrogen, it is possible to produce carbon-neutral steel.[14]

Exports

Most countries in MENA are developing nations with an increased demand for steel, resulting in relatively high domestic consumption. MENA steel producers could also export to markets where there is a growing demand for green steel, such as the European automotive industry.

Recent announcements of cooperation between steel producers and automakers, coupled with pledges for carbon neutrality, are signs of this movement. Volvo,[15]

[13] IEA. Iron and Steel Technology Roadmap. October 2020.
[14] Midrex. Transitioning to the Hydrogen Economy: 1st Quarter 2020. 2020.
[15] Volvo. Volvo Group launches world's first vehicle using fossil-free steel. 13 October 2021.

Mercedes,[16] BMW,[17] General Motors[18] and Volkswagen[19] are among the most ambitious manufacturers.

In 2020, Africa and the Middle East were net importers of steel.[20] However, in some specific products, for example flat steel products, they could play a role in the regional and global market.

From 2026, EU importers of steel from outside the EU need to purchase Carbon Border Adjustment Mechanism (CBAM) certificates. The EU has set out the regulatory framework for steel importers to include reporting direct and indirect embedded emissions in the final products.[21]

As the DRI-EAF route has lower emissions than BF-BOF, MENA's producers are already in a good place in terms of market positioning. They could enhance their competitive advantage in an increasingly carbon-constrained world by accelerating their transition to carbon-free steel from the H_2DRI-EAF route.

Power Supply and Renewables

Decarbonising steel relies on changing the source of energy used in the process.

Producers have been using carbon—mainly in the form of coal globally, and natural gas in MENA—to produce steel from iron ore. Almost all breakthrough technologies in steelmaking remain technically dependent on electricity, and the H_2DRI as a green solution is no exception.

As the cost of renewable energy has fallen dramatically in the past 10 years, solar photovoltaic (PV) and onshore wind could now compete with fossil-based electricity (generated from coal or natural gas) in most regions.[22]

The MENA region is blessed with reliable solar radiation

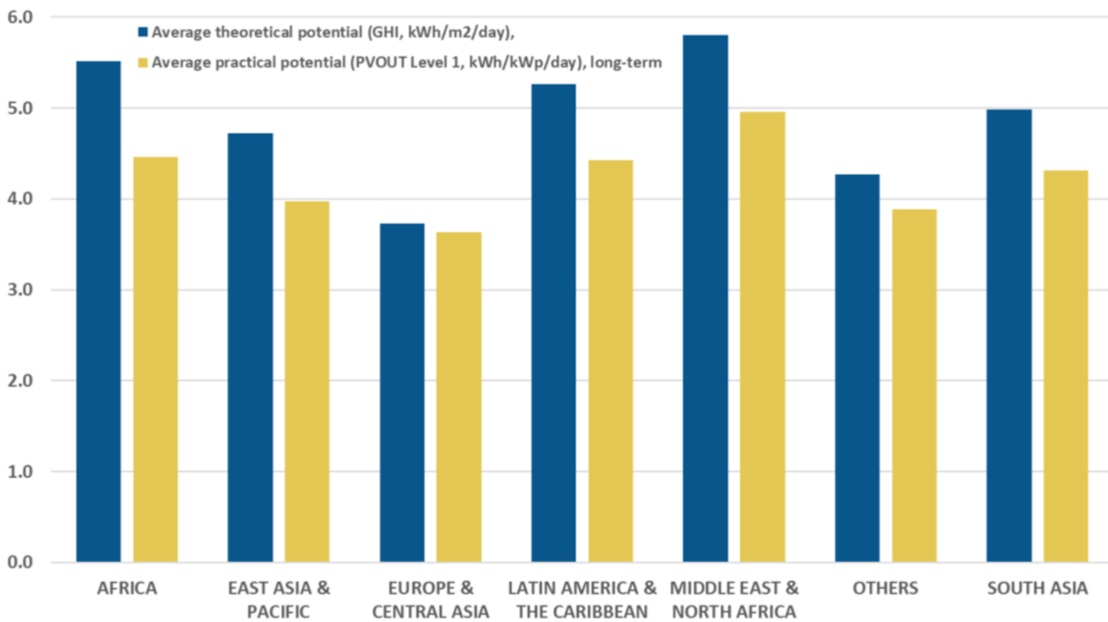
As with the region's steel industry, electricity production in MENA predominantly relies on gas-fired power plants. MENA's share of renewable energy

[16] Mercedes-Benz Group. From 2025: "Green" steel for Mercedes-Benz. 27 May 2021.
[17] BMW Group. BMW Group significantly increases use of low-carbon steel in series production at European plants. 1 February 2022.
[18] General Motors. General Motors, the Largest U.S. Automaker, Plans to be Carbon Neutral by 2040. 28 January 2021.
[19] Volkswagen Group News. Volkswagen Group and Salzgitter AG sign Memorandum of Understanding on supply of low-CO2 steel from the end of 2025. 21 March 2022.
[20] World Steel Association. 2021 World Steel in Figures. 2021.
[21] Shearman and Sterling. CBAM and revised EU ETS: Implications for the steel industry. 10 August 2021.
[22] IRENA. Renewable Power Generation Costs in 2020. June 2021.

is currently much lower than the global average, though the region has high potential for solar energy.[23]

In fact, MENA has the highest PV power potential globally,[24] according to the World Bank (Figure 2).

Figure 2: Global Photovoltaic Power Potential by Region



Source: World Bank.

Renewable investment has been gaining momentum in MENA predominantly due to the dramatic reduction in the cost of solar PV projects. The global levelised cost of solar electricity (or LCOE) has fallen from US$0.381/kWh in 2010 to US$0.057 in 2020—that is, an 85% reduction in 10 years. In 2020 the bids for solar PV recorded some new low prices in the Middle East from US$0.0157/kWh in Qatar to US$0.0135 in the United Arab Emirates (UAE) and even 0.0104 in Saudi Arabia. The International Renewable Energy Agency (IRENA) assessed that producing solar PV electricity in the Middle East at US$0.01/kWh is possible.[25]

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[23] World Bank. Global Solar Atlas. Solargis. 2022.
[24] World Bank. Global Photovoltaic Power Potential by Country. June 2020.
[25] IRENA. Renewable Power Generation Costs in 2020. June 2021.

Major projects are under construction in Saudi Arabia, Morocco, UAE, Israel and Egypt. IEA estimates that MENA's renewable energy capacity growth will double over the 2021–2026 period compared to the previous five years and reach 32GW, up from 15GW.[26]

Some of the latest renewable announcements in MENA include:

- Saudi Arabia's Al Qassim solar project has 1GW capacity and is estimated to cost US$450 million.[27] The Sudair, another solar farm with 1.5GW capacity, was announced with joint investment from Aramco, the Kingdom's sovereign wealth fund and ACWA Power.[28] Saudi Arabia plans to reach 50% renewable energy by 2030[29]—an ambitious target for the kingdom to reduce its dependence on fossil fuels.

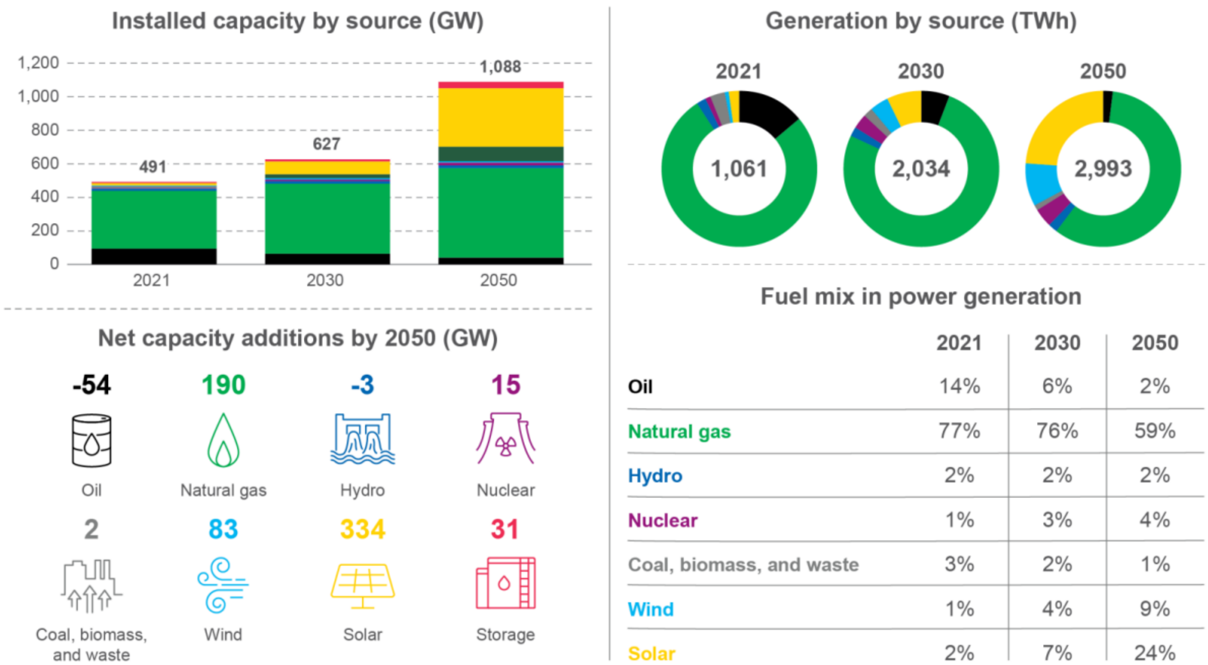
- UAE wants to invest more than US$163 billion in renewables[30] to reach an ambitious target of 44% clean energy in the 2050 energy mix.[31] Al Dhafra announced a 2GW solar PV project with expected completion in 2022. Running at full capacity it could reduce carbon emissions by 2.4Mt annually.[32]

- Manah I and II solar parks in Oman with a combined capacity of 1GW are expected to become operational in 2024. The initial investment was US$780.2 million.[33]

New renewable capacities will change the power mix in MENA by 2050. IHS Markit forecasts that 83GW of wind and 334GW of solar capacities will be added by 2050, which will increase the respective shares of wind and solar from 1% and 2% to 9% and 24% (Figure 3).[34]

[26] IEA. Renewables 2021. December 2021.
[27] S&P Global. Saudi Arabia awards 1 GW solar power projects. 7 March 2022.
[28] S&P Global. Saudi Aramco joins local 1.5 GW solar project with a 30% stake in renewables push. 15 August 2021.
[29] Kingdom of Saudi Arabia. A Sustainable Saudi Vision 2030. n.d.
[30] Reuters. UAE launches plan to achieve net zero emissions by 2050. 8 October 2021.
[31] UAE Government Portal. UAE Energy Strategy 2050. 12 October 2021.
[32] Power Technology. Al Dhafra Solar Project, Abu Dhabi. 17 August 2020.
[33] Renewables Now. Oman's 1-GW Manah solar parks to go online by Q4 2024 – report. 8 November 2021.
[34] IHS Markit. Middle East and North Africa Power and Renewables Market Briefing. April 2022.

Figure 3: Power Market in MENA



	2021	2030	2050
Oil	14%	6%	2%
Natural gas	77%	76%	59%
Hydro	2%	2%	2%
Nuclear	1%	3%	4%
Coal, biomass, and waste	3%	2%	1%
Wind	1%	4%	9%
Solar	2%	7%	24%

Source: IHS Markit.

Green Hydrogen

Among the most promising sources of sustainable future energies, green hydrogen has significant potential applications including heat, transportation, power generation and manufacturing.

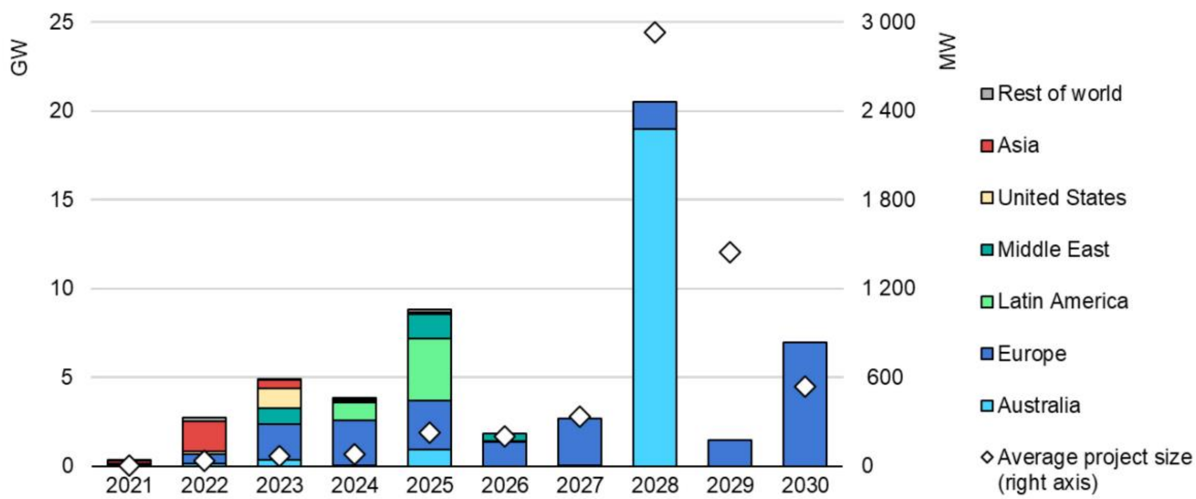
Green hydrogen is produced from water electrolysis, by splitting the bond between hydrogen and oxygen in water molecules. Producing green hydrogen requires the use of renewable electricity and it has yet to reach global price competitiveness.

Capacity and Future Potential

With the global energy transition accelerating, green hydrogen has become one of the most important investment options in the energy sector. The IEA predicts that by 2030, the installed global capacity of electrolysers will reach 54GW and the Middle East with 3GW will sit below Europe, Australia and Latin America.[35]

[35] IEA. Global Hydrogen Review 2021. October 2021, p. 117.

Figure 4: New Installed Electrolyser Capacity Based on Projects Under Construction or Planned, 2021–2030



Source: IEA, Global Hydrogen Review 2021.

The MENA region is developing export-oriented hydrogen projects. Saudi Arabia and Morocco are among the nations best placed to emerge as major green hydrogen producers by 2050.[36]

In most MENA countries, and specifically in the Gulf Cooperation Council (GCC) countries,[37] the hydrogen consumption rate could be lower than domestic production capacities, providing huge potential for export.[38]

Project Announcements

The global shift towards renewables is prompting fossil fuel-reliant countries and regions to review long-term strategies. Reflecting that transition, large energy companies in MENA are announcing green electricity and green hydrogen projects.

In the most recent announcements, Fortescue—one of the world's first movers in the green hydrogen industry—revealed a new investment in the MENA region. The company disclosed its intention to build a 9.2GW wind and solar green hydrogen facility in Egypt.[39] Fortescue has already announced different green hydrogen

[36] Renew Economy. How renewable hydrogen could shake up the geopolitics of energy. 17 January 2022.
[37] The six member states of the GCC are Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates.
[38] Strategy&. The dawn of the green hydrogen: Maintaining the GCC's edge in a decarbonized world. 2020.
[39] Renew Economy. Fortescue looks to build 9.2GW wind and solar green hydrogen project in Egypt. 11 September 2022.

projects in Australia, now expanding its business in other areas with natural capacities for renewables.

In May 2021, Siemens Energy, the Dubai Electricity and Water Authority (DEWA) and Expo 2020 Dubai commenced the operation of MENA's first green hydrogen plant powered by electricity from the Mohammed bin Rashid Al Maktoum Solar Park.[40] The solar park will produce 5GW of green electricity by 2030 and will be one of the largest in the world.

In August 2021, Emirates Steel and Abu Dhabi National Energy Company PJSC (TAQA) signed a memorandum of understanding to establish green hydrogen facilities to produce the first green steel in MENA.[41]

Saudi Arabia, with the aim of becoming the world's largest hydrogen producer, announced in October 2021 it would use a US$110 billion gas field to produce blue hydrogen.[42] By 2026, Saudi Arabia plans to begin green hydrogen production from a plant with a daily capacity of 650 tonnes, which could be the largest of its kind.[43] This plant, with an initial US$5 billion investment, will be powered by solar and wind power with a capacity of about 4GW.[44]

In June 2021, Oman also announced plans to construct a new green hydrogen plant. A consortium consisting of the state-owned oil and gas company OQ, the Hong Kong-based renewable hydrogen developer InterContinental Energy, and Kuwait-based energy investor Enertech will invest US$30 billion to 2038 with the aim of producing 1.8Mt of green hydrogen and up to 10Mt of green ammonia.[45]

The SalalaH2 project is another green hydrogen and ammonia project in Oman, with a 400MW electrolysis capacity and US$1 billion investment.[46]

Helios' project KIZAD in UAE, ACME green ammonia megaproject and HyPort Duqm in Oman, MASEN Pilot project in Morocco and Scatec Fertiglobe H_2 Project in Egypt are among other hydrogen projects in the early stages of planning.[47]

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[40] Government of Dubai. Dubai inaugurates Green Hydrogen project at Mohammed bin Rashid Al Maktoum Solar Park. 19 May 2021.
[41] TAQA. TAQA Group, Emirates Steel to Enable the Region's First Green Steel Manufacturing. 3 August 2021.
[42] Bloomberg. Saudi Arabia to Use $110 Billion Gas Field for Blue Hydrogen. 24 October 2021.
[43] Financial Times. Can Saudi Arabia become the world's biggest hydrogen producer? 14 February 2022.
[44] Bloomberg. Saudi Arabia to Start Building Green Hydrogen Plant in Neom. 17 March 2022.
[45] The Guardian. Oman plans to build world's largest green hydrogen plant. 27 May 2021.
[46] Oman Observer. 1bn project to create green ammonia export hub in Salalah. 13 December 2021.
[47] IHS Markit. Middle East and North Africa Power and Renewables Market Briefing. April 2022.

Upscaling

Having access to cheap solar energy is a regional competitive advantage for MENA countries in the future hydrogen economy. Scaling up solar power capacities to produce green hydrogen is a big challenge although the MENA region has two main advantages: land availability and solar radiation.

Access to cheap solar energy is a regional competitive advantage for MENA countries in the future hydrogen economy.

As PV solar can only produce electricity in daylight, the capacity factor for this technology is 22% to 25%. Compared to the scenario of using grid electricity, increasing the capacity for PV solar and electrolysers to produce the same amount of electricity and green hydrogen is inevitable.

It is estimated that about 1.2 to 1.3GW electrolyser capacity in full load (using grid electricity) is needed to produce 4Mt hydrogen-based steel in Europe. However, using solar PV instead of grid electricity, the electrolyser's capacity would rise to 4.5 to 5GW.[48]

As there is higher solar energy potential in MENA, hydrogen-based steelmaking could break even the transition to green steel at a lower price than European contenders.

Table 2 illustrates the difference between a European and North African country in terms of needed capacities and cost of production to change technology in a steel plant with an annual capacity of 4Mt from BF-BOF to H_2DRI-EAF using green hydrogen. Based on calculations by Hydrogen Europe, Tunisia requires 31% lower PV solar capacity and consequently lower electrolyser capacity.[49]

Table 2: Impact of Location Choice on Hydrogen Price

Item	Romania	Tunisia
PV installed power (GW)	6.4	4.4
PV LCOE (€/MWh)	44	29
Electrolysis power (GW)	4.5	3.3
Hydrogen LCOH (€/MWh)	4	2.9
Required storage (t)	47,000	20,500
Storage cost (€/kg)	0.9	0.36
H2 delivery price (€/kg)	5.3	3.7

Source: Hydrogen Europe, Steel from Solar Energy.

[48] Hydrogen Europe. Steel from Solar Energy. May 2022.
[49] Ibid.

Cost

The cost of hydrogen production via electrolysis is currently lower than blue hydrogen in Middle Eastern countries. In July 2022, the cost of alkaline electrolysis in Qatar was US$2.59/kg, Saudi Arabia US$3.20, Oman US$3.55 and UAE US$5.14.

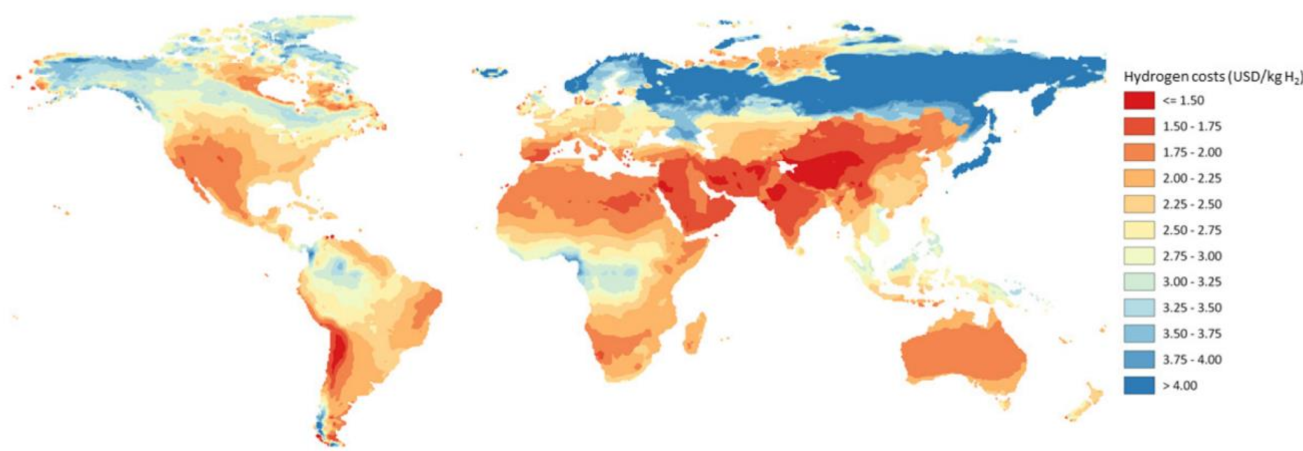
The cost of polymer electrolyte membrane (PEM) electrolysis is generally around US$1/kg higher than alkaline technology. The price of blue hydrogen, produced by the combination of steam methane reforming (SMR) and carbon capture and storage (CCS), is about US$7/kg in the Middle East.[50]

By 2050, the hydrogen price could fall to US$1/kg in the Middle East countries

The IEA foresees the Middle East as an area with scope for the lowest cost of green hydrogen production.

The IEA reported that by 2030 the cost of hydrogen production in the Middle East powered by solar PV could be less than US$1.5/kg based on capital expenditure of US$320/kW and electricity at US$17/MWh. By 2050, the hydrogen price could fall further to US$1/kg as the capex and electricity costs decrease to US$250/kW and US$12/MWh.[51]

Figure 5: Hydrogen Costs from Hybrid Solar PV and Wind Systems in 2030

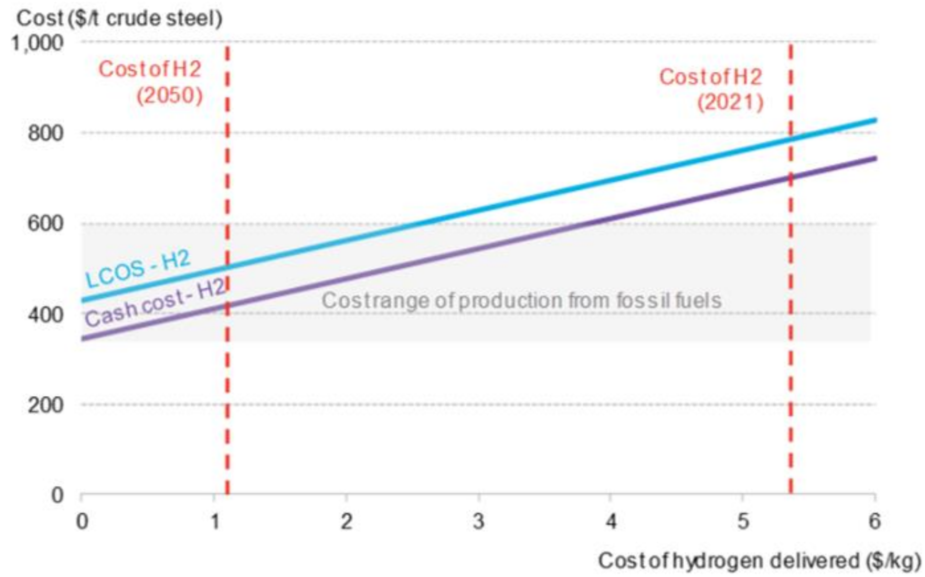


Source: IEA, Global Hydrogen Review 2021.

[50] S&PGlobal. Platts hydrogen price wall. July 2022.
[51] IEA. Global Hydrogen Review 2021. October 2021.

BloombergNEF suggests that with delivered green hydrogen priced below US$1.5/kg, H_2DRI-EAF technology could be cost competitive by 2050.[52]

Figure 6: Levelised Cost of Steel (LCOS) with Green Hydrogen Price, 2050



Source: BloombergNEF.
Note: Capex, opex and hydrogen prices assumptions are based on Germany.

As MENA could produce hydrogen domestically, the cost of transportation to steel producers could be lower than other areas. Based on the hydrogen carrier and the distance, the transportation price varies. MENA has good infrastructure and pipelines that could facilitate cheaper transportation domestically.

DR-grade Pellet Supply

DRI-EAF technology currently needs a different feedstock to meet rigid specifications for quality and physical properties. The DR-grade pellet must contain at least 67% of iron, requiring further processing of iron ore. Some steelmakers are investigating new technology combinations that could allow use of lower-grade iron ore in DRI process.[53]

MENA's steel and mining sector has already invested in the upstream value chain and can supply the high-quality pellets to feed steel companies.

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[52] BloombergNEF. Decarbonising Steel Technologies and Costs. 25 August 2021.
[53] IEEFA. Solving iron ore quality issues for low-carbon steel. 9 August 2022.

Iran is the largest pellet producer in MENA, with its capacity mostly captive to domestic DR plants. Iran produced 46Mt of pellets in the year to March 2021, all for domestic plants.[54] In the 10-month period ending 20 January 2022, Iran produced 31Mt of iron ore pellets.[55] Domestic mines supply the iron ore concentrate for pelletising plants.

Iran is the largest pellet producer in MENA, with its capacity mostly captive to domestic DR plants.

Other large pelletising plants with extra capacity to supply the market are in Oman and Bahrain.

Bahrain Steel is one of the major MENA DR-grade pellet suppliers with a production record of 12Mt in 2021. This plant imports iron ore from Brazil, Canada and Sweden. Most of the pellets are exported to MENA steel producers.[56]

Vale, the world's largest producer of iron ore pellets, operates a pelletising plant in Oman that mainly processes iron ore concentrate from Brazil. In 2021, this plant produced 8.2Mt.[57]

The remaining DR-grade pellet demand is met by Swedish pellet producer LKAB, Canadian producer IOC, Metinvest and Ferrexpo from Ukraine and Russia's Metalloinvest, among others.[58]

Net Zero Pledge

Some MENA countries are committed to the Paris Agreement and working on net zero emission ambitions.

Saudi Arabia, the world's largest oil producer and exporter, pledged to net zero emissions by 2060,[59] a less ambitious target than those of Japan, the EU and the U.S., which aim for 2050. The UAE, which will host COP28 in 2023, was the first country in the Middle East to announce zero emissions by 2050, with an interim target to reduce emissions by 23.5% by the end of this decade.[60] Oman committed to zero emissions by 2050 and Bahrain by 2060.

Iran is the world's largest gas-based DRI producer and has not made a net-zero target pledge.[61]

[54] Iran Daily. Iran's 12-month iron pellet production tops 46m tons: IMIDRO. 21 April 2021.
[55] Iran Daily. Iran's 10-month iron pellet output surpass 31m tons: IMIDRO. 21 February 2022.
[56] Bahrain Steel. Record Production of 12 Million Tons of Iron-Ore Pellets in 2021. 23 January 2022.
[57] Vale. Vale's Production and Sales in 4Q21 and 2021. February 2022.
[58] International Iron Metallics Association. The Global HBI/DRI Market: Outlook for seaborne DR Grade pellet supply. 16 December 2020.
[59] Climate Home News. Saudi Arabia pledges net zero by 2060, but no oil exit plan. 25 October 2021.
[60] Sustainable future. The Middle East: COP26 and the journey to net zero. 20 December 2021.
[61] Aljazeera. Iran's failure to tackle climate change – a question of priority. 9 November 2021.

Almost all North African countries have no commitment to net zero emissions. Egypt presented its national climate change strategy at COP26 without a commitment to net zero emissions.[62]

One of the main challenges of transitioning in MENA is the lack of government support. Some of these countries are relying on international communities and funds for investment in green technologies.

Almost all North African countries have no commitment to net zero emissions.

Headwinds

In addition to the technical barriers of using hydrogen for DRI production on a commercial scale, other headwinds include the supply of DR-grade pellet for further expansion projects, scaling up the renewables and green hydrogen value chain and the fact that MENA is a water-stressed region.

A significant scaling up of global DRI capacity using green hydrogen to reach net zero emissions in 2050 will require much more iron ore suitable for DRI. The average quality of iron ore has been in decline for years as mining has depleted higher grades.[63]

Although MENA has access to DR-grade pellet for the current capacity of DR plants, any further development and capacity increase must be planned simultaneously with the aim of balancing the whole value chain based on H2DRI-EAF.

Scaling Up Renewable and Electrolyser Capacity

Producing one million tonnes of green steel based on H_2DRI-EAF technology requires solar PV and electrolyser with an annual capacity above 1GW.[64] Regarding the capacity of projects currently in the pipeline, changing the DRI-EAF fleet to a hydrogen-based process supported by renewables is a big challenge even in the MENA region.

The solar PV and electrolysers also occupy hectares of land. A 1GW PV installation covers more than 6000–8000 acres,[65] a matter of lesser importance in the MENA area given the expanse of uninhabited lands with ample sunlight to allocate to this purpose.

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[62] Energy Monitor. COP27: Does Egypt have what it takes to ramp up global climate action? 17 February 2022.
[63] IEEFA. Iron Ore Quality a Potential Headwind to Green Steelmaking. June 2022.
[64] Hydrogen Europe. Steel from Solar Energy. May 2022.
[65] Green Coast. Solar Farm Land Requirements: Top 7 Tips for Farmers, Ranchers, and Landowners. 5 December 2021.

Water Scarcity

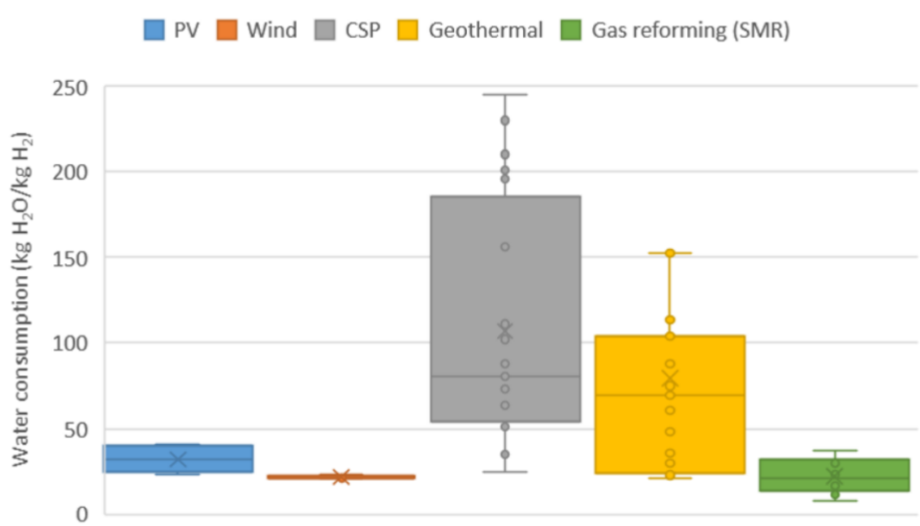
Twelve of 17 countries with extremely high baseline water stress are in MENA.[66] Locating in such arid areas is a challenge for any industry.

Under the impact of climate change, water scarcity has worsened and the area is facing an unprecedented challenge. More than 70% of MENA's GDP is produced in high water-stressed areas, with water scarcity likely to continue to affect economies.[67]

To produce 1kg of green hydrogen via solar PV and wind requires on average about 32kg and 22kg of water, respectively. These figures include total consumption for all production and process water (electrolysis) as well as the water needed in energy production. This is comparable to the water used in the production of hydrogen from natural gas—22kg per kg of hydrogen on average (Figure 7).[68]

More than 70% of MENA's GDP is produced in high water-stressed areas

Figure 7: Life Cycle Water Consumption for Various Hydrogen Production Pathways



Source: energypost.eu

[66] World Resource Institute. 17 Countries, Home to One-Quarter of the World's Population, Face Extremely High Water Stress. 6 August 2019.
[67] Unicef. Running dry: The impact of water scarcity on children in the Middle East and North Africa. August 2021.
[68] Energy Post. Hydrogen production in 2050: how much water will 74EJ need? 22 July 2021.

Even with exponential growth in the water consumption needed for electrolysers, global green hydrogen demand for water will still be far lower than other sectors. In 2050, irrigated agricultural, industrial consumption and municipal water usages are estimated to be 2,769, 768 and 464 billion cubic metres respectively, while for producing hydrogen, the water demand would be 25 billion cubic metres.[69]

Despite hydrogen's small global share in total water demand, it could be difficult to supply water as a feedstock reliably in MENA due to scarcity.

Most GCC countries take their water from desalination plants. About 50% of the world's desalination capacity is in MENA and Saudi Arabia is the largest producer of desalinated water.[70] Wastewater treatment, recycling and reuse are among solutions adopted recently by industrial sectors to augment supply.

The IEA suggests that added energy input via desalination could increase the total cost of hydrogen production by only US$0.01–0.02/kg. As such, water is not included as a main cost driver.[71]

In another study IRENA found using desalination plants in water-scarce regions will increase the cost of hydrogen production by US$0.05/kg, which is negligible.[72]

Conclusion

Developed nations including Australia, Germany, the U.S. and China have been the first movers in the green hydrogen breakthrough, though MENA could be a global leader of steel decarbonisation if the region shifts promptly towards green hydrogen and renewables.

There is no single solution for rapid steel decarbonisation. Tailored solutions are required for each country's capabilities and competitive economic advantage.

As well as producing green hydrogen for export, the MENA region could also use more domestically to produce low-carbon steel for export.

Providing green electricity, a big challenge for steel producers in some parts of the world, is less of a barrier in MENA.

Providing green electricity, a big challenge for steel producers in some parts of the world, is less of a barrier in MENA.

[69] Ibid.
[70] World Bank Group. Beyond Scarcity: Water Security in the Middle East and North Africa. 2018.
[71] IEA. Global Hydrogen review 2021. October 2021.
[72] IRENA. Global Hydrogen Trade to Meet the 1.5°C Climate Goal: Green Hydrogen Cost and Potential. May 2022.

With ample renewable energy potential, MENA could become a leader in hard-to-abate and carbon-intensive industries, specifically steel.

Compared to other regions, MENA has in situ capacity of DRI-EAF, which means no extra investment is needed to replace the base technology. All new investment could be focused on producing green hydrogen and expanding renewables.

MENA could possibly replace 30% of its natural gas with hydrogen in the existing fleet of DR plants without major modification of the equipment, then move towards 100% green hydrogen in a second phase.[73]

Many mining companies face the challenges of iron ore quality and the production of DR-grade pellets. The former is not an issue in MENA, though finding reliable resources for future expansion could be a challenge for steel producers in this region.

MENA's knowledge of this specific steel technology is an invaluable asset. Among the most important steel decarbonisation pillars, this production knowledge, coupled with further work on iron ore beneficiation, pelletising and DR plants, will greatly assist MENA's green transition.

[73] Midrex. The Winding Road Toward Zero-Carbon Iron. December 2021.

About IEEFA

The Institute for Energy Economics and Financial Analysis (IEEFA) examines issues related to energy markets, trends and policies. The Institute's mission is to accelerate the transition to a diverse, sustainable and profitable energy economy. www.ieefa.org

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