Perspectives for hydrogen from biomass in Brazil

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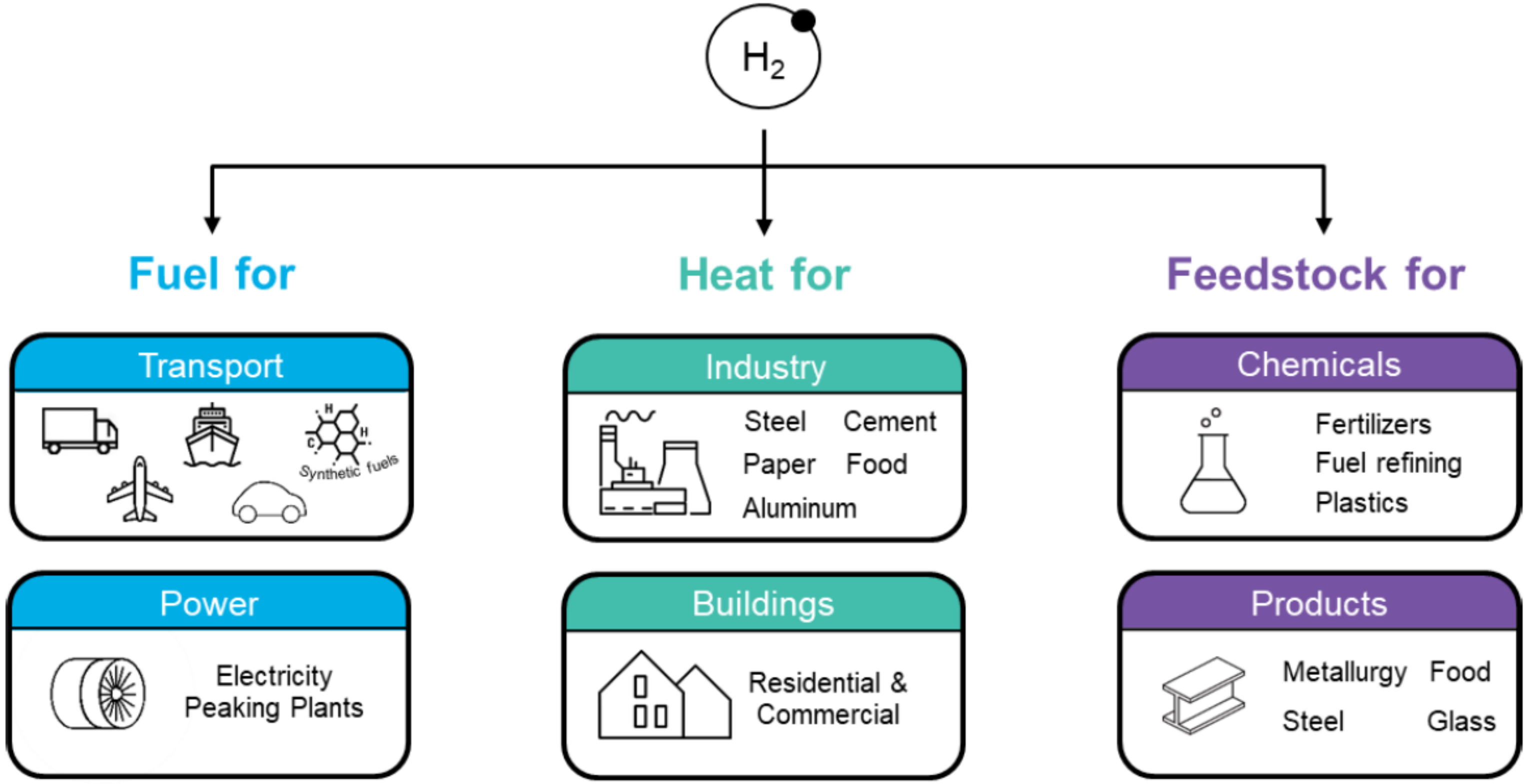
Why hydrogen?
Hydrogen is a key element of the energy transition



Source: BloombergNEF

Hydrogen colours:
feedstocks, technologies, GHG emissions

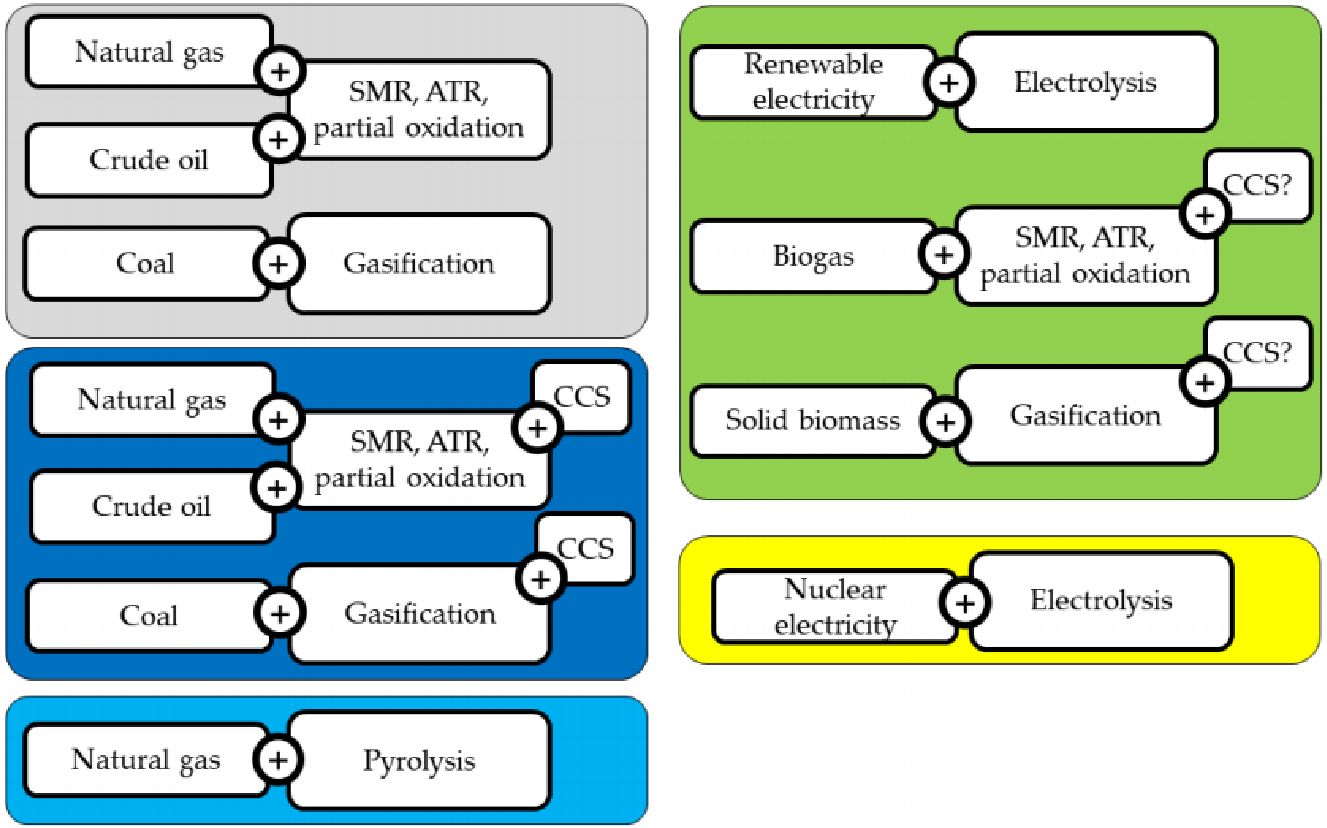
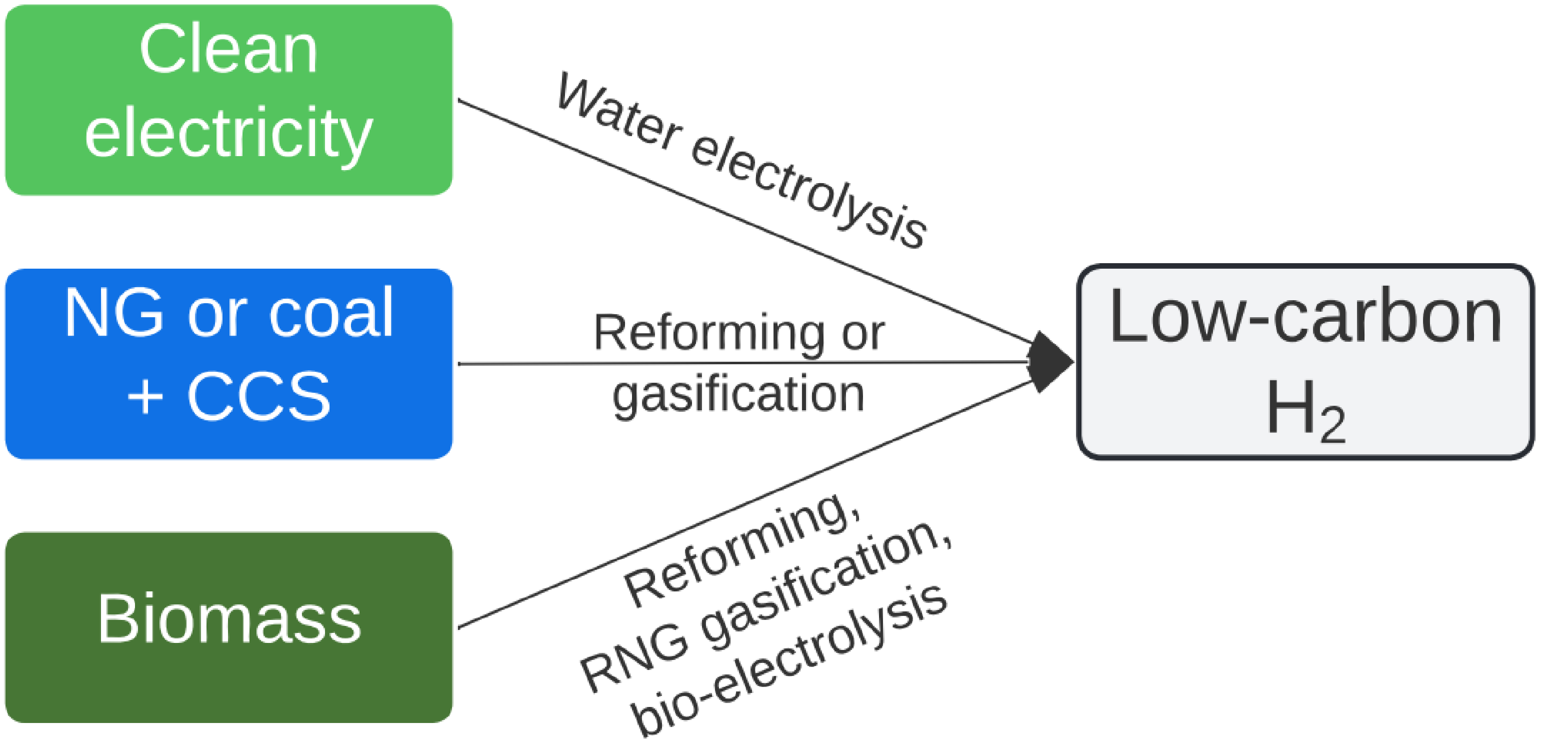


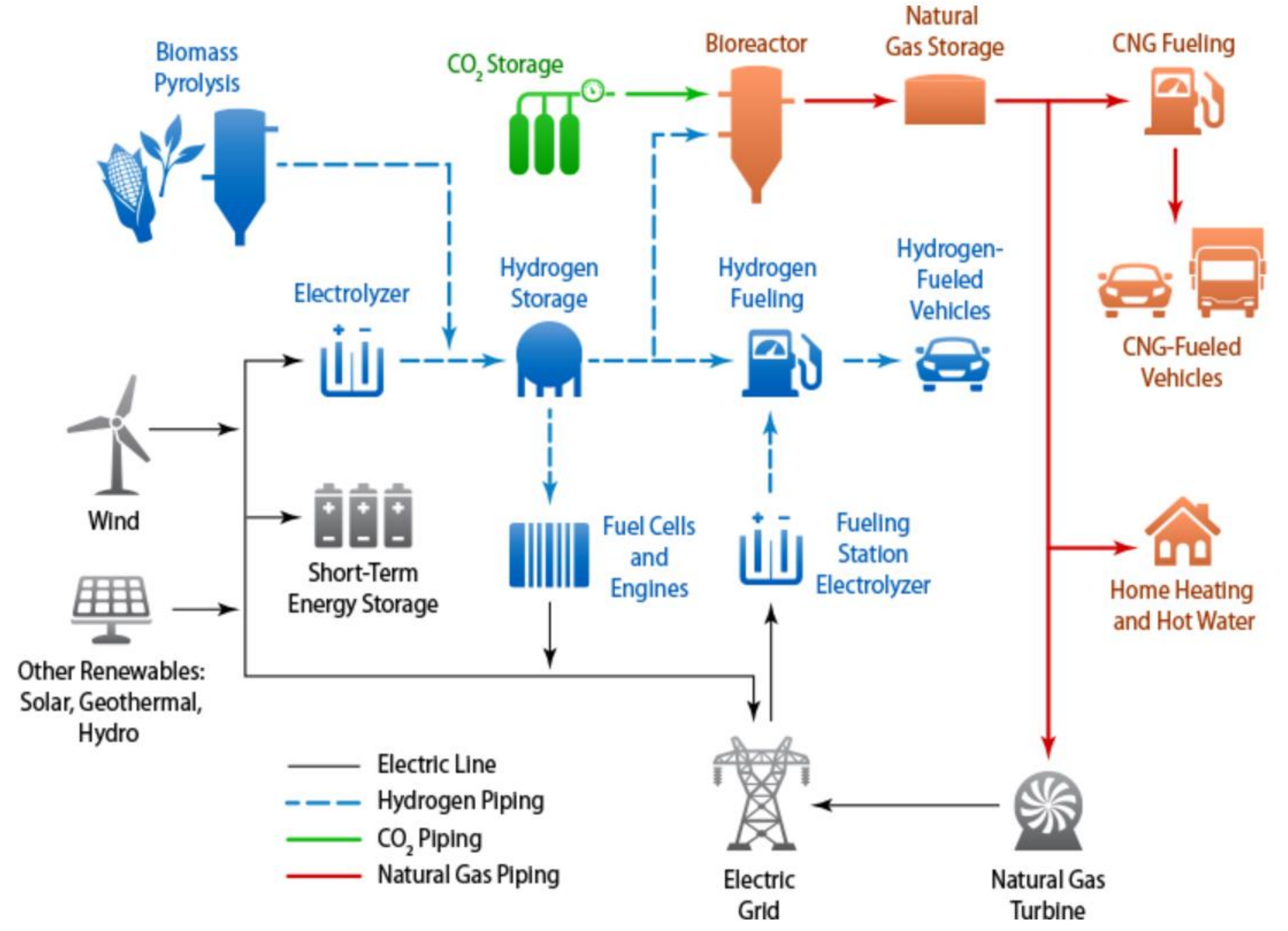
Figure 1. Different hydrogen generation pathways divided by colour. SMR: steam methane reforming, ATR: autothermal reforming, CCS: carbon capture and sequestration.

Fonte: Noussan, M. et al. (2021). *The Role of Green and Blue Hydrogen in the Energy Transition: A Technological and Geopolitical Perspective*. https://doi.org/10.3390/su13010298

Flexible hydrogen production



Energy system integration: hydrogen as a link

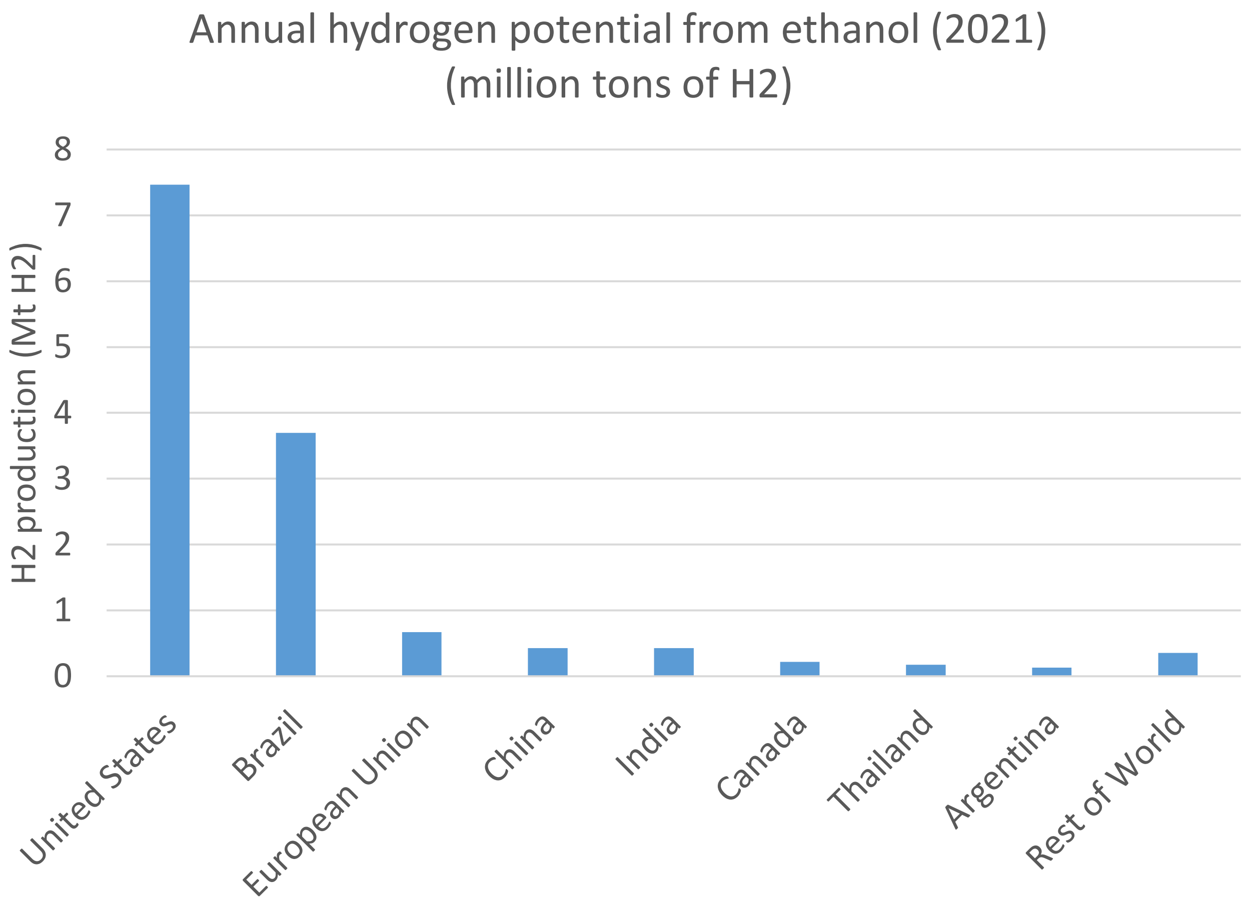


This diagram depicts various scenarios for producing renewable hydrogen and electricity.

Fonte: NREL
https://www.nrel.gov/hydrogen/renewable-electrolysis.html

Global hydrogen potential only from ethanol reforming

Country	2021 Ethanol production (MM m³)	H_2 potential (MM tons)
United States	56.8	7.5
Brazil	28.1	3.7
European Union	5.1	0.7
China	3.3	0.4
India	3.3	0.4
Canada	1.6	0.2
Thailand	1.3	0.2
Argentina	1.0	0.1
Rest of World	2.7	0.4
Total	103.2	13.6



Sources: ethanol data from RFA (2022); conversion factor from Raízen / Hytron

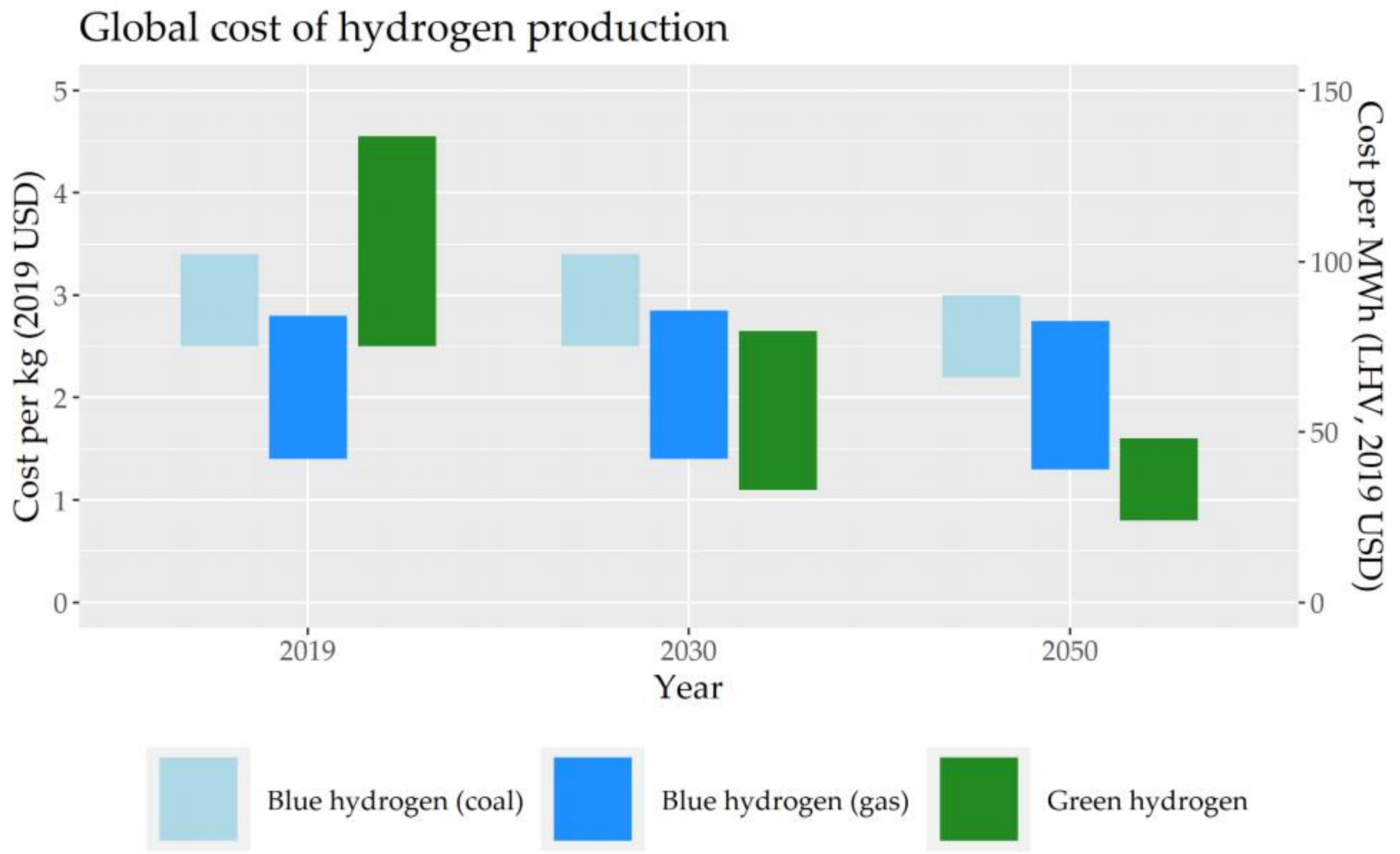


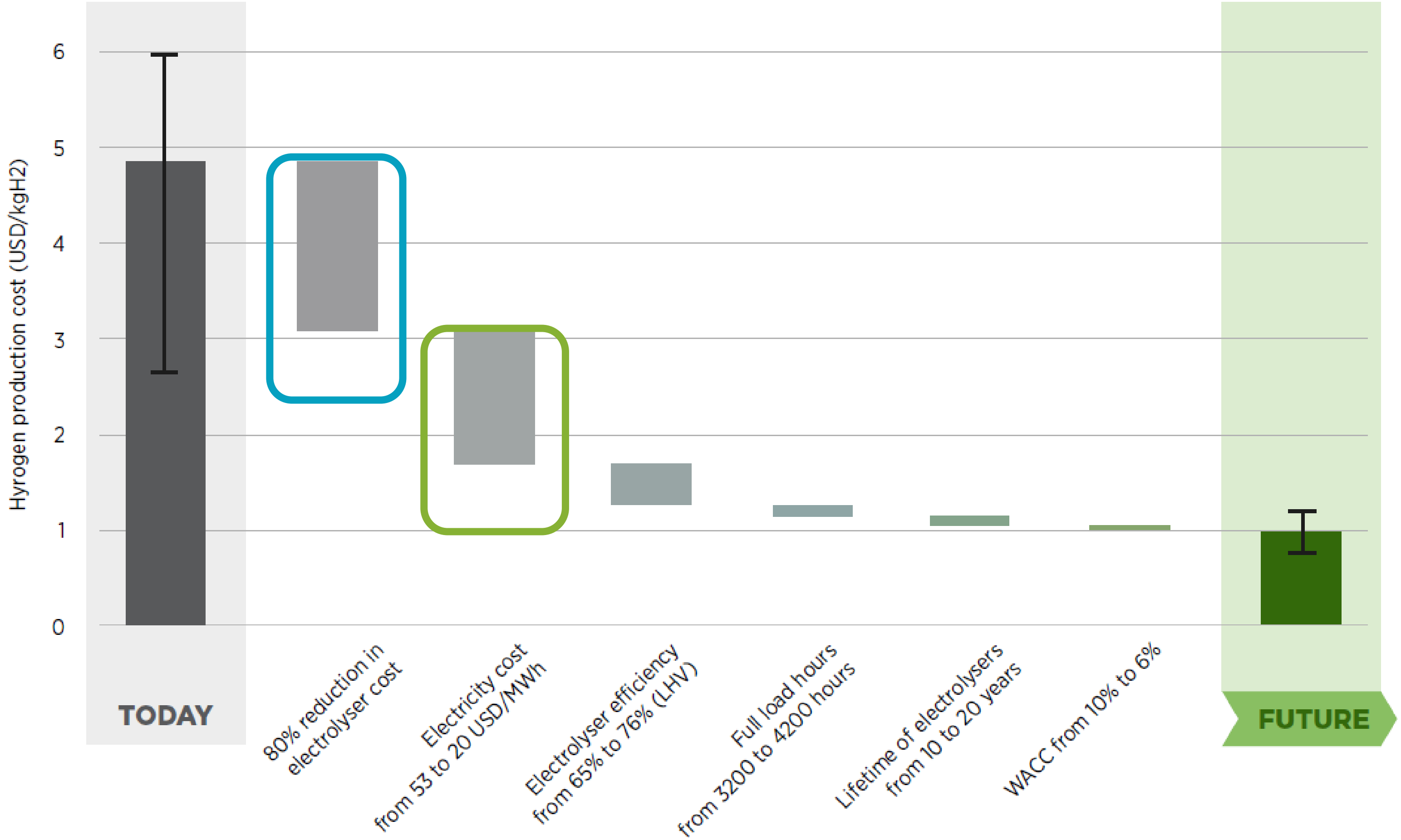
Figure 2. Estimation of future hydrogen costs for different pathways. Energy figures based on hydrogen lower heating value (LHV). Authors' elaboration on BNEF data, 2020 [14].

Fonte: Noussan, M. et al. (2021).
The Role of Green and Blue Hydrogen in the Energy Transition: A Technological and Geopolitical Perspective. https://doi.org/10.3390/su13010298

Expected Green Hydrogen cost reduction

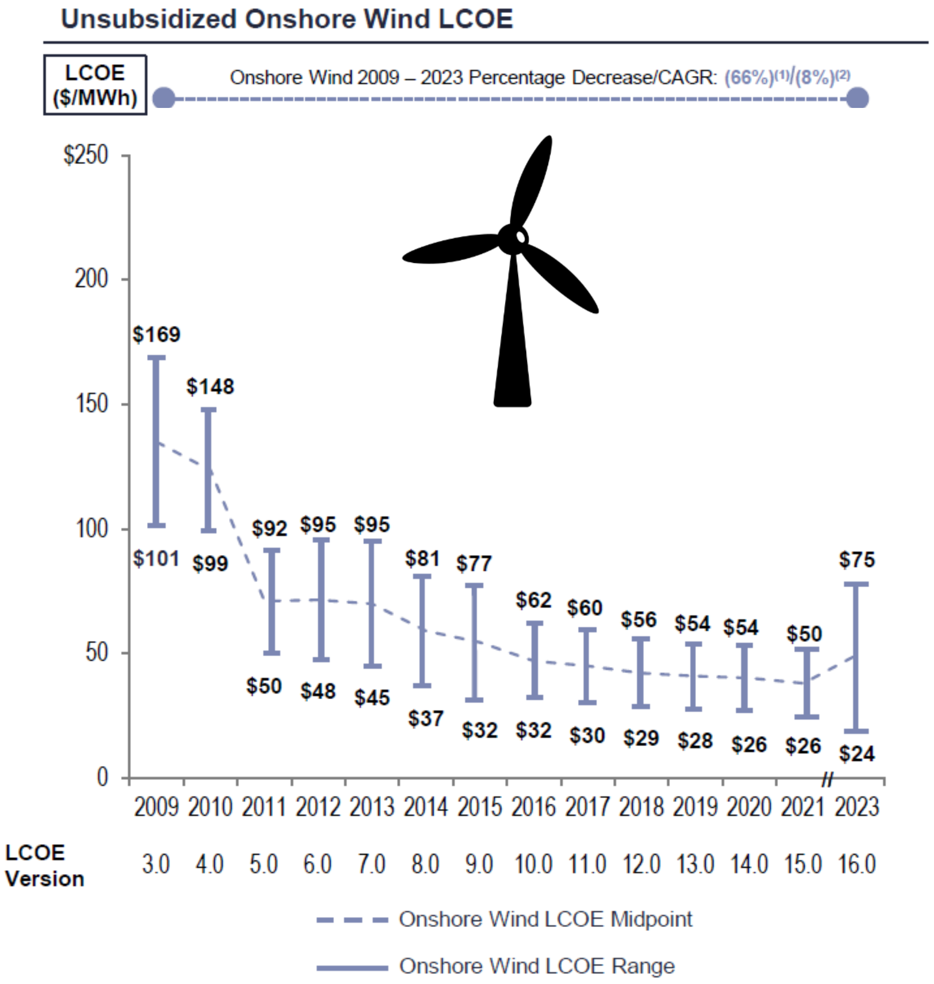
Elements:

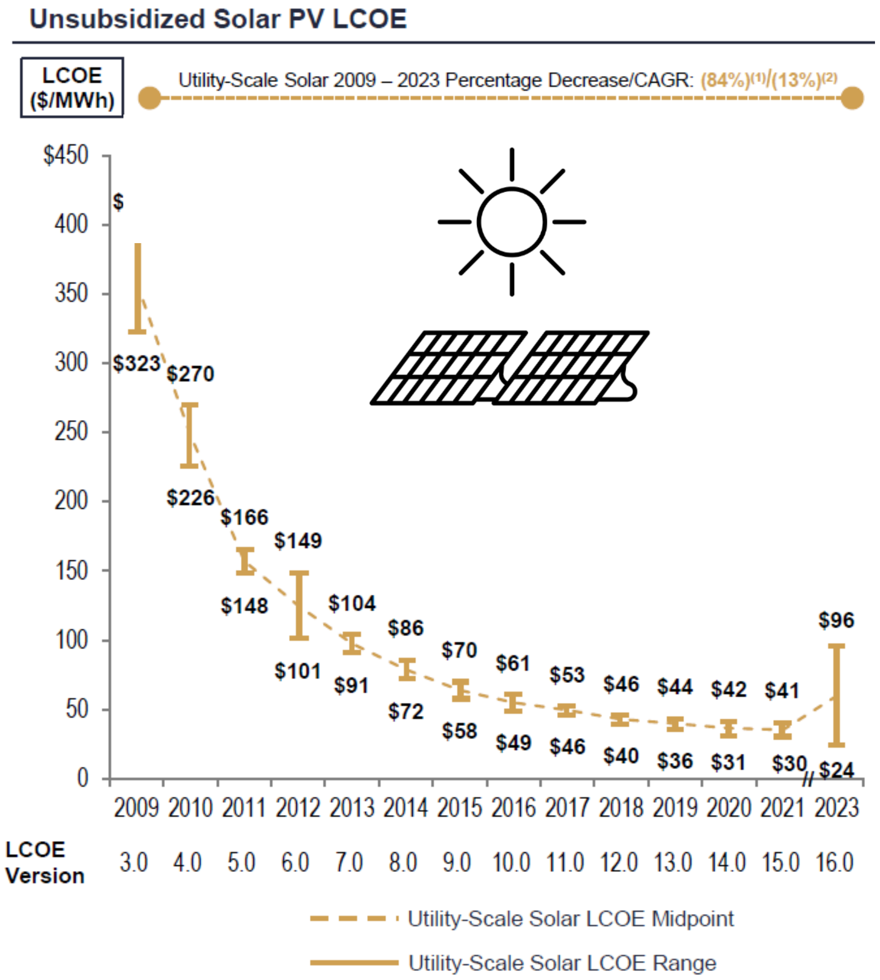
- Electricity cost
- Electrolyser cost
- Conversion efficiency
- Load hours
- Operating lifetime
- Cost of capital



Source: IRENA (2020)

Historical Renewable Energy LCOE





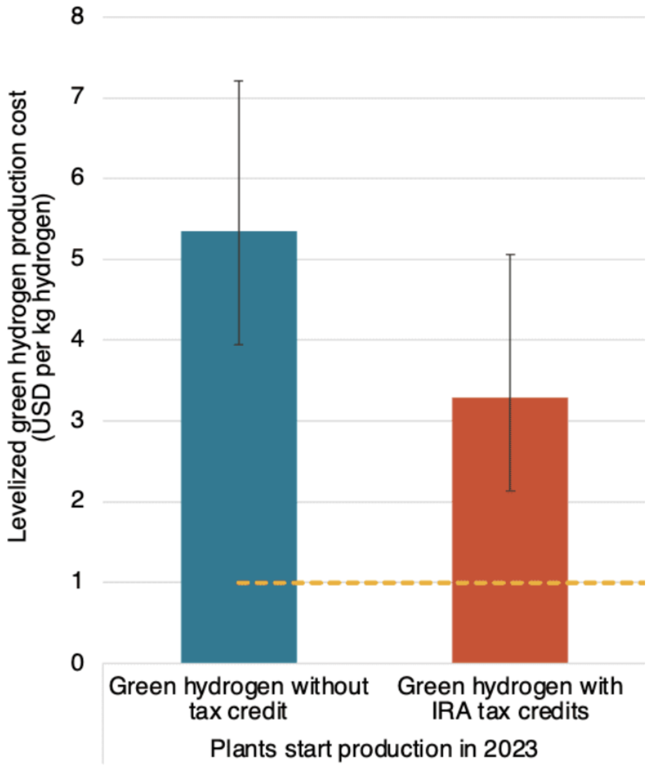
Source: Lazard's Levelized Cost of Energy Analysis — Version 16.0 (2023)

US and European hydrogen strategy

European Union:

- Hydrogen in 2022:
  - < 2% of Europe's energy consumption
  - Primarily used to produce chemical products, such as plastics and fertilisers.
  - 96% was produced from natural gas: significant CO_2 emissions.
- **European Commission proposal on renewable hydrogen, by 2030:**
  - **produce 10 million tonnes (Mt)**
  - **import 10 Mt**

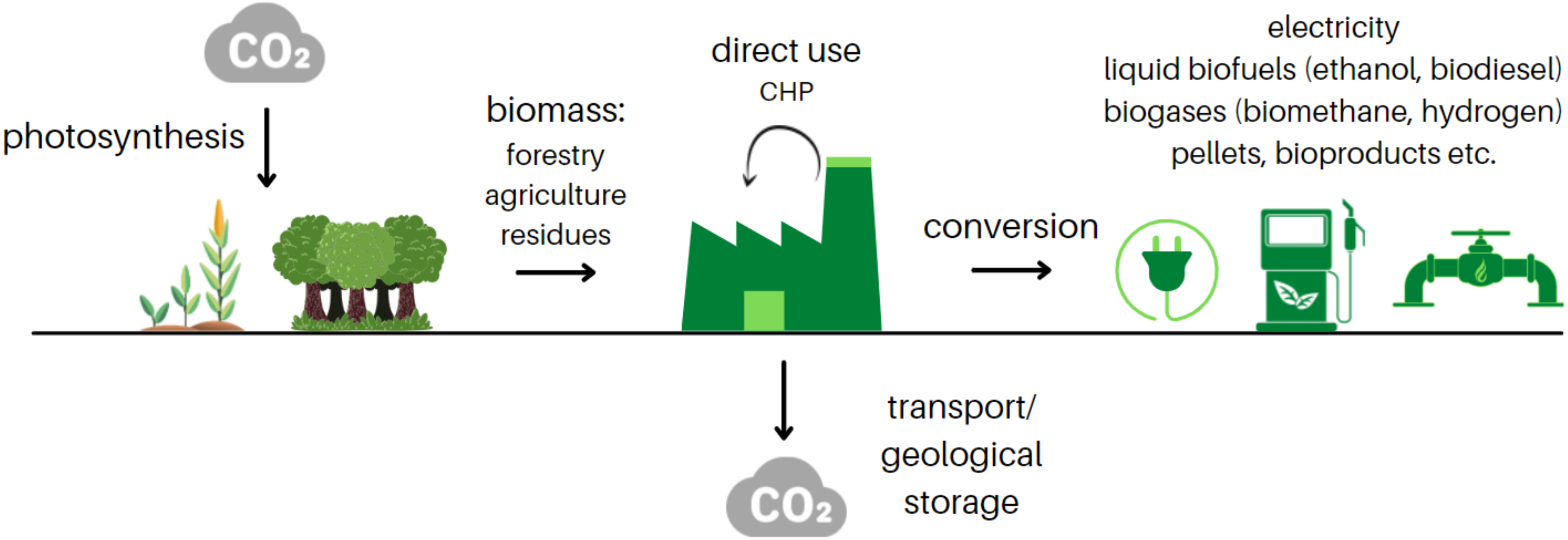
United States:



ICCT: CAN THE INFLATION REDUCTION ACT UNLOCK A GREEN HYDROGEN ECONOMY?

Sources: European Commission (2023); ICCT (2023)

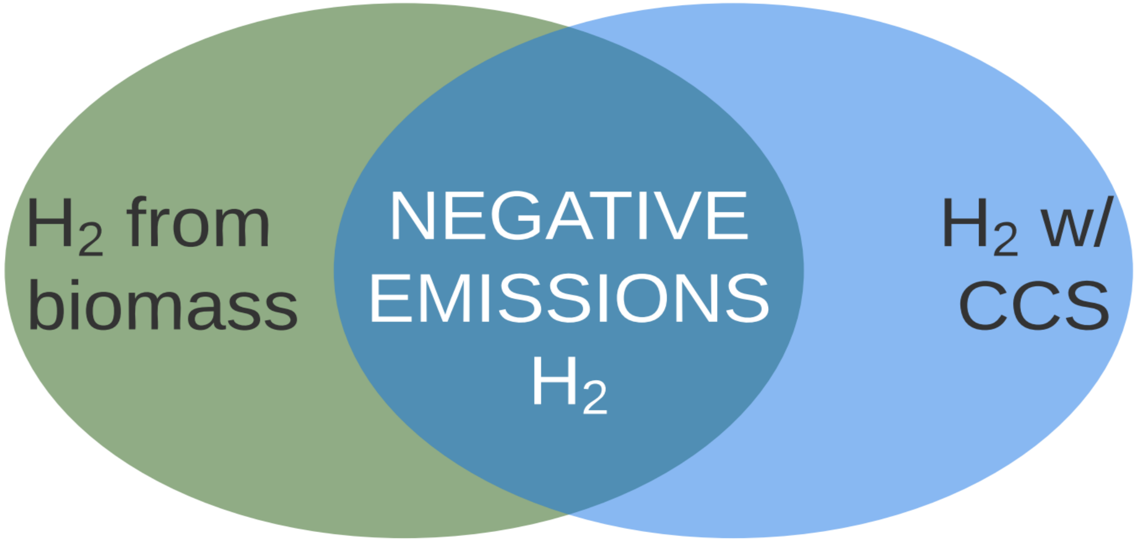
Rethinking existing bioenergy systems to deliver hydrogen and negative emissions (w/BECCS)



H_2

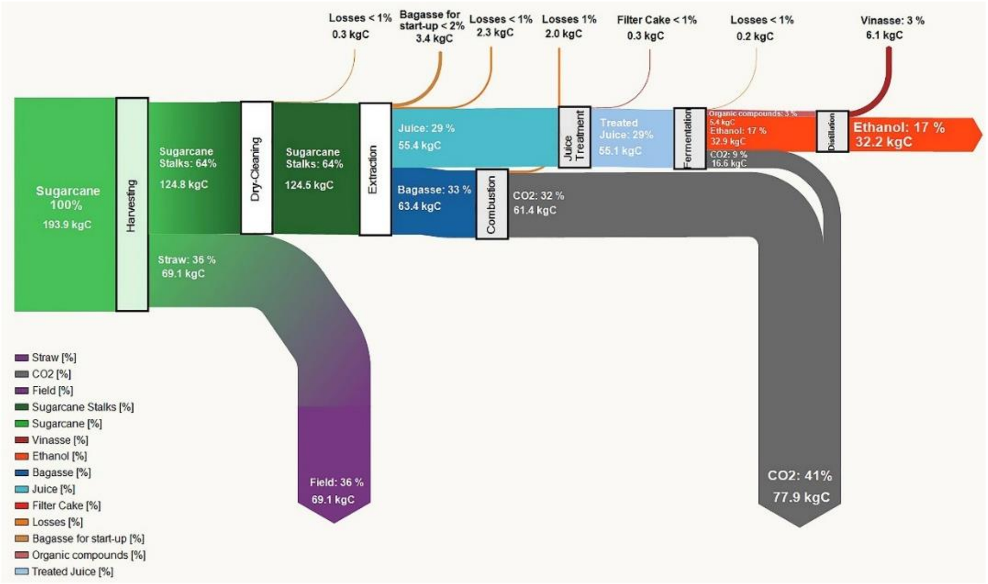
(Carbon-free energy vector – potential to maximise BECCS)

Negative emissions (BECCS): unique contribution from biomass-based hydrogen

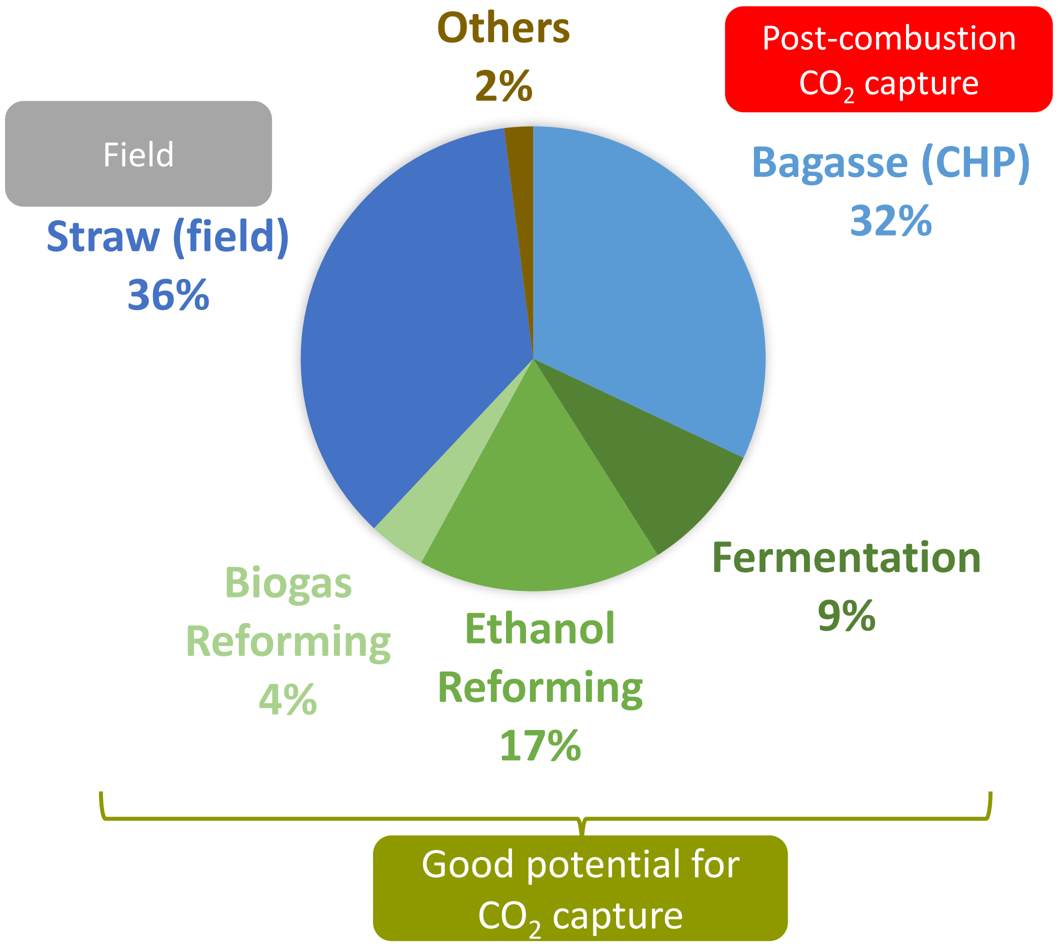


Bioenergy + H_2 + CCS: Good option

Maximising negative emissions: checking the biogenic Carbon Balance



Source: Barbosa et al. (2017)
[autonomous distillery]



Why hydrogen for Brazil?

- **Need for fertilisers**:
  - Brazil is a major **agricultural** producer (soybeans, corn, sugarcane)
  - Account for **30%** of the cost of major crops (Mato Grosso state)
  - Increase to 9.2 Mt of nitrogen fertilisers imported in 2018 (**2x than 2008**)
  - **More than 80%** of fertilisers used in Brazil are **imported**

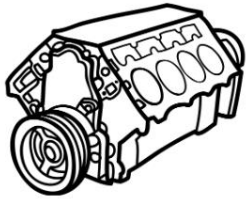
- **Next step in the energy transition:**
  - **High potential** from biomass + renewable power
  - Brazil **freight** is largely **road-based**
  - **Heavy** vehicles running on **diesel**:
    - hard to decarbonise
    - used in biofuels production process (switching to hydrogen would improve the carbon intensity of biofuels)
  - **Higher efficiency of fuel cells** - Hydrogen

Source for fertiliser data: EPE (2019)

Switching from ethanol to hydrogen: targeting *efficiency* and *heavy vehicles*

Ethanol
already replacing
gasoline (E-100)

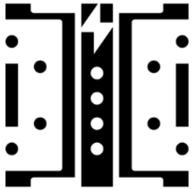
Hydrogen
to replace
diesel



Internal combustion
engine: 20-25%

Tank-to-wheel
efficiency

Fuel cell:
45-60%



Brazilian sugarcane industry: product portfolio (2020/21)

9.4 Mha
of harvested area with sugarcane (2019)

1.1% of Brazil
(851 Mha)

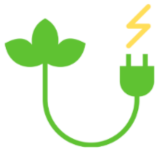
Data sources:
MapBiomas (2021)
EPE (2021)
CONAB (2021)
USDA (2021)

26.8 Mm³ of ethanol (1G + 2G)

- 38% of Brazil's light vehicles energy demand

42 Mton of sugar

- 23% of total global production (179 Mton)
- Largest producer
- 1st net-exporter of sugar
  - 32 Mton (76% of national production)



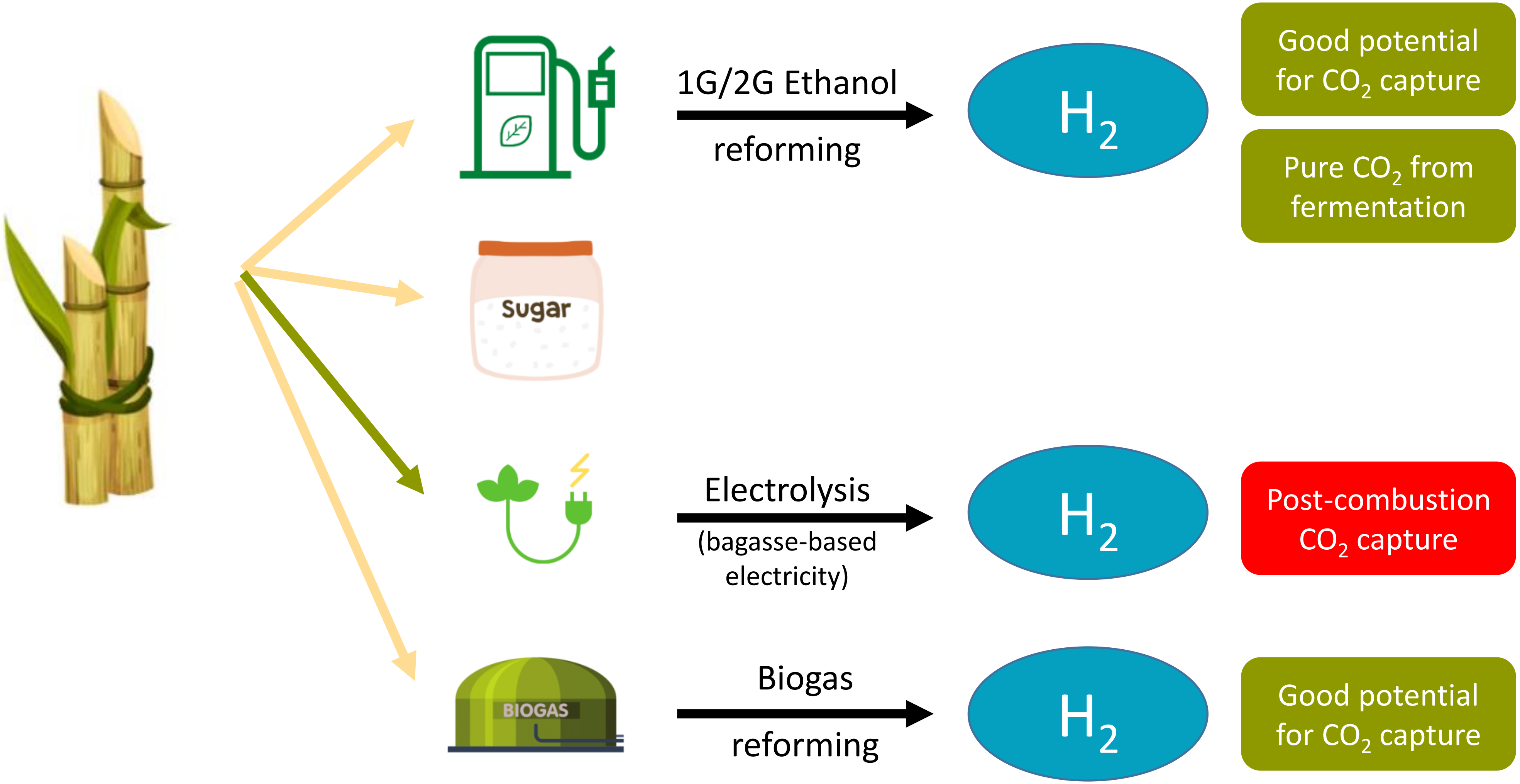
39 TWh of electricity generation

- 6.3% of total national supply (626 TWh)
- 16 TWh (41%) for self-consumption

New product: Biogas / Biomethane

- 2 commercial-scale plants in operation
  - 1 CHP: 20 MWe
  - 1 biomethane with dedicated distribution pipelines
- 1 biomethane plant announced

Rethinking the existing portfolio towards H_2 w/ BECCS



Hydrogen potential from Brazil's sugarcane sector

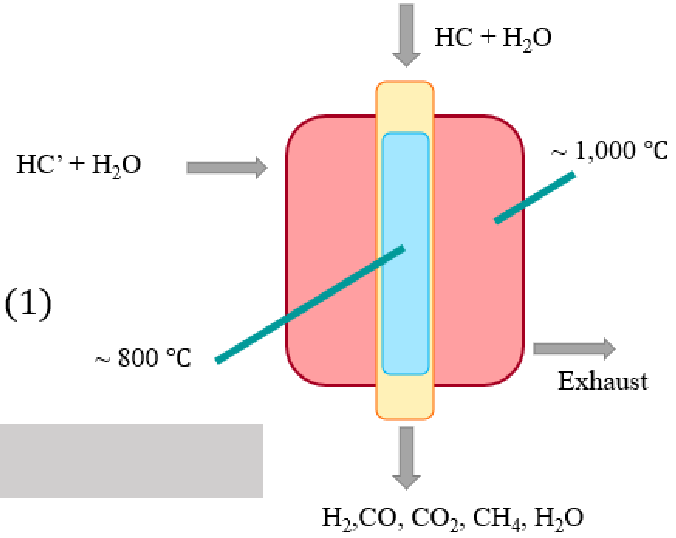
1. Ethanol reforming (1G/2G)
2. Electrolysis from surplus electricity generation
3. Biogas reforming

Feedstock	Feedstock potential	Hydrogen potential (kg/tc)	Hydrogen potential per area (kg/ha)
Sugarcane	80 t/ha	-	-
Ethanol 1G	40 l/tc*	5.25	420
Ethanol 2G	23 l/tc	3.03	242.4
Surplus electricity	49 kWh/tc	0.89	71.2
Biogas	8.9 Nm^3_{CH4}/tc	0.92	73.6
Total	-	**10.09**	807.2

Need for adequate policies → Sugarcane production (20/21) = 654 MM t cane
Hydrogen potential = 6.54 MM t H_2

*typical annexed distillery; autonomous distillery: ~ 80 l/tc, 10.5 kg H_2/tc

Hydrogen production from biogas

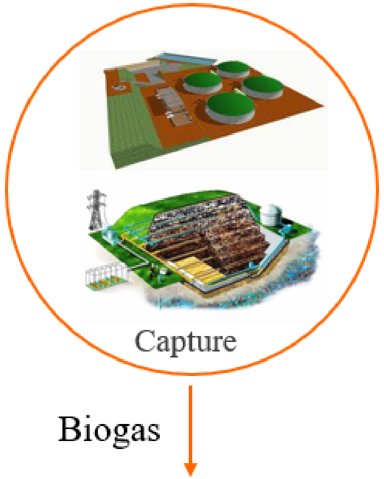


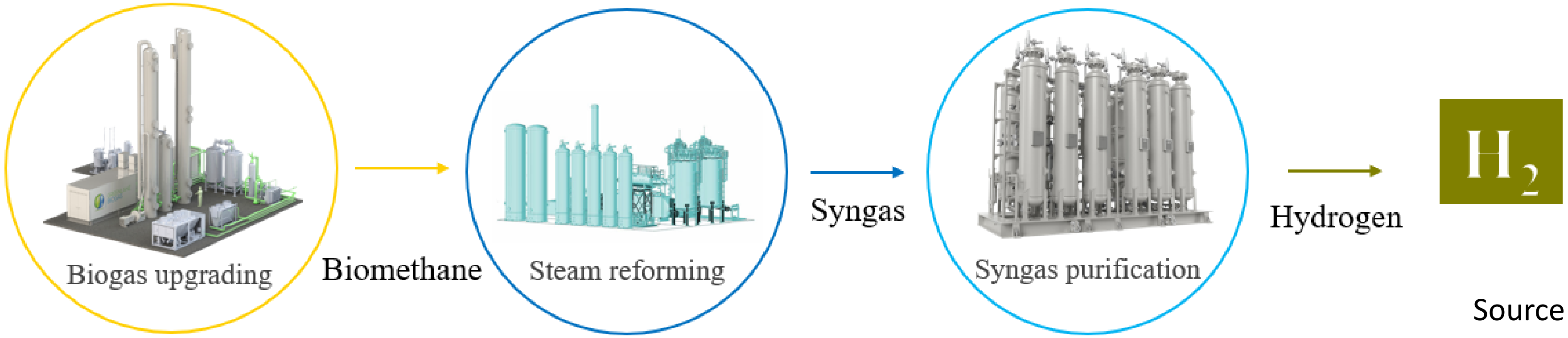
✓ Steam-methane reforming reaction:

$$CH_4 + H_2O \rightarrow CO + 3H_2 \quad \Delta H = 206.1\frac{kJ}{mol};\ T = 700 - 900\ °C \qquad (1)$$

✓ Water-gas shift reaction (WGSR):

$$CO + H_2O \rightarrow CO_2 + H_2 \quad \Delta H = -41.1\ \frac{kJ}{mol};\ T = 90 - 230\ °C \qquad (2)$$





Source: Andrea Gutierrez, PD fellow, 2022

Hydrogen from biogas reforming: under development

GNR Fortaleza – Caucaia landfill

- 15% of CEGAS utility gas supply
- 90,000 m³/day of biomethane from MSW
- Potential for 18,000 kg/day of H_2

Ceará state wants to use biomethane to produce clean hydrogen

EPBR, 12 January 2022

Ceará quer usar biometano para produzir hidrogênio limpo

Governor of Ceará state supports CEGÁS as a future clean hydrogen distributor

CEGÁS, 19 February 2021

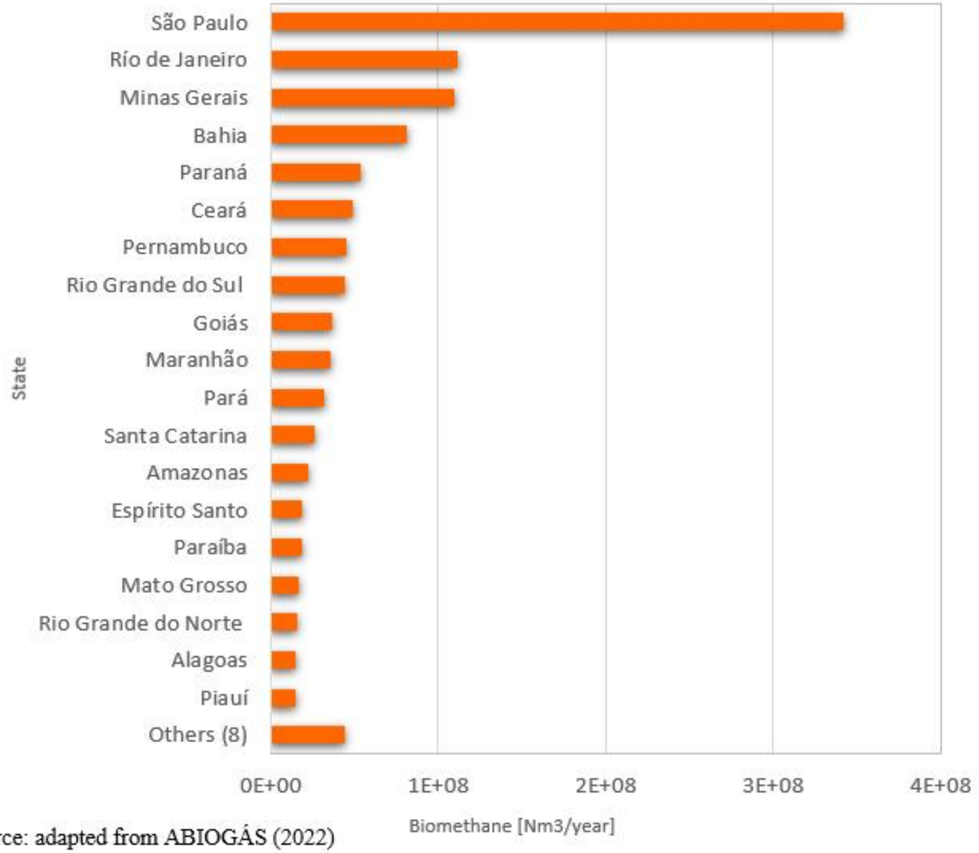
O governador do Ceará defende que CEGÁS distribua Hidrogênio Verde no futuro

por Rafael Vasconcelos • em 19/02/2021

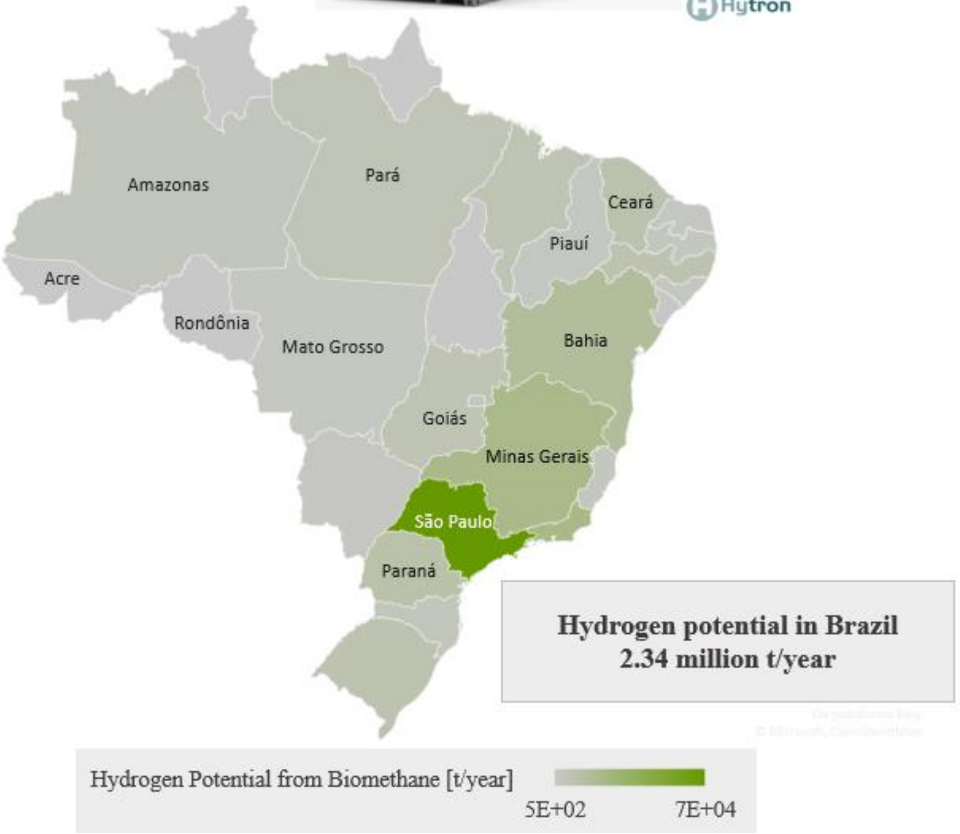
Potential for hydrogen production from biogas (sanitation sector)

Biogas potential in Brazil: 2.2 billion Nm^3/year

Biomethane potential in Brazil : 1.13 billion Nm^3/year



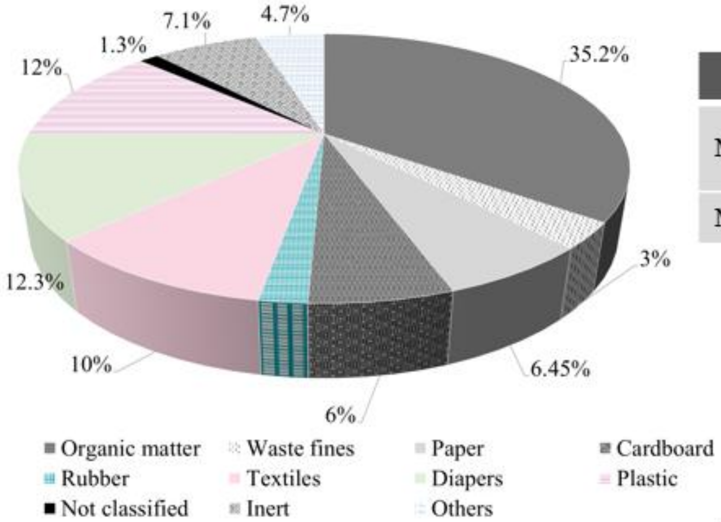
Source: adapted from ABIOGÁS (2022)



Source: Andrea Gutierrez, PD fellow, 2022

Hydrogen production from RDF gasification

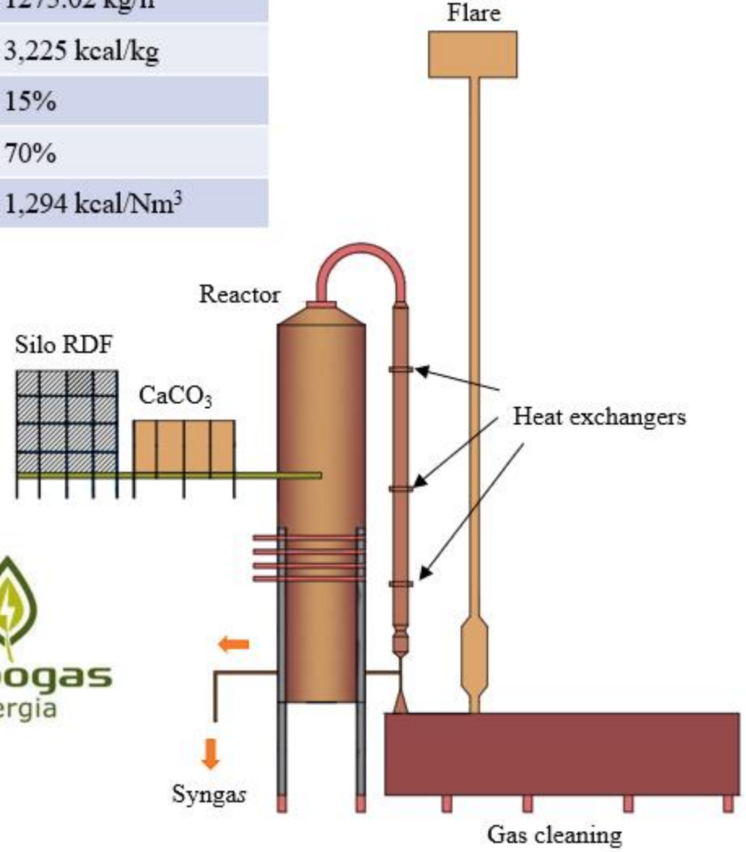
- ✓ Fluidized Bed Gasification:(Coelho et al., 2020) 50,000 ≤ population ≤ 1,000,000
- ✓ Municipalities: 656 (IBGE, 2022)
- ✓ MSW Generation per capita (kg/person/year):
  North (0.898);
  Northeast (0.971);
  Central-West (1.022);
  Southeast (1.262)
  South (0.805)
  (ABRELPE, 2021).



Inlet	
MSW	56 t/day 2333.33 kg/h
Moisture	50%

RDF

Inlet	
RDF	30.60 t/day 1275.02 kg/h
LHV_{RDF}	3,225 kcal/kg
Moisture	15%
$\eta_{gasification}$	70%
LHV_{gas}	1,294 kcal/Nm^3



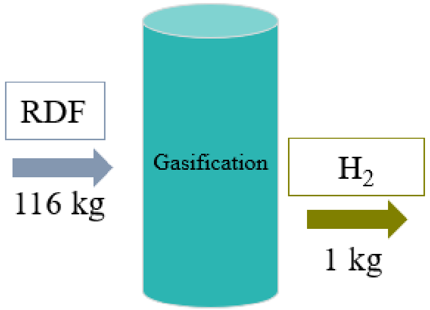
Source: adapted from CARBOGÁS, 2020

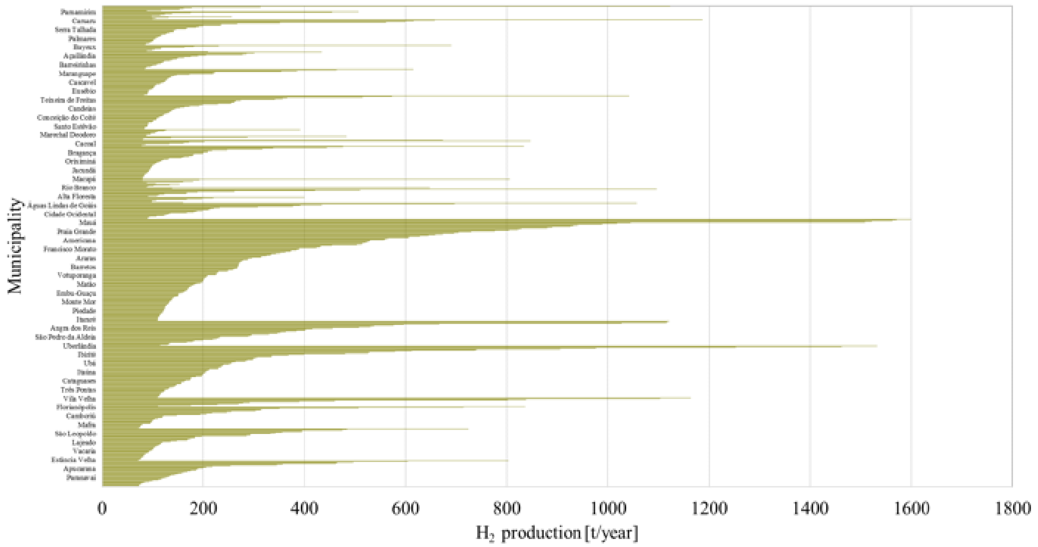
Source: Andrea Gutierrez, PD fellow, 2022

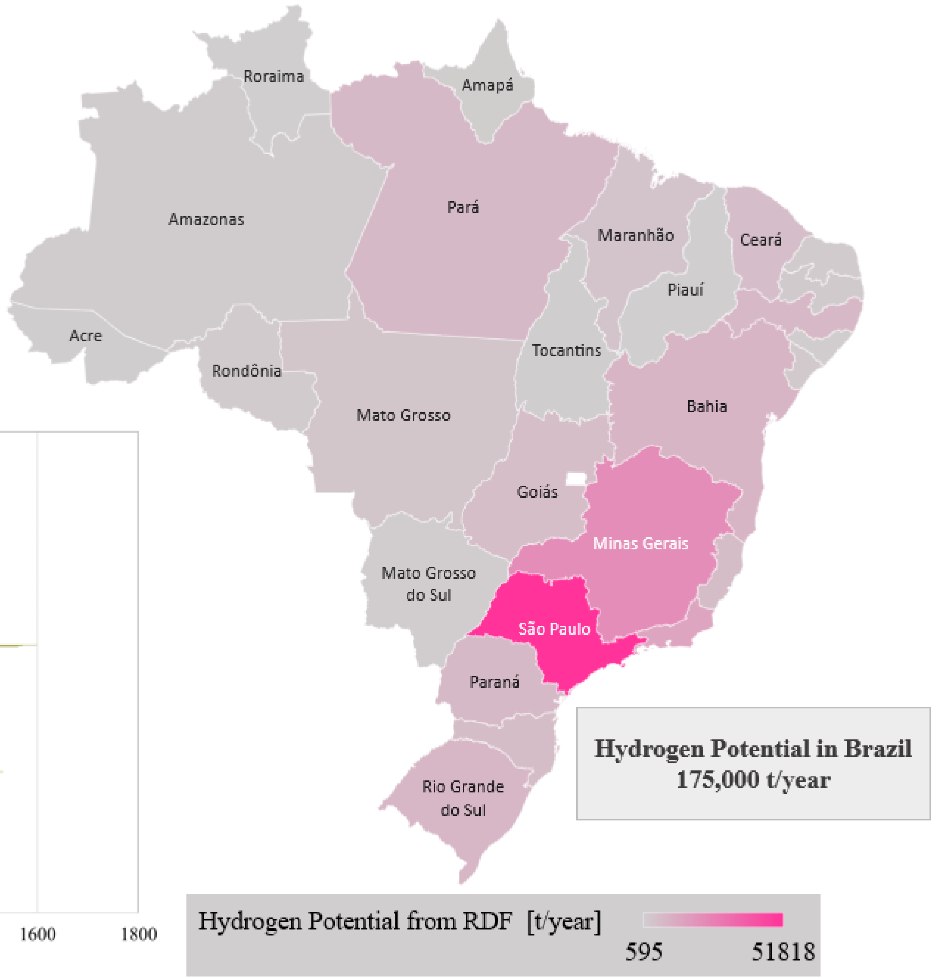
Potential for hydrogen production from RDF gasification (small and medium municipalities)

Average gas composition		
Gas	[%]	Nm^3/year
N_2	58	85,668.80
H_2O	6	8,862.29
CO_2	14	20,678.68
CO	8	11,816.40
H_2	6	8,862.29
C_nH_m	8	11,816.40

Source: adapted from CARBOGÁS, 2020







Source: Andrea Gutierrez, PD fellow, 2022

Latest News – Shell, Raízen, Hytron and USP (2023): Partnership to Convert Ethanol Into Renewable Hydrogen

SEPTEMBER 2, 2022

Four steps:

1. Sugarcane processing in the biorefinery produces ethanol (+ sugar, + electricity, + biomethane)
2. Ethanol is transported to the fuel station at USP and stored
3. Ethanol steam reforming produces hydrogen
   - 1 pilot plants of 4.5 kg H_2/h
   - ca. 38.5 L ethanol/h, 45 L water/h
   - To be scaled-up (10 x)
4. Hydrogen is compressed and stored, ready for refuelling
   - Potential to supply 4 campus buses

Hydrogen fuel stations: on-site ethanol reforming model

Advantages:

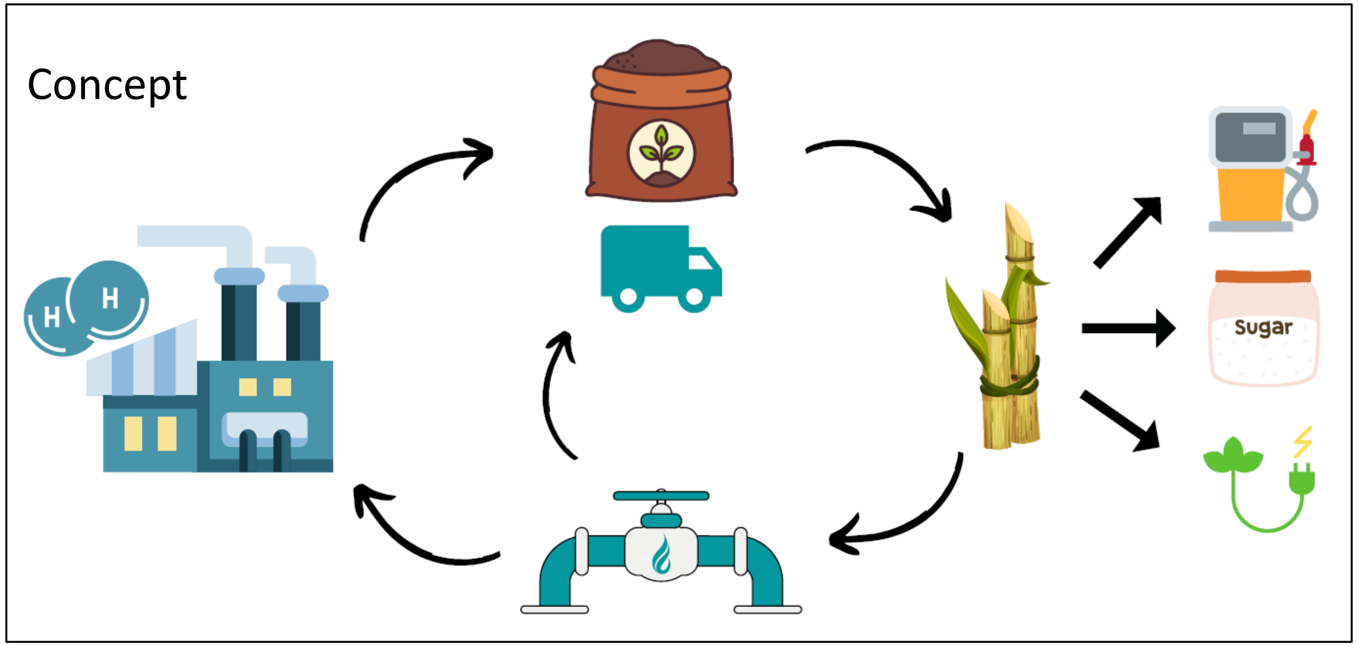
- No retrofitting of current biorefineries
  - Focus on other investments: biogas/biomethane, CCS, 2G ethanol
- No hydrogen pipelines
  - Makes use of existing liquid fuel distribution
  - Avoids costs and deadlocks in building of new infrastructure
  - Reduces chances of H_2 leakage
- Potential for on-demand H_2 production
  - Reduces H_2 storage capacity requirements vs. weather-dependent green H_2

Biomethane: a low-carbon link between sugarcane and fertiliser industries

- Yara's fertiliser plant to purchase **20,000 m^3/day** from Raízen's sugarcane biorefinery
- It will replace **3% of current natural gas** use
- Plans to run **100% on biomethane by 2030**
- Biomethane **potential** for Yara region was performed by **GBIO/USP**
- Biomethane injected to Comgás utility pipelines and delivered to Yara
- Circular economy **concept**: studies for using **biomethane-powered trucks** to transport fertilisers to farms

Yara Fertilizantes to deliver first Brazilian green ammonia by end-2023

bnamericas | 25



Conclusions

- Significant ***potential*** for hydrogen from sugarcane and other sources
- Cleaner fuel and possibility for ***negative carbon footprint*** with BECCS
- ***Decarbonisation*** of heavy vehicles
- Potential use for ***fertiliser*** production
- ***Hydrogen from sugarcane plants*** in Brazil should come soon (?)
- ***Brazilian civil society*** must understand the need for change for hydrogen: to inform the several publics that would be impacted by changes.
- Need for ***adequate policies*** (not yet in place)

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