Solar fuels for industry de-carbonization

Focused on Green Hydrogen and the Swedish Context

Hydrogen and Beyond - November 2021

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KTH Royal Institute of Technology

Main Campus – Stockholm, Sweden

- Since 1827
- 14.000 students
- 4.000 employees
- Top 30 (9 EU)

Industrial Engineering & Management

↓

Energy Technology

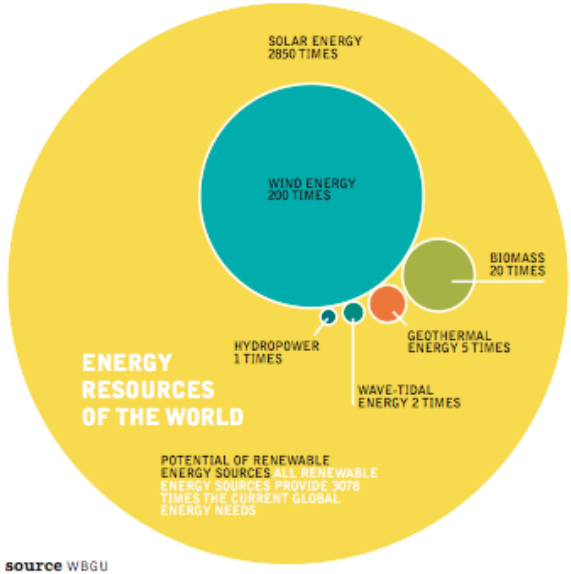
↓

Div. Heat & Power

- Renewable Energy Techs and Systems
- Energy Storage & Power-to-X
- Thermal Systems

Solar Fuels – what ? / why?

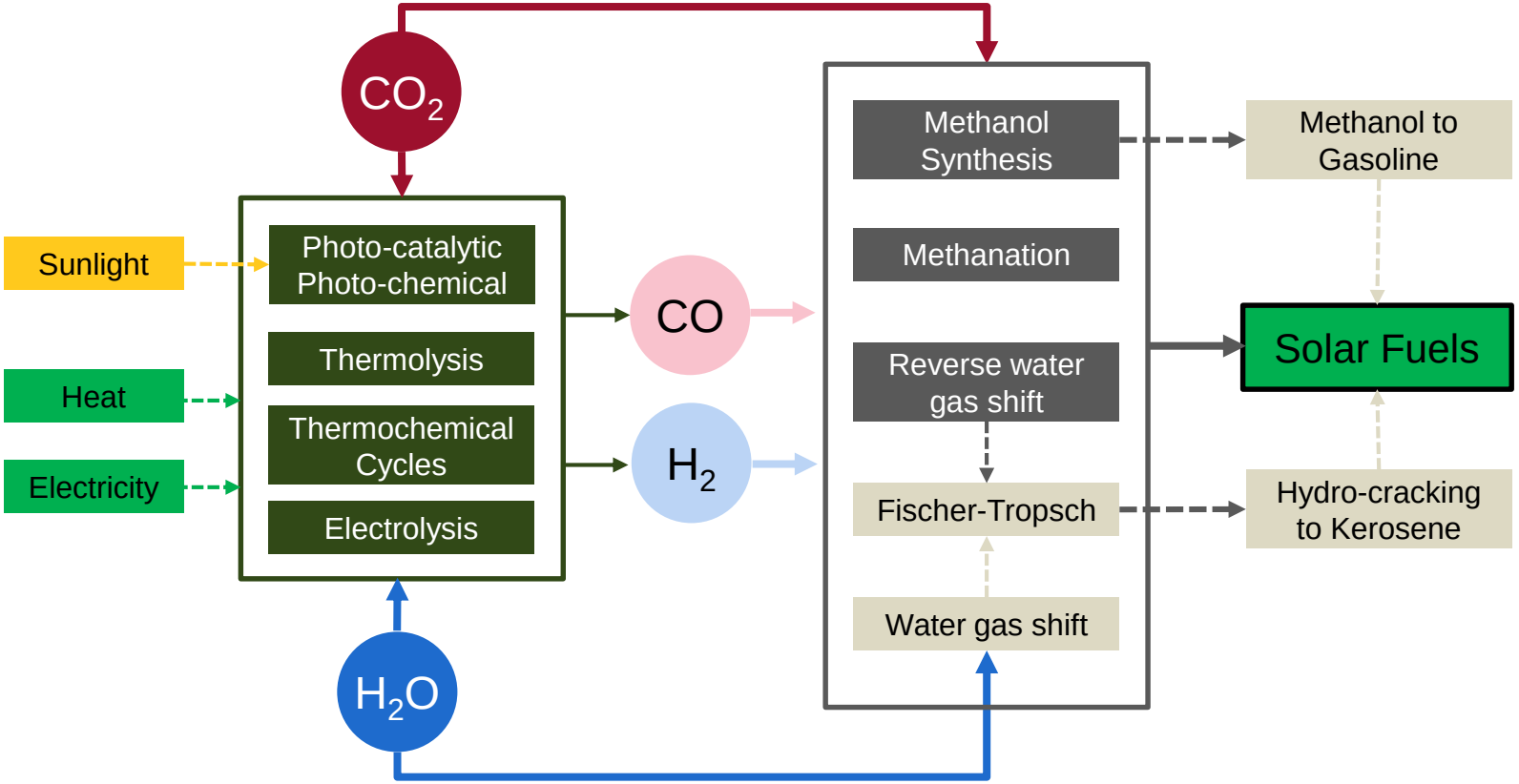
"a synthetic chemical fuel produced from solar energy"



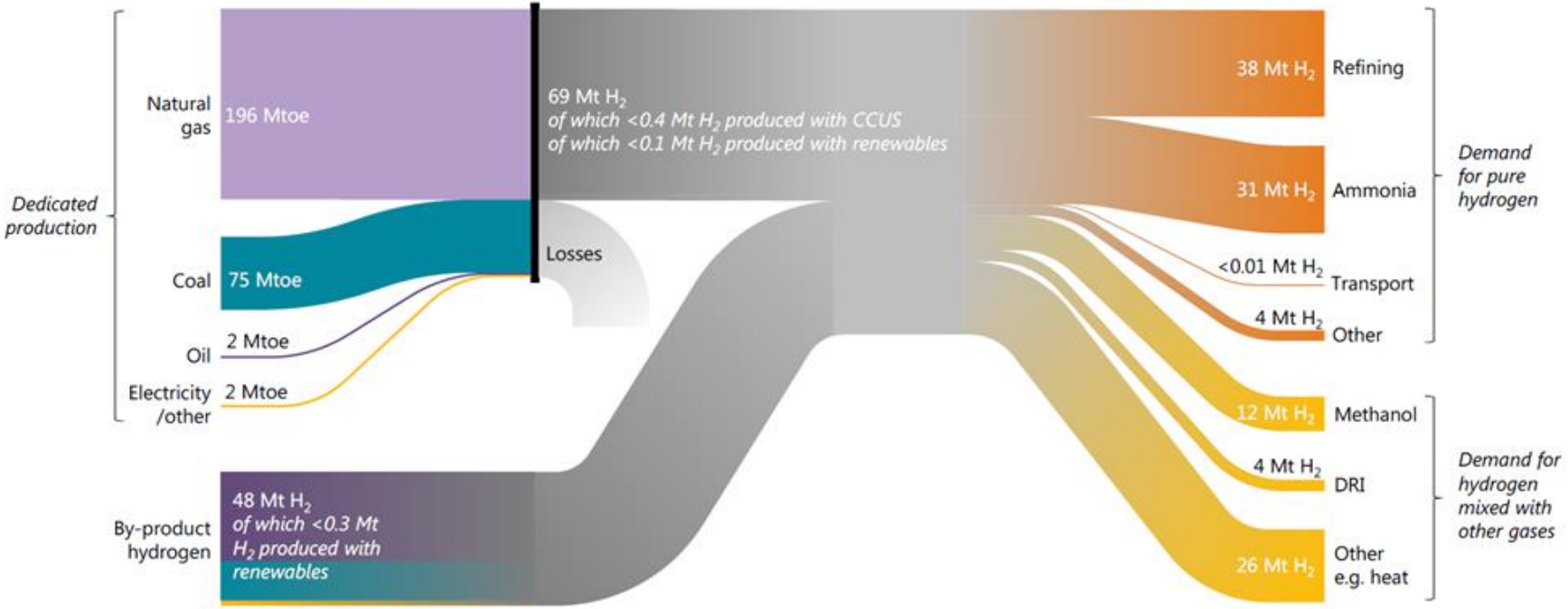
IRENA, 2021

Most investigated: Hydrogen, Syngas, Ammonia, Methanol,…

Solar Fuels – how ?

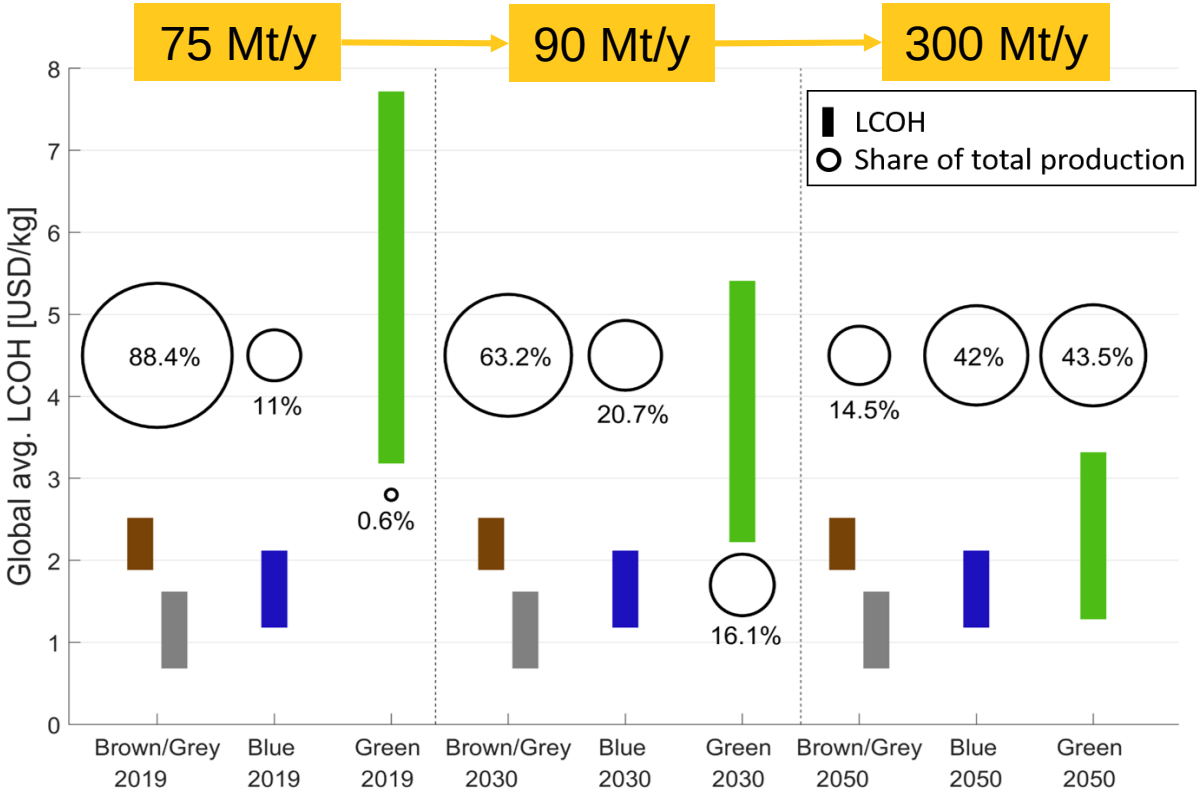


Hydrogen: Sources and Demand Today



IRENA, 2019

Hydrogen: Future Projections



- Fossil H_2 is cheapest and will be unless new policies
- Demand will increase, driven by green H_2
- Drivers for green H_2 are expected cost reduction and policies to drive new <u>demand and infrastructure</u>

“Green” Hydrogen Momentum

- **Technology improvements**: reduction in solar LCOE, and in electrolyzer costs.
- **Decarbonization goals**: countriessetting legally binding targets for zero emissions.
- Increasingly view that hydrogen will be necessary to achieve zero-carbon targets.
- **A broad coalition of proponents**: several major economies as well as a wide spectrum of industries are advocating the use of hydrogen in multiple sectors.

Challenges

- H_2 is almost entirely supplied from natural gas and coal today
- Besides low-temperature electrolysis, most processes are yet immature.
- Producing green H_2 is still costly, even from electrolysis, and requires vast resources.
- Hydrogen is difficult to store, transport, and deliver.
  - Opportunity for (solar) fuels as both final product and storage/carrier
- The development of H_2 infrastructure is slow and holding back adoption.
- H_2 must be used more widely. Today it is used mostly in oil refining and for ammonia.
  - Comprehensive policy is required to drive demand and industry

Hydrogen Use in Industry

Hydrogen

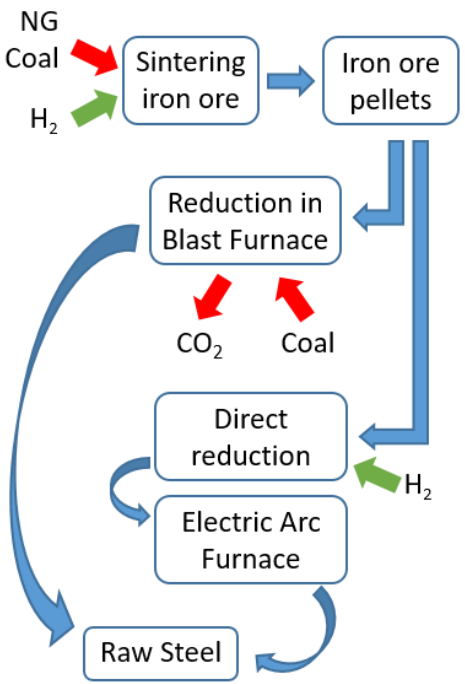
- **Industry**
- Buildings & gas grid
- Power generation
- Transport

Others in industry

- Cement, Aluminum Glass
- Fuel for high-grade heat
- Requires big changes in equipment and practices
- H_2 for partial fossil fuel substitution

Iron & steel

- H_2 as energy source and feedstock



Chemical production

- H_2 is well established in chemical sector
- Requires aprx. 70% of today's H_2 production
- H_2 is feedstock and energy source for:

Oil refining

- 40% of H_2 used is by-product
- Hydrotreatment (remove sulfur from crude oils)
- Hydrocracking (hydrocracking)

Ammonia

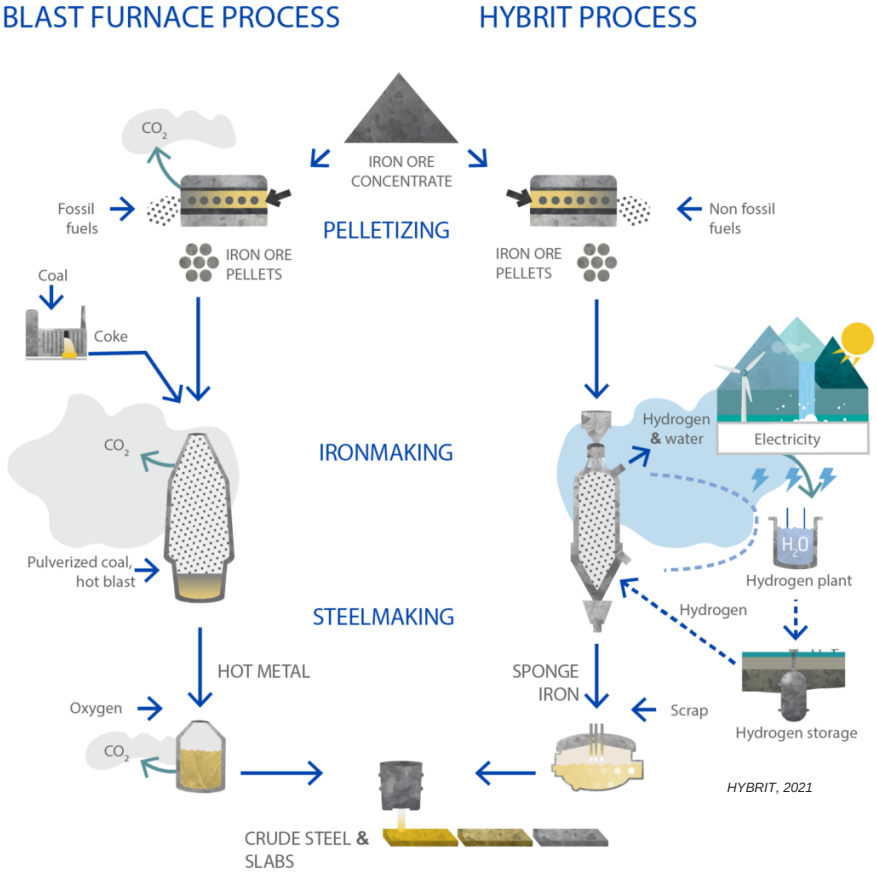
- Fertilizers
- Explosives
- Syn. Fibers
- Potential fuel (ships)

Methanol

- Solvents
- Gasoline
- Plastics

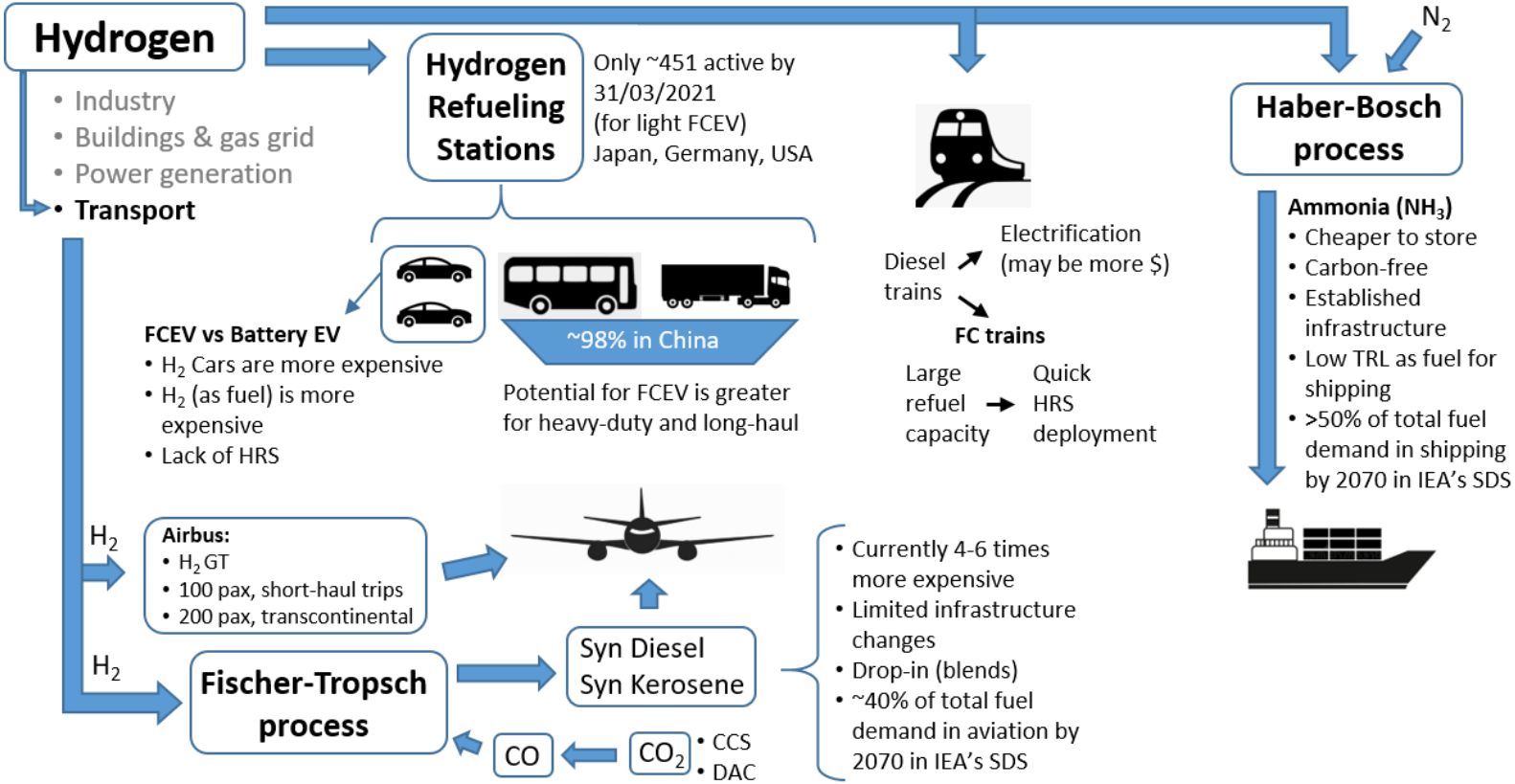
HYBRIT

- Target: fossil free steel.
- 2018-2024:
  - Fossil free pellets trials
  - H_2-based reduction smelting trials
  - H_2 storage (underground)
- 2025-2026:
  - HYBRIT demo
  - First fossil free in the market



HYBRIT, 2021

Hydrogen Use in Transportation



Hydrogen Use in Power Generation

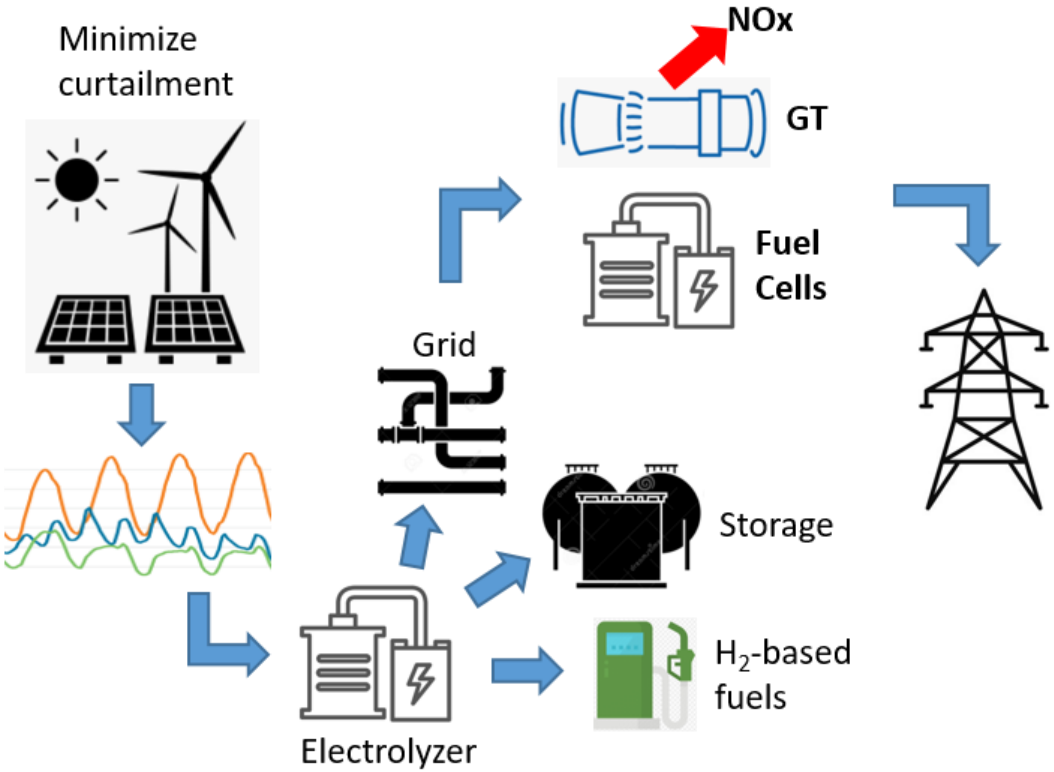
Hydrogen

- Industry
- Buildings & gas grid
- **Power generation**
- Transport

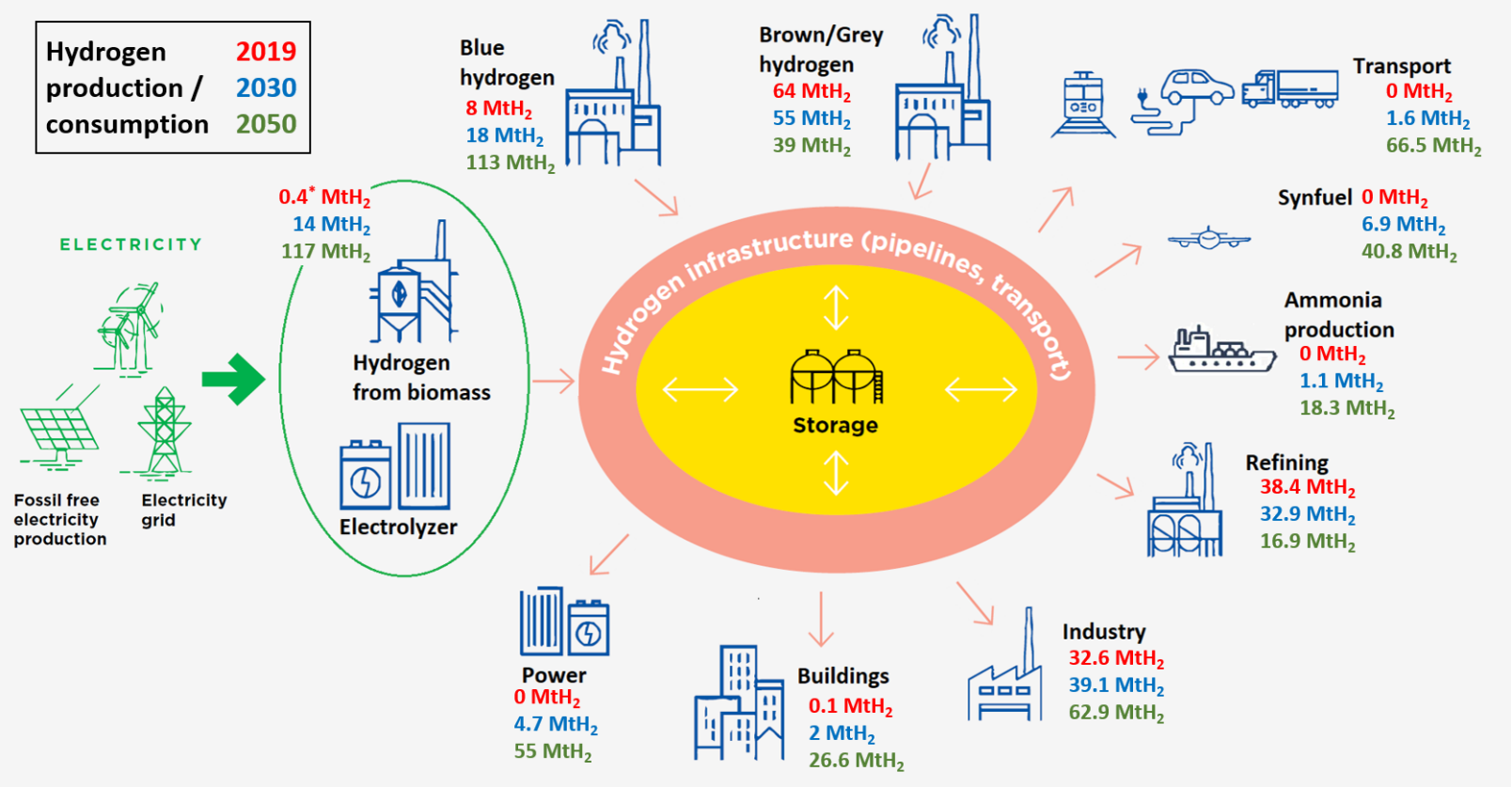
Retrofit

NG → H_2

0-10% H_2 → Minor adjustments
10-30% H_2 → Moderate changes
>30% H_2 → Major changes, NOx



Hydrogen Scenarios (compiled)



Green H_2 in Swedish Industry (Examples)

Biofuels

Refineries in Lysekil and Gothenburg. H_2 from biogass, CCS, electrolysis.

Expanded H_2 production for its biorefinery in Gothenburg

Chemicals

Perstorp's "Project Air" – methanol from electrolytic H_2, residual streams, CCU and gasification. Planned plant (2025) with 25MW electrolyzer in Stenungssund

Nouryon – Replace all fossil H_2 with electrolytic H_2 for hydrogen peroxide production in Bohus and Ånge

H_2 GT

In Finspång is currently able to offer GT with 50-60% H_2 in gas mixtures and aims to demonstrate 100 % H2 on an industrial scale in 2030.

E-fuels

Coallaboration e-methanol in Finland. E-fuels in Gothenburg by 2025. Plans of collaboration with CHP for e-methanol.

10 e-methanol plants in Scandinavia by 2030. First plant by 2024 in Övik Energi's Hörnebergsverket

Pilot producing aviation fuel next to their CHP in Östersund

Heating steel

Replacing fossil fuels with H_2 for steel processing. Planned 16 MW_{el} electrolyzers for 2022. Potential in Sweden is 800 MW_{el}

Announced that they have similar plans to Ovako's to adapt their rolling mills

Heat

Cross-sectoral partnerships for use of residual heat from H_2 production

- Vattenfall
- Ö-vik Energi
- Liquid Wind
- Skellefteå Kraft
- Rabbalshede Kraft
- Jämtkraft

Reduction in smelters

Investigating replacing fossil coal with H_2 for zinc recovery in their plant in Rönnskär.

Metal powder

Replace gas-based H2 with H2 from biogas reforming, gasified biomass and electrolysis (6MW_{el} by 2024 and 30 MW_{el} by 2030)

Agriculture / Ammonia

Yara + Lantmännen → pilot project aimed at creating the world's first certified food chain with fossil-free mineral fertilizer on market in 2023

"Invest in Norrbotten" and LKAB planning large-scale facilities for ammonia production from electrolytit H_2.

EU Hydrogen Strategy

2024

- 6 **GW** of renewable hydrogen electrolysers
- Replace **existing hydrogen production**
- Regulation for liquid hydrogen markets
- Start planning of hydrogen infrastructure

2030

- **40 GW** of renewable hydrogen electrolysers
- New applications in **steel and transport**
- Hydrogen for electricity balancing purposes
- Creation of “Hydrogen Valleys”
- Cross-border logistical infrastructure

2050

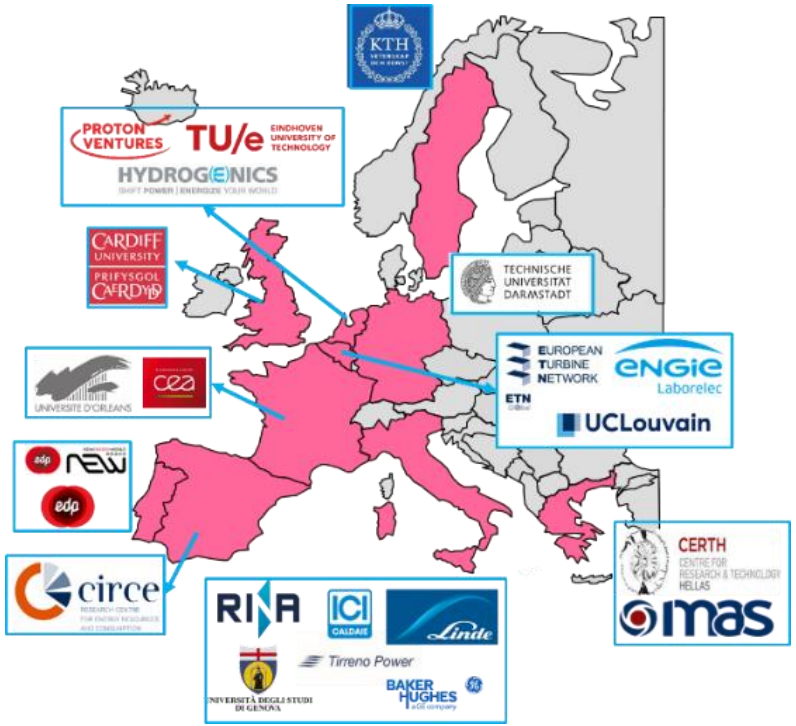
- Scale-up to **all hard-to-decarbonise sectors**
- Expansion of hydrogen-derived **synthetic fuels**
- EU-wide infrastructure network
- An open international market with € as benchmark

Key Takeaways

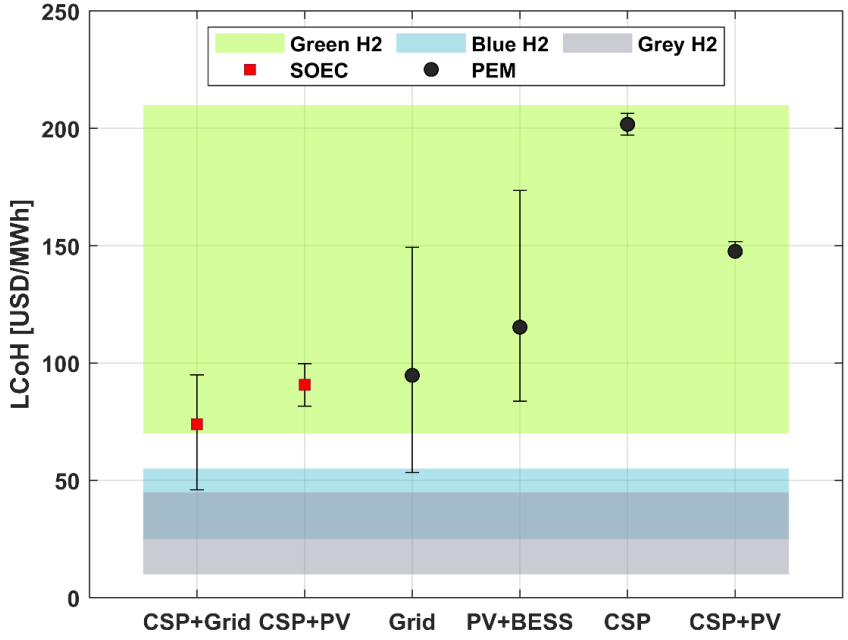
- Solar fuels can play an important role in decarbonizing transport and industry.
- H_2 is the most investigated "solar fuel", but <u>not the only one</u>.
- There are several paths for producing H_2 from the Sun, <u>not just electrolysis</u>.
- Solar fuels (H_2) are still costly, and it is hard to store H_2 and transport it as such.
  - Opportunity for new technologies and fuels as final product and storage/carrier
  - By 2050, and with policies and targets, green H_2 can account for 50% of demand
- Policies and awareness needed to drive adoption and techs sustainably
  - New infrastructure is needed and new industrial actors need to adopt use of H_2
- We need SolarFuelsNow!

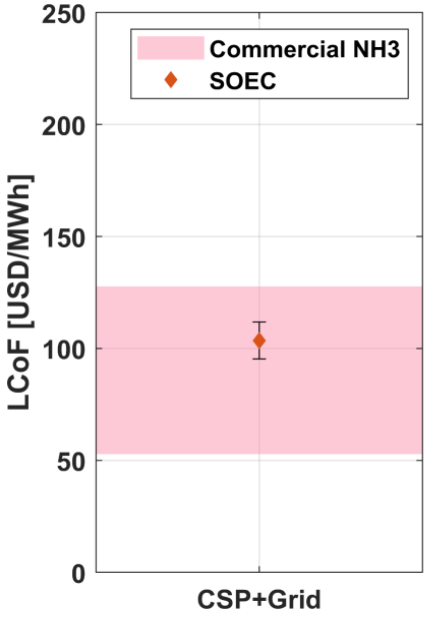
KTH-EGI Research: Flexnconfu H2020

- Combining and enhancing thermal power plants and renewables via power to H_2 / NH_3 technologies
- April 2020 – March 2024.
- MW-scale demo site in Portugal
- New components: PEM elec., NH_3 reactor, H_2 / NH_3 storage and flexible combustors
- New system models



KTH-EGI Research: System Analysis





High temp. CSP + Solid Oxide Electrolysis seem most promising solar H_2 techs

Other KTH Research in H_2

- KTH-EGI is also looking into H_2 technologies for flexible combustion and use in airplanes
- Chemical / Material Engineering → HYBRIT: investigating alternatives for production and large-scale hydrogen storage / Reduction of iron ore with the help of hydrogen
- Applied Physics participates in the project "H_2 energy by solar activation of cellulose" which aims to use sunlight to transform cellulosic materials into useful H_2 energy.
- Applied Electrochemistry focuses in electrochemical power sources (lithium batteries, ZEBRA batteries, molten carbonate / polymer electrolyte / direct methanol fuel cells).

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