Hytron

Agenda

.Company History & Activities

.Why to Produce Hydrogen?

.Renewable Hydrocarbons

  .Challenges from Aviation Sector

  .Technologies for SAF Production

  .Fischer-Tropsch Synthesis

.Hytron Technologies

  .Thermochemical

  .Electrochemical

.Power-to-X

Renewable Hydrocarbons for Aviation and for a Decarbonized Future

1° Congresso da Rede Brasileira de Bioquerosene e Hidrocarbonetos Renováveis para Aviação

Mesa Redonda 4 – Hidrocarbonetos Renováveis para Aviação

Antonio Marin (antonio@hytron.com.br)

R&D and Operations Director

Our History

Hytron is a Technology Company founded in 2003, focused in Hydrogen Production & Utilization, Alternative Power Generation and Energy Storage

spin-off from the Hydrogen Laboratory at University of Campinas (UNICAMP), considered the best university in Latin America by Times Higher Education - World University Ranking, 2017

high capacity process Integrator

highly specialized professionals Including PhD´s, Masters and Specialists

Brazilian Pioneer in the Demonstration of Hydrogen Technologies

Worldwide Pioneer in Producing Hydrogen from Ethanol

Internationally Recognized Innovative Technology Projects

Our Activities

Energy

.Power-to-X (Hydrogen Applications)
.Photovoltaic
.Biogas Upgrading & Utilization
.Process Integration, Control & Supervision
.Energy Storage
.IoT

Gases

.On-site Generation of Industrial Gases
.Consultancy for Industrial Gases Consumers
.IIoT

R&D

.Alternative Fuels for Hydrogen Production
.Alternative Power Generation
.Waste Heat Recovery (Organic Rankine Cycle)
.Energy Storage Technologies (inc. Flow Batteries)
.SynGas & e-Products

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Why to Produce Hydrogen?

Industrial Applications (Current Demanding Market)

.Hydrogenation of Oils

.Production of Chemicals and Pharmaceuticals

.Metallurgy

.Flat Glass Production

.Semiconductor Industry

.Power Industry

Why On-Site Production?

.Security of Supply

.Turn-key Solution

.Lower Costs

.Ultrapure H_2 (up to 99.9999%)

.Less Emissions

Why to Produce Hydrogen?

Energy Applications (Developing Market)

.Efficient Power Generation (Fuel Cells or Gensets)

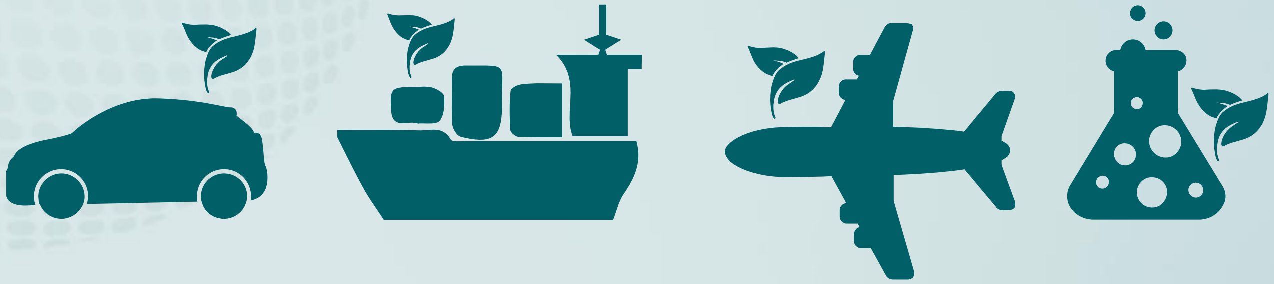
.Power-to-X (production of **e-Products**, that stands for **electro-Products**):

.X = Power: **Long Term Energy Storage**

.X = Gas: **Production of H_2 or Synthetic Natural Gas**

.X = Mobility: **H_2 fuelled Cars, Trains, Trucks, Boats, Forklifts, ..., or Path to Synthetic e-Fuels**

.X = Chemicals: **Path to Green Chemistry**



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Renewable Hydrocarbons for Aviation and for a Decarbonized Future

Challenges from Aviation Sector

.Commercial and Executive aviation demands **high autonomy** from the fleet

.**Mass and Volume Power Densities** are crutial for feasibility (payload and range extension)

.**Standardization** is essential in the sector

.Since aircraft are not able to switch to alternative energy sources (like hydrogen or electricity), in the near-term future, **aircraft will remain to rely on liquid fuels**

.**Estimative:** more than 99% of airline emissions and approximately 50% of airport emissions are related to the combustion of Jet fuel

.**Estimative:** Aviation currently accounts for approximately 2% of anthropogenic global carbon emissions. This represents close to 20 million tonnes of CO_2 equivalent per year for air transportation sector in Brazil (2014)

.**CORSIA** (ICAO, 2016)

.But information above stands for the direct Jet fuel usage (burned in turbines)…

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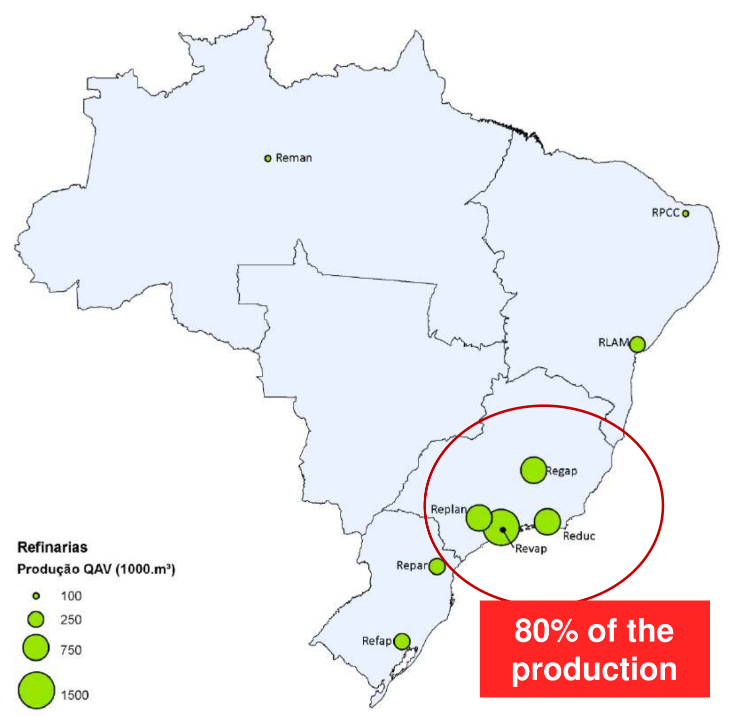
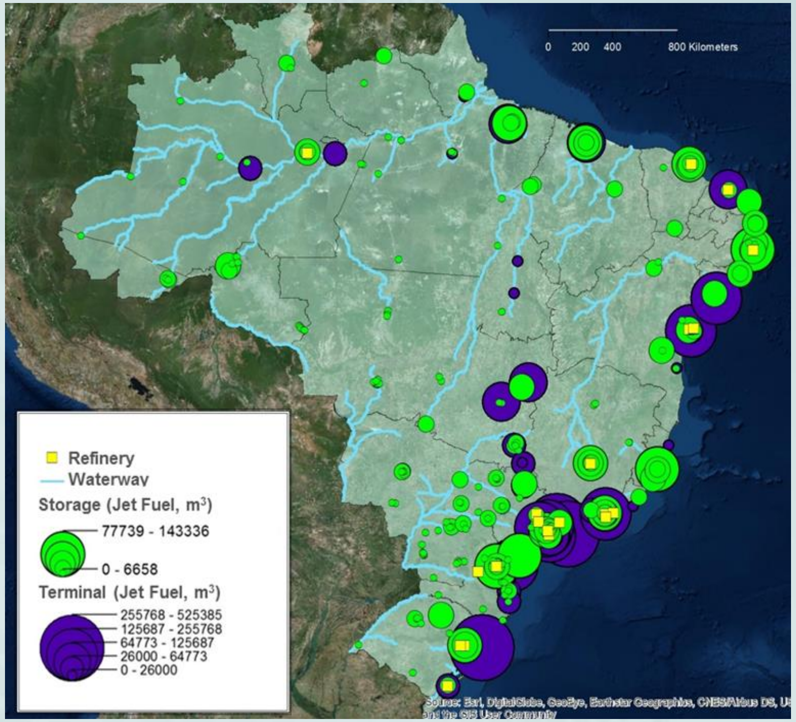
Challenges from Aviation Sector – Brazil's Jet Fuel Infrastructure

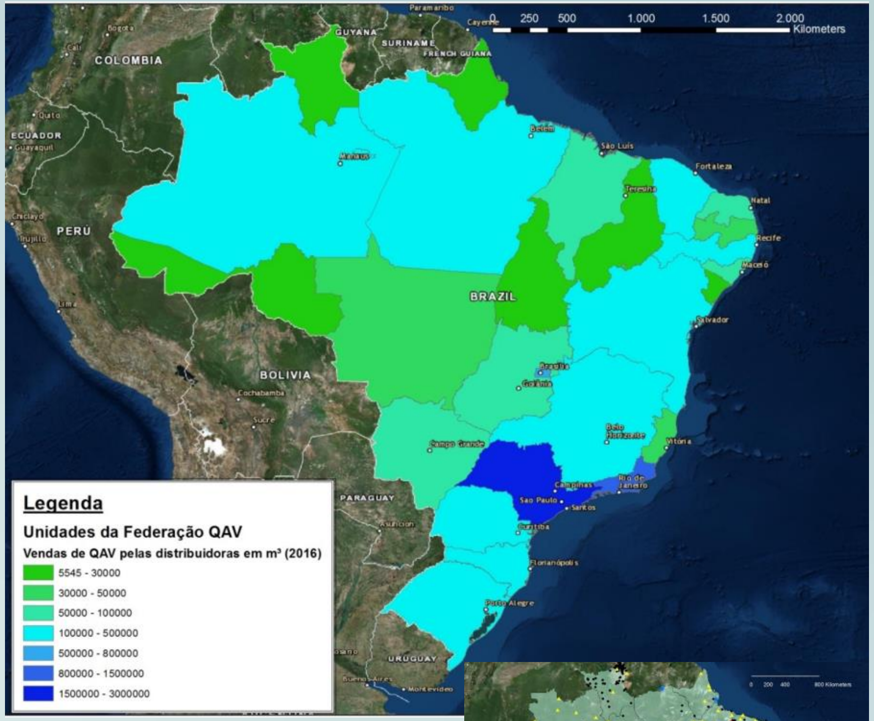
Production



Distribution & Storage



Consumption



Source: Executive Summary – ProQR. GIZ Cooperation (2017); *apud* IBGE, ANAC, EPE

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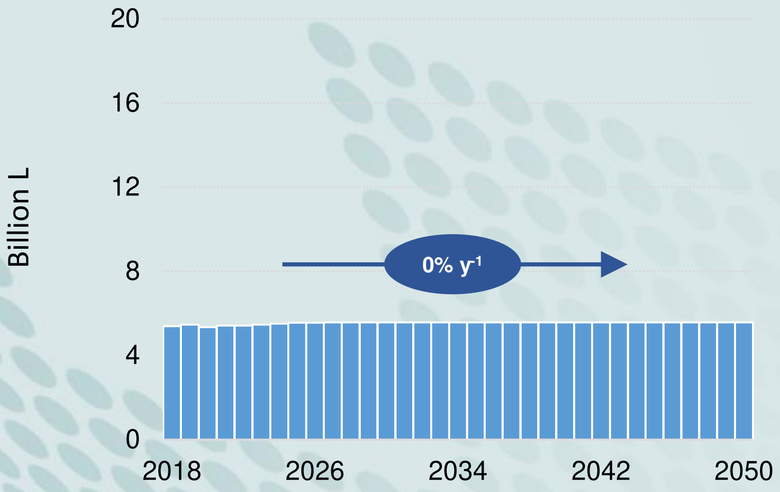
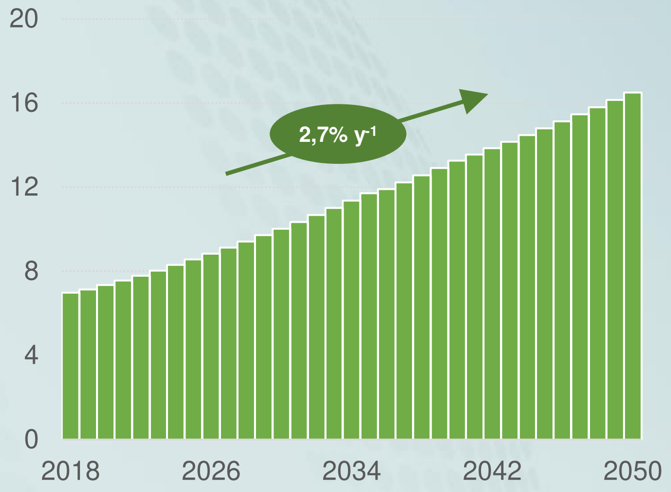
Challenges from Aviation Sector – Brazil's Jet Fuel Forecast

Production



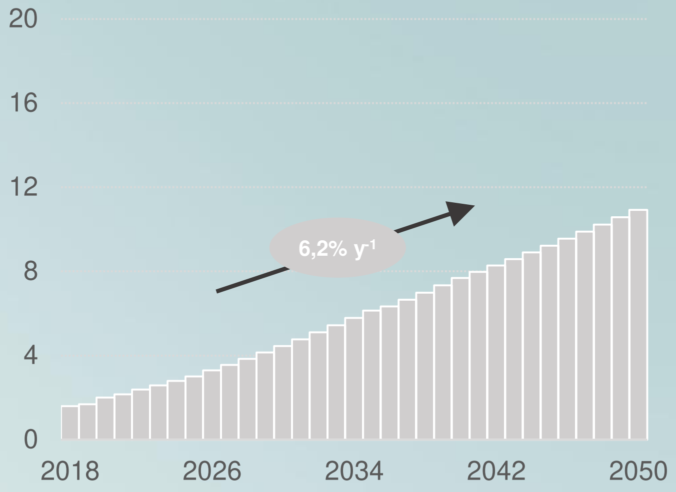
Stagnation of the production between close to 6.5 billion L/year (2018)

Demand



Forecasted demand to increase from 7.2 billion L in 2018 to 14.8 billion L in 2050 (linked to economic scenario)

Importation



Forecasted demand indicates growth in importations over the next decades, from 0.8 billion L in 2018 to 8.2 billion L in 2050

Rises attention to the long-term national supply security

Source: EPE – Empresa de Pesquisa Energética

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Technologies for SAF Production

.Co-Processing: vegetable oils, waste and/or fats co-processed with conventional crude oil feedstocks, in existing refineries

.Alcohol to Jet (AtJ): ethanol or iso-buthanol are de-oxygenated and the remaining chains are subjected to oligomerization (blending limited to 30%)

.Synthesized Iso-Paraffins (SIP): biological route that converts C6 sugars into farnesene, which is **hydrotreated** in order to reach a SAF specification (blending limited to 10%)

.Hydrotreated Esters and Fatty Acids (HEFA): vegetable oils, waste and/or fats are de-oxygenated and then **hydrotreated** in order to reach a SAF specification. **(Hydro)Isomerization** necessary (blending limited to 50%)

.**Fischer-Tropsch (FT): syngas (H_2+CO) is used to synthesize a group of desired hydrocarbons, from potentially any hydrogen and carbon source** (blending limited to 50%)

*SAF: Sustainable Aviation Fuels

Fischer-Tropsch Process

.Thermochemical synthesis of hydrocarbons, typically straigh-chain alkanes, but also alkenes and alcohols, from synthesis gas (H_2+CO):

.Complex chemical systems, in which products distribution are dependent of the boundary conditions (temperature, pressure, stoichiometry, etc.)

.Gaseous fraction (inc. LPG): C1-C4

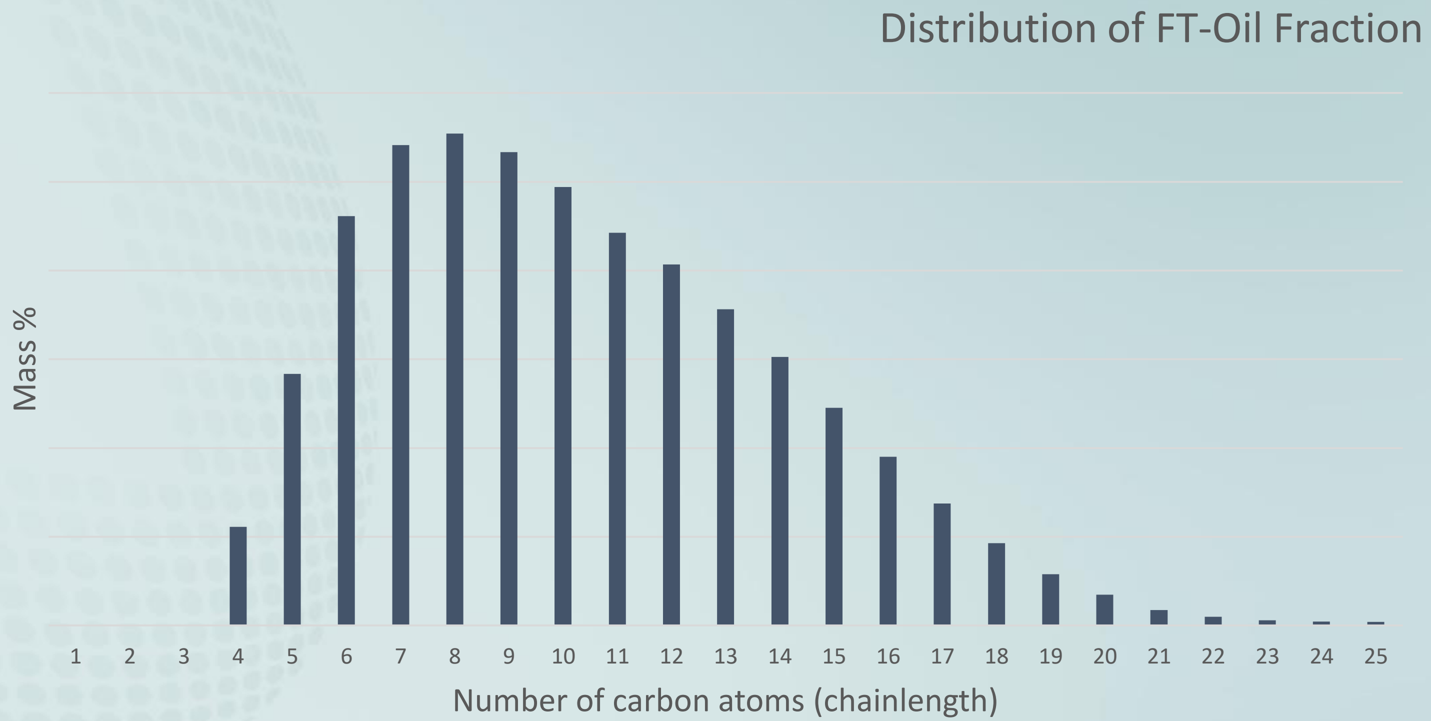
.Gasoline fraction: C5-C6

.Kerosene fraction: C7-C12

.Diesel fraction: C13-C18

.Heavier fraction (inc. waxes): C18+

.Olefins, n-alcohols also included



Fischer-Tropsch System

From **integrator** point-of-view:

.**Syngas** (source, H_2:CO, contaminants, P, T, ...)

.Post-processing:

.Hydrocracking

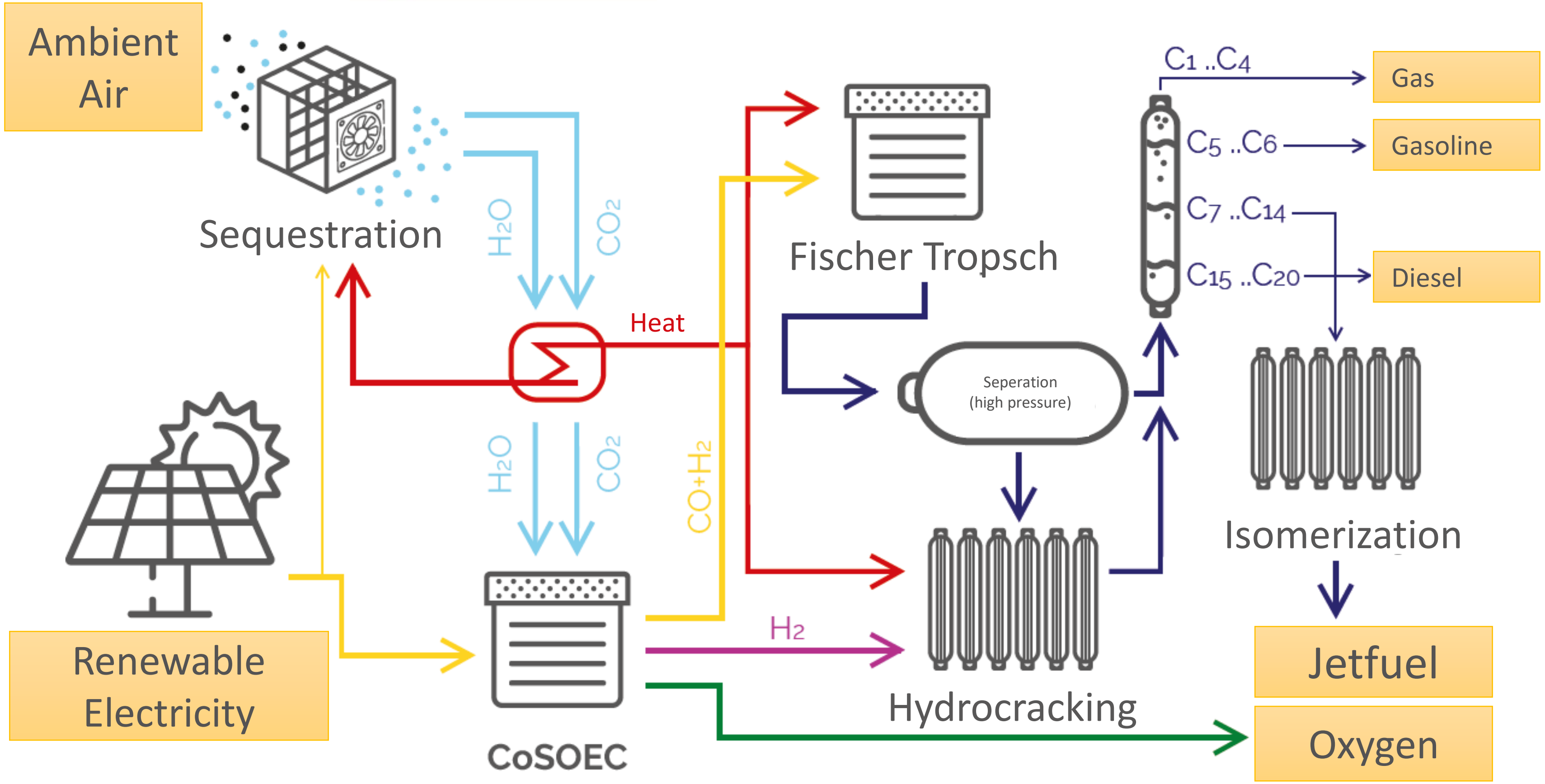
.(Hydro)isomerization

.Light gases recovery

.Fractionation, ...

.Heat Recovery & Integration

.Automation (SU, SS, SD)



Fischer-Tropsch System

.Syngas Production and Feeding:

.High Molecular Weight Fuels (Gasification – POX, Pirolysis, Pre-Reforming)

.Intermediate and Light Fuels (Steam-Reforming, Autothermal Reforming – CPOX)

.Power-to-Liquids (Alkaline Water Electrolysis, PEM, Solid Oxide Electrolysis, co-SOE)

.CO_2 (SOE, Reverse Water Gas Shift – RWGS)

Where the CO_2 Comes From?

Direct Air Capture

Ethanol / Biogas

Industrial Processes

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How to Produce Hydrogen?
Hytron's Project and Product Portfolio – Thermochemical

Natural Gas and Ethanol Reforming

.Integrated, Autonomous and Supervised Systems

.Proprietary Supervisory Platform (SCADA) & Control Software

.Up to 250 Nm^3/h H_2 (single unit)

.Hydrogen Purity up to 99.9999% (6.0)

.Typical Operating Pressure: 10 bar_g

."All-in-One" Solution (Feed Treatment, Water Purification, Reforming & Shift Conversion, Thermal Management, Heat Recovery, H_2 Purification and Purity Supervision)

R&D Scope:

Reforming of Alternative Feedstocks

.Biogas

.Glycerol

.Vegetable Oil

.Tars

Rotary Kiln Slow Pyrolysis of Solid Wastes

.Biomass

.Industrial Residues

.Municipal Solid Waste

Fuel Reformers

Natural Gas

0.43 Nm³ / Nm³ H_2

Water

1.85 L / Nm³ H_2

Electricity

0.42 kWh / Nm³ H_2

H_2

Up to 240,000 Nm³ H_2 / month

Process: Steam-Reforming

H_2 Purification: PSA (Pressure Swing Adsorption)

H_2 Purity: up to 99.9999% (6.0)

H_2 Pressure: 10 bar_g (typical)

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Natural Gas Steam-Reforming for H_2 Production

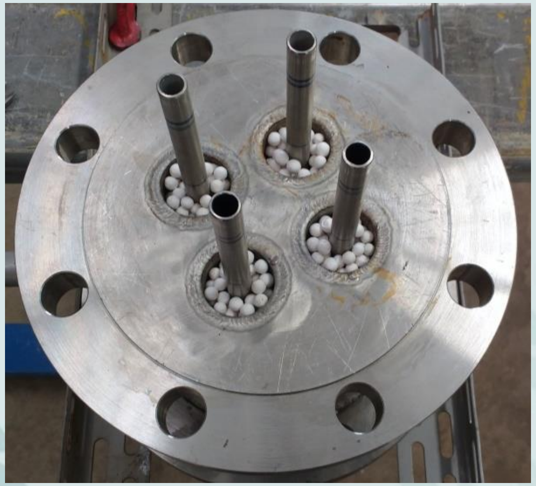


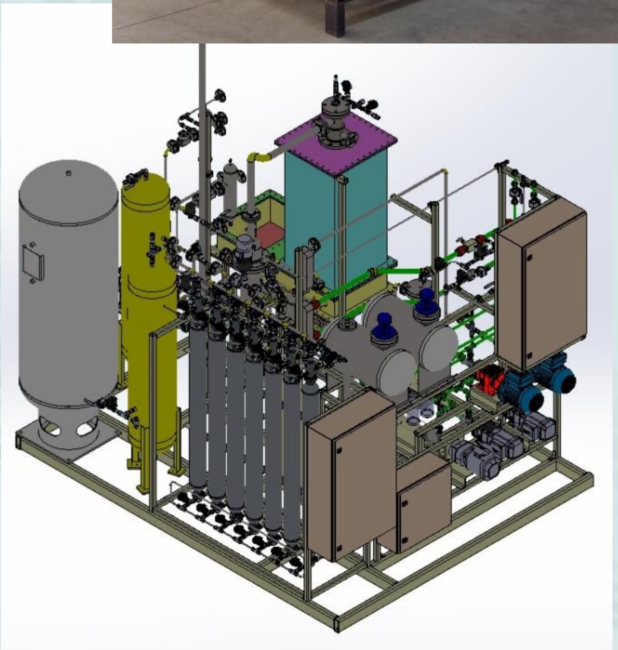

Technical Specifications	
Process	Steam-Reforming
Fuel	Natural Gas[2]
Specific Fuel Consumption[3]	0.43 Nm^3 GN / Nm^3 H_2
Specific Water Consumption[3,4,5]	1.85 L H_2O / Nm^3 H_2
Reformate Output Pressure	10.5 bar_g
Reformate Output Temperature	Up to 5°C Below environment
Standard H_2 Purity[6]	99.999% (v/v)
H_2 Purification Process	PSA (Pressure Swing Adsorption)
H_2 Output Pressure	10.0 bar_g
Specific Power Demand (inc. Utilities)	0.42 kWh / Nm^3 H_2
N_2 Consumption[7]	5.5 Nm^3

[2] LHV_{NG}=10,960 kcal/kg (Mass $Density_{NG}$=0.7541 kg/Nm^3 @ 101.3 kPa; 30°C)
[3] Producing H_2 5.0
[4] Tap Water (Process Water Purification Integrated)
[5] Without Condensate Recovery
[6] Higher Values Under Request
[7] Each Complete Cycle of Start-up & Shutdown

NG-SR Pilot Plant fully Operational

Ethanol Steam-Reforming for H_2 Production





Technical Specifications	
Process	Steam-Reforming
Fuel	Hydrated Ethanol[1]
Specific Fuel Consumption[3]	0.68 L EtOH / Nm^3 H_2
Specific Water Consumption[3,4,5]	1.60 L H_2O / Nm^3 H_2
Reformate Output Pressure	10.5 bar_g
Reformate Output Temperature	Up to 5°C Below environment
Standard H2 Purity[6]	99.999% (v/v)
H_2 Purification Process	PSA (Pressure Swing Adsorption)
H_2 Output Pressure	10.0 bar_g
Specific Power Demand (inc. Utilities)	0.21 kWh / Nm^3 H_2
N_2 Consumption[7]	5.5 Nm^3

[1] LHV_{EtOH}: 4,975 kcal/L (Mass $Density_{EtOH}$: 0.7893 kg/L @ 30°C; 96.4% GL)
[3] Producing H_2 5.0
[4] Tap Water (Process Water Purification Integrated)
[5] Without Condensate Recovery
[6] Higher Values Under Request
[7] Each Complete Cycle of Start-up & Shutdown

EtOH-SR Pilot Plant under Construction

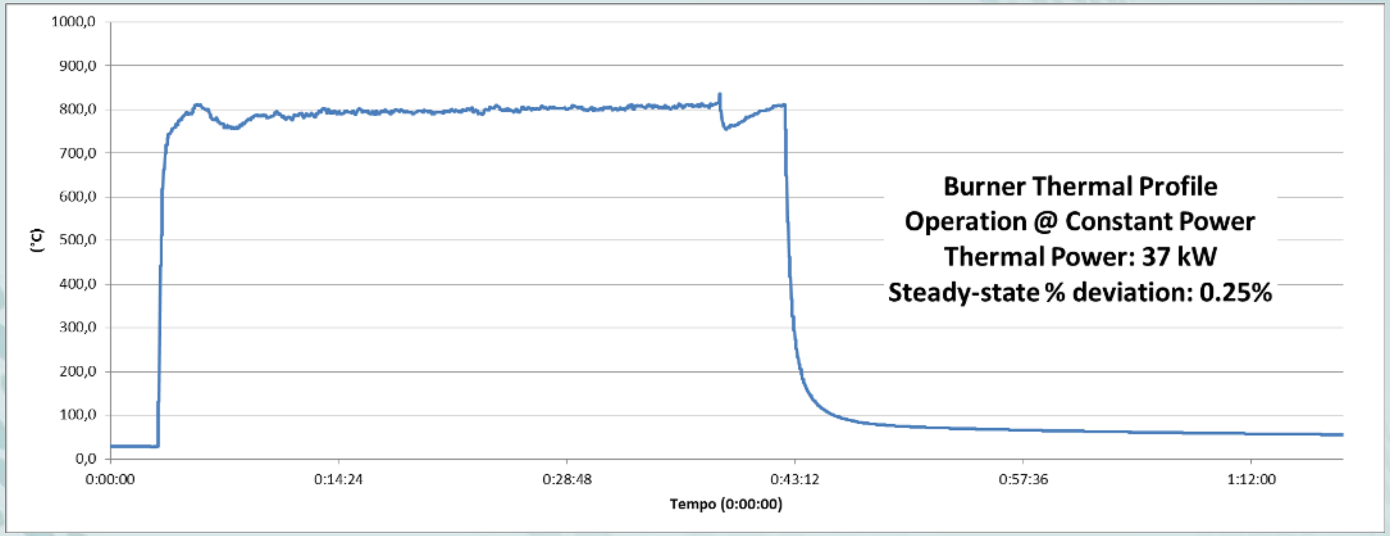
Non-Catalytic Partial Oxidation (POX)

POX Pilot Plant Basic Specifications	
Process	Non-Catalytic Partial Oxidation
Fuel	Hydrated Ethanol
Fuel Flowrate (Reforming)	16.0 L/h
Fuel Flowrate (Heat)	4.0 L/h
Process Water Flowrate[4,5]	19.5 L/h
H_2 Rated Capacity[3]	21 Nm^3/h
Specific Power Demand	0.206 kWh/Nm^3 H_2

[1]LHV_{EtOH}: 4,975 kcal/L (Mass $Density_{EtOH}$: 0.7893 kg/L @ 30°C; 96.4% GL)
[3]Producing Reformate
[4]Tap Water (Process Water Purification Integrated)
[5]Without Condensate Recovery

EtOH-POX Pilot Plant Ready for Operation

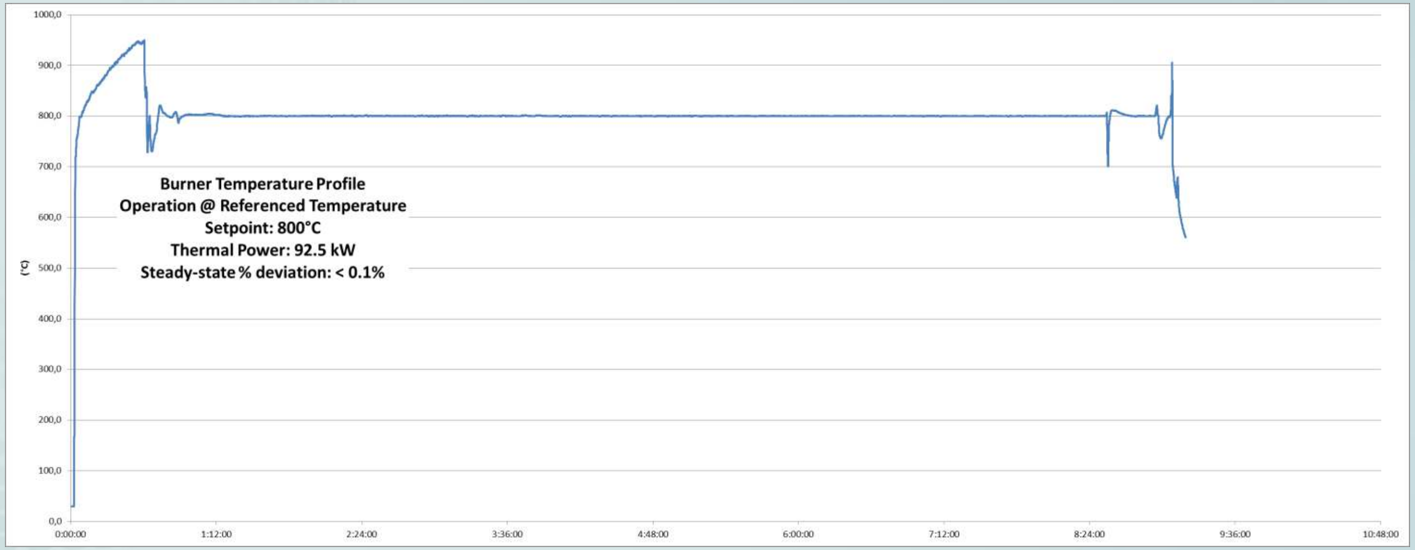
Non-Catalytic Partial Oxidation (POX)



PID Parameters Tunned According to Technical Demands

Upper Profile: Burner @ Oxidizing Conditions
Heat Generation to Steam-Reforming Process

Right Profile: Burner @ Reducing Conditions
Reformate Generation through Partial Oxidation



AES Brasil Shell Hytron

How to Produce Hydrogen?
Hytron's Project and Product Portfolio – Electrochemical

Water Electrolysis

.PEM and Alkaline Technologies

.Integrated, Autonomous and Supervised Systems

.Proprietary Supervisory Platform (SCADA) & Control Software

.Up to 420 Nm^3/h H_2 (single unit)

.Hydrogen Purity up to 99.9999% (6.0)

.Typical Operating Pressure: 40 bar_g

."All-in-One" Solution (Process Water Purification, Electrolysis, Thermal Management, H_2 Purification and Purity Supervision)

R&D Scope:

.Partnership in SOEC (Solid Oxide Electrolysis Cell) for:

.Water Electrolysis (H_2 Production)

.Carbon Dioxide Electrolysis (CO Production)

.Co-Electrolysis for e-SynGas Production

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Water Electrolysis Technology Assessment

	Alkaline	PEM	SOEC
Operating Pressure	**< 30 bar_g**	**< 85 bar_g**	**< 1 bar_g (10)**
Operating Mode	**Balanced**	**Differential**	**Balanced**
Operating Temperature	< 80°C	< 80°C	< 800°C
Current Density	**< 400 mA/cm²**	**< 6.000+ mA/cm²**	**< 600 mA/cm²**
DC Spec. Power Cons. (BoL)	**4.2 – 5.8 kWh/Nm³ H_2**	**4.0 – 4.7 kWh/Nm³ H_2**	**3.7 – 4.0 kWh/Nm³ H_2**
Stack Lifetime	< 90,000 h	> 90,000 h	NA
System Lifetime	< 90,000 h	172,000 h	NA
Operating Range	25 – 130%	1 – 300%	25 – 110%
Start-up	**60 – 600 s**	**1 – 180 s**	**~ 3.600 s**
Ramp-up	0,2 – 20%/s	Up to 100%/s	NA
Ramp-down	0,2 – 20%/s	Up to 100%/s	NA
Shut-down	**60 – 600 s**	**10 – 60 s**	**~1.200 s**
Process Water	< 5 $\mu S.cm^{-1}$ (500 $k\Omega.cm^{-1}$)	< 0.1 $\mu S.cm^{-1}$ (10 $M\Omega.cm^{-1}$)	< 1 $\mu S.cm^{-1}$ (1 $M\Omega.cm^{-1}$)
Bulk H_2 Purity	**99,5%**	**99,99+%**	**99,5%**

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Alkaline Water Electrolysis

Technical Specifications	
Process	Alkaline (Bipolar Pressurized) - 60°C
Electrolyte	KOH_{aq} (25-30% w/w)
Capacity	1 Nm^3/h H_2
H_2 Output Pressure	12 bar_g
H_2 Output Temperature	Up to 5°C above environment
Raw H_2 Purity[2]	99.5% (v/v)
Process Water Spec.	< 5 $\mu S.cm^{-1}$
DC Specific Power Demand	5.70 kWh / Nm^3
AC Specific Power Demand (+ Utilities)	**6.35 kWh / Nm^3**
N_2 Consumption[3]	1.0 Nm^3

[2]Without additional purification
[3]Each complete cycle of start-up and shutdown

Eletrobras Eletrosul AES

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PEM Water Electrolysis

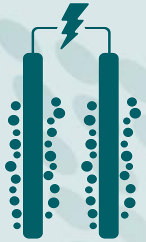
Technical Specifications	
Process	PEM (Bipolar Pressurized) - 70°C
Capacity	20 Nm^3/h H_2
H_2 Output Pressure	40 bar_g
H_2 Output Temperature	Ambient
Raw H_2 Purity	99.99+% (v/v; saturated)
O_2 Content in H_2 Stream	8 – 20 ppm
H_2 Content in O_2 Stream	< 0.1% (v/v; saturated)
Final Hydrogen Purity	99.99% (v/v; dewpoint ≤ -30°C)
Purification Process	Adsorption Dryer
Process Water Specification	< 0.1 $\mu S.cm^{-1}$ (10 $M\Omega.cm^{-1}$)
DC Specific Power Demand (@3.000 mA/cm^2)*	4.7 kWh / Nm^3
DC Specific Power Demand (@1.500 mA/cm^2)	4.2 kWh / Nm^3
AC Specific Power Demand*	5.5 kWh / Nm^3
AC Specific Power Demand (+ Utilities)*	5.7 kWh / Nm^3
N_2 Consumption	0 Nm^3

PEM Electrolyser under Comissioning

What the Renewables Could Lead For? Power-to-X

co-SOEC

H_2O →
CO_2 →



→ $H_2 + CO$ → e-Chemicals

Fischer-Tropsch Synthesis

↓ O_2

Synthesis System Can be Optimized for Preferred Products, such as:

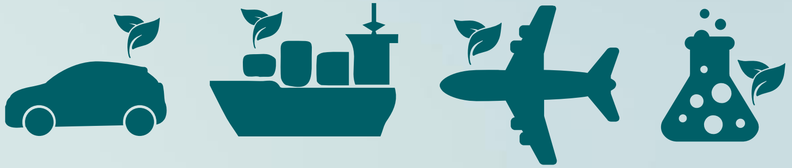
.e-Kerosene
.e-Gasoline
.e-Diesel
.e-Olefins
.e-Plastics
.e-Cosmetics
.e-Specialties
...

Where the CO_2 Comes From?

Direct Air Capture

Ethanol / Biogas

Industrial Processes



Current, and Improved, Technologies

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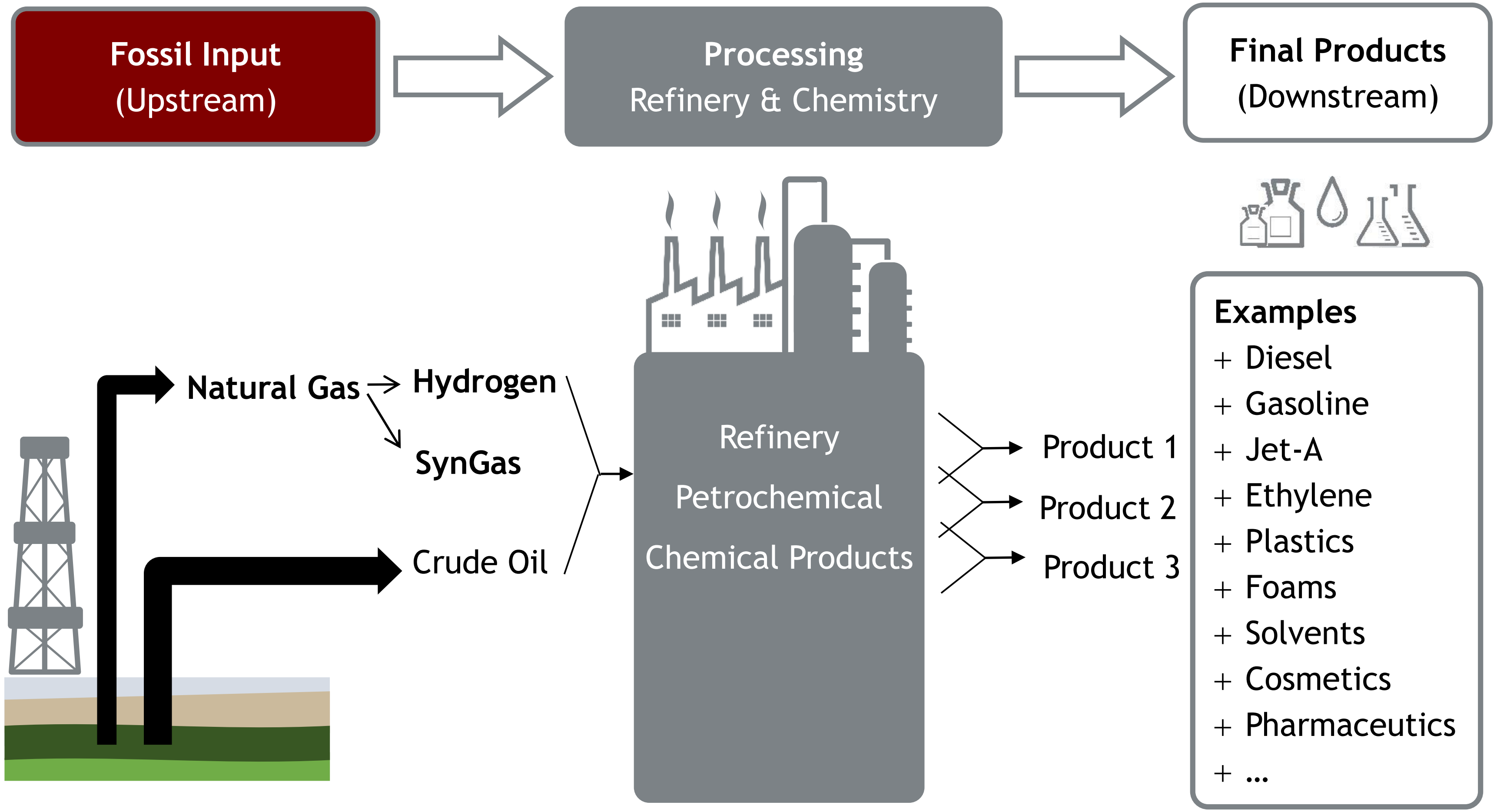
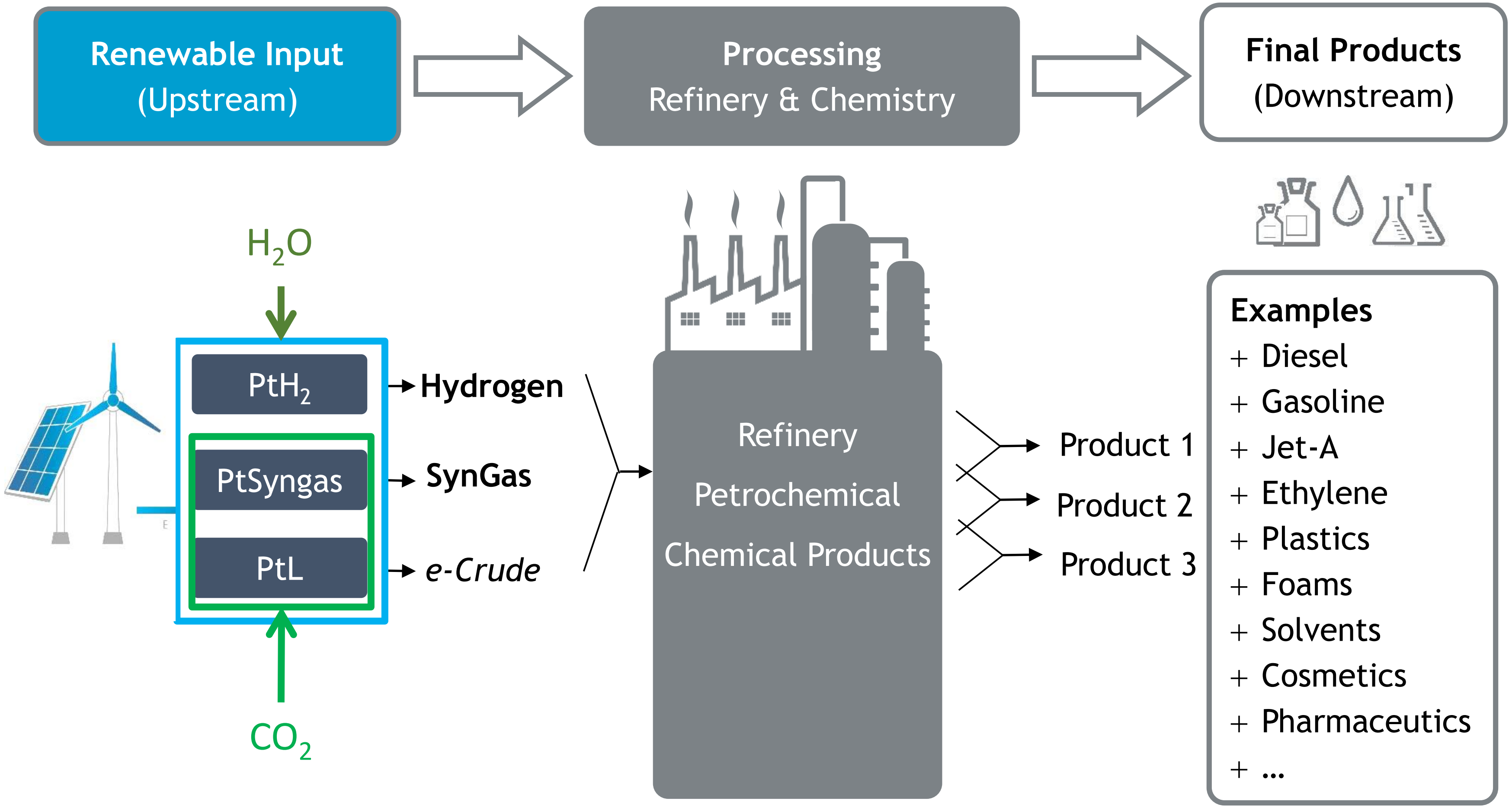
Current Paradigm



Source: Sunfire

Decarbonization for a Renewable Economy



Source: Sunfire

Customers

comgas

CPFL ENERGIA

CESP Companhia Energética de São Paulo

Shell

Cargill

enel

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anp
Agência Nacional do Petróleo, Gás Natural e Biocombustíveis

arsesp
agência reguladora de saneamento e energia do estado de São Paulo

FAPESP

CNPq
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