Opportunities and Challenges of the Hydrogen Economy in the GCC

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1. Overview of hydrogen and relevance for the Gulf States

2. Hydrogen economy’s opportunities in the GCC

3. Hydrogen economy’s challenges in the GCC

4. The economics

5. Strategy and policy Implications
Introduction: Rising Importance of Hydrogen for Energy

• The energy transition, climate change mitigation, energy security
• Cannot be found alone so production requires extraction
• An energy carrier or storage medium rather than an energy source in itself
• Required as a clean feedstock in industry when recycling captured carbon

Advantages:
• Abundance
• 33.33 kWh/kg H2 vs. 12 kWh/kg petrol and diesel
• Versatility
• low carbon

Challenges:
• Expensive to extract and roll out
• Storage
• Transportation
• Safety and flammability

Hydrogen production paths and potential uses. Source: Shehabi (2021, work in progress).
Global Hydrogen Demand and Supply

- Vast majority of hydrogen is produced from fossil fuels without CO₂ capture
- Increased focus on green H₂, $150 billion worth of green hydrogen projects, possibly increasing with net zero emission target

Source: IEA (2019).

Source: Hydrogen Council (2018)
Are GCC States Lagging Behind?

By 2021, 20 countries adopted national hydrogen strategies

**Domestic** (China, France, Germany, Japan, Norway, South Korea, UK, the EU); **Export** (Australia, Brunei, China, Netherlands).

- 2017: Air Liquide purification plant supplies hydrogen to oil refinery
- Aramco and Air Products to build the first hydrogen fuel cell vehicle fueling station in KSA
- 2018: Jazan Greenfield Integrated Gasification Combined Cycle (IGCC) power plant project producing power, “grey” hydrogen, and utilities for Saudi Aramco
- 2020: shipped its maiden blue ammonia cargo to Japan to burn possibly together with coal and natural gas for zero-carbon power generation
- 2020: Neom: Helios Green Fuels Project $5 b plant owned by Air Products, Saudi’s ACWA Power and Neom; to power a green hydrogen plant using 4 GW of renewable electricity; produce 650 tons of green hydrogen and 3,000 ton of ammonia daily
- 2020: Neom: Germany to supply a 20 megawatt (MW) electrolysis plant

- 2019: MoU between Dubai Electricity and Water Authority (DEWA), Expo 2020 Dubai and Siemens for the first solar-driven hydrogen electrolysis facility
- 2020: Announced investments in green and blue hydrogen projects including a fledgling fuel cell electric vehicles (FCEVs) fleet
- 2020: Hydrogen alliance (ADNOC, sovereign wealth fund Mubadala Investment Co., and ADQ)
- 2020: UAE’s NDC to the UNFCCC confirmed standards for electric, hydrogen and autonomous vehicles are under development. Reduction of 23.5% in GHG emissions by 2030.
- 2020: A national hydrogen economy strategy
- 2020: Signed a Hyport Cooperation Agreement with DEME Concessions and OQ Alternative Energy to develop a green hydrogen plant in Special Economic Zone at Duqm
- 2021: ACME Group to invest $2.5bn for a facility to produce 2,200 m tonnes of green ammonia/day in Duqm.

- 2018-2019: KISR earned patent for enhancing magnesium’s hydrogen storage for use in fuel cells; launched 1st prototype electric vehicle fueled by hydrogen stored in magnesium hydride (MgH2) MgH2), a nanoscale metal hydride.
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Opportunities

1. Potential existing markets and opportunity for capturing lost oil export demand
   - Comparative advantage in hydrocarbons
   - Well-established export trade in energy
   - Synergies and cost savings via retention of oil and gas skills, infrastructure, and assets
   - Proximity to hydrogen markets:
     - Access to low cost natural gas
     - Access to depleted oil wells for CCUS

2. Potential comparative advantage in blue hydrogen
   - Comparative advantage in hydrocarbons
   - Well-established export trade in energy
   - Synergies and cost savings via retention of oil and gas skills, infrastructure, and assets
   - Proximity to hydrogen markets:
     - Access to low cost natural gas
     - Access to depleted oil wells for CCUS

3. Potential comparative advantage in green hydrogen

4. Potential nuclear-hydrogen nexus; least competitive

5. Opportunity for CCUS

6. Environmental opportunity to abate emissions

Direct normal irradiation (kWh/m2/yr)

Source: IEA (2018)

Source: IRENA (2018)
Hydrogen Opportunity 1: Capturing Lost Export Demand

Triple challenge of declining export revenue

- Increased domestic consumption
- Consistent low oil price
- Uncertainty in demand (e.g., COP 26, net zero emissions targets, national climate commitments)


Sources: Shehabi calculations based on national budgets, data from IMF (2020).
For Oil Exporters, Two Types of Hydrogen Products in a Decarbonizing World

- **Fossil fuels** ↓↓ ↓?
  - *Subject to prices, taxes, policies, and markets*
  - \( \uparrow \text{H2 demand competitive with fossil fuel} \)
  - \( \uparrow \text{H2 Demand (blue & green)} \)
  - \( \downarrow \text{H2 (grey)} \)
  - \( \uparrow \text{Renewables} \)

- **Renewables**

**Accelerated energy transition 2030**

**Current 2020**

*Drawing not to scale; demonstrative only*
Potential Market Size

- **2050:**
  - 13%-27% of total energy demand
  - US$400-700 b (hydrogen & products)
  - Potential market US$70-200 billion*
    *Assuming price of $1.5-2/kg of hydrogen

- **New exports?** Hydrogen exports vs. hydrocarbon exports?
  - 15% of global energy demand has hydrogen applications compete with other low carbon alternatives by 2030
  - Hydrogen to displace 10% of global energy demand by 2040 (1,400 Mtoe)

- **Example in transportation:** 1% commercial vehicles covert to hydrogen (2.6 million)
  - Require 50 plants the size of NEOM

- Larger market size if fuel economy-adjusted price parity with gasoline
  - In 2025, 1 kg of hydrogen (~ 0.26 gallons of petrol) could be dispensed for $6-$8.50
• Possible opportunity for storage depending on geological circumstances

• Cost savings and economic benefits of CCUS in domestic uses
  – Decarbonised gas supplies to create a secure, flexible, low carbon energy mix
  – Reduce costs of fully electrifying homes and fully electrifying large vehicles
  – CCUS infrastructure are a prerequisite for developing Greenhouse Gas Removal (GGR) technologies
  – Geological assessments for storage
  – Lower costs for lower transportation distances (onshore storage near production) and reusing existing pipeline & storage

• Needs to be provide a back up with other low/zero carbon technologies

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**Country** | **NDCs** | **NCs** | **Energy** | **Oil & Gas** | **Other industries**
--- | --- | --- | --- | --- | ---
Bahrain | CCUS |  |  |  | Refinery, Petrochemical
Kuwait | CCS | CCS | EOR |  | Desalinated water generation
Iraq | CCS | CCS |  |  | Cement, Ammonia, Iron
Qatar | CCS |  | Research Project on CCS technologies |  | 
Oman |  | EOR |  | Research and development | 
Saudi Arabia | CCUS | CCUS | EOR |  | Research Projects; Petrochemica
UAE | CCUS | CCUS | EOR |  | Masdar CCS Network, Steel and Oil Field

Source: ESCWA (2016)

Source: Fuel Cells (2020)
Outline

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Challenges

1. Low R&D Budgets & Innovation:
   - Low funding, high oligopolistic industries, public dominance in energy

![Graph showing government RD&D budgets for hydrogen and fuel cells]

Notes: Government spending includes European Commission funding, but does not include sub-national funding, which can be significant in some countries. Data for 2018a is estimated. RoW = rest of world.

Source: IEA (2018a), R&D Statistics.
1. Low R&D Budgets & Innovation:
   - Low funding, high oligopolistic industries, public dominance in energy

2. Low renewable power generation

3. Limited water resource,
   - Limited fresh water, limited renewable sources to desalinate water, high energy and economic costs for desalination

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**Table: Renewable Energy (RE) Summary**

<table>
<thead>
<tr>
<th></th>
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<td>1</td>
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<td>6</td>
<td>0.1%</td>
<td>6</td>
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<tr>
<td>Qatar</td>
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<td>43</td>
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<td>Saudi Arabia</td>
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<td>United Arab Emirates</td>
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<td>1</td>
<td>589</td>
<td>2.0%</td>
<td>144</td>
<td>137</td>
<td>137</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>613</strong></td>
<td><strong>200</strong></td>
<td><strong>14</strong></td>
<td><strong>39</strong></td>
<td><strong>867</strong></td>
<td><strong>0.6%</strong></td>
<td><strong>289</strong></td>
<td><strong>262</strong></td>
<td><strong>210</strong></td>
</tr>
</tbody>
</table>

Source: IRENA, 2018a; IRENA estimates.

Note: 2018 data are available only for Kuwait and the UAE. Oman's 7 MWs solar enhanced oil recovery plant and the newly finished first phase of 1 GWs Mirah Solar EOR is not included because this table addresses only electricity. PV = photovoltaic; CSP = concentrated solar power; RE = renewable energy. Totals may not add up due to rounding.
Challenges

1. Low R&D Budgets & Innovation:
   - Low funding, high oligopolistic industries, public dominance in energy

2. Low renewable power generation

3. Limited water resource,
   - Limited fresh water, limited renewable sources to desalinate water, high energy and economic costs for desalination

4. Competing mandates and interests of the power and the hydrocarbon sectors
   - Example: Kuwait’s Law 19 for 2015
Challenges

1. Low R&D Budgets & Innovation:
   - Low funding, high oligopolistic industries, public dominance in energy

2. Low renewable power generation

3. Limited water resource,
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   - Example: Kuwait’s Law 19 for 2015

5. Decarbonization policy gap

6. Funding and financing

7. Economic viability for H2 production

8. Domestic energy subsidies

CCUS Regulatory Gaps (2018)

<table>
<thead>
<tr>
<th>Regulatory Domain</th>
<th>Bahrain</th>
<th>Kuwait</th>
<th>Oman</th>
<th>Qatar</th>
<th>Saudi Arabia</th>
<th>UAE</th>
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<td>Ownership of surface facility</td>
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<td>CO₂ capture regulation</td>
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<tr>
<td>CO₂ transportation regulation</td>
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<td>X</td>
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<td>CO₂ storage regulation</td>
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<td></td>
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<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Liability during post-closure period</td>
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<td>X</td>
<td>X</td>
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<tr>
<td>Regulation for CCS with EOR</td>
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<td>X</td>
<td>X</td>
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<tr>
<td>Incentives</td>
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<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Note: “X” indicates a lack of both the implicit regulation and the explicit regulation; blank indicates close-to-no or no inadequacy.
Challenge 6: Funding and Financing is Key

- Long-term investments, large capex, constrained funding, uncertain markets, difficult to secure long-term offtake agreements, limited investments
- 1/3 energy investment in well-developed financial systems and good access to foreign capital; 40% in mixed conditions
- Importance attached to decarbonization and H2 on government policies

Various available sources
- SWF, NOCs, domestic industry as developers, R&D, SMEs
- International technology companies (e.g., Siemens, Air Product)
- Special funds: E.g., German Federal Ministry for Economic Affairs and Energy (BMWi)
  €2 billion for international partnerships for green hydrogen

Policy challenge
- Governance: Transparency & efficiency
- Rechanneling available funds & SWF
- Equity vs. debt and loan guarantees
- Attracting national and international private sector
- Required renewable infrastructure level to access green hydrogen funds
- Additional financeable revenue streams (co-production with electricity), monetize CCUS, sales of byproduct O2 sales
Challenge 7: Economic Viability for Exports

Establishing an economic and reliable infrastructure for transmission and storage of hydrogen

Two markets: competing with oil/fossil fuels vs. other hydrogen products

- Opportunity cost: how much oil and gas export revenue forgone to produce 1 KG of hydrogen; cost is higher
- Competitive cost
  - Economies of scale
  - Blue hydrogen costs vs. speculative green hydrogen costs
  - Analysis of value chain blue H2 with CCS vs. value chain of H2 green with electrolysis
  - Cost uncertainty depending on technology, demand, and government policy (on supply and demand sides)

- Profitable production: Marginal revenue > marginal cost
  - $1.5/kg hydrogen to compete coal, oil and gas without a carbon price
  - Requires renewable cost drop by approximately 50% and electrolyser costs decline by 75%

Policy Challenge: Economic profitability, technology, expansion of consumption, fiscal

Hydrogen exports will not be a substitute for economic diversification needs
Challenge 8: Domestic Energy Subsidies

- Maintaining current energy price levels = significant rise in subsidy costs
- High subsidies are extremely distortionary

Domestic market: important policy questions?
- Does it make sense to set a fixed share reserved for the domestic market?
- Welfare implications vs. reduced consumption
- Competitive pricing, size of subsidy, incidence
- Green hydrogen vs. blue hydrogen: feedstock cost and renewable energy cost

Mathematical expressions:
- $D = \alpha S$
- $P_D < P_W$
- Marginal price: $P_M = \alpha P_D + (1-\alpha) P_W$
- Ideal production in S: $MC = MR$
- Reduces both total production and total exports, but increases domestic share compared to an undistorted equilibrium
- With subsidy: $\alpha > \alpha^*$
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Economic Assessments Needed for Each State

- Potentially allows both vertical and horizontal energy diversification
- Global demand depends on costs and government policy
- Popularized strategy: blue hydrogen with CCUS for short to medium run, focusing on exports, continued to long term; deployment of renewable energy & hydrogen in medium to long run for domestic & exports
- Might not be the right strategy with the opportunity cost, but could reveal the economics of (blue H2) exports, shipping, etc.
- What is needed to make the strategy successful.
- Detailed economic assessments required:
  - Modeling price competitiveness to calculate cost, opportunity cost, potential revenue, requiring
    - Supply/demand balances
    - Production costs per fuel type, technology (e.g., type of electrolyzer), efficiency, carbon storage, and CAPEX
    - Market prices for each feedstock based on conversion into hydrogen and technology
  - Modeling of the levelized cost of hydrogen (LCOH) production for each feedstock and conducting a comparative assessment of competing sources to assess comparative advantage
  - Modeling costs of a CCS technology at individual sites depend on a range of sector- and site-specific factors, including: CO₂ concentration; CO₂ partial pressure; CO₂ volumes; ease of industrial integration; and location
  - Modeling of sectoral, fiscal, and economy-wide effects at current policies and change in policy environment (e.g., changes in subsidies, employment, new industries)
  - Determining uses of an energy carrier or feedstock, identified technology, uses (fertilizers, shipping) and identified marketable products (H2, liquid H2, NH3, etc..)
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Integrative Policy for Hydrogen Strategy

Proceed if profitable, or modify

Point of market development

Regulatory
- Industry targets
- Private sector involvement
- Business environment reform
- Power & water sectors, versus oil sectors
- Specific rules for deployment of fossil fuel vs. renewable energy
- Exemptions of hydrogen from specific surcharges
- Emissions standards
- Create necessary institutions

Technology
- Acquisition
- Support of ongoing research, R&D, patents
- Energy efficiency
- Ongoing technology to reduce costs
- Private sector reform

Financing
- Use of savings for investments
- Fiscal reform
- Reform for private sector involvement and contribution
- Foreign vs. domestic
- Role of government and private sector

Infrastructure for blue hydrogen & CCUS
- Immediate opportunity using existing infrastructure
- CCUS infrastructure
- Cost savings
- Economies of scale
- Competitive CCUS and products

Renewables projects
- Domestic use
- Green hydrogen possibility

Green hydrogen
- At which cost would green hydrogen be feasible?
- Domestic vs. export markets

Economic modeling
- Economic drivers (fuel prices, technology, emissions)
- Domestic energy subsidies
- LCOE
- LCOH
- Transportation and other costs
- Carbon pricing
- Subsidy restructure
- Sectoral and economy wide assessments

Uptake
- Identify market segments
- Identify products
- Identify what is technically feasible in short, medium, and long runs
Thank you