New energy sources:
hydrogen and renewables perspective

Building a Carbon-Free Future on Power-to-X

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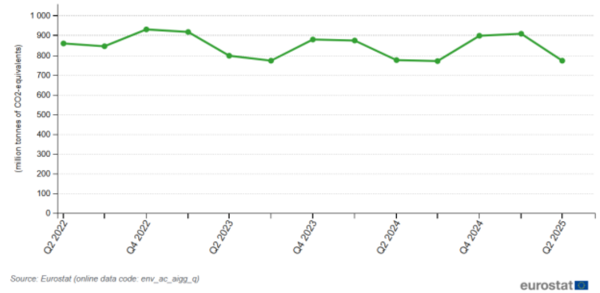
Quarterly greenhouse gas emissions in the EU

Q2 2025

772 Millones

tonnes de CO_2 eq

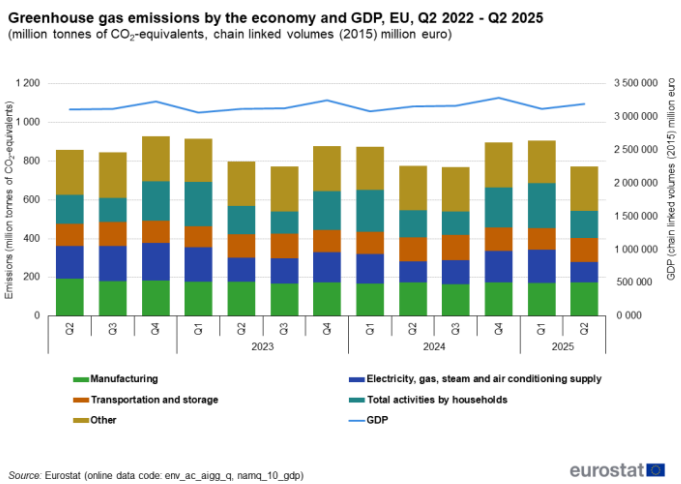


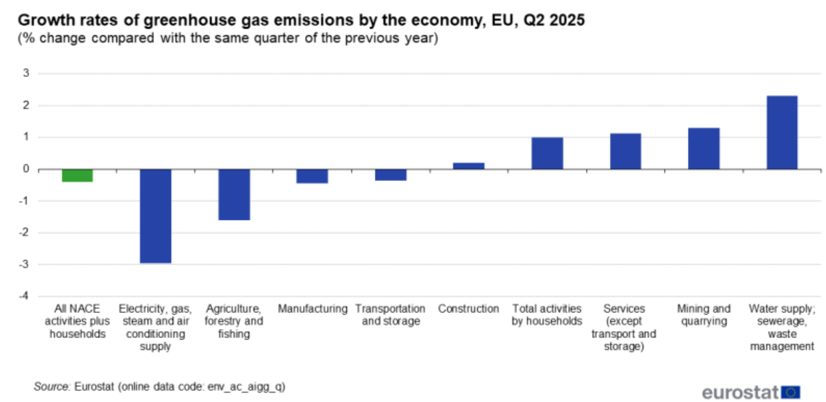
Variation

-0.4%

with respect to Q2 2024

Greenhouse gas emissions - All NACE activities plus households*





The future of global energy is dominated by four trends

Declining role for hydrocarbons

The search for cleaner alternatives is leading to a gradual reduction in dependence on fossil fuels.

Rapid expansion in renewables

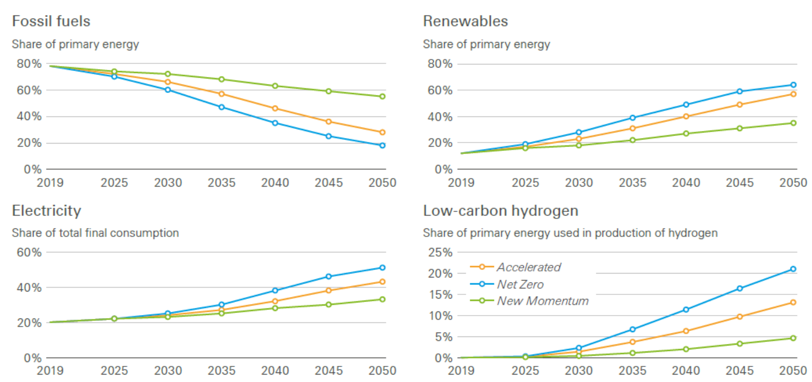
Rapid increase in renewable energy capacity, exceeding 3.7 GW by 2028.

Growing Electrification

Increased electricity use across all sectors, driven by energy efficiency.

Low-carbon hydrogen

The adoption of hydrogen is growing as an energy carrier for storage and transport, being crucial for decarbonization.



Predictions for 2028

- Renewables will be the largest source of electricity
- Wind and solar PV will become the largest sources in 2025 and 2026
- Renewables will account for more than 42% of global electricity

Source: 2024 BP Report

What is Power–to–X?

Definition

Power-to-X describes the conversion and storage of electrical energy into an energy carrier (gas, fuel or raw material) or a product.

It is a collective term for:

- **Power-to-Gas**
- **Power-to-Liquid**
- **Power-to-Fuel**
- **Power to-Chemicals**
- **Power-to-Product**

PtX bridges the gap enabling deep decarbonization of sectors that cannot be directly electrified.

PtX PRODUCTS & STRATEGIC RELEVANCE

Comparison of Key Hydrogen Derivatives

PARAMETER	Ammonia (NH_3)	Methanol (CH_3OH)	Synthetic Natural Gas (SNG)	Sustainable Aviation Fuel (SAF)
Production	Green H_2 + N_2 (Haber-Bosch process)	Green H_2 + CO_2 (DAC/biogenic)	Green H_2 + CO_2 (methanation)	Fischer-Tropsch/PtL or eFining™ (H_2 + CO_2)
Storage & Transport	Pressurized (10–15 bar) or refrigerated (-33°C)	Liquid at ambient conditions	Compressed (200–250 bar) or LNG (-162°C)	Similar to jet fuel (ambient liquid)
Technology Readiness Level (TRL)	7–8 (maritime engines: 6)	7 (production), 9 (maritime use)	8–9 (methanation)	8–9 (Fischer-Tropsch), 6–7 (eSAF)
Storage Conditions	Moderate pressure/cryogenic	Ambient liquid	High pressure/cryogenic	Ambient liquid
Volumetric Energy Density (MJ/L)	12.7 (liquid)	15.6	22.7 (LNG)	35–40 (similar to jet fuel)
Gravimetric Energy Density (MJ/kg)	18.6	19.9	50–55 (methane)	43–44
Safety	Toxic, requires leak detection	Flammable, less toxic than NH_3 3	Similar to LNG (flammable, odorless)	Similar to jet fuel (flammable)
End-Use Sectors	Shipping, power generation, fertilizers	Shipping, chemicals, fuel cells	Gas grid, heating, transport	Aviation (ReFuelEU mandates)

Current EU Hydrogen Production (2025)

EU Hydrogen Production

Type	Volume (Mtpa)	Notes
Total Production	8–9 Mtpa	Dominated by grey hydrogen (from fossil fuels without CCS) 59.
Green Hydrogen	~0.02 Mtpa	From electrolysis powered by renewables; minimal progress toward targets 56.

EU 2030 Targets vs. Projections

Category	Target (Mtpa)	Realistic Projection (Mtpa)	Gap
Domestic Production (REPowerEU)	10.0	2.7 (max projected)	7.3
Imports (REPowerEU)	10.0	1.9–4.3 (ATS scenario)	5.7–8.1
Total Demand (RED III mandates)	—	2.2–2.8	—
Accelerated Transition Scenario	—	Up to 7.0	—

2030 STRETCH TARGETS

Key Challenges

- **Slow Project Development**: Only 17% of announced projects are likely to materialize by 2030.
- **Cost Barriers**: Green hydrogen remains 2–3× more expensive than grey hydrogen.
- **Infrastructure Gaps:** Only one hydrogen pipeline is under construction. Most projects lack finalized plans; 98% of projects are in concept/feasibility stages.
- **Demand Uncertainty:** Current renewable hydrogen demand is 0.3% of total H_2 consumption. Steel and shipping sectors (potential demand drivers) face adoption delays.

Regional Insights

- **Germany, Netherlands, France, Belgium**: Concentrate ~60% of mandated demand (refineries, chemicals).
- **Spain & Nordic Countries**: Potential production hubs due to renewables, but lack infrastructure to transport H_2 to demand centers.

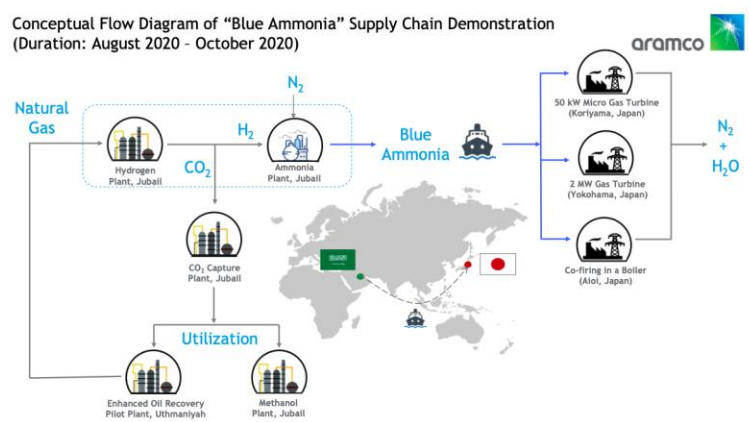
Ammonia as a Global Hydrogen Derivative

EU Trade Dynamics & Current Global Ammonia Trade

- **Major Exporters**: The Middle East, North Africa (MENA), Trinidad and Tobago, and the US dominate global ammonia exports, leveraging low-cost natural gas for production.
- **EU's Position**: The EU is a net importer, relying heavily on intra-EU trade and imports from MENA/Russia (pre-sanctions) for fertilizer and industrial use.
- **Trade Shifts**: Post-2022, Russian ammonia exports declined due to sanctions, while the US increased exports via fracking-derived gas

EU-Ammonia Trade Partnerships

Region	Trade Potential	Key Projects
MENA	High (solar-based H_2)	NEOM (Saudi Arabia) to supply 1.2 Mtpa green ammonia to EU .
North America	Rising (US Gulf CCS hubs)	CF Industries' blue ammonia (500 ktpa) for EU energy/fertilizers .
Latin America	Emerging (renewables)	Chile/Brazil projects aim to replace EU fertilizer imports .



Ammonia Challenges & EU Policy Drivers

Cost Competitiveness
Grey ammonia (from natural gas) remains cheaper; green ammonia costs 3–6× more.

Regulatory Push

✓ **RED III**: Mandates 42% renewable H_2 in ammonia production by 2030.
✓ **CBAM**: Carbon tariffs on imports may incentivize low-carbon ammonia trade.

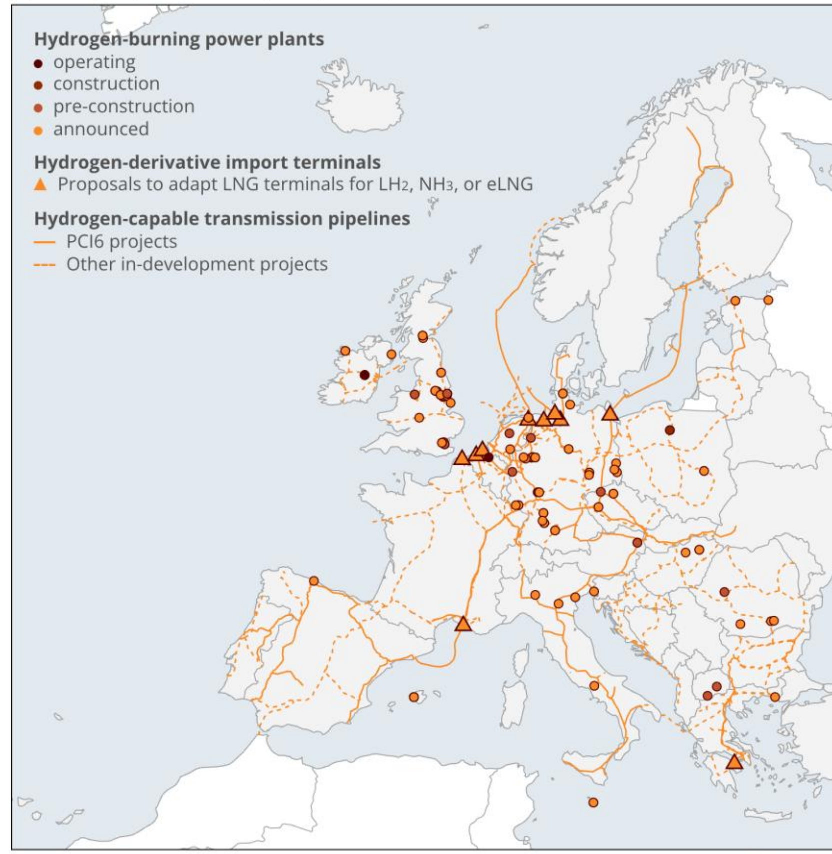
Infrastructure Gaps

Limited EU port capacity for LH_2/NH_3 and cracking facilities to convert ammonia back to H_2.

Future Outlook

- **By 2050**: Ammonia trade could triple globally, with the EU as a top importer

Europe's hydrogen buildout risks prolonging gas dependence
In-development infrastructure related to Europe's hydrogen buildout, including pipelines, import terminals, and power plants



Source: Europe Gas Tracker, January 2025 release, Global Energy Monitor

Global Energy Monitor

Methanol as a key export commodity in Europe:

Category	Current Status (2025)	Future Outlook (2030)
Production Capacity	Major facilities in Germany & Netherlands	Expansion of green methanol plants expected
Trade Balance	Net importer (conventional), net exporter (green)	Becoming dominant green methanol exporter
Main Export Products	- Green methanol (e-methanol) - Bio-methanol	- Shipping fuel methanol - H_2 carrier methanol
Key Export Markets	1. Asia (chemicals) 2. Africa (biodiesel) 3. Americas (fuel)	Growing maritime fuel demand globally
Competitive Advantage	- Kassø plant (42kt/yr) - ISCC certification	- FuelEU Maritime compliance - RED III incentives
Market Value	$2.8 billion (2025)	$4.41 billion projected (9.23% CAGR)
Main Challenges	- Price competition from ME/US - Scaling production	- Infrastructure development - Cost reduction

While Europe imports conventional methanol, it is becoming a **major exporter of renewable methanol, driven by decarbonization policies and technological leadership**.
Key growth areas include e-methanol for shipping and hydrogen logistics

SNG as a Global Trade Commodity: EU Perspective

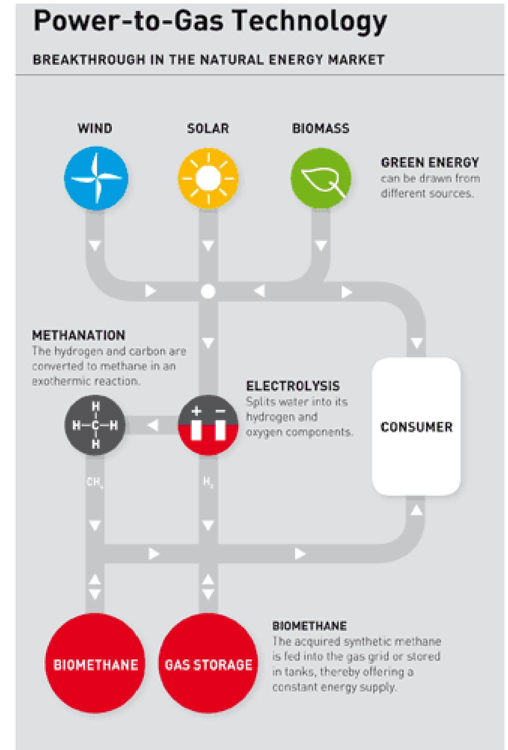
Production and Trade Overview

Definition: SNG is artificially produced methane, chemically identical to natural gas, derived from coal, biomass, or renewable-powered Power-to-Gas (PtG) processes (hydrogen + CO_2).

EU Trade Position:

- **Net Importer**: Relies on intra-EU production and imports from MENA/Russia (pre-sanctions) for industrial use 16.
- **Export Potential**: Emerging in green SNG (renewable H_2 + captured CO_2), with projects like Germany's 6 MW PtG plant

Feature	Benefit	Relevance for EU Trade
Infrastructure	Compatible with existing gas grids/pipelines .	Enables seamless integration with EU's gas network.
Energy Density	Higher than liquid H_2; easier to transport than ammonia .	Cost-efficient for long-distance shipping.
Decarbonization	Carbon-neutral when using renewable H_2 + captured CO_2	Aligns with EU's RED III and CBAM



Challenges

- **Cost**: PtG-SNG is **2–3× more expensive** than fossil gas due to electrolysis/CCS costs .
- **Infrastructure**: **Limited** EU **port capacity** for SNG imports and cracking facilities .
- **Regulatory Gaps**: Lack of global standards for **green SNG certification**

Sustainable Aviation Fuel (SAF) as a key hydrogen derivative for international trade, with a focus on the EU's regulatory framework, global dynamics, and challenges:

SAF as a Hydrogen Derivative: EU and Global Trade Landscape. ReFuelEU Aviation **Mandates**:

- 2025: **2% SAF blend at EU airports, rising to 70% by 2050**
- Synthetic SAF (e-SAF) sub-target: 1.2% by 2030, 35% by 2050, requiring renewable hydrogen (RFNBO).

Key Challenges

- Feedstock Dependence: 80% of EU SAF relies on imported used cooking oil (UCO), raising sustainability concerns.
- UK/EU lack clear hydrogen roadmaps for aviation, despite SAF mandates.
- Competition for renewable hydrogen with maritime/industry sectors.
- Infrastructure Gaps: Limited PtL production capacity and H_2 trans. Networks.

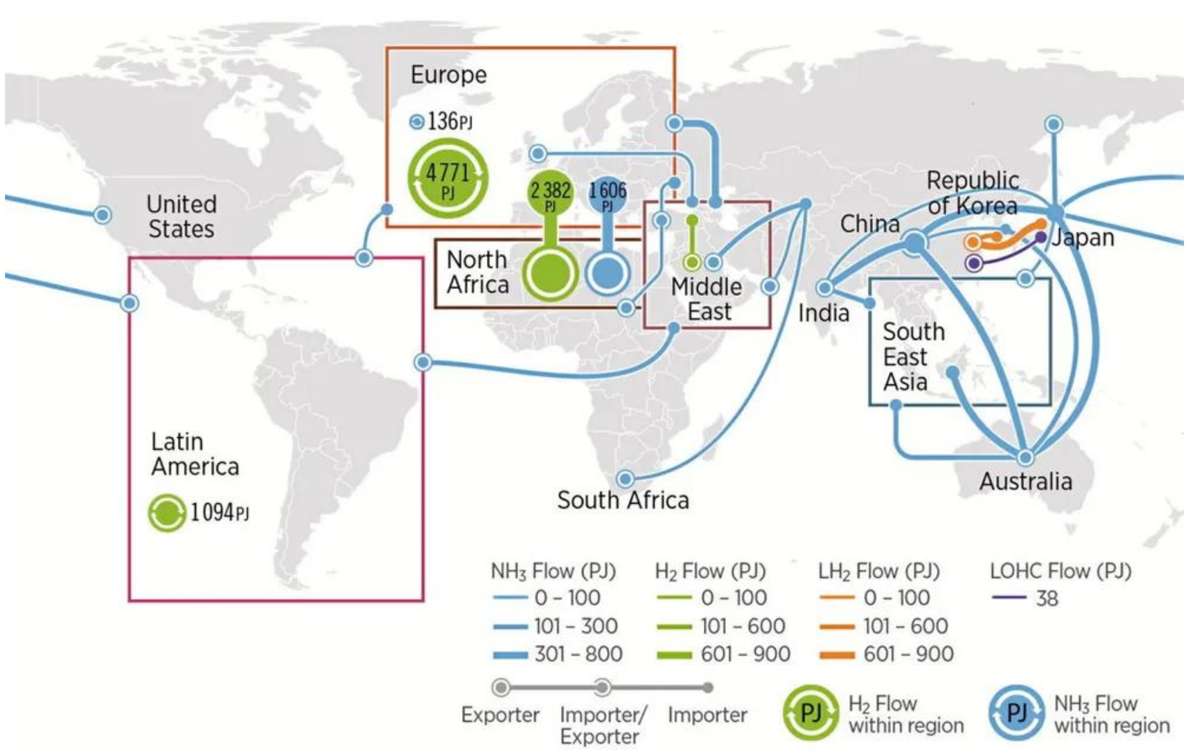
Future Outlook

- **By 2030**: EU demand could reach 7–10 Mtpa, driven by shipping (e-SAF), power generation, and fertilizer sectors.

Region	Role	Key Projects
EU	Largest SAF importer (UCO from Asia)	30+ e-SAF plants announced, but lagging 2030 targets .
MENA	Solar-H_2 for e-SAF exports	NEOM (Saudi Arabia) targets EU market .
North America	Blue H_2/CCS-based SAF	U.S. aims for 3 billion gallons/year by 2030 .
Nordics	Green H_2 from hydropower/wind	Norway's offshore wind-to-SAF initiatives

EU Hydrogen Strategy Summary:

The EU aims for hydrogen to meet **13–14% of its energy needs** to achieve climate neutrality. Demand could reach **3–6 MTPA of H_2 by 2025**, 15–27 MTPA by 2030, and 20–32 MTPA post-2030. Germany is exploring imports, including from Australia, which could supply **1 MTPA by 2025** and **15 MTPA by 2030** (via Rotterdam)



Estimated global hydrogen trade volumes by 2050 in from of different carriers as established by IRENA.

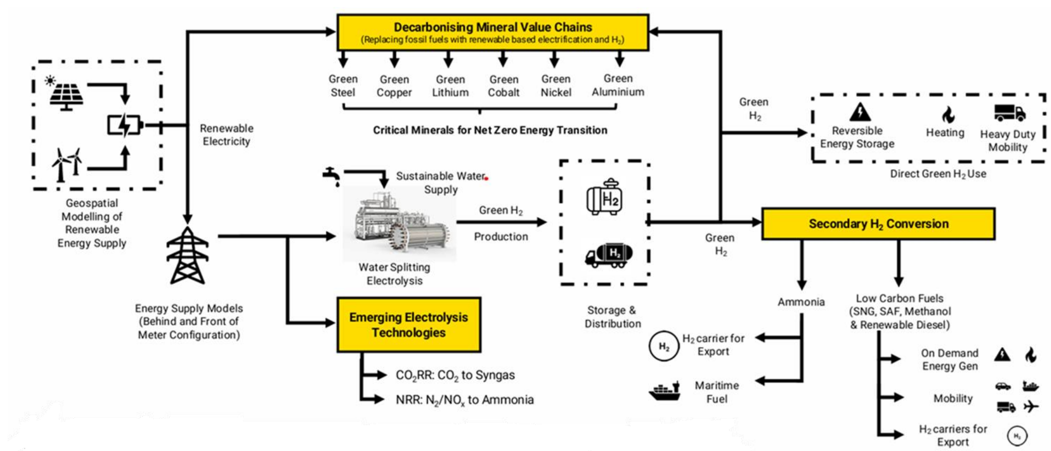
Integrating Renewable Electrification and Hydrogen Carriers for Decarbonization

Strategies for integrating renewable electrification with hydrogen carriers for industrial decarbonization.

Electrification Renewable

Integration and Storage

Hydrogen Carriers



Electrochemical Storage

Storage systems that directly couple electrical energy with chemical hydrogen carriers.

Industrial Sector

Integration of electrical and hydrogen systems to decarbonize high-heat industrial processes

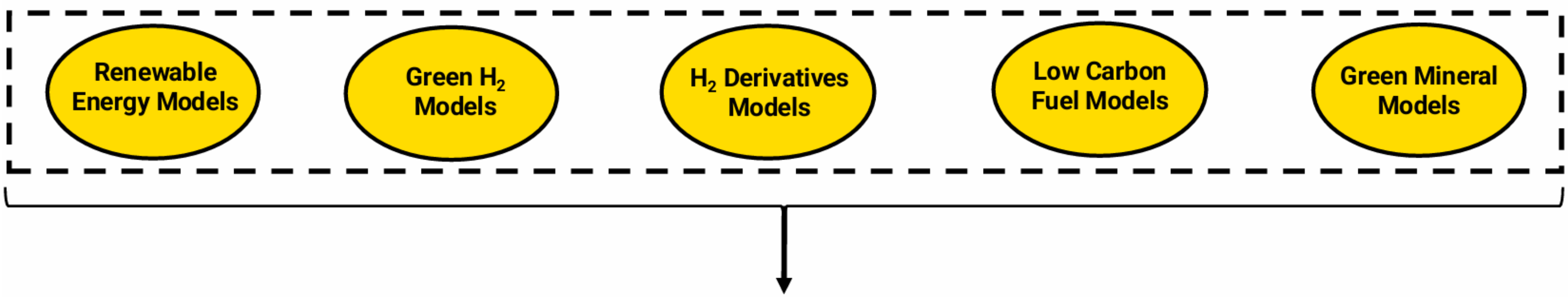
Regional Economies

Integration models adapted to different geographical and economic contexts.

Benefits of Integration

- Greater energy efficiency
- Long-term storage
- Reduction of emissions

Supporting Government and Industry in Decarbonising



Model Name	Primary Focus & Inputs	Core Output / Energy Vector	Key Characteristics & Purpose
Renewable Energy (RE) Model	Generate electricity from solar, wind, hydro, geothermal.	Electricity (kWh)	Direct electrification. Most efficient path for sectors like buildings, light transport, and some industry.
Green Hydrogen (H_2) Model	Use renewable electricity for electrolysis of water.	Gaseous or Liquid Hydrogen (H_2)	An energy storage & carrier for hard-to-abate sectors (e.g., heavy industry, long-term storage).
H_2 Derivative / E-Fuel Model	Use Green H_2+ a carbon source (e.g., captured CO_2).	Liquid or gaseous fuels (e-Fuels).	Creates drop-in replacements for fossil fuels in aviation, shipping, chemicals (e.g., e-methanol, e-kerosene).
Low-Carbon Fuel Model	Broad category for reduced carbon intensity vs. fossil fuels.	Various fuels (biofuels, e-fuels, blue H_2).	Transitional or sector-specific solutions where direct electrification or pure H_2 is not yet viable.