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Biofuels: An EQ Perspective on Market Opportunities

January 2024

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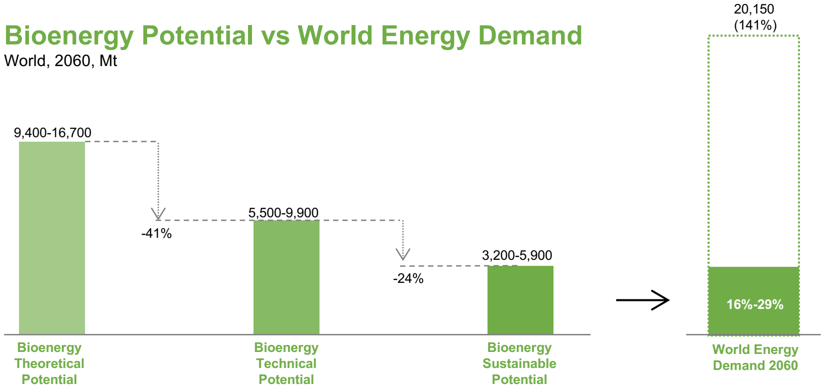
Overview

- Interest in advanced biofuels has skyrocketed because of an intensified public and private sector focus on the clean energy transition
- Favorable policy, corporate commitments, and heightened awareness around energy security is driving production, offtake, and investment
- Biomass-derived energy could theoretically decarbonize sectors representing 50 percent of global GHG emissions via direct use in transport and buildings, heat and power generation, and industry
- Despite criticism that biofuels incentivize waste, the runway for these transition fuels is long; hard-to-abate sectors remain out of electrification's reach and reliant on existing infrastructure
- First generation biofuels emerged in the 1990s and have been more recently followed by a second generation that uses waste and residues as feedstock
    - **Biofuels 1.0:** mature biofuels such as ethanol and biodiesel use mostly food crops as feedstock (e.g., corn and sugarcane, also known as 'energy' crops)
    - **Biofuels 2.0:** biofuels such as renewable natural gas (RNG), renewable diesel (RD), and sustainable aviation fuel (SAF) use cellulosic biomass as feedstock
- Value chains are complex, involving multiple inputs and energy transformation pathways that often rely on pioneering technologies
- These processes must be optimized for cost, energy efficiency, scalability, and by-products; for example, biogas is ideally produced via anaerobic digestion
- Factors shaping biofuel industry trends include feedstock supply, infrastructure maturity, process economics, and government regulations
- The US has become a global focal point for biofuel production in part due to Inflation Reduction Act (IRA) incentives and a growing number of regional low carbon fuel standard (LCFS) programs

Bioenergy Potential vs World Energy Demand

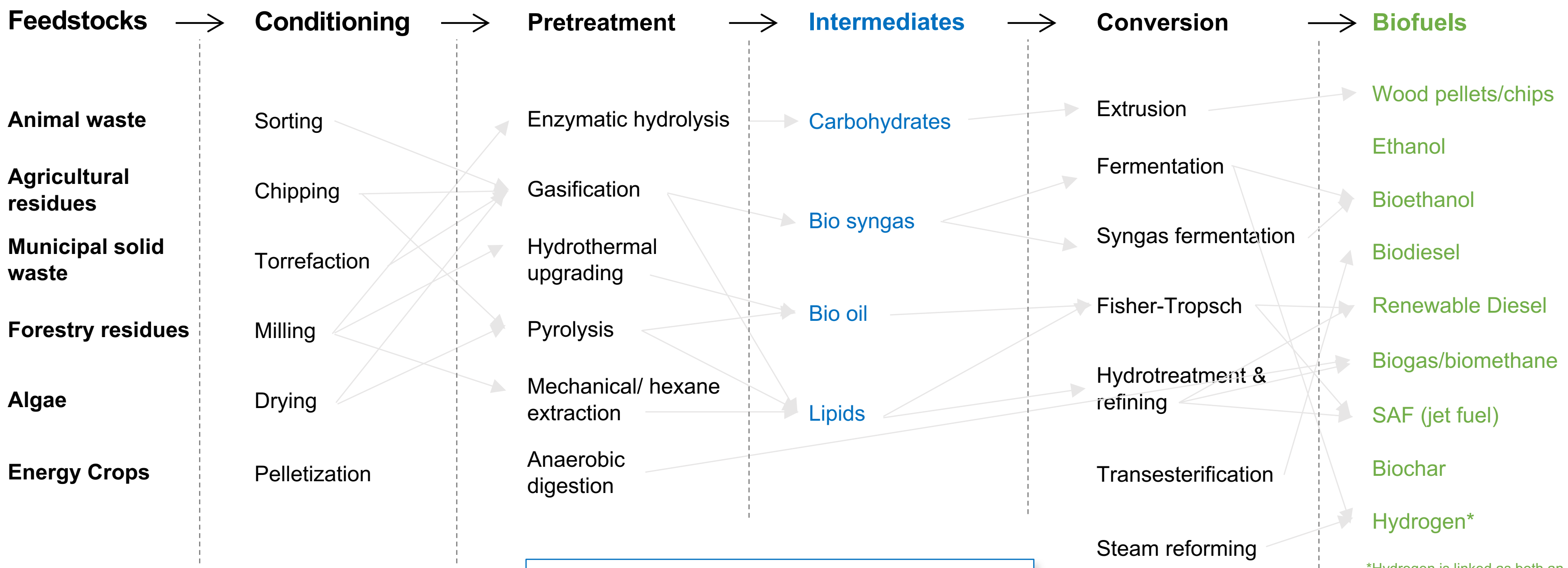
World, 2060, Mt



Approximately 70 percent of the sustainably supplied biomass feedstock can be sourced from agriculture residues and energy crops

Source: Kearny | Energy Transition Institute, EQ proprietary research

Biofuels Value Chain Pathways



*Hydrogen is linked as both an input and output to numerous biofuel pathways

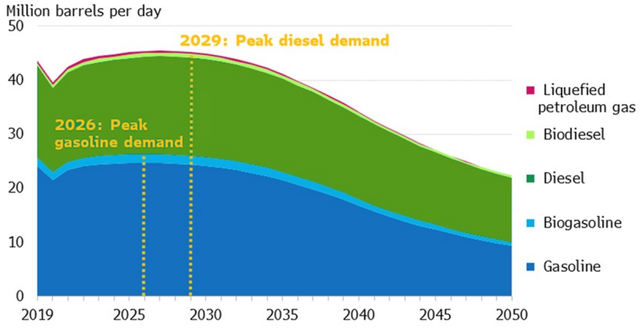
Overlap between complex, varied production pathways can create feedstock competition and project development challenges

Source: Kearny | Energy Transition Institute; EQ proprietary research

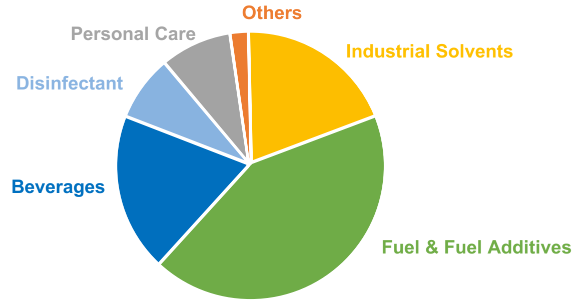
Biofuels 1.0: Ethanol and Biodiesel

- Traditional ethanol and biodiesel are the two most common types of biofuels in use today and represent the first generation of biofuel technology
- Both industries are mature, with established infrastructure, defined markets, and significant government support
- Barriers to entry are high, in part because projects are capital intensive and rely on scale, upstream feedstock ownership/contracts, and subsidies for economic viability
- Production capacity currently exceeds demand, and both products are viewed as homogenous commodities that compete on lowest cost
- The transportation sector, specifically gasoline and diesel-fueled light duty vehicles, accounts for 80% of the market; EV adoption means that peak demand is less than five years away
- Sustainability criticisms of conventional biofuels, i.e., around deforestation and increased food prices, are generally unproven; however, both the traditional ethanol and biodiesel markets are expected to shrink vis-a vis the next generation of biofuels, which constitute drop-in fuels and offer lower carbon intensity (CI) scores
- In addition to the by-product production of distiller's corn oil (a key feedstock to the rapidly-growing RD market), a longer-term bright spot for low carbon ethanol is its potential in the production of SAF
- IRA provisions are incentivizing carbon reduction strategies along the ethanol value chain; given limited availability of other low CI feedstock, stronger demand for low-CI ethanol could emerge once alcohol-to-jet (AtJ) SAF technology scales, i.e., 2030+

Nearing the peak for gasoline and diesel demand



Global ethanol market share by current application

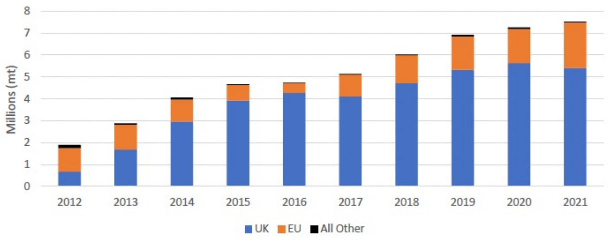


Source: BNEF, EIA, BMO, Biodiesel Magazine, Grandview Research, EQ proprietary research

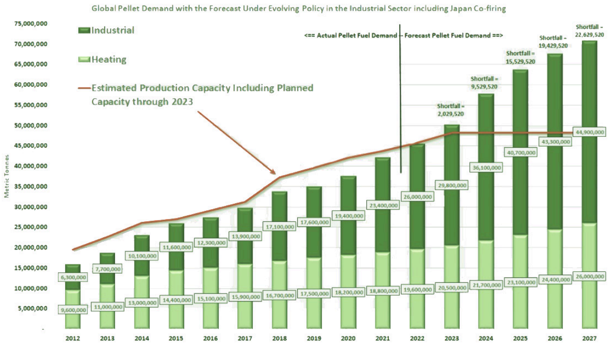
Biofuels 1.0: Wood Pellets

- The wood pellet market has grown substantially since the 2000s
- Globally, production is concentrated in the southeastern US; however, the domestic market is relatively small
- The sector is considered mature and consolidated, and utilizes long-proven technologies
- Industrial pellet demand is primarily driven by power plants in the EU and Asia; it has doubled over the past decade with increasing use in co-firing with, or replacing, coal
- In 2022, US wood pellet exports reached a record $1.5 billion although industry economics have reportedly been impacted by rising production costs
- EU policy deems wood pellets to be renewable energy, with zero carbon emissions, and the region's climate change goals depend on the continuation of this controversial designation
- Legislative attempts to prohibit EU countries from burning whole trees to meet energy goals have been partially successful and subsidies have ended, but wood remains classified as renewable energy
- From a sustainability perspective, projects that can point to waste and residue vs. whole trees as inputs will be more attractive though pellets will generally remain a commodity
- The current US market remains dependent on EU demand; Asia could represent a new market but would be more challenging to supply from slower growing, more regulated forests in the Pacific Northwest

US Wood Pellet Exports, Destinations, Quantity



Global Pellet Demand and Forecast*

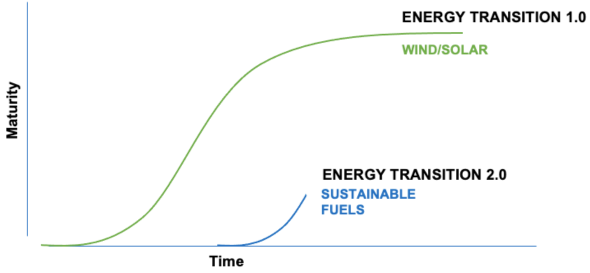


*Forecasted growth in part driven by Japan and Germany co-firing policy

Source: Argus, Eastin, "Opportunities for US Wood Pellets", USITC DataWeb/Census, Canadian Biomass, FAO, Bioenergy Europe, EQ proprietary research

Biofuels 2.0: Introduction

- Growth in demand for next generation biofuels, including RNG, RD, and SAF, is being supported by technological innovation, production incentives, and capital inflows
- Production from waste addresses greenhouse gas and feedstock policy objectives vs. the energy crops used to produce conventional biofuels
- Waste is becoming an increasingly valuable and expensive, impacting project economics
- Favorable policy structures in the US, including the IRA, Renewable Fuel Standard (RFS), and Low Carbon Fuel Standard (LCFS) programs, have made the country a focal point for investment
- Outside of federal and state regulated markets, biofuel producers are increasingly looking to voluntary offtake, which has the potential to grow rapidly as end users look to green supply chains
- The biofuels 2.0 outlook is positive although consolidation is likely as oil and gas majors and utilities drive vertical integration
- While EV adoption will cut into current market share, other end uses such as aviation, shipping, and hydrogen production will continue to support demand
- CCUS's role within the biofuels sector is expanding, with increased investment interest in point-source emissions applications



Sustainable "Drop-In" Fuels
Emerging and growing to scale

Subsectors of Sustainable Fuels

RNG	Other Biofuels	Carbon Management	Next Gen Fuels
Dairy, Food Waste, Landfill, etc.	Renewable Diesel, SAF, Biodiesel	Carbon Capture, Sequestration, etc.	Hydrogen, Ammonia, etc.

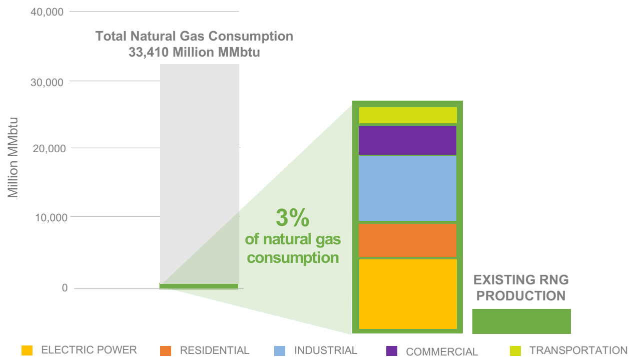
Source: S&P, BNEF, Wood Mackenzie, Argus, EcoEngineers, EQ proprietary research

Biofuels 2.0: Renewable Natural Gas

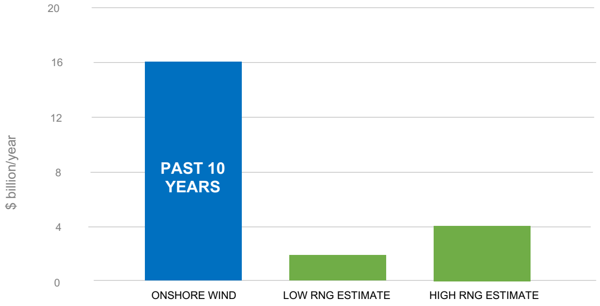
- There are two primary markets for RNG:
  - Policy-driven compliance markets – demand is legislated by state or federal authorities
  - Voluntary markets – private mandates and goals drive a focus on sustainable operations
- While transportation compliance markets are the current highest and best use for RNG, voluntary markets are growing and have significant expansion potential
- The volume required to replace just a fraction of conventional natural gas use is indicative of a massive supply-demand imbalance
  - RNG now constitutes <0.5 percent of current US usage, which totaled 33.4 quads in 2022
  - Increasing RNG's share of conventional natural gas usage to 3.0 percent would require more than 900 million Mmbtu of additional production
- These figures dwarf current estimated RNG production and highlight the theoretical potential to develop trillions of dollars of additional projects
- Considering feedstock, infrastructure/technology, and other economic constraints, there remains the potential for $2-$4 billion in annual average investment through 2030
- These requirements are in addition to transportation demand, which constitutes >80% of US demand
- Even assuming near-saturation of the CA transportation market, low-CI RNG will continue to be attractive across an expanding set of geographies and uses
- RNG could also potentially be used to lower the CI of blue hydrogen although recent guidance around IRA incentives may make this pathway less promising

Source: BNEF; DOE; Wood Mackenzie; EQ proprietary research

RNG Share of Natural Gas Consumption



BNEF Average Annual RNG Investment to 2030 vs. Historical Onshore Wind Investment

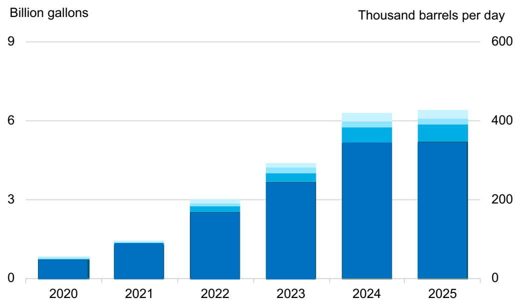


Assumes RNG production cost of $20 per MMBtu

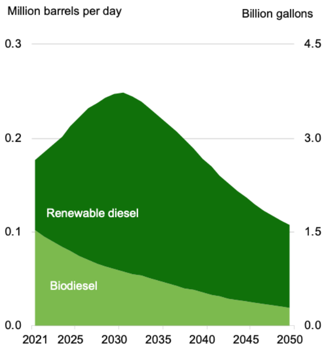
Biofuels 2.0: Renewable Diesel

- RD has the potential to deliver substantial emissions reductions for hard-to-abate transportation segments like trucking
- Biodiesel has been blended into the diesel pool at low levels for more than a decade, but usage is capped; RD constitutes a “drop in” biofuel and is not subject to blending limits
- High production costs (generally more than double conventional diesel) mean RD adoption is limited to regions with supportive policy
    - 70 percent of US RD consumption occurs in California
    - RD already accounts for one-quarter of California’s diesel pool
    - Economical low-CI feedstock is expected to remain a constraint
- More than 90 percent of CA consumption has historically been imported from Neste’s Singapore plant; however, US production is growing and is forecast to reach 5-6 billion gallons by 2025
- Expanding LCFS programs will increase demand; however, incentives may shift to local production and require lower CI feedstock
- Oil refiners dominate supply; 50 percent of the RD project pipeline is comprised of oil refinery conversions and by 2025, refiners are expected to own 90 percent of RD and SAF companies, 70 percent of which will be US-based
- While facility openings have paused, large refiners are not expected to be deterred by an oversupply of credits; they can still capitalize on efficiency and feedstock hedging benefits
- Although SAF is a by-product of the process used to make RD, production incentives remain more attractive for RD

Announced RD Capacity Additions



Outlook for US Biodiesel and Renewable Diesel Demand



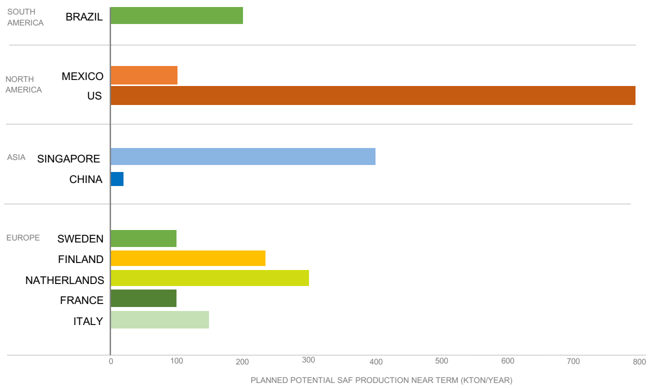
Source: Platt’s Analytics, BNEF, Argus

Biofuels 2.0: Sustainable Aviation Fuel

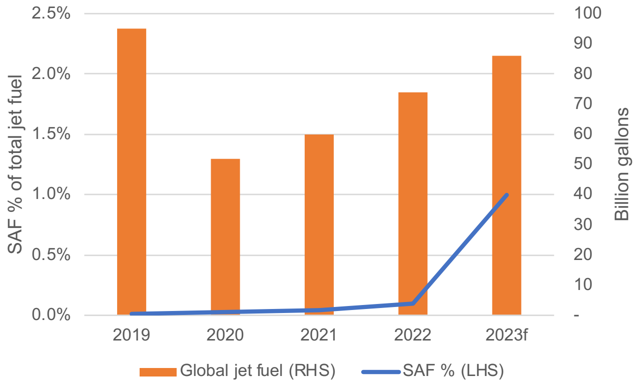
- The SAF industry remains relatively nascent; only the HEFA pathway is fully commercialized, in part due to minimal infrastructure requirements and existing downstream supply chains
- Other pathways include Power-to-Liquid (PtL) via the Fischer-Tropsch process and Alcohol-to-Jet (AtJ)
- In the US, plans to scale up the AtJ pathway are based on the diversion of low CI ethanol into SAF
- While the ethanol sector is optimistic about this possibility, it may not be the most economic pathway

- The demand-supply gap is significant with SAF comprising just 0.1% of global commercial jet fuel consumption despite a 200 percent volume increase from 2021 to 2022
- Announced project capacity would have increased SAF production to 2.4 percent of global jet fuel consumption by year end 2023; however, slower-than-forecast development make it more likely to reach 2.0 percent by 2025
- The commercial airline sector is driving demand with highly-publicized net zero commitments, e.g., Southwest is aiming for up to 10 percent SAF blend by 2030

Current & Potential Global SAF Capacity



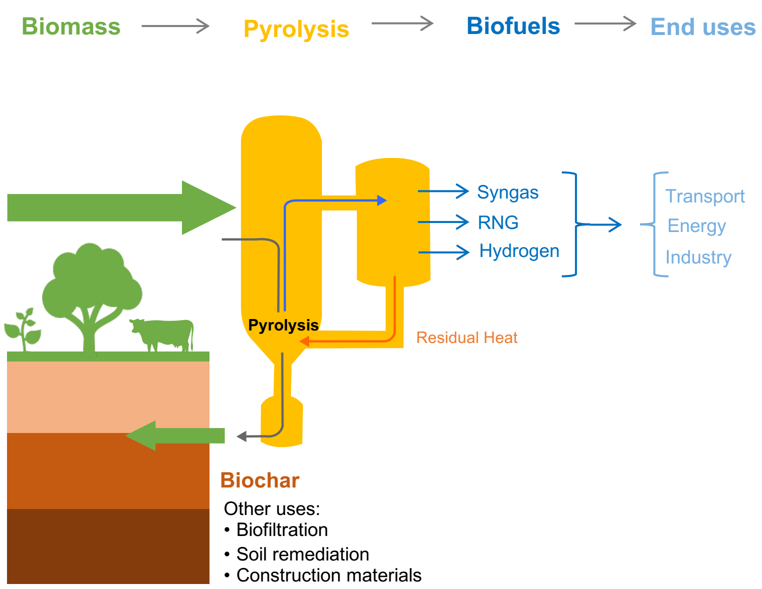
Global Jet Fuel Consumption vs. SAF Production



Source: Sustainable Aviation Futures; IATA; ResearchGate; EQ proprietary research

Biofuels 2.0: Biochar

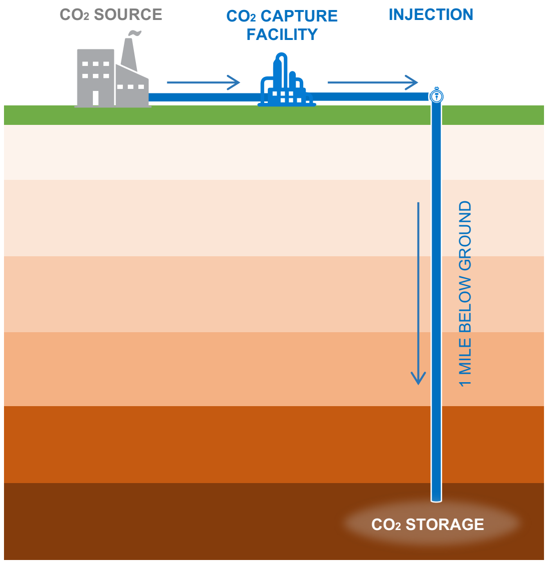
- Biochar is a fine-grained residue produced via a relatively proven, simple process with the result being a stable, solid carbon sink
- Sustainably sourced biochar could soak up an estimated 12 percent of global GHG
- Beyond its carbon sequestration capabilities, biochar can be used as a soil supplement to enhance fertility and productivity, reduce fertilizer requirements, retain water, and stimulate microbial activity
- It can also be used as a filter material, and as a building material component
- Wastewater treatment plants are also trialing the use pyrolysis in place of landfilling sewage sludge, with biochar positioned as a valuable by-product
- Despite all the positive attributes of what is a relatively low capex-to-carbon value process, the biochar sector has struggled to scale, in part because of:
    - Feedstock competition from higher value end uses
    - A price sensitive end market in agriculture
    - A lack of standardized technology and equipment
- Numerous projects are proposed and are expected to benefit from continued expansion of a more structured, robust voluntary carbon market, additional value streams (e.g., syngas), and economies of scale



Source: The Insight Partners, Net Zero Investor, Biochar Life, Carbon Capture Magazine, Johannes Lehmann

Carbon Capture and Storage

- CCS has numerous applications, including its use in biofuels projects
- The most logical early adopters are the oil, gas, and ethanol sectors, followed by hydrogen; potential in the power sector is limited by its intermittent nature
- High costs will dampen use in hard-to-abate industries such as steel and cement production
- Despite its obvious application as a climate change solution, CCS faces significant hurdles:
  - A lack of commercial scale examples, including of project structures and agreements
  - Extremely slow permitting processes
  - An absence of consistent frameworks across states
  - Public opposition reflecting concern about risks and environmental impacts
  - Assembling complex “floorspace”, i.e., securing control of pipelines, suitable storage, and right-of-ways
  - Ensuring permanence, i.e., that all CO2 captured is sequestered
- As a result, it can easily take more than five years from project inception to groundbreaking, a timeframe not appealing to most investors
- More positively, the US is well-positioned in terms of both incentives and geographical areas suitable for storage
- Direct air capture (DAC) is also touted as having considerable potential but remains at a very pioneering stage; while DAC offsets can generate $250 to $600 per ton, technology costs still offset these revenues



Source: Argus; Reuters; EQ proprietary research

Summary of Biofuel Use Cases

Biomass-to-bioenergy:

Final Outputs and Corresponding Industry of Application

○ APPLICABLE

● HIGH PERFORMING

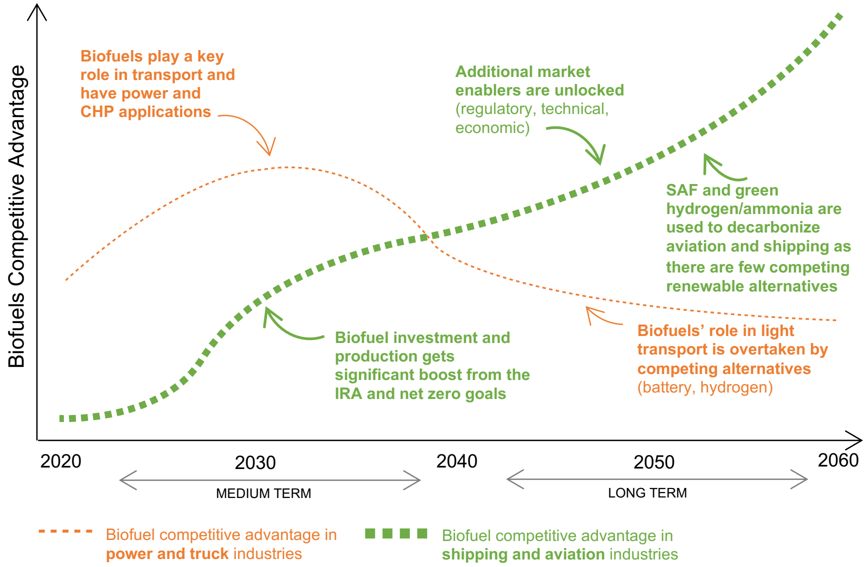
BIOFUELS		BIOENERGY									
		ENERGY			TRANSPORT				INDUSTRY	BUILDINGS (HEAT)	AGRICULTURE
		Power	Heat	CHP	Cars	Trucks	Aviation	Shipping			
SOLID	Wood Chips & Pellets	○	○	○					○	○	
SOLID	Biochar	○	○	○						○	●
LIQUID	Ethanol/Bioethanol				○	○		○		○	●
LIQUID	Biodiesel				○	○		○			
LIQUID	Renewable Diesel				●	●		●			
LIQUID	SAF						●				
GASEOUS	Biogas	○	○	○						○	○
GASEOUS	RNG	●	●	●	●	●		●		●	○
GASEOUS	Hydrogen*	○	○		○	●		●	●		●

*Hydrogen is not a biofuel but is linked both as an input and output to numerous biofuel pathways

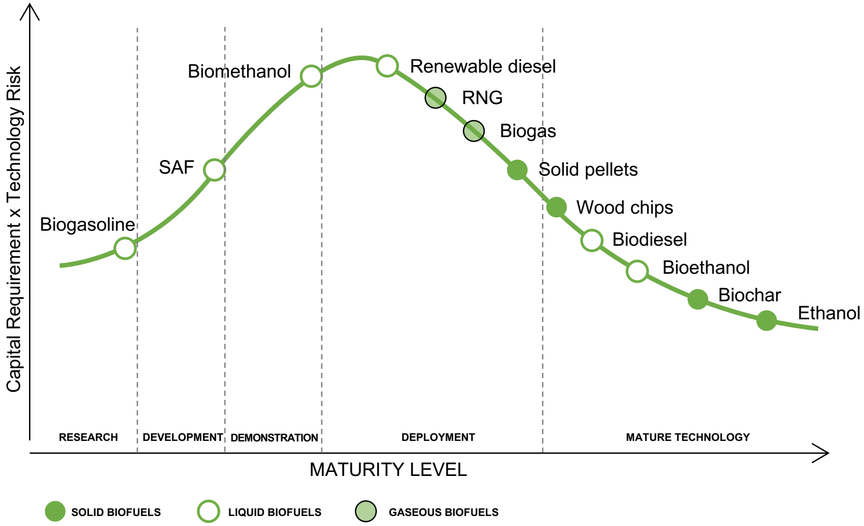
Source: Kearny Energy Transition Institute, EQ proprietary research

Biofuels Maturity Curves

Biofuels markets show distinct medium- and long-term shifts



Biofuels maturity curve

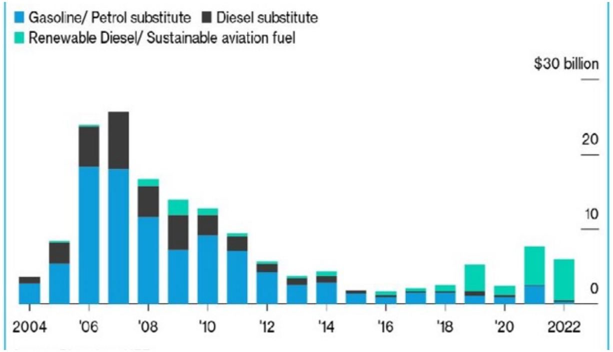


Source: Kearny Energy Transition Institute, EQ proprietary research

Conclusions

- Growth in mature, first-generation biofuels segments is limited by blending requirements and competition from a new generation of renewable alternatives
- For biofuels 2.0 to replace even a fraction of current conventional fuel usage, an enormous expansion in production is needed
- Expanding markets and net zero commitments mean supply will significantly lag demand
- Technological innovation and policy are driving a rapid increase in investment opportunities that range from inputs like feedstock, tech, and equipment, to production facilities, distribution infrastructure, and a wide range of end uses
- The US is becoming the focal point for this investment, in part because incentives have a significant impact on the feasibility of scale up requirements
- Permitting remains a significant hurdle, as does clarification around pathway approvals, disparate programs, and specific tax credit guidance
- Economical low CI feedstock remains a bottleneck and access will be a key competitive differentiator
- **RNG is currently the most promising biofuel**; the anaerobic production pathway is proven, it utilizes existing infrastructure, and it has a wide range of end uses beyond transportation
- **RD production will mostly stay in the realm of large refineries**, and faces global feedstock risks as well as limits on transportation end uses
- **Most other technologies, e.g., CCS, SAF, remain in the proof-of-concept phases**, with high production costs, undeveloped supply networks, and unproven technologies; financing is challenging, and patient capital is required for them to hit the critical mass necessary for scale and mainstream application
- While the investment landscape includes governments and venture capital financing at the high-risk early stages and industry corporates looking to vertically integrate sustainable upstream processes, **opportunities for real asset and growth equity exist where solid technical teams are scaling up distributed systems that can capitalize on energy transition demand, regulatory/policy tailwinds, and voluntary carbon markets**

Global investment in biofuels



Source: BloombergNEF, EQ proprietary research