SULZER

Propane to Propylene Technology

A low-carbon pathway for obtaining environmentally friendly propylene from propane with optional co-production of hydrogen

July 12. 2023

Disclaimer

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These forward-looking statements are subject to change based on known or unknown risks and various other factors, which could cause the actual results or performance to differ materially from the statements made herein.

About SULZER

We help our customers build a better world

Sulzer is a global industry leader, with two centuries of experience developing innovative products and services that drive sustainable progress — and help our customers build a better world.

3.2
Billion sales (CHF) 2022

12’900
Employees

40
Production locations

140
Service centers

100
Countries with Sulzer presence

Sustainability at Sulzer

Minimize – Enable – Engage

Gas to X Technologies

From 2004 to today

2004 - 2013

- Start of working on Gas-to-Fuel process using bromine activation
- Integrated pilot unit testing in SWRI
- Demo plant constructed & operated
- 1-st commercial GTF process design

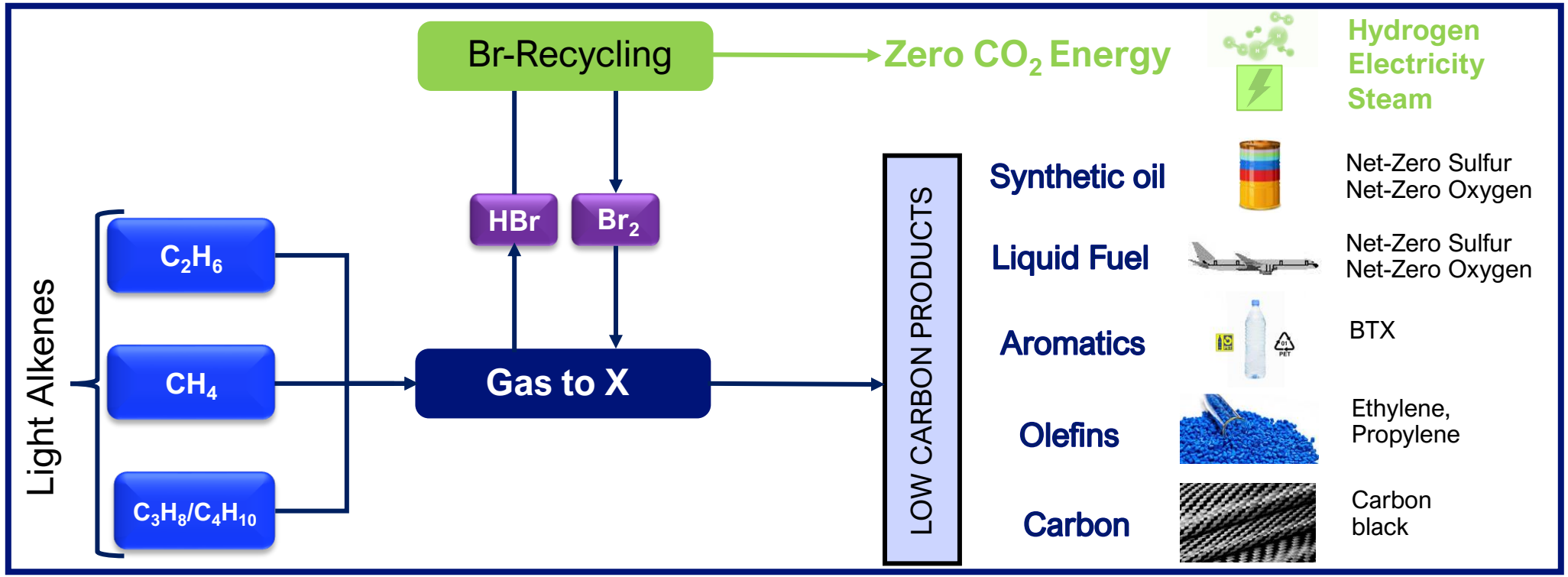
2014 - 2019

- Acquisition of the technology by GTC
- JDA with Total Energies in Methane-to-Olefins

2019 to today

- Acquisition of GTC by Sulzer
- Development of HBr electrolysis
- Extension of technology to C_2-C_4 feedstock
- G2X portfolio commercialization

Gas to X in a nutshell



Gas to X – a universal technology portfolio for the monetization of light alkanes

Gas to X - technology portfolio

Value adding with side products and minimizing carbon footprint

Methane to Carbon

Decarbonization of methane to produce high value carbon with either energy self-sufficiency or energy efficient co-production of hydrogen with no impact on regional water security

Gas to Liquid

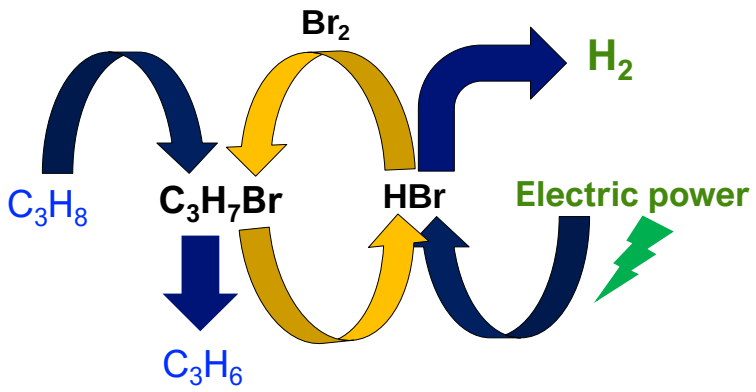
A low-carbon, economical pathway for converting gas into a liquid to be used as synthetic oil, liquid fuel or aromatics, eliminating the need for gas flaring

Propane to Propylene

A low-carbon pathway for the production of propylene from propane that is attractive for all feed volumes but especially for small and medium feedstock sources

Propane to Propylene technology

P2P with co-production of hydrogen



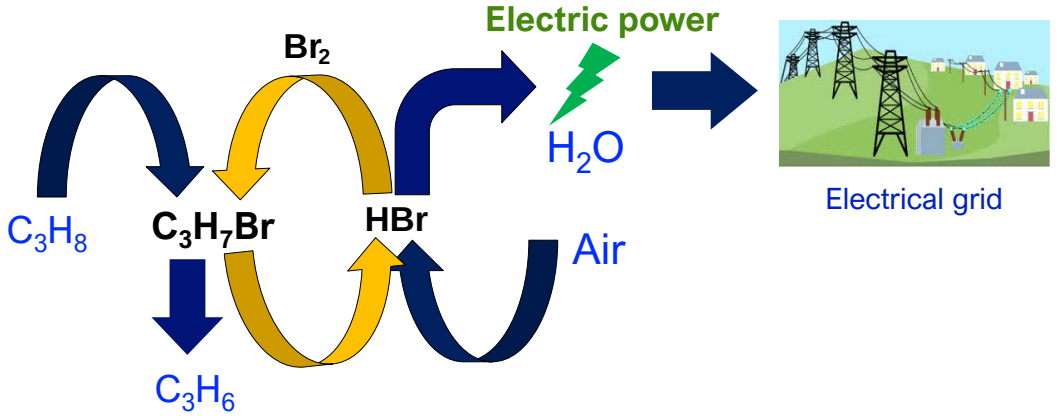
$C_3H_8 + Br_2 \rightarrow C_3H_7Br + HBr$ exothermic reaction

$C_3H_7Br + \text{⚡} \rightarrow C_3H_6 + HBr$ endothermic reaction

$2HBr + \text{⚡} \rightarrow H_2 + Br_2$ HBr electrolysis

$C_3H_8 + \text{⚡} \rightarrow C_3H_6 + H_2$

P2P with co-production of zero-emission energy



$C_3H_8 + Br_2 \rightarrow C_3H_7Br + HBr$ exothermic reaction

$C_3H_7Br + \text{⚡} \rightarrow C_3H_6 + HBr$ endothermic reaction

$2HBr + \frac{1}{2}O_2 \rightarrow Br_2 + H_2O + \text{⚡}$ HBr thermal oxidation

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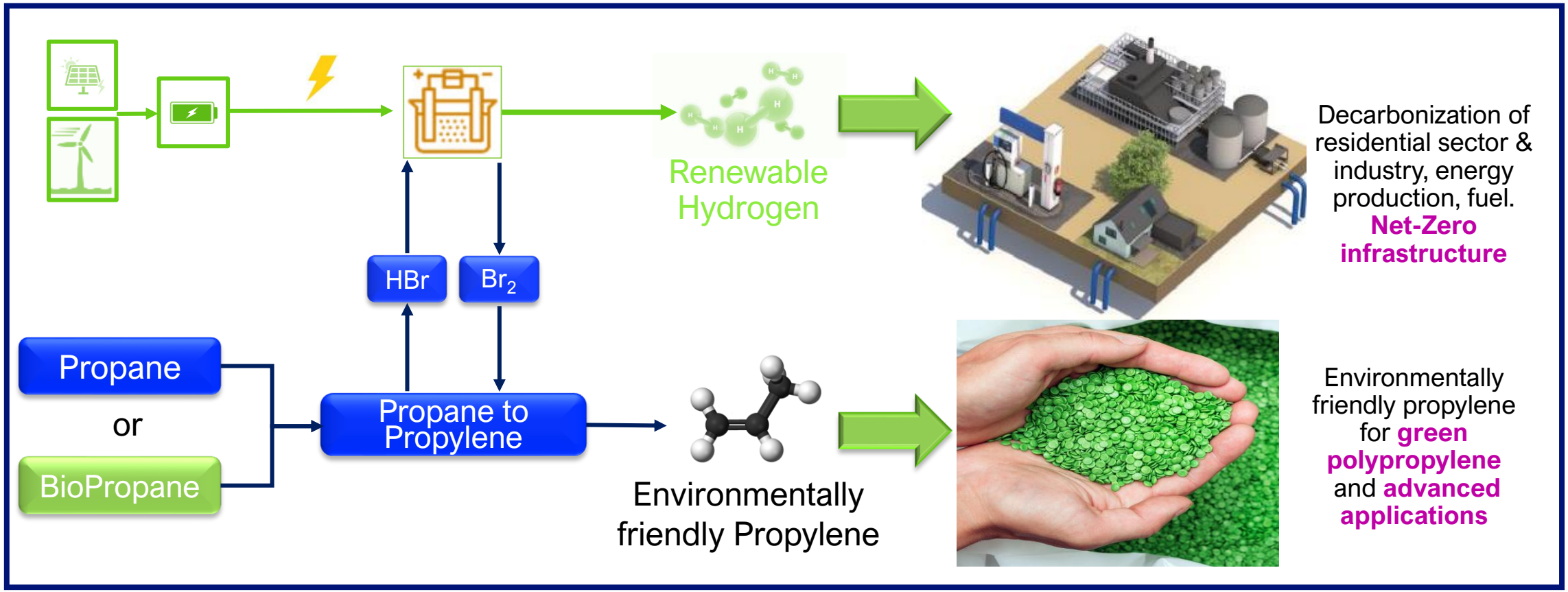
$C_3H_8 + \frac{2}{2}O_2 \rightarrow C_3H_6 + H_2O + \text{⚡}$

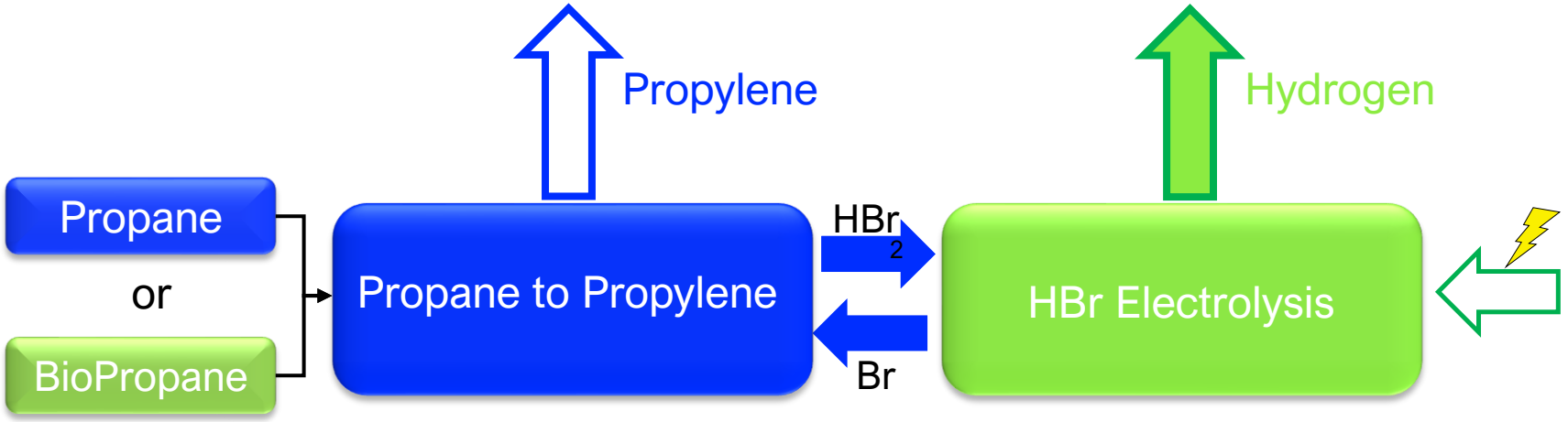
Value proposition with Propane to Propylene technology

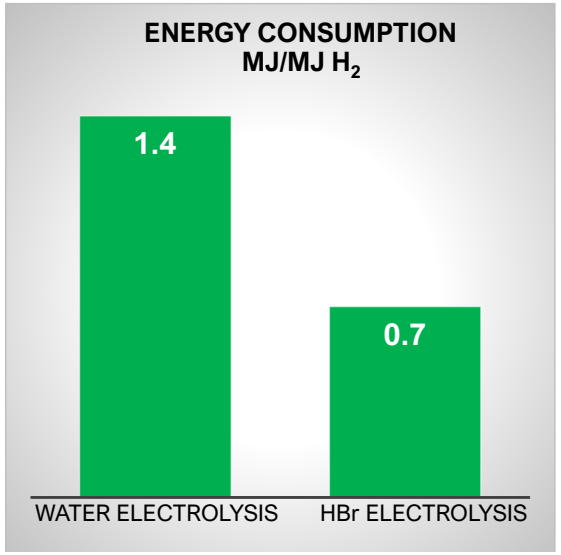


P2P is a low-carbon process for producing propylene from propane that simultaneously generates renewable hydrogen, using half as much energy as water electrolysis

Propane to Propylene in a nutshell

Low carbon, electrified technology for obtaining environmentally friendly propylene while co-producing hydrogen





- Eliminates propane – propylene equilibrium constraint
  ➔ no C3-splitter required for polymer grade propylene, attractive for small to medium production scale
- 200°C lower reaction temperature than direct propane dehydrogenation
  ➔ very high selectivity for propylene, complete conversion per pass
- Significantly lower GHG emissions than in direct propane dehydrogenation
- **Hydrogen** is produced electrochemically in an environment free of hydrocarbons
  ➔ 100% electrified process and no need for downstream separation and purification

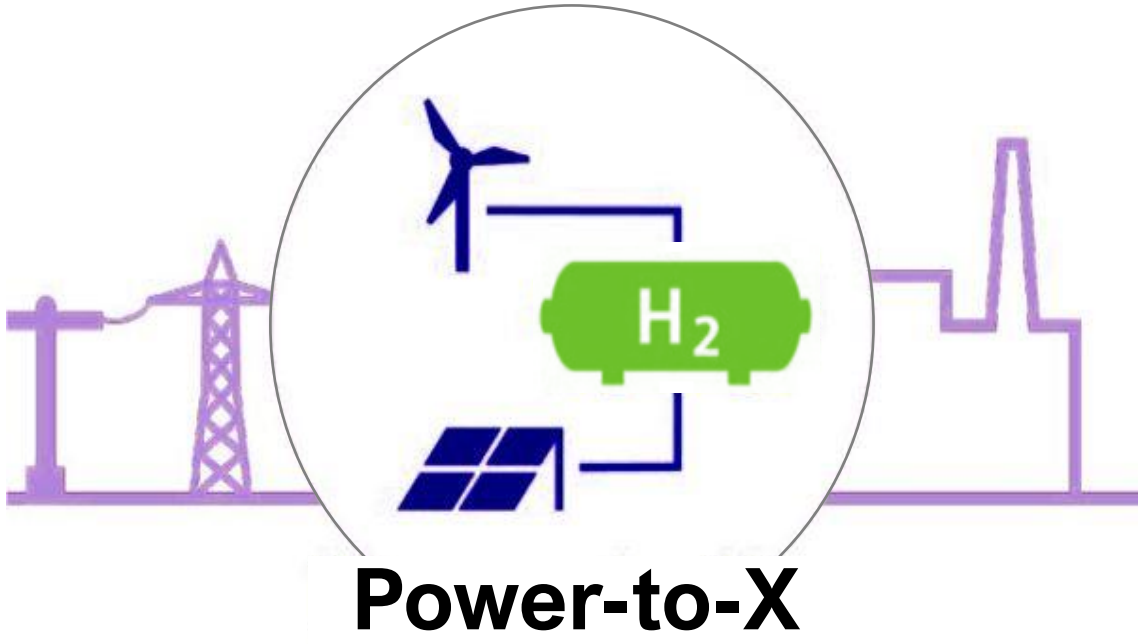
Propane to Propylene technology benchmark

Technology	Propane to Propylene	Propane Dehydration – Technologies			
Licensor	Sulzer	A	B	C	D
Reaction temperature, °C	300-400	570-650	620-650	510-580	650
Catalyst type	non noble metal catalyst	CrO_x/Al_2O_3	Sn-Pt-Cl-Al_2O_3	Pt-Sn-Zn/Ca aluminate	Pt-Ga-P/Al_2O_3
WHSV, h^{-1}	8	1	-	6	-
Time between regenerations	>1 month	10 min	10 days	7 hours	2 min
Yield, wt% C-basis	>92	84-85	84-86	81-82	>90

Source: AIChE 2016, FCDh Paper

Propane to Propylene - Part of Power-to-X

- Power-to-X (P2X) as a key technology in sector coupling, offers the possibility of converting energy from renewable resources into a chemical form and thus storing it for independent use, E-Hydrogen is the core component
- The X in the terminology refers to one of the following conversion targets: ammonia, chemicals, fuel, gas, hydrogen, liquids, methane, food, power or syngas
- Propane to Propylene is the second step in P2X, using renewable energy for production of green hydrogen and coproduction of high-quality carbon for advanced applications



https://assignmentpoint.com/power-to-x/

Power-to-X refers to the use of sustainably produced electricity to generate storable energy, chemicals and other essential products while minimizing GHG emissions.

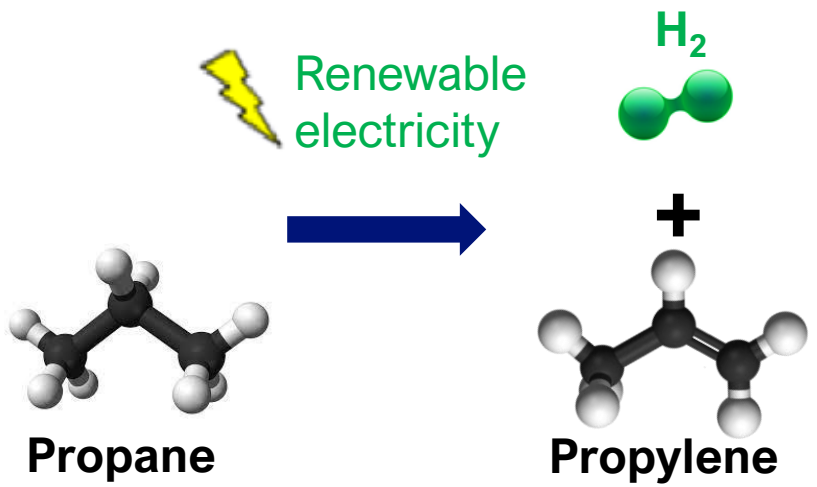
Light alkanes for green hydrogen

- "Low-carbon H_2" standard sets a "cradle-to-gate" emissions threshold of 36.4 gCO_2/MJH_2
- "Green H_2" meets the criteria for low-carbon H_2 and, moreover, is produced exclusively using renewable energy

CertifHy

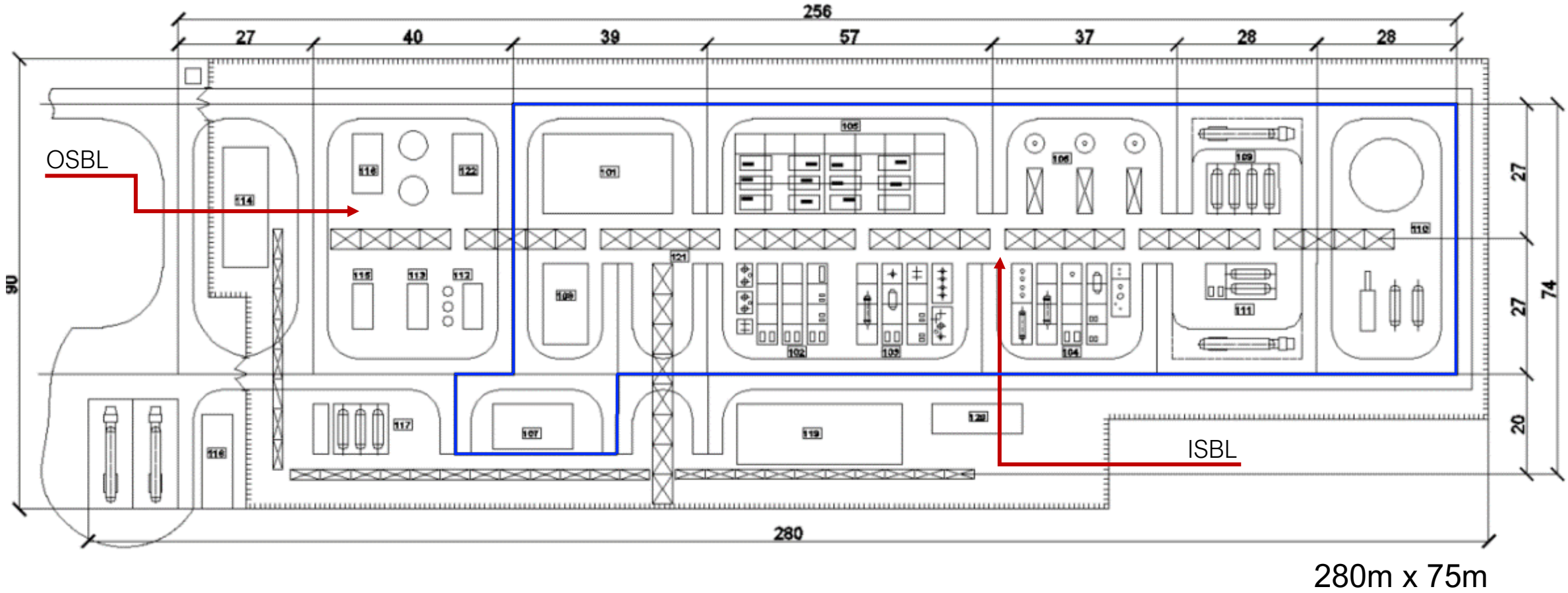
Source: EU Directive CertifHy-SD Hydrogen criteria

- It is not the source of feedstock for hydrogen that matters
  It is the environmental impact and the energy to obtain it
- Electrified processes to produce H_2 from propane become particularly attractive in near future due to credits for low carbon & green hydrogen production

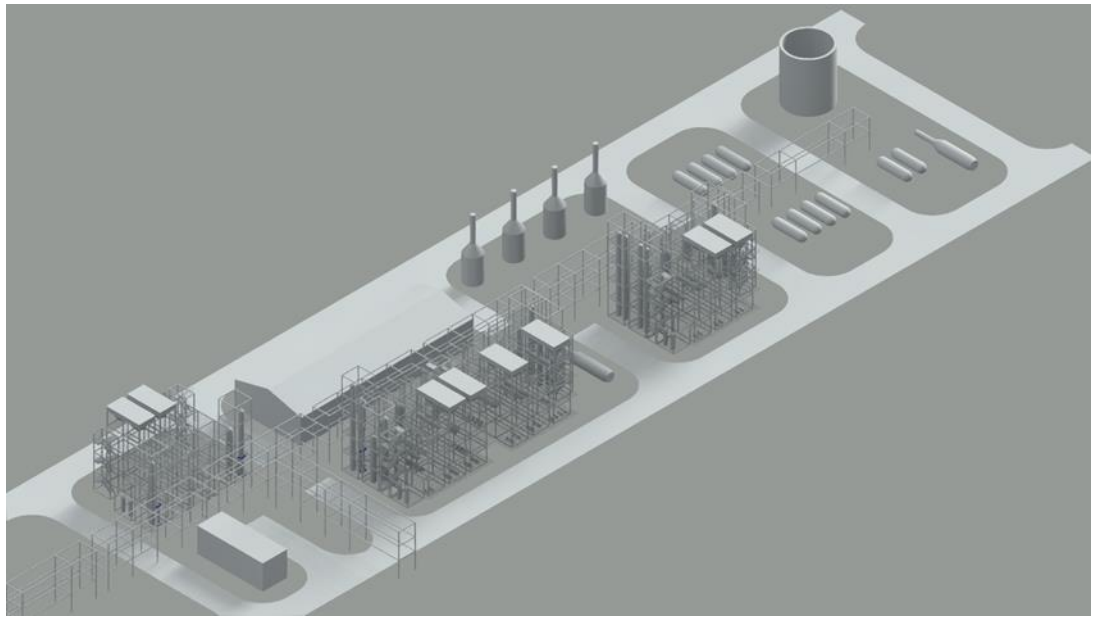


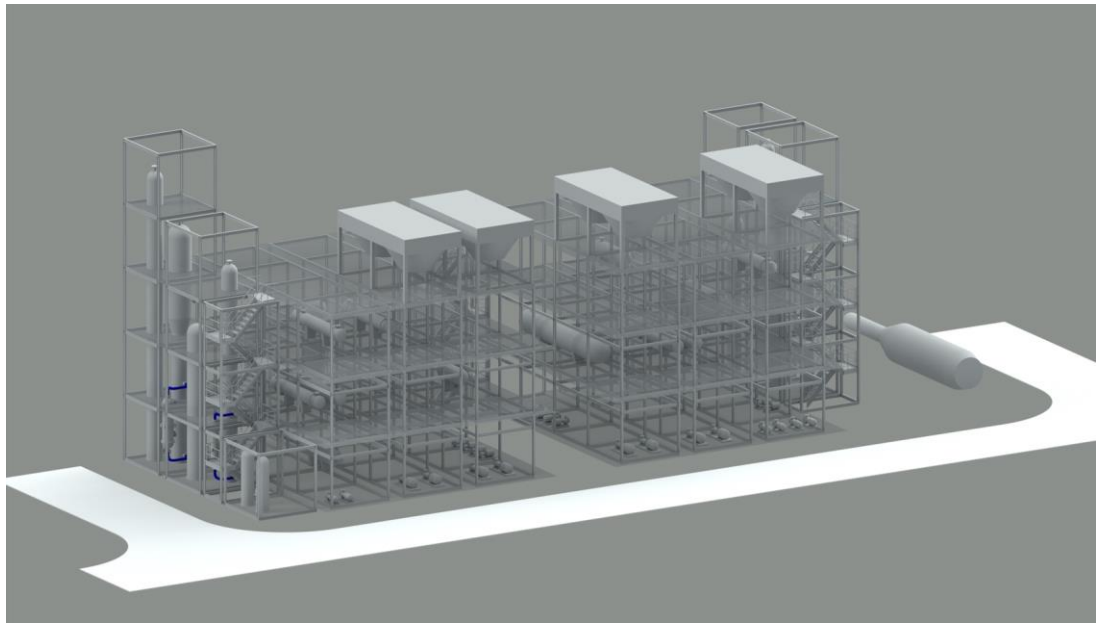
Plant plot industrial scale

Typical



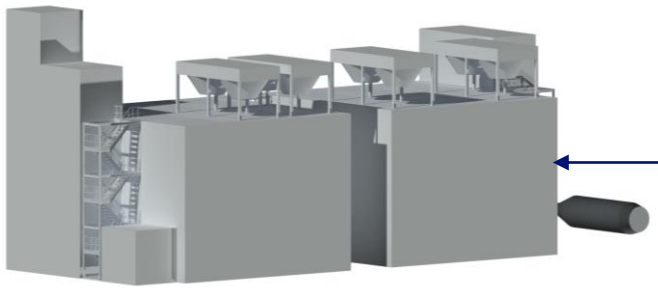
3-D Impressions



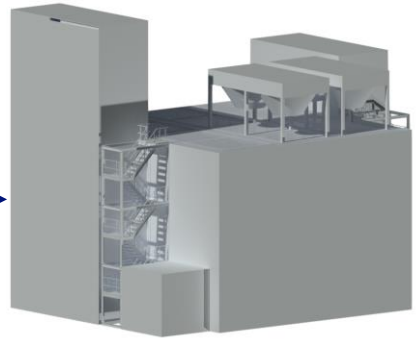


Plant installation will be adapted to local, project individual site conditions

Design details



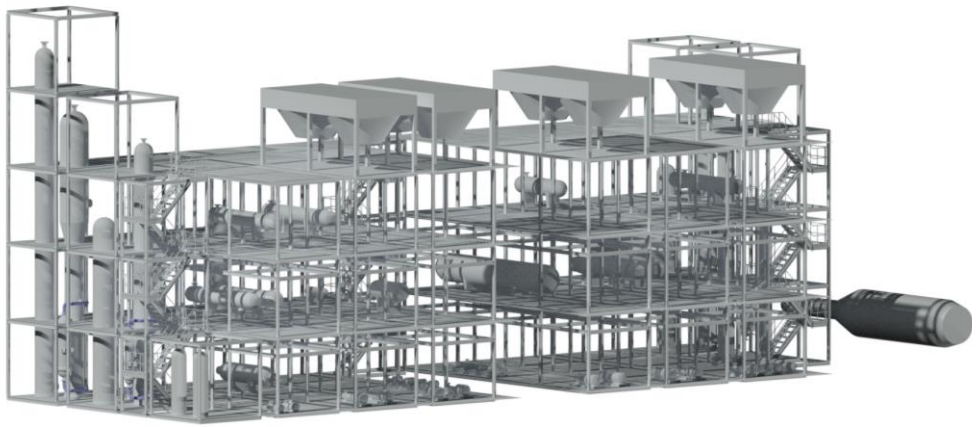
Protected panels
or louvers

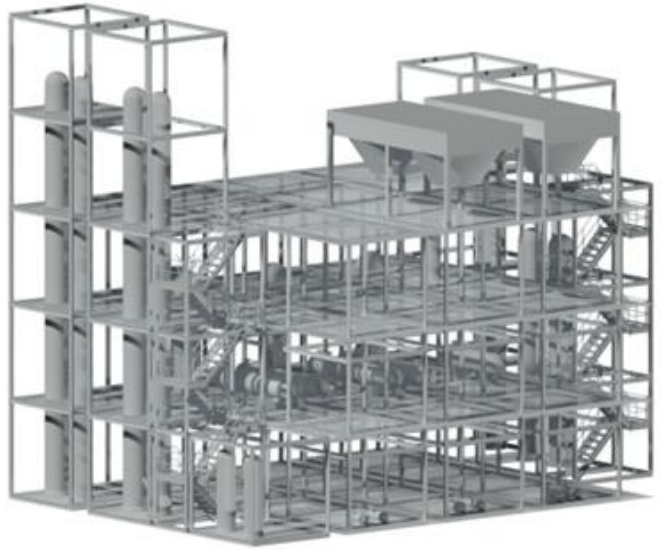


Bromination section

Bromine recovery section

Synthesis section





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Contact

Clean Fuels and Chemical Licensing

Gas Solutions

E mathias.pfeil@sulzer.com

Sulzer Chemtech Ltd

Neuwiesenstrasse 15
8401 Winterthur
Switzerland

sulzer.com

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