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Plasmatechnology as a gamechanger in a Circular Economy

Hans Linden

Proud partners
Sitech Services
TNO
Maastricht University
Brightlands Chemelot campus

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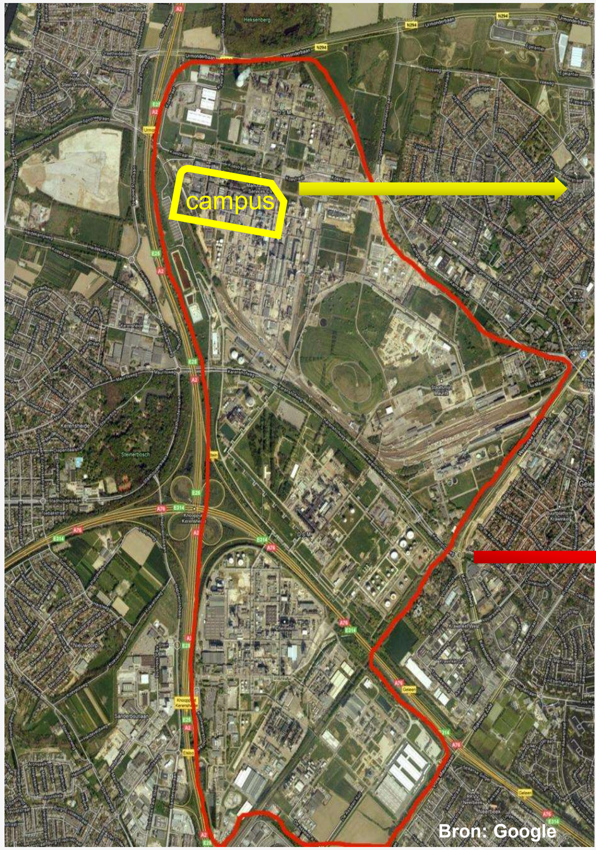

The chemical industry needs to drastically reduce its carbon emissions to mitigate climate change and meet sustainability goals.

The European Climate Law sets the target of reducing greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels and climate neutrality by 2050.

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The chemical industry is at the dawn of a revolution, drastic steps are necessary to reduce the CO_2 emission and to reach the climate goals:

- Transition to renewable energy sources: electrify what can be electrified
- Maximize CO_2 free energy generation
- Prioritize on Energy Efficiency
- **Unlock / disclose alternative feedstock (first recycling and selective biomass)**

Slide 4

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Linden, J.L. (Hans); 2023-11-15T14:11:17.219

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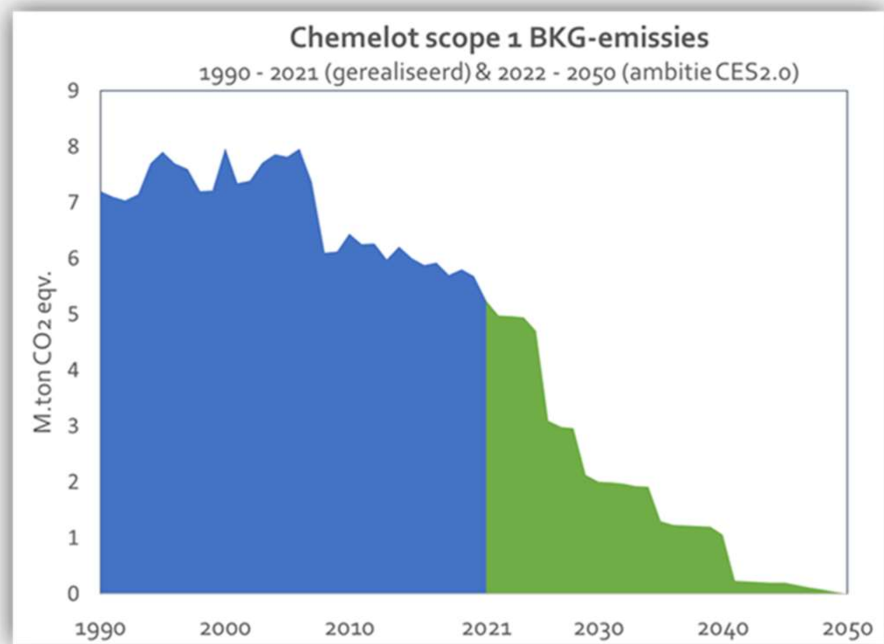
Sustainability



- Chemelot is one of the largest CO_2 emitters in the Netherlands
- Chemelot goal: zero emissions in 2050

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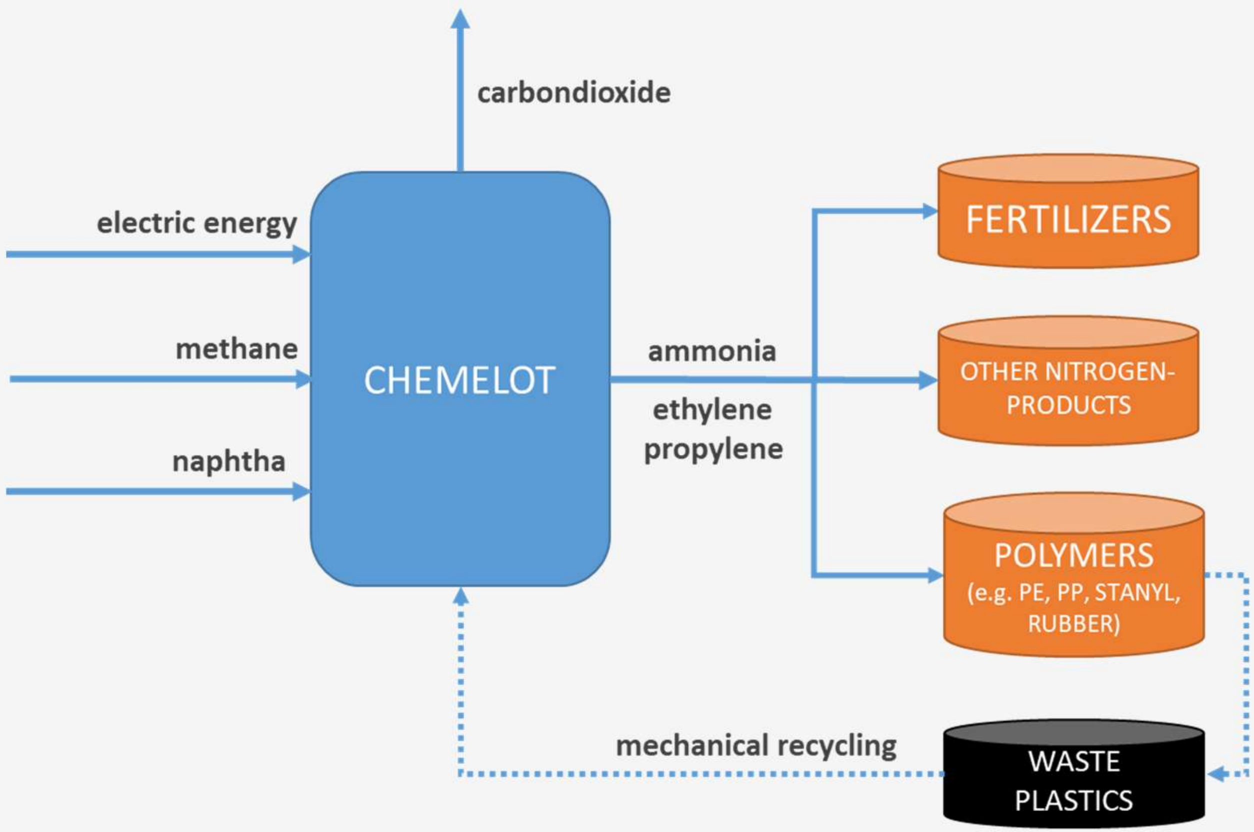
Present situation Chemelot



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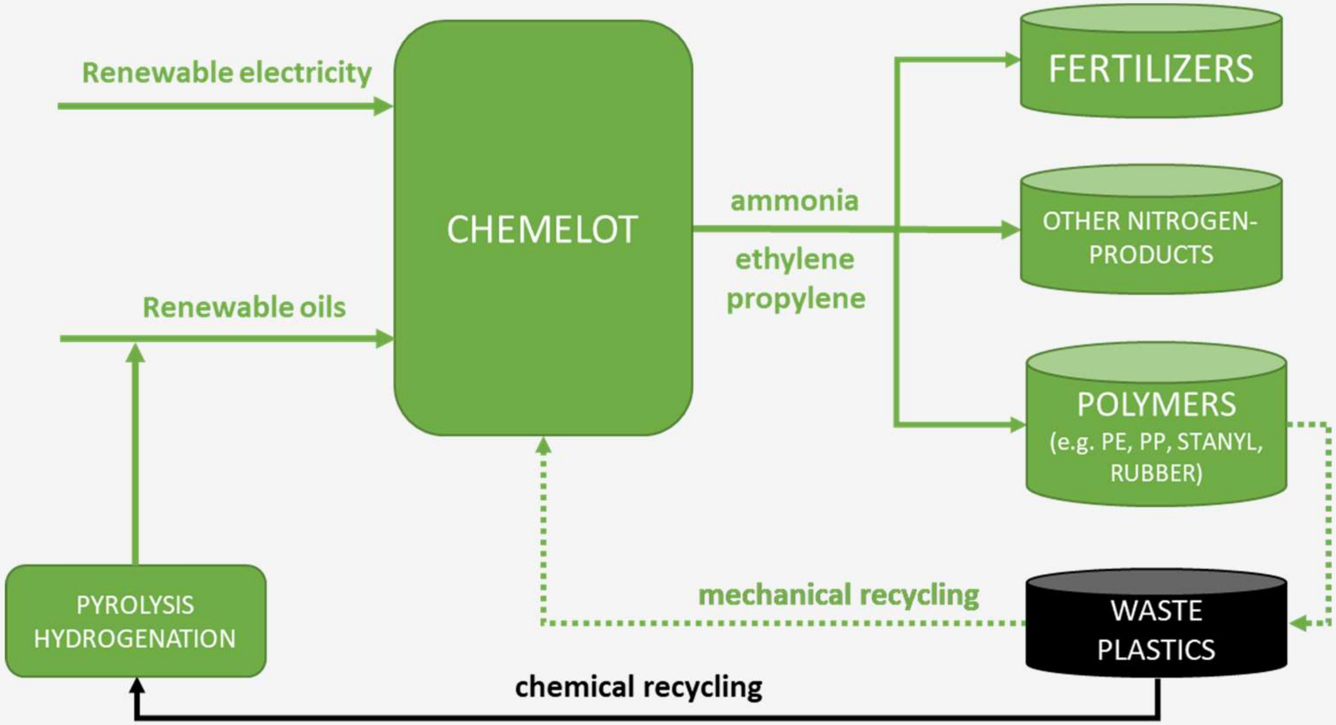
Possible future situation Chemelot 2050



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2 energy intensive routes for circular feedstock

- Synthetic molecules, e.g. H_2 and CO from H_2O and CO_2
- Renewable carbon: CO_2, biomass and waste

Courtesy Arnold Stokking

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Slide 9

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We believe that plasma technology can play a role in helping the chemical industry to reduce its carbon emissions to mitigate climate change and meet sustainability goals

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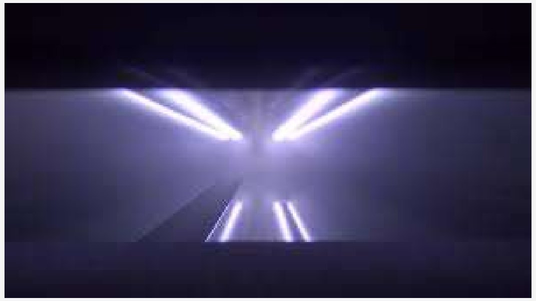
Plasma

- Fourth state of matter
- Ionized gas with equal numbers of positively charged ions and negatively charged electrons
- Electrical conductive

Examples:

Lighting

Aurora Borealis



HR+ glass coating (Pilkington)

Welding

Neon Light

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Methane

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Green house gas emission in the chemical industry

Ammonia Plant:
Typically 9 ton CO_2 is emitted per 1 ton of hydrogen

Steam Cracker:
Typically 1 ton CO_2 is emitted per 1 ton of olefins

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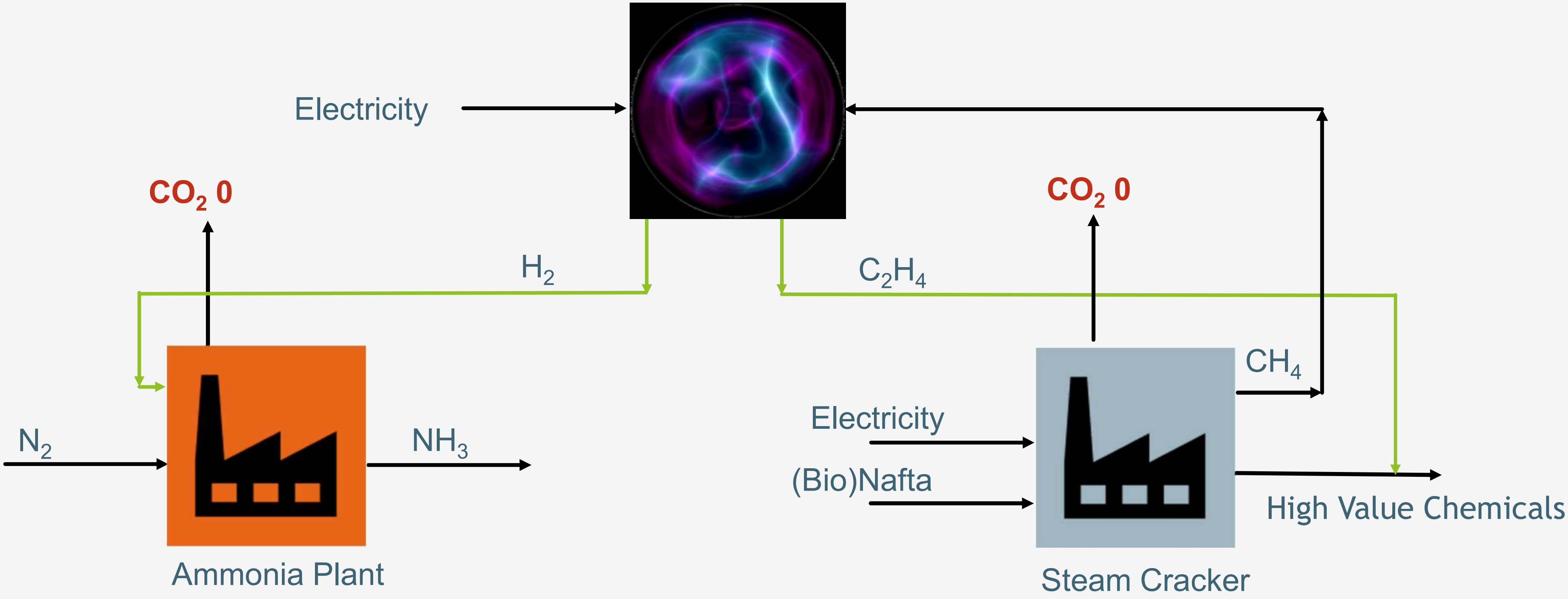
Combined Transition



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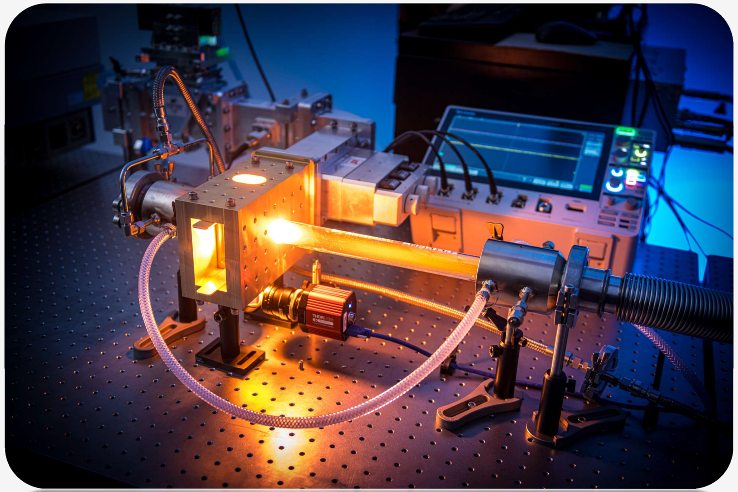
Plasma: a disruptive pyrolysis technology to transform methane into hydrogen and high-value chemicals

- Efficient production of **hydrogen and acetylene/ethylene,** building blocks to produce fertilizers and plastics
- No scope 1 CO_2 emission
- **Based on a proven technology (Hüls process)**
- Efficient heating with high temperatures
- Intermittent operation possible



Plasmas are the fourth state of matter, distinct from solids, liquids and gases. They are formed when a gas is heated to such high temperatures that its atoms or molecules become ionized, resulting in a mixture of free electrons and positively charged ions.

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Motivation for plasma decarbonization

2 kg CH_4 + 4.5 kg H_2O → 32 MJ steam-methane reforming → 1 kg H_2 (121 MJ) + 5.5 kg CO_2 → Option with CCS towards Blue Hydrogen

9 kg H_2O → 142 MJ electrolysis → 1 kg H_2 (121 MJ) + 8 kg O_2

4 kg CH_4 → 19 MJ plasmolysis → 1 kg H_2 (121 MJ) + 3 kg C

5.3 kg CH_4 → 63 MJ plasmolysis → 1 kg H_2 (121 MJ) + 4.3 kg HC≡CH → Various CH Product options

Thermodynamic numbers, no heating or cooling

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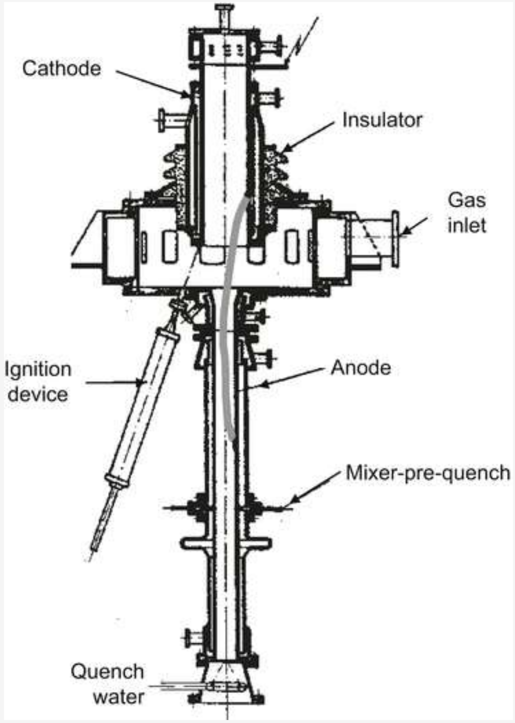
Hüls process

INSPECTION OF SYNTHETIC RUBBER PLANT OF
CHEMISCHE WERKE HULS, HULS, GERMANY

Date of Inspection: April 11, 1945

Object: This target is primarily a synthetic rubber plant using, as one of the principal materials, acetylene manufactured from natural gas. The investigation of this target was undertaken by the Oil Team to obtain the information available on the production of acetylene and other products from natural gas.

The plant consists of 14 arcs with 12 arcs running at any one time. One arc consumes 7000 kw. and produces 700-800 kgs. of acetylene per hour. The cost of manufacturing acetylene by this process is reported to be 25-30 pfennings per kg. of 95-96% acetylene. The following is the consumption of utilities per 100 kgs. of acetylene produced:



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Commercial activities Monolith

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Nitrogen

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Birkeland-Eyde process

Source: http://www.notoddenhistorielag.no/index php?page=lysbueovnen

Plasma going commercial:
- Notodden, 1906 operational
- 32 arc furnaces of 750 kW
- electricity from waterfall power station, built at the same time with the factory.

Surpassed by Haber-Bosch

ON THE OXIDATION OF ATMOSPHERIC NITROGEN IN ELECTRIC ARCS.

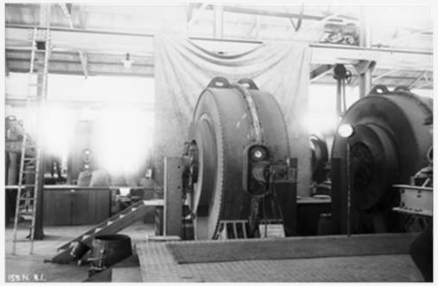
BY KR. BIRKELAND, PROFESSOR OF PHYSICS AT THE UNIVERSITY OF CHRISTIANIA.

(*A Paper read before the Faraday Society on Monday, July 2, 1906, PROFESSOR S. P. THOMPSON, F.R.S., in the Chair.*)

Last year, in the month of May, a factory was started at Notodden, in Norway, for the manufacture of calcium nitrate from air and limestone by the aid of electric flames (see Figs. 1 and 1a).

Thanks to the rapid progress made by electrotechnics, it has thus already become possible to evolve from the famous old discovery of the chemical combination of nitrogen and oxygen in an electric spark, a technical method for the production of saltpetre.

The nitrate problem, as we know, has gained, within a short space of time, a very important place among technical problems, a fact which is due to the enormous consumption of Chili saltpetre.




Source: http//no.w kipedia.org/wiki/Birkeland-Eyde-prosessen

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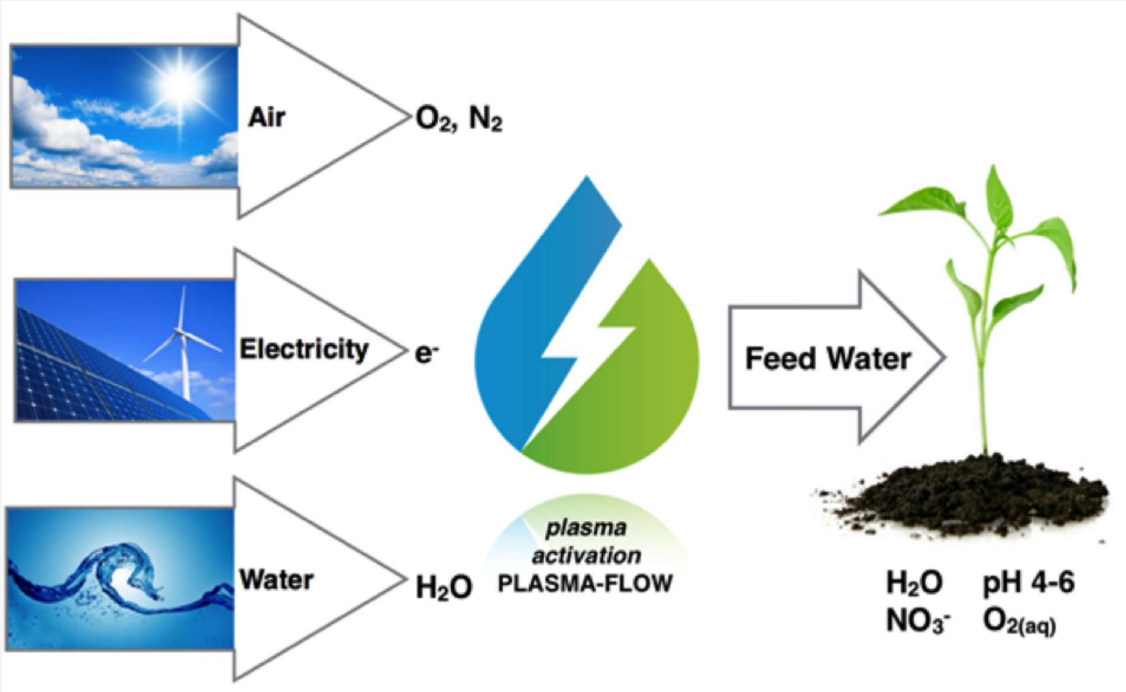
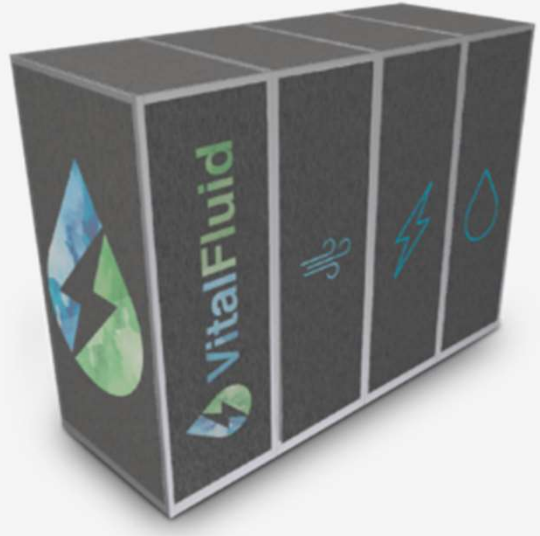
Commercial activities Vitalfluid





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Plastic waste

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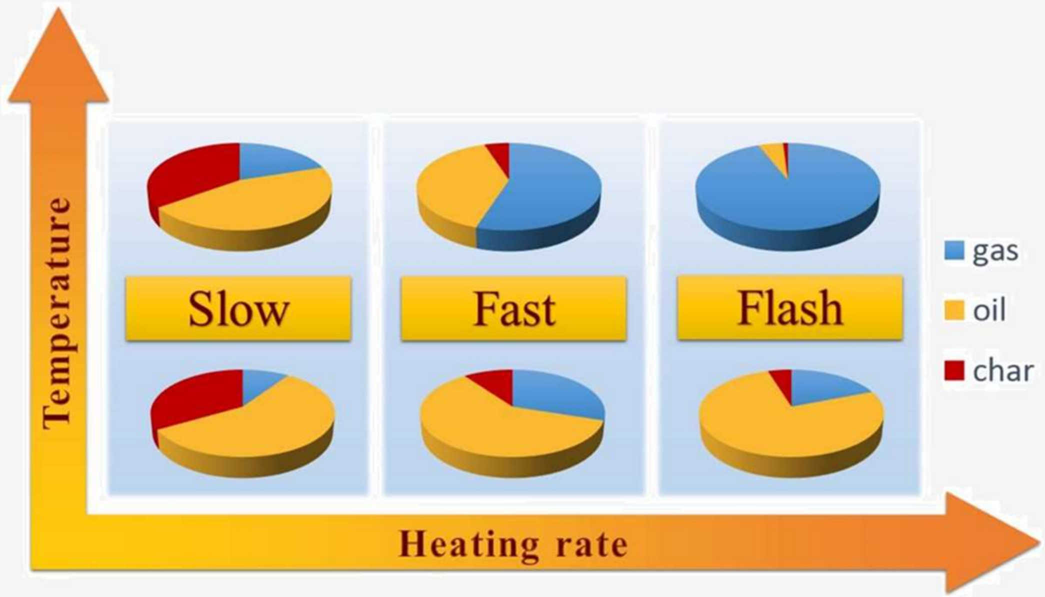
Plastic recycling

Gasification: conversion of plastic containing waste with oxygen to syngas (CO and H2) -to chemicals



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SGH2 Energy builds world's largest waste-to-hydrogen plant near L.A.

The world's largest green hydrogen plant is being developed by SGH2 Energy in Lancaster, a city situated some 70 miles north of Los Angeles. The facility will transform plastic waste into hydrogen for use as a fuel for transport and power generation.

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CO_2 utilization
First results in the1978

The physics of a chemically active plasma with nonequilibrium vibrational excitation of molecules

V. D. Rusanov, A. A. Fridman, and G. V. Sholin

I. V. Kurchatov Institute of Atomic Energy
Usp. Fiz. Nauk **134**, 185–235 (June 1981)

The results of experimental and theoretical studies of chemical reactions in nonequilibrium plasmas are reviewed. Special attention is given to processes stimulated by vibrational excitation of the ground electronic state of the reacting molecules in the plasma. General patterns in the kinetics of these reactions are discussed, and the optimum discharge parameters for maximum energy efficiency are noted. Specific plasma-chemical processes—the dissociation of CO_2 and H_2O and the synthesis of nitrogen oxides—are described. Experimental results are presented for hf, microwave, glow, plasma-beam, and non-self-sustained discharges, for plasma radiolysis, etc.

PACS numbers: 52.40. — w, 52.80. — s

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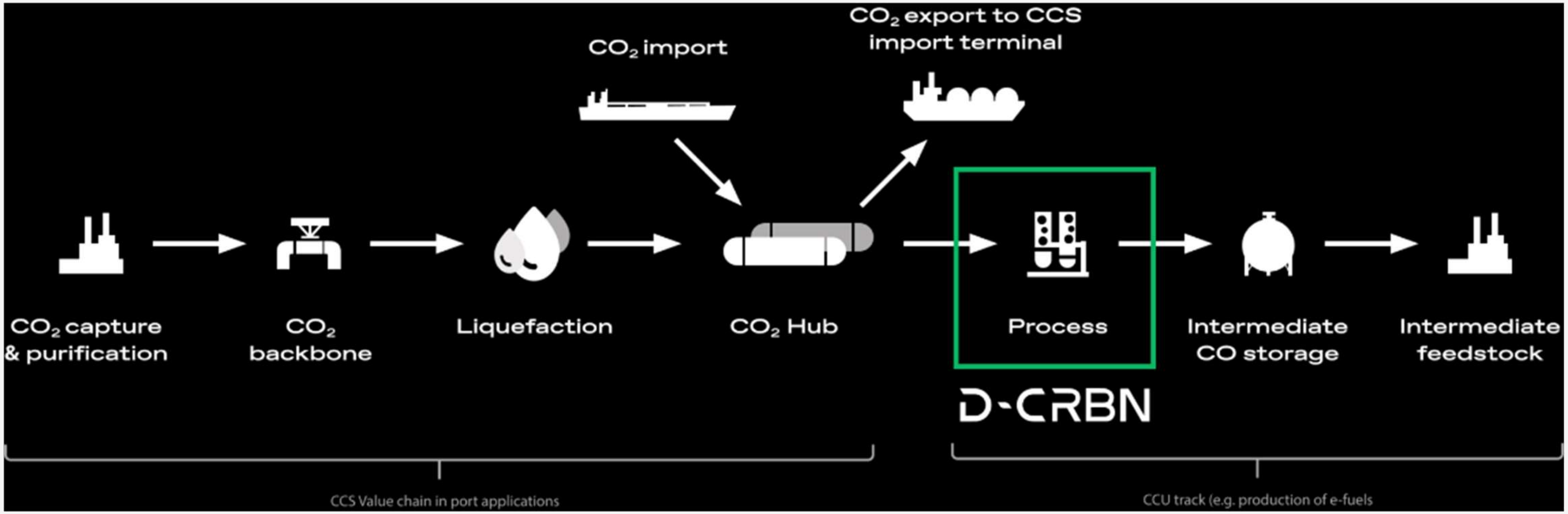
Commercial activities



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Plasma technology at Brightsite

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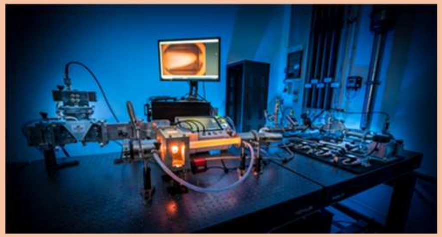
Three generations in parallel

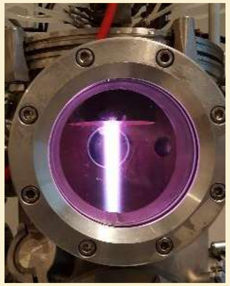
Lab Scale
TRL 1-3

- Started in 2020
- R&D program for the direct formation of Ethylene using Microwave plasma (1-10 kW)



Bench Scale
TRL 4-5

- Started in 2021/2022
- R&D program to optimize the Hüls process using arc technology and microwave plasma (50 kW)



Pilot Plant
TRL 6-7

- Started in 2022/2023
- Hüls process for the formation of hydrogen and acetylene using arc technology (150~500 kW)

Plasma Lab at Brightsite

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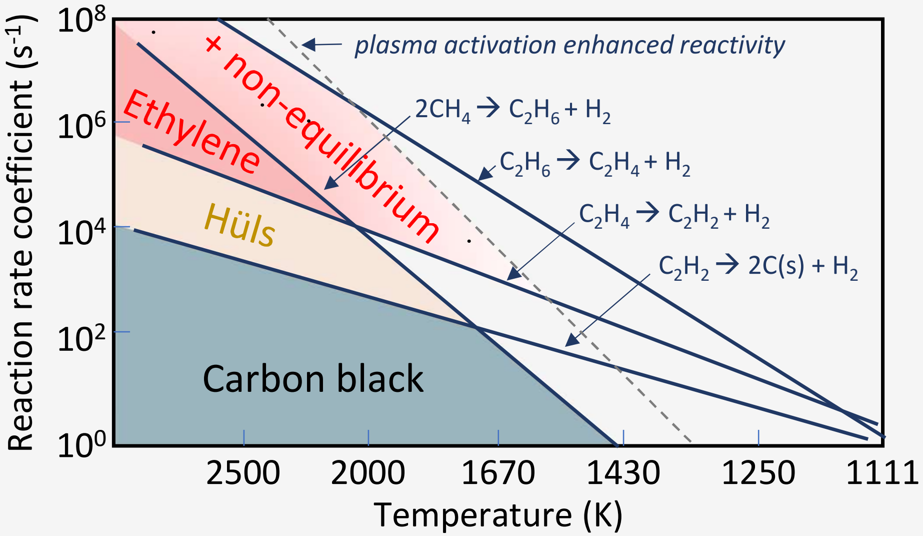

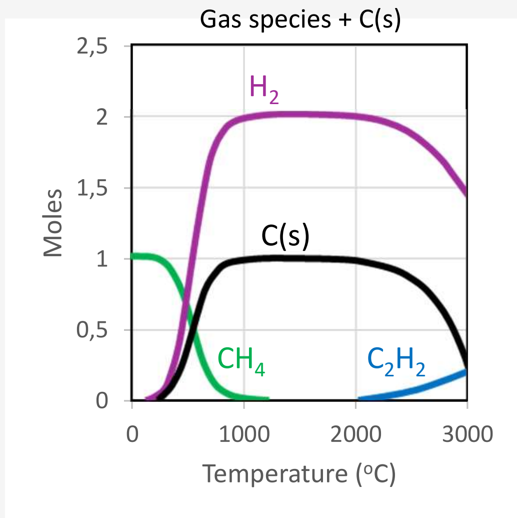

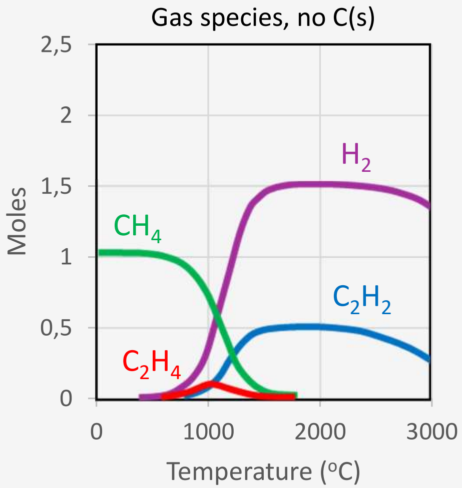

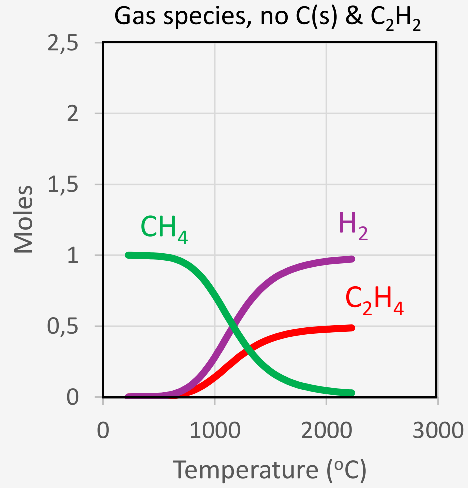

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Timeline plasma technology

2020-2040

Lab Plasma Trl 1-3	Benchscale Plasma + Hydrogenation Trl 4-5	Pilot Plant Plasma + Hydrogenation TRL 6-7	Demo Plant 10 kt/a H2 2025 TRL 7-8	Commercial Plant 0,2 Mt/a H2 TRL 9 2030-2040
2020 3 kWe R&D program	2021-2022 50 kWe R&D program	2022-23 1-3 t/a H2 C2H4/C **Pilot gen 1** **500 kWe**	2025-2027 1-10 kt/a H2 **Demo gen 2**	2030-2040 0,2 Mt/a H2 **Demo gen 3**

Plasma lab at Brightlands

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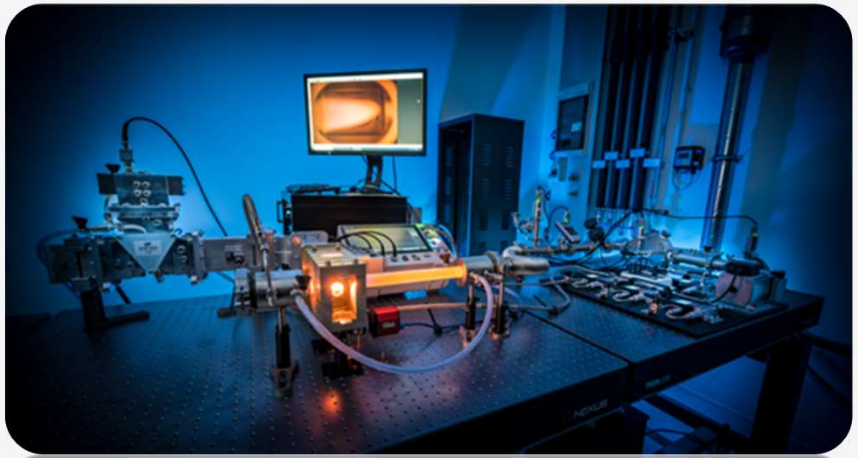
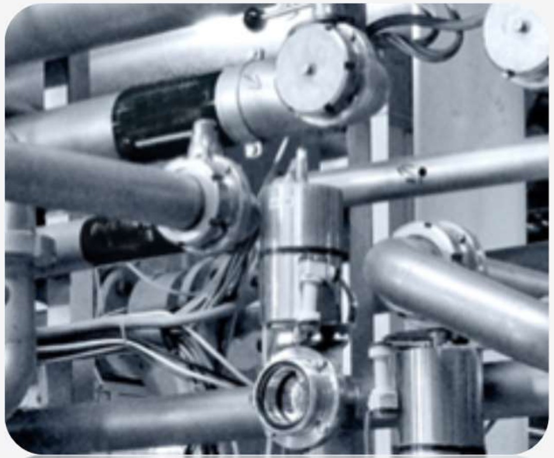
Accelerate scale-up by collaborative innovation

NXT GEN HIGHTECH





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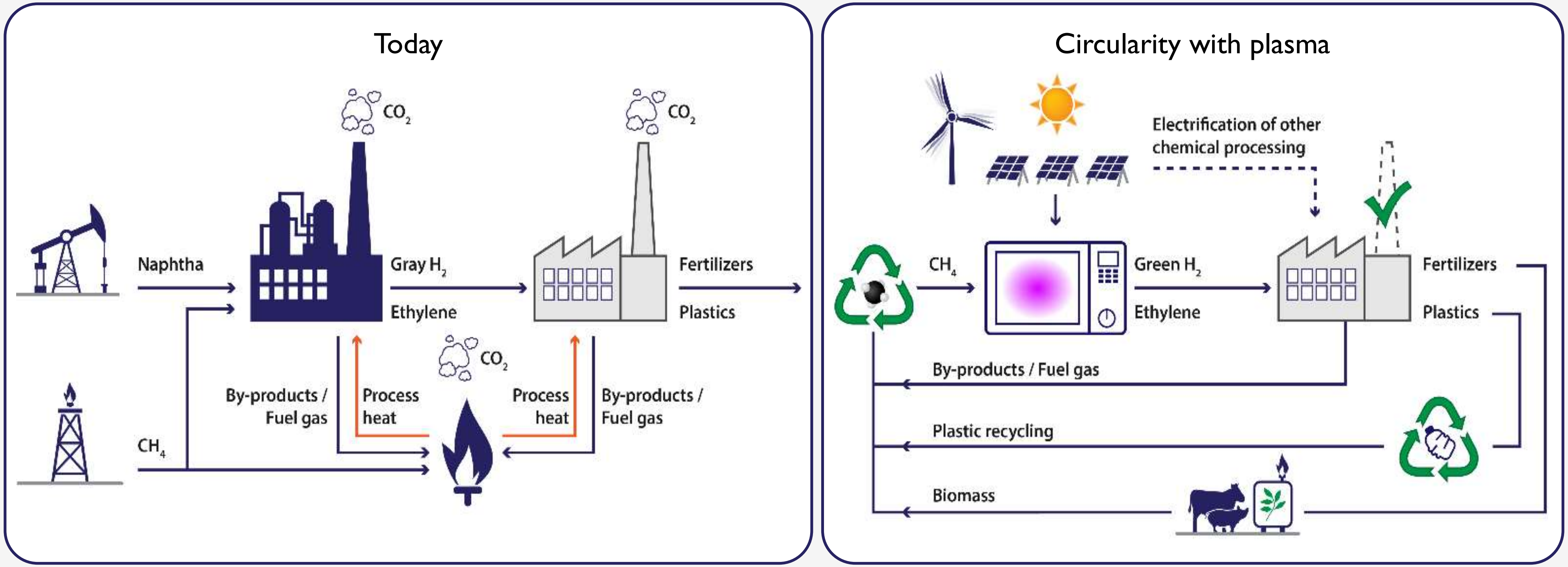
Plasma technology an important step towards the ultimate circular chemistry



Courtesy Gerard van Rooij

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