SCENARIO MAKING WITHIN THE FRAMEWORK OF GECF
GLOBAL GAS OUTLOOK: HYDROGEN SCENARIO

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Gas Exporting Countries Forum (GECF)

**MEMBERS**

- Algeria
- Bolivia
- Egypt
- Equatorial Guinea
- Iran
- Libya
- Nigeria
- Qatar
- Russia
- Trinidad and Tobago
- Venezuela

**Proven Natural Gas Reserves**

- GECF: 144 tcm
- World: 205 tcm

**Marketed Gas Production**

- GECF: 1678 bcm
- World: 3960 bcm

**Pipeline Gas Exports**

- GECF: 427 bcm
- World: 825 bcm

**LNG Exports**

- GECF: 246 bcm
- World: 481 bcm

**OBSERVERS**

- Angola
- Azerbaijan
- Iraq
- Kazakhstan
- Malaysia
- Norway
- Peru
- United Arab Emirates

*Source of data: GECF Annual Statistical Bulletin 2020*
Carbon neutrality and the hydrogen role

Carbon neutrality (Energy Aspects)
- Clean energy supply
- Energy Conservation
- Energy efficiency advancement
- Carbon offsets
- Policy and regulations
- supply-demand-based optimization

Hydrogen
- Natural gas with CCUS
- Blue Hydrogen
- Green Hydrogen

Renewables
Introduction and basics

GECF Reference Technology Map and the Hydrogen production spectrum
Model Architecture

- Econometric time-series models
  - Economic projections Sub-model
  - Energy pricing Sub-model
  - Energy demand Sub-model

- Policy Drivers & technology options
- Supply sub-model (linear programme)

- Time series data
  - Production profiles
  - Trade potential
  - Contracted volumes
  - Cost of production
  - Transport costs

- Seasonal load profile
- Seasonal supply profile
- Gas storage

Source: IHS Markit
The GGM provide energy projections on 34 energy sectors

- **Final Sectors**
  - Industry
    - Iron & Steel
    - Chemical
    - Construction
    - Mining & Quarrying
    - Non-Ferrous Metals
    - Non-Metallic Minerals
    - Other Manufacturing
  - Feedstocks
  - Domestic
    - Residential
    - Commercial
    - Agricultural, Forestry and Fishing
  - Transport
    - Motorbikes
    - Passenger Cars
    - Light Commercial Vehicles
    - Heavy Goods Vehicles
    - Rail
    - Aviation
      - International Aviation
      - Domestic Aviation
  - Shipping
    - International Bunkers
    - Inland and Inshore Bunkers
    - Other (incl. pipelines)
  - **Transformation Sectors**
    - Power
      - Central Generation
      - CHP
    - District Heating/Cooling
    - Refineries
      - Conventional Refineries
      - Condensate Splitters
      - Gas-to-Liquids
      - Coal-to-Liquids
      - Biofuel Refining
    - Energy
      - Own-Use
      - Transmission & Distribution Losses
      - Gas Works Gas
    - Non-Energy
      - Other Uses
The GGM provide energy projections of 35 fuels:

- Electricity
- Natural Gas
- Coal
  - Steam Coal
  - Lignite/Brown Coal
  - Coking Coal
- Crude
  - Crude Oil
  - Condensate
  - NGL
- Natural Gasoline
- Oil Products
  - Gasoline
  - Aviation Gasoline
  - Gasoil
    - Diesel
    - Heating Oil
  - Fuel Oil
- LPG
- Naphtha
- Jet
- Kerosene
- Other Liquids
- Thermal Renewables
- Primary Electricity
  - Nuclear
  - Hydro
  - Geothermal
  - Tidal
  - Solar
    - Photovoltaic
    - Concentrated Solar Power
- Wind
  - Onshore
  - Offshore
- Secondary Electricity
  - Pump Storage
  - Batteries
- Biomass & Waste
  - Ethanol/Biogasoline
  - Biodiesel
  - Biojet
  - Other Biomass
- Hydrogen
Hydrogen production spectrum

\[ \text{Water} (H_2O) \rightarrow \text{Electrolysis} \rightarrow \text{Hydrogen} (H_2) + \text{Oxygen} (O_2) \]

\[ \text{Reforming} \rightarrow \text{Gasification} \rightarrow \text{Hydrogen} (H_2) \]

\[ \text{Pyrolysis} \rightarrow \text{Hazer Process} \rightarrow \text{Hydrogen} (H_2) + \text{Carbon} (C) \]

\[ \text{CCUS} \rightarrow \text{Hydrogen} (H_2) + \text{Carbon Dioxide} (CO_2) \]

Renewables: Green
Nuclear: Yellow
Turquoise
Blue
Grey
Hydrogen source map

Raw Materials
- Water
- Fossil fuels
- Biomass

Energy needed
- Renewable resources
- Fossil fuels
- Solar radiation

Processes:
- Electrochemical process
- Thermochemical process
- Photochemical process
Technology Status
Steam Methane Reforming

Desulfurization

Reformer Temperature 850-900°C

Shift Conversion

Heat Recovery

Water-gas shift reaction
$\text{CO} + \text{H}_2\text{O} \rightarrow \text{CO}_2 + \text{H}_2$ (+ small amount of heat)

Steam-methane reforming reaction
$\text{CH}_4 + \text{H}_2\text{O} (+ \text{heat}) \rightarrow \text{CO} + 3\text{H}_2$

Heat (Fuel)

Will be captured in blue hydrogen

Mostly remains unabated

CO$_2$

CH$_4$

H$_2$

CO$_2$
Autothermal reforming

Steam-methane reforming reaction
\[ \text{CH}_4 + \text{H}_2\text{O} (+\text{O}_2) \rightarrow \text{CO} + 3\text{H}_2 \]

Much less unabated CO\(_2\) due to less fuel combustion

Water-gas shift reaction
\[ \text{CO} + \text{H}_2\text{O} \rightarrow \text{CO}_2 + \text{H}_2 \]
Pyrolysis

CH$_4$ → Methane Decomposer → Carbon + Catalyst → Seperator → Carbon Black (Solid Carbon)

Methain

H$_2$ → Seperator → Catalyst re heater → Catalyst Recycle
Hydrogen Scenario (2020)
Hydrogen consumer sectors (potential and existing)

Transportation
- Forklift or towing trucks
- Light passenger cars
- Vans and city buses
- Trains
- Passenger ships
- Freight ships and airplanes (synfuels)

Industry
- High grade heat (energy)
- Low and medium heat (energy)
- Refining
- Ammonia and methanol
- Olefins, BTX
- Steel

Residential and commercial
- Heat (hydrogen-enriched natural gas)
- Heat (pure hydrogen)

Power Generation
- Fuel cells power plants (pure hydrogen)
- Combine cycles (hydrogen-enriched natural gas)
- ICEs (hydrogen-enriched natural gas)
- Open cycle power plants (hydrogen-enriched natural gas)
Building and Power sectors

Hydrogen share in building sector

Hydrogen fuel cells power in Hydrogen Scenario (MW)

Hydrogen Share in Residential Sector

Hydrogen Share in Commercial Sector

Hydrogen fuel cells additions in Hydrogen Scenario
Transport Sector

Number of Hydrogen Light Commercial Vehicles (Million)

Number of Hydrogen Passenger Vehicles (Million)

- Blue line: Number of Hydrogen Light Commercial Vehicles in Hydrogen Scenario
- Black line: Number of Hydrogen Light Commercial Vehicles in Reference Case Scenario

- Blue line: Number of Hydrogen Passenger Vehicles in Hydrogen Scenario
- Black line: Number of Hydrogen Passenger Vehicles in Reference Case Scenario
Industry Sector

Hydrogen Share in Iron & Steel Sector

Hydrogen Share in Chemical Sector
Results (1)

Sectorial share for hydrogen demand

- **2019**
  - Refinery (Feedstocks): 14%
  - Power Generation: 22%
  - Transport: 33%
  - Residential & Commercial: 6%
  - Industry (Feedstocks): 17%
  - Industry (Energy Fuel): 16%

- **2050 Base Case Scenario**
  - Refinery (Feedstocks): 11%
  - Power Generation: 17%
  - Transport: 33%
  - Residential & Commercial: 6%
  - Industry (Feedstocks): 15%
  - Industry (Energy Fuel): 15%

- **2050 Hydrogen Scenario**
  - Refinery (Feedstocks): 11%
  - Power Generation: 17%
  - Transport: 33%
  - Residential & Commercial: 6%
  - Industry (Feedstocks): 15%
  - Industry (Energy Fuel): 15%

Hydrogen demand outlook by sector (Mt of H₂)

- **2019**
  - Refinery (Feedstocks): 50 Mt H₂
  - Power Generation: 50 Mt H₂
  - Transport: 100 Mt H₂
  - Residential & Commercial: 100 Mt H₂
  - Industry (Feedstocks): 100 Mt H₂
  - Industry (Energy Fuel): 100 Mt H₂

- **2050 Reference Case Scenario**
  - Refinery (Feedstocks): 45 Mt H₂
  - Power Generation: 45 Mt H₂
  - Transport: 150 Mt H₂
  - Residential & Commercial: 150 Mt H₂
  - Industry (Feedstocks): 150 Mt H₂
  - Industry (Energy Fuel): 150 Mt H₂

- **2050 Hydrogen Scenario**
  - Refinery (Feedstocks): 50 Mt H₂
  - Power Generation: 50 Mt H₂
  - Transport: 150 Mt H₂
  - Residential & Commercial: 150 Mt H₂
  - Industry (Feedstocks): 150 Mt H₂
  - Industry (Energy Fuel): 150 Mt H₂

**Total Hydrogen Demand: 475 Mt H₂**
Outlook for hydrogen production share by source

In the form of grey hydrogen

Mostly in the form of blue hydrogen

Results (2)
Outlook for CO2 emission (Mt CO2)

The annual emission forecast in Base Case Scenario 2019

More than 3.5 gigatones of CO₂ abatement annually by 2050 in Hydrogen Scenario compared with Base case Scenario 2020

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