Executive Summary

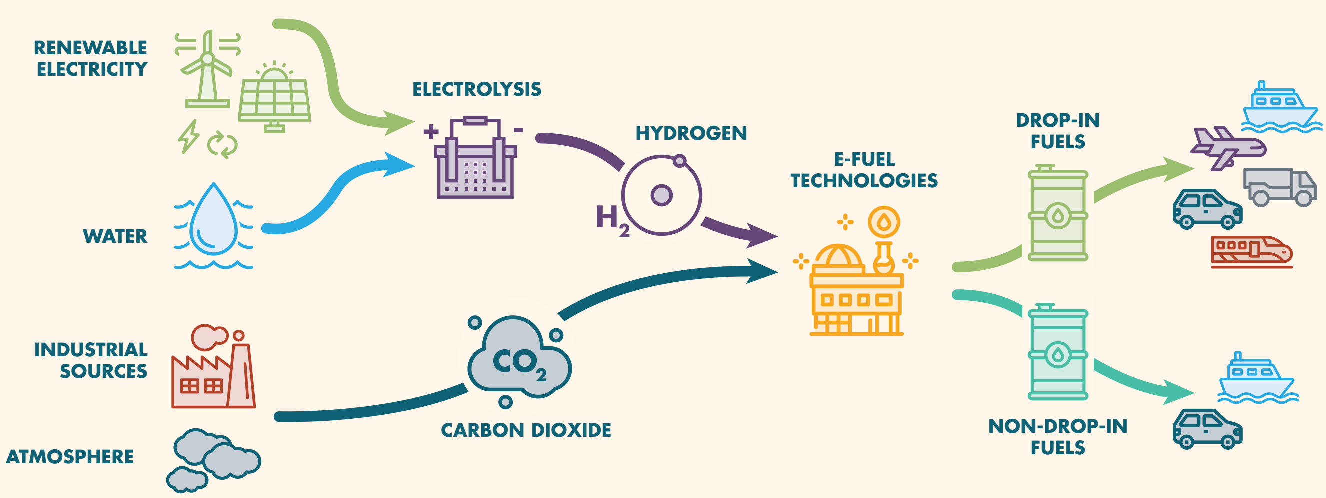
Evaluating the Viability of Commercially Deploying E-fuels in Road Transport

The United States road transport sector accounts for 22% of US greenhouse gas (GHG) emissions. Policies have been put in place to reduce emissions in the road transport sector – both on a federal and state level in the U.S., as well as around the globe. Many decarbonization technologies are available and are being incentivized under such policies, each facing a unique set of challenges as they are deployed commercially. Amongst these options, e-fuels (or synthetic fuels) are a renewable technology that can be used in existing and new vehicles while potentially yielding near-zero emissions.

WHAT ARE E-FUELS?

E-fuels are renewable fuels produced from water, renewable electricity and carbon dioxide (CO_2) via chemical or biochemical processes, which can be used to decarbonize the road, aviation, maritime, and rail sectors.

FIGURE ES-1. E-FUEL PRODUCTION PROCESS

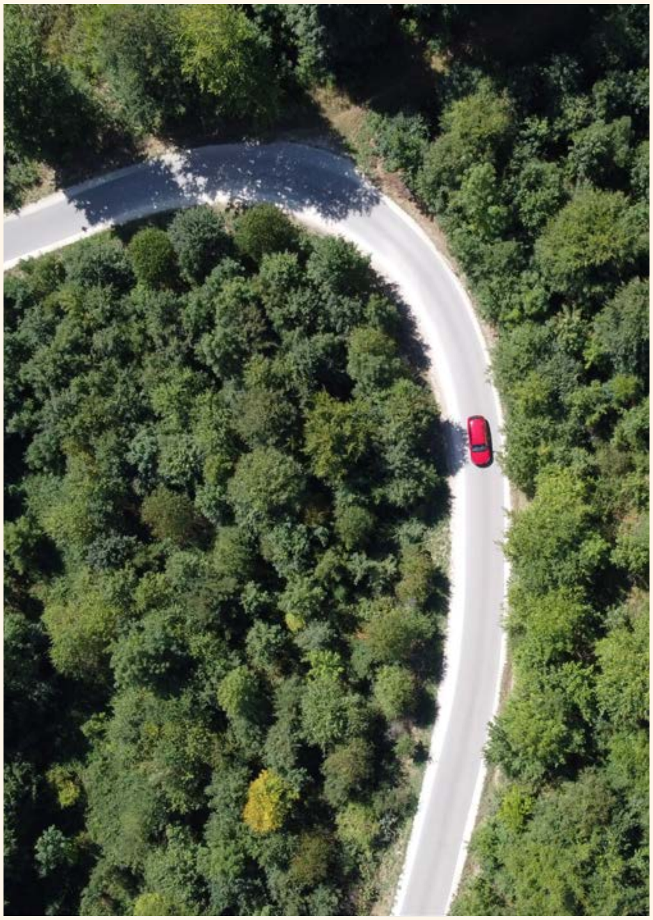


WHY IS THERE GROWING INTEREST IN E-FUELS?

E-fuels can achieve up to 75-99% GHG savings compared with fossil fuels, when made from additional renewable electricity (i.e. renewable electricity which meets incrementality, deliverability and temporal correlation requirements).

They are highly compatible with existing infrastructure and vehicles in the road, aviation, shipping and rail sectors.

E-fuels are produced from renewable electricity, carbon dioxide, and water which are **highly abundant resources globally.**



However, most e-fuels technologies are at a low level of technological and commercial development today. Key challenges are the technical risks associated with production processes, high costs, and limited policy support to bridge the cost gap with fossil fuels.

To contribute meaningfully to decarbonization across the transport sector, e-fuels will have to become commercially available and be deployed at large scale. This will depend on technical progress, feedstock availability in particular locations, availability of funding, strong policy support, and the speed in which other transport decarbonization options ramp up.

This report evaluates the viability of e-fuels in the U.S., based on their current technical suitability, emission reduction potential, scalability, and economic competitiveness, and how this could change by 2040. It focuses on e-fuels' potential contribution to the sustainable transition of the road sector and other transport energy sectors.

WILL E-FUELS BE NEEDED TO DECARBONIZE U.S. ROAD TRANSPORT?

E-fuels could close potential emission reduction gaps or accelerate emission reduction efforts in road transport in the U.S. The U.S. currently lacks a clear path for road transport decarbonization, leading to uncertainties in how quickly low carbon technologies could be adopted. Battery electric vehicles (BEVs), which are cost-effective and have high GHG savings, will play a significant role in emission reduction, but the speed at which they could replace existing internal combustion engine vehicles (ICEVs) is uncertain due to the technical and infrastructure challenges they currently face, and a lack of policy certainty. As a result, it is expected that ICEVs will continue to be on the road into the 2040s. E-fuels could be deployed to achieve higher emission reductions from existing vehicles, particularly if the supply of sustainable biofuels is slow to ramp up.

> **The strongest demand signals for e-fuels come from the aviation sector but e-fuels could be supplied for both aviation and road transport.**

HOW COULD DEMAND FROM OTHER TRANSPORT SECTORS INTERACT WITH E-FUELS SUPPLY FOR ROAD VEHICLES?

Whether e-fuels will be supplied to the road transport sector in the U.S. will be largely influenced by policy. E-fuel production capacity in the U.S. could grow significantly between now to 2040. We estimate that they could be scaled up significantly to achieve an annual production capacity of 6-14 million tonnes (approximately 2-5 billion gallons) by 2040, but this volume is small (around 6-14%) compared to projected demand for low carbon fuels in transport overall. Currently, e-fuels are much more costly to produce than fossil fuels and biofuels, and while costs could come down in future, they are unlikely to reach cost parity. Because of this, policy support plays a key role in bridging the cost gap, but also in determining in which transport sectors e-fuels could be deployed.

Current policy landscape could result in e-fuel producers favoring markets outside of the U.S. Today, Inflation Reduction Act (IRA) tax credits (TC) in the U.S. could help bring down e-fuel production costs but the lack of widespread blending mandates for e-fuels means there is currently no guaranteed market demand for e-fuels. In contrast, fuel policies in the EU and UK include sub-targets for e-fuels and penalties for non-compliance, which create clearer and stronger demand signals, particularly in the aviation sector. Under this policy environment, e-fuels are likely to be produced in the U.S. but sold to the EU/UK markets, so that producers can capitalize on financial support from both supply and demand policies in the U.S. and Europe (including the UK).

The strongest demand signals for e-fuels come from the aviation sector but e-fuels could be supplied for both aviation and road transport. E-fuel producers may tune production capacity to maximize e-sustainable aviation fuel (e-SAF) volumes over road fuels due to the higher policy premium being available through ReFuelEU Aviation, the UK SAF Mandate, and the premium offered to SAF under the 45Z Clean Fuel Production TC, and interest from the aviation industry and customers. However, most e-SAF pathways produce diesel and naphtha as co-products, and so their ramp-up will also provide additional fuel for the road sector. High willingness to pay (WTP) from the aviation industry could potentially also help to support road e-fuel prices.

KEY ACTIONS NEEDED TO SUPPORT E-FUEL UPTAKE

E-fuels are (and will continue to be) more expensive to produce than their fossil counterparts, making policy support critical for projects to be economically viable. Today, the production cost of e-fuels is 2.5-4 times more than fossil fuels when using low-cost renewable electricity. Despite policy support being available, it could still be challenging for most early e-fuel plants to be economically viable in the near future. The cost gap could fall to 1.5-3 times current fossil fuel prices by 2040 [1], [2]. Policy support in the U.S. could help close this price gap in the future - however this relies on the availability of TCs and the ability to stack them.

Further policy drivers are needed to provide additional confidence for investments in e-fuels and to support their uptake. Without a guaranteed market, e-fuel uptake will also be highly unpredictable in the road transport sector given that cheaper alternatives are already commercially available. Given this highly uncertain outlook, enabling the uptake of e-fuels requires a multifaceted approach across technology, sustainability, policy, and market development. If U.S. policymakers are keen to further incentivize e-fuel uptake in the transport sector, some recommendations they could consider include the following:

RECOMMENDATION 1: Set Clearer Transport Decarbonization Pathways, Targets and E-fuels Road Map

- **Develop a knowledge base on U.S. transport decarbonization, including all decarbonization options:** There is currently very little detailed analysis and scenarios that show the role of all transport decarbonization options in all modes in the U.S.

- **Set clear emission reduction targets for the transport sector, including by mode:** Allow market to anticipate what types of low emission transport solutions (including e-fuels) will be needed in road transport decarbonization.
- **Develop a U.S. roadmap for e-fuels production and use:** Include the demands of the road, aviation, maritime and rail transport sectors, so that the production plants, infrastructure and policy for these can be developed together, rather than being seen as competing markets.

RECOMMENDATION 2: Set Requirements to Ensure E-fuels are Developed Sustainably

- **Standardize lifecycle assessment methodologies:** The U.S. currently does not have an agreed and published methodology for calculating the GHG emissions of e-fuels, including the treatment of renewable electricity used. Because some policies set GHG thresholds to determine eligibility or provide higher support for options that provide greater GHG emissions reductions, developing standardized methodologies that account for the benefits of e-fuels will allow stakeholders to evaluate the environmental performance quantitatively to make informed decisions about prioritization.

1 The reference prices for 2023 for gasoline is 3.50 U.S.$/gal (930 U.S.$/tonne).

2 EIA (2024): Short-term Energy Outlook. Available from: [Link]

RECOMMENDATION 3: Implement Policies to Further Incentivize Market Development

- **Guarantee markets for e-fuel producers:** The U.S. e-fuel policy landscape currently lacks demand-side policy support to promote the uptake of e-fuel. Policy makers could consider mandating a minimum share of e-fuel use in the road transport sector. Unlike the technology-neutral approach taken by the Low Carbon Fuel Standard (LCFS), an e-fuel sub-target is the most direct way to facilitate market access and provide market certainty to e-fuel developers and investors. The cellulosic sub-target within the Renewable Fuel Standard 2 (RFS2) is an example of this. This could be designed to ensure that e-fuels plants in the U.S., which will receive production-side support, prioritize domestic demand instead of being drawn away to the UK/EU with mandated markets. Some have argued that a technology neutral carbon intensity (CI)-based target is more appropriate for meeting GHG reduction goals, however guaranteed markets for emerging technologies can help to give confidence in markets and so secure investment.

RECOMMENDATION 4: Create Funding Opportunities for E-fuels

- **Increase public funding for e-fuel projects**: E-fuel production is capital intensive with capital expense (CAPEX) contributing 17-24% of the levelized production costs. It is challenging to secure private investment for early development technologies due to large risks associated with low maturity plants. Having access to public funding to secure capital costs for early plants could help promote e-fuel plant roll-out in the U.S., like the Advanced Fuels Fund (AFF)[3] in the UK. While funding programs for biofuel and hydrogen projects are available in the U.S., none to our knowledge exist which targets e-fuels. Securing public funds can also provide confidence to investors and unlock additional private investment to projects as well.

3 For more information on the AFF, see [Link]