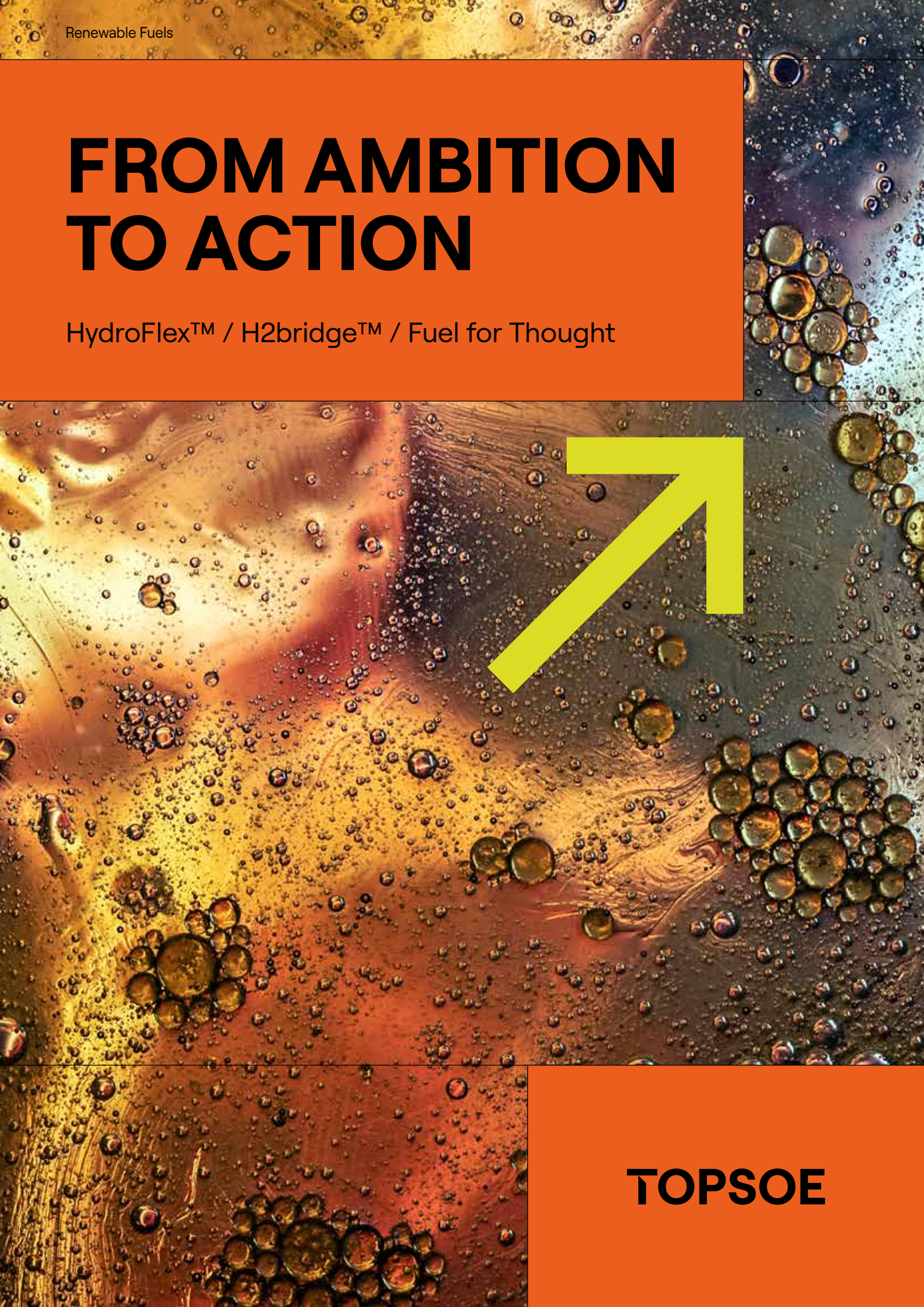
FROM AMBITION TO ACTION

HydroFlex™ / H2bridge™ / Fuel for Thought

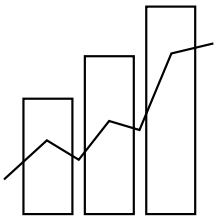


TOPSOE

FROM PROMISES TO PROGRESS

The global energy transition is in full swing. But we must not think the work is over. On the contrary. Now is the time to work harder to lower greenhouse gas (GHG) emissions and fully realize the goals of a net-zero world. Further industry, transport, and infrastructure decarbonization is needed, and energy must be produced more sustainably.

The solutions for sustainable production of renewable fuels already exist.
The hydrotreating unit HydroFlex™, which as an option can be complemented by the hydrogen unit H2bridge™, allows you to future-proof your refinery and produce renewable fuels with almost zero emissions – from a wide variety of feedstock.



LEGISLATIONS ARE DRIVING SUSTAINABLE PRODUCTION

Governments and states worldwide are taking measures to lower GHG emissions through subsidies and legislation. In fact, 137 countries have pledged to be carbon-neutral, and most are aiming for a year 2050 deadline.

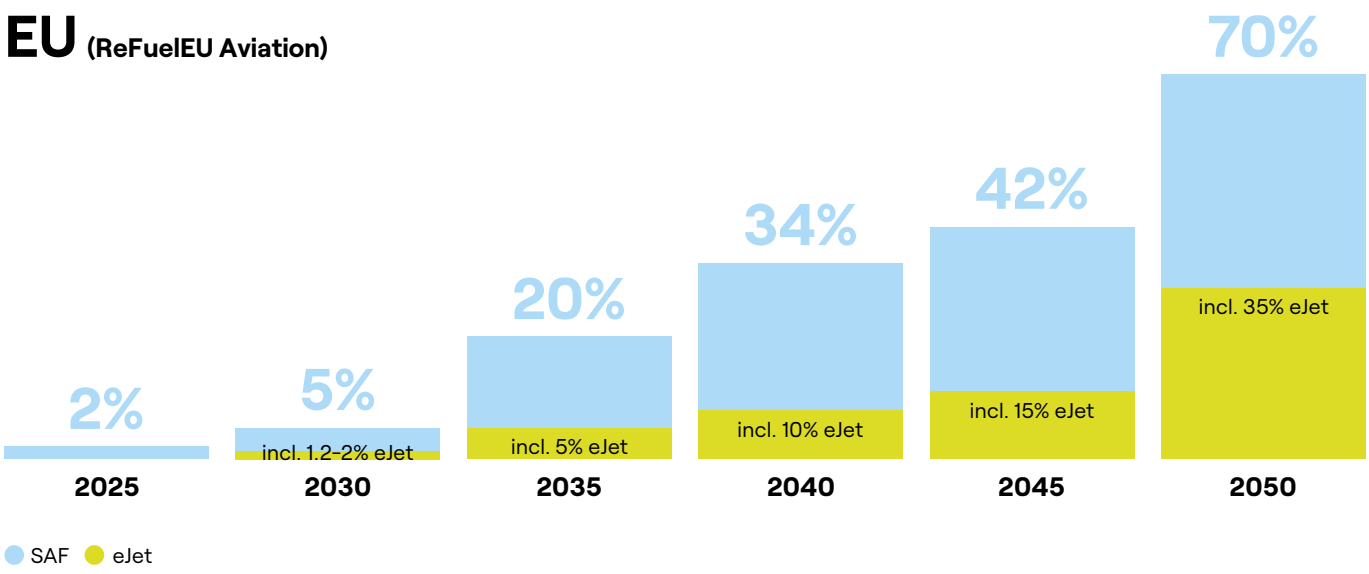
The repercussions for the refining industry are undeniable and far-reaching. The US has the renewable fuel standard (RFS) program in place to reduce GHG emissions and expand the nation's renewable fuels sector while reducing reliance on imported oil.

Late 2022, the European Parliament approved amendments to the EU's Renewable Energy Directive (RED III). As a result, the renewable energy contribution target was updated to 45% of final energy consumption by 2030.

BLENDING MANDATES ARE ON THE GLOBAL AGENDA

As a great example of the attention renewables are getting, countries worldwide are discussing and putting blending mandates for sustainable aviation fuel in place.

EU (ReFuelEU Aviation)



USA

20%
Reduction in GHG emissions by **2030**

3 bn
Gallons SAF by **2030**

CLEAN FUELS TAX CREDIT (IRA)

UK (RTFO)

10%
SAF proposed mandate in **2030**

75%
SAF proposed mandate in **2050**

JAPAN

10%
SAF mandate in **2030** being discussed

INCREASE THE BUSINESS VALUE

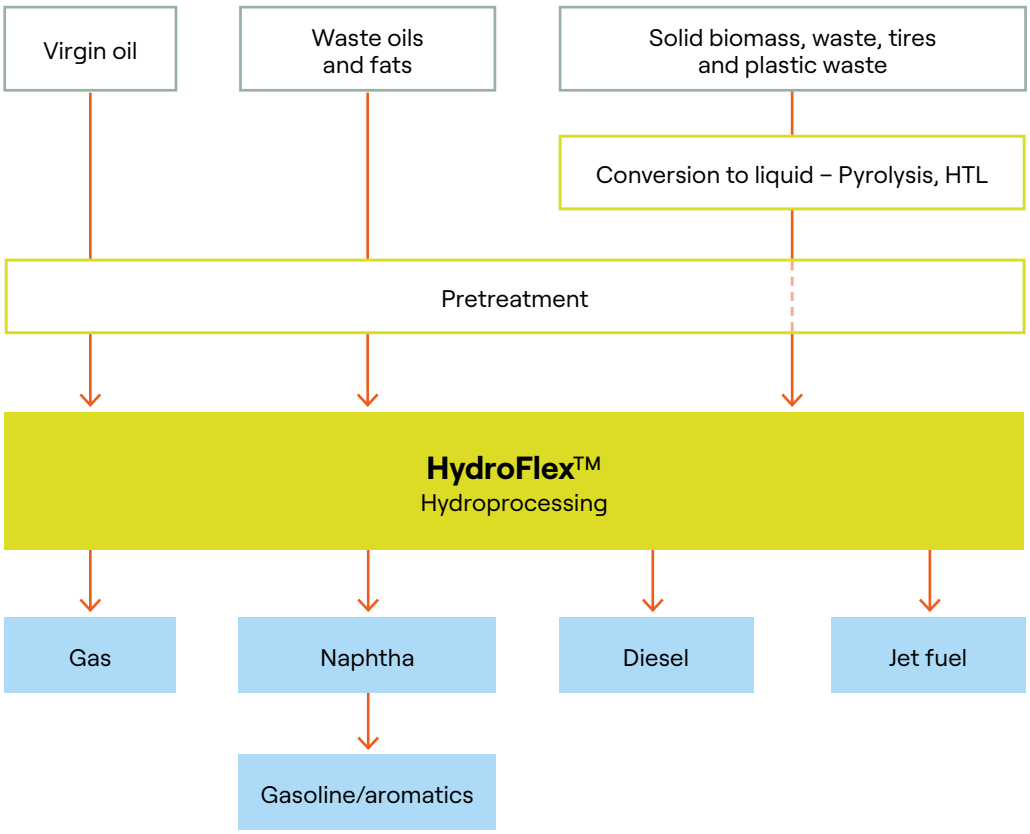
Whether you want to produce renewable diesel, sustainable aviation fuel, renewable naphtha or gasoline, you need to consider that the setup and requirements for hydrotreating and hydroprocessing are very different from the processes of refining non-renewable feedstocks.

But it is as profitable as it is needed.

Not only can you produce this wide range of renewable fuels/products, but you can also process different feedstock to produce, at any given time, most of the product, diesel or jet fuel, which is in demand and has the highest profit margin.

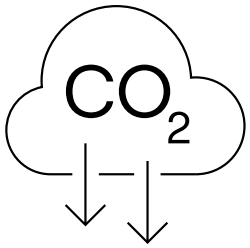
- Feed
- Process
- Process (Topsoe)
- Product

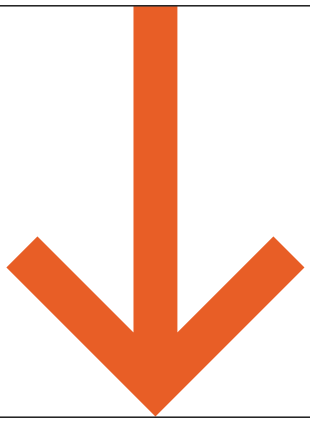
TOPSOE PATHWAY OVERVIEW



LOWER THE CARBON INTENSITY

Producing renewable fuel with the lowest possible carbon intensity (CI) will change the energy game. Why? Because the carbon intensity is all about calculating the value chain's total environmental impact. Not just the combustion GHG emissions. A focus on low CI will contribute significantly to reducing total GHG emissions and help reach the Paris Agreement's 2050 commitment to limiting global warming to 1.5°C.





FROM WASTE TO VALUE

While the future remains bright for renewable fuels, feedstock issues still face the market. First- and second-generation feedstocks do not necessarily possess the volume to meet future demand. And the global biofuels market is already tense, with varying feedstock supply and prices climbing.

This will intensify the need to successfully be able to process third generation feedstocks. Solid wastes such as agricultural residue, forestry residue, plastic waste, organic fraction of municipal solid waste, or sewage sludge to name a few.

The third-generation feedstocks are available in far larger quantities than any waste or edible oils, and they are set to power the world of biofuel production into the future.

> 500 Mtoe/y* of 3rd generation feedstocks available globally

3rd generation biofuels are needed to fill the gap

** WEF report 2020* *** UFOP report*

1ST GENERATION**

VIRGIN OILS (180 MT/Y)

- Rapeseed oil
- Palm oil
- Sunflower oil
- Soybean oil

2nd GENERATION*

WASTE OILS & FATS (30–40 MT/Y)

- Used Cooking Oils (UCO)
- Animal fats
- Distillers Corn Oil (DCO)
- Crude Tall Oil (CTO)
- Acid oils
- Palm Oil Mill Effluent oil (POME oil)
- Palm Fatty Acid Distillate (PFAD
- Spent Bleaching Earth Oil (SBEO)
- Empty Fruit Bunch oil (EFB oil)

3rd GENERATION

SOLID BIOMASS WASTE

- Agricultural residue
- Sewage sludge
- Forestry residue
- Organic fraction of MSW

LOW ILUC/ROTATIONAL CROPS

- Carinata
- Castor
- Micro or macro algae

RECYCLED CARBON

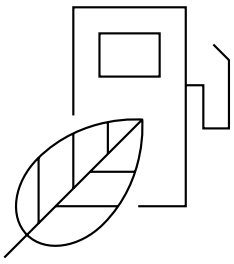
- Mixed plastic waste
- End of life tires

YOU NEED FULL FEEDSTOCK FLEXIBILITY

Processing renewable feedstocks is complex. Their range is extremely wide, and they can be processed in many ways. Because of this diversity, unit design is crucial – as is selecting and loading the right catalysts in combination with the best internals for the job.

We can give you the flexibility you need to turn practically any renewable feedstock into an on-spec fuel. So, you can future-proof your business against changing demands and take advantage of new opportunities to stay competitive and extend your market share.

Our trusted catalysts and technologies give you the flexibility to process a wide range of feedstocks – if needed, alongside fossil fuels. The result is consistently high-grade fuel.



FUEL FOR THOUGHT:

When you produce exceptionally clean renewable fuel with a high market value you will raise the profitability of your business and have a positive impact on the planet.

FROM PERHAPS TO PROVEN

Processing renewable feedstocks is not as straight forward as processing non-renewables.

For one thing, it requires extra hydrogen. We are the leading provider able to integrate the hydrogen unit with the hydrotreater – and we license both technologies.

With our HydroFlex™ and H2bridge™ technologies, you can produce renewable fuels in a fully self-sustaining solution resulting in some of the lowest carbon intensity fuels in the world. The solutions are available for both revamps and grassroot plants and let you convert low-value feedstocks to renewable fuels that continuously meet changing specifications and legislative requirements.

HydroFlex™ AND H2bridge™ INTEGRATED FOR OPTIMAL PERFORMANCE

Region: North America

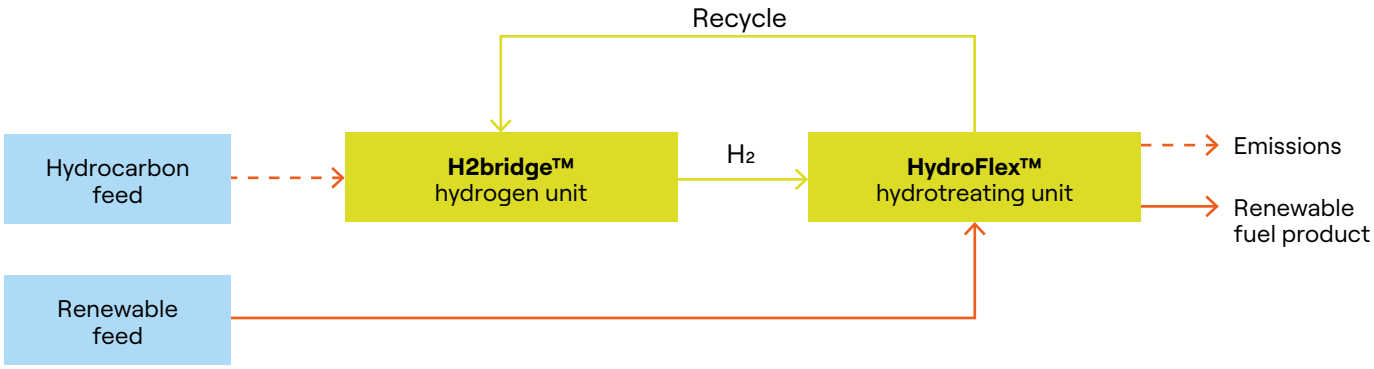
Project: Grassroot

Renewable fuel: Diesel

Status: In operation

Production BPD: 6,500

RENEWABLE FUELS
Integration provides the lowest carbon footprint



ONE SOLUTION. MANY ADVANTAGES.

With our patented H2bridge™ integrated unit, you can gain the last piece of the puzzle to convert renewable feedstock into fuel. The unit works in combination with the HydroFlex™ technology to integrate the hydrogen and the hydrotreater units. This creates new optimization possibilities.

FROM FADING TO FUTURE-PROOF

HydroFlex™ is our tried-and-tested technology for hydrotreating renewable feedstocks. We tailor unit design and catalyst selection to the specific demands of your refinery business, resulting in high-grade diesel and jet fuel. Not only do these fuels meet international standards, but they are also fully compatible with modern combustion and jet engines and can be blended safely with regular fuels.

We have been developing and refining our HydroFlex™ technology since 2004 in anticipation of these new market trends. As a result, you can find many HydroFlex™ units running alongside conventional units all over the world.

Each HydroFlex™ unit can be tailored to the specific needs and specifications of your refinery, location and business. From grassroot units to revamps for co-processing or fully renewable applications, HydroFlex™ enables you to hydrotreat almost any kind of renewable oil. Giving you the opportunity to win greater market share. And grow your business.

No two refineries are alike. The same is true of renewable feedstocks. So, you need a hydrotreating unit that:

- Fits in with the specifics of your refinery's size, location, and target product slate
- Can guarantee that the resulting fuels always meet your specified quality
- Has the flexibility to process feedstocks of varying quality and type

Renewable feedstocks offer you several advantages over first-generation FAME (fatty acid methyl esters) or conventional diesel.

	CONVENTIONAL DIESEL	1st GENERATION DIESEL FAME	RENEWABLE DIESEL
CETANE	40 – 55	50 – 60	70 – 80
COLD FLOW PROPERTIES	++	+	+++
BLEND IN	-	max. 7%	0-100%
MARKET VALUE	++	+	++++

FROM CONTAINED TO CIRCULAR

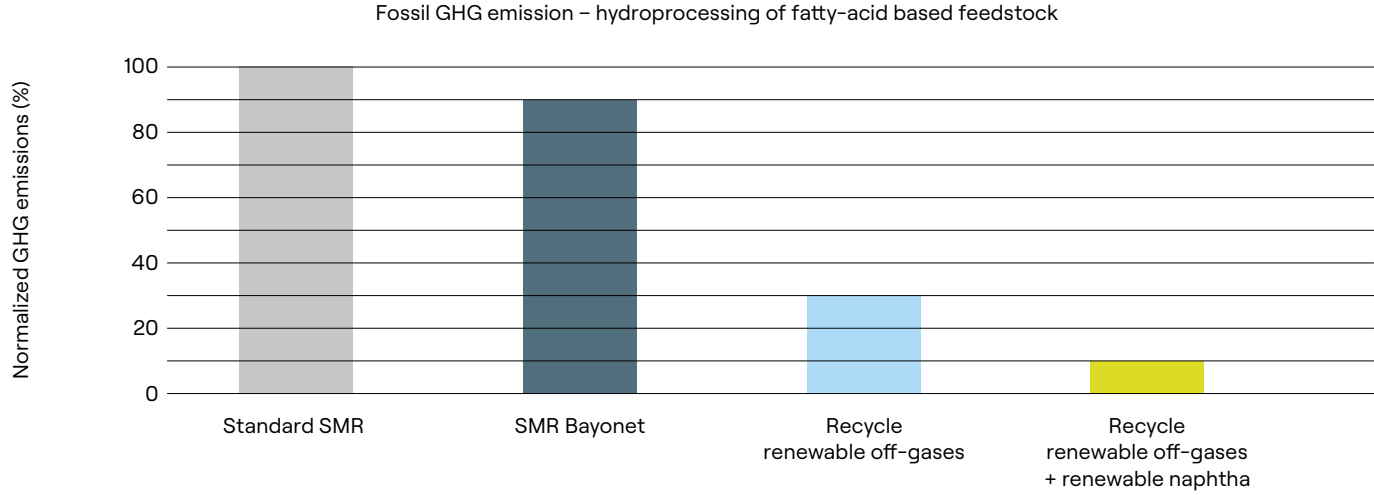
A significant portion of GHG emissions come from the consumption of hydrogen used to hydrotreat renewable feedstocks which contain oxygen and unsaturated compounds. With the addition of our patented H2bridge™ hydrogen unit, refineries and biorefineries gain a self-sustaining solution that helps replace import of fossil feedstock, with renewable LPG and naphtha, to produce hydrogen. The tight integration of the hydrogen unit with the hydrotreater allows for the unique opportunity to lower both CAPEX and OPEX.

REDUCE PRODUCTION COSTS AND RISK, AS WELL AS EMISSIONS

H2bridge™ doesn't just lower greenhouse gas emissions. It also reduces expenses for the entire renewables process. The integration of the HydroFlex™ and H2bridge™ units allows the size of the H2bridge™ unit to be reduced, thereby lowering CAPEX and OPEX costs. OPEX costs are further reduced with H2bridge™ because the process improves heat integration and drops the use of water to the lowest levels in the industry.

Working closely with you, we tailor the process to the layout of your plant, your intended range of feedstocks, and the specifications of the renewable fuels you aim to produce – all while complying with local emission allowances.

90% REDUCTION
Gain unprecedented greenhouse gas savings



CATALYSTS FOR OPTIMAL PERFORMANCE

If your catalysts aren't working optimally, neither is your renewable fuel process. HydroFlex™ combines leading-edge unit design with a comprehensive range of high-performance proprietary catalysts for renewable fuels production. The catalysts help ensure great yield, on-spec quality and optimal performance.

As renewable feedstocks are completely different than fossil feedstocks different chemical reactions occur compared to fossil hydrotreating. Also, processing renewable feedstocks entails more severe contaminants than processing fossil feedstocks. That makes it even more important that you have the right catalyst type and loading in your reactors to get the desired product.

With scores of different catalysts in our portfolio and more constantly being developed, we can tailor catalyst selection to the precise demands and needs of your business. In fact, we have been helping refineries like yours get the most out of feedstocks since the earliest days of renewable fuels production.

STATE-OF-THE-ART REACTOR INTERNALS

As renewable feeds pose new challenges for protecting your catalyst, state-of-the-art reactor internals are a must have. We are a market leader in internals, and continuously develop the portfolio in a combination of in-house research and feedback from the industry. We design our internals to fit your unit needs and design for maximal fouling resistance and catalyst utilization as we have done for more that than 400 hydrotreaters running with Topsoe internals and for the many HydroFlex™ units running.

RENEWABEL DIESEL PRODUCTION SINCE 2010

Region: Europe

Project: Revamp

Renewable fuels: Diesel

Status: In operation

Production BPD: 20,000

GET THE MOST OUT OF YOUR EXISTING ASSETS

Saving time and money is always an interest if you run a fuel business. And while building a greenfield biorefinery has advantages, such as always making tailor-made choices for your unit, there are several benefits by retrofitting existing hydroprocessing assets.

A revamp offers existing refiners a unique opportunity to quickly bring renewable fuels to the market and with CAPEX savings starting at 30%, the advantages are clear. And though it can be challenging to do a revamp due to operating within sometimes constrained operating conditions or a plot plan, it is a challenge we master at Topsoe. In fact, a lot can be achieved with tailor-made catalysts and careful considerations for what can be reused and what new assets are critical to add.

Through many years of experience with revamps and nine running renewable references based on previously existing assets, we have the experience to guide you.

A carefully thought-out revamp will allow existing refineries to go from fossil operation or co-processing to full renewable production with the same starting point – their original asset. And with the added benefit of up to two years of construction time saved.

FROM CLOUDED TO ClearView®

ClearView® renewables is a digital, connected service that delivers closer collaboration between your unit, its personnel, and Topsoe's experts to enhance the overall performance of your renewables unit. The solution is based on a state-of-the-art IoT and analytics platform that enables secure live streaming of your unit's operational data.

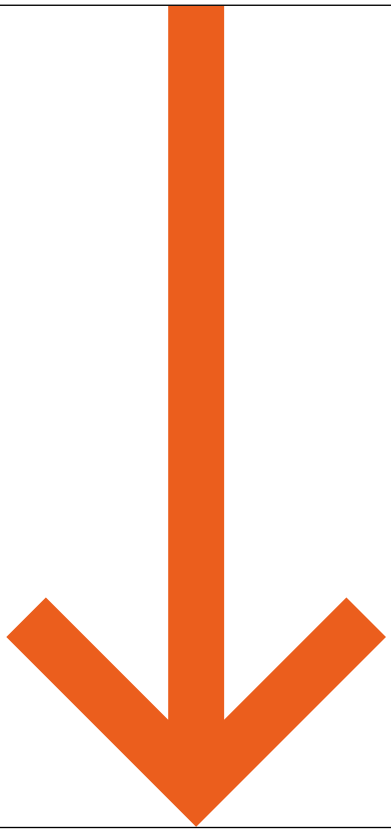
With three primary features, At-a-glance Performance, Analytics Dashboards and a Knowledge Hub you get smooth and efficient support, since our experts have access to the same data as your plant personnel. This shortens response time and allows us to further empower your plant personnel with insights that help optimize performance and establish best practices for the operation of the unit.

FROM GUESSWORK TO GUIDANCE

When you work with us, not only are you investing in new capabilities but also in a team you can trust to go the extra mile in future-proofing your business.

For more than 80 years, we have pushed the limits of science and engineering to do the things others say can't be done. And we continue to do so with a yearly investment of 9% of our revenue in research and development, ensuring you access to industry-leading know-how and a competitive edge.

We can help you implement game-changing technologies right now. From feasibility study to commissioning and beyond, we ensure optimal processes and solutions to help your business and our collaboration thrive. Even when design, construction, commissioning, and start-up are complete, we are there to ensure your HydroFlex™ and H2bridge™ units continue to run at peak performance.



SAF AND RENEWABLE DIESEL CO-PRODUCTION

Region: North America

Project: Revamp

Renewable fuels: Diesel & jet fuel

Status: In operation

Production BPD: 15,000

DESTINATION CLEANER FUELS

The race for net-zero is in full swing, with refineries and other industries bringing profound change to how we power our world. Here are some of the visionary companies already working successfully with Topsoe technologies.

LISTEN TO FUEL FOR THOUGHT WHEREVER YOU GET YOUR PODCAST

... or on
renewables.topsoe.com/podcast

GET MORE FUEL FOR THOUGHT

Have you listened to the world's first podcast about renewable fuels, trends and technologies. If no, we can only recommend you do.

Sylvain Verdier and Mikala Grubb from Topsoe, look into some of the most pressing topics, including new legislation and its impact, emerging technologies and current market drivers and trends.

Together with a series of key industry players, experts, and influencers, they discuss some of the challenges facing fuel production, so you can benchmark your business, learn more about what is driving our industry, and where it is heading.

Founded in 1940, Topsoe is a global leader in developing solutions for a decarbonized world, supplying technology, catalysts, and services for worldwide energy transition.

Our mission is to combat climate change by helping our partners and customers achieve their decarbonization and emission-reduction targets, including those in challenging sectors: aviation, shipping, and production of crucial raw materials. From low-carbon or zero-carbon chemicals, to renewable fuels and plastic upcycling, we are uniquely positioned to aid humanity in realizing a sustainable future.

Topsoe is headquartered in Denmark, with 2,400 employees serving customers all around the globe. To learn more, visit **topsoe.com**

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