bp

The future of refining

The future of refining **is change**

Refined oil products are a driving force behind modern society

Whether it's gasoline for cars, diesel for trucks, trains and ships, or jet fuel for planes – refined oil products keep the world on the move.

Refined oil products are everywhere. They are in the plastic packaging that protects goods – keeping food fresh and medicine safe. They can be found in the equipment used by health professionals in hospitals. And in the asphalt in the roads and rubber in the tyres used by the ambulances that take people there.

Refined oil products are also in the textiles used for clothes and the detergents used to clean them. And they are in laptops, tablets and smartphones – helping keep the world connected in the digital age.

Flexing for the future

Refineries have served communities, supplied industries, and powered economies for more than a century – transforming as the energy system has changed.

As societies transition towards a lower-carbon future, refineries have an opportunity to play an important role – helping provide the energy solutions for tomorrow while meeting the demands of today. Transforming to produce not only traditional energy products, but becoming integrated energy hubs, capable of producing lower carbon products such as biofuels, as well as green and blue hydrogen.

The continued importance of "molecules" in the energy mix

In 2022, electricity accounted for less than 20% of global energy use, according to data from the Statistical Review of World Energy by the Energy Institute. The remaining 80% of energy was consumed in the form of molecules, such as oil and gas.

For many energy users, switching to low carbon electricity can be an effective and cost-efficient way to reduce emissions. That is why electrification is expected to become a major driver of the energy transition. Over time, the share of electrons in the energy mix will grow and the share of molecules fall.

There are limits to electrification, however. Hard-to-abate industries and transport sectors cannot rely on commercial electrification, for example because they require high energy densities or high temperatures that electricity cannot provide. These sectors will continue to rely on molecules to power their activities. Their ability to decarbonize depends on access to low-carbon molecules. Any net zero strategy therefore needs to address both energy vectors: low-carbon electrons and low-carbon molecules.

As we will see, refineries can rely on low-carbon electrons for some of their operations, while becoming a user and producer of low-carbon molecules, offering new products that help hard-to-abate sectors decarbonize.

This brochure outlines pathways for the transformation of a conventional refinery into an integrated energy hub. Whether and when low-carbon technologies become investable will depend on several factors, including government policy and demand growth for low-carbon products. The future of refining is change. But what will not change is bp's commitment to safe, reliable and compliant operations. This will always be our number one priority.

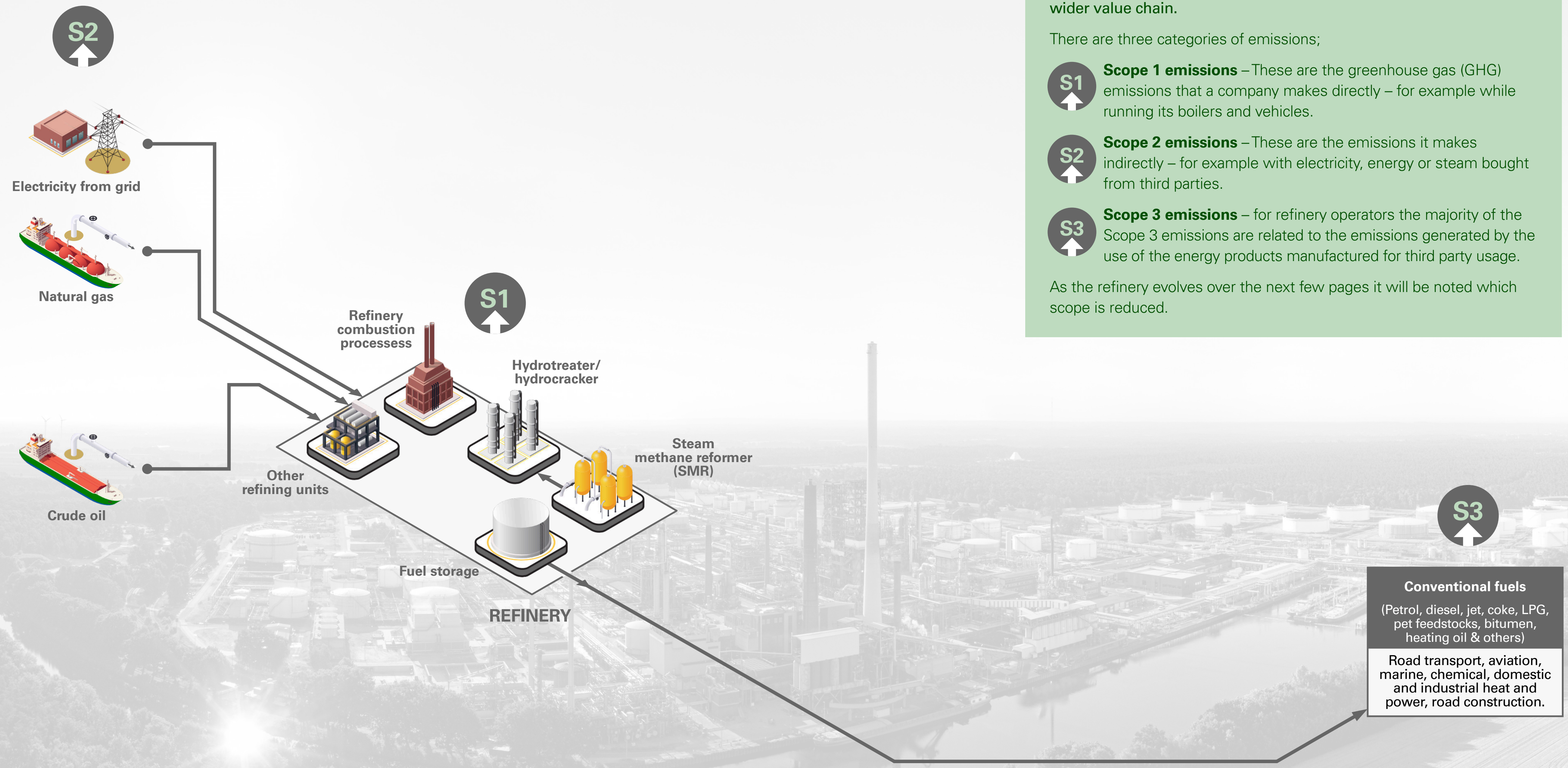
What are Scope 1, 2 and 3 emissions?

Scope 1, 2 and 3 is a way of categorising the different kinds of carbon emissions a company creates within its own operations, and in the wider value chain.

There are three categories of emissions;

- S1 **Scope 1 emissions** – These are the greenhouse gas (GHG) emissions that a company makes directly – for example while running its boilers and vehicles.
- S2 **Scope 2 emissions** – These are the emissions it makes indirectly – for example with electricity, energy or steam bought from third parties.
- S3 **Scope 3 emissions** – for refinery operators the majority of the Scope 3 emissions are related to the emissions generated by the use of the energy products manufactured for third party usage.

As the refinery evolves over the next few pages it will be noted which scope is reduced.



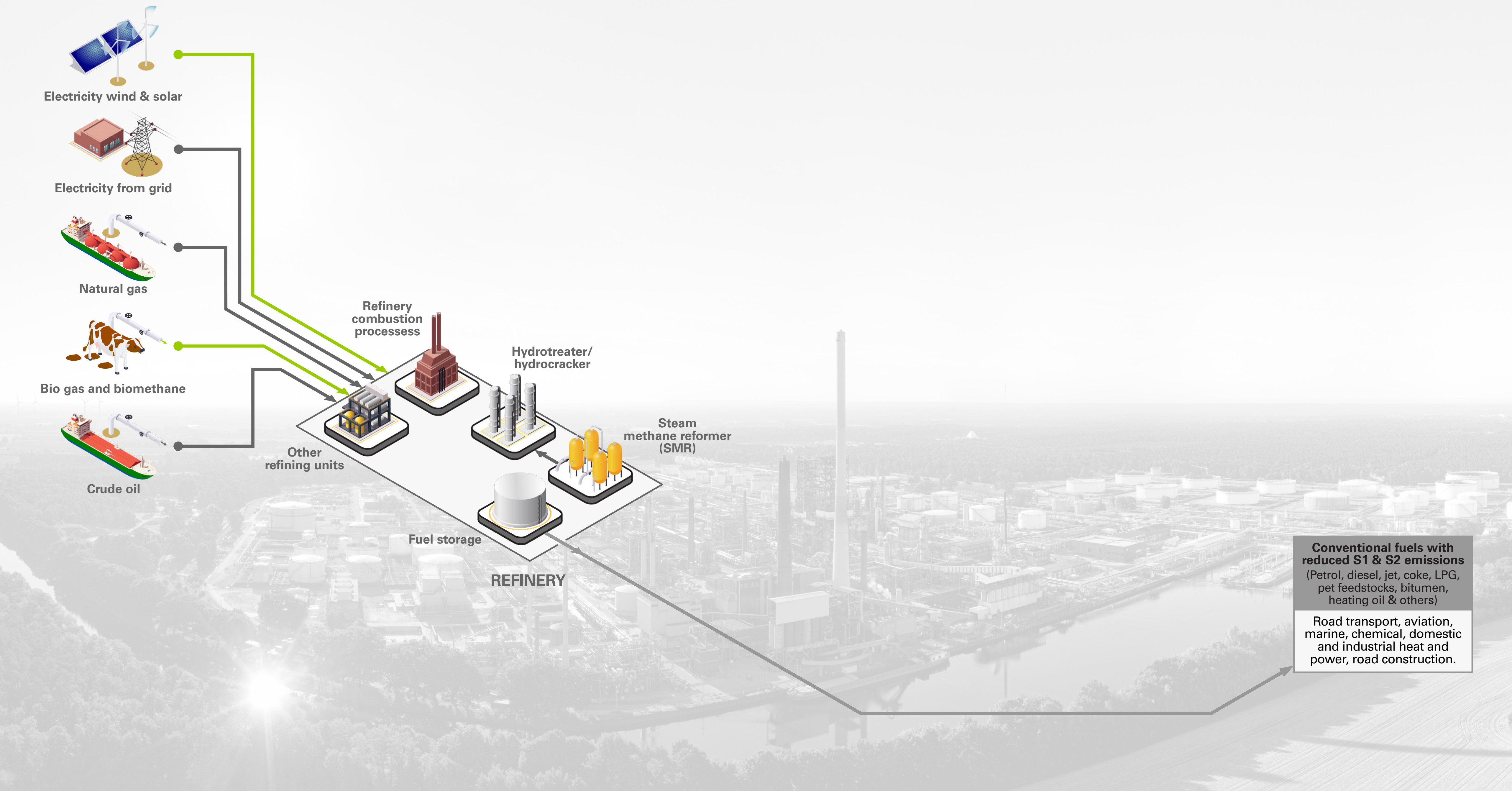
Conventional refining set-up

In a conventional refinery, the oil's journey begins with its transport to the site by ship or pipeline. Once there, different refinery units process it to create conventional products, such as fuels or chemicals, that are essential for the everyday life of our societies today.

The hydrotreatment and hydrocracking units are at the core of the refining process. They require a substantial amount of hydrogen. Today, this is usually 'grey hydrogen' produced with fossil feedstocks using, for example, a steam methane reformer (SMR) operating on natural gas.

Natural gas and refinery fuel gas (RFG), a by-product of the refining processes, power the refineries' furnaces, boilers, and gas turbines. Electricity from the grid or refinery cogeneration units supply other refining operations.

Refineries usually invest in heat recovery and other technologies to reduce costs from energy consumption and operational (Scope 1) emissions.



Alternative energy sources

The introduction of lower-carbon energy sources is a first step to shift the refinery's emissions profile. The refinery still produces conventional products but reduces its emissions from its operations and local power production (Scope 1) and emissions from the energy sources it buys from third parties (Scope 2).

Typically, renewable electricity sources can replace electricity either with direct connection or through the grid via power purchase agreements (PPAs). In addition, biogas or biomethane can replace natural gas.

If the refinery sources some or all lower carbon energy locally, it will help to support local low carbon industry e.g. local biogas plants or solar/wind developments and possibly increase energy security.

Biofuels production

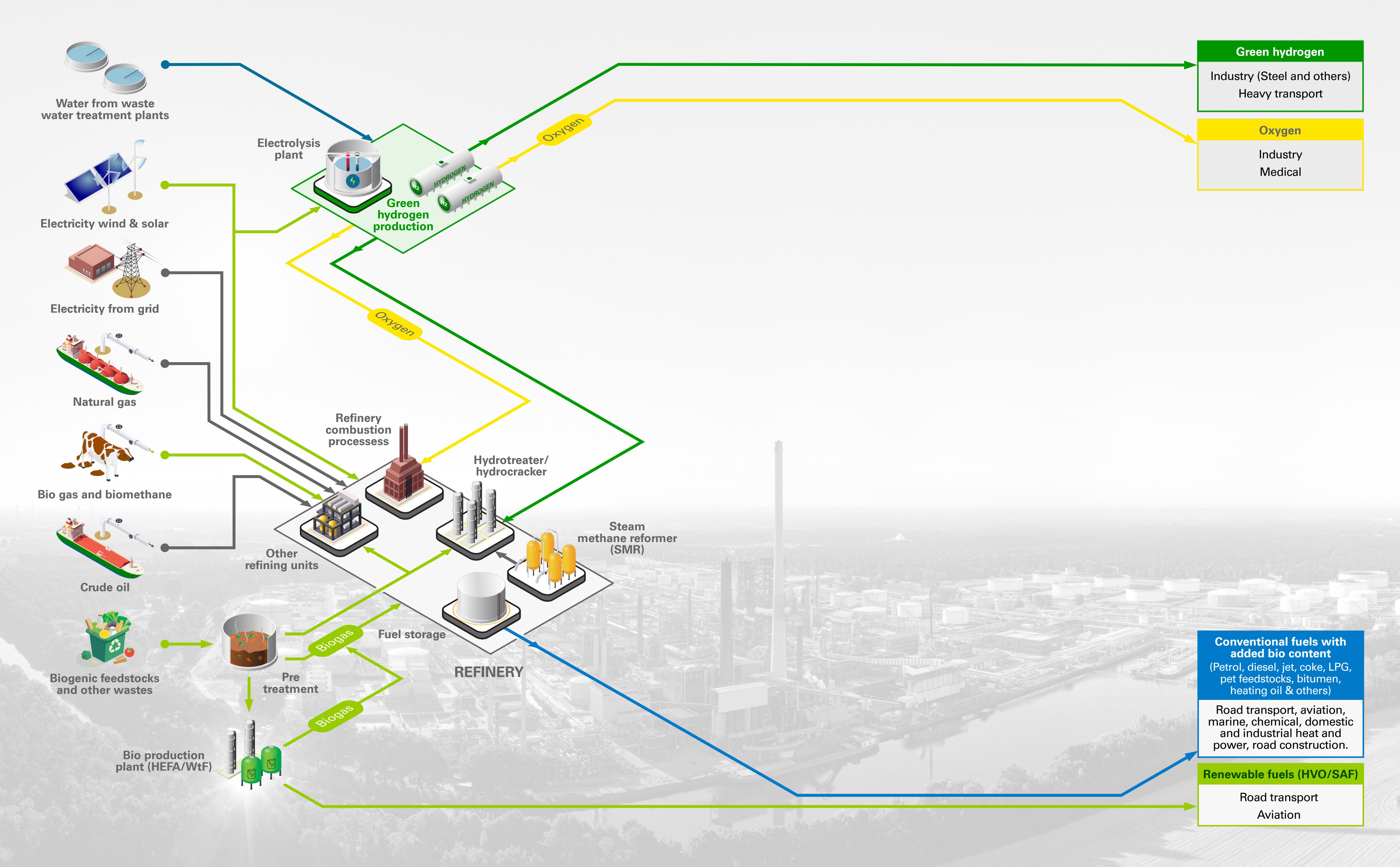
The refinery can reduce end consumer emissions (Scope 3) and tap into new markets by adding biofuels to its portfolio. Biofuels are often based on biogenic feedstock from residual origin: used cooking oils, non-edible vegetable oils or animal fats, municipal organic waste, or agricultural and forestry residues. Eligible feedstocks are subject to detailed sustainability regulations.

Biofuels through co-processing

After the bio-feedstock arrives by ship or truck, a pre-treatment plant removes its impurities. The refinery then processes the bio feedstock alongside conventional hydrocarbons. This delivers conventional fuels with added biofuel content, resulting in lower carbon fuels. One advantage of co-processing is its cost-effectiveness. The refinery can use its existing infrastructure with only limited adaptations, while reducing end-user emissions (Scope 3).

Biofuels from standalone units

This option uses a dedicated facility to produce biofuels from sustainable feedstocks. Several technologies are available, but 'HEFA' (hydroprocessed esters and fatty acids) is more mature than other options like waste-to-fuels. Products include sustainable aviation fuels (SAF) or renewable diesel (HVO) that can either be blended with conventional fuels or used directly as drop-in fuels with substantially lower net emissions. These can help decarbonize otherwise hard-to-abate sectors like aviation and heavy-duty transport (Scope 3). While more capital-intensive than co-processing, standalone units that are co-located with refineries can still take advantage from existing infrastructure like utilities, blending and terminal capacity.



Green hydrogen

Lower-carbon hydrogen will play a crucial role in the refinery of the future, with zero-carbon 'green hydrogen' being one of its representatives. Green hydrogen is produced by splitting water from refinery or third party (e.g urban) treatment plants or other sustainable sources of water into hydrogen and oxygen using renewable power in an electrolyser. Oxygen can be used either at the refinery (e.g. FCC or oxycombustion) or sold as a product.

Green hydrogen has two main applications:

Intermediate in refining

Firstly, it can replace grey hydrogen in the refinery, reducing its operational emissions (Scope 1):

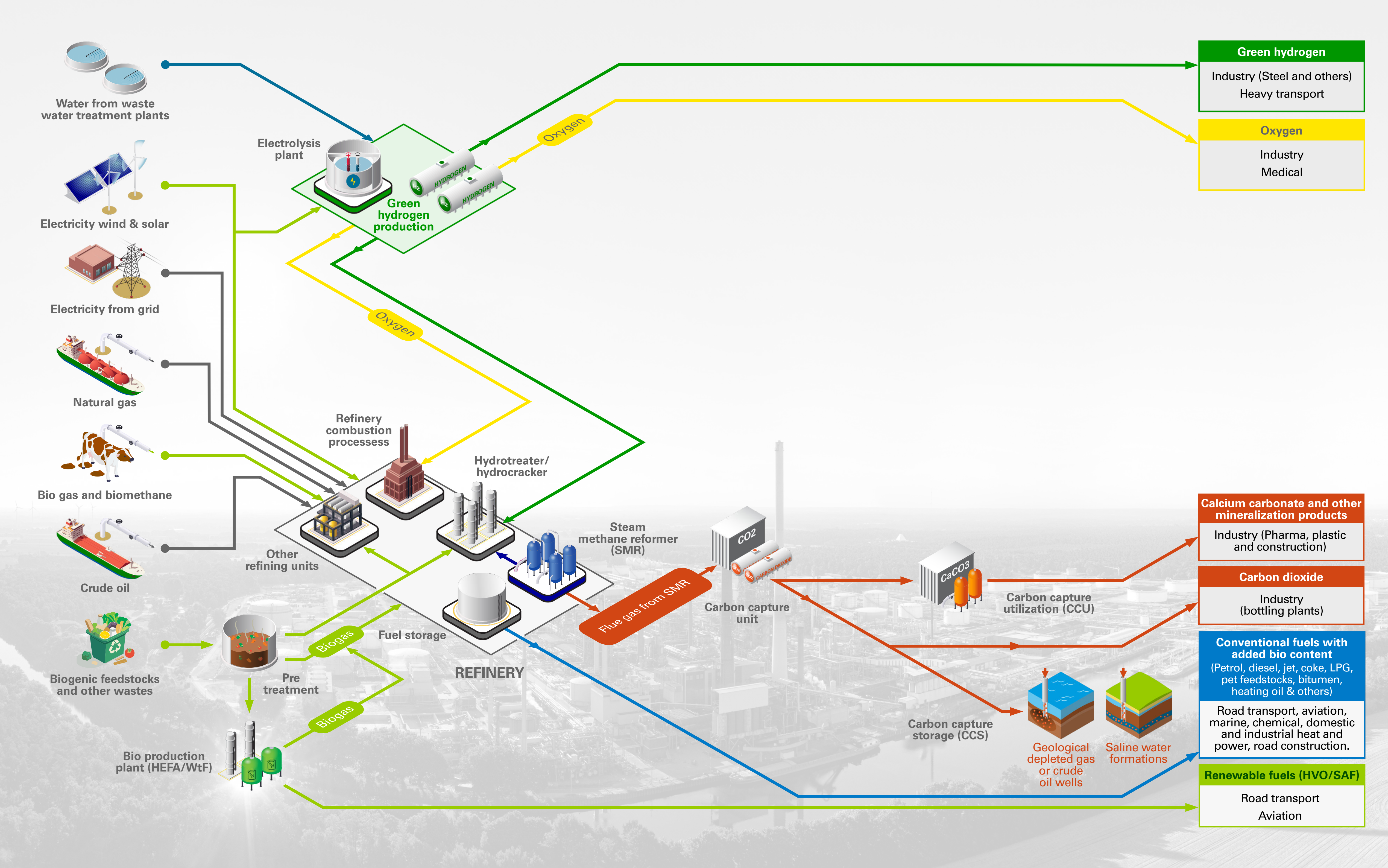
- in conventional fuel production at the hydrotreaters and hydrocrackers,
- in biofuels production at the stand-alone unit for the bioproduction.

As most of the green hydrogen will chemically bond with the conventional fuels produced, it will also reduce their carbon footprint (Scope 3).

Decarbonized product

Secondly, green hydrogen can serve as a decarbonized feedstock or product (Scope 3):

- by selling it to hard-to-abate and energy-intensive industries such as steel production,
- as a fuel for H_2 vehicles (FCEV – fuel cell electric vehicles),
- as a means to produce e-fuels,
- source for low-carbon ammonia: a specific plant can transform it into low-carbon ammonia.



Carbon capture from conventional hydrogen production

Carbon capture, utilization, and storage (CCUS) can help refineries reduce their process and product emissions (Scope 1 and 3) and offer a new range of products. However, integrating CCUS into refinery operations is complex and requires new infrastructure and material investments.

Blue hydrogen with low or negative emissions

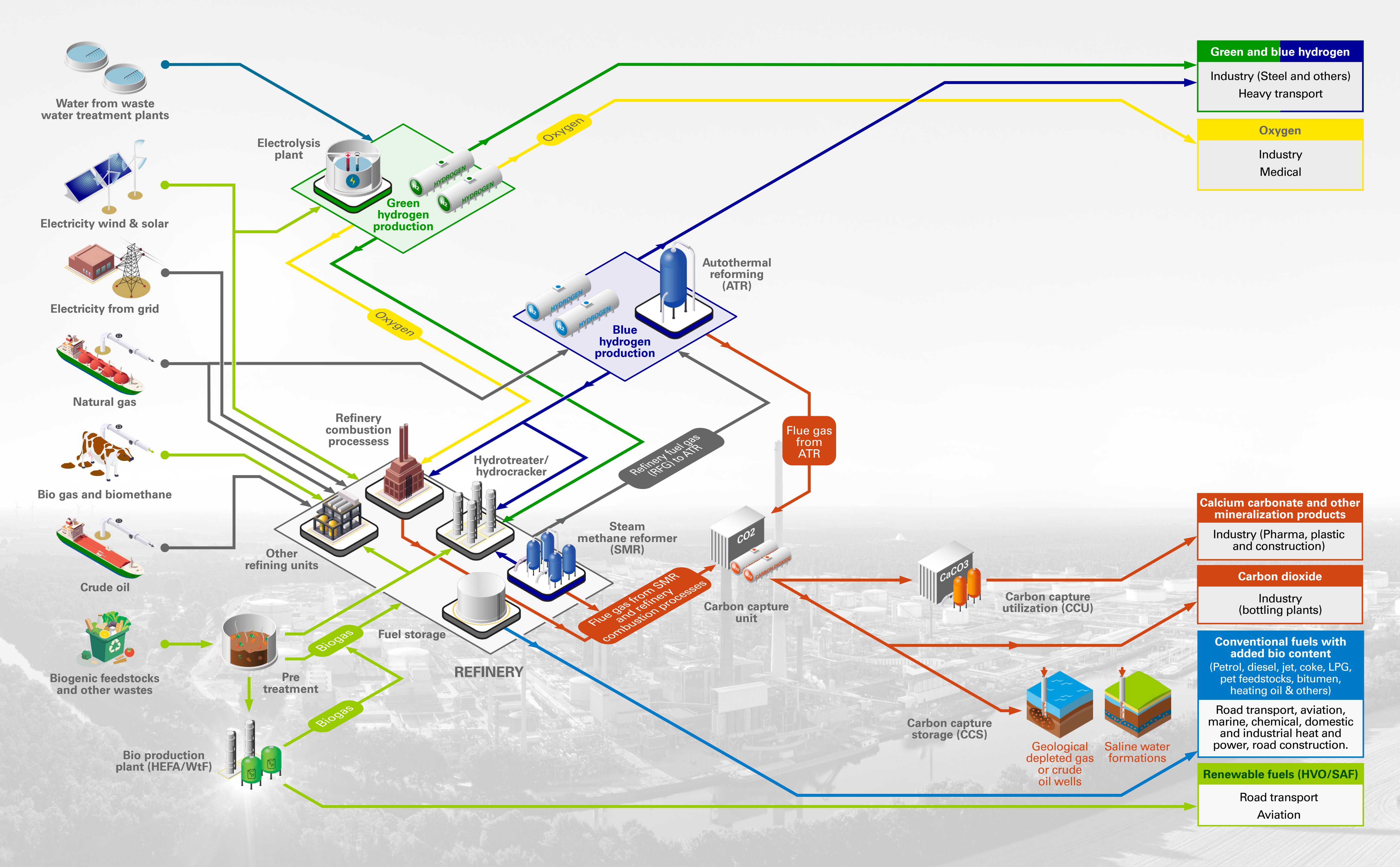
The refinery can produce low-carbon 'blue hydrogen' by capturing the CO_2 emitted from its conventional hydrogen plants, such as steam methane reformers (SMR) or partial oxidation (POX) units. If, in addition, the refinery replaces the natural gas used in its hydrogen plants with biomethane, the captured CO_2 will be of biogenic origin, and the blue hydrogen will have below-zero (negative) emissions. Blue hydrogen can serve the same purposes as the green hydrogen on the previous page.

Storing or using the carbon

Captured CO_2 can be geologically stored in depleted gas or crude wells or underground saline water formations, where it will eventually mineralise.

Alternatively, the CO_2 can also serve as a feedstock:

- to produce synthetic fuels (e-fuels)
- for calcium-carbonate-type (or other mineralization processes) to manufacture products widely used in construction, plastics and the pharmaceutical industry,
- or be used by other sectors, such as bottlers of fizzy drinks.



Decarbonization of the refinery combustion equipment

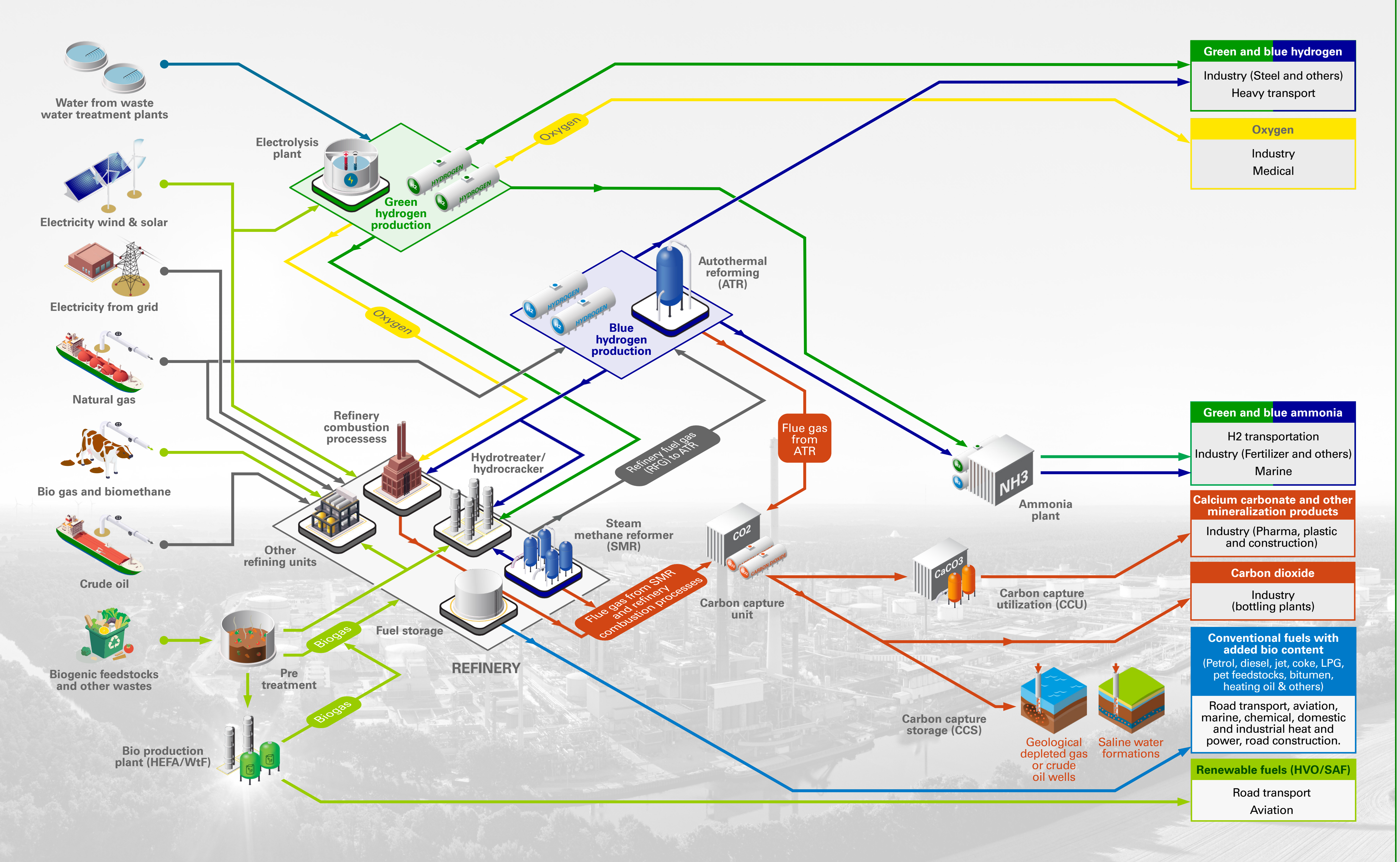
Conventional refineries use natural gas and refinery fuel gas (RFG), a fossil byproduct from refining, to power their furnaces, boilers, and gas turbines. Two options exist to reduce operational emissions (Scope 1) from these combustion processes:

Post-combustion capture collects the CO_2 of the flue gas after the combustion of the fossil gases in the furnaces, boilers, and gas turbine stacks for future use or storage (CCUS).

Pre-combustion capture uses autothermal reforming (ATR) to transform the RFG – and possibly additional natural gas – into blue hydrogen, using carbon capture and storage (CCUS) to remove the CO_2 from the process.

The blue hydrogen can directly power the combustion equipment of the refinery, replacing the RFG and natural gas and thereby resulting in near-zero emissions. Alternatively, it can serve the same purposes as the low-carbon hydrogen on previous pages:

- as intermediate in the refinery, replacing grey hydrogen,
- as a product for hard-to-abate industries or fuel cell electric vehicles (FCEV),
- or as a source for blue ammonia with further uses in decarbonizing transport and hard-to-abate sectors.



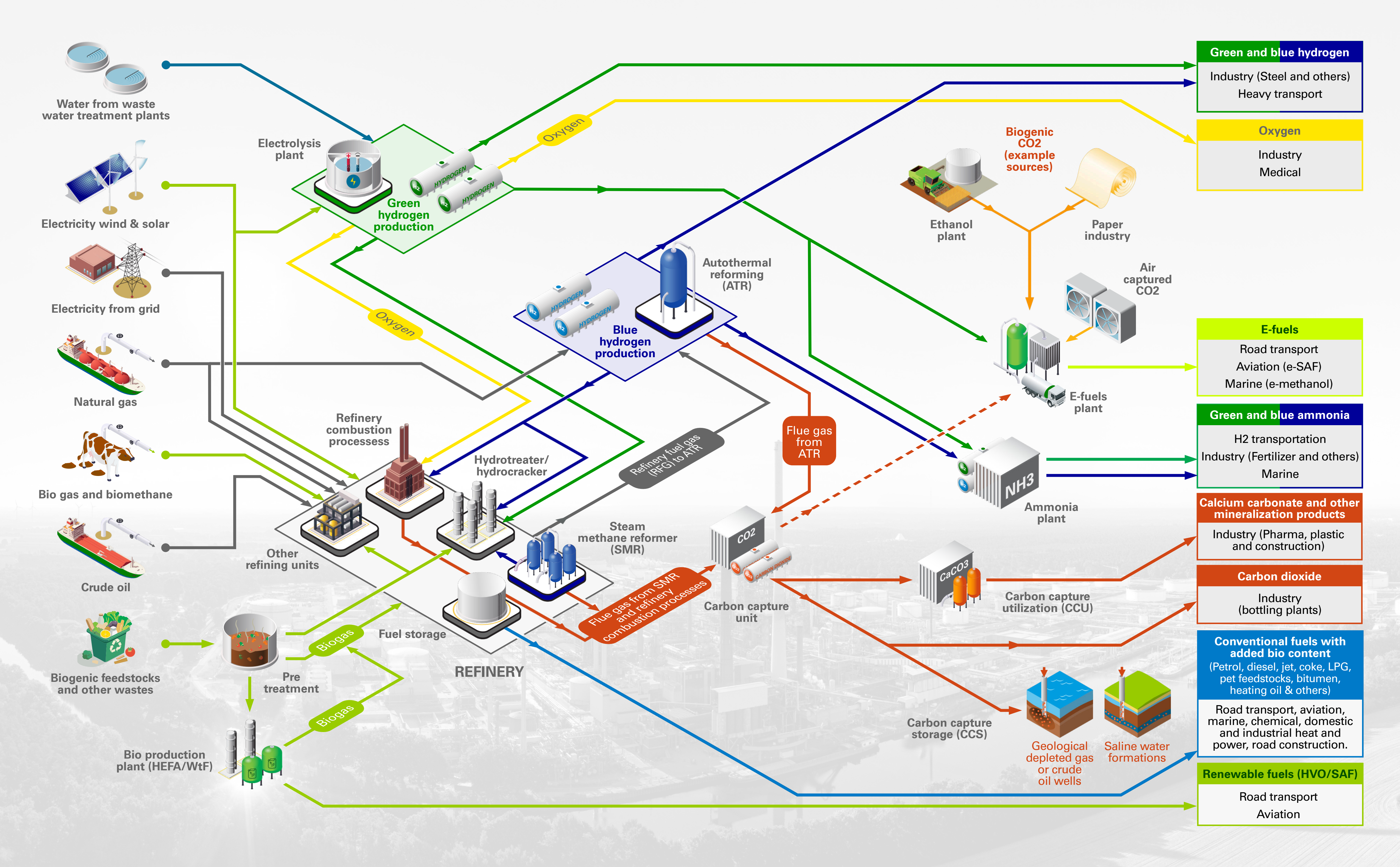
Low carbon ammonia

A dedicated ammonia plant can transform any green or blue hydrogen produced at the refinery into low-carbon ammonia and thereby help decarbonize industry and transport sectors in at least three ways (Scope 3):

Firstly, the hard-to-abate fertilizer industry can use low-carbon ammonia as a feedstock to decarbonize its products.

Secondly, the shipping industry can use low-carbon ammonia as a combustion fuel for its vessels.

Thirdly, while transporting hydrogen over long distances is challenging and expensive, suppliers can ship low-carbon ammonia and crack it back into hydrogen at the destination of use.



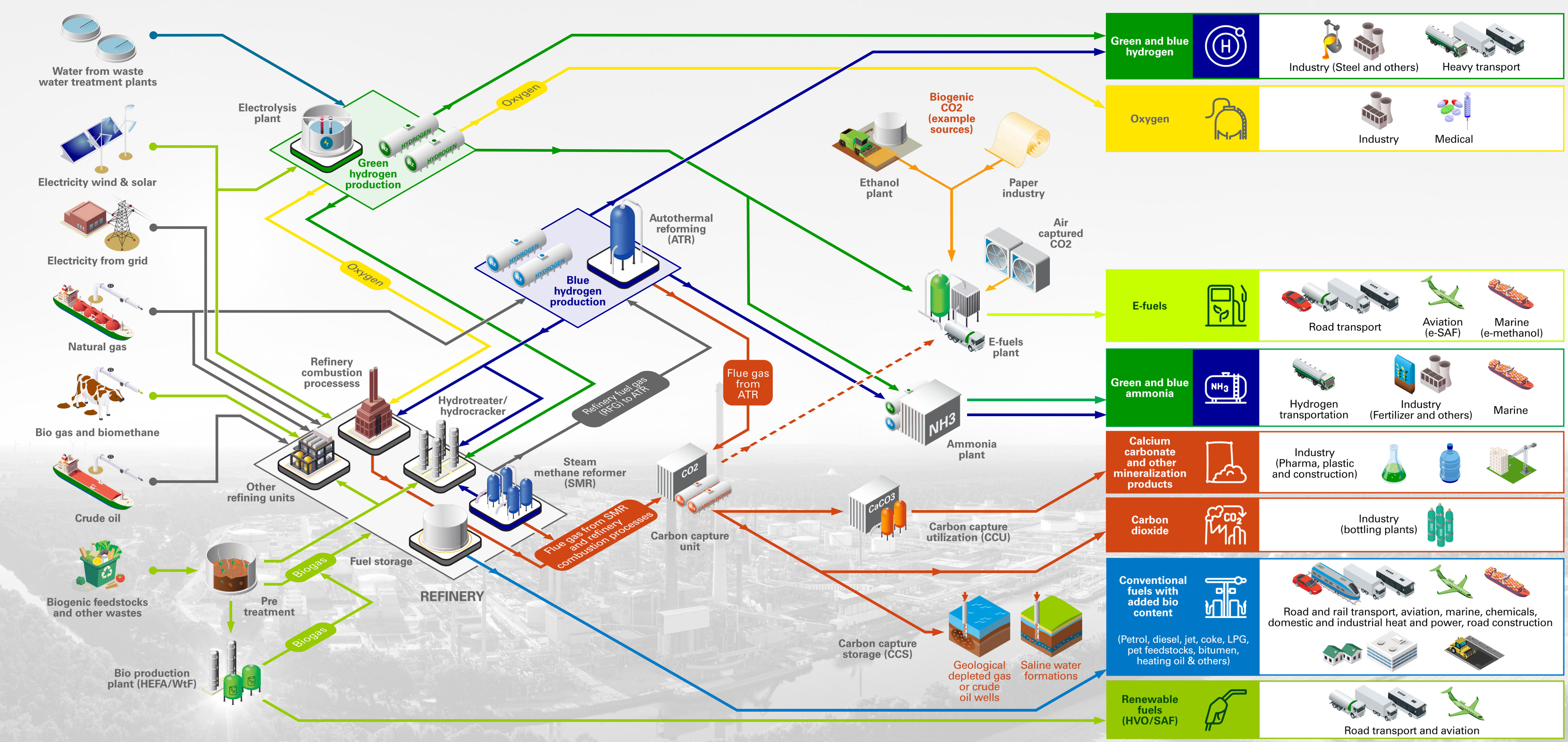
E-fuels

The production of e-fuels fundamentally alters the refinery's output by adding a suite of carbon-neutral fuels to its product mix (Scope 3).

Also known as 'synthetic fuels', e-fuels use the Fischer-Tropsch process to combine CO_2 and hydrogen into synthetic hydrocarbon molecules. This process allows for the creation of a diverse range of hydrocarbons, each with the same properties and compositions as conventional fuels like gasoline, diesel, or jet.

E-fuels achieve near-to-zero emissions thanks to the quality of their feedstocks: low-carbon hydrogen and CO_2 won from direct air capture (DAC) or biogenic sources, such as ethanol plants or the paper industry.

E-fuels have the technical potential to decarbonize the transport and mobility sector, through products such as e-SAF for the aviation sector or e-methanol for the marine industry. However, to date the expected costs of e-fuel production remain high.


Water from waste water treatment plants
Electricity wind & solar
Electricity from grid
Natural gas
Bio gas and biomethane
Crude oil
Biogenic feedstocks and other wastes
Pre treatment
Bio production plant (HEFA/WtF)
Biogas
Biogas
Electrolysis plant
Green hydrogen production
Oxygen
Oxygen
Blue hydrogen production
Autothermal reforming (ATR)
Refinery combustion processes
Hydrotreater/ hydrocracker
Refinery fuel gas (RFG) to ATR
Other refining units
Steam methane reformer (SMR)
Fuel storage
REFINERY
Flue gas from SMR and refinery combustion processes
Flue gas from ATR
Carbon capture unit
Biogenic CO2 (example sources)
Ethanol plant
Paper industry
Air captured CO2
E-fuels plant
Ammonia plant
Carbon capture utilization (CCU)
Carbon capture storage (CCS)
Geological depleted gas or crude oil wells
Saline water formations
Green and blue hydrogen
Industry (Steel and others)
Heavy transport
Oxygen
Industry
Medical
E-fuels
Road transport
Aviation (e-SAF)
Marine (e-methanol)
Green and blue ammonia
Hydrogen transportation
Industry (Fertilizer and others)
Marine
Calcium carbonate and other mineralization products
Industry (Pharma, plastic and construction)
Carbon dioxide
Industry (bottling plants)
Conventional fuels with added bio content
(Petrol, diesel, jet, coke, LPG, pet feedstocks, bitumen, heating oil & others)
Road and rail transport, aviation, marine, chemicals, domestic and industrial heat and power, road construction
Renewable fuels (HVO/SAF)
Road transport and aviation

The transition to low-carbon molecules is complex and will require government support

The following table sets out some differences between the transition towards low-carbon electrons and low-carbon molecules. The molecule transition is important but will require government support to succeed.

	Electricity transition	Molecule transition
Product	One product	Many different products
Demand	Demand for electrons expected to grow over a long period of time	Demand for molecules expected to decline from a large basis as the share of electrification grows
Competition	Regional competition only	Global trade and competition
Scale	Modular and scalable from small domestic to large projects	Requires billion-dollar investments into large installations that will serve several sectors
Operations	Usually 10-20 years	Often over 30 years
Policy support	Often supported through dedicated policy	Supported through disconnected, sector-specific policies
Technology and pricing risks	Lower – first learning curves completed	Unlikely to become competitive against fossil fuels in the foreseeable future without regulatory support
Business case	Relatively stable	Higher technological, commercial and regulatory risks

The future of refining **is change**

Refineries – part of the solution, today and tomorrow

Today, refineries provide the bulk of the molecules that society needs to produce products vital to everyday life. As societies choose to decarbonize, refineries can build on their strengths to meet demand for low-carbon products. Their transformation pathway will depend on many factors, including government policy.

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