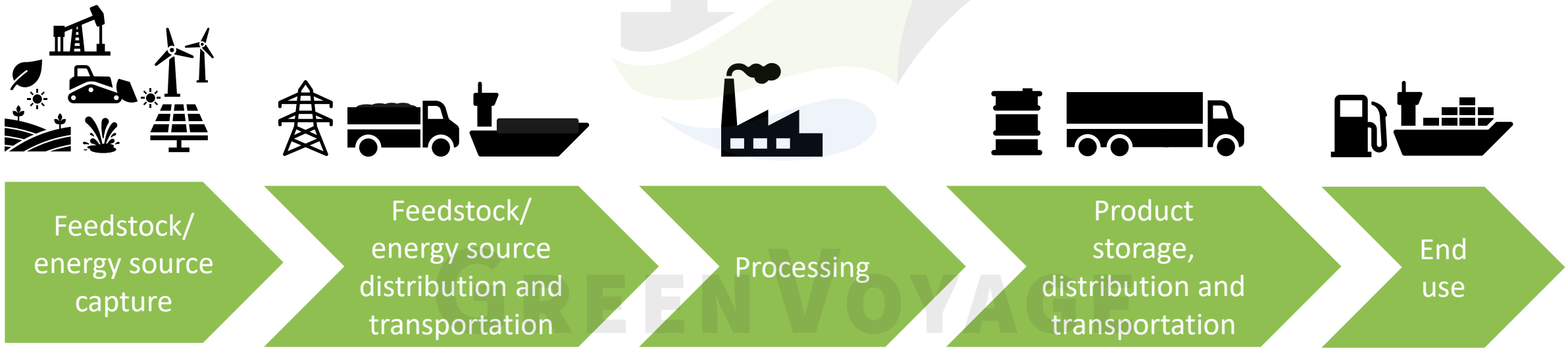
Key Concepts

Fuel value chains

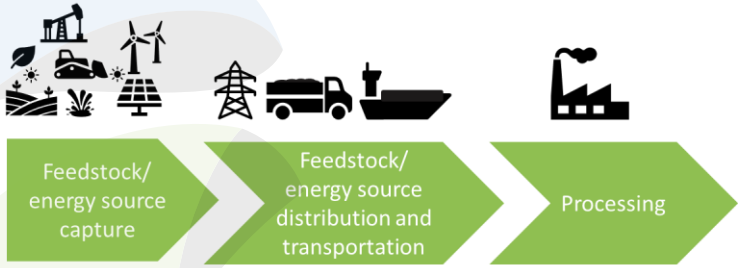
- As part of this training course, we will examine alternative fuel options by looking at their **value chains**.
- A value chain describes all the various activities that make up the process of producing and using the fuel.
- A simplified summary of a generic fuel value chain is shown below.



Key concepts we will cover

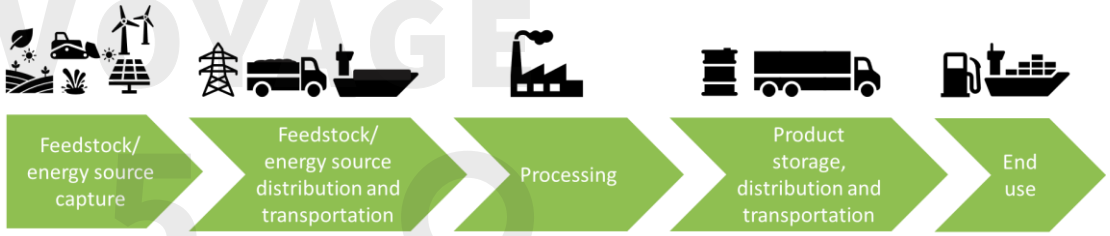
- In this section we will look at key concepts related to different parts of the value chain:

1. Concepts related to **fuel production, distribution and processing**



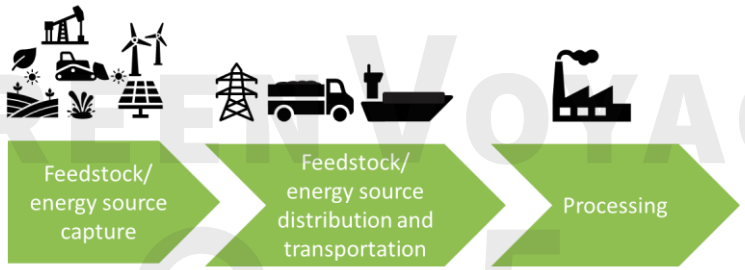
1. Concepts related to **bunkering and use of the fuel**

2. Concepts related to the **whole value chain**



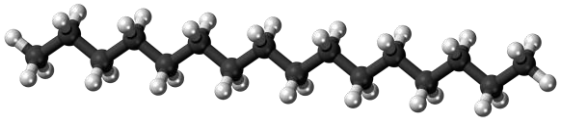
KEY CONCEPTS

1. FUEL PRODUCTION, DISTRIBUTION AND PROCESSING



Key concept: what can we make fuels with?

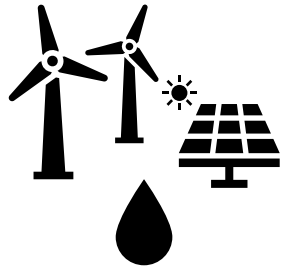
- Fuels are fundamentally made from: C Carbon **and/or** H Hydrogen



Example fuel oil molecule

- To produce fuels, firstly a source of carbon and/or hydrogen must be found. **Here are some examples**:

Biomass/ waste/oils (Source of C + H)



Electricity and water (Source of H)

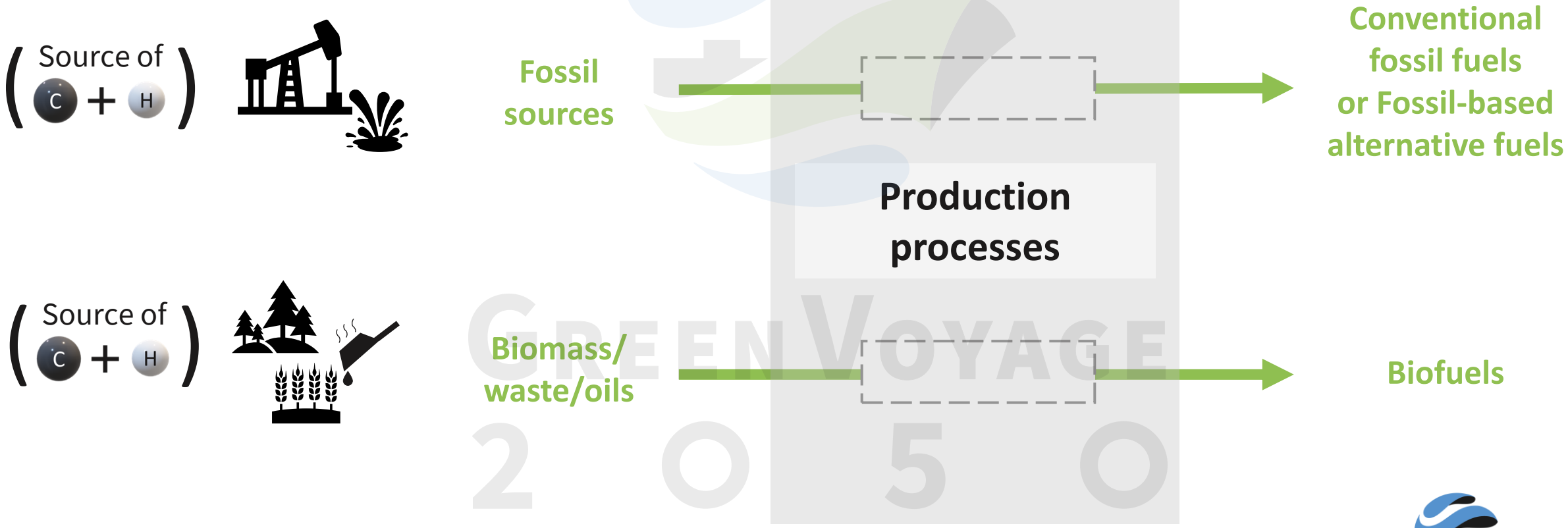
Fossil sources (Source of C + H)

Point source/ atmospheric CO_2 (Source of C)

- Input materials used in fuel production are generally referred to as **feedstocks**.

Key concept: what can we make fuels with?

- **Feedstocks** and **energy sources** can be used to produce different fuel types



Key concept: what can we make fuels with?

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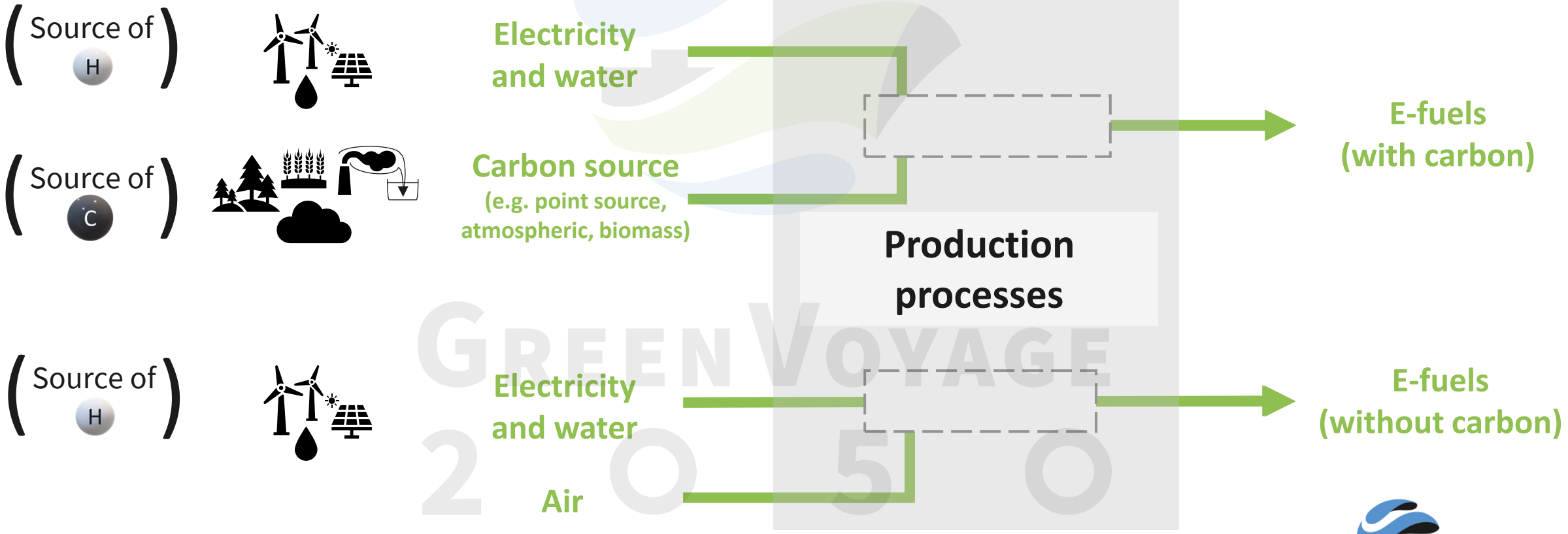


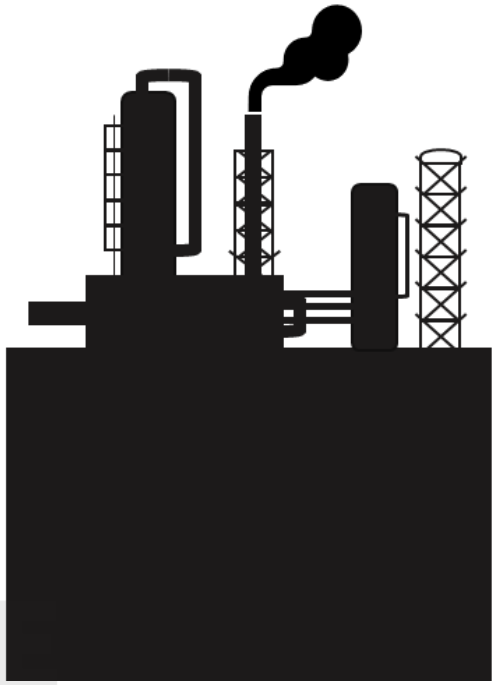
Key concept: production processes

- A variety of different processes and techniques are used to produce traditional and alternative fuels
- While many factors can influence the choice of process, such as the type of feedstock, cost of processing and desired properties of the products from the process
- Here we will look at the following:
  - Refining
  - Reforming
  - Electrolysis
  - Gasification

Key concept: production processes

Refining

- Refining is a process that turns a substance into a more useful form, either by extracting useful products or removing impurities. One of the most common refining processes is the refining of crude oil, in which vapour is condensed into various oil products in a distilling column.
- Several techniques can be used in a refining process, but one of the most important ones used in fuel production is **distillation**, which separates components of a liquid mixture that have different boiling points.
- Another important set of processes in refining are conversion processes, where higher boiling point (but less valuable) molecules are converted into lower boiling point, more valuable molecules. Examples of such processes include fluidised catalytic cracking and hydrocracking.

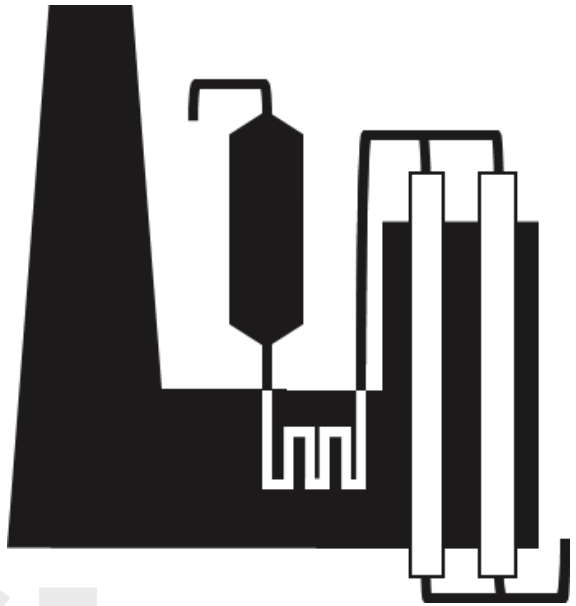


Key concept: production processes

Steam reforming

- One of the most common reformation reactions is steam reforming of natural gas to produce hydrogen.

$$CH_4 + H_2O\ (+ \text{heat}) \rightarrow CO + 3H_2$$



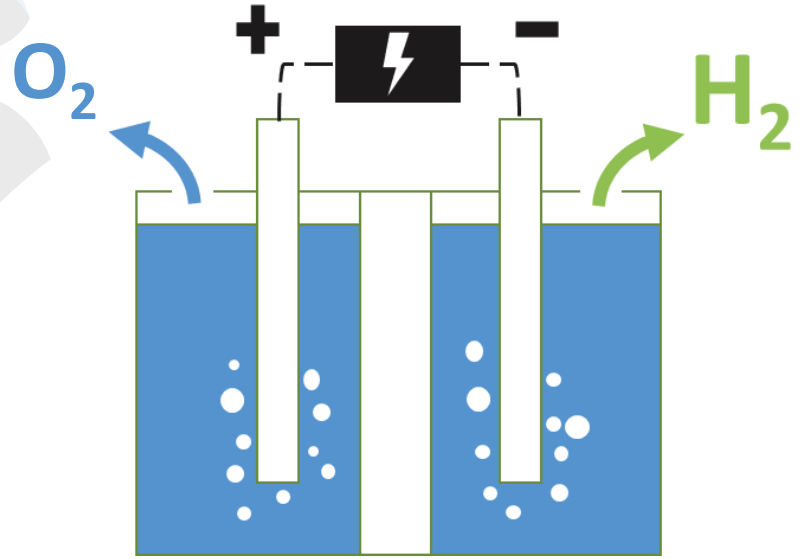
Key concept: production processes

Electrolysis

- Electrolysis is a process that uses electricity to break down a substance into separate components.
- While many substances could be electrolysed, the most relevant to this training course is the electrolysis of water to produce hydrogen and oxygen.

$$2H_2O \rightarrow 2H_2 + O_2$$

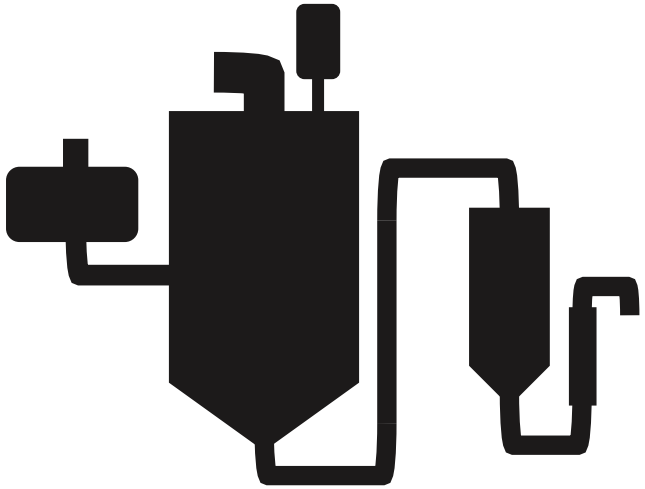
- Electricity passed through a pair of electrodes, providing one with a positive charge and the other with a negative charge.
- Ions (charged particles) are attracted to each of the electrodes, where they form the separate molecules.



Key concept: production processes

Gasification

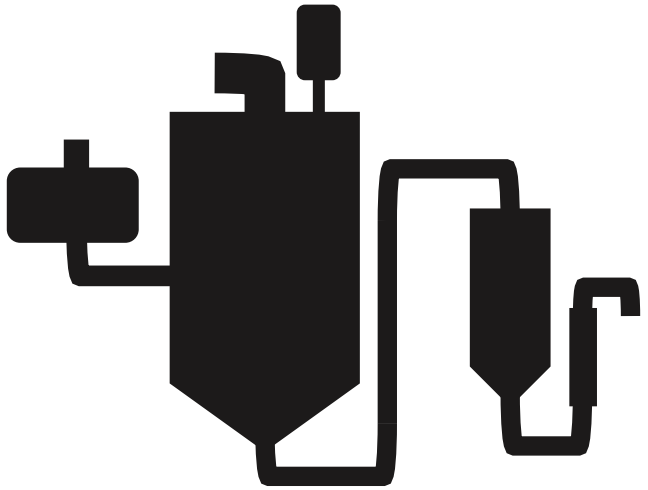
- Gasification is a common form of processing used in the production of bio-based fuels.
- It converts biomass or other carbon-containing feedstocks into gases using high temperatures and controlled amounts of steam and oxygen.
- In fuel production, gasification is used to produce **syngas**, a gas composed of CO, H_2 and other gases.



Key concept: production processes

Pyrolysis

- Pyrolysis uses heat to decompose biomass or other carbon-containing substances in the absence of oxygen. This produces a mixture of oil, gas and solid char.
- The heating rate is important for pyrolysis, which can be adjusted to produce different ratios of these products.
- For example, ‘slow’ pyrolysis produces a greater yield of solid char product, whereas ‘fast’ pyrolysis produces a greater yield of oil product.



Hydrothermal liquefaction (HTL)

- HTL is similar to pyrolysis, although it uses a large amount of water in the heating process (in addition to high pressures) to produce a crude-like bio-oil as a product.

Key concept: production processes

Synthesis processes

- Synthesis describes a process in which two or more substances are reacted to form a new compound substance.
- There are many examples of synthesis reactions, but in this training course we will cover these common examples:
  - **Methanol synthesis**

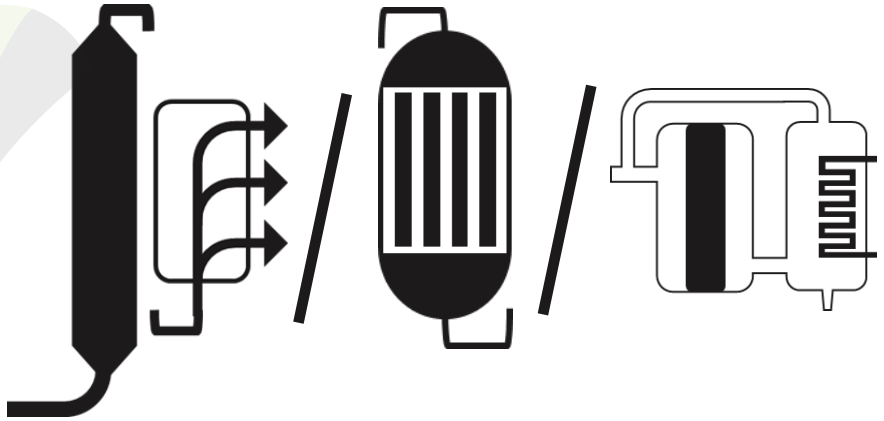
    $CO + 2H_2 \rightarrow CH_3OH$

  - The **Haber-Bosch** process (ammonia synthesis)

    $3\,H_2 + N_2 \rightarrow 2\,NH_3$

  - The **Fischer-Tropsch** process (synthesis of paraffinic hydrocarbons)

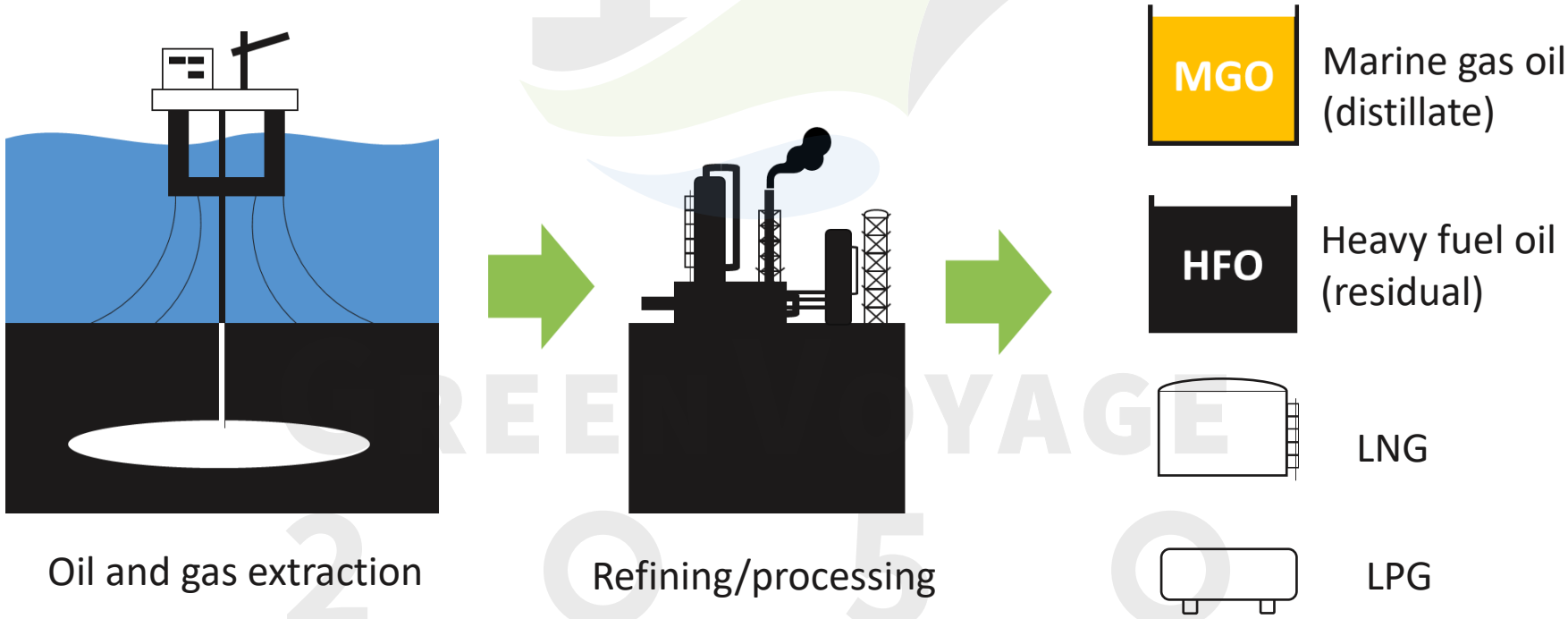
    $(2n+1)\,H_2 + n\,CO \rightarrow C_n H_{(2n+2)} + n\,H_2O$



Key concept: what can we make fuels with?

Conventional fossil fuels

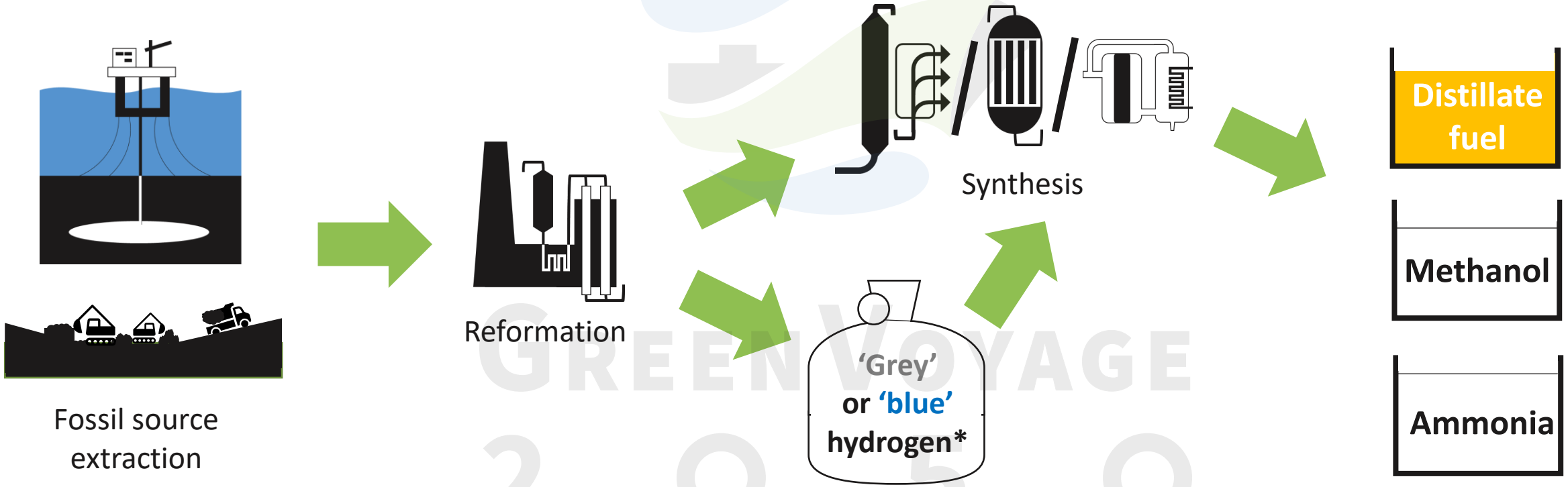
- Crude oil is extracted and refined to produce conventional hydrocarbon marine fuels, such as HFO and MGO.
- When used, these fuels **emit carbon that was stored millions of years ago**, and is therefore **not sustainable**.



Key concept: what can we make fuels with?

Fossil-based alternative fuels

- Raw fossil sources, such as natural gas or coal, can also be used to make a variety of alternative fuels.

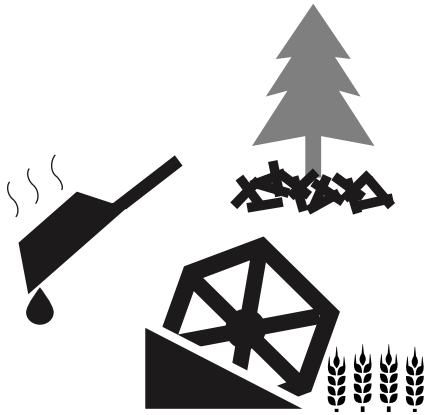


* **Grey** = production carbon emissions not captured
Blue = production carbon emissions captured using CCS

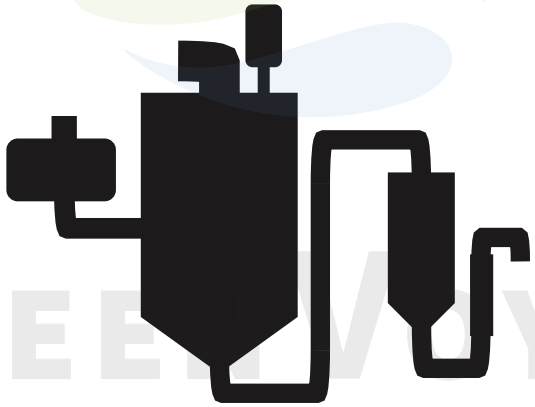
Key concept: what can we make fuels with?

Biofuels

- Biofuels can be made out of a variety of feedstocks, which we will explore in detail during the biofuels session.
- Given that they release carbon that has only been stored relatively recently, the use of biofuels does not increase atmospheric carbon dioxide when burned*. However, the ultimate sustainability of biofuels depends on the nature and type of their feedstocks.



Feedstock harvesting/extraction



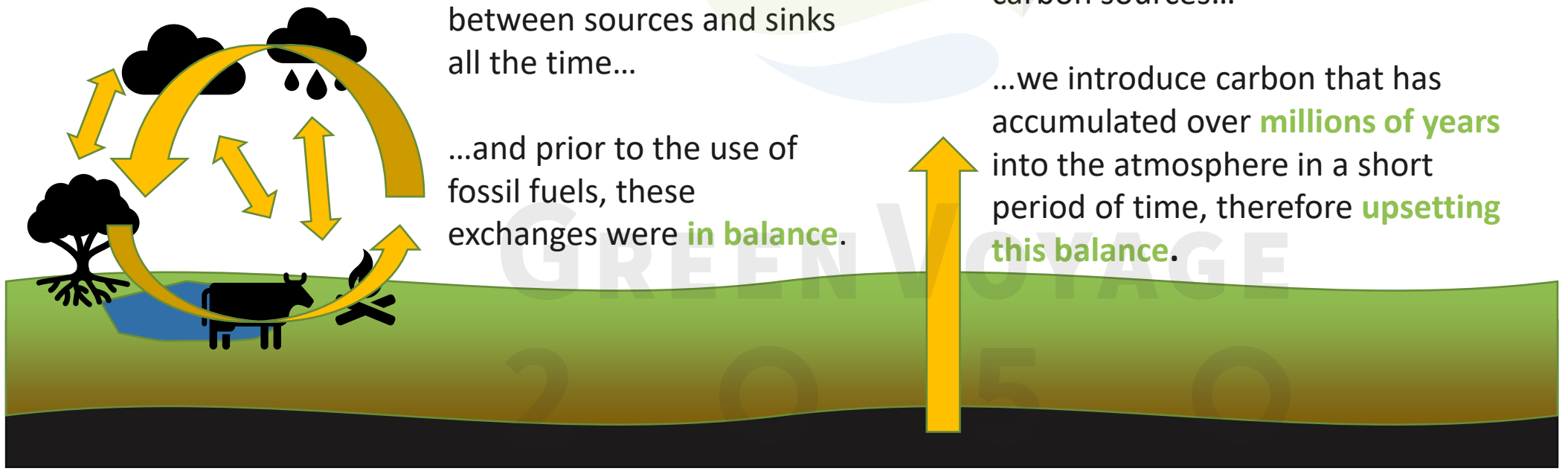
Processing

Distillate Biofuel/ biodiesel

Residual Biofuel

A brief side note…

- So far we've seen three ways in which **sources of carbon** can be used in fuels.
- Some of these options **can be** sustainable, while others **cannot**.
- This depends on the original source of the carbon that is ultimately emitted into the atmosphere.



Carbon is being exchanged between sources and sinks all the time…

…and prior to the use of fossil fuels, these exchanges were **in balance**.

By extracting and burning fossil carbon sources…

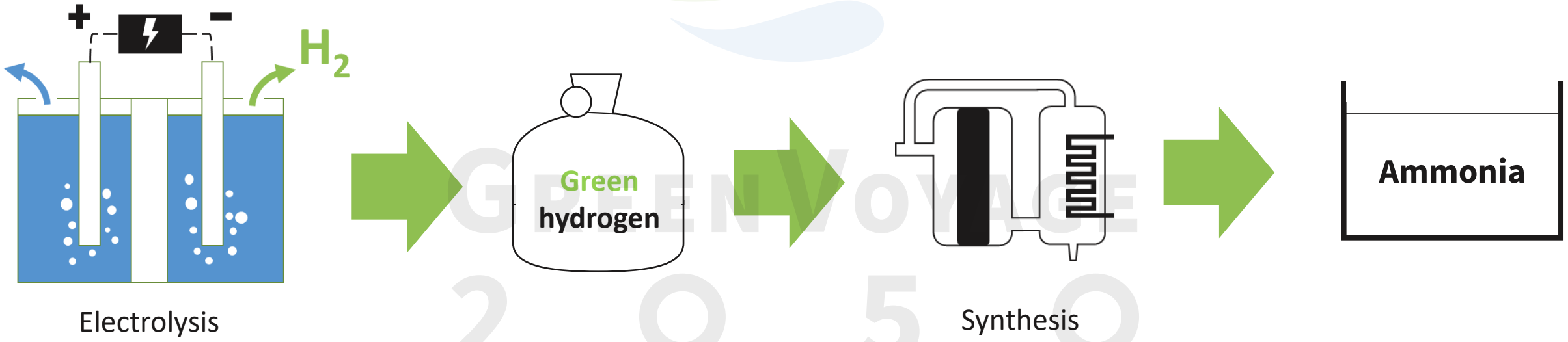
…we introduce carbon that has accumulated over **millions of years** into the atmosphere in a short period of time, therefore **upsetting this balance**.

This causes an overall **increase in carbon in the atmosphere**.

Key concept: what can we make fuels with?

E-fuels (without carbon)

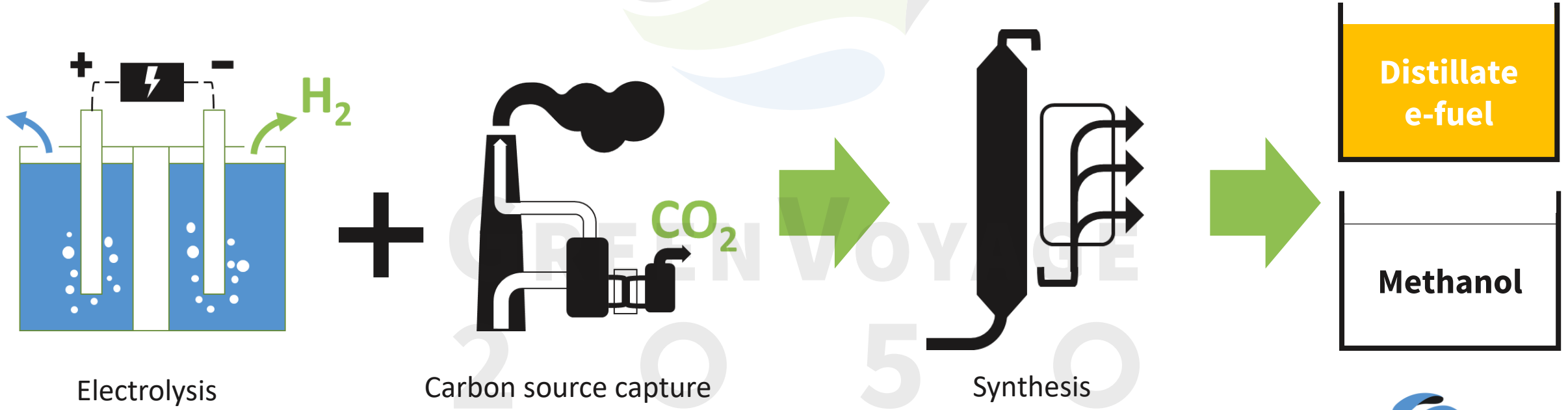
- Hydrogen, produced by the electrolysis of water, can also be used directly as a fuel, or used in an onward process to produce other fuels.
- In this training, we will refer to fuels made in this way as **'e-fuels (without carbon)'**.



Key concept: what can we make fuels with?

E-fuels (with carbon)

- Hydrogen, produced by the electrolysis of water, can be combined with carbon from a carbon source to create a synthetic fuel or an alcohol such as methanol.
- Fuels made in this way are called **'e-fuels'**, given the electricity required in the electrolysis process.



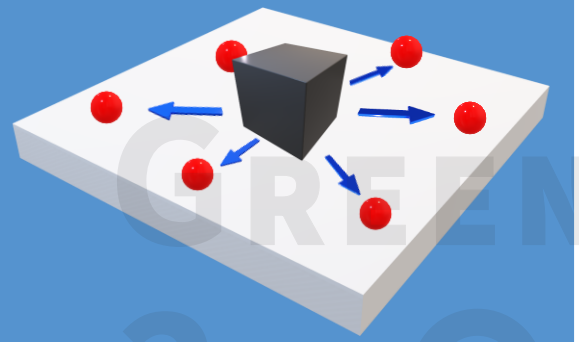
Key concept: Resource availability

- Each of the fuel types we have seen so far are made using different feedstocks and energy sources.
- Availability of these feedstocks and energy sources for use in fuel production is affected by the following:
  - **How much of it exists –** the amount of resource will likely vary (e.g. by geography or over time), and could be widely available in one place but scarce in another.
  - **How much of it can be viably harvested –** while enough of the resource may exist, extracting the required amount for use in fuel production may be too expensive, unsustainable or not practically feasible.
  - **How much competition there is for its use –** when demand for a certain feedstock is high, different fuel producers, industries and end-user sectors may compete for its use, restricting availability for some parties.
  - **How easily it can be transported to production sites –** required resources are conveyed to production sites via supply chains. Some energy sources, such as green electricity, are difficult to transport over very long distances.
  - **Whether use of that resource is permitted –** policies may be put in place to limit some uses of certain feedstocks (e.g. stipulating limits on extraction or specifying prioritised end-use sectors).
- The most viable locations for fuel production will be those for which these factors are most favourable.

Key concept: centralised vs decentralised production

Centralised

- Fuel is produced at **larger** production facilities
- Fuel is transported to the end-users as a finished product
- Generally better when demand for fuel is high (utilising economies of scale)

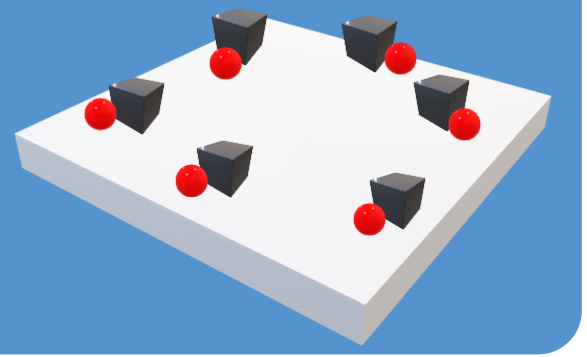


Fuel production facility

End-user

Decentralised

- Fuel is produced at **smaller** production facilities located closer to end-users (e.g. at filling stations)
- Generally better when overall demand for fuel is low



Fuel production facility

End-user

Key concepts: biofuels

Crop-based biofuels

- Made from crop feedstocks that are often also used for food (such as corn, soybeans or virgin vegetable oil).
- Concerns about **indirect land use change** and negative impact on food supply ('food vs fuel' debate).
- Often called 'first-generation' biofuels.

Advanced biofuels

- Made from lignocellulosic biomass (e.g. agricultural /forestry residues), **energy crops**, waste or algae.
- Avoids direct competition with food crops and the effects of **indirect land use change**.
- Often called 'second-generation' biofuels.

Indirect land use change (ILUC)

- Conversion of agricultural land to be used for biofuel production could result in conversion of land elsewhere for agriculture in a way that causes net CO_2 emissions to rise (e.g. through deforestation).

Energy crops

- Woody or grassy crops grown specifically for energy production that can have lower competition with land for food and low indirect land use change impacts.

Key concepts: biofuels

Waste oil biofuels

- Biofuels made from waste vegetable oils and animal fats such as used cooking oil and tallow

Novel oil crops

- Oil yielding crops grown that have lower competition with land for food and low indirect land use change impacts.