E-Fuels: Useful valorization of CO2

From residue to raw material in ultra low carbon fuels for aviation and transport

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Alba Emission Free Energy S.A. (Petronor)

alba Emission Free Energy by Petronor

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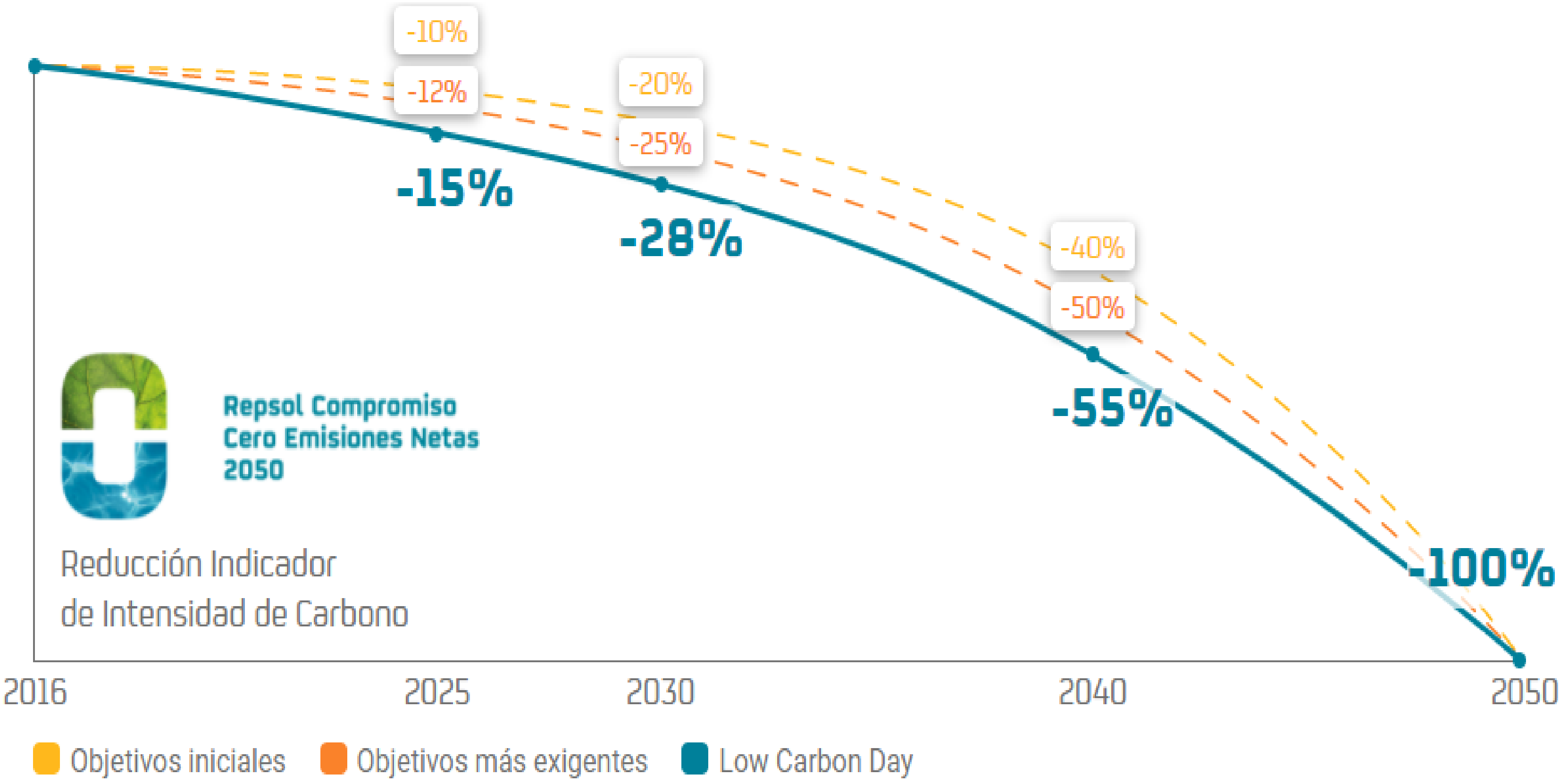
Context

Repsol Group: Public Compromise (late 2019) to become a net zero emission company by 2050 (Scope 1-2-3)



- Commitment of Net Zero Emissions by 2050
- https://www.repsol.com/es/sostenibilidad/cambio-climatico/cero-emisiones-netas-2050/index.cshtml

The Repsol Commitment
Net Zero Emissions
by 2050

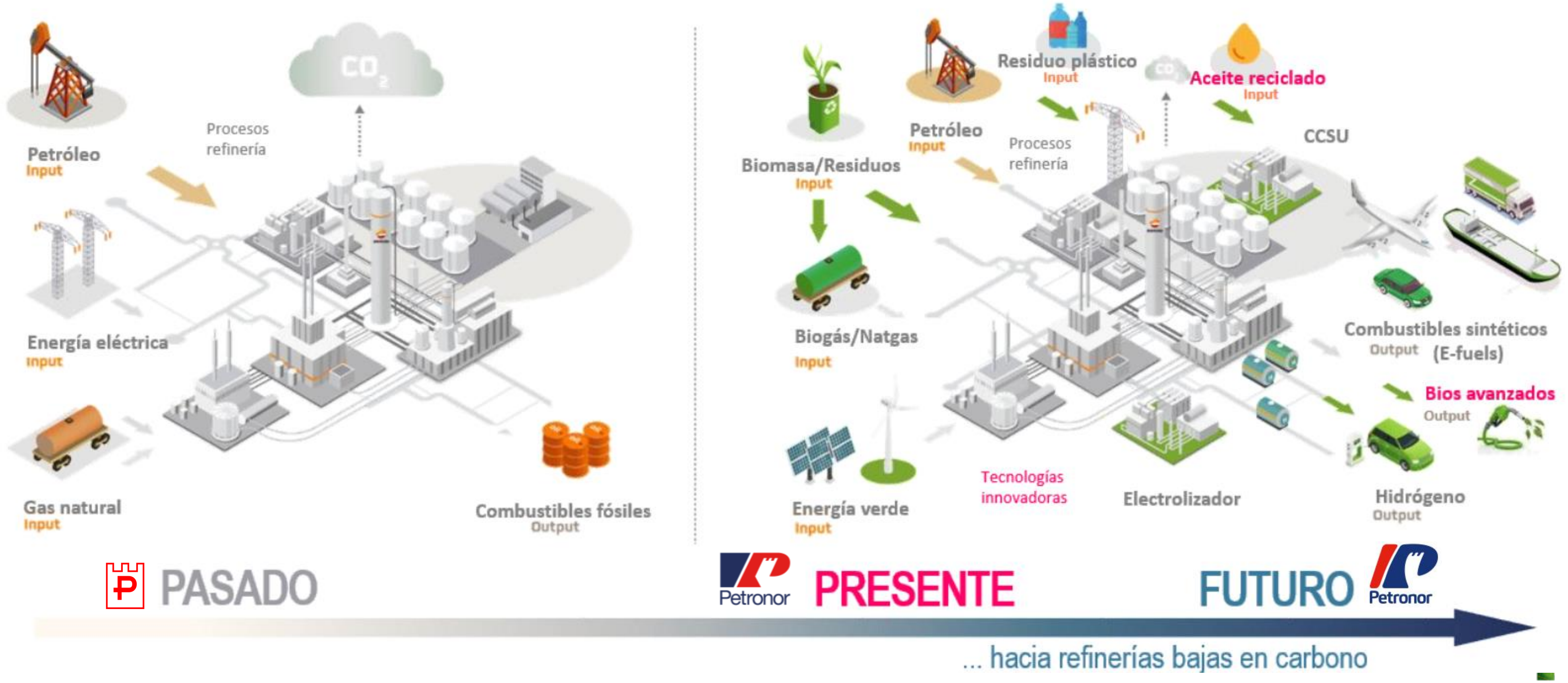
Context

Repsol Group: Transforming our business model towards decarbonization

REPSOL

Scope 1-2: Energy & Process

Scope 3: Raw materials



The Repsol Commitment Net Zero Emissions by 2050

Context

Petronor key figures

Petronor

1,015 employees

Production 12 M tonnes/year 220k bbl/d

+ 6,200 indirect jobs

9.7 % of GDP in Bizkaia region

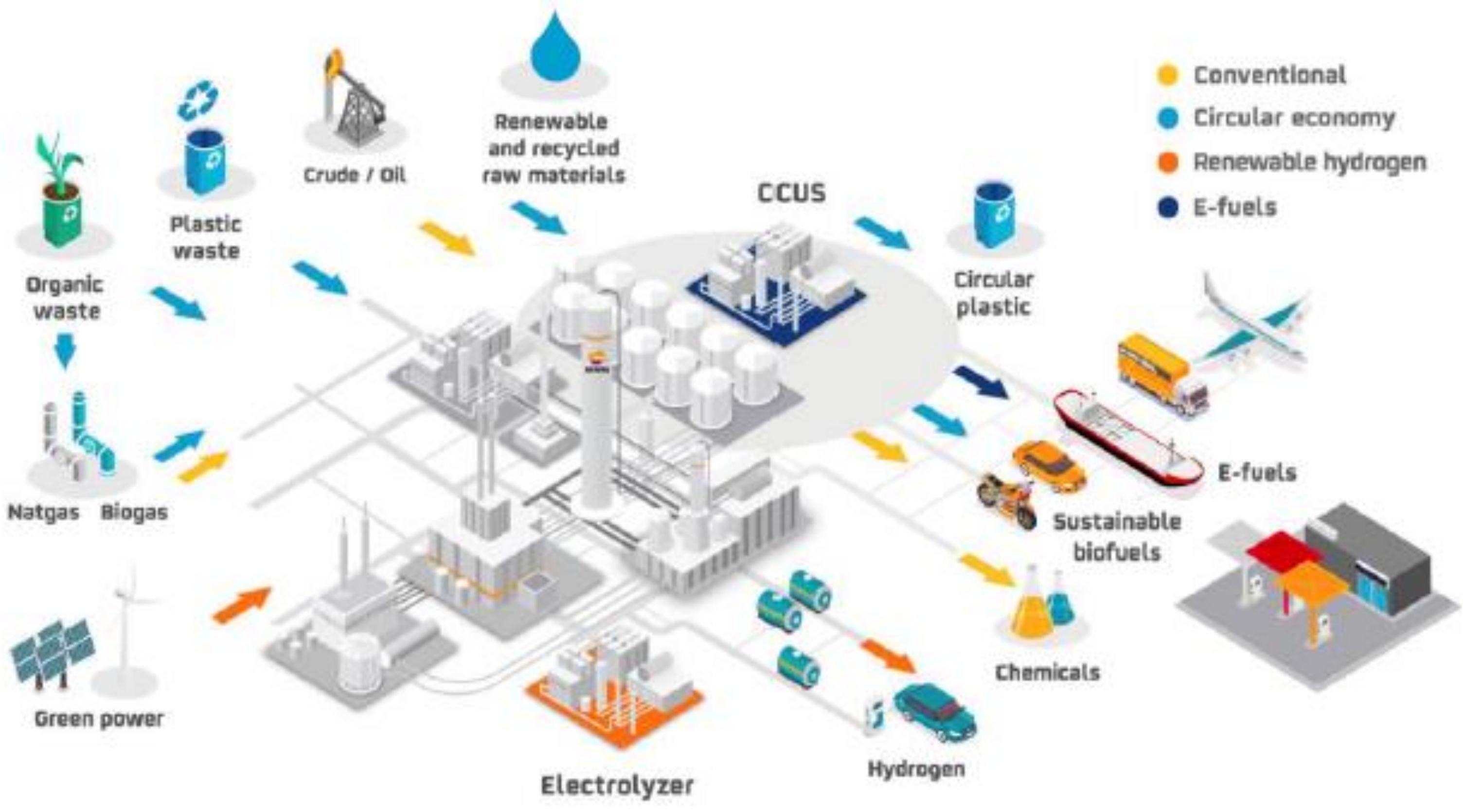
40% of **vessel traffic** through the **Port of Bilbao**

Petronor is the industrial leader of the BH2C BASQUE HYDROGEN CORRIDOR

REPSOL

Petronor Is part of REPSOL 1st company in the sector with the objective Repsol 2050 Net Zero Emissions Commitment

Industrial transformation



Context

Petronor has a history of constant evolution

Hitos societarios | Hitos industriales | Hitos medioambientales

1968
Autorización instalación refinería en Bizkaia
Accionariado: CAV 9,5%
CAM, 9,5%
BB 19%
BV 19%
RÍO GULF 5%
GULF Corp 38%

1972
Refinería 1
(7M t/año)

1975
Inauguración puerto en Punta Lucero

1979
Refinería 2
(5M t/año)
Accionariado:
Incorporación PEMEX
Salida GULF CORP

1985
Unidades Conversión
Vacío/viscorreductora; craker catalítico; desulfuración gasoil de vacío; producción de hidrógeno; recuperación de azufre

1986
Primera Refinería española en producir gasolina sin plomo

1990
Adquisición por Repsol participación Pemex, BB y BV
Accionariado:
REPSOL 85,98%
BBK 10,95%
CLH 3,07%

1993/4
Nuevas plantas:
- Alquilación
- Desulfuradora de Gasóleos
- Recuperación de Azufre
- Cogeneración

1999/2006
Nueva planta de hidrógeno
Reducción benceno en reformado catalítico
Ampliación capacidad desulfuradoras
Transformación a hidrocraqueo suave
Nuevas plantas desulfuradoras:
- Gasolina y gasóleo
- Recuperación de azufre

2012
URF
Modificación unidades para crudos pesados

2016
Creación de la sociedad: Petronor Innovación

2017
Primera parada del área de URF

2018
50 urte/años energiaz/con energía Petronor

2020
Creación de la sociedad: Edinor Energía Distribuida

2021
Creación de las sociedades: alba Emission Free Energy by Petronor
REPSOL INDUSTRIAL TRANSFORMATION
REPSOL CUSTOMER CENTRIC
The Repsol Commitment Net Zero Emissions by 2050

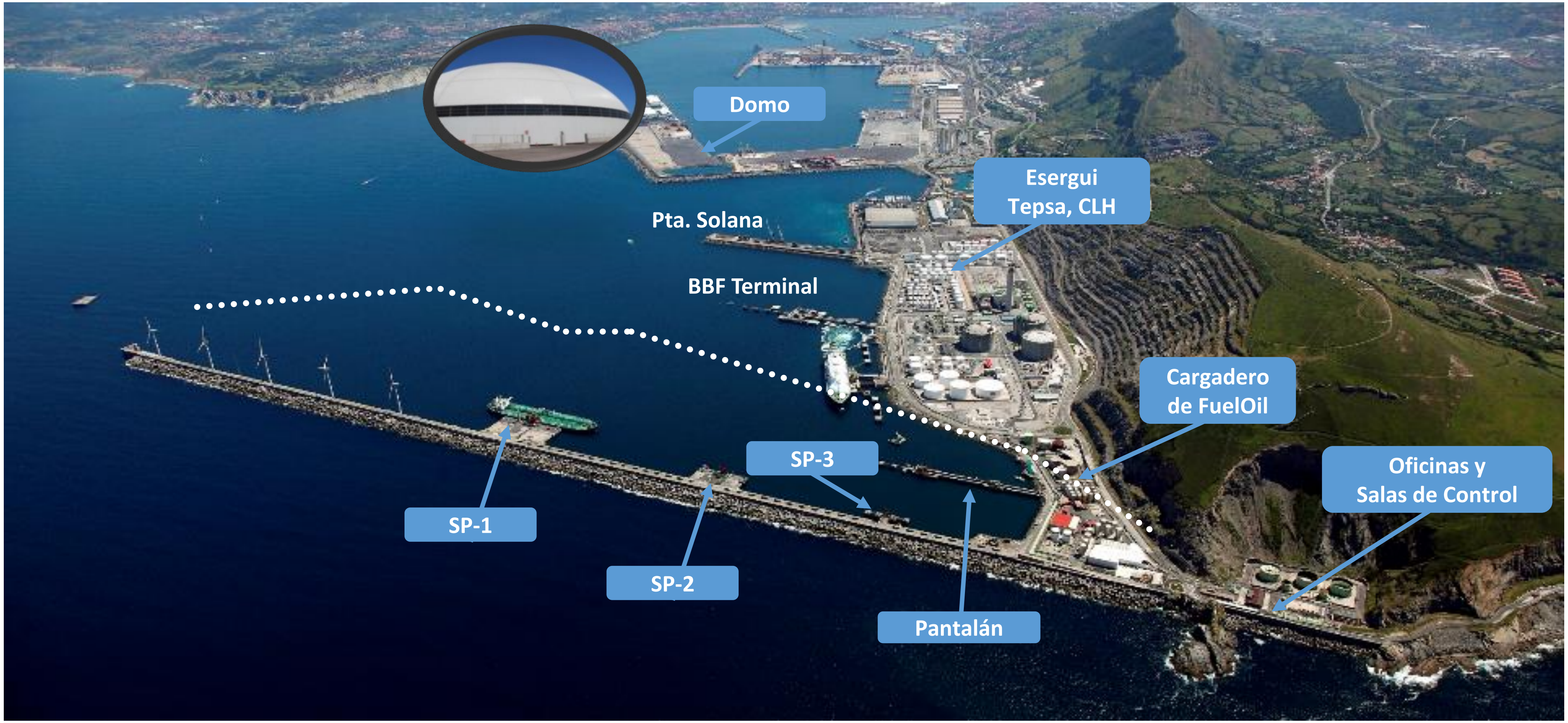
Context

Petronor today

An urban refinery of 220 Ha (300 football fields) and refining capacity for 220kbd/day…

Context

Petronor today



… and deeply integrated with the Port of Bilbao (40% of the Port's traffic)

Context

Renewable Fuels are a real and efficient solution to GHG emissions reduction in transport and important to achieve Net Zero in the sector

SUSTAINABLE

- Net Zero Emissions in their use
- From 65% to 95% GHG reduction
  vs fossil fuels in a Well to Wheel analysis
- Audited by third parties in the whole value chain

COMPATIBLE WITH…

- Existing Fleet
- Existing Infrastructure

A SOLUTION FOR...

- Hard–to-abate sectors
  Heavy duty, aviation and marine transport
  Cement, Steel and other intensive industries
- Waste & Residue Management – Circular Economy

Context

Renewable Fuels can be obtained through different Routes

Route		WASTE USED	TECHNOLOGY	MARKET
Lipidic		Used Cooking Oils and lipidic waste from agrifood industries	**Hydrogenation**	▪ Light Duty, Heavy Duty and Marine : HVO-**renewable diesel** ▪ Aviation: HEFA-**SAF** ▪ BioC3 y bionaphtha for the **petrochemical Industry and hydrogen** production
Biological	  	OF-MSW, Industrial Organic Waste Agriculture and Livestock sector waste	**Anaerobic Digestion and Fermentation**	▪ **Biomethane** for heavy duty and marine, industry and residential. ▪ **Bioethanol** for gasoline production and SAF. ▪ **Fertilizers and biochar** as by-products
Thermochemical	 	Municipal Solid Waste Agricultural and forestry waste	**Gasification and Pyrolysis**	▪ **Renewable diesel** for heavy transport and marine ▪ **Aviation**: FT and ATJ ▪ BioC3 and bionaphtha for the **petrochemical Industry and hydrogen** production ▪ **Renewable methanol** for marine and chemicals
E-fuel		CO_2 H_2O Renewable electricity	**E- fuels**	▪ E-naphtha for gasoline and for the **petrochemical Industry** ▪ **E-diesel** for light and heavy transport and marine ▪ **E-jet for aviation**

Public

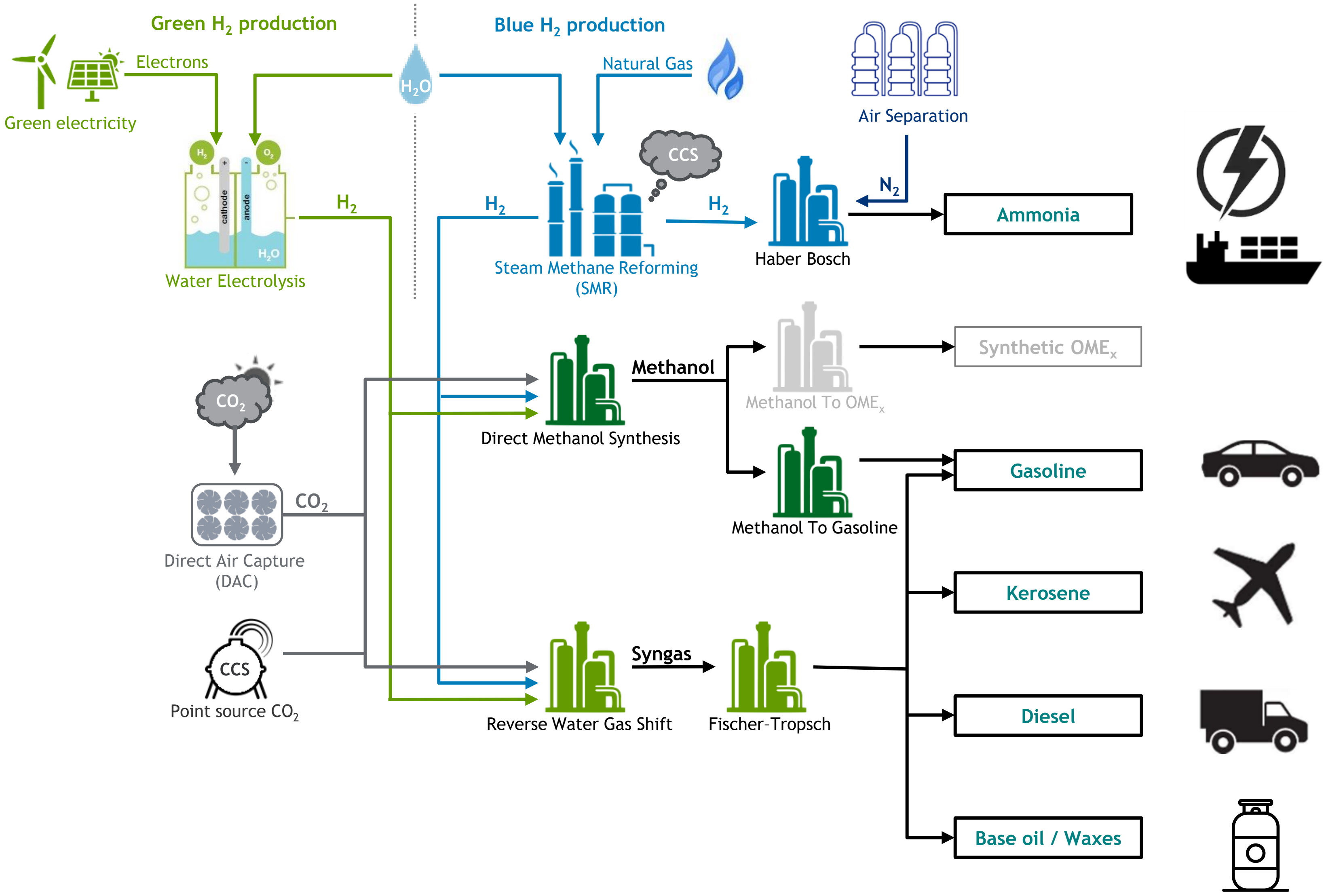
Context

What is "Power-to-Liquids" (PtL)

e-Fuels are synthetic hydrocarbons, resulting from the combination of **renewable hydrogen** and **CO_2 captured** either from concentrated (point) source or from the air (DAC).

e-fuels are also named as RFNBOs, power-to liquid (PtL), power-to-X (PtX) or power-to-gas (PtG) and synthetic fuels(1).

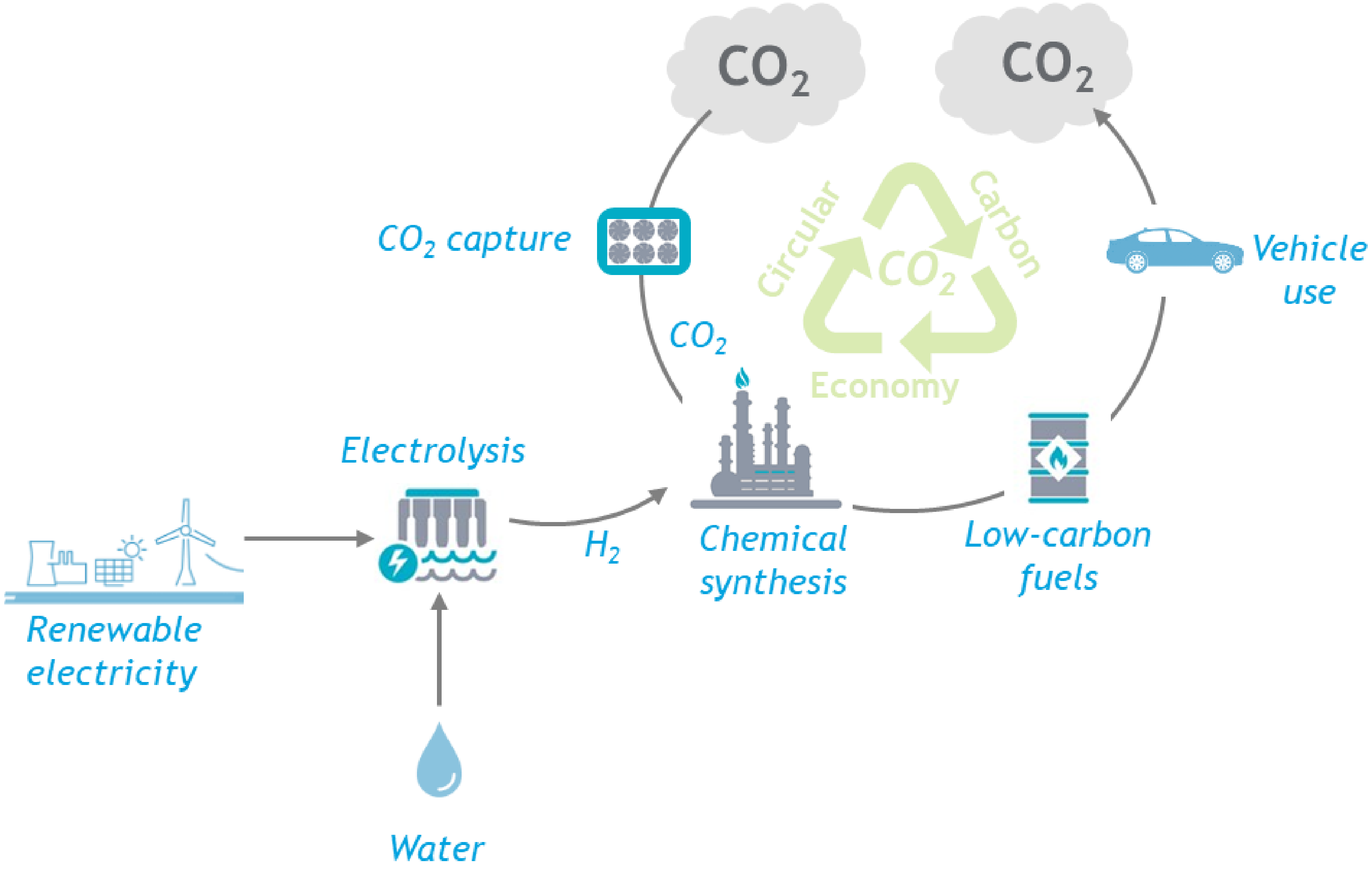
Renewable Fuels of Non-Biological Origin (RFNBOs) are defined as *"liquid or gaseous fuels which are used in the transport sector other than biofuels or biogas, the energy content of which is derived from renewable sources other than biomass"* (2)



(1) A look into role of e-fueks in the transport system in Europe (2030-2050). Concawe Review

Context

Towards a circular carbon economy: closing the loop in carbon cycle with e-fuels



Context

Why Power-to-Liquids

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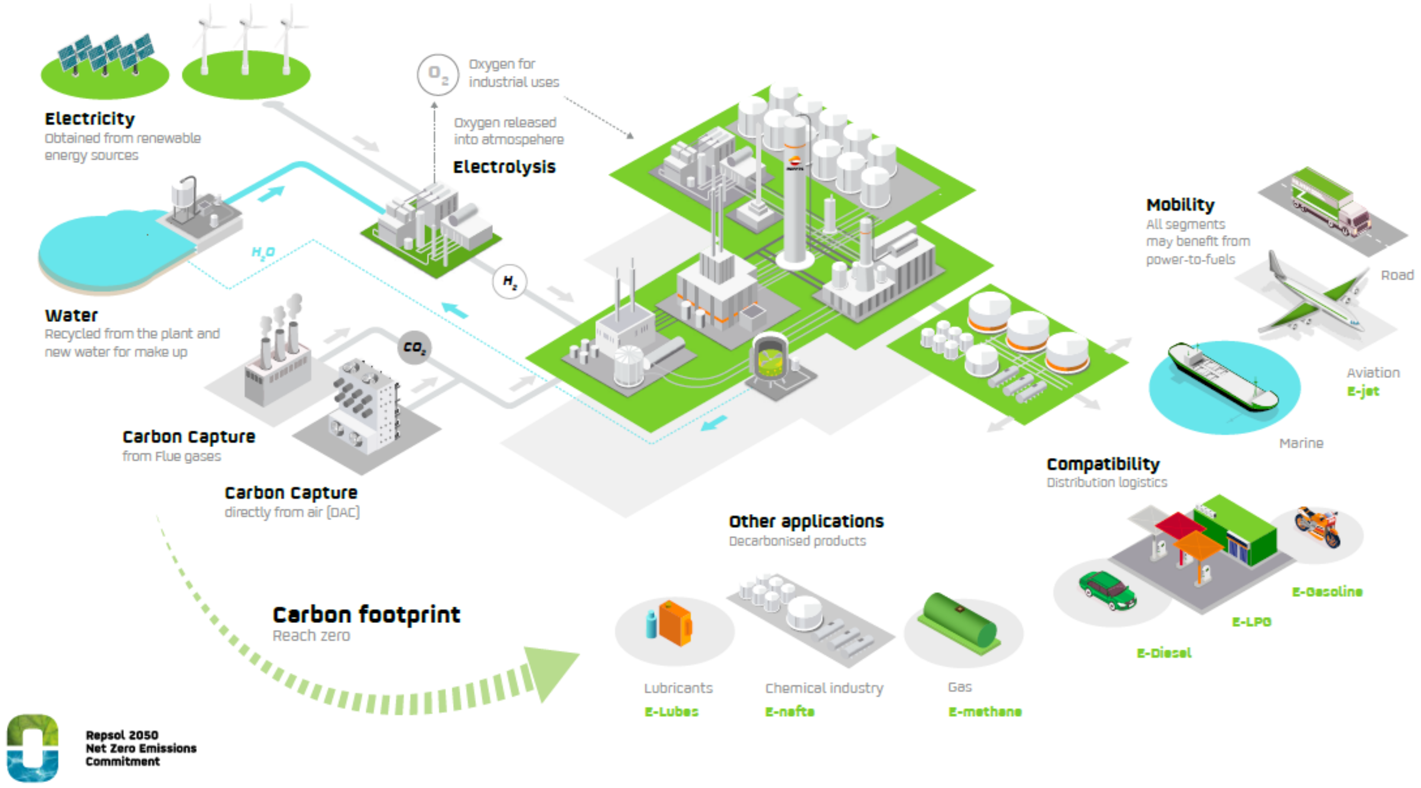
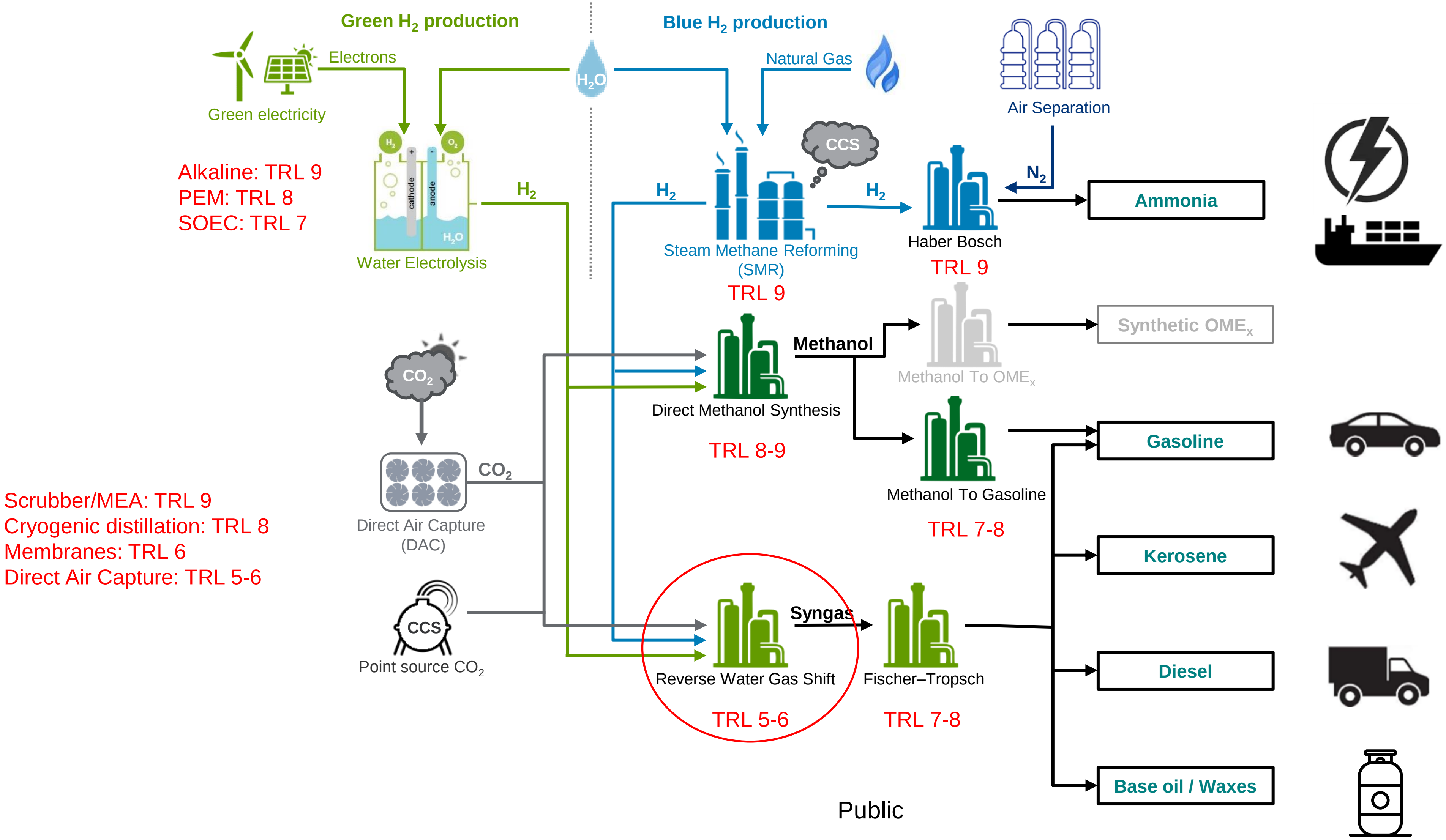
1. **Significant decarbonization potential**
2. **Compatibility with existing infrastructure and fleet**
3. **Serving fuels to wide range of sectors**
4. **Scalability potential and low footprint**
5. **Alternatives for non-fuel products (e-chemical, e-lubes)**
6. **Renewable energy vector**



Context

Drivers of PtL adoption. Technology readiness level

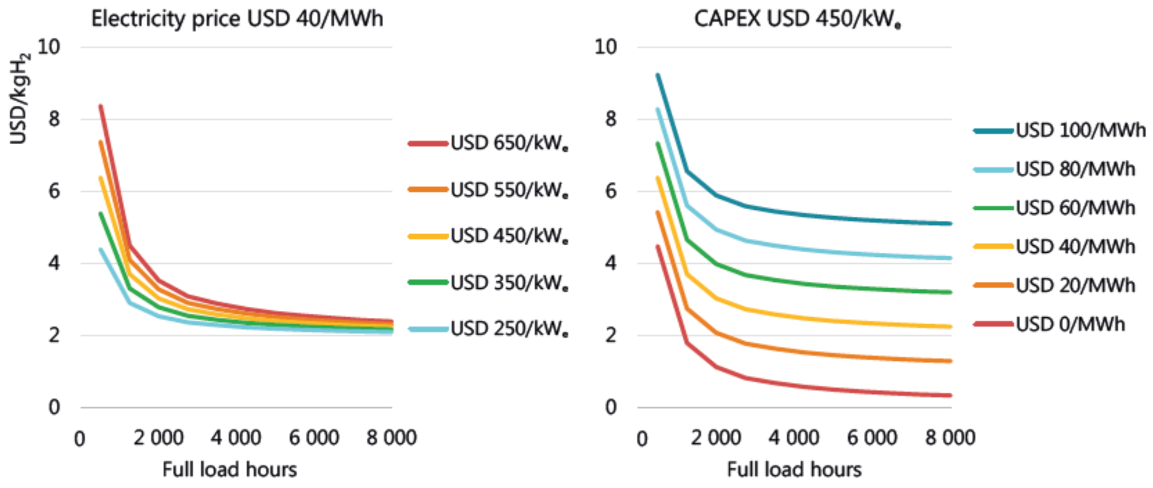
The production of e-fuels is in most cases a combination of proven technologies that through technology optimization and other cost reduction measures can make them commercially viable in coming years.

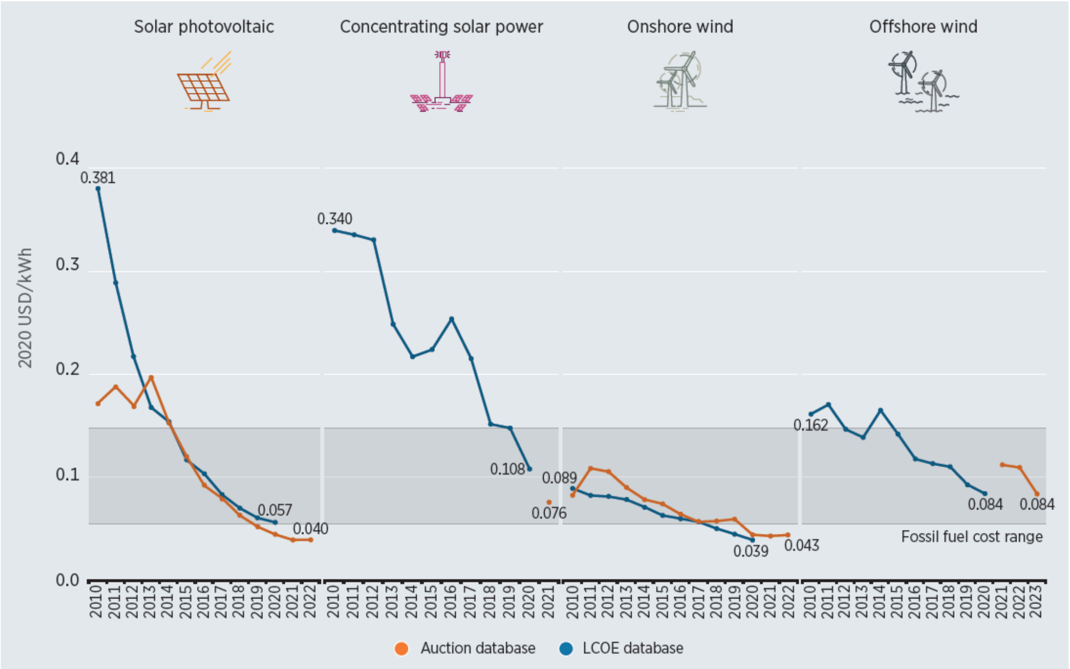


Context

Drivers of PtL adoption. Costs

The **key enabler** for a cost competitive e-fuels production is the price of **renewable hydrogen**, which is mainly driven by electricity cost.





Scale-up of electrolysers and automated production in combination with declining cost of solar PV and wind can lead to **significant CAPEX and OPEX reduction**.

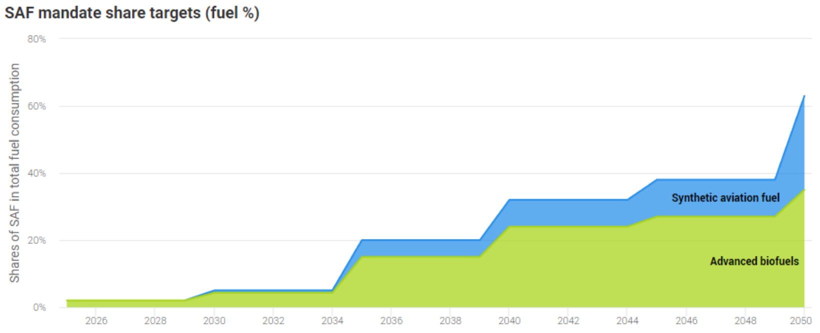
[1] IRENA. Report: Renewable Power Generation costs in 2021 (2021)
[2] IEA. The Future of Hydrogen. Report prepared by the EIA for the G20, Japan (2019)

Context

Drivers of PtL adoption. Regulatory framework

RED II. Renewable Energy Directive: Legislation currently requires 14% of energy in transport fuels to come from renewable sources by 2030, with the final share consumption of advanced biofuels and biogas (Annex IX Part A) at least 3,5% of energy by 2030 and a specific target of 2,6 %e/e for RFNBO. New proposal on REDIII increase objectives to 16% GHG intensity reduction and at least 5,7% in 2030

Fit for 55. RefuelEU Sustainable Air Transport: Aircrafts departing from EU must have a **kerosene-SAF blend** from 2025 **including 0,7% of e-fuel** starting 2030 under the ReFuelEU legislation, reaching **63% share of SAF in 2050**.

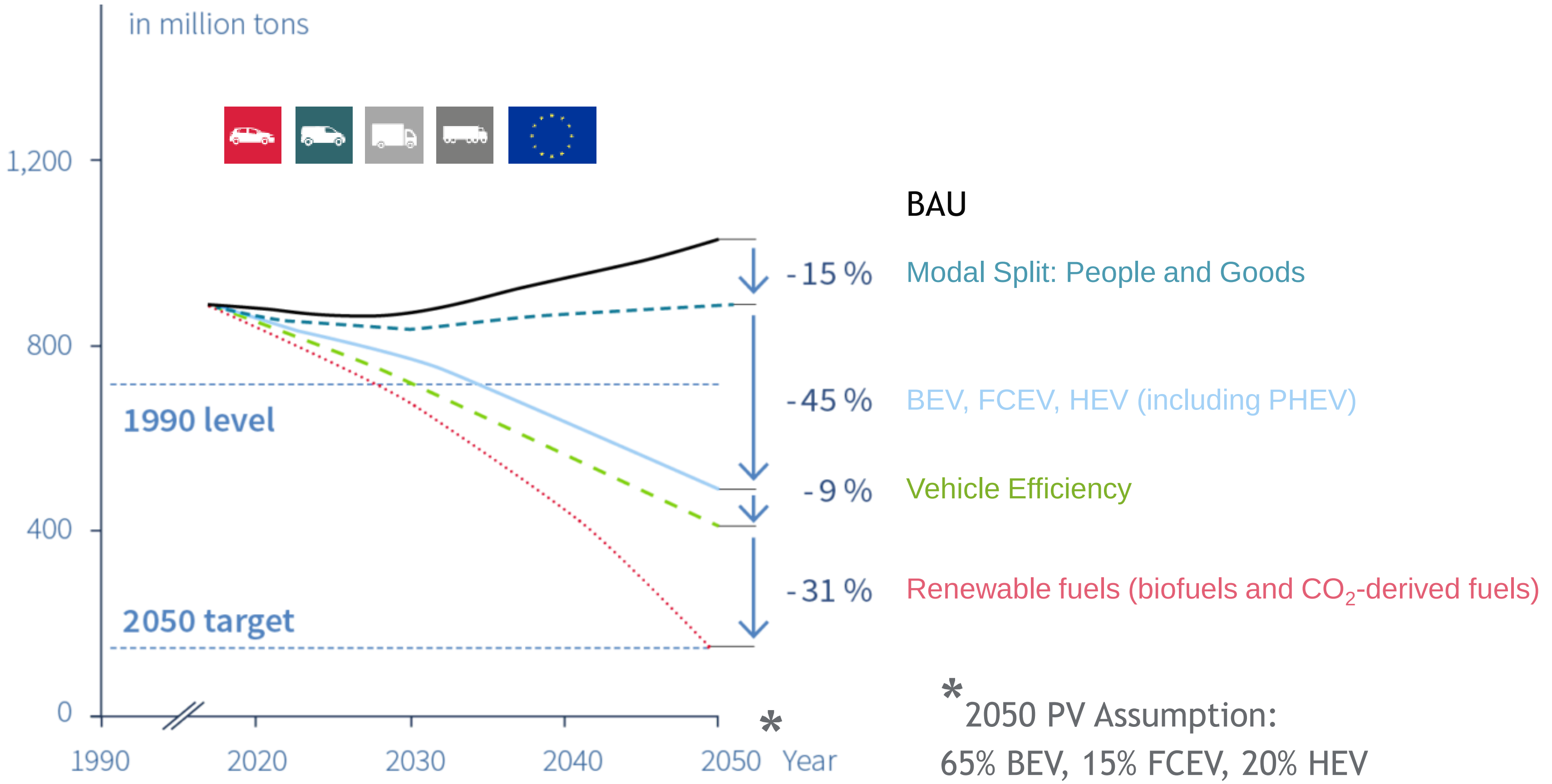


FuelEU Maritime Initiative: Initiative Launched to regulate low-carbon fuels in maritime transport, including RFNBO. MEPs adopted long-term limits on GHG reduction -20% as of 2035 and -80% as of 2050. A subquota of 2% renewable fuels by 2030 was introduced.

Regulatory certainty, clarity, and stability are key requirements to encourage private and public sector investments in e-fuels for Europe

Context

Drivers of PtL adoption. Regulatory framework



*2050 PV Assumption:
65% BEV, 15% FCEV, 20% HEV

90% CO_2 reduction demands a mix of technologies, and low-carbon fuels play a significant role

[3] https://magazine.fev.com/en/category/featured-article-en/, FEV, May, 2020

Context

Drivers of PtL adoption. Regulatory framework

Power Generation & H_2 Source

- Impact of intermittency and role of grid exchange
- Cost effectiveness of electrolysis
- Low carbon H_2

H_2

CO_2 Source

- Acceptance of CO_2 from point sources
- Acceptance of import of CO_2 from other countries
- Cost effectiveness of DAC

CO_2

Refinery & Products

- Cost effectiveness
- Integration within existing refineries
- Product certification & GHG calculation

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Planned Demonstration Plant PtL

Project plan details

DEMONSTRATION PLANT

Operational date

2025 (Demo)

Project capacity

2,3 kton/y (Demo)

CO_2 abatement

6,9 Kton/y (Demo)

Renewable electricity

10 MW (Demo)

Objective

Planned development of **first of a kind e-Fuels plant** using captured CO_2 and green hydrogen*.

Key insights

- **Drop-in** fuel that can be blended in existing engines in LDVs, HDVs, airplanes and ships.
- Demonstrate the **whole value chain of producing synthetic fuel** from CO_2 and renewable hydrogen.
- Perform **real fleet test** market/clients/partners.

Project overview

- **Synthetic fuel plant** consisting on RWGS + Fischer Tropsch unit and Upgrading unit with capacity to produce e-jet, e-diesel, e-gas, e-naphtha.
- **Flexibility scheme** to produce e-lubricants, e-paraffin wax or chemical feedstock.

Identified Partnerships

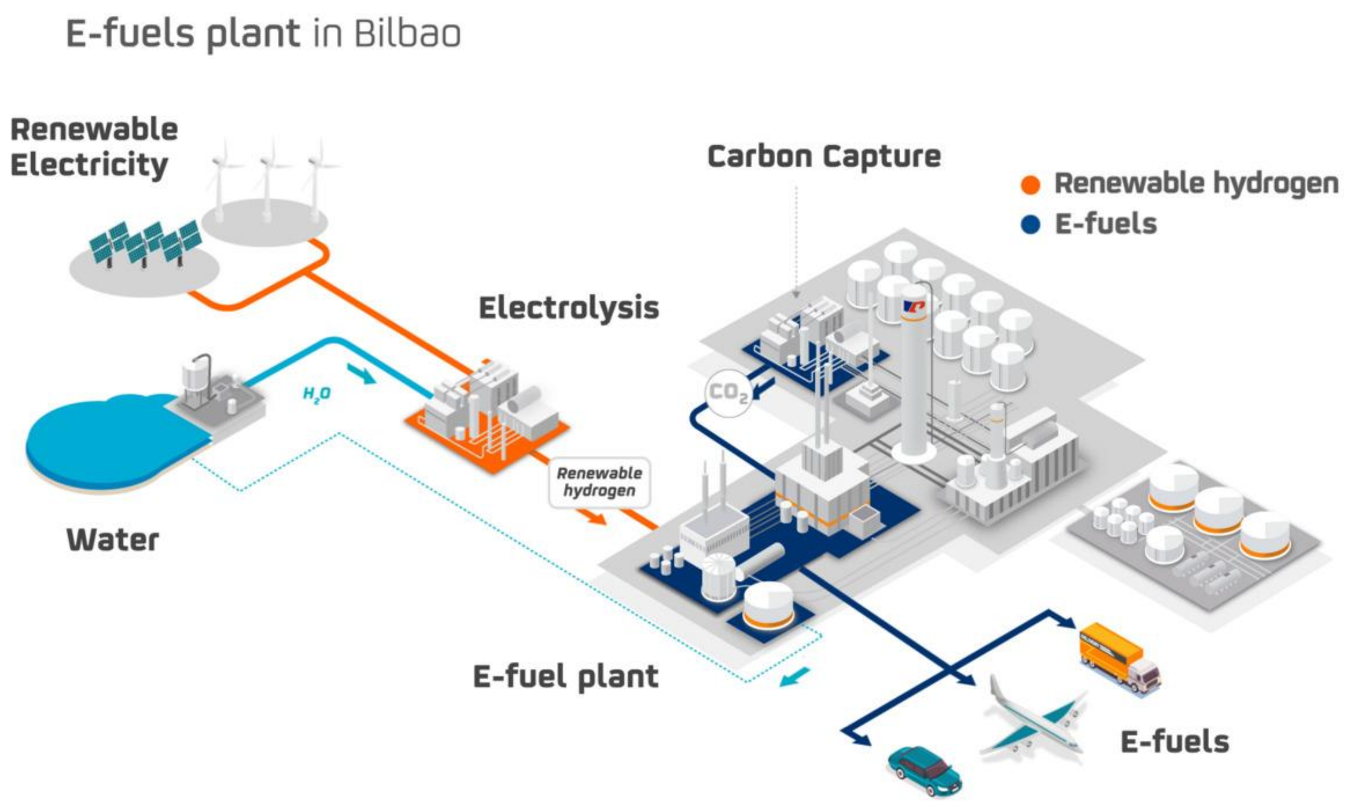
aramco	Project proponent and partner
REPSOL	Project proponent and partner
Petronor	Operation and refinery integration
JM	Technology partner
Axens	Technology partner

Planned Demonstration Plant PtL

Process Scheme and TRL

Demonstrate **technical and economical feasibility** of synthetic fuel production through Fischer Tropsch pathway, integrating and operating the technologies to produce (**e-Fuels**) from green hydrogen and CO_2 as raw material.

The Demo (**50 BPD**) located in Bilbao would allow reducing the risk on future scale up to industrial scale while producing e-fuel to homologate and perform fleet test in real conditions for target transport sectors (aviation, HD, Marine).



Planned Demonstration Plant PtL

Location

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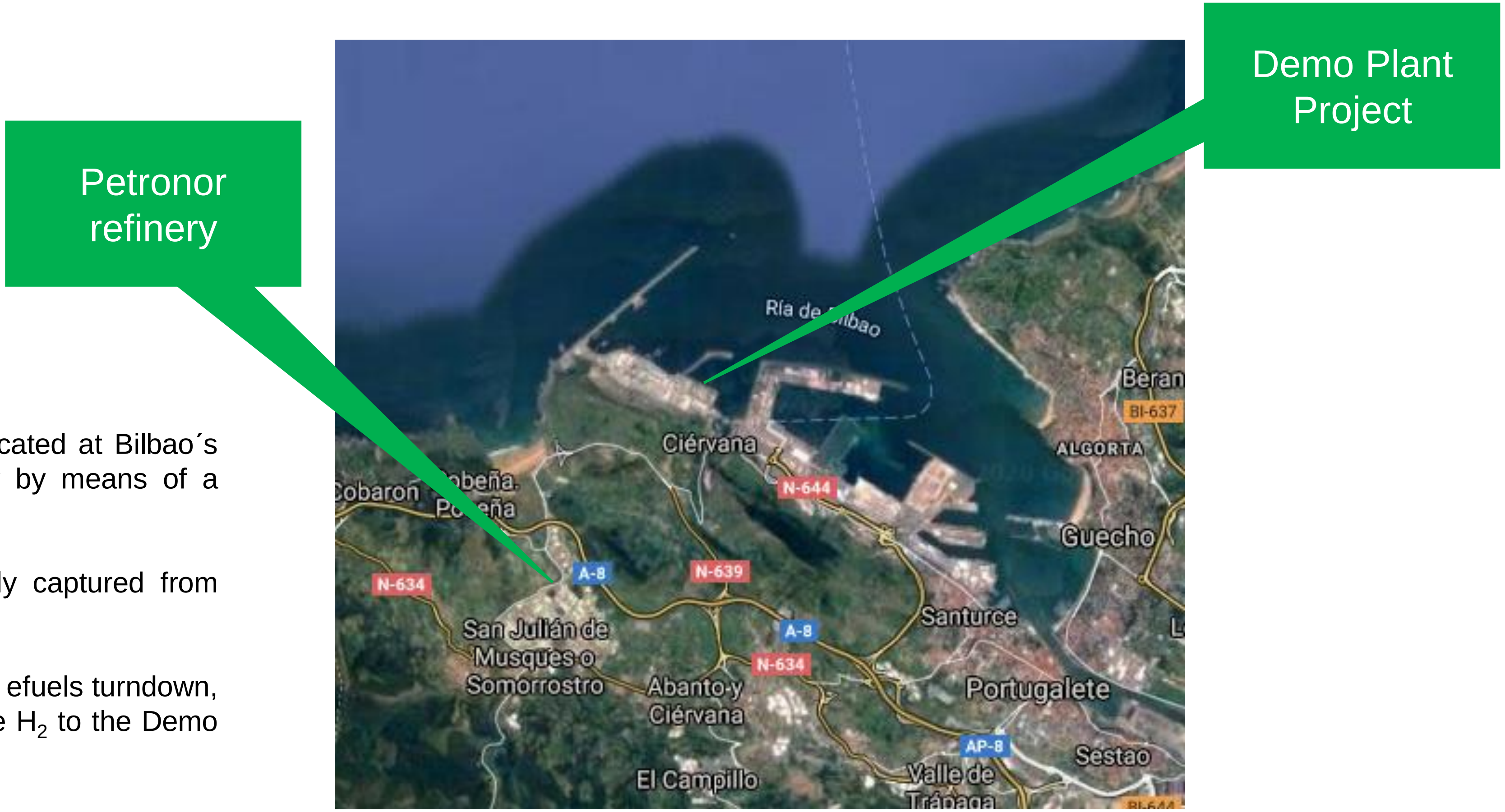

The Demo plant project has been planned to be located at Bilbao´s Harbor and fully integrated with Petronor Refinery by means of a reverse pipeline to share the following streams:

- **CO_2** from refinery to Demo asset. CO_2 currently captured from SMR and future plan for replacement with DAC
- **Hydrogen** from the Demo asset to Refinery when efuels turndown, catalyst changes. This line is reversible to provide H_2 to the Demo in case of electrolyzer failure or turndown.
- **Off gas & Purges** from Demo plant to valorize as e-fuel in Refinery furnaces.

Planned Demonstration Plant PtL

Location within the Port of Bilbao

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E-fuels Scale-up

Challenges

Efuels are expected to play a significand role in decarbonizing the transport sector allowing to accomplish the goals established but it is still expected to face some **challenges to scale up the technology**. On the other hand **new opportunities and synergies** shall arise within industrial clusters.

Business Challenges

- Cost and investment necessary for producing PtL.
- Policy framework
  - Obligation of synthetic fuel in transport sector. Fitfor55, Refuel EU Aviation.
  - CO_2 source origin
  - Hydrogen origin
  - GHG calculation
- Integration in current assets

Technology Challenges

- Scale up pilot and demo scale technologies (TRL < 7)
  - RWGS
  - Electrolysis (SOEC)
  - DAC (Direct Air Capture)
  - …
- Validation and integration the whole processes in a economically and steady operation. ***First of a kind***
  - Optimization of operation
  - Integration & energy efficiency

Engineering challenges

- Deployment of renewable Hydrogen infrastructure.:
  - Scale up of electrolyzer & grid connection
  - Scale up of biogenic Hydrogen
- Availability of pure CO2 at scale.

E-fuels Scale-up

Opportunities

E-fuels are expected to play a significand role in decarbonizing the transport sector allowing to accomplish the goals established but it is still expected to face some **challenges to scale up the technology**. On the other hand **new opportunities and synergies** shall arise within industrial clusters

Business Opportunities

- ReFuelEU legislation set up a minimum synthetic fuel in blended Kerosene SAF from 2030, and scaling up afterwards. Drop in fuel blended with conventional kerosene.
- PtL produce high quality products (low density, paraffinic) which would allow lower qualities streams when blending the finished products
- Potential opportunity to integrate e-fuels manufacturing within EU refinery complex by repurposing and reusing existing process units.
- Accelerating transport decarbonization enabled by e-fuels compatibility with existing vehicles and fueling infrastructure.

Conclusions

- Reaching ambitious GHG goals requires a mix of energy sources and technology options
- A holistic framework for GHG accounting can encourage innovation and lead to a lasting impact on GHG emissions
- Synthetic fuels are technically feasible and commercially viable, especially in areas with affordable renewable power and water
- Synthetic fuel can foster H_2 economy and CO_2 recycling investments
- Supportive regulatory framework will be key to encourage investments in the e-fuels value chain.
- Integration within a refinery offers multiple optimization opportunities
- The planned Demonstration Plant at the Port of Bilbao aims to demonstrate the whole e-fuels value-chain, which will be key for any future commercialization efforts and for decarbonization of aviation.

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