Ethanol to Hydrogen Pilot Plant

7th edition of the cross-disciplinary International Summer School INFIERI series

2nd September 2023

Julio R Meneghini and Thiago Lopes

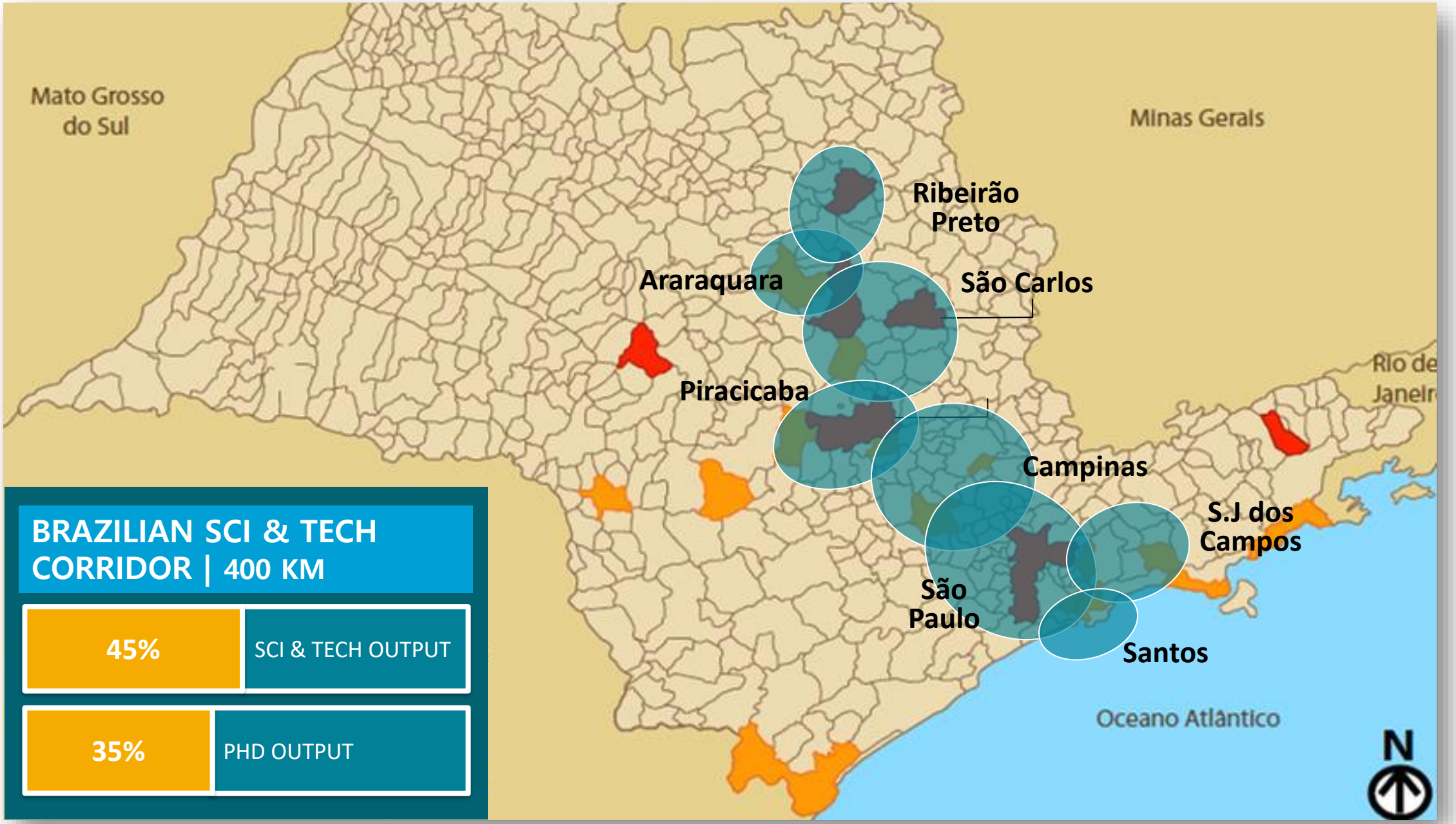
Research Centre for
Greenhouse Gas Innovation

Research Centre for Greenhouse Gas Innovation

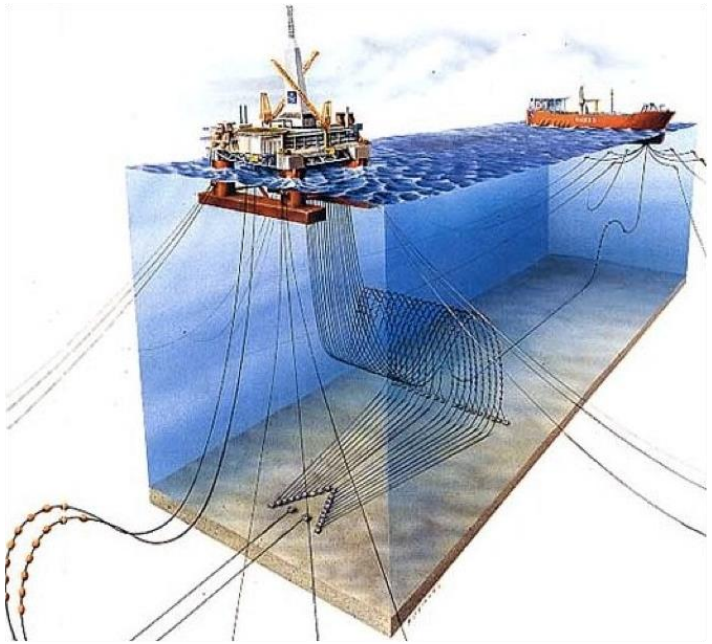
RCGI

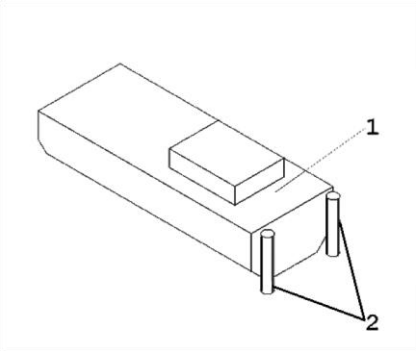
- ✓ Focus on the reduction of GHG emissions
- ✓ Supporting Brazil to achieve its NDCs through Research and Innovation

Research Centre for Greenhouse Gas Innovation


Mato Grosso
do Sul
Minas Gerais
Ribeirão
Preto
Araraquara
São Carlos
Piracicaba
Campinas
S.J dos
Campos
São
Paulo
Santos
Oceano Atlântico
N
BRAZILIAN SCI & TECH
CORRIDOR | 400 KM
45%
SCI & TECH OUTPUT
35%
PHD OUTPUT

Importance of Public/Private Partnerships in Research, Development and Innovation





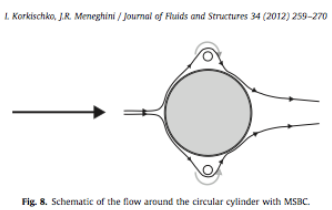
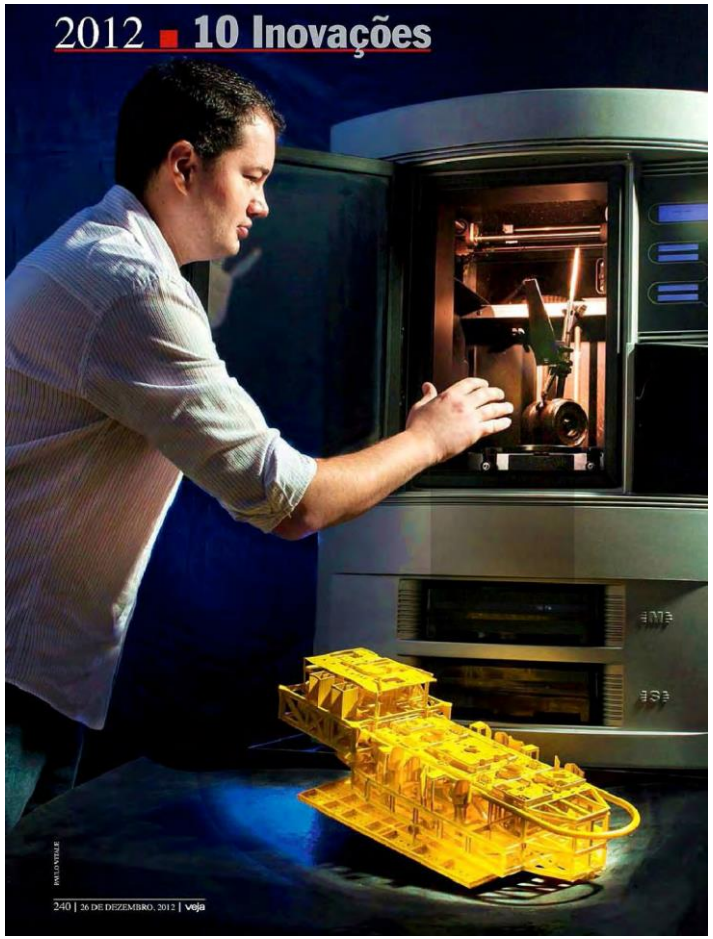
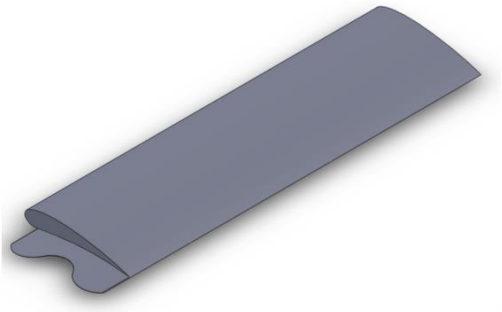


Fig. 8. Schematic of the flow around the circular cylinder with MSBC.





Research Centre for Greenhouse Gas Innovation

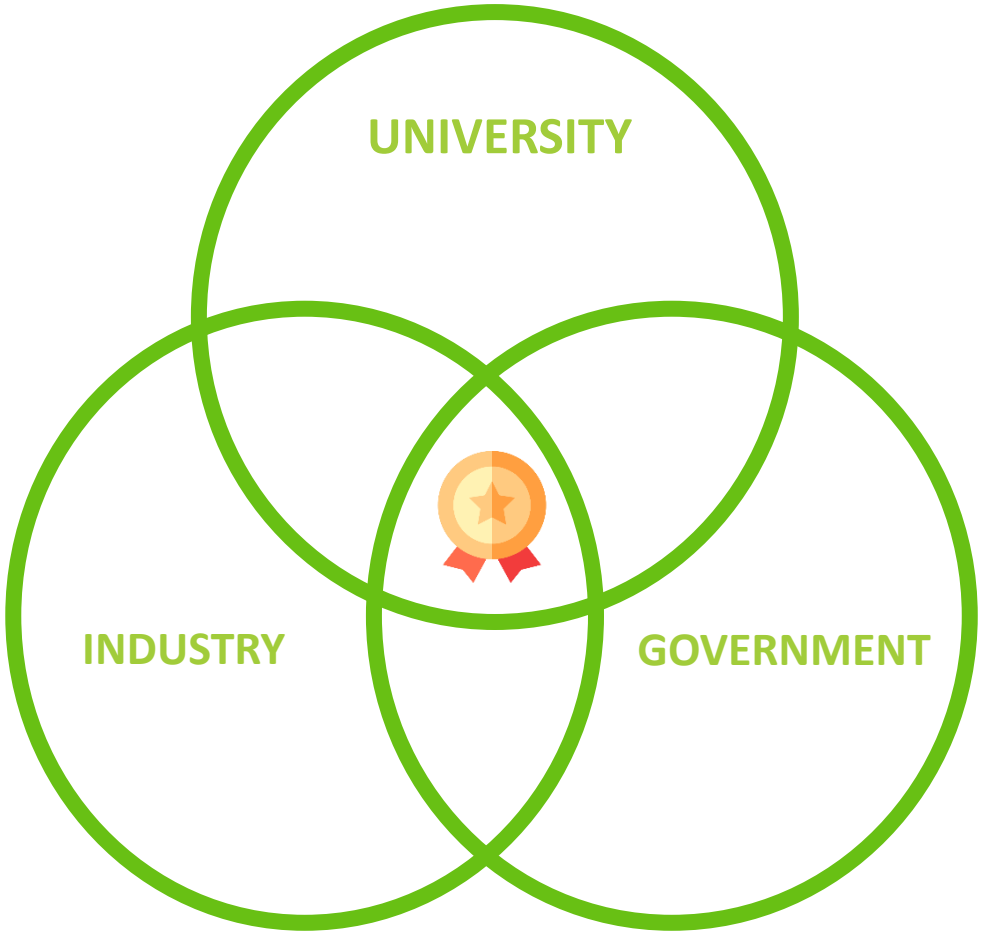
Founding Sponsors

Research Centre for Greenhouse Gas Innovation

Triple Helix Strategic Interactions

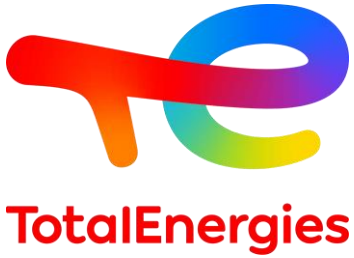
NEW PRODUCTS IDEAS
INNOVATIONS

FUNDING AND
STRATEGIC DEMANDS



Founder Sponsors:

Sponsors:



Partner Institutions:

International Collaborations: Centre to Centre (C2C)

SGI-Imperial: Sustainable Gas Institute

Nacional Science Foundation (NSF) and FAPESP Centre to Centre Collaboration:

POETS (https://poets-erc.org/) - RCGI (www.usp.br/rcgi)

CISTAR (https://cistar.us/) - RCGI (www.usp.br/rcgi)

Centre National de la Recherche Scientifique (CNRS) and FAPESP Collaboration:

Under creation/submission (2022)

Research Centre for Greenhouse Gas Innovation

RCGI IN NUMBERS

+530 Researchers

+170 Events hosted

28 Laboratories

5 Awards received

4 Patent filings

3 Startups

+480 Papers in journals

+506 Papers in conference

+150 Book chapters

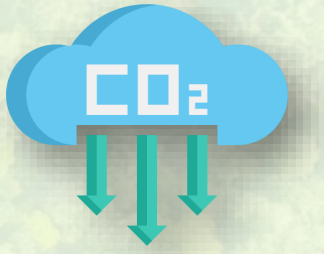
40 National partners

57 International partners

BRAZIL ROUTES FOR CARBON NEUTRALITY

BRAZIL ROUTES FOR CARBON NEUTRALITY

Onshore



Favourable energy mix

New renewable sources

Nature-Based Solutions

Forestry, Agriculture, Pasture

Bioenergy, Biofuels

Carbon Capture Utilization & Storage

Heavy Industry & Transport

BRAZIL ROUTES FOR CARBON NEUTRALITY

Offshore

Oil & Gas

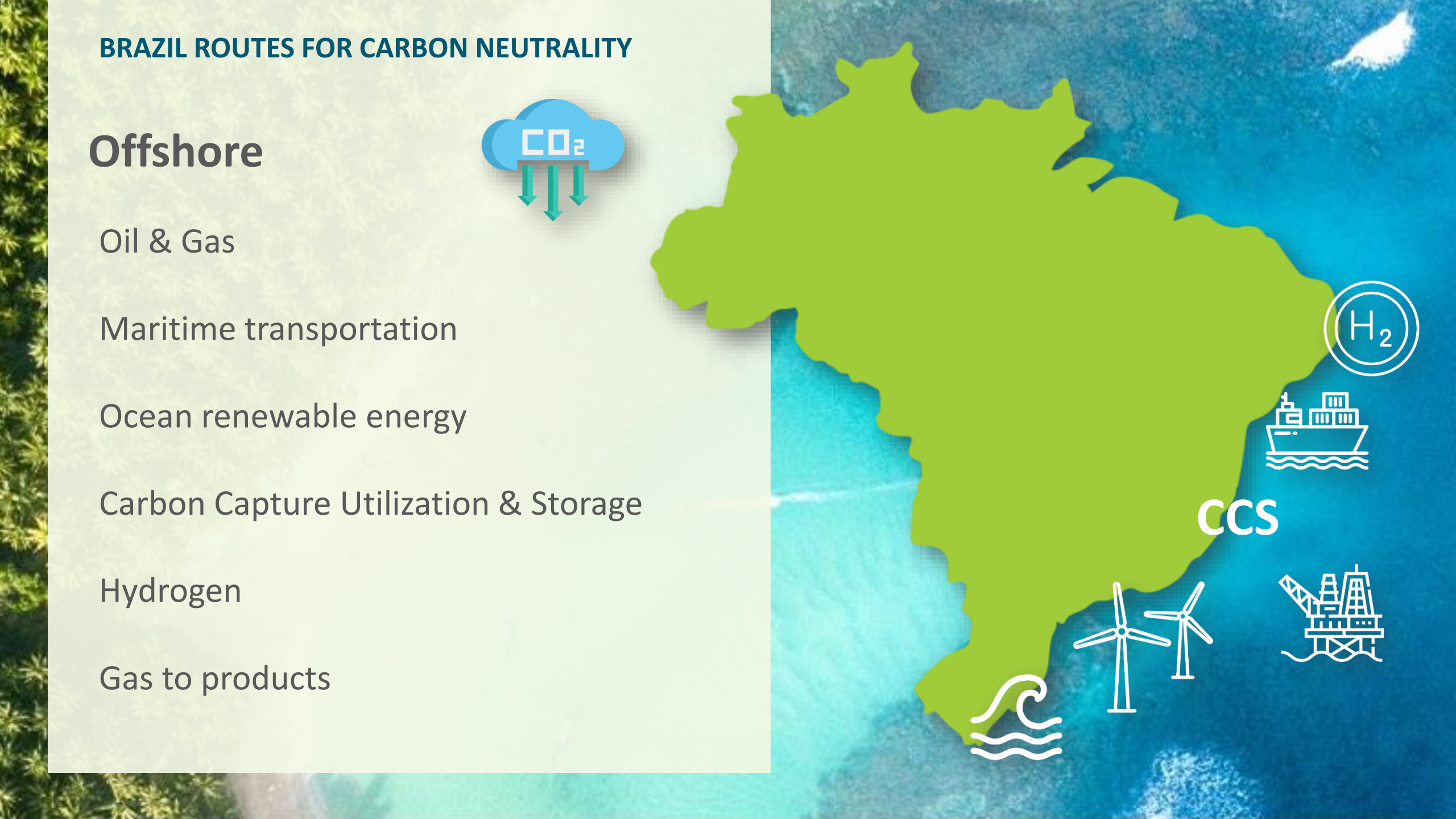
Maritime transportation

Ocean renewable energy

Carbon Capture Utilization & Storage

Hydrogen

Gas to products



BRAZIL ROUTES FOR CARBON NEUTRALITY

Onshore + Offshore

Brazil has a real chance of becoming GHG neutral

Research Centre for Greenhouse Gas Innovation

Programmes

NBS

How **to incorporate** Nature Based Solutions to abate CO2?

BECCS

How **to achieve** negative carbon intensity biofuels?

CCU

How **to create and deploy** value chains that unlock novel carbon products?

GHG

How **to develop** new technologies to reduce greenhouse gas emissions?

Advocacy

How **to unlock** CO2 abatement technologies with the support of standardization, regulation and social acceptance?

InnovaPower

How **to construct** long-term solutions centered on the decarbonization of electrical power systems?

Decarbonization

How to **contribute** with technologies that focus on a decarbonized future?

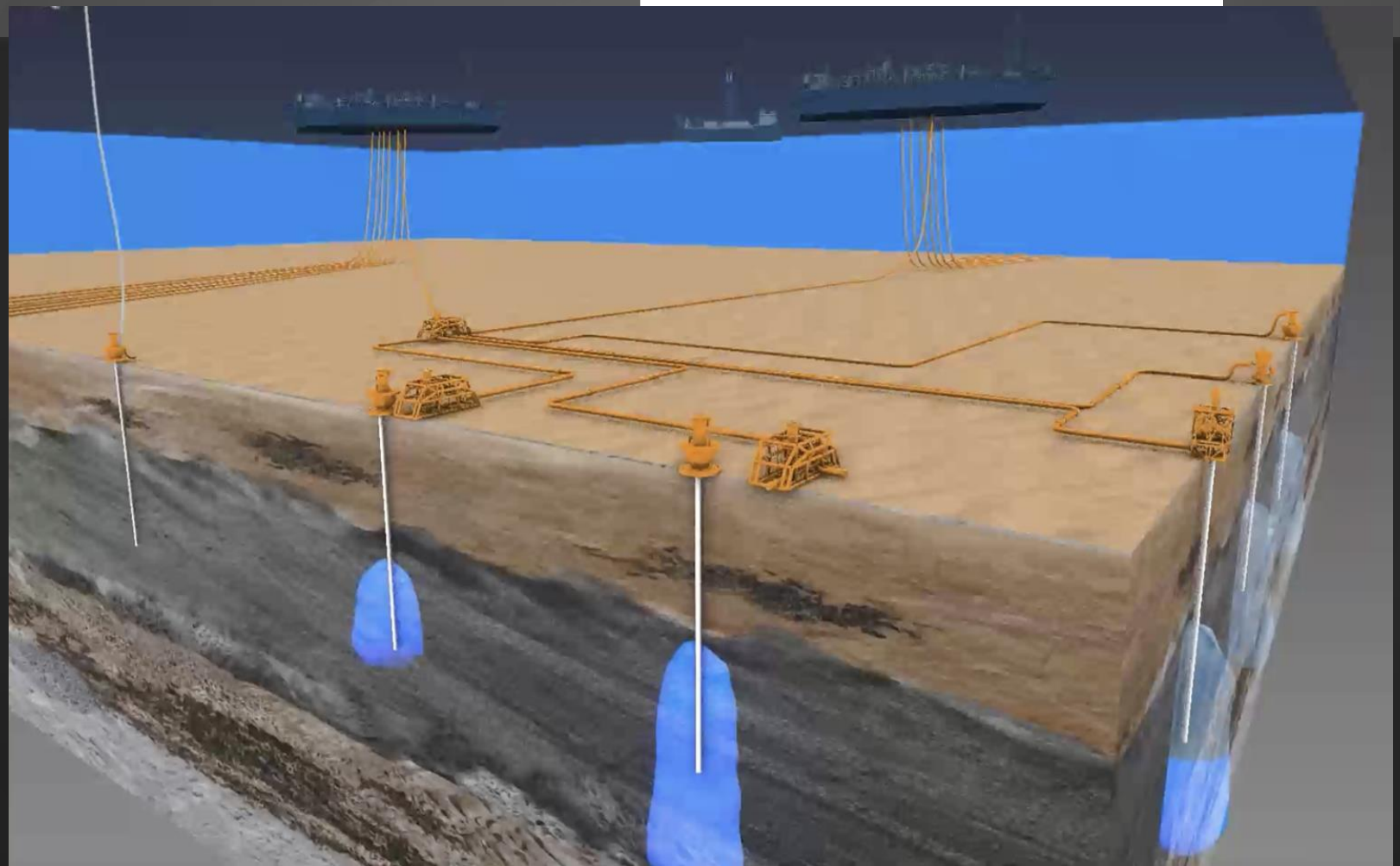
Centre 2 Centre

How to **establish partnerships** between centres around the world concerned with solutions to improve our environment?

Research Centre for Greenhouse Gas Innovation

NET ZERO

RESEARCH & INNOVATION FOR CARBON NEUTRALITY

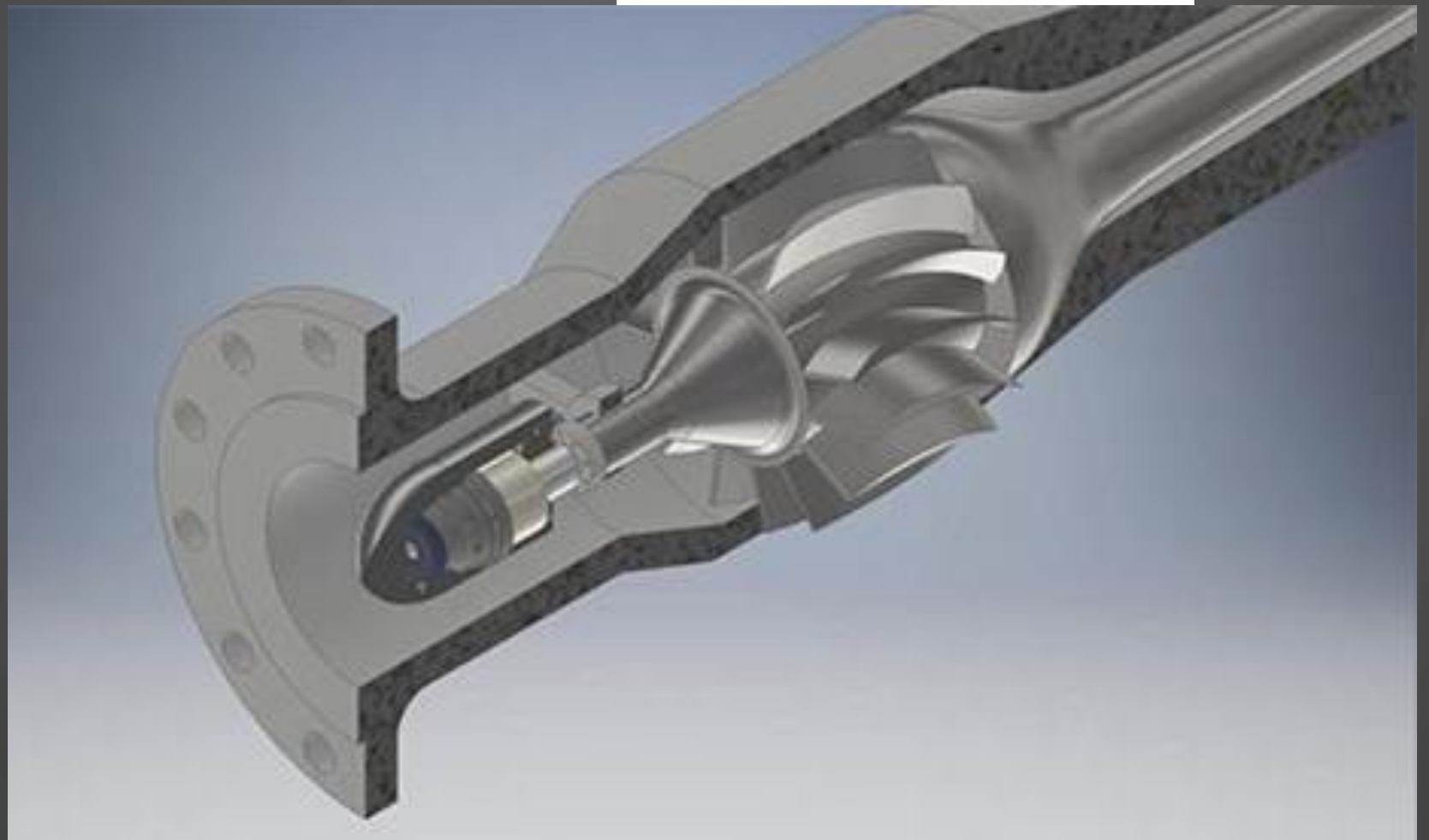


USP

Research Centre for Greenhouse Gas Innovation

NET ZERO

RESEARCH & INNOVATION FOR CARBON NEUTRALITY

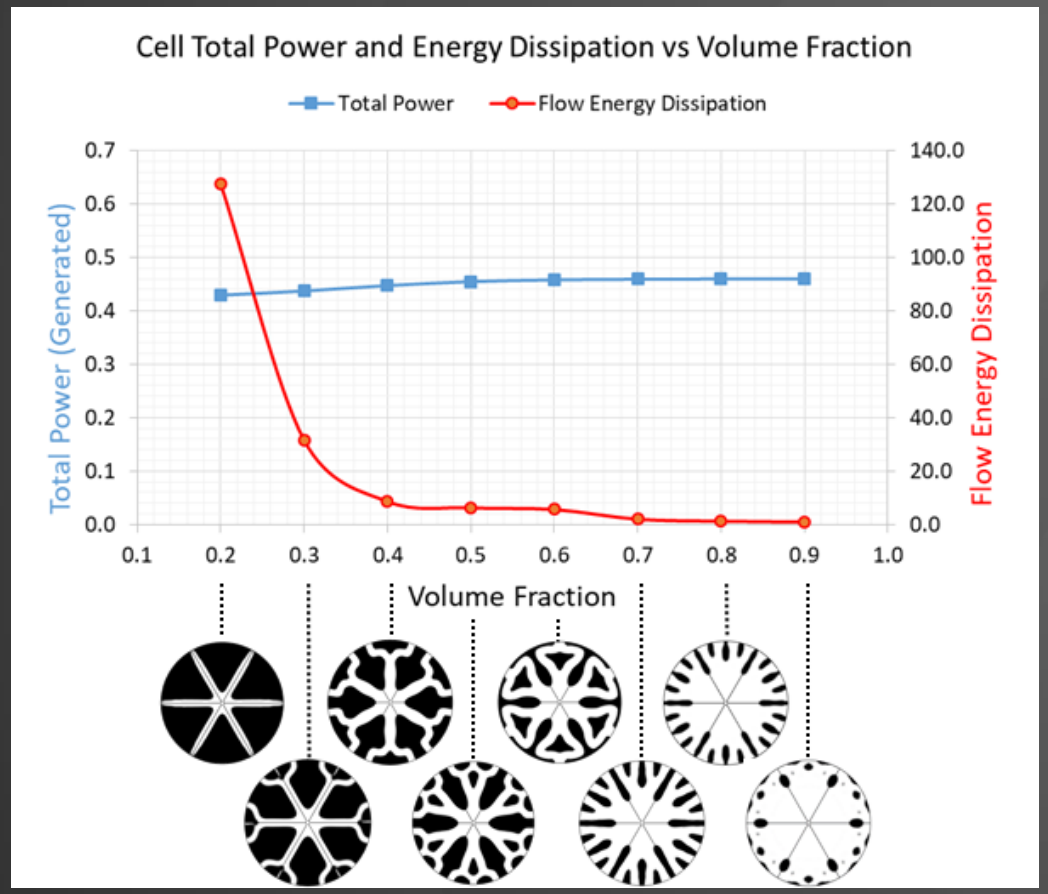


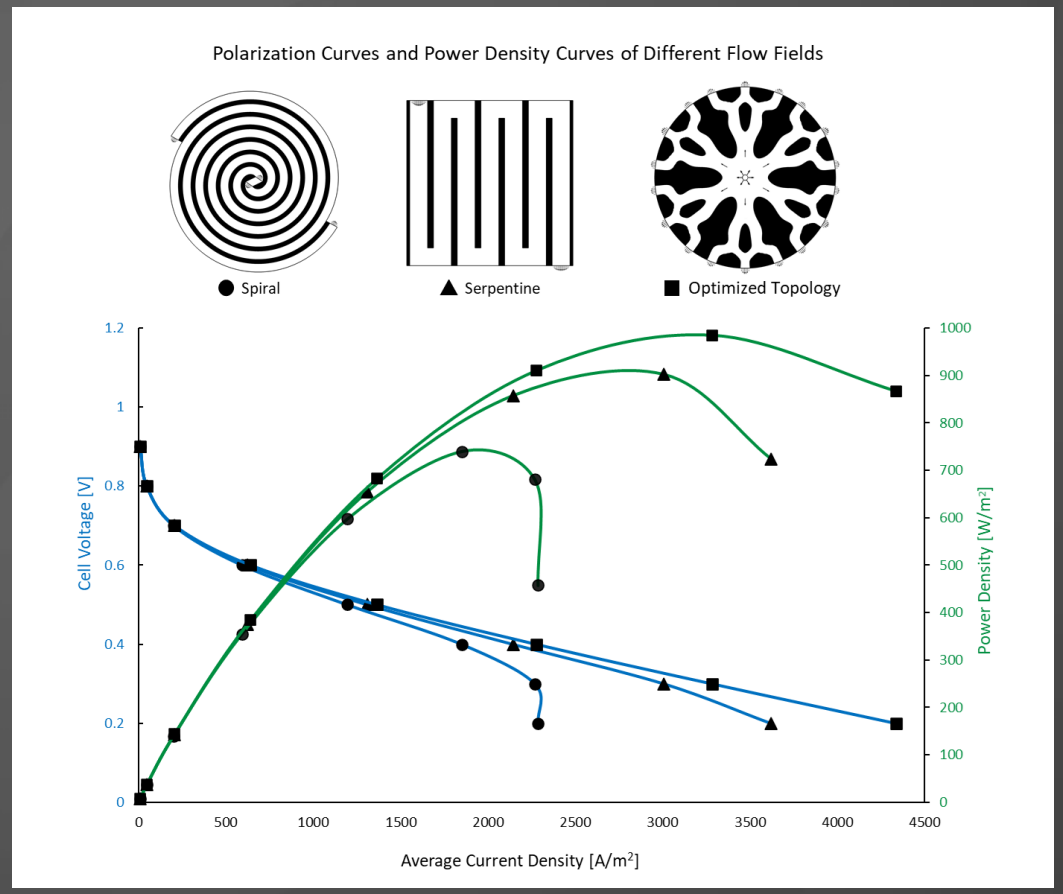
USP

Research Centre for Greenhouse Gas Innovation

NET ZERO

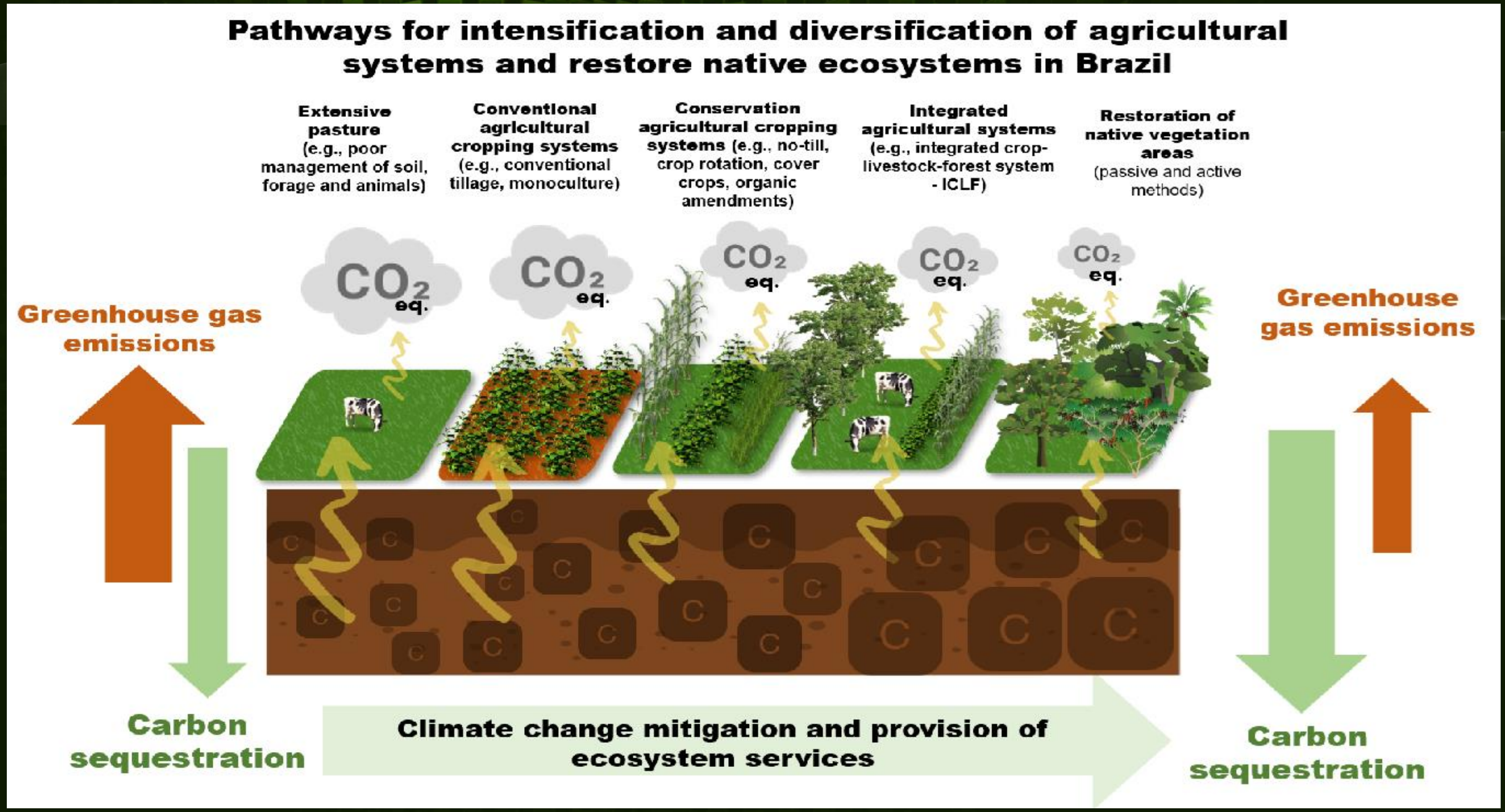
RESEARCH & INNOVATION FOR CARBON NEUTRALITY





USP

Nature Based Solutions

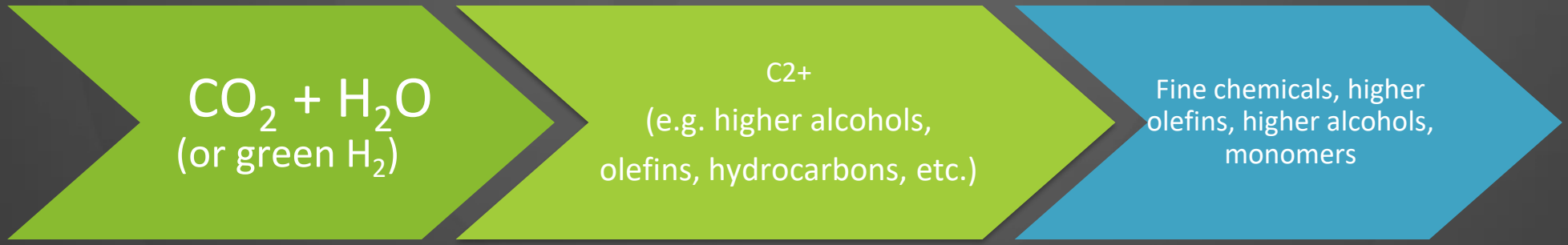


Carbon Capture and Utilization Program

The CCU program goal is to ***create value from CO_2 emissions*** through the design of integrated processes for carbon capture and conversion to tackle climate change. In this circular carbon economy concept, **CO_2 is considered a valuable C1 building block to CO_2-derived chemicals**, such as intermediates, monomers, building materials and fuels.

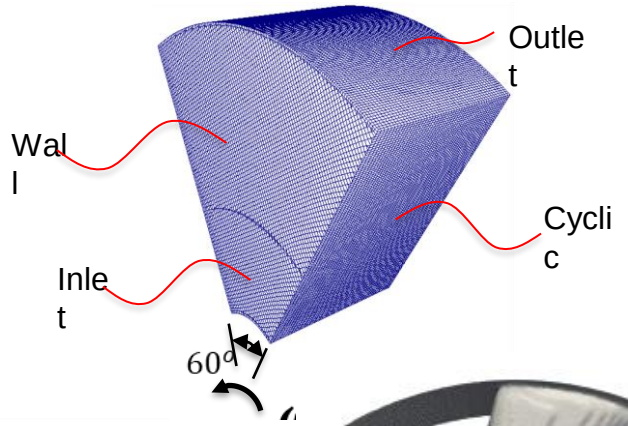
$CO_2 + H_2O$ (or green H_2)

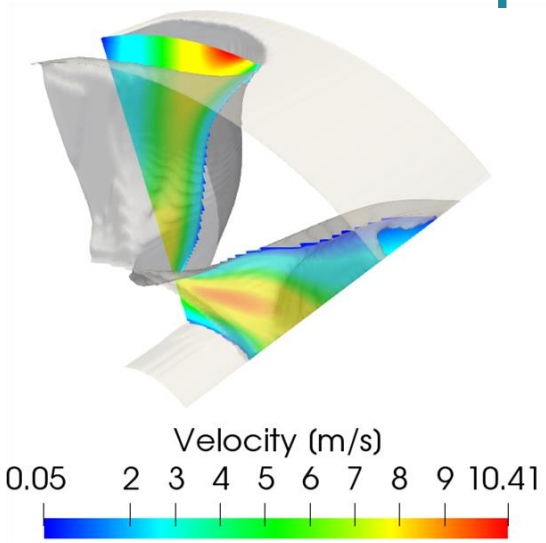
Areas of expertise: Photocatalysis and/or electrocatalysis and/or bioconversion and/or chemical catalysis

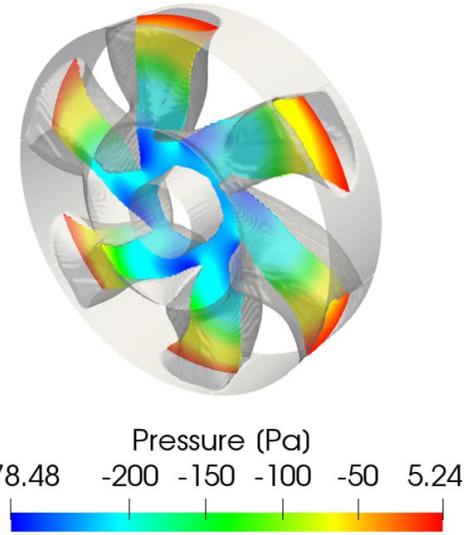


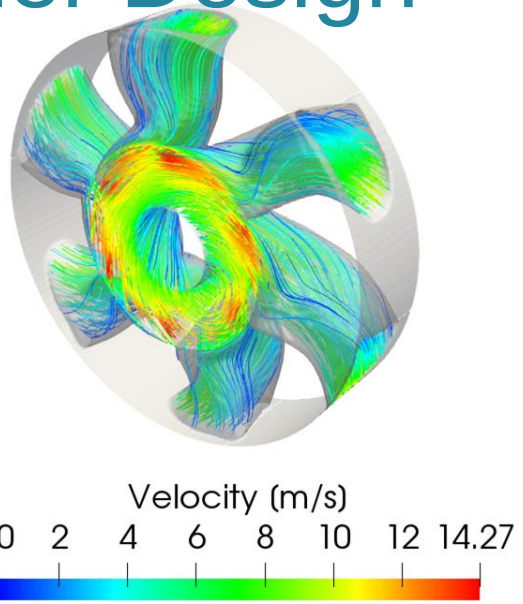
Topology Optimization for Fluids – Impeller Design

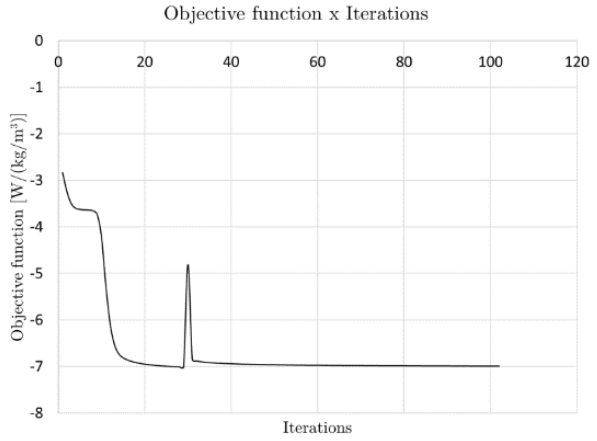
Numerical examples: 60º sector + 50% volume constraint + 1000 rpm





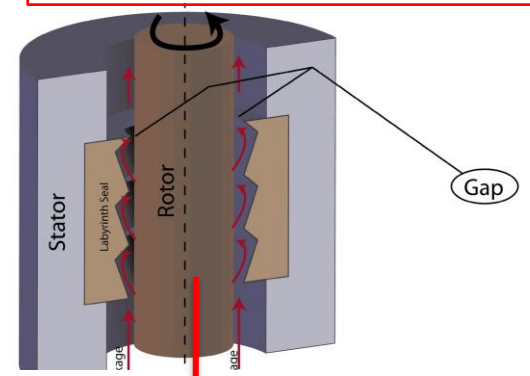


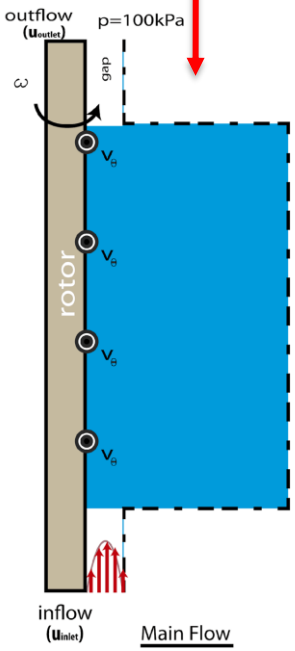


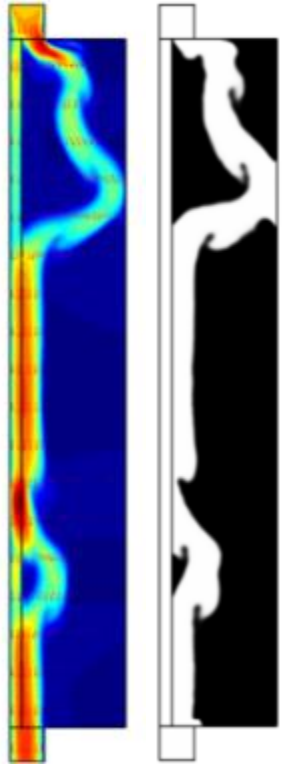


LABYRINTH SEAL DESIGN

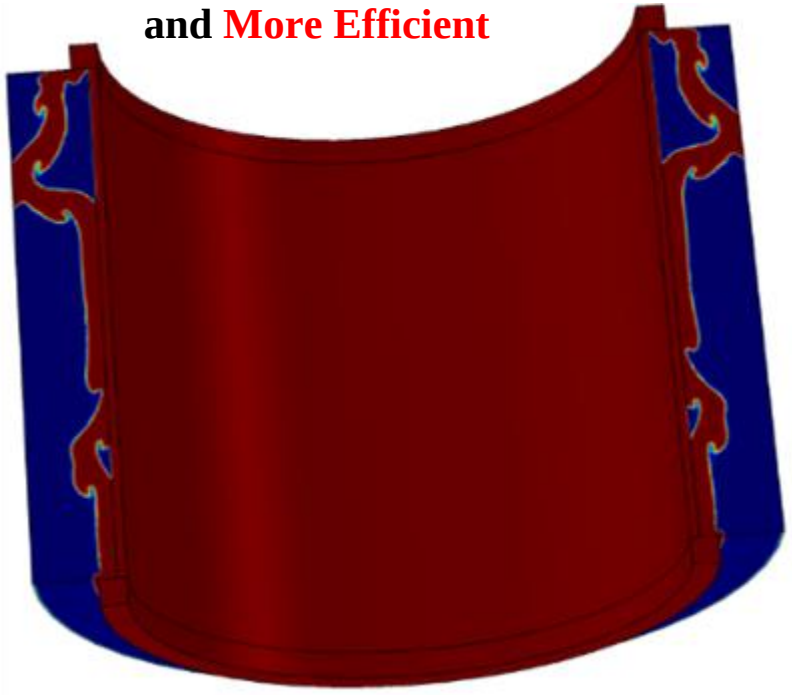
Topology optimization Procedure







2D



3D

Labyrinth seal design for Methane Compressors Application

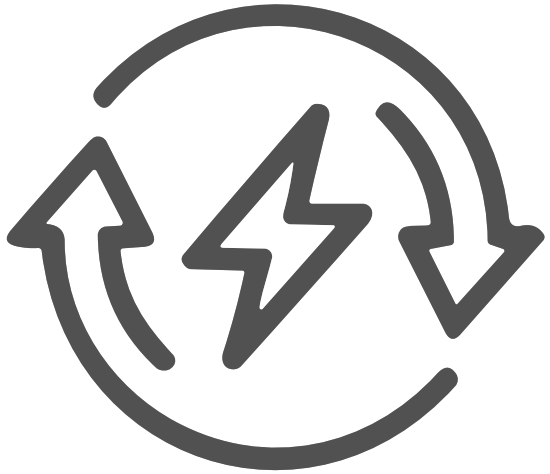
Objective function Diodicity

Compared to Traditional Model:
Less Leakage up to 50%
and More Efficient

Rotation = 3000 rpm
Volume Constraint < 0.3

Power Systems Innovation Hub - InnovaPower

The Power Systems Innovation Hub (InnovaPower) aims to develop innovative and sustainable solutions focused on the decarbonization of electrical power systems. This program addresses several aspects such as environmental impact assessment, eco-efficient materials, increased availability and efficiency of electricity production, optimization of distributed energy resources and integration with agriculture. These initiatives contribute to the transition to a cleaner and more sustainable energy system, in line with the challenges of global decarbonization and United Nation 2030 Agenda for Sustainable Development.



Program Goals:

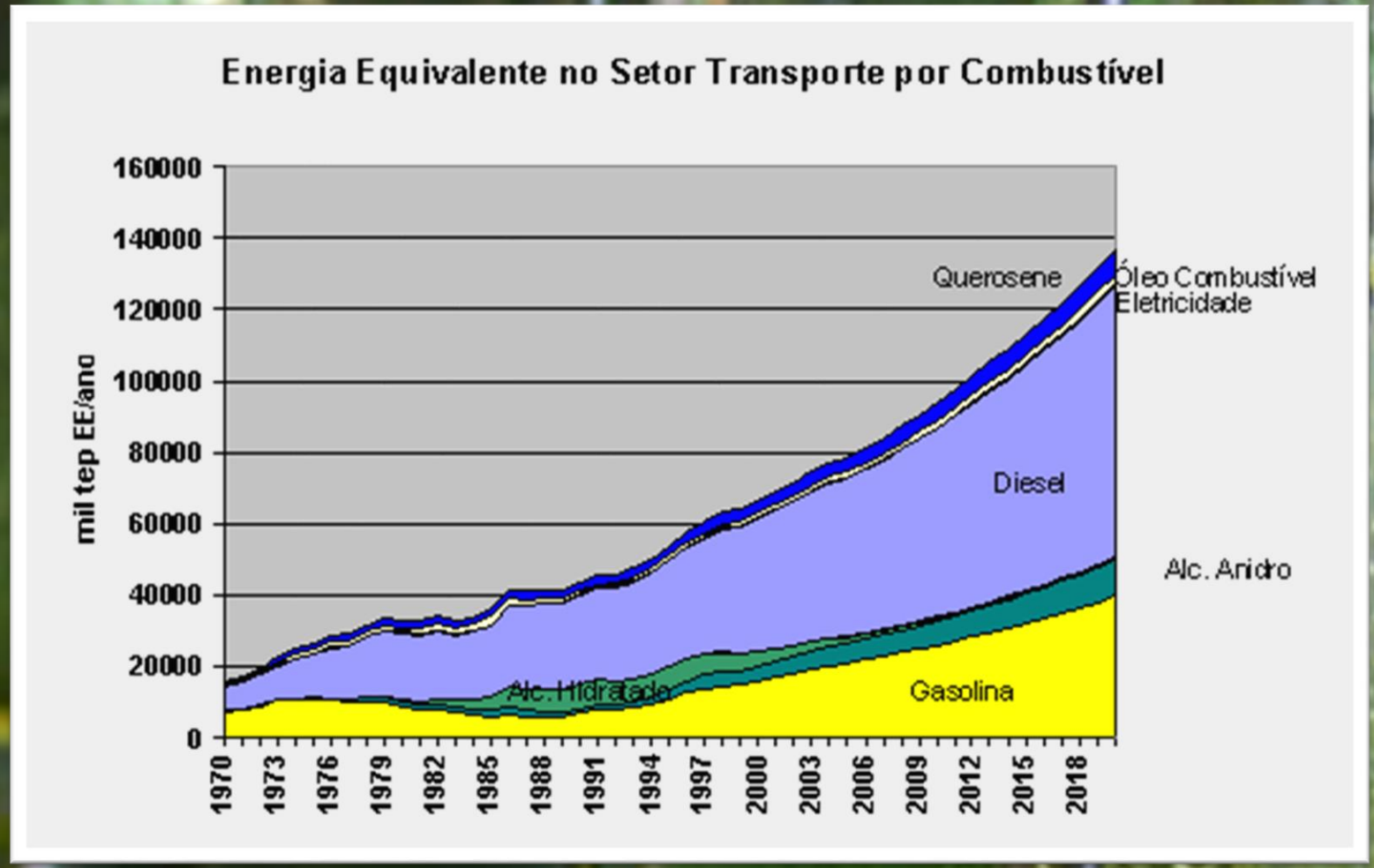
1. Develop innovative and sustainable solutions for the decarbonization of electricity systems.

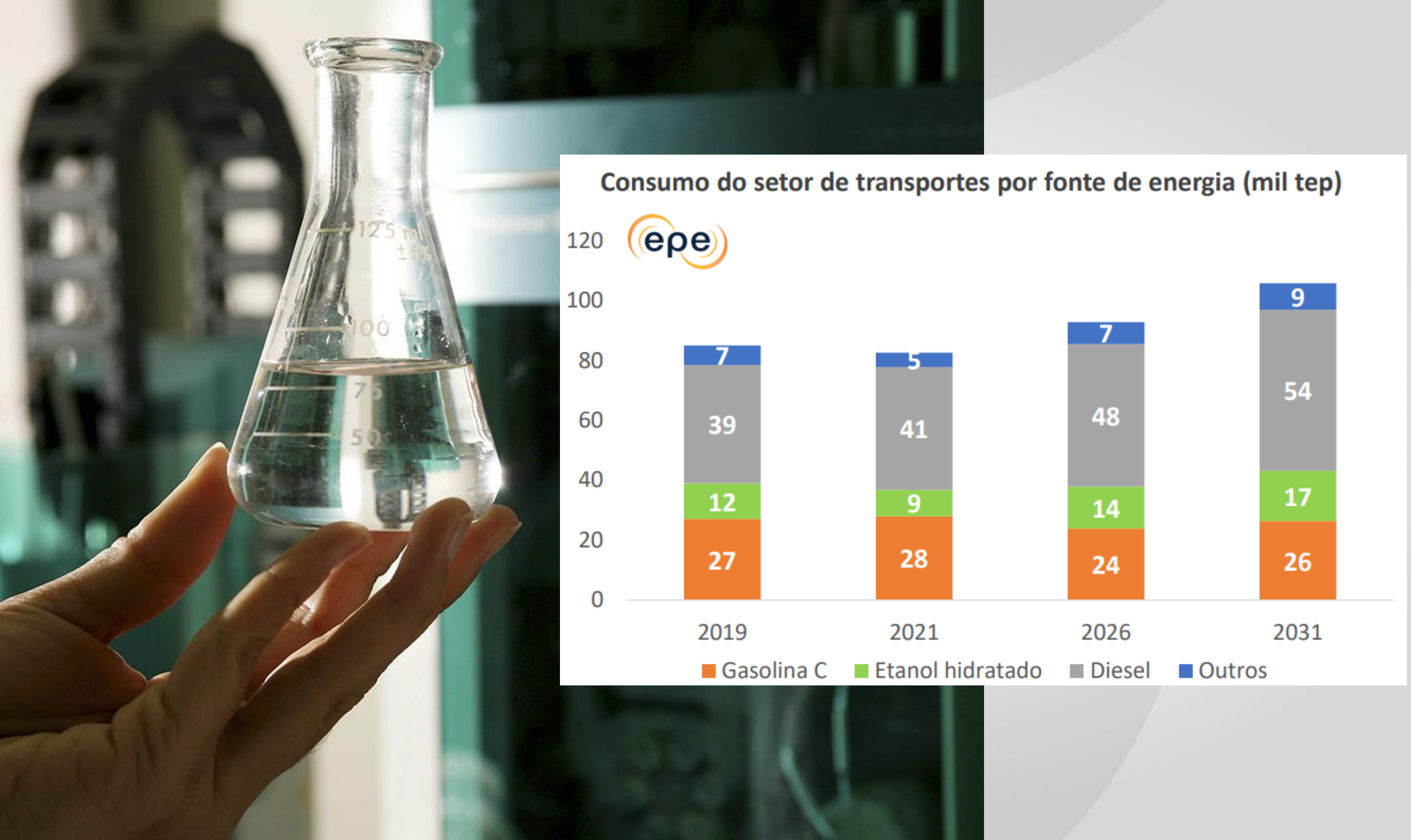
2. Increase the efficiency of electricity production and optimize the integration of renewable energy resources.

Ethanol to Hydrogen Pilot Plant

Research Centre for
Greenhouse Gas Innovation

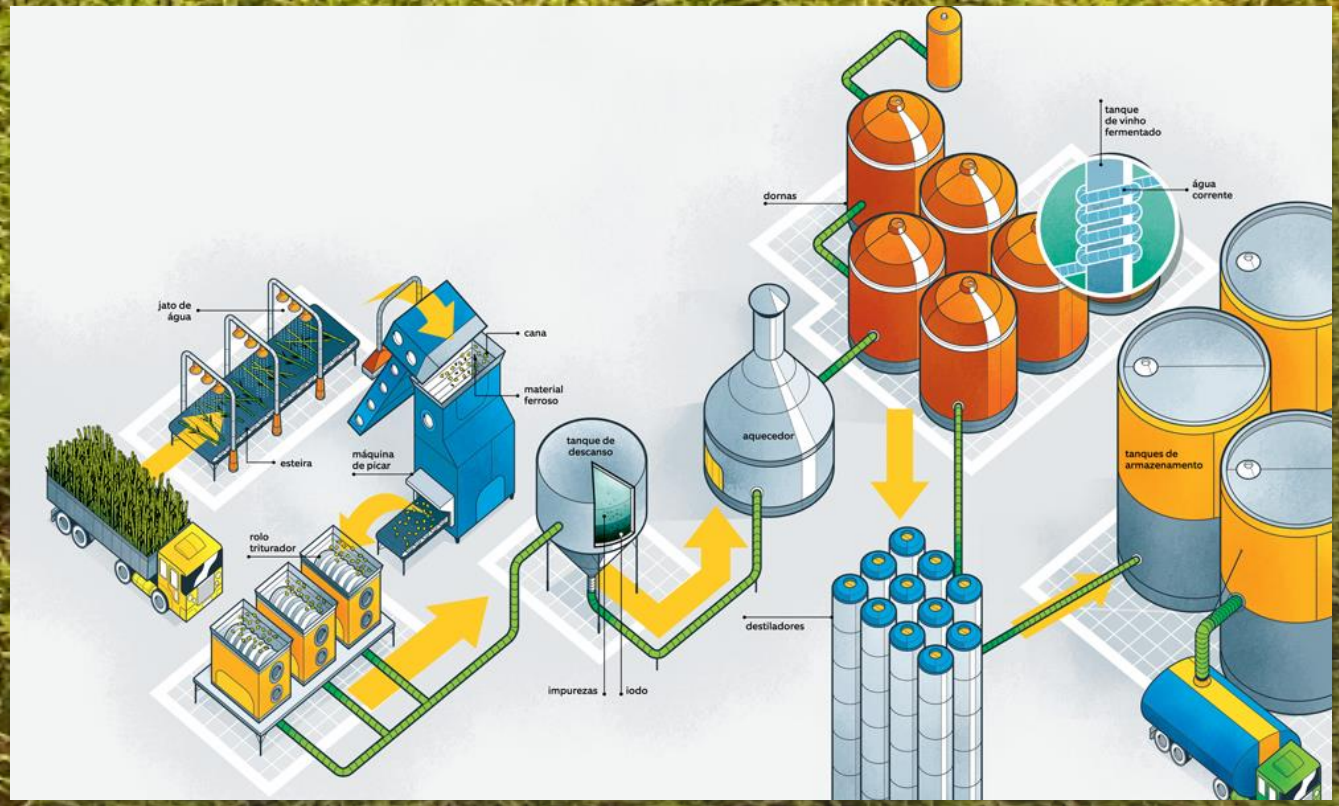

GYS-4307


Energia Equivalente no Setor Transporte por Combustível
mil tep EE/ano
160000
140000
120000
100000
80000
60000
40000
20000
0
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
2015
2018
Querosene
Óleo Combustível
Eletricidade
Diesel
Alc. Anidro
Alc. Hidratado
Gasolina



Consumo do setor de transportes por fonte de energia (mil tep)

Ethanol cycle with CCUS: efficient point-source capture



HYDROGEN FROM ETHANOL

A BRAZILIAN VOCATION

BRAZIL:
Ethanol infrastructure and logistics since 1975

No more diesel buses in São Paulo city

The city has banned new diesel buses. The current fleet will be replaced in 10 years.

Today the city has about 14,000 buses (only 2% electric).

CIDADE DE SÃO PAULO


ESALQ
Universidade de S.Paulo CAMPUS DE PIRACICABA
DBA-1020


CAIO
USP
CMW-1707

USP


CIRCULAR-2
USP
B.R.A.B.U.S. | Especial 500º Post

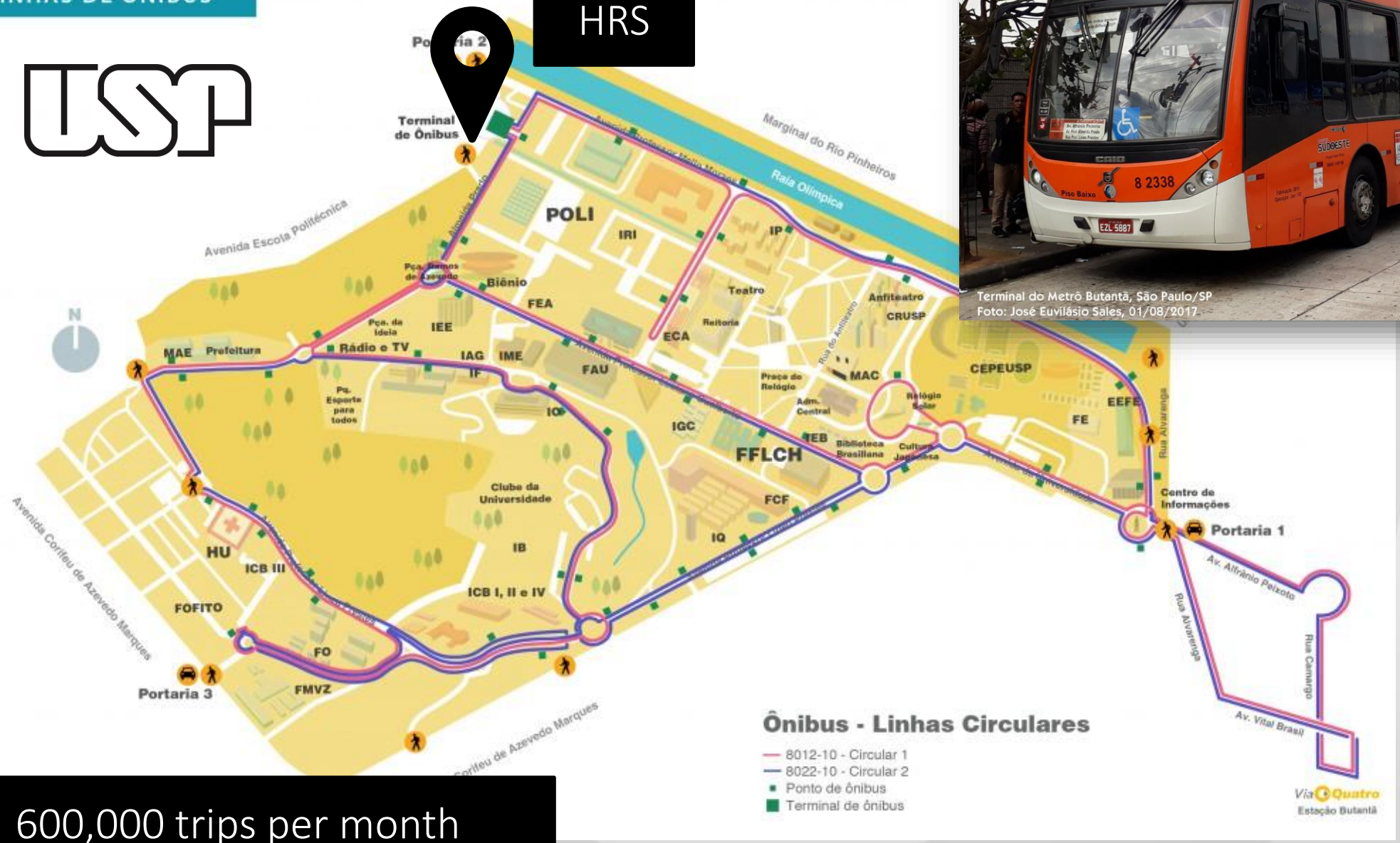

BUSP
USP
SPTrans
TPG/2013

LINHAS DE ÔNIBUS

USP

HRS

Terminal do Metrô Butantã, São Paulo/SP
Foto: José Euvilásio Sales, 01/08/2017.



600,000 trips per month


GOVERNO DO ESTADO
DE SÃO PAULO


HIDROGÊNIO


HIDROGÊNIO

THE VEHICLE

Marcopolo Viale BRS

Hydrogen fuel cell, electric motors
Regenerative breaking system

Autonomy: 200km
Capacity: 70 passengers

Air conditioning
Wide ailes
Wheelchair accessible

Marcopolo

PARTNERSHIP

Research Centre for Greenhouse Gas Innovation

USP

EMTU

Hytron

SENAI

raízen

TECHNOLOGY

Electricity

Hydrogen

Ethanol

Water

Power Utility

Water Utility

Ethanol

Ethanol Reformer (2nd Gen)

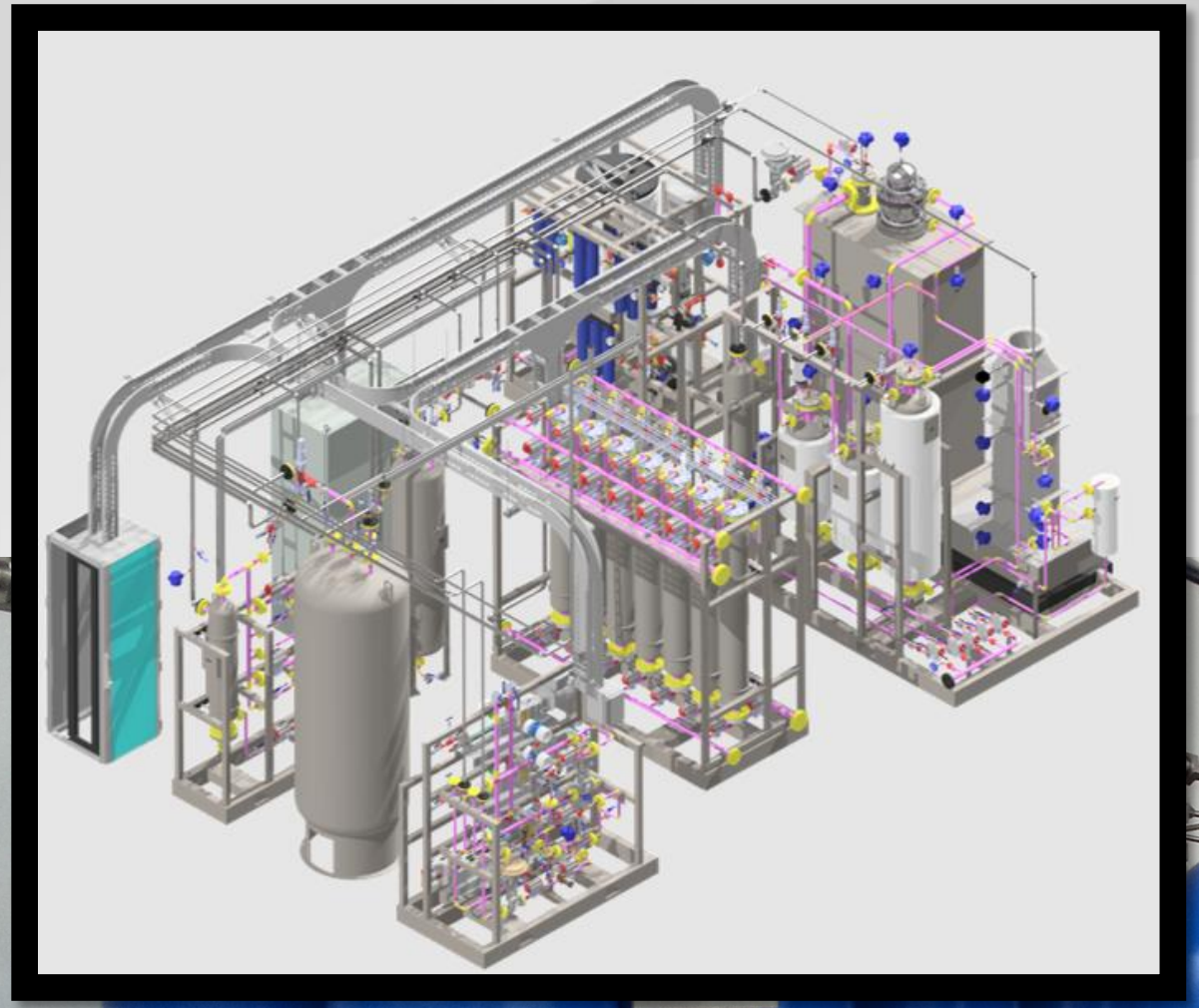
Including the Topologically Optimized Ethanol Steam-Reforming Reactor

Compressor

Hydrogen Storage

H_2 Dispenser

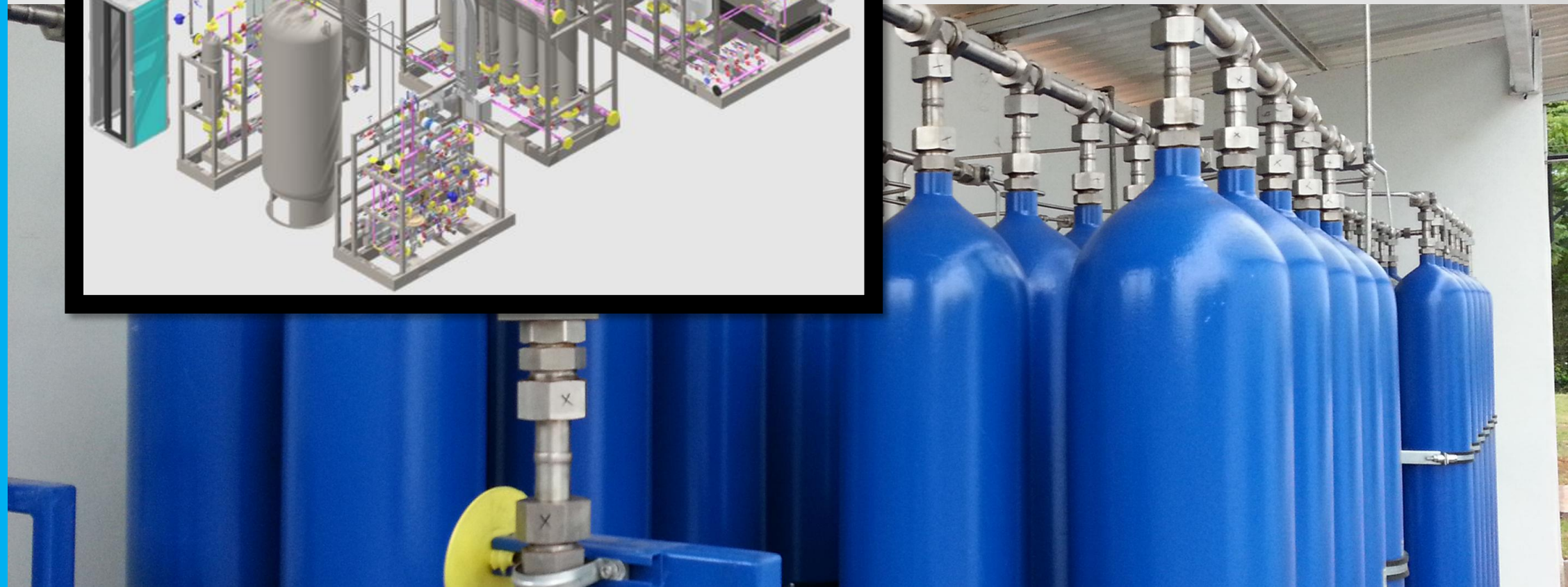
TECHNOLOGY



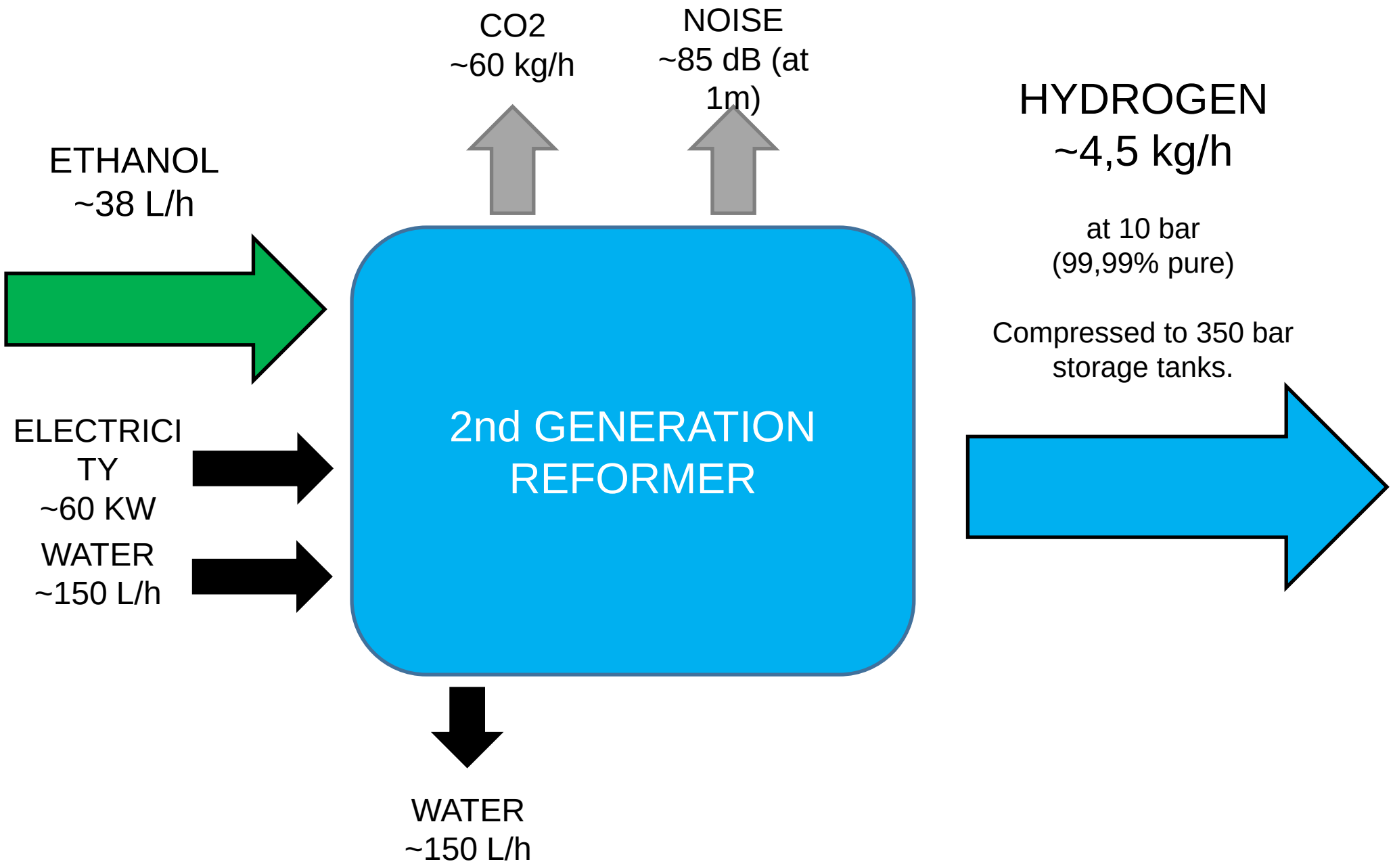
2nd Generation Ethanol Reformer

Hytron

NEA GROUP



TECHNOLOGY


CO2
~60 kg/h
NOISE
~85 dB (at 1m)
HYDROGEN
~4,5 kg/h
at 10 bar
(99,99% pure)
Compressed to 350 bar storage tanks.
ETHANOL
~38 L/h
ELECTRICITY
~60 KW
WATER
~150 L/h
2nd GENERATION REFORMER
WATER
~150 L/h

PILOT STATION

HRS Hydrogen Refuelling Station

Operational for 18 hours per day
Hydrogen production rate: 4,5kg/h
Hydrogen storage at 350 bar

Feedstock storage: 10,000 litres of Ethanol in suspended tanks (no underground tanks).

Bus load of 30kg of Hydrogen (approx. 200km)

Future station: 45kg/h at 350 bar


GOVERNO DO ESTADO
DE SÃO PAULO
METROPOLITANO
EMTU

NEAR FUTURE

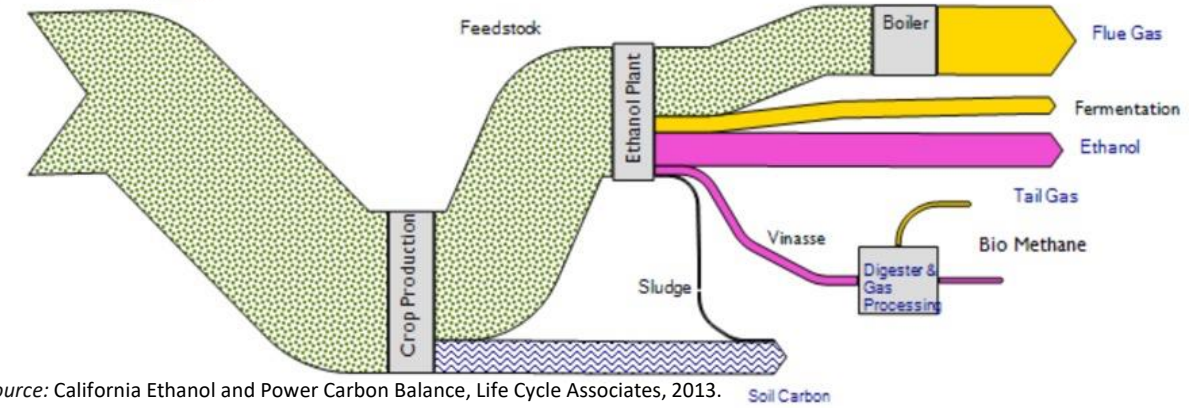

OPERACIONAL
GUARDA UNIVERSITÁRIA
SUPERVISÃO
VTR 20
3091.4222


GUARDA UNIVERSITÁRIA
Apoio à pessoa
com mobilidade reduzida

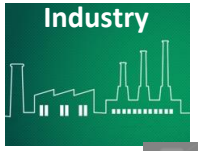
GFI-6063
FTZ-7072
FZB-9585
FTG-0218

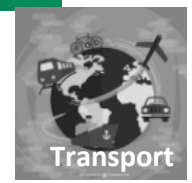
$EtOH^{Sink}$ ---- $H_2^{Abatement}$

Carbon Uptake



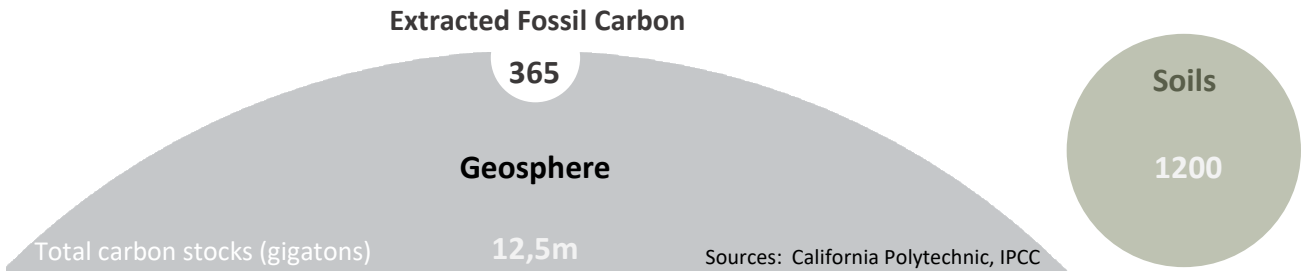
Source: California Ethanol and Power Carbon Balance, Life Cycle Associates, 2013.



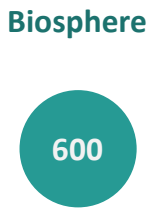


...

Sink



Abatement



EtOH^{Sink} ---- H_2^{Abatement}

BR E1G: 24.8 g CO_2/MJ_{fuel}
Source: JEC 2014

BR E1+2G: 17 g CO_2/MJ_{fuel}
Calculated based on Wang 2014

possible

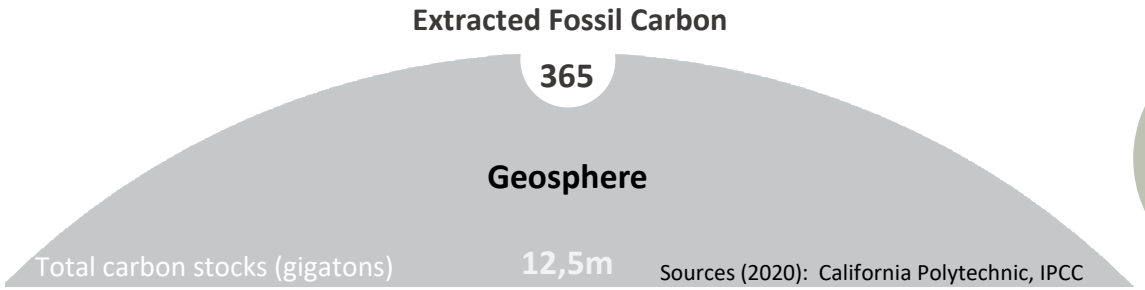
CA: -25.7 g CO_2/MJ_{fuel}
Calculated based on California Ethanol and Power Carbon Balance, Life Cycle Associates, 2013.

Only **sinks** can solve **cumulative emissions**

14.61 $GtCO_2eq$
Source: Our World in Data

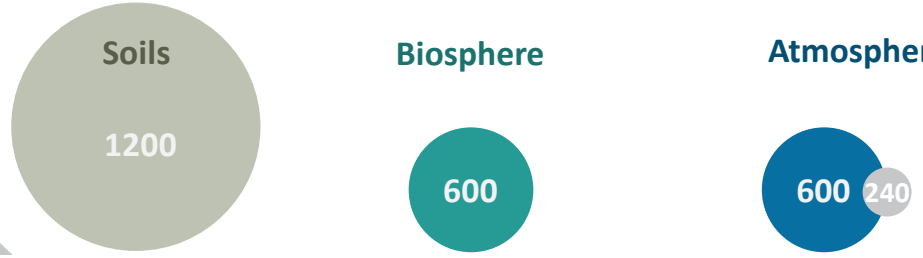
… speeded up if with **abatement**

Sink

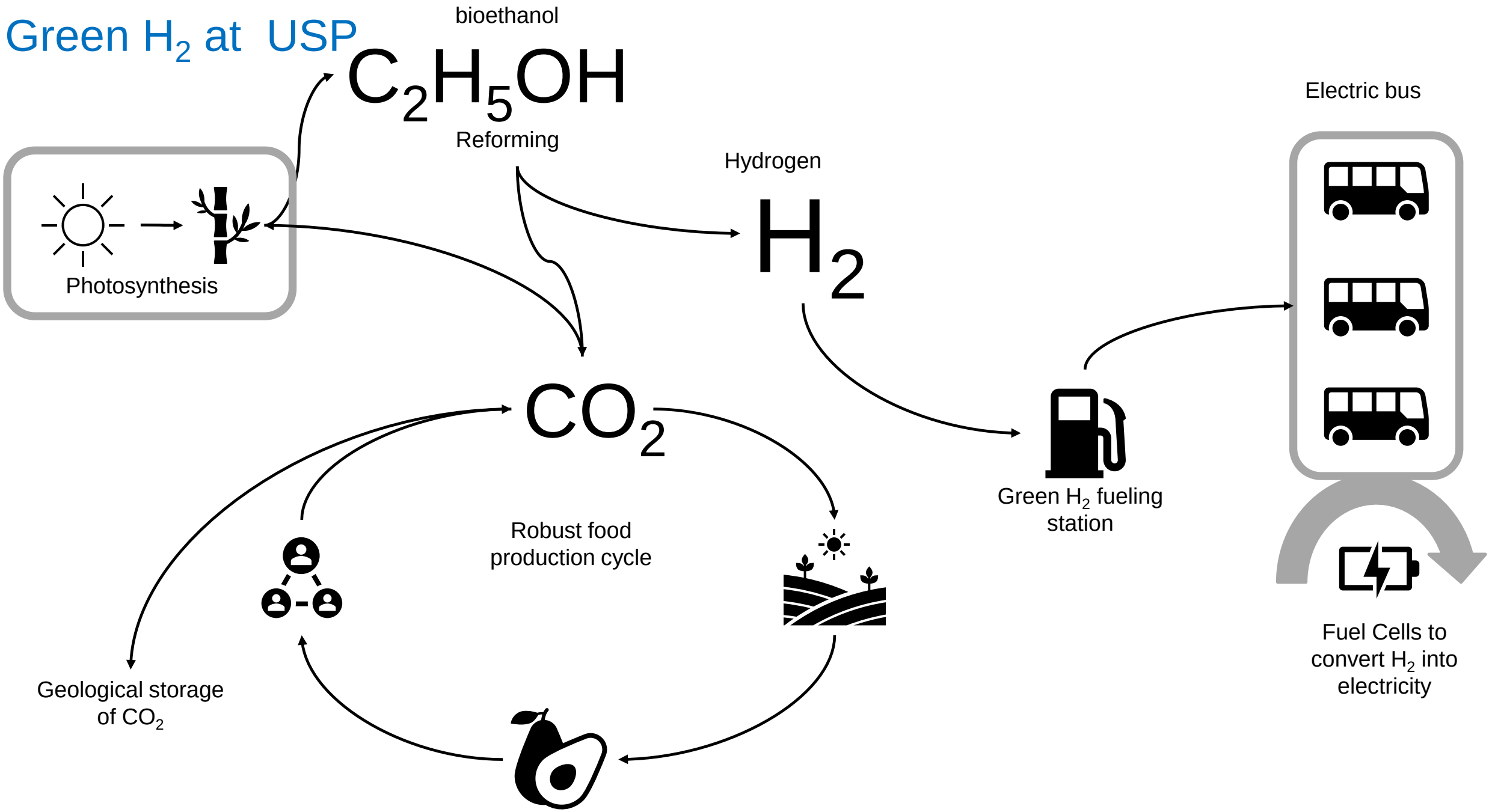


Sources (2020): California Polytechnic, IPCC

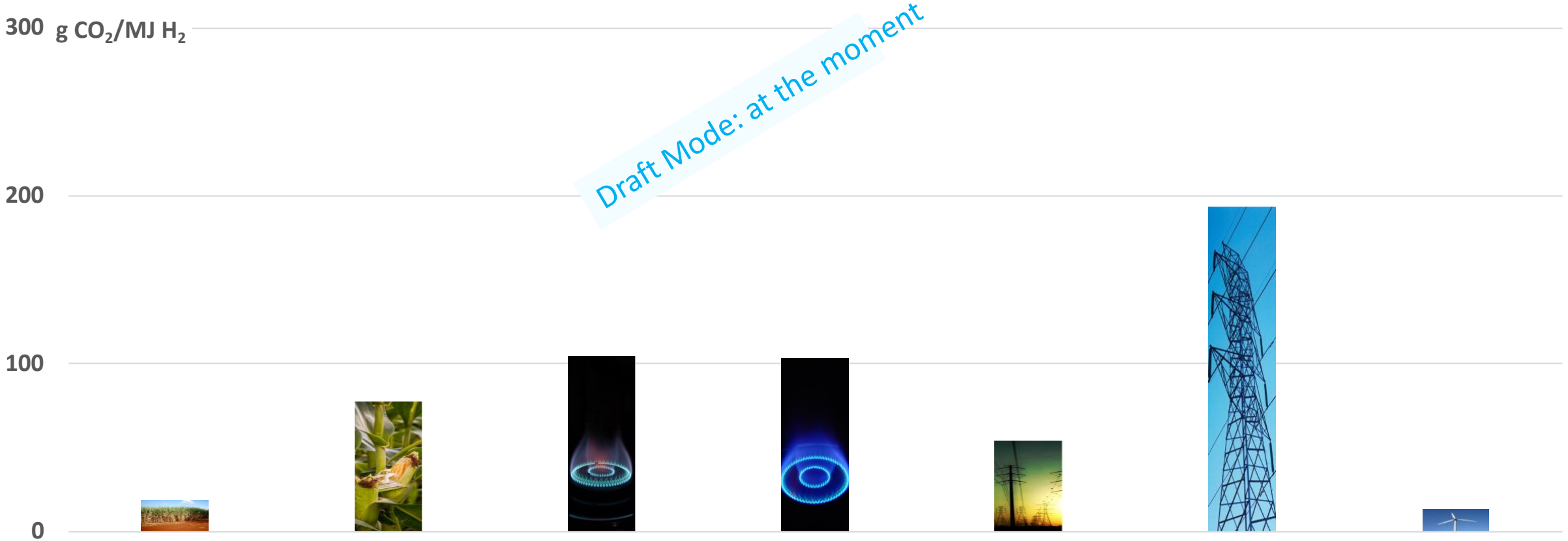
Abatement



Green H_2 at USP



HRS Bridging the Gap: GHG emissions

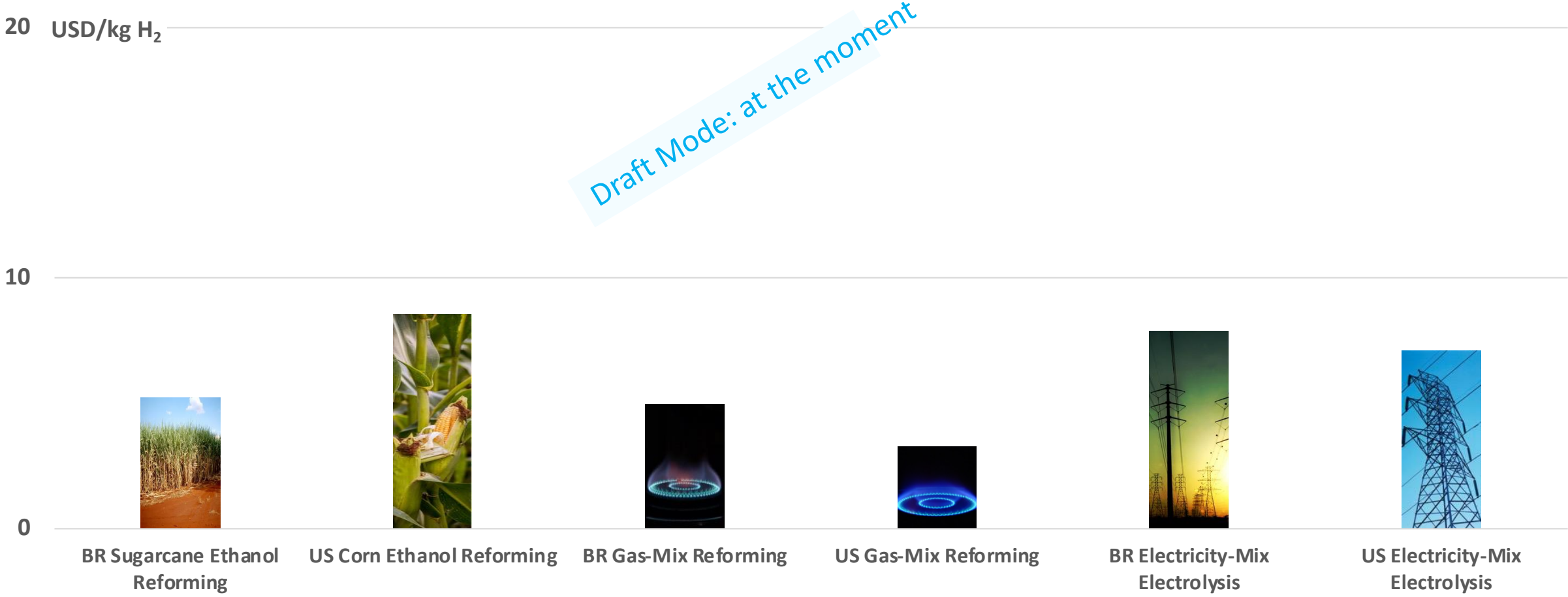


SP = ≈85% renewable

Calculated (harmonized initial estimation) decentralized:

Source: Shell Hydrogen Study

HRS Bridging the Gap: costs



Calculated (harmonized initial estimation) decentralized

Electricity or H_2 from Ethanol

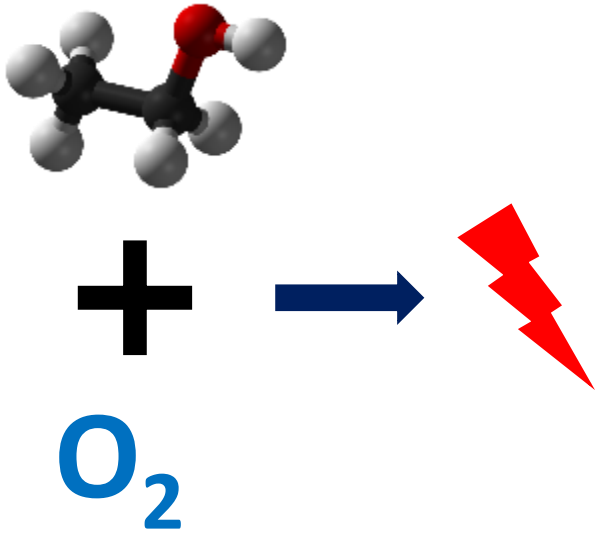
Fundamental studies

Micro-kinetic description: experiments, modeling and numerical simulations

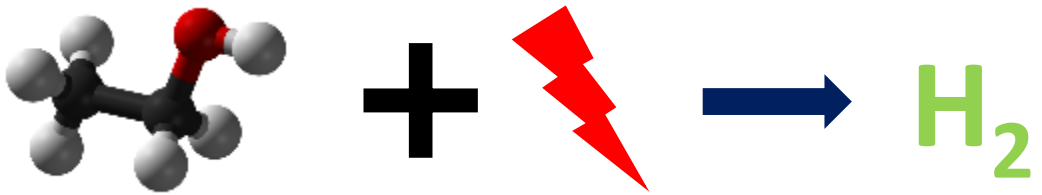
(basic and) applied research

Proton Exchange Membrane Electrolysis Cell & Fuel Cell (25-80 °C)

Solid Oxide Electrolytic Cell & Solid Oxide Fuel Cell (600-800 °C)



Fuel Cells Mode



Electrolysis Mode (electrochemical reform of Ethanol)

Thank you!

www.usp.br/rcgi

Research Centre for
Greenhouse Gas Innovation