Sundyne

Pumps & Compressors for Sustainable Aviation Fuel and Renewable Diesel Production

Sundyne Pumps

Sundyne Compressors

ANSIMAG Sealless Pumps

HMD Kontro Sealless Pumps

Marelli Bombas

PPI Diaphragm Compressors

SUNFLO

Hydrocarbons consist of molecules of hydrogen and carbon and are combusted for thermal energy. Hydrocarbons, such as gasoline, diesel and jet fuel have traditionally been derived from petroleum. Hydrocarbons can also be produced from biomass sources, vegetable oil, used cooked oil, animal fats, through a variety of biological and thermochemical processes. Renewable hydrocarbon fuels are compatible with today's engines and infrastructure, because they are nearly identical to the petroleum-based fuels they are designed to replace.

Sustainable Aviation Fuel – SAF

Sustainable Aviation Fuel, made from non-petroleum feedstocks, is an alternative fuel that reduces emissions caused by air transportation. Non-petroleum renewable feedstocks used to produce SAF include food crops, municipal waste, woody biomass and fats/greases/oils. Currently ASTM approved SAF can be blended at different levels with limits of 5% to 50%, depending on the feedstock and how the fuel is produced.

Renewable Diesel – RD

Renewable Diesel, also known as Green Diesel, is a replacement for diesel. It can be used to fully replace diesel, or it can be blended with diesel. RD & SAF production both use the same hydrotreating and separation processes that are used for petroleum diesel, and they require the same basic infrastructure and equipment.

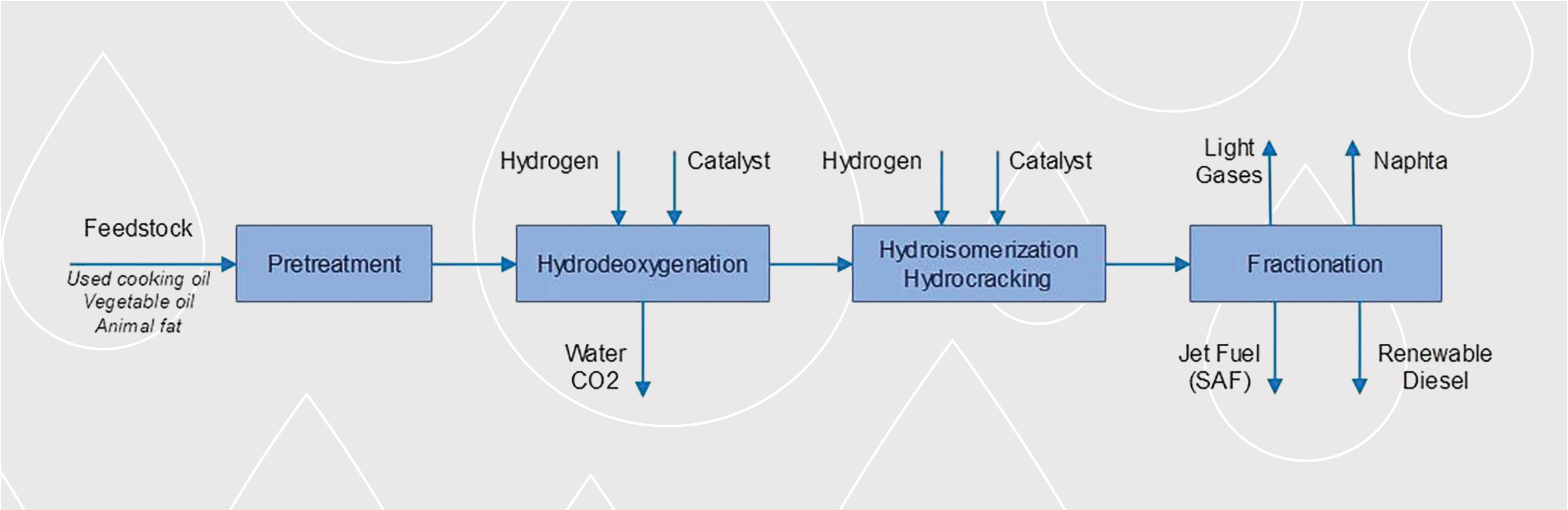
Multiple Pathways

Several pathways have been developed to produce RD and SAF. This document covers the following three pathways:

1. Hydro-processed Esters and Fatty Acids (HEFA) jet fuel
2. Alcohol-to-Jet fuel (ATJ)
3. Fischer-Tropsch (FT) synthesis or Power-to-Liquid (PtL)

Hydro-processed Esters and Fatty Acids (HEFA) Jet Fuel

Any type of oil, such as animal fat, waste grease, vegetable oil or algal is hydrogenated and isomerized to produce long-chain hydrocarbons. An additional selective cracking process yields aviation fuel.



Pretreatment

Pretreatment of renewable feedstock is required to eliminate contaminants, such as trace metals, chlorides, phosphorus, polyethylene, nitrogen and sulfur – which can poison hydrotreating catalysts and corrode equipment. Most pretreatment systems use bleaching clay in a bleaching, degumming, filtration and deodorizing process.

Plant-based feedstocks, such as soybean oil, are water-degummed, acid-degummed, bleached and deodorized to produce refined, bleached and deodorized (RBD) soy oil.

Animal-based feedstocks, such as tallow, are bleached and treated to make them suitable technical fats for industrial uses. Pretreatment also includes the application of sodium chlorite and activation with sulfuric acid, to produce chlorine dioxide.

Hydrodeoxygenation

The first step in making SAF and RD starts with hydrodeoxygenation (HDO). HDO is a process in which the feedstock reacts with hydrogen under elevated temperature and pressure in the presence of a catalyst to remove oxygen from the feedstock. Oxygen is removed either as water or carbon dioxide, depending on the availability of hydrogen. The high-performance hydrocarbon molecules that remain throughout the production process become a pure renewable fuel.

HEFA Process

Hydroisomerization

This stage of the process takes the leftover hydrocarbon molecules and changes their structure without changing the number of atoms. The straight-chain paraffins (n-paraffins) are converted to their branched-chain counterparts (isoparaffins) whose component atoms are the same but are arranged in a different geometric structure. Isomerization is the process that allows the fuel to be efficient in cold weather by preventing freezing. The process works by changing the long-chain n-paraffins into iso-paraffins of the same length. While this process helps improve cold flow, it only makes minor changes to the boiling point, reducing the risk of yield loss to lower boiling fractions.

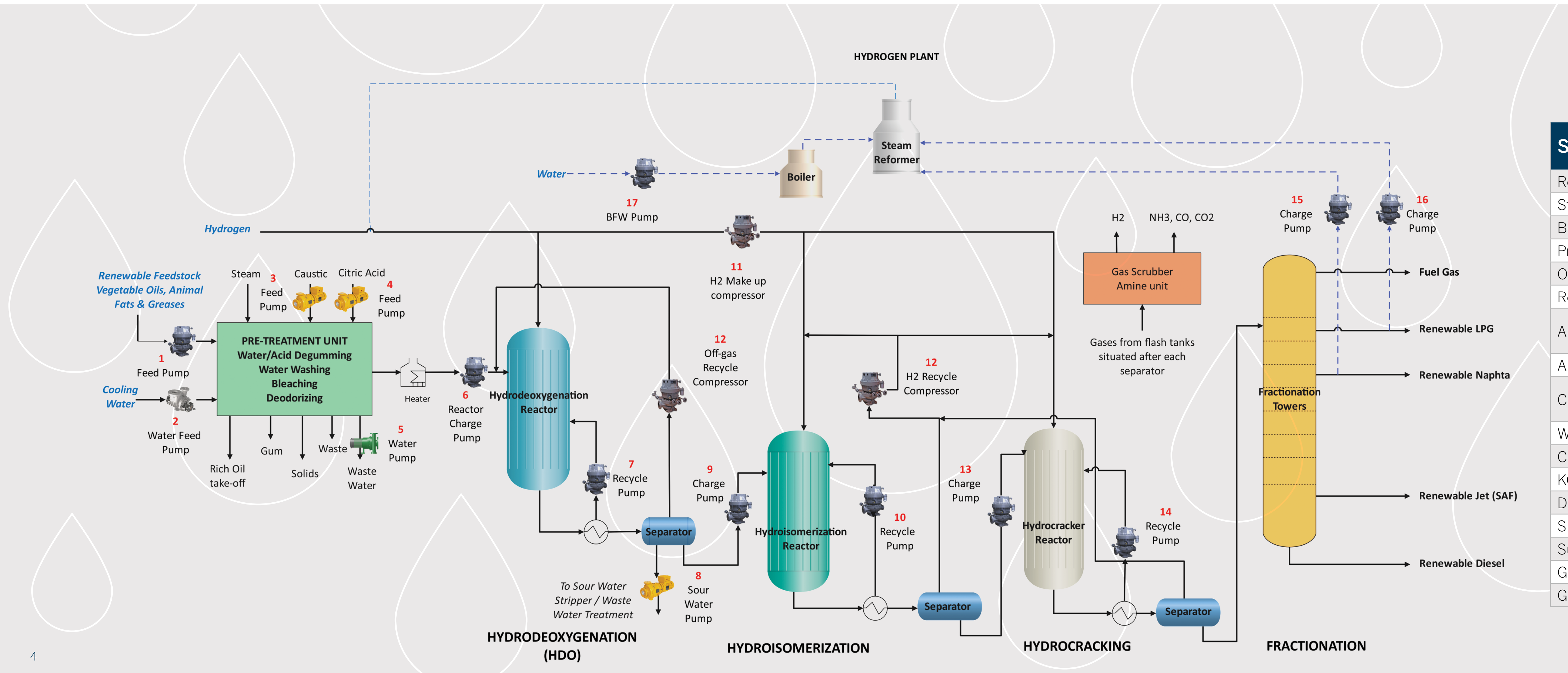
Hydrocracking

Hydrocracking is an additional step required to produce SAF. Renewable Diesel molecules must be broken into shorter chains of hydrocarbons that make up SAF. The broken bonds that connected carbon atoms must be filled with hydrogen.

Fractionation

At the next stage of the SAF and RD process, the product goes through a chemical process which separates it into liquids, allowing it to become a finished product ready for distribution. Fractionation helps to create a product that can be stored, until businesses purchase it. Renewable diesel can be stored at different temperatures – even extreme cold temperatures if done correctly.

Location	Service	Sundyne Equipment Type	Medium
1	Feed Pumps	OH6, BB2, BB3	Used Cooking Oil, Vegetable Oil, Animal Fats
2	Water Feed Pumps	OH6, OH2, BB2, BB3	Water
3	Caustic Pumps	HMD or Ansimag Sealless	Caustic
4	Citric Acid Pumps	HMD or Ansimag Sealless	Citric Acid
5	Water Pumps	OH2	Water
6	HDO Reactor Feed Pumps	OH6, BB3	Treated Feedstock
7	HDO Recycle Pumps	OH6, OH2, BB2	Hydrocarbon
8	Sour Water Pumps	HMD Sealless, OH6	Sour Water
9	Hydroisomerization Reactor Charge Pumps	OH6, BB5	Hydrocarbon
10	HDI Recycle Pumps	OH6, OH2, BB2	Hydrocarbon
11	H_2 Make-up Compressor	BMC, Pinnacle, LMC	Hydrogen
12	Recycle Gas Compressors	LMC, BMC, Pinnacle	Hydrocarbon, CO_2, CO, H_2
13	Hydrocracker Reactor Charge Pumps	OH6, BB2	Hydrocarbon
14	Recycle Pumps	OH6, OH2, BB2	Hydrocarbon
15	Naphta Charge Pumps	OH6	Naphta
16	LPG Charge Pumps	OH6, VS6	LPG
17	Boiler Feed Water Pumps	OH6, BB3	Water

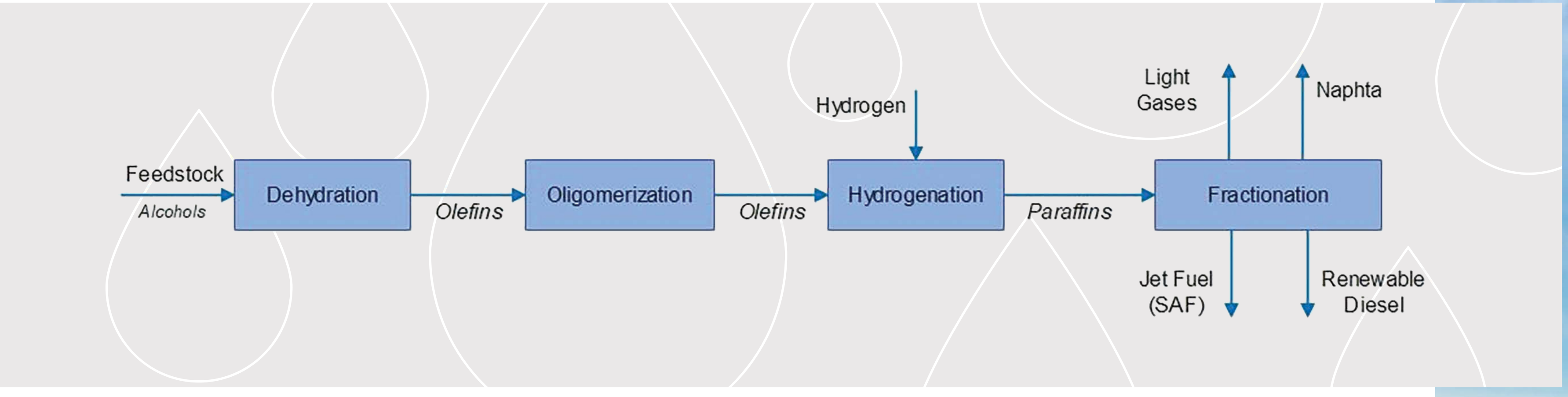


Other Services

Service	Sundyne Equipment Type
Reflux Pumps	OH6, BB2
Stabilizer Reflux Pumps	OH6, BB2
Bottoms Pumps	OH6, OH2, BB2, VS4
Product Pumps	OH6, BB2, OH2
Overhead Pumps	OH6, BB2, OH2
Reboiler Pumps	OH6, OH2
Amine Solution Pumps	OH6, OH1, OH2, HMD or Ansimag Sealless
Amine Sump Pumps	VS4
Caustic Circulation Pumps	OH6, OH1, OH2, HMD or Ansimag Sealless
Washing Water Pumps	OH6
Condensate Pumps	OH6, OH2
KO Drum Pumps	OH6, OH2
Drain Pumps	OH2
Slop Pumps	OH2, VS4
Surge Oil Pumps	OH6
Gas Stripper Bottoms Pumps	OH2
Gas Stripper Reflux Pumps	OH2, VS4

Alcohol-to-Jet (ATJ)

The Alcohol-to-Jet pathway utilizes alcohol as a source (either Iso-butanol or Ethanol) for production of SAF and RD. Alcohol can be produced from sugary, starchy and biomass feedstocks. ATJ converts alcohols into SAF and RD by removing the water (Dehydration) and linking the molecules together to get the desired carbon chain length (i.e., Oligomerization). Further processing includes Hydrogenation and Fractionation to get the SAF and co-products, such as Renewable Gasoline (Isooctane) or Green Diesel.



Dehydration

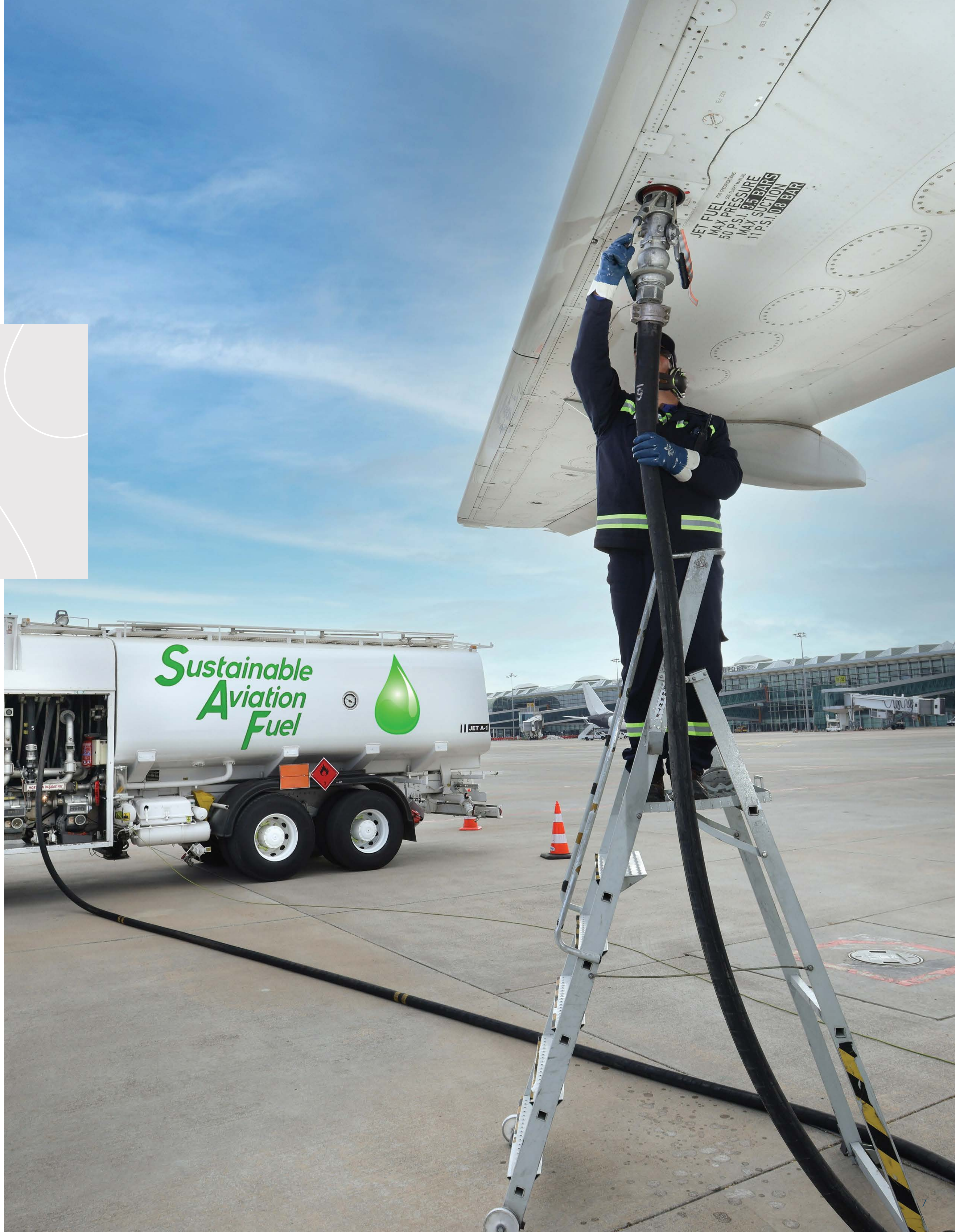
In dehydration stage, water molecules are removed from ethanol molecules through an acid catalytic reaction to produce ethylene gas: C_2H_5OH + catalyst → C_2H_4 + H_2O

Oligomerization

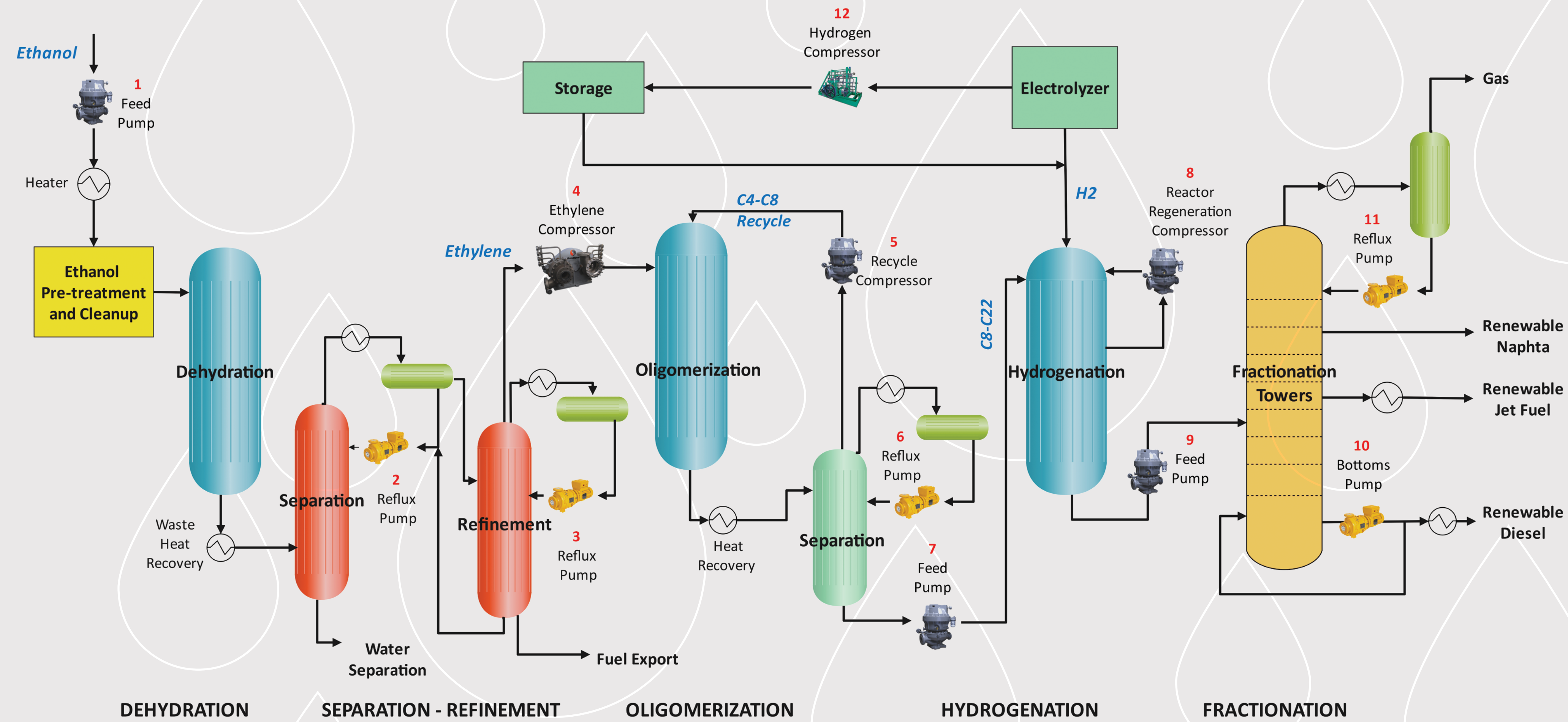
The oligomerization process is the conversion of ethylene (short-chain molecules) into linear α-olefins (long-chain molecules) via a catalytic reaction. Typically, the reaction takes place in the presence of sulfonic acid resins, solid phosphoric acid or acidic zeolites at a temperature range of approximately 100 to 300°C and high pressure. The operating condition depends on the type of catalyst used and feedstock.

Hydrogenation

The α-olefins (C9-C16 and >C16) are subjected to hydrogenation process by the addition of hydrogen in the presence of nickel, palladium or platinum on an activated carbon catalyst or zeolite support, operating at a temperature range of 300-400°C. The purpose of this hydrogenation is to saturate the remaining double bonds of the olefins after completion of the oligomerization. A sufficiently saturated product is critical to ensure a low reactivity of the fuel.



Alcohol-to-Jet (ATJ) Process



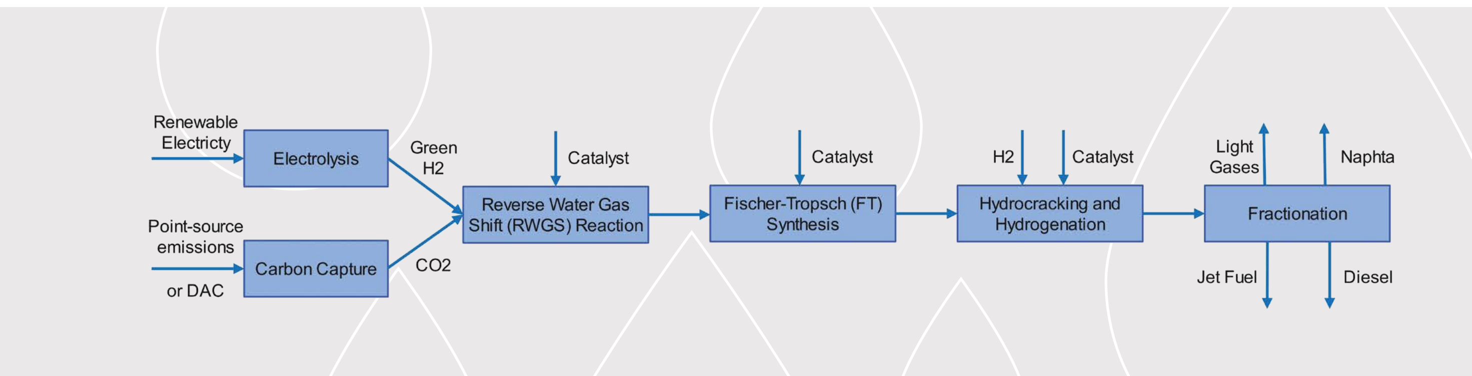
Note, any source of hydrogen can be used in alcohol-to-jet SAF production. Here, we show green hydrogen produced via electrolysis

Location	Service	Equipment Type	Medium
1	Feed Pumps	OH6, OH2, BB2	Ethanol
2	Ethylene Separation Column Reflux Pumps	OH6, OH2, BB2, VS6, HMD Sealless	Ethylene, DEE Water
3	Ethylene Refinement Column Reflux Pumps	OH6, OH2, BB2, VS6, HMD Sealless	Ethylene, DEE Water
4	Ethylene Feed Compressor	LMC, BMC, Pinnacle	Ethylene
5	Oligomerization Flash Gas Recycle Compressor	LMC, BMC, Pinnacle	C4-C8 Recycle Gas
6	Separation Column Reflux Pumps	OH2, VS4	Hydrocarbon
7	Hydrogenation Reactor Feed Pumps	OH6, OH2, BB2	Hydrocarbon
8	Reactor Regeneration Gas Compressor	LMC, BMC, Pinnacle	Hydrocarbon, N_2
9	Fractionator Feed Pumps	OH6, OH2, BB2	Hydrocarbon
10	Fractionator Bottoms Pumps	OH6, OH2, BB3, HMD Sealless	OLIG 2 Product
11	Distillation Tower Reflux Pumps	OH6, BB3, VS4	Hydrocarbon
12	Hydrogen Storage Compressor	PPI Diaphragm Compressor	Hydrogen
Other Services			
	Hydrogenation Recycle Pumps	HMD Sealless, OH6	Hydrocarbon
	Jet Fuel Product Pumps	HMD Sealless, OH2, BB2, BB1	Jet Fuel
	Diesel Product Pumps	HMD Sealless, OH2, BB2, BB1	Diesel
	Naphta Product Pumps	HMD Sealless, OH2, BB2, BB1	Naphta
	Desuperheater Pumps	LMV, Sunflo	Water
	Water Separation Column Reflux Pumps	HMD Sealless	DEE, Ethylene, Water
	LP Flare Pumps	HMD Sealless, OH6, VS6	Hydrocarbon
	HP Flare Pumps	HMD Sealless, OH6, VS6	Hydrocarbon
	Slop Oil Pumps	HMD Sealless, VS4	Slop Oil
	Refrigerant Gas Compressor	Pinnacle	Propane or refrigerant gases
	Deoctanizer Bottoms Pumps	OH2, VS4	Hydrocarbon
	RO Booster Pumps	BB3, VS1	Water
	BFW Pumps	OH6, BB3	Water
	C_4 Pumps (butane)	VS6	Butane

Fischer-Tropsch (FT) Synthesis or Power-to-Liquid (PtL) SAF

The Power-to-Liquid (PtL) pathway offers the lowest carbon footprint of all RD and SAF production processes. The PtL process uses “green” hydrogen and captured carbon dioxide as the feedstock and converts these gases into liquid hydrocarbons via Fischer-Tropsch synthesis.

If the hydrogen feedstock is produced via other methods (such as “grey” hydrogen from reforming of natural gas, or biomass gasification to product a syngas), then the remaining processing steps for SAF production remain the same. In this case, the end-product is often termed **Fischer-Tropsch Synthetic Paraffinic Kerosene** (FT-SPK) instead of **Power-to-Liquid SAF**.

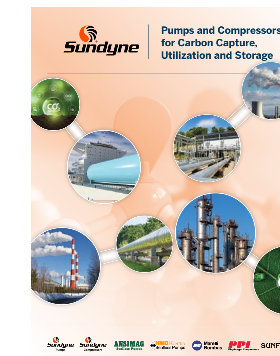


Green H_2 Production:

Green hydrogen is produced from splitting water into hydrogen and oxygen through electrolysis powered by renewable electricity. The **Power**-to-Liquid pathway requires the use of “green hydrogen” as a feedstock (hence the name, “Power-to-liquid” – converting renewable electricity (**power**) into a **liquid** fuel). Sundyne also offers pumps and compressors suited for hydrogen production and compression, as outlined in our ***Clean Hydrogen Value-Chain*** brochure.

Carbon Capture:

Carbon dioxide (CO_2) is the other input needed for the FT synthesis process. CO_2 can be captured via direct air capture (DAC) or via point source capture at an industrial emissions source. Once the CO_2 is captured, it is purified and compressed for use in the synthetic fuel production. Sundyne also offers pumps and compressors suited for carbon capture and CO_2 compression, as outlined in our ***Carbon Capture, Utilization, and Storage*** brochure.



Fischer-Tropsch (FT) Synthesis or Power-to-Liquid (PtL) SAF

Syngas Production and Fischer-Tropsch Synthesis:

At this stage, the hydrogen and CO_2 are combined to produce a syngas, which is a combination of carbon monoxide (CO) and hydrogen (H_2). The CO and H_2 are reacted in the Fischer-Tropsch synthesis process to produce liquid hydrocarbons. A catalyst is added to promote the reaction at each step.

Reverse Water Gas Shift (RWGS) reaction:

$$CO_2 + H_2 \rightarrow CO + H_2O$$

Fischer-Tropsch Synthesis reaction:

$$nCO + (2n + 1)H_2 \rightarrow C_nH_{2n+2} + nH_2O$$

The primary byproduct is water in both steps. This water can be recycled and used in other services, including to the electrolyzer for hydrogen production.

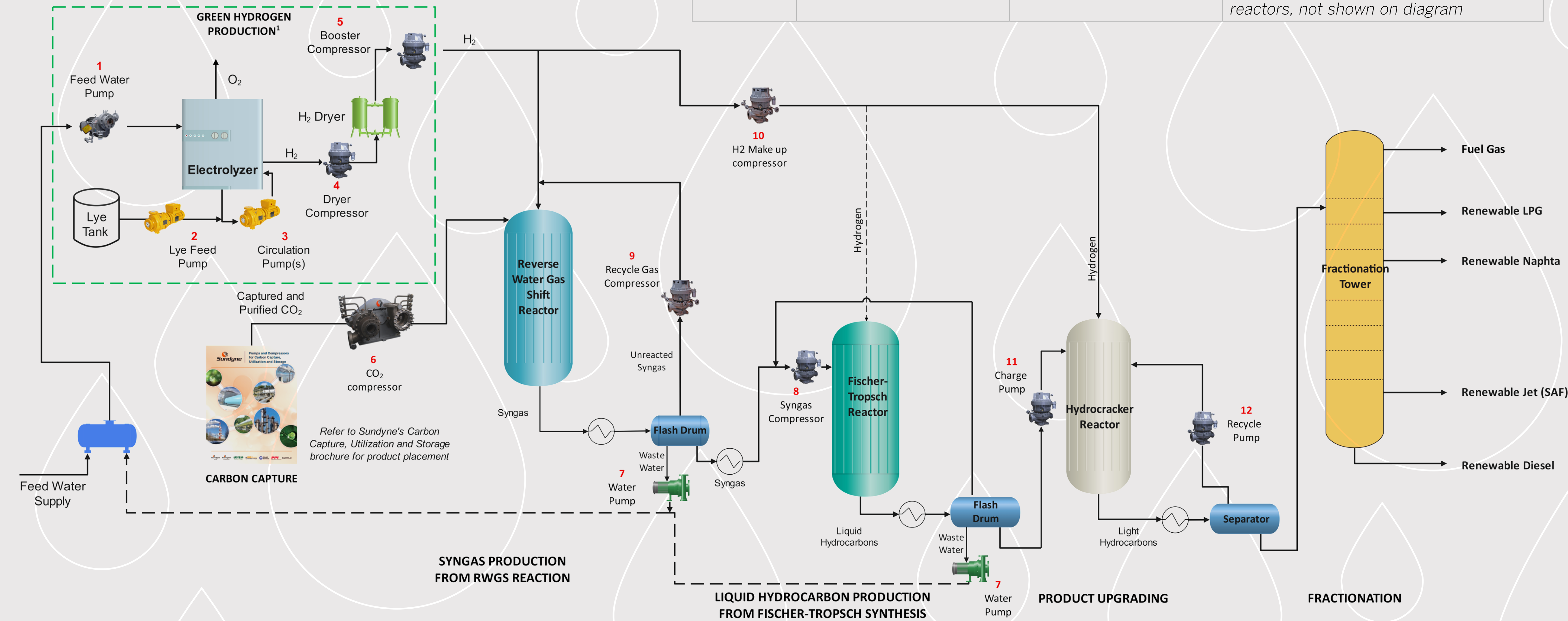
Hydrocracking:

Next, the synthetic crude is processed in a hydrocracking unit – similar to a traditional refining process. The long-chain hydrocarbons are broken down into shorter-chain molecules for RD or SAF. Contaminants are also removed (such as sulfur and nitrogen compounds) in this product upgrading step. If needed, there may also be an additional hydrogenation reactor, which adds hydrogen in the presence of another catalyst to improve the fuel properties for aviation.

Fractionation:

Finally, the product goes through a chemical process to separate it into its different yields based on the desired product slate. Fractionation occurs in a distillation column, where the produce is heated and vaporized, condensing at different heights based on its weight. Once the SAF yield is produced, it is typically blended with traditional jet fuel for commercial use by airlines.

Location	Service	Equipment Type	Medium
1	Feedwater Supply	Marelli OH/VS Sunflo w/ air cooler	Water
2	Lye Feed Pump	Sundyne HMD, Ansimag or Marelli	PEM: deionized water Alkaline: KOH electrolyte
3	Circulation Pumps (2 qty)	Sundyne HMD, Ansimag or Marelli	PEM: deionized water Alkaline: KOH electrolyte
4	H_2 Dryer Compressor	Sundyne LMC or BMC	Wet H_2
5	Booster Compressor	Sundyne LF-2000, LMC or BMC	H_2
6	CO_2 Compressor	Sundyne LF-2000	CO_2
7	Waste Water Pump	Marelli, Sunflo	Water
8	Syngas Compressor	Sundyne LF-2000, LMC or BMC	Syngas (H_2 + CO)
9	Recycle Gas Compressor	Sundyne LF-2000, LMC or BMC	CO_2, CO, H_2
10	H_2 Make-up Compressor	Sundyne LF-2000, LMC or BMC, or PPI	H_2
11	Charge Pump	Sundyne LMV	Liquid hydrocarbon
12	Recycle Pump	Sundyne LMV	Liquid hydrocarbon
-	BFW Pump	Sundyne LMV, Sunflo	Boiler Feedwater *Required for steam generation for reactors, not shown on diagram*



Sundyne's Value Proposition for SAF and RD Production

Sundyne's portfolio of pumps & compressors is specifically designed to address SAF and RD production requirements. For over 50 years, Sundyne has provided pumps and compressors to the refining market. This experience translates to the renewable fuel market. Sundyne's unique combination of technology, expertise and support provides a 360-degree, full lifecycle service that spans everything from project pre-feed to comprehensive 24x7 support, utilizing a global network of Authorized Service Centers and aftermarket specialists.

Sundyne Integrally-Geared Pumps

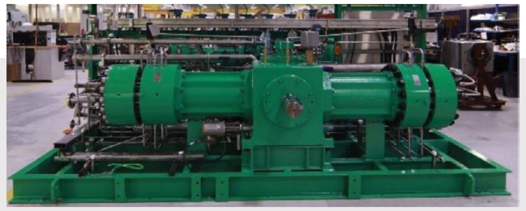
Sundyne integrally geared pumps are optimized for low flow-high head applications. Applications such as charge, reflux and overhead are ideally suited for Sundyne LMV pumps. Other services include boiler feed water pumps and high-pressure washing water pumps. The single impeller running at high speed produces the same head as multistage pumps running at synchronous speed. The compact and simple design reduces installation cost and the number of spare parts, making maintenance easier. Sundyne LMV pumps have the added benefit of offering the highest efficiency in the low flow range.

Marelli Pumps

Marelli pumps leverage a track record of more than 60 years in centrifugal pump design, development, manufacturing and service, to fulfill the latest standards for oil & gas, petrochemical and green markets. SAF/RD production requires a variety of API 610 pumps. Marelli pumps are designed for extreme reliability and a wide range of flow rates, to accommodate the most stringent customer specifications.

Sundyne Sealless Pumps – HMD and ANSIMAG

Sundyne has been the market leader in sealless magnetic drive pump technology for several decades.
Sundyne HMD Kontro metallic and Ansimag lined sealless pumps offer total product containment in a simple, compact design. These pumps handle harsh, hazardous and corrosive liquids and other difficult to seal applications within SAF/RD production with increased reliability, minimized maintenance and the highest levels of safety. Helping to minimize energy consumption, Sundyne HMD Kontro sealless pumps are available with the non-metallic ZeroLoss containment shell that eliminates magnetic coupling losses and in turn increases energy efficiency and reliability when handling heat sensitive liquids. All Sundyne sealless pumps operate without the need for complicated seal support systems and deliver the lowest total cost of ownership across ANSI, ISO and API platforms.



PPI Diaphragm Compressor

Sundyne enables organizations to deliver Net-Zero through sustainable, safe and environmentally conscious compression solutions with the broad portfolio of advanced Hydrogen compressors and packages renowned for highly reliable, leak-free performance that deliver the critical non-contaminating compression of Hydrogen required for the production of SAF. Aftermarket support for PPI Diaphragm compressors is provided via Sundyne's global network of channel partners.

Sundyne Integrally-Geared Compressors

Sundyne Integrally-Geared Compressor line features a robust and compact design with an integrated gearbox that runs multiple stages, resulting in space-saving installations. In the refining industry, where process optimization and control are critical, Sundyne compressors offer improved efficiency and precise control of operating conditions. Sundyne integrally-geared small to medium size compressors provide a superior solution, particularly for applications such as Hydrogen Compressors or Recycle Gas Compressors that involve compressing low molecular weight gases.

Sundyne compressors, available from standard to full API compliant configurations, can operate continuously for up to 5 years without requiring maintenance or service. With easy access to internal components like impellers and bearings, maintenance downtime and cost are significantly reduced.

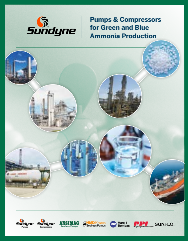
When it comes to Sustainable Aviation Fuel and Renewable Diesel Production, Sundyne is the **Safer, Better, Best** choice.

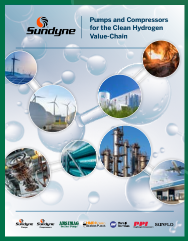
Safer for Operations
Better for the Environment
Best Total Lifecycle Value

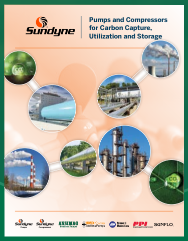
For more information please visit www.sundyne.com and fill out the Contact Me form. A Sundyne representative will contact you.

For more information on Sundyne's product fit in Clean Energy Markets, refer to our other clean energy brochures:

- Green and Blue Ammonia Production
- Clean Hydrogen Value-Chain
- Carbon Capture Utilization and Storage







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