ESCUELA DE INGENIERÍA
FACULTAD DE INGENIERÍA

EDUCACIÓN PROFESIONAL

Captura y utilización de dióxido de carbono

El gran paso hacia la carbono neutralidad

Roberto Canales y Junior Lorenzo


PRESENTAN:
Roberto Canales Muñoz
Junior Lorenzo Llanes

Temas

01 Contexto Global y Nacional de Emisiones de CO_2

02 Contexto General de Captura de CO_2

03 Tecnologías de Captura de CO_2

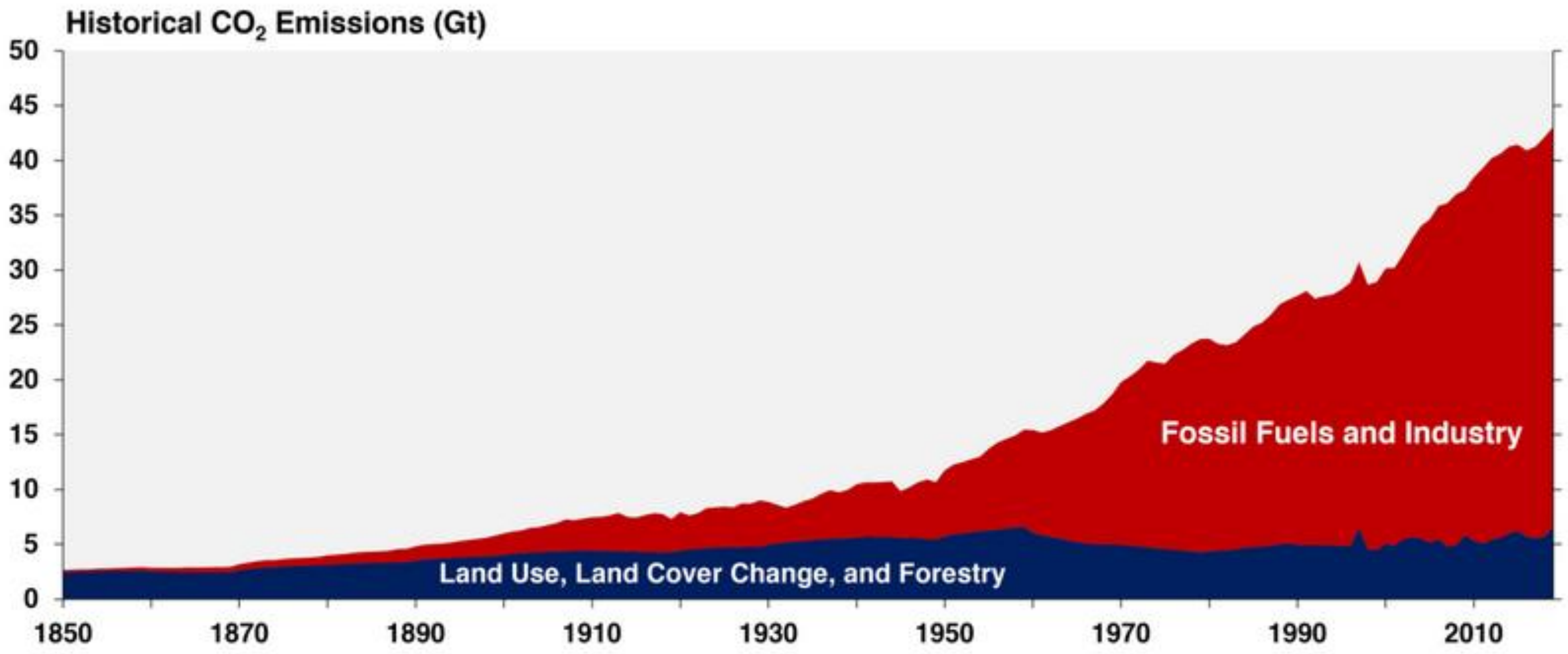
04 Alternativas de Valorización del CO_2

05 Herramientas para la Evaluación de Proyectos de Captura y Utilización de CO_2

06 Barreras para la Implementación

Emisión de gases de invernadero

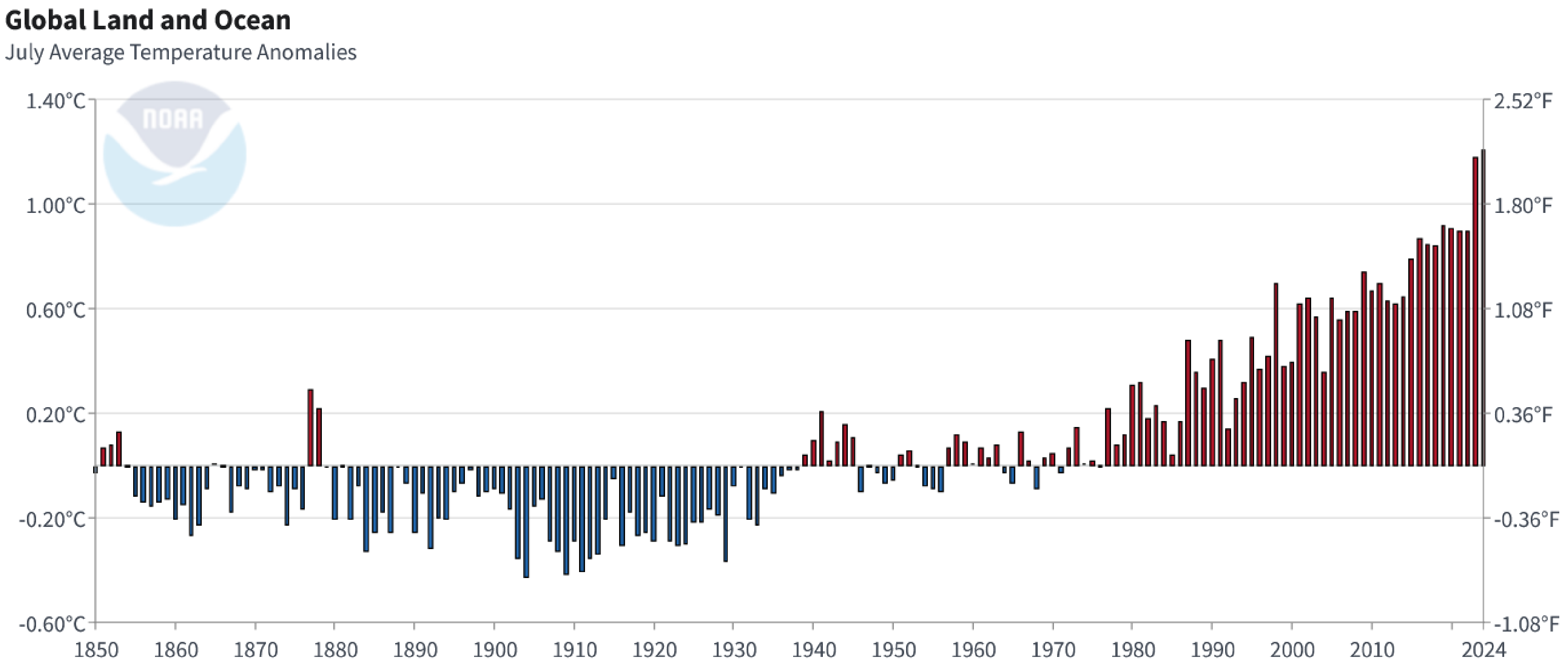
¿Cómo se ven las emisiones históricas?



Datos desde Grupo Intergubernamental de Expertos sobre el Cambio Climático (2022); Basado en las emisiones globales de 2019

Emisión de gases de invernadero

Correlación entre emisiones y promedio de temperatura global

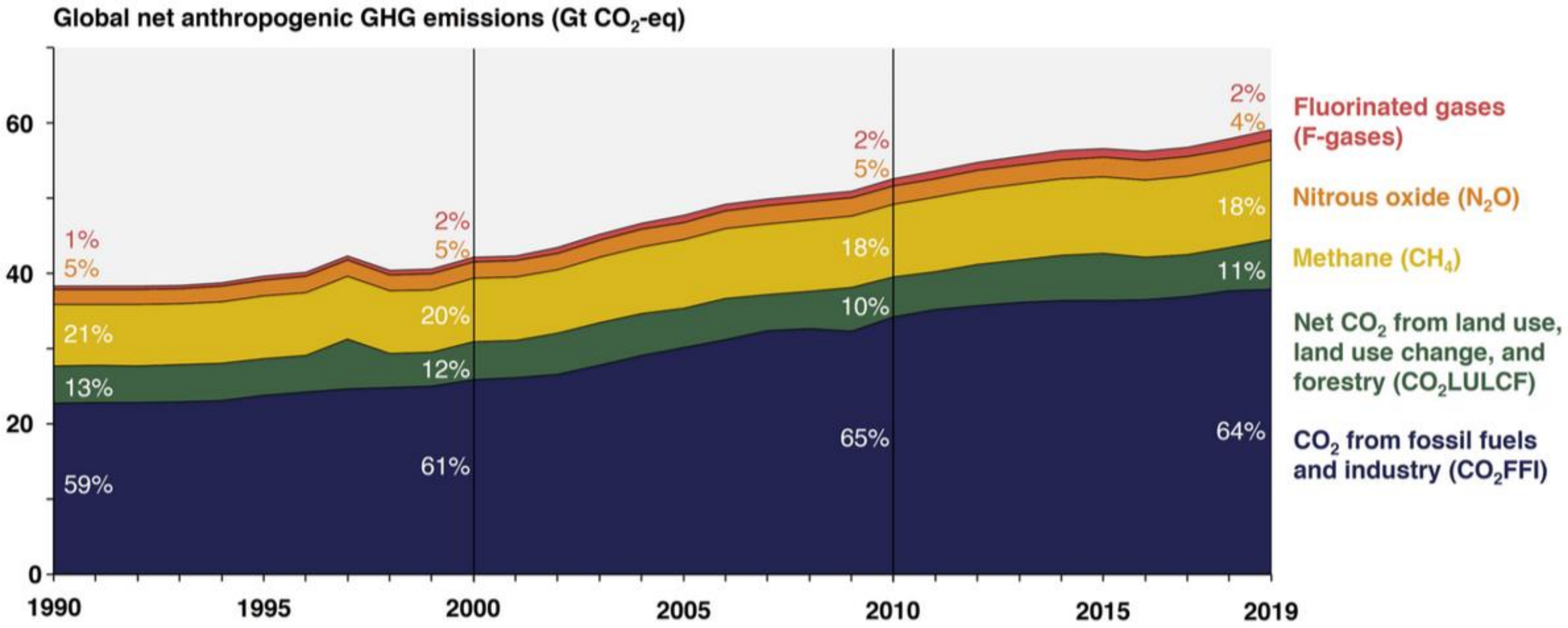


https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/global/time-series/globe/land_ocean/1/7/1850-2024

Emisión total de gases de invernadero

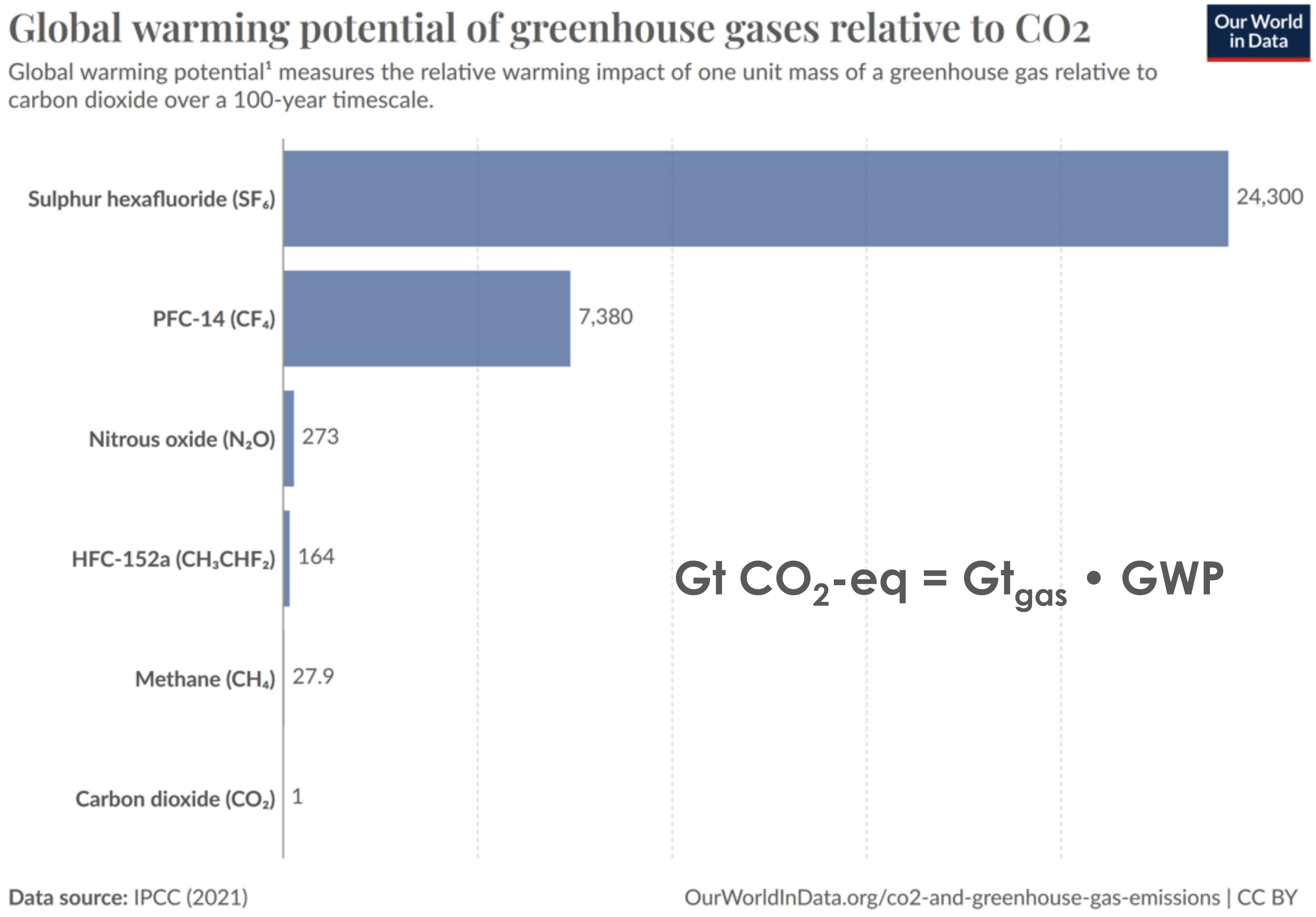
¿Por qué se habla principalmente de CO_2 como causante del calentamiento global?

$$Gt\ CO_2\text{-eq} = Gt_{gas} \cdot GWP$$



Datos desde Grupo Intergubernamental de Expertos sobre el Cambio Climático (2022); Basado en las emisiones globales de 2019

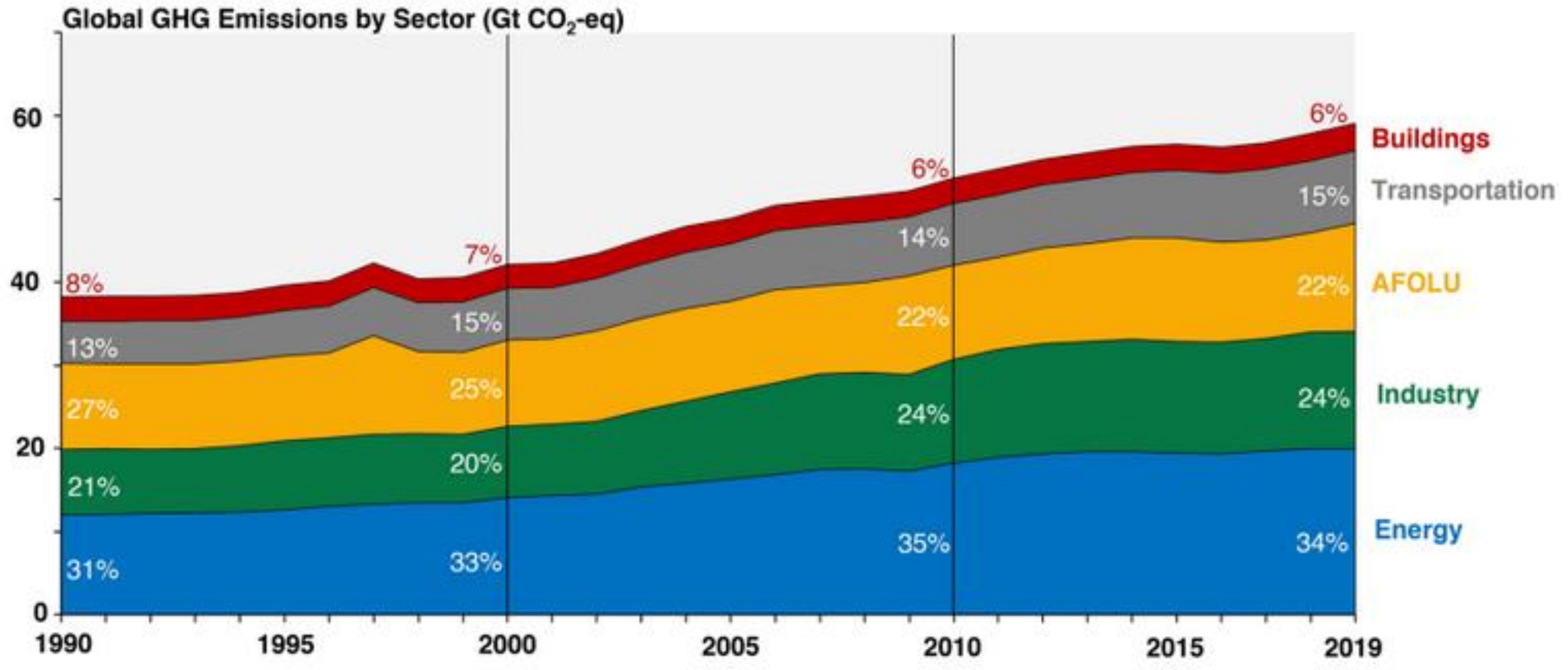
Potencial de calentamiento global (GWP)



$$\text{Gt } CO_2\text{-eq} = \text{Gt}_{gas} \cdot \text{GWP}$$

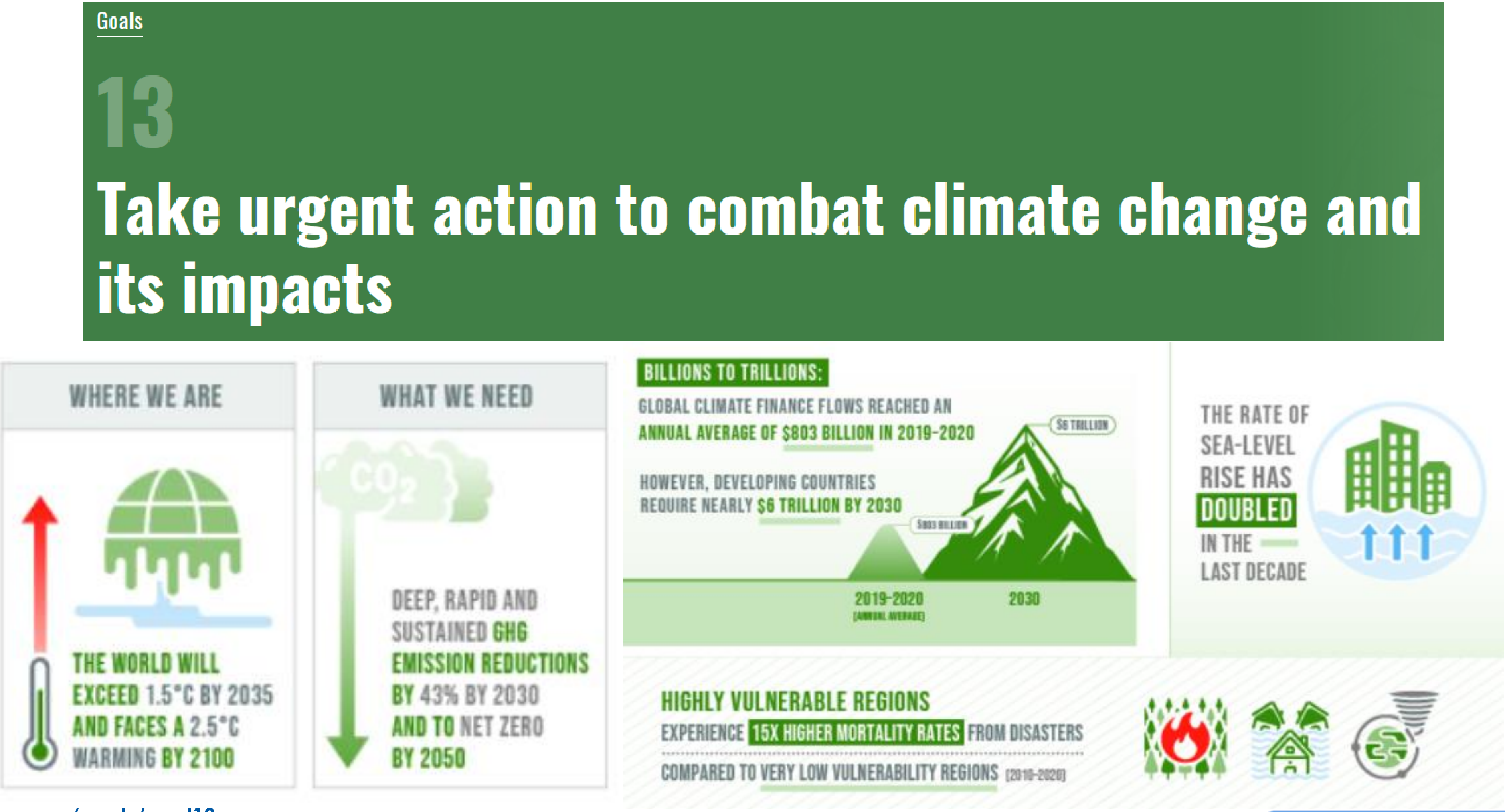
Emisión de gases de invernadero

¿Cómo se ve la distribución de emisiones por sector?



Datos desde Grupo Intergubernamental de Expertos sobre el Cambio Climático (2022); Basado en las emisiones globales de 2019

Objetivos de desarrollo sustentable: Reporte 2023



https://sdgs.un.org/goals/goal13

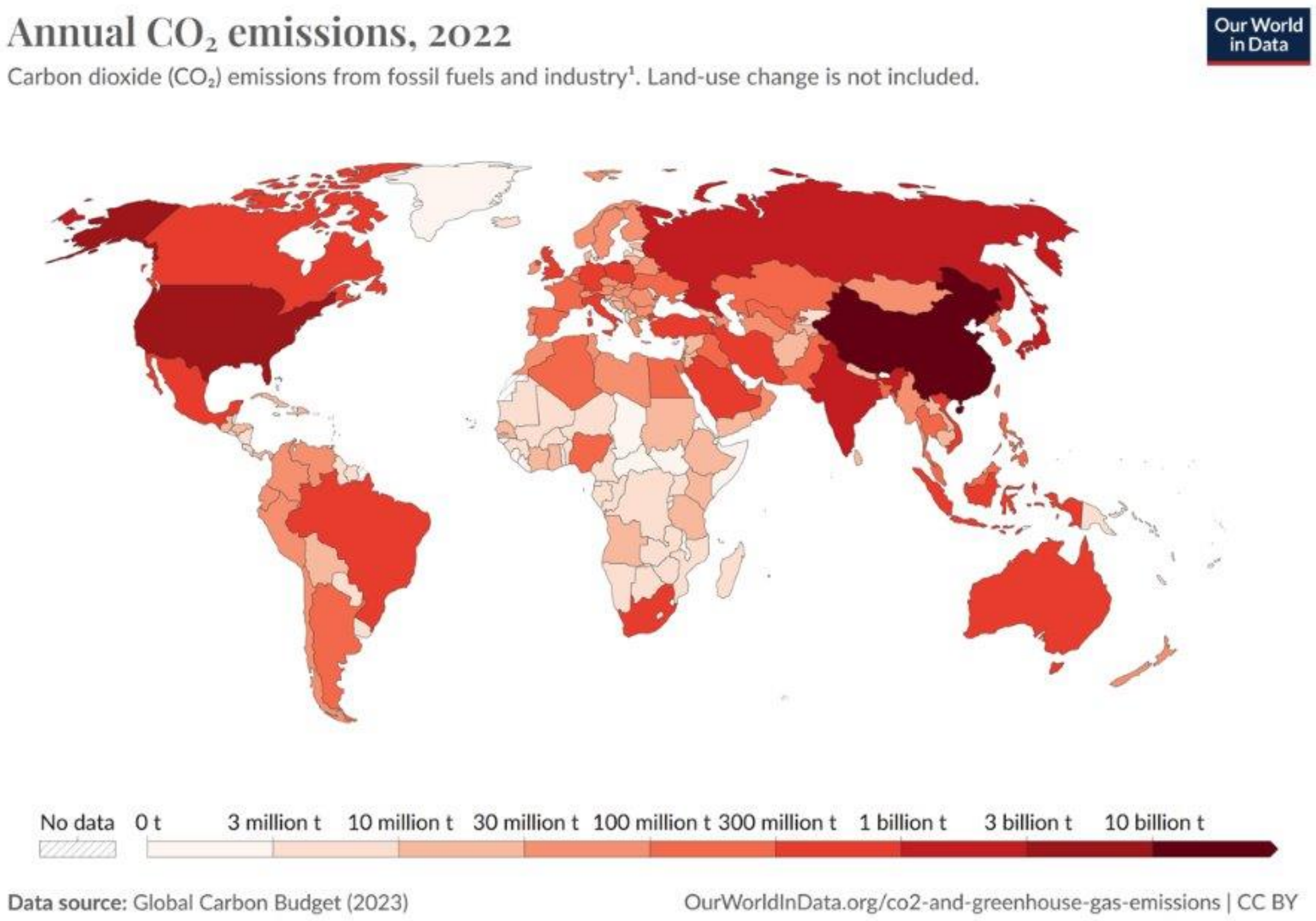
Acuerdo de París (2015)

Tratado internacional sobre cambio climático de la COP21

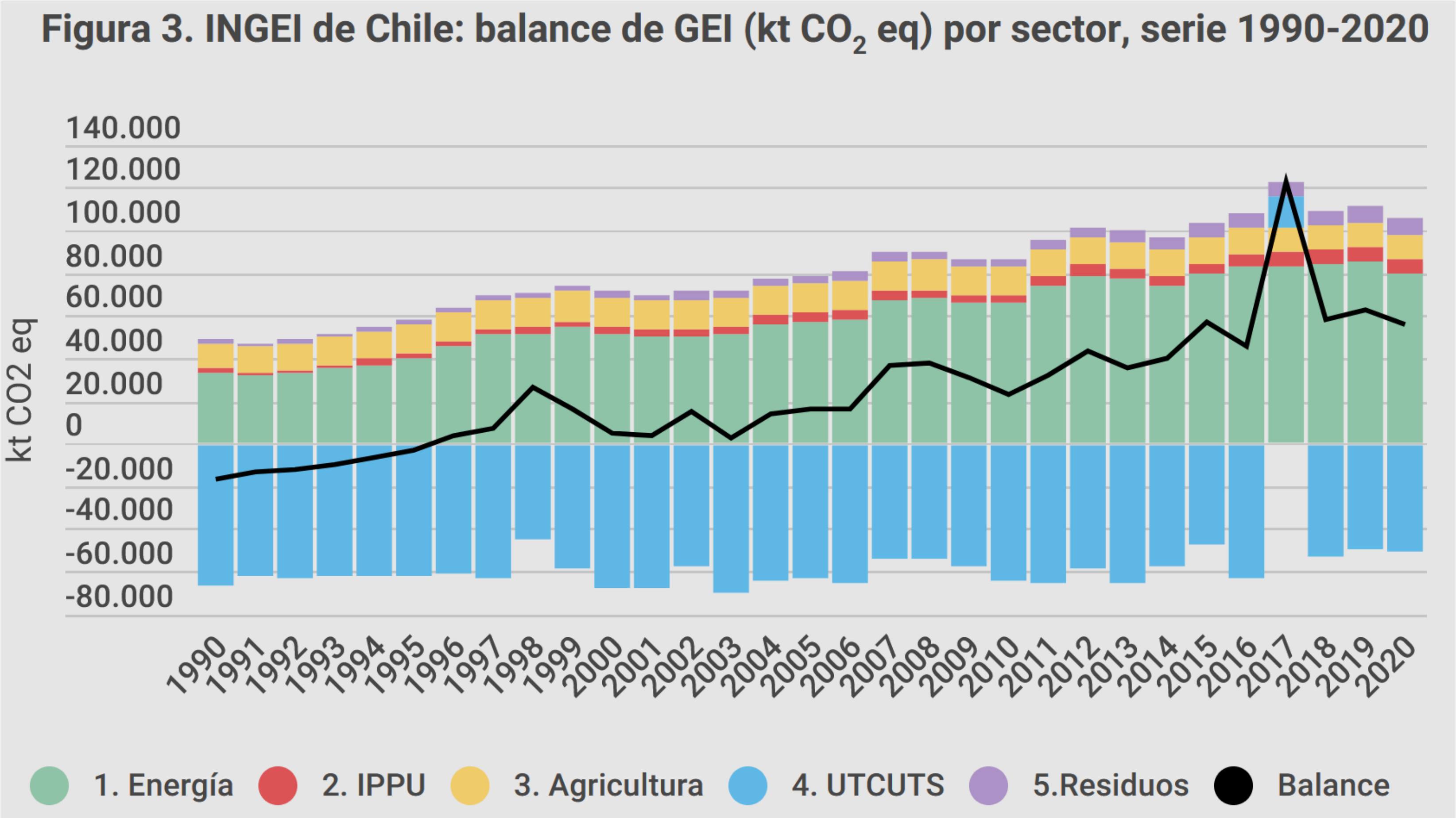
Limitar incremento de temperatura global a 2°C con respecto a era pre-industrial, preferentemente 1,5°C como máximo

https://unfccc.int/es/acerca-de-las-ndc/el-acuerdo-de-paris

Emisiones globales



Emisiones en Chile



https://cambioclimatico.mma.gob.cl/emisiones/

¿Para qué podríamos capturar CO_2 en Chile?

De acuerdo con el ranking Climatescope de Bloomberg 2023, **Chile es una de las tres economías a nivel mundial más atractivas para la inversión en energías limpias**. Además, se calcula que la Estrategia Nacional de Hidrógeno Verde permitirá oportunidades de inversión por US $475 mil millones en los próximos diez años.

https://www.marcachile.cl/si-es-hidrogeno-verde-el-mundo-comienza-por-chile/

HIF

HIF Cabo Negro e-Fuels Facility

The plant will use renewable energy from the wind and a process called electrolysis to produce green hydrogen. The project will also capture CO_2 from biomass, industrial sources or directly from the atmosphere, and use a process of synthesis to combine the CO_2 and hydrogen to produce e-Fuels, including carbon neutral methanol (e-Methanol), gasoline (e-Gasoline) and carbon neutral Liquefied Gas (e-LG).

Quick Facts

384 MW Plant

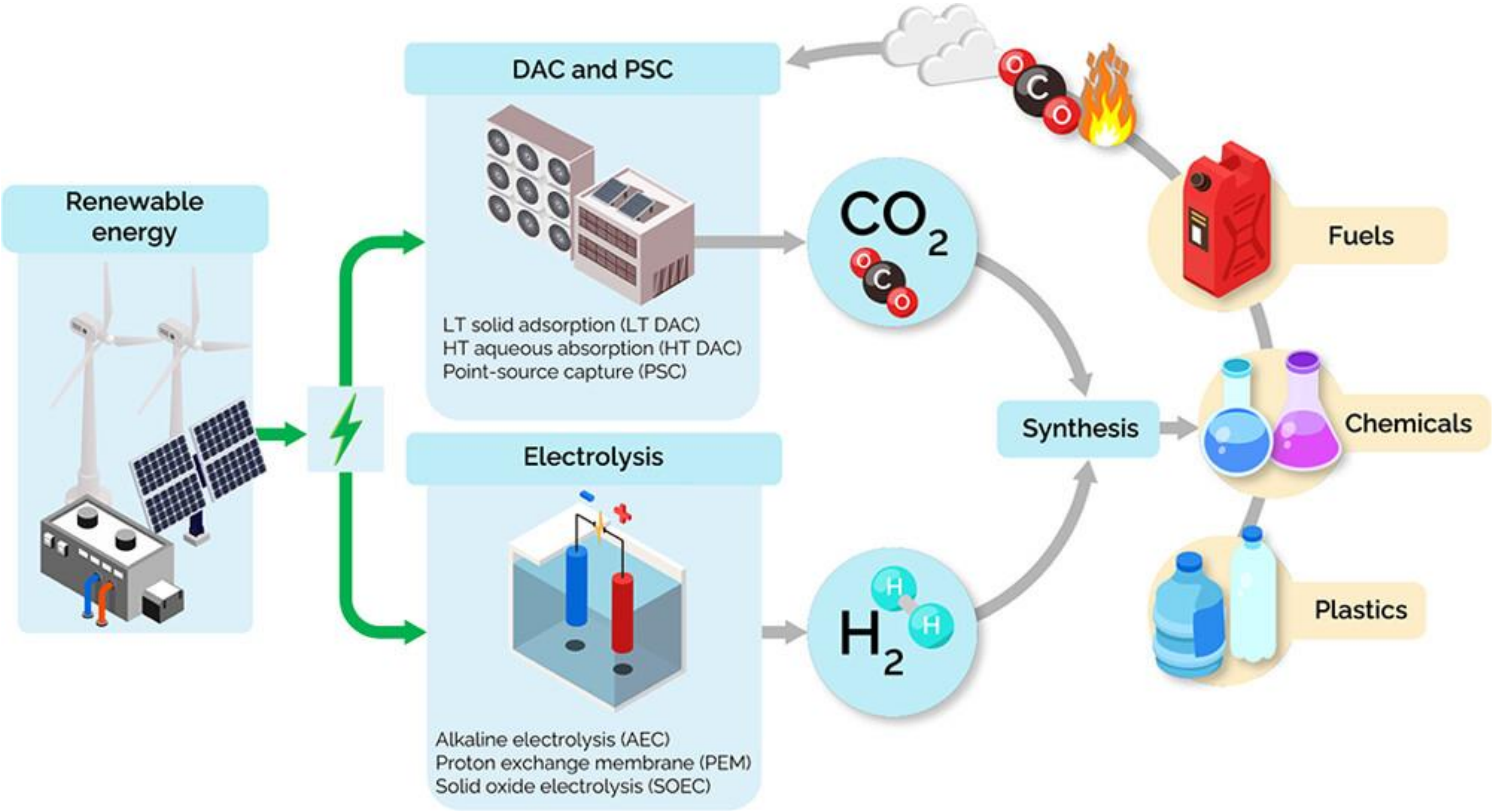
175,000 tons/year of e-Methanol

215,000 tons CO_2 captured/year

242 MW electrolyzer capacity

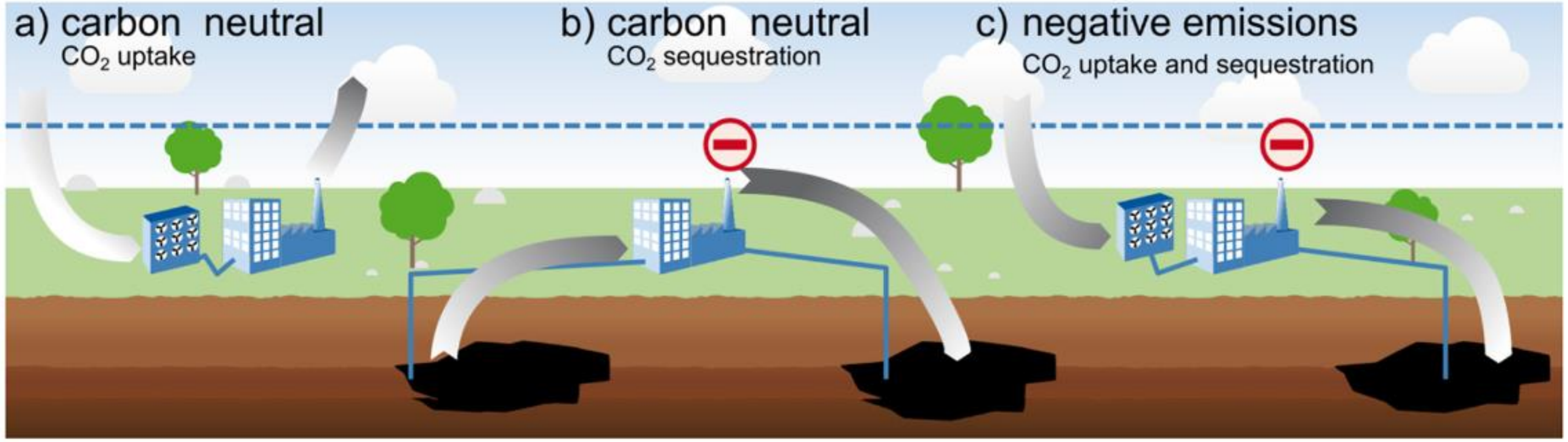
https://hifglobal.com/region/hif-latam

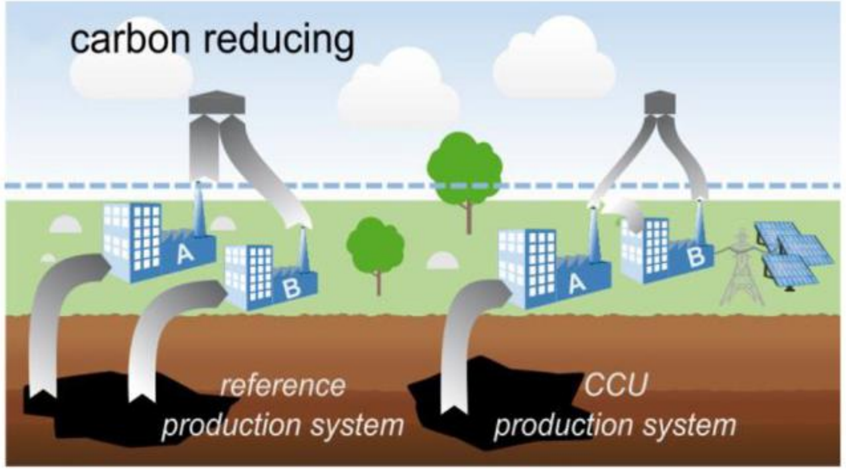
Captura e hidrogenación de CO_2



Allgoewer, L. et al., Cost-Effective Locations for Producing Fuels and Chemicals from Carbon Dioxide and Low-Carbon Hydrogen in the Future, *Industrial & Engineering Chemistry Research* 2024 63 (31), 13660-13676

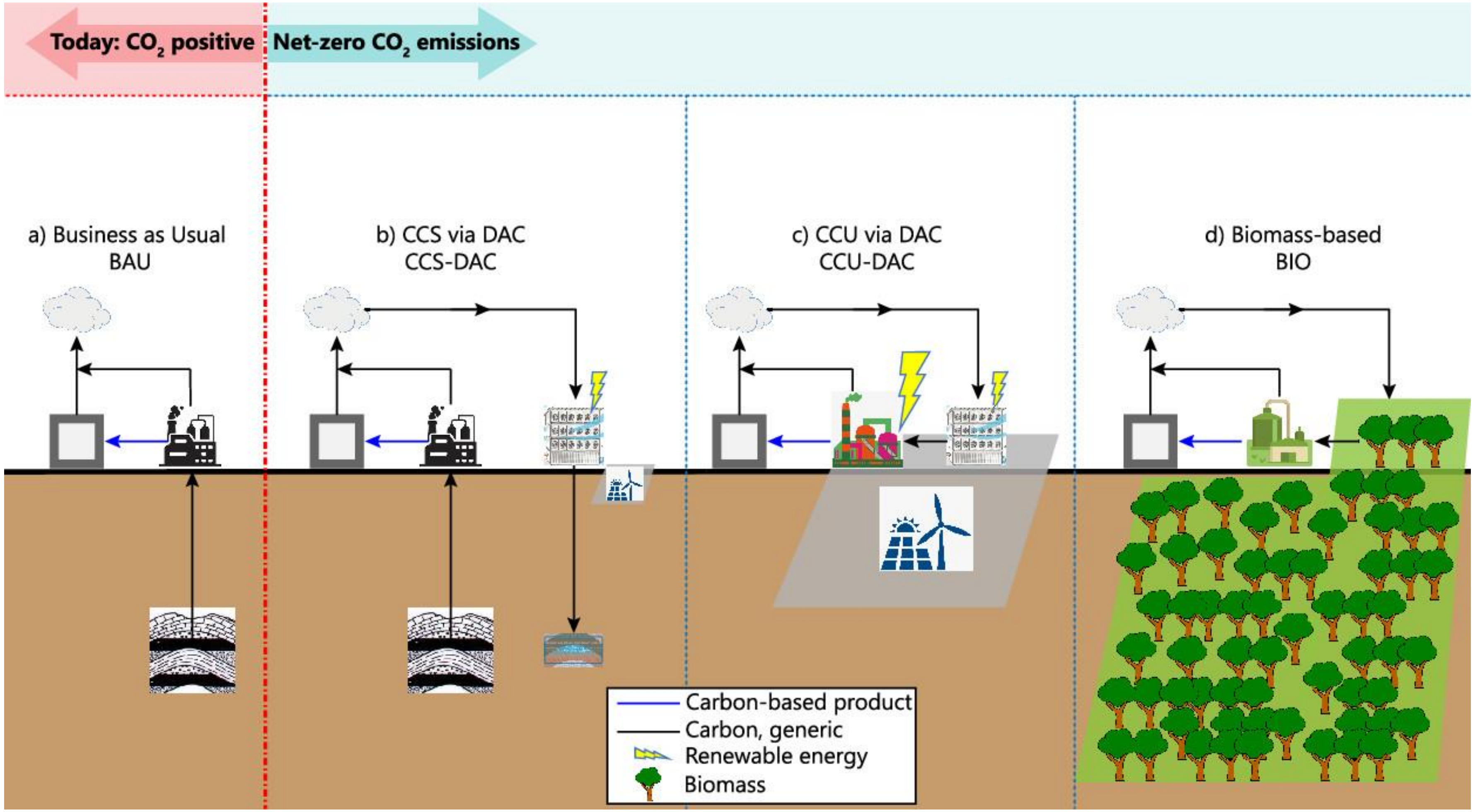
Antecedentes de Captura de CO_2





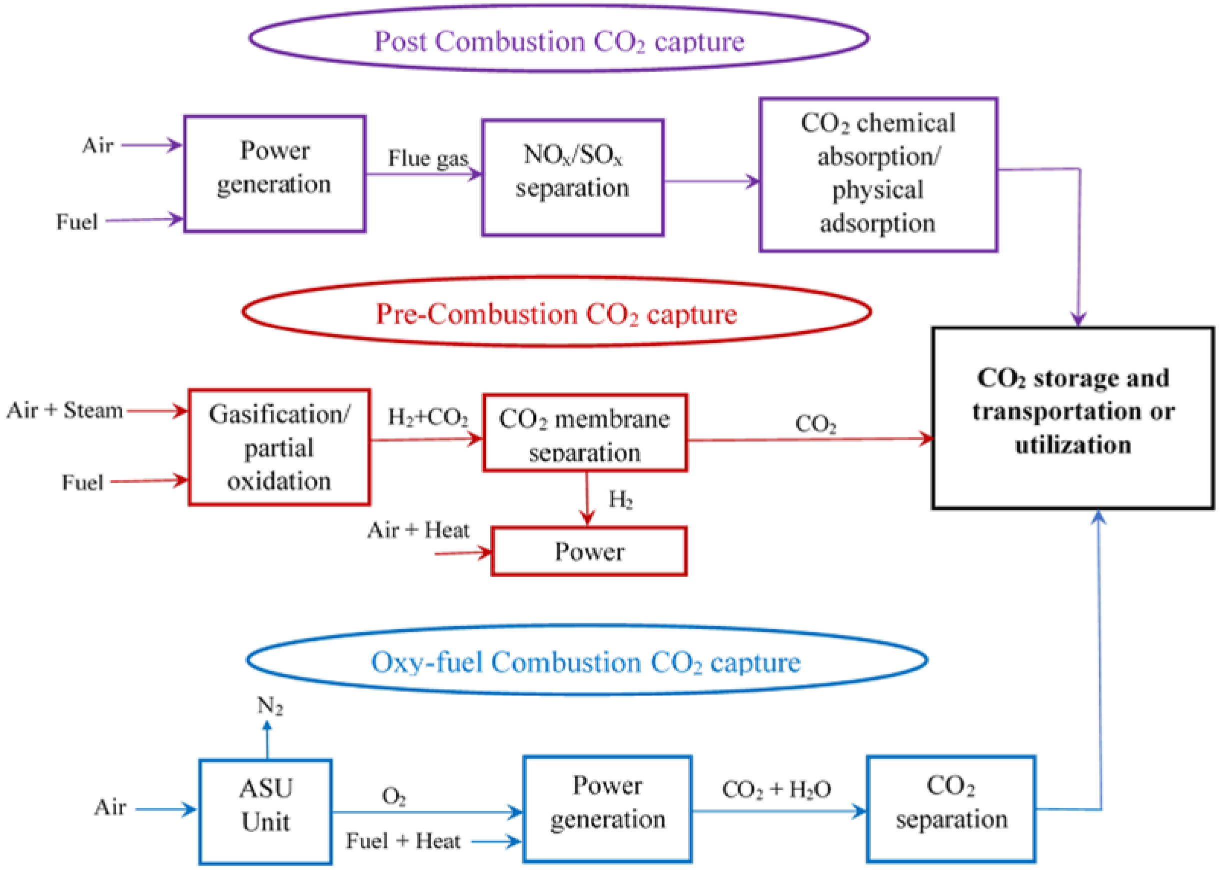
Müller, L. J., et al. (2020). "A Guideline for Life Cycle Assessment of Carbon Capture and Utilization." Frontiers in Energy Research 8.

Captura directa del aire (DAC)



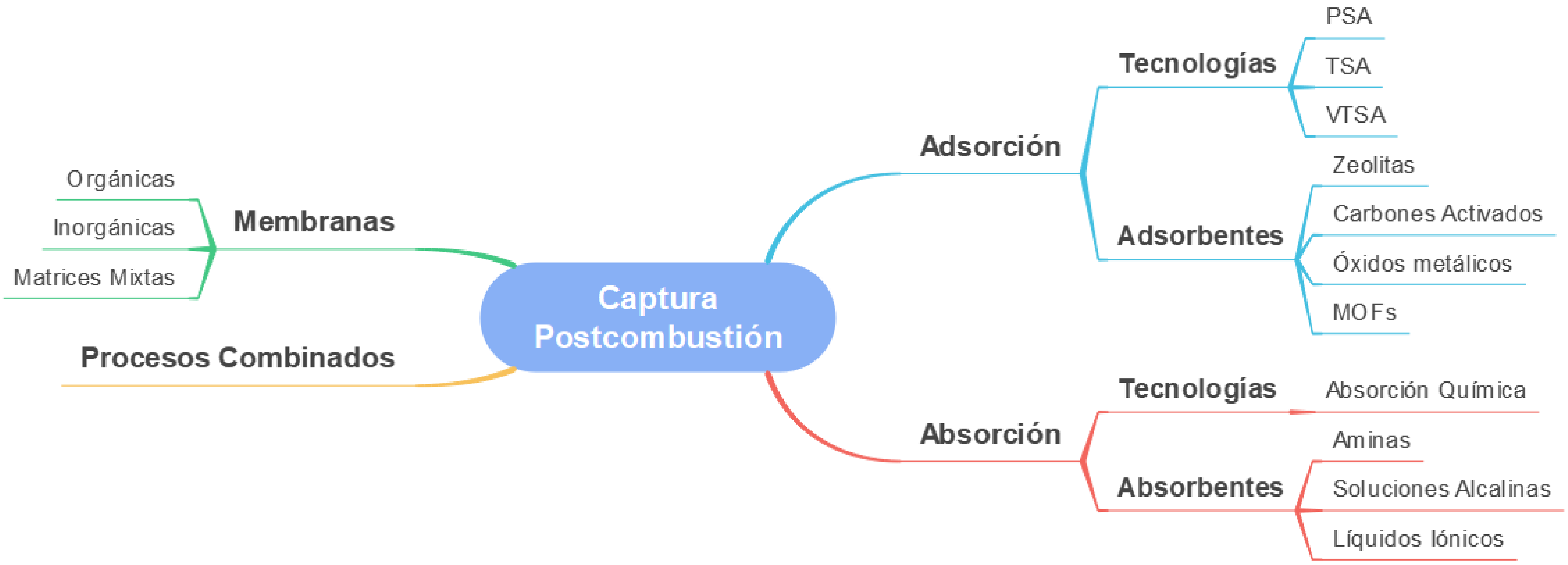
Gabrielli, P., The Role of Carbon Capture and Utilization, Carbon Capture and Storage, and Biomass to Enable a Net-Zero-CO2 Emissions Chemical Industry, *Industrial & Engineering Chemistry Research* 2020 59 (15), 7033-7045

Tecnologías de Captura de CO_2



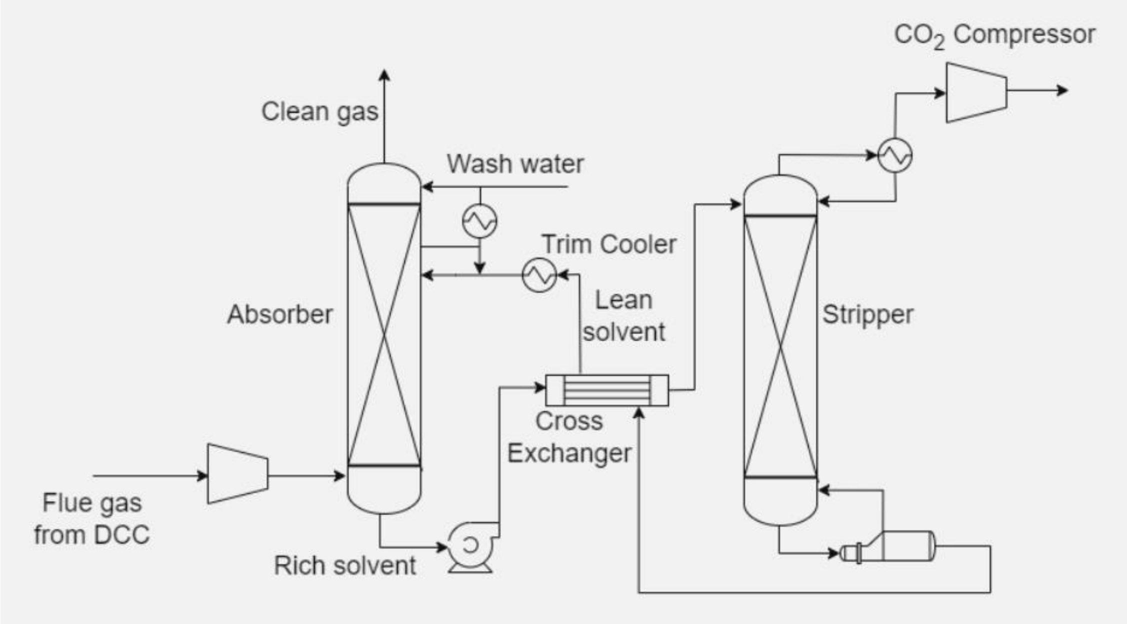
Jiang et al. (2024). Emerging Technologies Review: Carbon Capture and Conversion to Methane and Methanol.

Tecnologías de Captura de CO_2

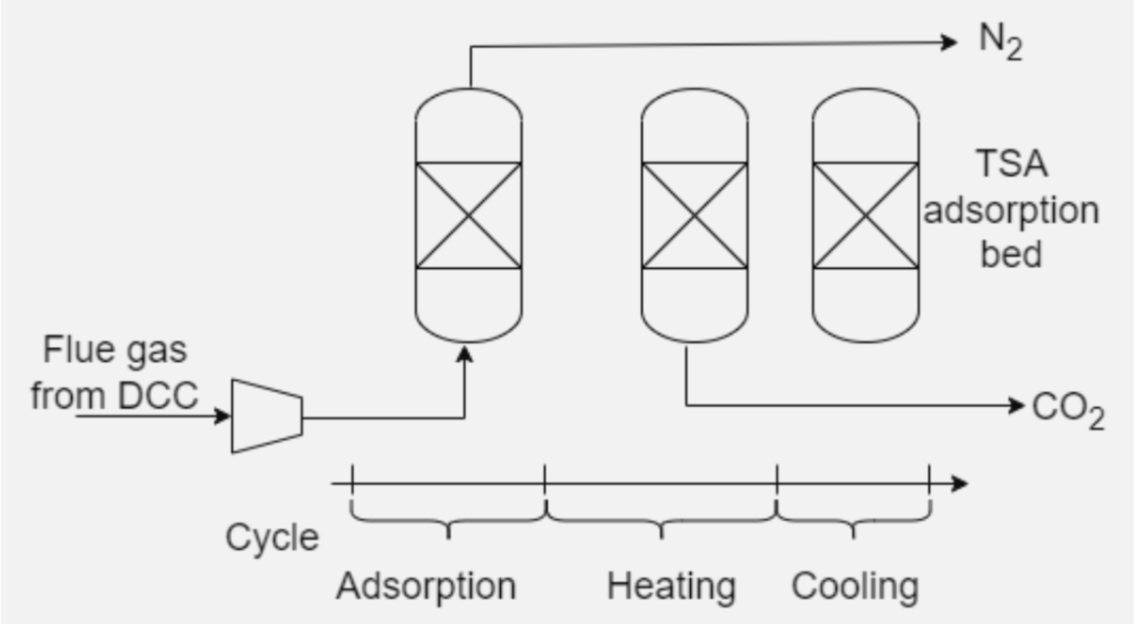


Tecnologías de Captura de CO_2

Absorción Química



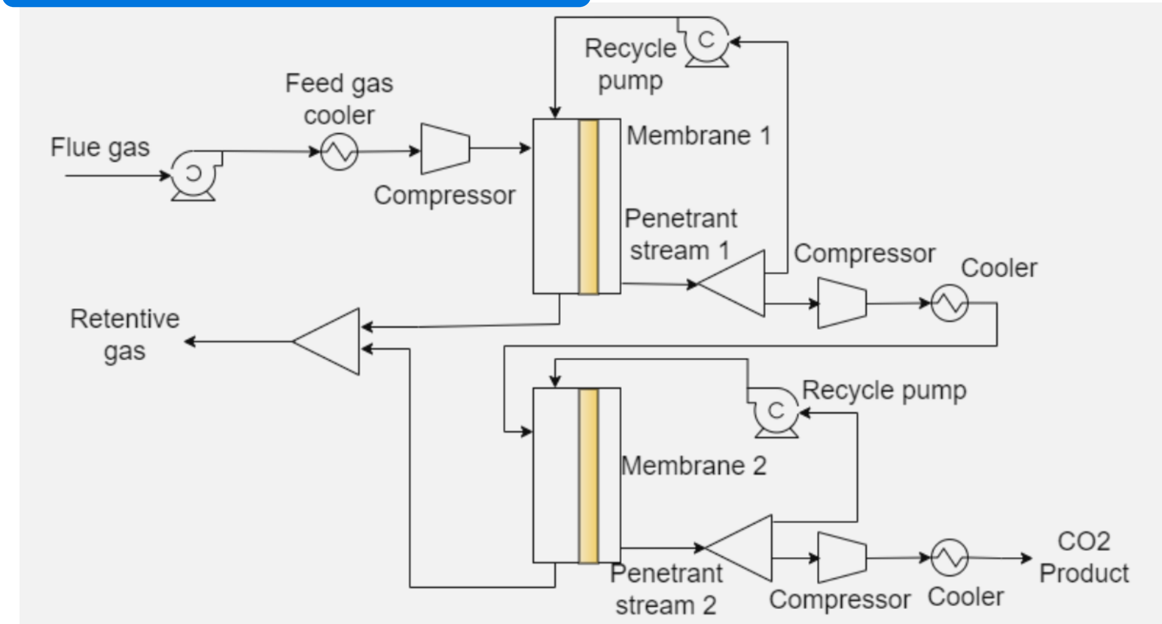
Adsorción



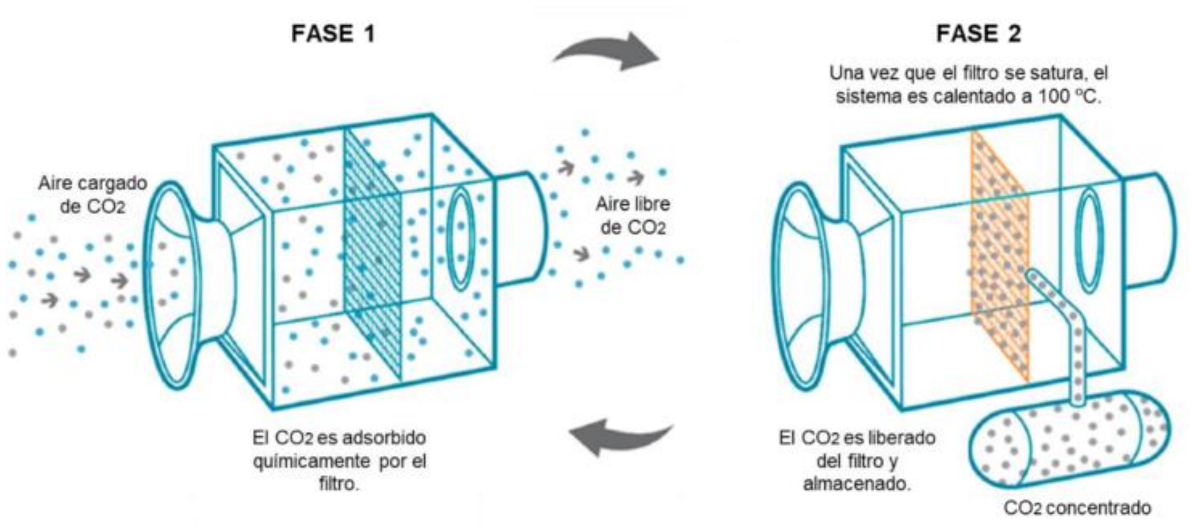
Jiang et al. (2024). Emerging Technologies Review: Carbon Capture and Conversion to Methane and Methanol.

Tecnologías de Captura de CO_2

Membranas



Captura Directa del Aire



Jiang et al. (2024). Emerging Technologies Review: Carbon Capture and Conversion to Methane and Methanol.

Tecnologías de Captura de CO_2

LINDE

ADVANCED AMINE-BASED POST-COMBUSTION CO_2 CAPTURE (PCC)

ccus@linde.com   www.engineering.linde.com/CO_2

HIGHLIGHTS

- Compact footprint
- High CO_2 capture rate even at low CO_2 concentrations
- With a final CO_2 product purity of 99.9 vol% (dry), a further purification step may not be necessary
- 20% lower energy consumption and 20% lower circulation rate compared to MEA solution
- Low solvent degradation rate even at elevated oxygen content in flue gas, and therefore low solvent consumption rate
- Different options for energy and heat integration

KEY DATA

TRL	9	Capture Rate Range (tpd)	200 - 7,000	Modular (Y/N)	Yes
Source CO_2 Concentration	3 - 25%	Energy Consumption (GJ/tCO_2)	2.5 - 3.2	Capture Efficiency (%)	>95%
Number of Commercial Plants	>60	Number of Pilot Plants	3		
Target Industries	Cement & lime, power generation (natural gas, biomass, coal), iron & steel, petrochemical, oil & gas				

Global CCS Institute (2024). State-of-the-Art: CCS Technologies 2024

Tecnologías de Captura de CO_2

LINDE

CO_2 PSA

ccus@linde.com   www.engineering.linde.com/CO_2

HIGHLIGHTS

- Mature and robust purification technology
- Negligible electricity consumption
- No steam required for regeneration (thereby no additional CO_2 generation)
- No solvents are applied, so therefore no negative environmental impact due to the emission of solvent traces in exhausts or in the CO_2 product
- No extra cost for solvent makeup and handling
- Low CAPEX and OPEX technology

KEY DATA

TRL	9	Capture Rate Range (tpd)	10 - 5,000	Modular (Y/N)	Yes
Source CO_2 Concentration	>7%	Energy Consumption (GJ/tCO_2)	0[1]	Capture Efficiency (%)	99%
Number of Commercial Plants	>15	Number of Pilot Plants	~		
Target Industries	Iron & steel, (petro-)chemical, cement & lime, oil & gas, hydrogen				

Global CCS Institute (2024). State-of-the-Art: CCS Technologies 2024

Tecnologías de Captura de CO_2

NUADA

Nuada
Capturing the future

MOF-BASED VPSA PROCESS

contact@nuadaCO_2.com www.nuadaCO_2.com

BENEFITS

- Ultra-Energy Efficient: The energy penalty for carbon capture is reduced by up to 80% compared to incumbent solutions.
- No Complex Integration: An end-of-pipe and fully electrified solution; no heat or steam required.
- Wide Applicability: CO_2 can be recovered from a broad spectrum of point sources and at different scales.
- Mature Process Technology: VPSA is a mature, proven and readily scalable separation technology that has been applied for decades at an industrial scale.
- High-Purity CO_2 Product: Purity up to 99% without extra purification step; No oxygen or solvent-based impurities in the CO_2 stream.
- Dynamic Operation: The rapid capture and release cycles provide flexibility to address operational challenges such as flue gas fluctuations or facilitate quick startups and shutdowns.

KEY DATA

TRL	6	Capture Rate Range (tpd)	1 - 4,000	Modular (Y/N)	Yes
Source CO_2 Purity Range	>5%	Energy Consumption (GJ/tCO_2)	0.7	Capture Efficiency (%)	>95%
Number of Commercial Plants	0	Number of Pilot Plants	2	Product CO_2 Purity	Up to 99%
Target Industries	Cement, Lime, Waste-to-Energy, Steel, Oil & Gas, Chemicals				

Global CCS Institute (2024). State-of-the-Art: CCS Technologies 2024

Tecnologías de Captura de CO_2

PETRONAS

PETRONAS

MEMBRANE CONTACTOR (MBC)

khairul_rostani@petronas.com

nanthini.raman@petronas.com

BENEFITS

- **Minimises Overall Carbon Footprint:** MBC's state-of-the-art multi-cartridge membrane contactor modules, achieve an impressive 50% reduction in the overall volume while maintaining high carbon capture efficiency, all within a compact design.
- **Tailored Solutions for Every Need:** MBC offers unparalleled scalability, allowing seamless adjustments to match the unique requirements of our clients. MBC adaptable nature ensures flexibility by catering to clients' evolving operational needs.
- **Competitive Cost to Capture:** Lower compression cost due to high regeneration pressure up to 5 barg, and lower solvent circulation rate up to 30%, as first of its kind modular technology. Aimed at achieving CO_2 capture for a competitive cost of US$30-50 per tonne, MBC ensures maximum value for every investment.

KEY DATA

TRL	5	Capture Rate Range (tpd)	10 - 600	Modular (Y/N)	Yes
Source CO_2 Purity Range	3 - 30%	Energy Consumption (GJ/tCO_2)	<2.9	Capture Efficiency (%)	>95%
Number of Commercial Plants	~	Number of Pilot Plants	4	Pressure Drop	<0.2bar
Target Industries	Refineries, Hard-to-abate industries (Cement, Steel, Chemicals and Power & Gas Plants)				

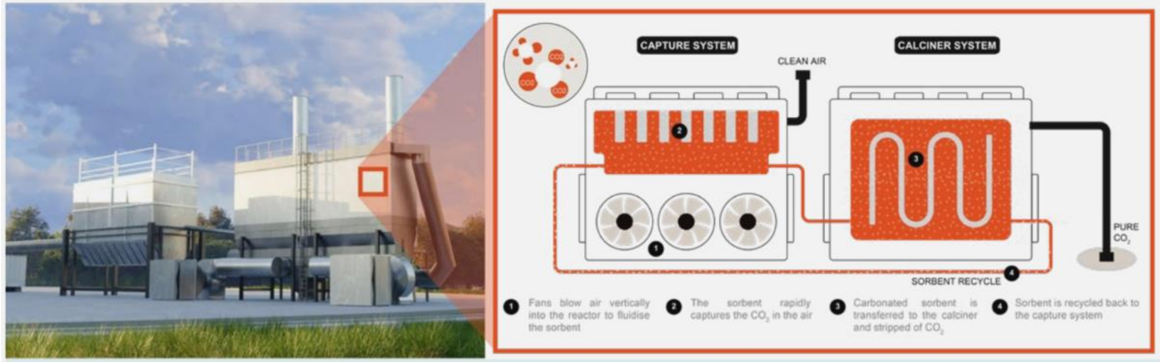
Global CCS Institute (2024). State-of-the-Art: CCS Technologies 2024

Tecnologías de Captura de CO_2

Airhive

AIRHIVE

DIRECT AIR CAPTURE (DAC)



hello@airhive.earth www.airhive.earth

BENEFITS

The Airhive DAC system is:

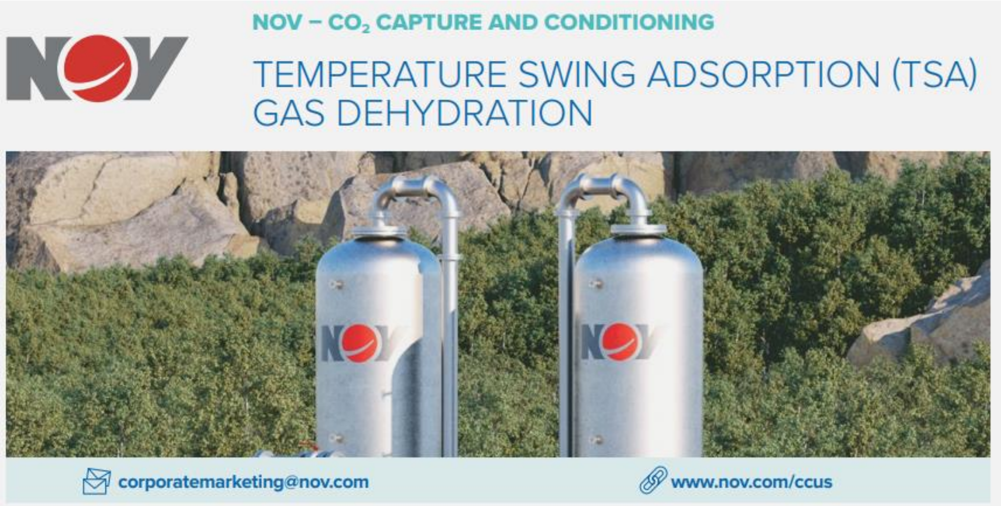
- **Fast:** The nano-structured sorbent removes 99% of CO_2 from the air in <0.1 seconds and fully saturates in under three hours.
- **Sustainable and easy to scale:** The technology is built on existing industrial equipment and supply chains, configured in new ways for DAC. The naturally abundant mineral sorbent is widely available, non-toxic and can be reused for many cycles of carbon removal.
- **Low-cost:** Estimated cost at pilot scale is <$379 per net tCO_2 with pathways to estimate at-scale costs of $93 per net tCO_2.
- **Energy efficient:** The system is targeted at 1.5 MWh/ tCO_2, and can be fully powered by low carbon energy. It also has in-built thermochemical energy storage potential, allowing it to run when there is no external energy source available.

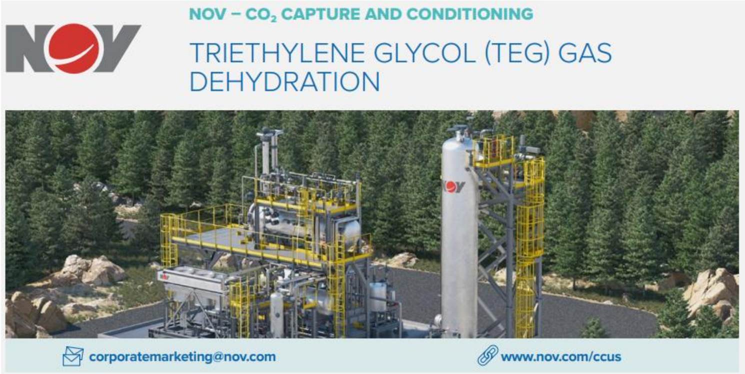
KEY DATA

TRL	6	Capture Rate Range (tpd)	3.8 tpd/reactor	Modular (Y/N)	Yes
Source CO_2 Purity Range	~	Energy Consumption (GJ/tCO_2)	3.6 (1 MWh/tCO_2)	Capture Efficiency (%)	99%
Number of Commercial Plants	0	Number of Pilot Plants	3 (2 commercial)		
Target Industries	Chemicals, Food and Beverage, Green Fuels, CDR credit buyers				

Global CCS Institute (2024). State-of-the-Art: CCS Technologies 2024

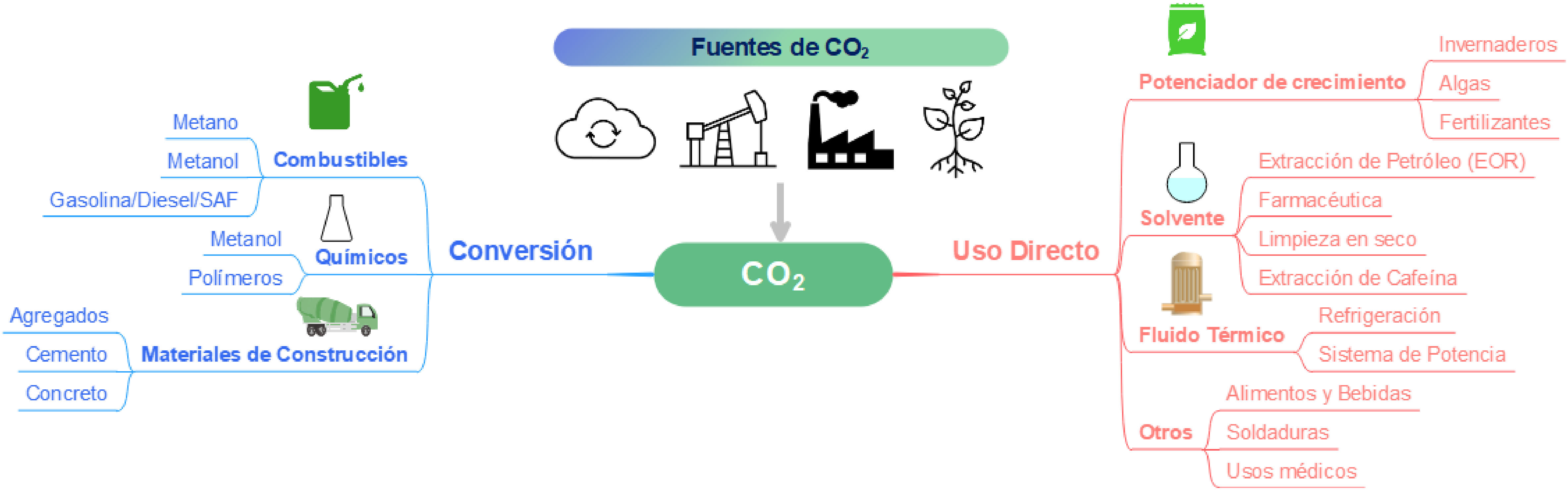
Tecnologías de Captura de CO_2



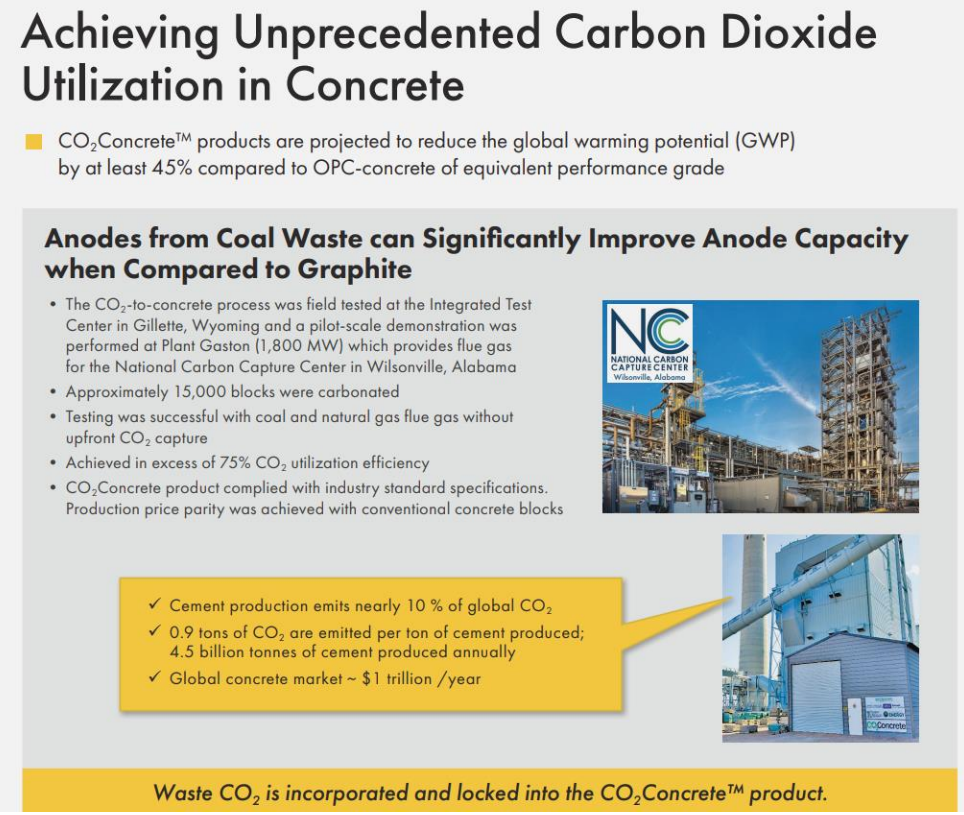


Global CCS Institute (2024). State-of-the-Art: CCS Technologies 2024

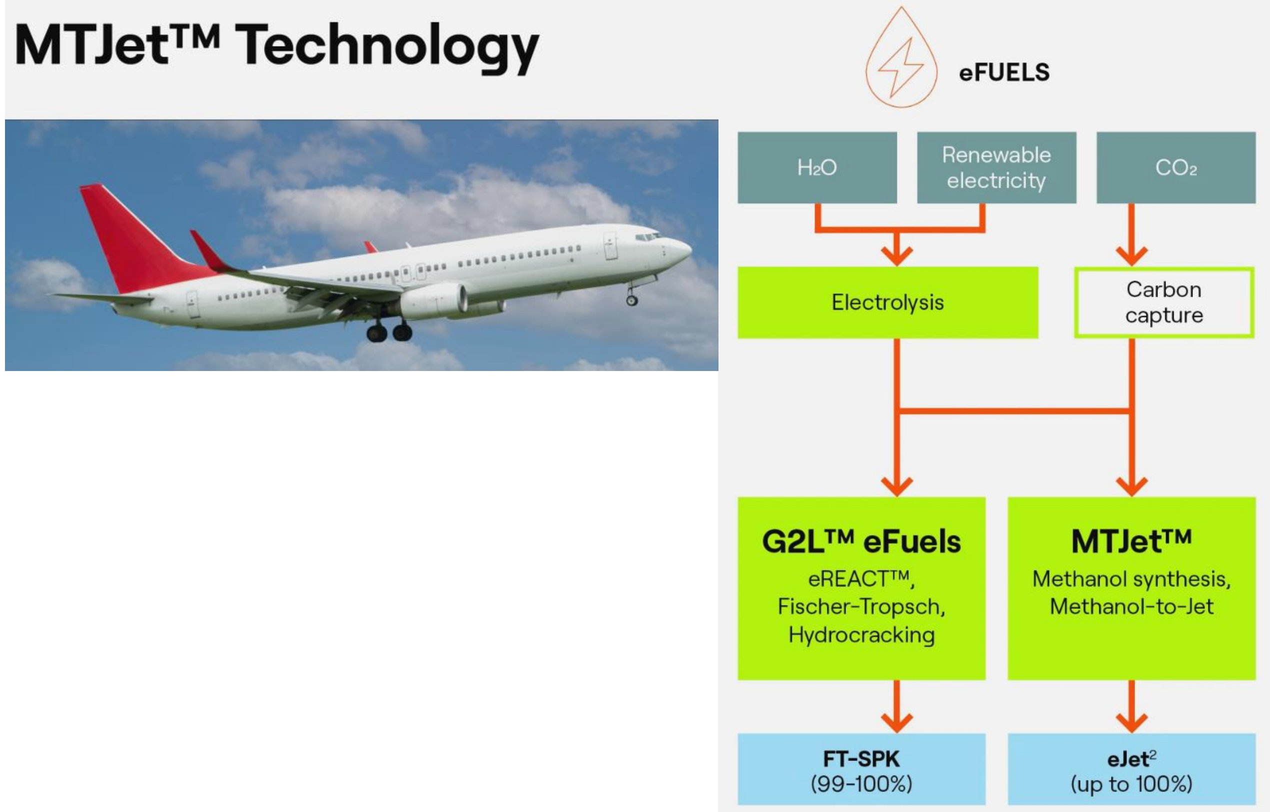
Alternativas de Valorización de CO_2



Alternativas de Valorización de CO_2

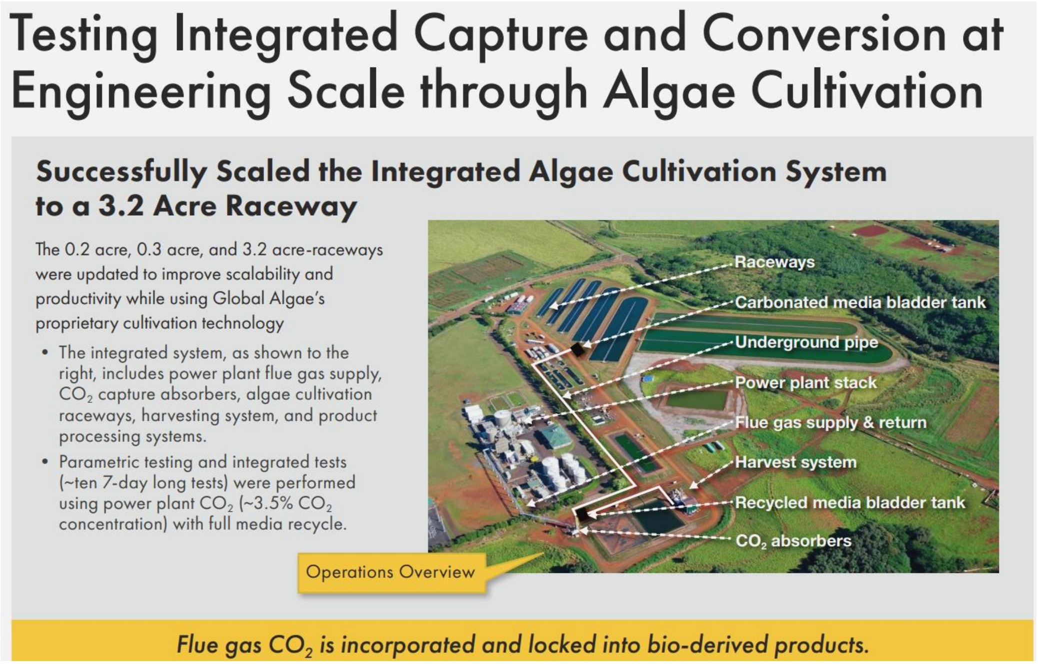


https://netl.doe.gov/carbon-management/carbon-conversion



The pathways to Sustainable Aviation Fuel | Topsoe

Alternativas de Valorización de CO_2



https://netl.doe.gov/carbon-management/carbon-conversion

Haru Oni (hifglobal.com)

Herramientas de Evaluación de Proyectos

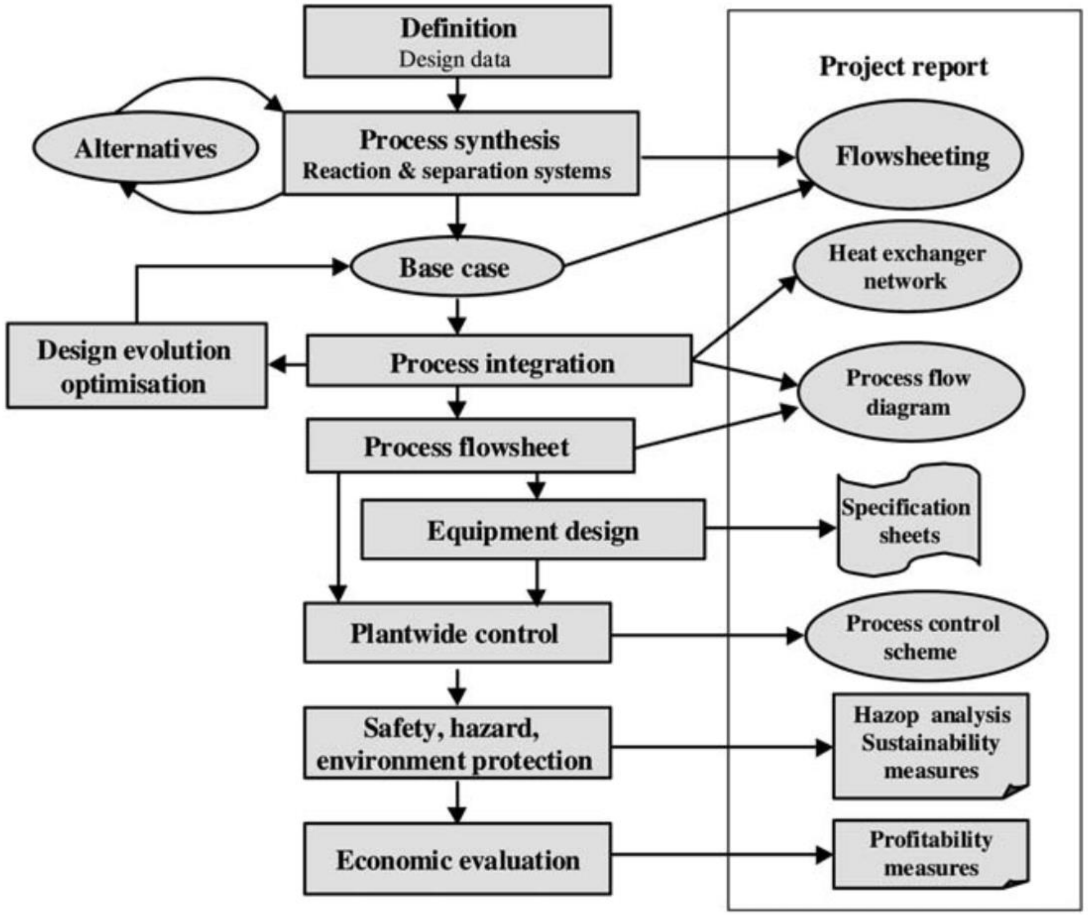


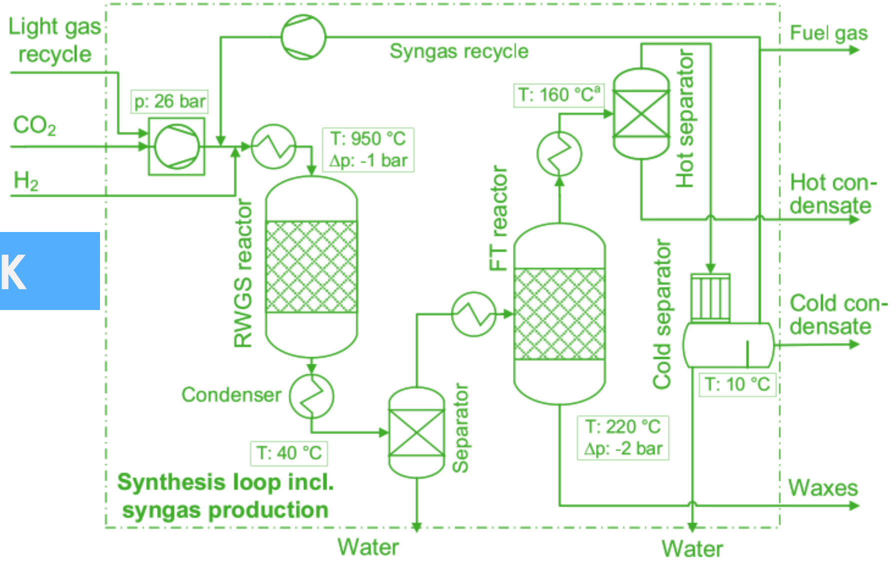
Figure 1.1 Outline of a design project.

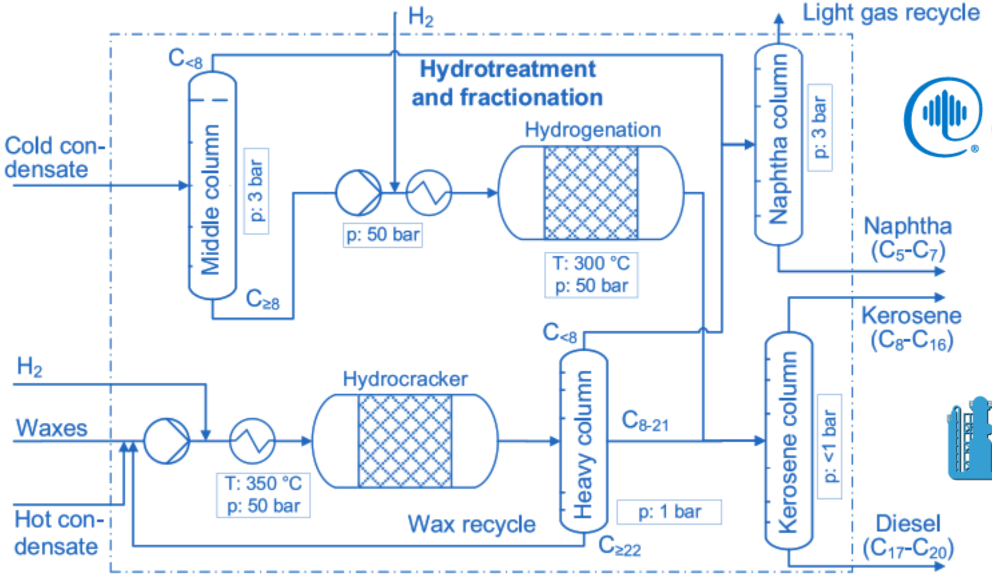
El **Diseño de los Procesos Químicos** es un procedimiento que aplica e integra varias técnicas de ingeniería, economía y principios científicos para crear un proceso que fabrique un producto específico.

Herramientas de Evaluación de Proyectos

Eficiencia	Energía	Medio Ambiente	Economía

FT-SPK





aspentech

DWSIM Chemical Process Simulator

FT-SPK: Fischer-Tropsch Synthetic Paraffinic Kerosene

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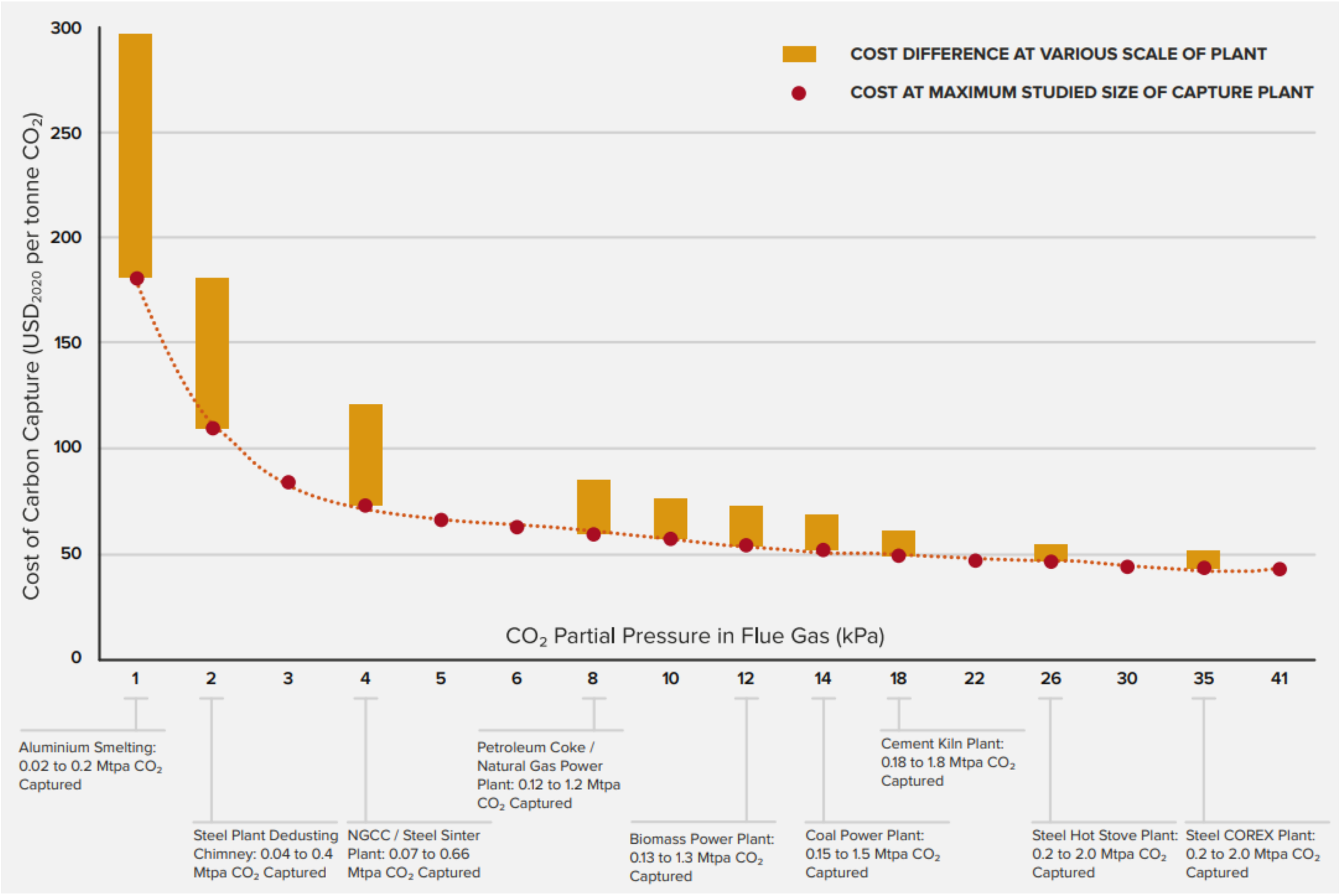
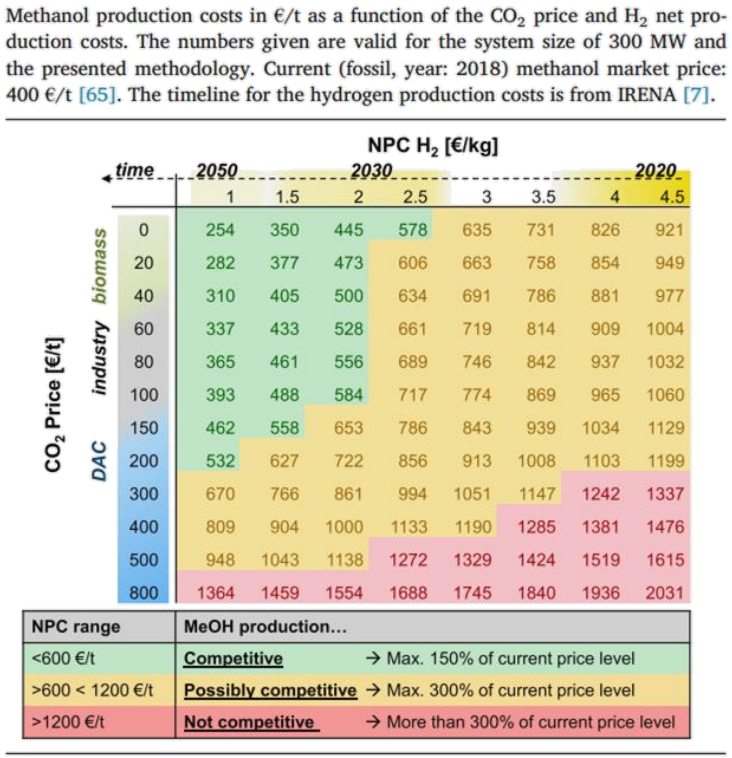
Herramientas de Evaluación de Proyectos



Herramientas de Evaluación de Proyectos

Metanol



Methanol production costs in €/t as a function of the CO_2 price and H_2 net production costs. The numbers given are valid for the system size of 300 MW and the presented methodology. Current (fossil, year: 2018) methanol market price: 400 €/t [65]. The timeline for the hydrogen production costs is from IRENA [7].

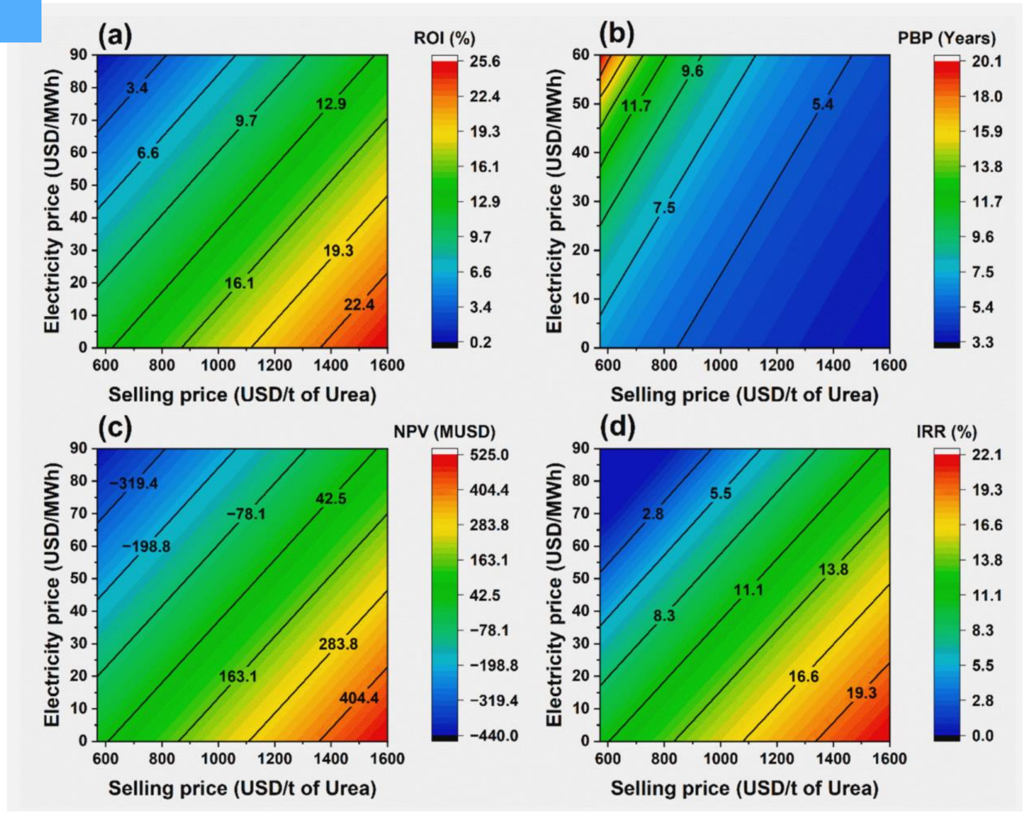
NPC H_2 [€/kg] (time: 2050 → 2030 → 2020)

CO_2 Price [€/t]	1	1.5	2	2.5	3	3.5	4	4.5
0 (biomass)	254	350	445	578	635	731	826	921
20 (biomass)	282	377	473	606	663	758	854	949
40 (biomass)	310	405	500	634	691	786	881	977
60 (industry)	337	433	528	661	719	814	909	1004
80 (industry)	365	461	556	689	746	842	937	1032
100 (industry)	393	488	584	717	774	869	965	1060
150 (DAC)	462	558	653	786	843	939	1034	1129
200 (DAC)	532	627	722	856	913	1008	1103	1199
300 (DAC)	670	766	861	994	1051	1147	1242	1337
400 (DAC)	809	904	1000	1133	1190	1285	1381	1476
500 (DAC)	948	1043	1138	1272	1329	1424	1519	1615
800 (DAC)	1364	1459	1554	1688	1745	1840	1936	2031

NPC range	MeOH production...
<600 €/t	Competitive → Max. 150% of current price level
>600 < 1200 €/t	Possibly competitive → Max. 300% of current price level
>1200 €/t	Not competitive → More than 300% of current price level

Schorn, F., et al. (2021). "Methanol as a renewable energy carrier: An assessment of production and transportation costs for selected global locations." Advances in Applied Energy 3: 100050.

Urea



Devkota, S., et al. (2024). "Decarbonizing urea: Techno-economic and environmental analysis of a model hydroelectricity and carbon capture based green urea production." Applied Energy 372: 123789.

Herramientas de Evaluación de Proyectos

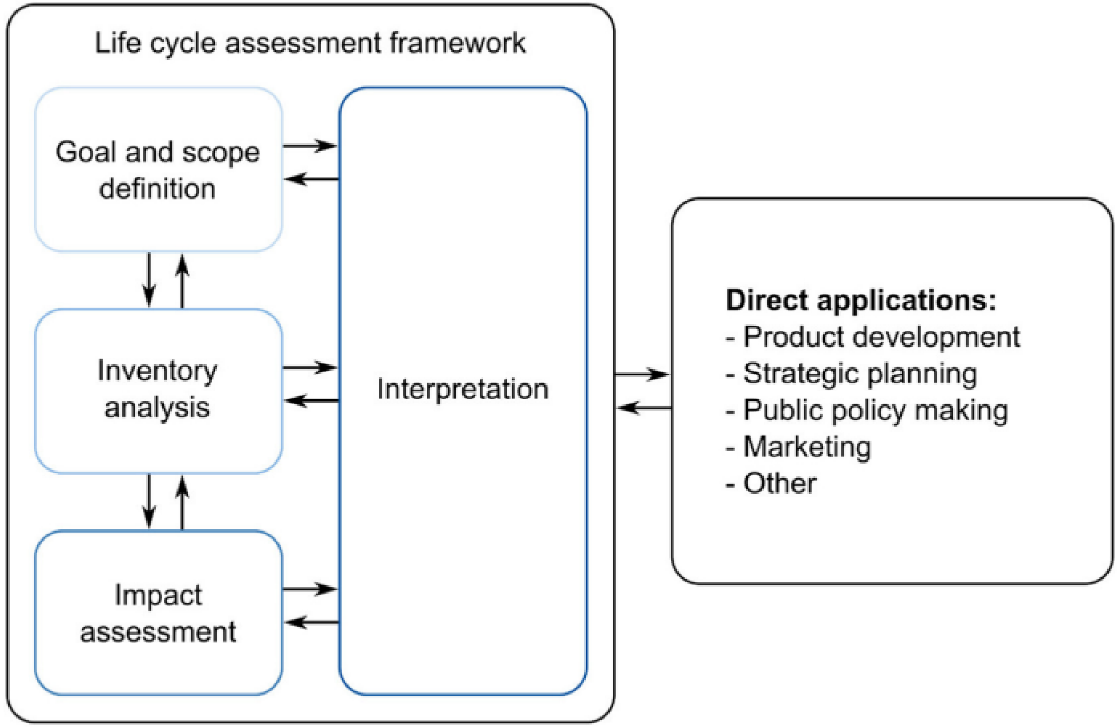


FIGURE 2 | General framework for life cycle assessment (European Committee for Standardisation, 2009).

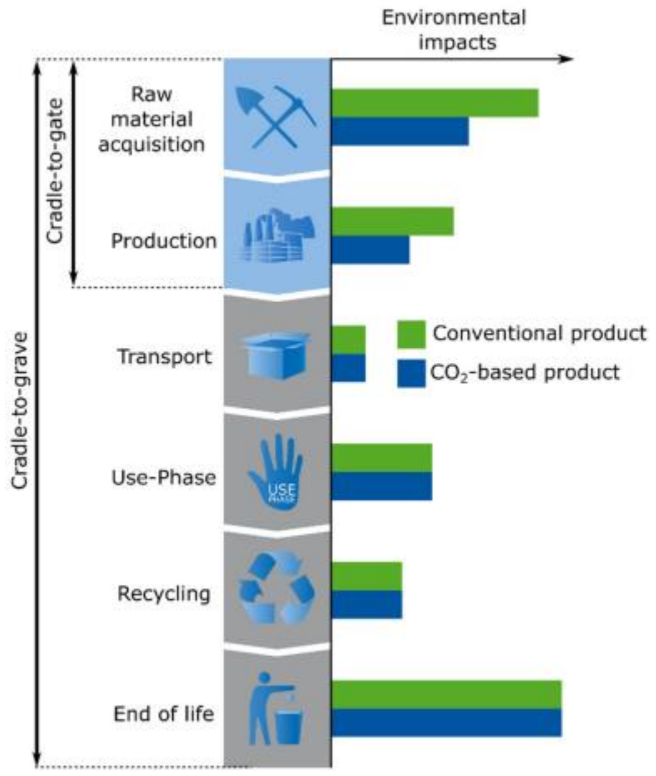
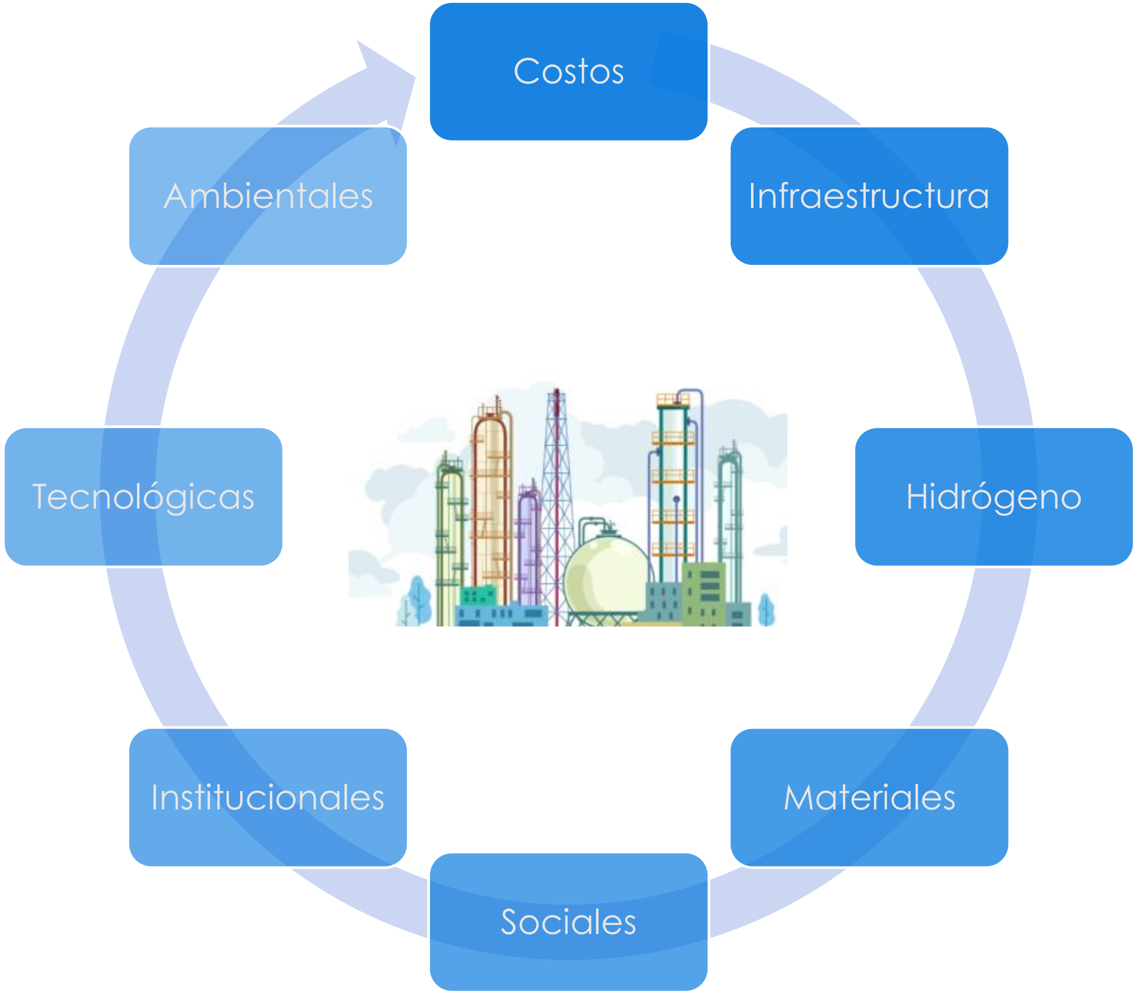
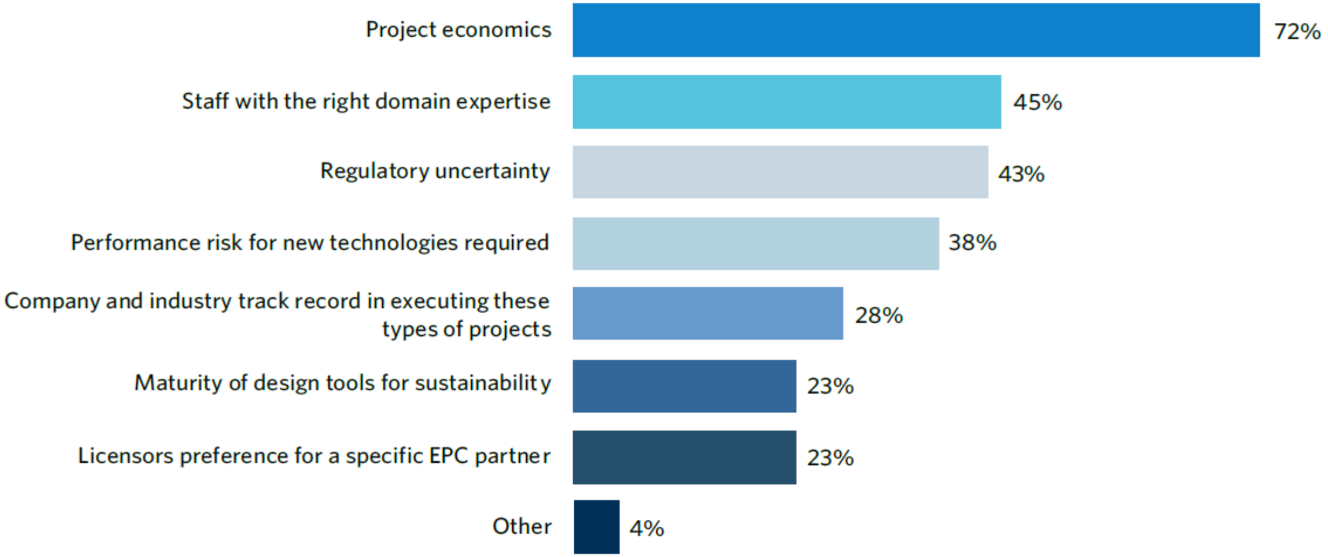


FIGURE 3 | Illustration of a comparison of environmental impacts for products with identical chemical structure and composition over the entire life cycle. Impacts shown as bars on the x-axis only differ during the phases raw material acquisition and production and thus, comparative studies only have to consider these phases.

Müller, L. J., et al. (2020). "A Guideline for Life Cycle Assessment of Carbon Capture and Utilization." Frontiers in Energy Research 8.

Barreras para Implementación





Aspen Tech Sustainability Global Survey, Febrero 2022

Profesor(a): **Roberto Canales – Junior Lorenzo**

Diplomado en Captura y utilización de CO_2

Curso 1

Emisiones, captura, almacenamiento y conversión de CO_2

Curso 2

Tecnologías de captura y conversión de CO_2

Curso 3

Análisis técnico-económico y marcos regulatorios de procesos de CO_2

Curso 4

Taller de evaluación de proyecto de CO_2

https://educacionprofesional.ing.uc.cl/?diplomado=diplomado-en-captura-y-utilizacion-de-co2

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