THE OXFORD INSTITUTE FOR ENERGY STUDIES

Opportunities and Challenges of the Hydrogen Economy in the GCC

Dr. Manal Shehabi
OIES-KFAS Research Fellow
manal.shehabi@oxfordenergy.org

April 7, 2021

Citation and Disclaimer

Citation (APA):

Shehabi, M. (2021). *Opportunities and Challenges of the Hydrogen Economy in the GCC*. OIES-KFAS Workshop 2021. [Webinar PowerPoint slides]. Oxford Institute for Energy Studies.

Disclaimer:

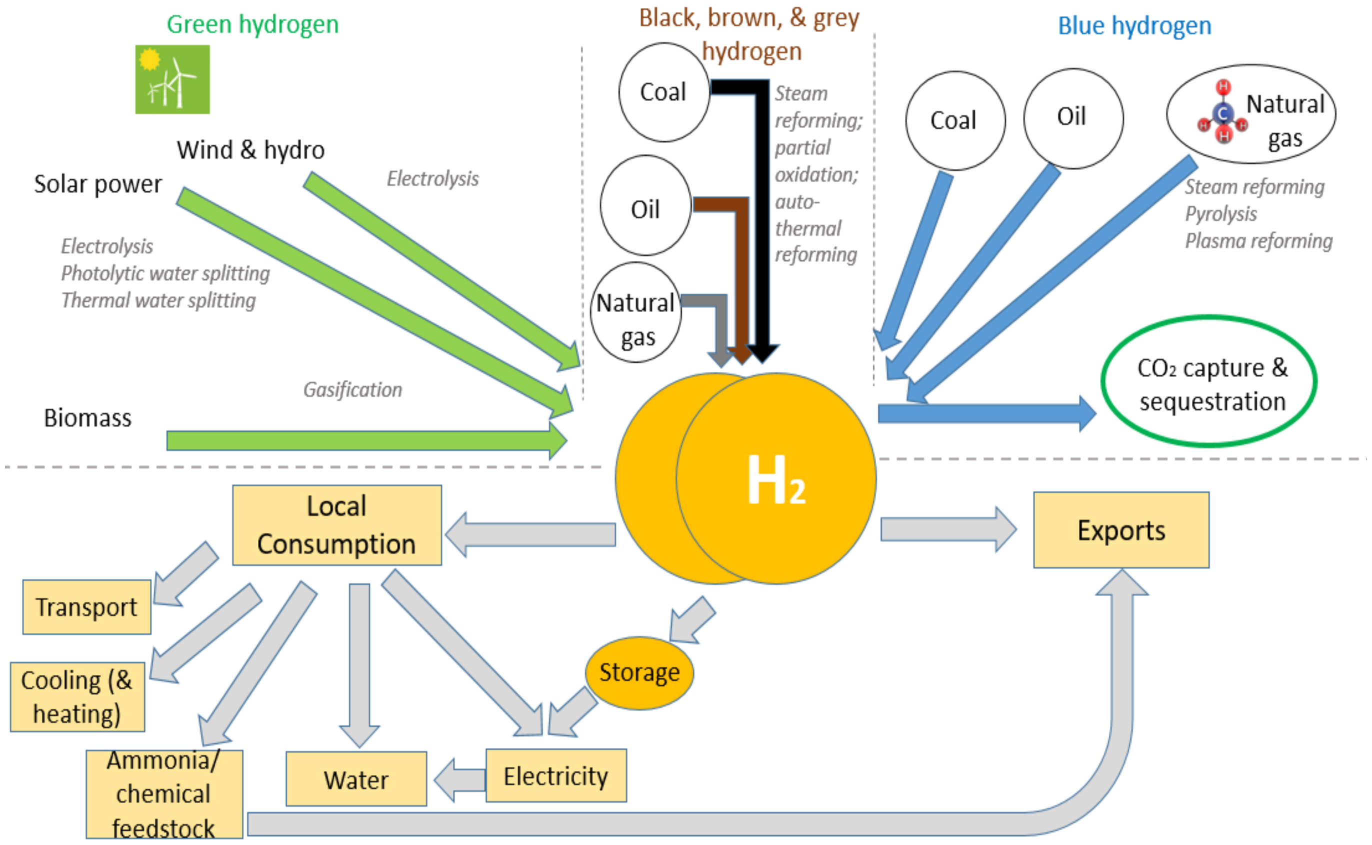
The contents of this presentation are the authors sole responsibility. They do not necessarily represent the views of the Oxford Institute for Energy Studies or any of its Members.

Outline

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



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

Advantages:

- Abundance
- 33.33 kWh/kg H2 vs. 12 kWh/kg petrol and diesel
- Versatility
- low carbon

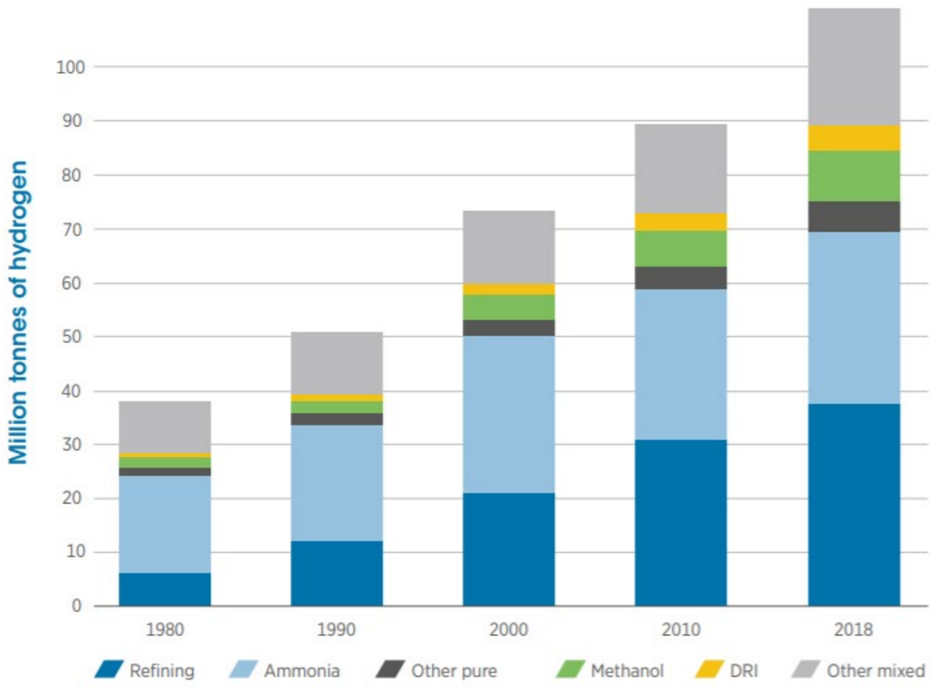
Challenges:

- Expensive to extract and roll out
- Storage
- Transportation
- Safety and flammability

Global Hydrogen Demand and Supply

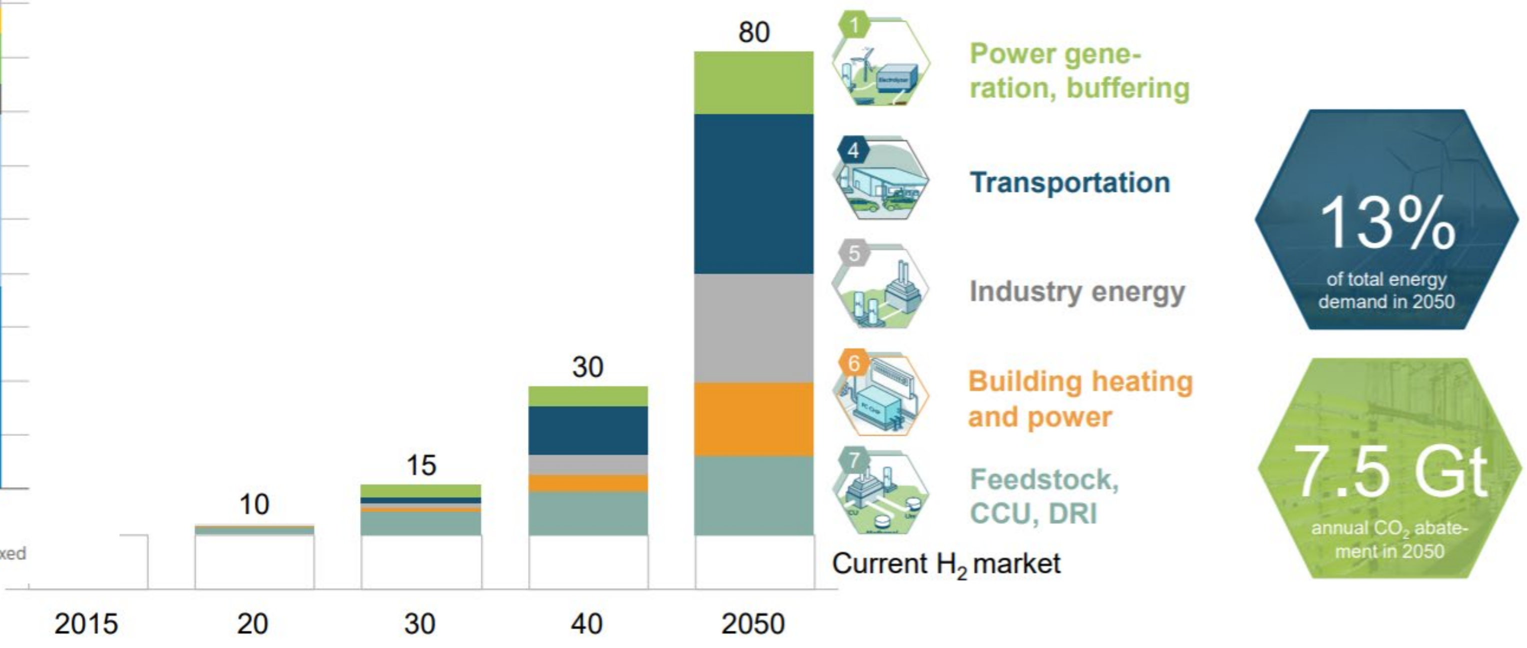
- Vast majority of hydrogen is produced from fossil fuels without CO_2 capture
- Increased focus on green H2, $150 billion worth of green hydrogen projects, possibly increasing with net zero emission target

Global annual demand



Source: IEA (2019).

Global Energy demand supplied with hydrogen, Exajoule (EJ)



Source: Hydrogen Council (2018)

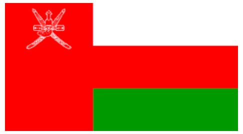
Are GCC States Lagging Behind?

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.

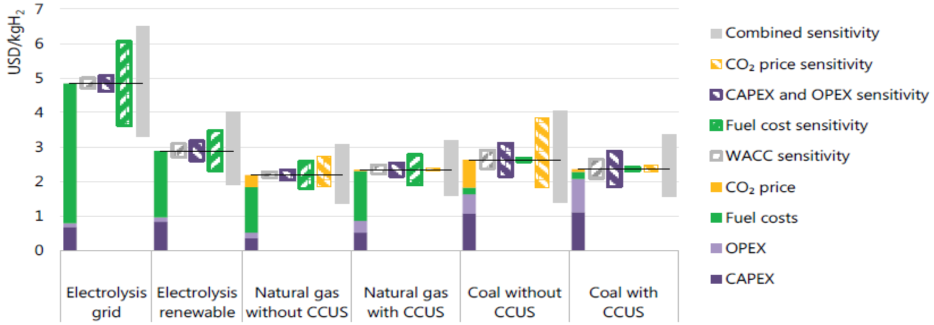
- 2018-2019: KISR earned patent for enhancing magnesium’s hydrogen storage for use in fuel cells; launched 1st prototype electric vehicle fueled by hydrogen stored in magnesium hydride (MgH2) MgH2), a nanoscale metal hydride.
- 2020: White Paper for National Hydrogen Strategy

Outline

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

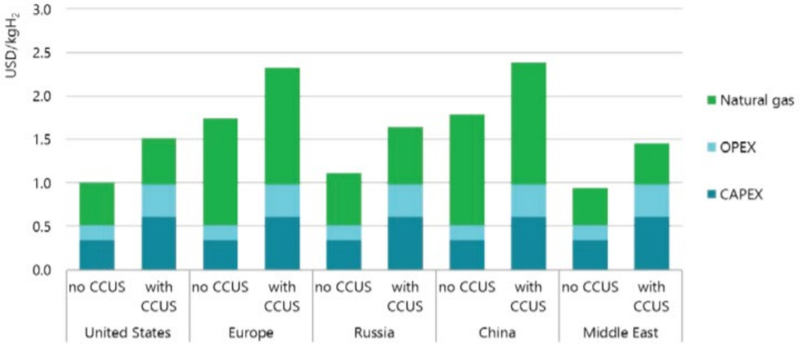
Opportunities

1. Potential existing markets and opportunity for capturing lost oil export demand
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



Notes: WACC = weighted average cost of capital. Assumptions refer to Europe in 2030. Renewable electricity price = USD 40/MWh at 4 000 full load hours at best locations; sensitivity analysis based on +/-30% variation in CAPEX, OPEX and fuel costs; +/-3% change in default WACC of 8% and a variation in default CO_2 price of USD 40/tCO_2 to USD 0/tCO_2 and USD 100/tCO_2. More information on the underlying assumptions is available at www.iea.org/hydrogen2019.

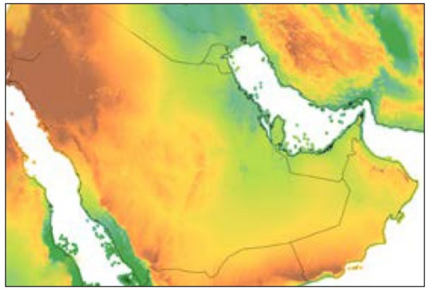
Source: IEA 2019.



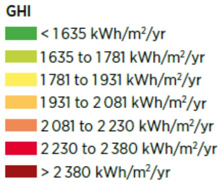
Notes: kgH2 = kilogram of hydrogen; OPEX = operational expenditure. CAPEX in 2018: SMR without CCUS = USD 500–900 per kilowatt hydrogen (kWH2), SMR with CCUS = USD 900–1 600/kWH2, with ranges due to regional differences. Gas price = USD 3–11 per million British thermal units (MBtu) depending on the region. More information on the underlying assumptions is available at www.iea.org/hydrogen2019.

Source: IEA (2019)

Direct normal irradiation (kWh/m2/yr)



Source: IRENA (2019b): Global Atlas, Map Data: World Bank, 2018, Direct Normal Irradiation kWh/m² World 1km 1994/1999/2007-2015 WBG, World country borders using Global Administrative Boundaries (GADM) database.

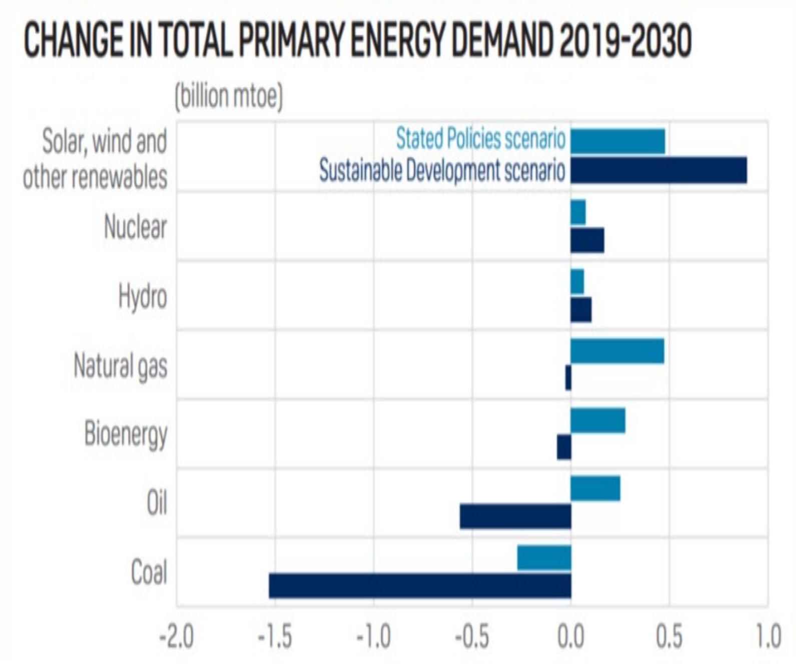


Source: IRENA (2018)

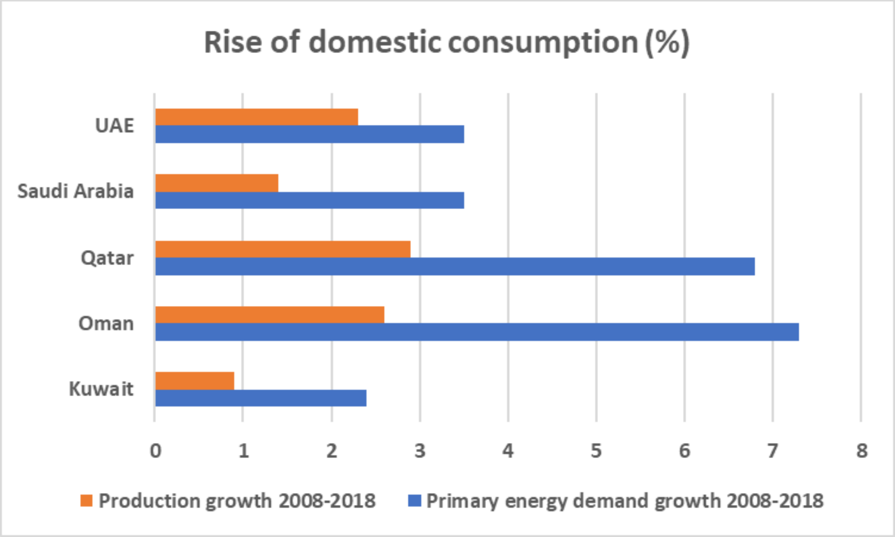
Hydrogen Opportunity 1: Capturing Lost Export Demand

Triple challenge of declining export revenue

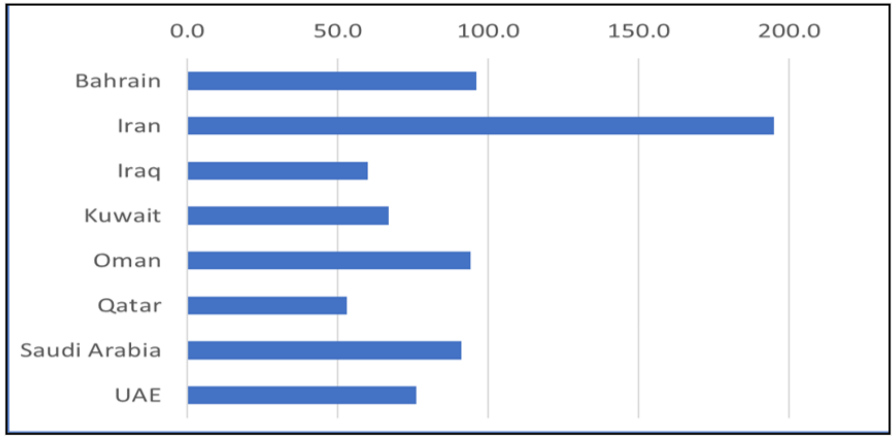
- Increased domestic consumption
- Consistent low oil price
- Uncertainty in demand (e.g., COP 26, net zero emissions targets, national climate commitments)



Source: International Energy Agency (IEA) (2020), *World Energy Outlook 2020*.

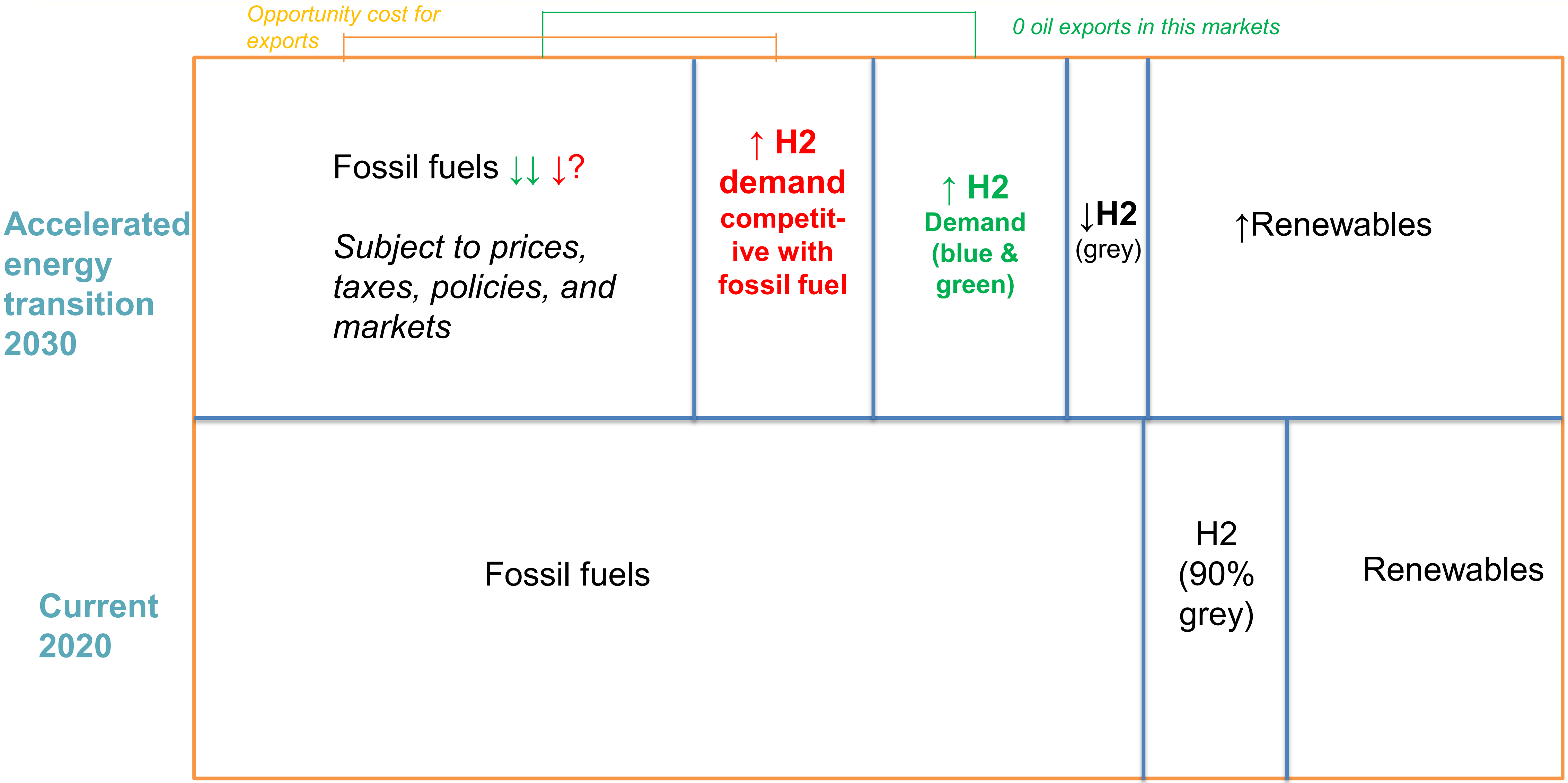


Estimated fiscal breakeven oil price for 2019, excluding investment income ($/bp)



Sources: Shehabi calculations based on national budgets, data from IMF (2020).

For Oil Exporters, Two Types of Hydrogen Products in a Decarbonizing World



*** 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

Opportunity 5: CCUS Decarbonization & Economic Opportunity

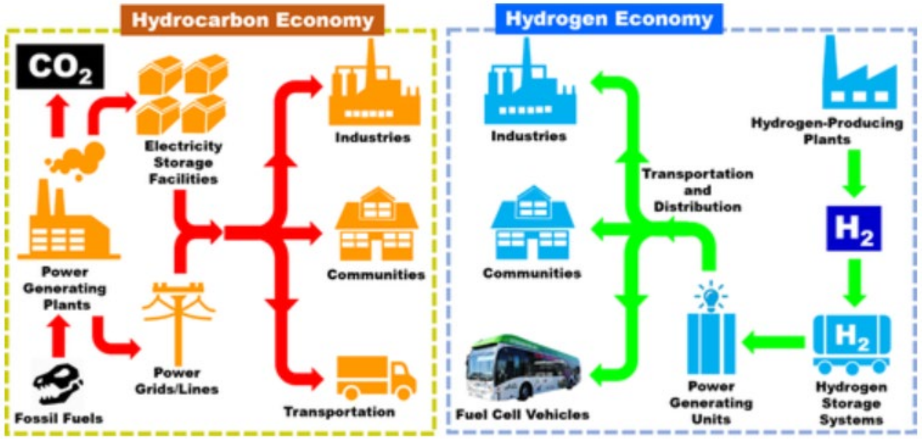
CCS, CCUS in NDCs and NCs Actions

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)

CCUS unlocks a hydrogen economy

H2 and sector coupling



Source: Fuel Cells (2020)

- **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**

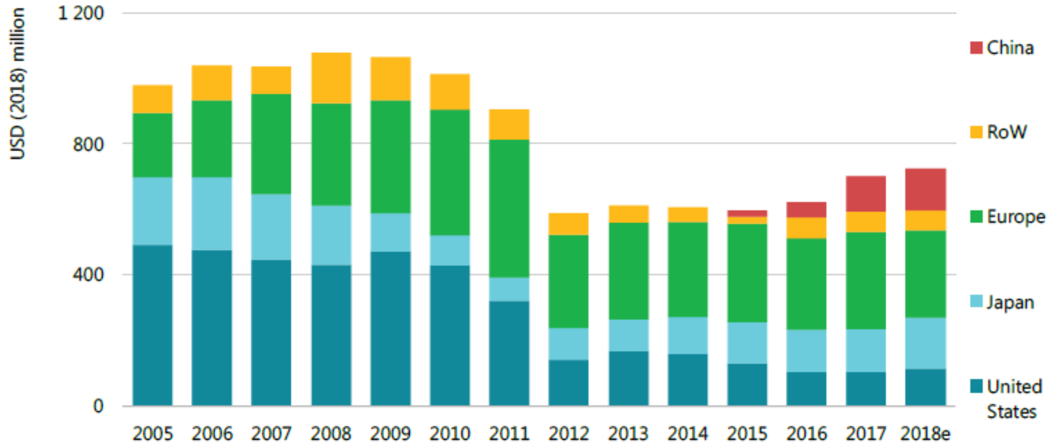
Outline

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

Challenges

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

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. 2018e = estimated; RoW = rest of world.

Source: IEA (2018a), *RD&D Statistics*.

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

	2017 - 2018						2016	2015	2014
Country	PV	CSP	Wind	Biomass and waste	Total RE (in MW)	Share of RE in total electricity capacity	Total RE	Total RE	Total RE
Bahrain	5	0	1	0	6	0.1%	6	6	6
Kuwait	19	50	10	0	79	0.4%	20	1	0
Oman	8	0	0	0	8	0.1%	2	2	1
Qatar	5	0	0	38	43	0.4%	43	42	42
Saudi Arabia	89	50	3	0	142	0.2%	74	74	24
United Arab Emirates	487	100	1	1	589	2.0%	144	137	137
Total	**613**	**200**	**14**	**39**	**867**	**0.6%**	**289**	**262**	**210**

Source: IRENA, 2018a; IRENA estimates.

Note: 2018 data are available only for Kuwait and the UAE. Oman's 7 MW_{th} solar enhanced oil recovery plant and the newly finished first phase of 1 GW_{th} Miraah 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.

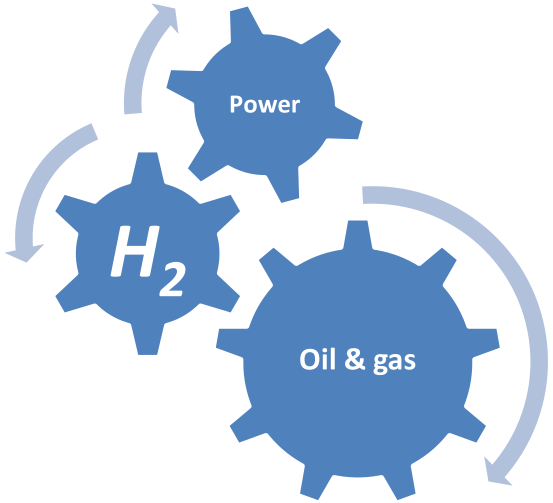
Challenges

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,
   - 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
5. Decarbonization policy gap
6. Funding and financing
7. Economic viability for H2 production
8. Domestic energy subsidies

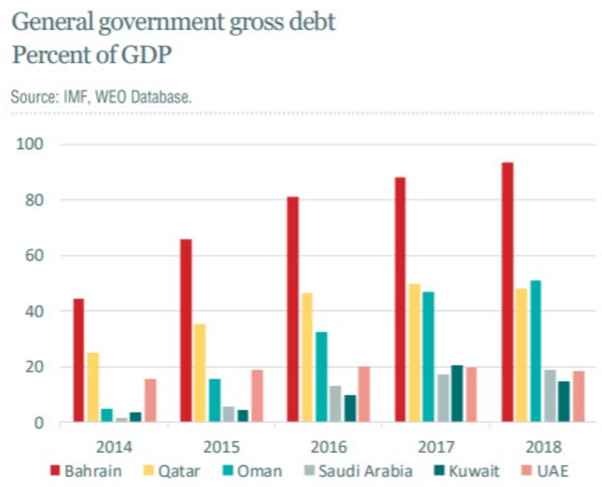
CCUS Regulatory Gaps (2018)

Regulatory Domain	Bahrain	Kuwait	Oman	Qatar	Saudi Arabia	UAE
CO_2 classification	X	X	X	X	X	X
Ownership of surface facility		X		X	X	
Transboundary CO_2	X	X	X	X	X	X
CO_2 impurity	X	X	X	X	X	X
CO_2 capture regulation		X		X	X	
CO_2 transportation regulation		X		X	X	
CO_2 storage regulation	X	X	X	X	X	X
Liability during post-closure period	X	X	X	X	X	X
Regulation for CCS with EOR	X	X	X	X	X	X
Incentives			X			

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

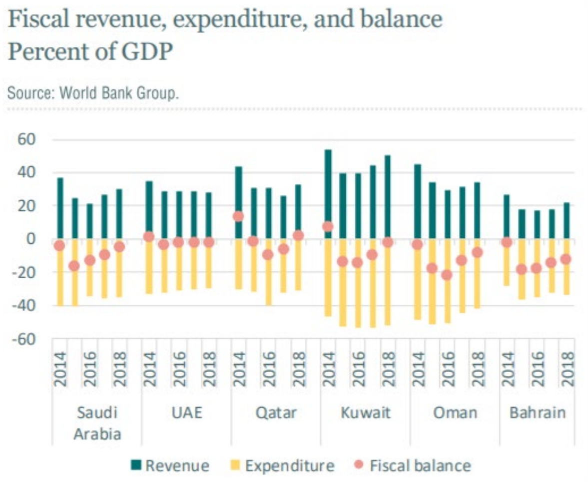
Establishing an economic and reliable infrastructure for transmission and storage of hydrogen

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%**

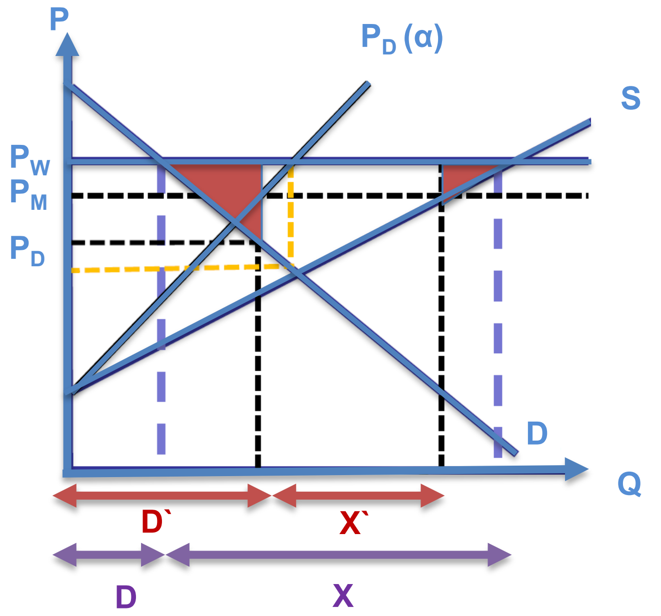
***Policy Challenge:* Economic profitability, technology, expansion of consumption, fiscal**



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 distortionar



- D=αS
- $P_D < P_W$
- 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: α > α*

Domestic market: important policy questions?

- **Does it make set a set 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

Outline

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

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: CO_2 concentration; CO_2 partial pressure; CO_2 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..)

Outline

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**

Integrative Policy for Hydrogen Strategy

Proceed if profitable, or modify

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

Point of market development

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