Resources: CO_2 and Hydrogen

Availability of Resources in Different Countries
Commonalities and Differences

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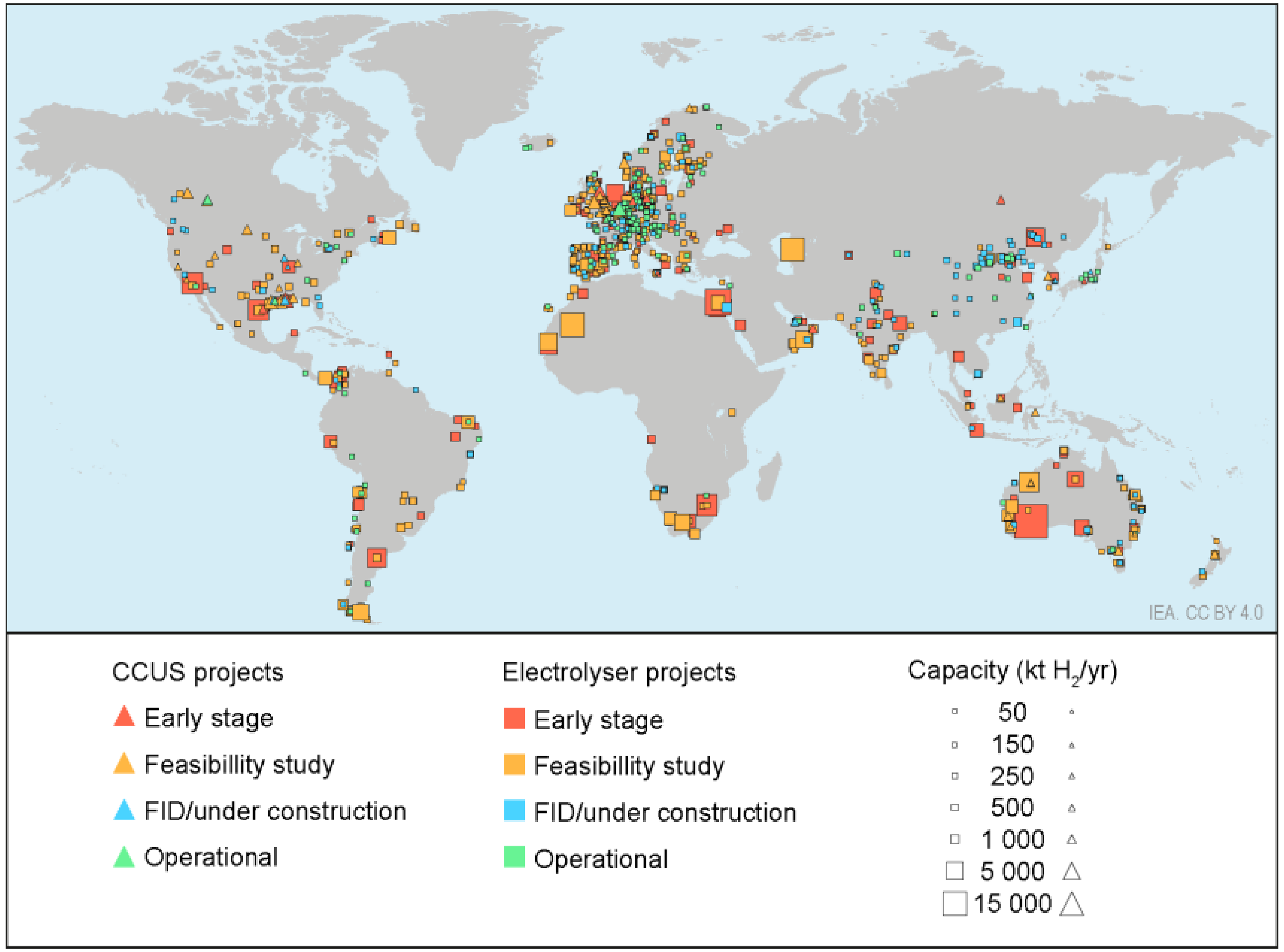
Resources: CO_2 and Hydrogen

- e-fuel production -> availability of (renewable) power for low emission hydrogen production as well as CO_2.
- CO_2 -> can stem from industrial flue gas (e.g., steel, cement, ethanol), biogenic sources, or direct air capture (DAC).
- Today, hydrogen is mainly produced from fossil-based fuel,
  - it can be produced from biomass or by using renewable electricity.
- A substantial increase in the amount of e-hydrogen is expected, as well as a significant cost reduction.
- Despite advances in technology development, renewably produced hydrogen from electrolysis will only be able to compete with the production costs of current fossil-based hydrogen production if CO_2 prices are set accordingly.

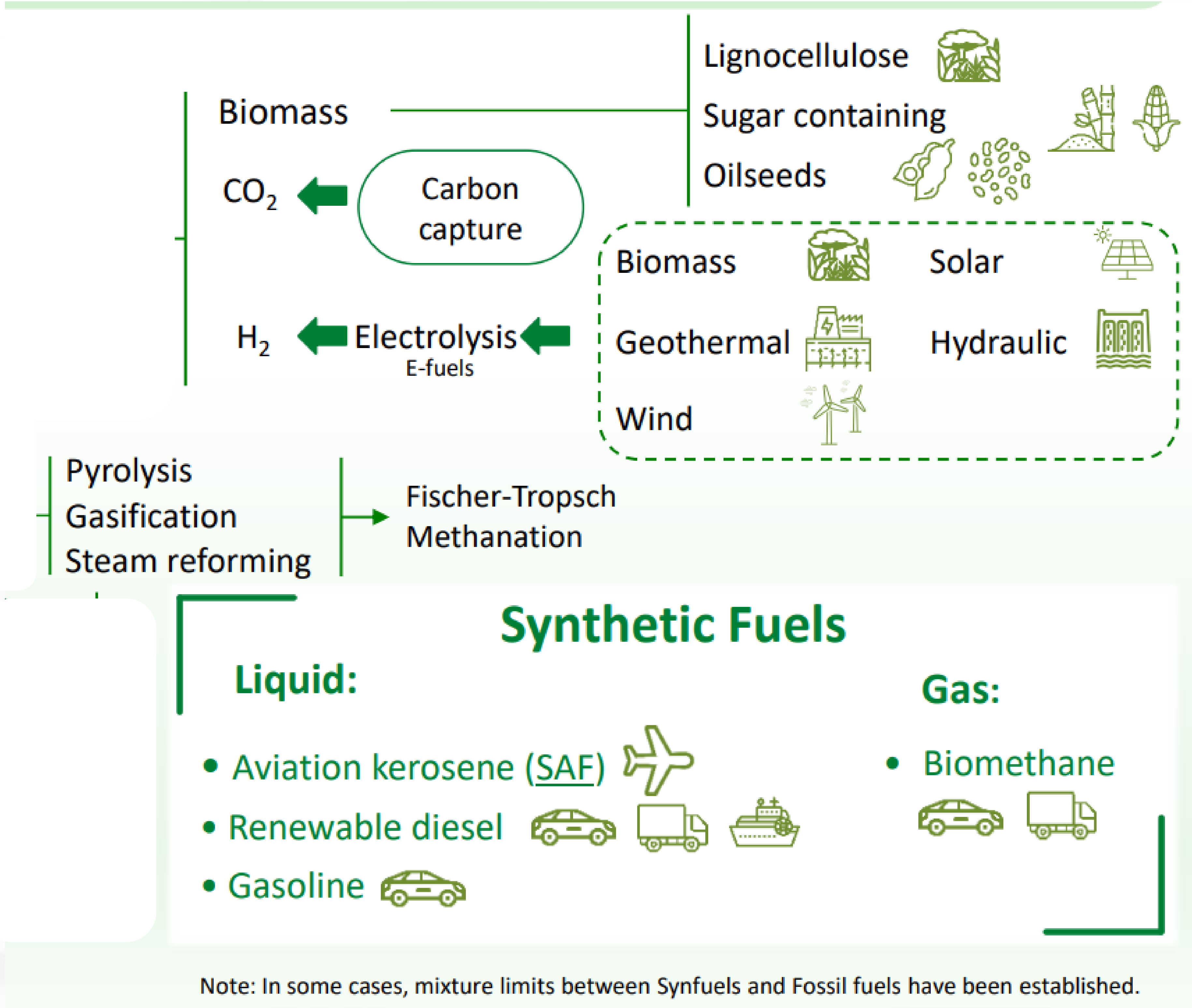
Map of announced low-emission hydrogen production projects

Figure ES.1 Map of announced low-emission hydrogen production projects



Note: Map includes also announced projects starting after 2030.
Source: IEA Hydrogen Projects database.

Possible technical routes of an integrated e-biofuels process combining elements from biomass gasification and e-fuels pathways



Source: Synthetic Fuels Fact Sheet, EPE (2024)

Synthetic Fuel Sources and Routes

Synthetic Fuel Sources	Route
Plant biomass	• Gasification of lignocellulose
Agro-industry • Forest residues, animal and agricultural wastes • Bioethanol • Biodiesel • Biogas	• Biomass Gasification • Bagasse Gasification • Reforming or gasification of glycerol • Methane Reforming
Urban waste • Urban solid wastes • Wastewater treatment	• Gasification • Methane Reforming
Pulp and paper industry	• Gasification of bark and black liquor
Electrolysis from renewable energy and carbon capture and use from industry	• E-fuels

Sources: ProQR (2021) e Royal Society (2019)

Source: Synthetic Fuels Fact Sheet, EPE (2024)

Availability of Resources in different Countries

Resources by country: Brazil

- Considering the importance of flexible paths for the energy transition Brazil, given all its potential, has great opportunities in hydrogen economy.
- Brazil has a large potential for hydro, wind and solar electricity. And as the production grows in general (+ 30 % are expected until 2030), more biogenic waste is generated which can be used for energetic purposes. Especially wastes from soy, sugar cane and corn production are available in a large amount.
- Currently, roughly 25 % of the transport matrix in Brazil is renewable (mainly ethanol and biodiesel).
- CO_2 can be obtained by renewable processes (from ethanol plants, biogas purification and bioelectricity).
- Brazil has eight commercial plants and two pilot plants for hydrogen production.

Source: https://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/plano-decenal-de-expansao-de-energia-2034

Resources by country: China

- The sources of hydrogen and CO_2 are not necessarily in the context of low-emission energy (i.e., renewable H_2 and CCUS-CO_2). For example, COG-H_2 is seen as feedstock.
- However, CCUS has great prospects in China, since China's CO_2 capture demand might reach 20-408 million tons, 0.6-1.45 billion tons, and 1-1.82 billion tons in 2030, 2050, and 2060, respectively.
- Further information: CCUS Progress in China – A status report. https://www.globalccsinstitute.com/wp-content/uploads/2023/03/CCUS-Progress-in-China.pdf

Resources by country: Denmark

- Largest project, BrintØ, Danish North Sea, will deliver 10 MW wind power corresponding to 6 GW electrolyzer capacity.
- Total 2040 Hydrogen production capacity forecast: High Case 16.3 GW, Mid Case 11.1 GW, Low Case 6.0 GW (DNV).
- CO_2 is available from cement factories, and from biogas upgrading.

Resources by country: Finland

- News mapped 23 hydrogen projects in various development phases around Finland in 2023, of which 10 were planning to produce synthetic fuels.
- Fossil and biogenic CO_2 emissions (41.4 Mt CO_2 in 2020) are available from large point sources such as power and heat production plants and other industrial facilities.

Resources by country: Germany

- Hydrogen has been identified as one of the most important renewable energy sources by the German Federal government. In order to assure availability an import strategy for hydrogen and its derivatives is being developed. The German government reached an agreement with Norway on the long-term supply of hydrogen in March 2022.
- Low-emission hydrogen is mostly being promoted under the National Hydrogen Strategy, however until sufficiently available, other low-emission hydrogen can also be used – especially the comparatively climate-friendly hydrogen from waste, for example. Low-emisson hydrogen from natural gas using CCS, i.e. CO_2 storage, hydrogen from methane combustion, and hydrogen from waste and residues will also be subsidize

Resources by country: Switzerland

- Run-of-river power plants are currently regarded as the most promising plants for hydrogen production, as large renewable electricity capacities are available at these locations.
- Ideally, the CO_2 for the processes stems from concentrated sources like cement plants, waste-incineration plants, biogas upgrading plants (e.g. combined with waste water treatment plants), or alternatively from direct air capture.

Resources by country: United States

- Several studies show the available CO_2 resources in the United States
- In 2023 Billion-Ton Report: An Assessment of U.S. Renewable Carbon Resources, stationary CO_2 resources were evaluated along with the estimated costs for CO_2 capture and purification.
- The Pathway To: Carbon Management Commercial Liftoff also presents U.S. CO_2 resources by types and regions along with the pipeline infrastructure needed to transport CO_2.
  - This report also shows the ranges of the cost for capturing and transporting CO_2.
- Argonne also published papers discussing **the potential of e-fuel production** (FT-fuel and methanol) using stationary CO_2 sources. **Point sources in the U.S. include fermentation CO_2 from ethanol plants, CO_2 from ammonia and hydrogen plants, cement plants, and other sources such as electric power plants**. The price for the CO_2 is mainly defined by post-combustion technologies like capture, purification, compression and cooling.

Resources by country: United States

- In the United States, the **high purity CO_2** from industrial sources **serve as low-cost feedstock for electro fuels production**. With industrial CO_2, **the potential e-fuels production volume can exceed the current U.S. jet fuel demand and meet over one third of diesel demand**. All the high purity CO_2 sources in the U.S. can produce 39 billion gallons of jet (exceeding the current production of petroleum counterpart) and 23 billion gallons of diesel (about 38% of current distillate production).
- Argonne published a report regarding the hydrogen demand in the U.S., which is based on DOE's H_2@Scale Initiative.
- One market/resource analysis project under the CO_2 Reduction and Upgrading for e-Fuels Consortium is currently evaluating the needed resources (CO_2, electricity, and H_2) for targeted e-fuel production in different US regions.

Resources by region: EU

- In the EU, a proposal for the regulation of hydrogen production is being discussed. It includes low-emission hydrogen but not hydrogen from COG. The CO_2 source is not strictly regulated in Europe. Hydrogen must be renewable, CO_2 not.

NOT USED FOR SENSITIVITY ANALYSIS

Scenario 2 (bagasse): 35.1 tH_2/day
[additional to scenario 1]

Commonalities

- **Renewable Energy Sources:** Many regions, including Brazil , China, Denmark, Finland, Germany, Switzerland, the United States, and the EU, **recognize the importance of renewable energy sources such as biomass, solar, wind, and hydroelectric power for e-fuel production**. Specifically for Brazil, with its long and robust history with hydropower, and the strongly growing solar and wind sources, the opportunities for e-fuel production have been unfolding.
- **CO_2 Capture and Utilization:** Several regions identify sources of CO_2 emissions from industrial processes like cement factories, waste incineration plants, ethanol and biogas upgrading plants for e-fuel production.
- **Hydrogen Production:** There's a widespread focus on hydrogen production through electrolysis, utilizing renewable energy sources to generate low carbon emission hydrogen.

Differences

- **Energy Mix:** The composition of renewable energy sources varies from region to region and is not always reflected in the current energy mix. For example, there are still some countries where the electricity supply is currently very CO_2 -intensive.
- **CO_2 Sources:** The sources of CO_2 emissions vary from region to region and are, for example, industrial plants or biomass plants. The availability and accessibility of CO_2 for the production of e-fuels **depends in particular on the local economy** (i.e. whether it is industrial or agricultural, etc.).
- **Policy Focus:** There are differences in policy focus and approach towards e-fuels, such as the inclusion or exclusion of certain hydrogen production methods (e.g., hydrogen from coal gasification) in regulations
- **Low-emission methanol:** The European countries are very strict on a low-emission methanol and e-fuel production whereas other countries are more open to also include fossil methanol production.
- **Tolerance regarding fossil produced e-fuels**: EU is more stringent, whereas other non-Europeans are more flexible.

Thank you!

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