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Lowering your emissions through innovation in transport and energy infrastructure

An Introduction to Agriculture Fuels and Vehicles for the Future

Cenex Insight - September 2022

Green hydrogen can have major emission reduction for agriculture vehicles, and if combusted in an ICE, there is potential for lower NOx emissions than diesel, plus other benefits. Image: JCB

Phasing out Red Diesel

Diesel has been agriculture's fuel of choice for generations, but the challenge now is to find environmentally friendly replacements that will fuel the farm vehicles of the future.

The agricultural sector currently gains real economic benefit from the red diesel rebate. Although it is exempt in the subsidy removal bill from April 2022, it is expected to end before 2030. Any delays could impact the sector's carbon ambitions.

The transition to 'non-diesel' farm powertrains will not happen quickly. However, it is not yet clear which technology (or technologies) will power the net zero agricultural equipment beyond 2030.

Predicting the best fuels for farm transport is challenging because of the wide variety of vehicles in use, from tractors to mowers, quad bikes, and front-loaders. Each has differing operational requirements that make like-for-like comparison difficult. Vehicle energy demand will also be affected by farm specific characteristics such as arable or pastoral farming, type of crop, topography and soil.

Manufacturers are designing vehicles powered by low carbon fuel options: biodiesel and biomethane, hydrogen and battery electric. As with many sectors, no one technology will prevail, with farms predicted to utilise a combination across different applications.

As typical tractor lifetimes are around 15 to 20 years, 2030 would be the last year when traditional diesel tractors should be sold in order to meet net zero targets in 2050; equipment sold after 2030 should be designed to support low and zero emission conversion.

Biofuels

Biofuels and biomethane offer the opportunity to reduce carbon emissions immediately using current proven farm-scale technologies which, in best practice, primarily utilise the carbon energy from wastes and residues.

They are generally categorised as 'sustainable' energy sources as the carbon dioxide added to the atmosphere from burning biofuels is largely absorbed by the organic matter used to produce them, presenting the agricultural sector with a unique opportunity for biofuels within a more localised, circular economy.

The next 10-20 years are an opportunity for biofuel deployment to reduce CO_2 emissions while fully zero emission solutions are developed.

HVO and FAME biodiesel are like-for-like replacements for fossil-derived diesel (assuming operational changes to service times for equipment and fuel stores are acceptable) and can be used in modern diesel engines without modification.

An advantage of biofuels over electricity is its technological maturity and speed of re-fuelling. For a farm with a gas fuel dispensing point, a complete fill need only take a few minutes - comparable to diesel re-fuelling – providing vehicles with more time in the fields.

However biofuels to do not provide air quality benefits and a methane "slip" (where unburned gases escape) can result in higher greenhouse gas impacts than fossil fuels.

Renewable biodiesel is already used in some farm vehicles. Vehicle manufacturers provide a warranty for blends up to B30, with some going up to B100.

Biomethane can be dispensed at farm production sites or distributed to other farms using biomethane trucks. While it may not be compatible with future net zero targets, it offers immediate carbon savings

Biofuels

in the short to medium term.

Cenex analysis for RASE suggests that biodiesel can be considered as like-for-like replacements for fossil derived diesel, assuming changes to service times and for fuelling are acceptable.

Methane based systems have a slightly lower energy density which will require additional refuelling stops, however, daily refuelling should be sufficient for low energy scenarios and some high energy scenario.

New Holland have developed a 100% methane powered production tractor. It is reported to have comparable power output to its diesel equivalent, with up to 30% lower running costs, 99% less particulate matter, and at least 80% lower emissions overall emissions if using farm supplied biomethane.

Battery Electric

Electric powertrains are inherently more efficient than the internal combustion engine (ICE), as there is no need to convert the stored chemical energy into another form to drive a mechanical system.

The use of battery powered vehicles on farms is growing, especially with smaller on- and off-road vehicles where the battery does not unbalance the weight-to-power ratio, such as quad bikes for moving around the farm and new 'compact' tractors.

In larger vehicles (tractors or combines) this ratio is critical. BEV tractors available in the UK have low power output to preserve battery demand and limit weight. For 'agricultural tractors' over 50 hp, the battery pack required to provide the equivalent power to a diesel engine would be so heavy that energy needed to carry the battery would consume most of the power it produced.

Where duty cycles are long, BEV solutions are much less likely. Analysis by Cenex across tilling, planting and harvesting shows that BEV would require around 17 times more refuelling events (2.8 events for harvesting) compared to biodiesel (0.2 events) per hectare. Given the average farm in the UK is 64 ha, this amounts to 176.6 refuelling events for a high energy harvest and 43 for low energy.

With developments in battery technology, heavy tractors may soon be able to provide more power for longer duration and complete more field tasks. It remains to be seen what higher power electric tractors will be available by 2030.

Battery technology will need to develop to cope with modern tractor demands

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Hydrogen

Hydrogen is well suited to farms of the future due to its quick refuelling compared to BEVs (and similar times to diesel) and high energy density. It can be combusted as a dual fuel in an ICE or used to power an electric vehicle through a fuel cell.

When used in an ICE, hydrogen is typically mixed with another fuel and is therefore not considered net zero, but may act as an intermediary to increase hydrogen demand and the support the case for renewably sourced green hydrogen from electrolysis.

When powered by green hydrogen, hydrogen fuel cells are considered a net-zero technology. Based on real-world observations of road fuel cell vehicles, even fossil fuel derived hydrogen can achieve up to 50% reduction in GHG emissions; a similar reduction should be possible in agricultural equipment.

The technology is in its infancy for transport, and refuelling systems are underdeveloped and suffer from a significant price premium, which has stalled the uptake of hydrogen powertrains.

On-farm generation of green hydrogen may be possible should sufficient renewable electricity be available, though until electrolysers are much cheaper, local generation of hydrogen will not be viable.

Hydrogen vehicles are in development. Manufacturer JCB (page 2) is developing a pure hydrogen-fuelled internal combustion engine (H2 ICE) as an alternative to using fuel cells. Their H2 ICE back-hoe loader will be commercially available in 2022 and there are plans to extend this engine to other vehicles for farm use.

There is some expectation that hydrogen will be more widely available in heavy road transport from 2030 onwards. If this proves to be the case, then increased scale of production and supply infrastructure could mean that fuel cell powertrains for farm vehicles may become viable in the longer term.

Connected and Autonomous Vehicles

Since at least 2014, the increase in use of digital technologies, drones, precision farming techniques, robotics, automation and artificial intelligence (AI) has been astonishing. Many critical farm operations now rely on global positioning satellites (GPS), smart vision systems, and laser guidance.

Vehicles with this technology can use any energy source, but because it is smaller and lighter (in the absence of steering system and other technology for manual operation) than fossil fuelled equipment it can be more easily adapted to battery electric using local renewable electricity.

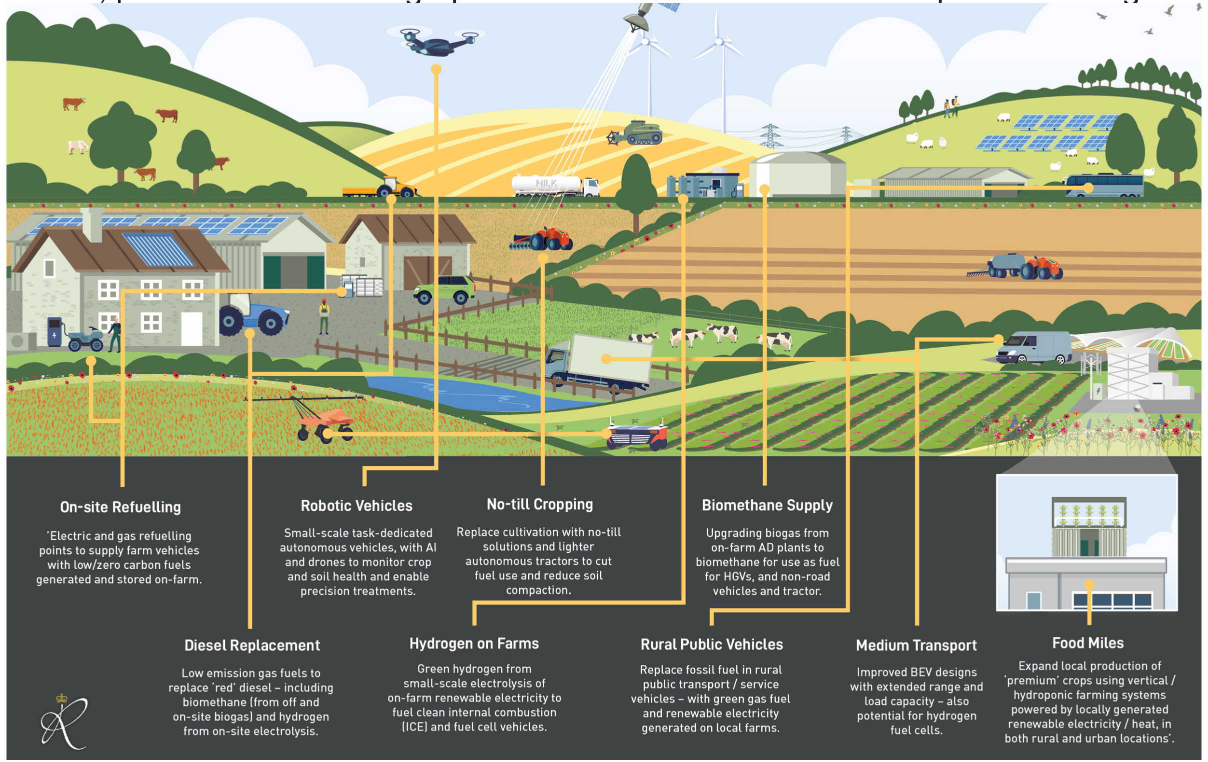
Connected and autonomous vehicles (CAV) prototype testing and demonstration projects are already taking place across the UK and globally, with some already commercially available, including:

> Electric tractors with an optional driverless mode that enables the unit to complete pre-programmed tasks, or the vehicles can be slaved to follow other vehicles
> Autonomous weeding, fruit picking and seeding robots
> Drones for spraying and surveying crops
> Controlled traffic farming (CTF) for operating field equipment repeatedly on the same routes through the crop,

Many of the benefits of autonomous crop equipment depend on some level of AI. It should be noted that effective use of AI technology and related equipment often depends on wireless connectivity (4G and 5G) which can be sparse in rural Britain.

Farm of the Future

Cenex co-authored sections, and was part of the editorial team, for Royal Agriculture Society of England's suite of reports, Farm of the Future: Journey to Net Zero. A technical paper, Decarbonising Farm Vehicles and Future Fuels, produced the below graphic to demonstrate different transport technologies on a farm.



Technology Suitability

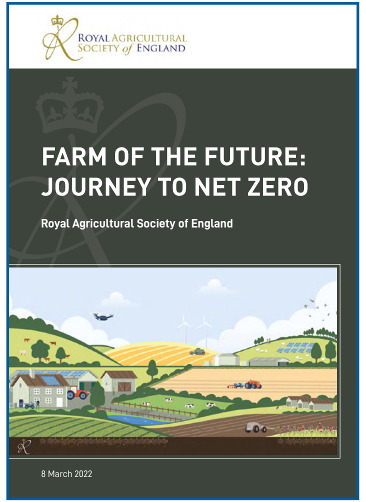
No clear roadmaps for alternative fuels for agri-sector equipment exist yet, however Cenex expects agriculture plant to follow the same overall trends as rigid HGVs and anticipate similar proliferation of vehicles and refuelling infrastructure in agriculture. The table below, though, summarises low emission fuel technologies against key metrics.

	HVO	FAME	Methane	Hydrogen Dual Fuel	Battery Electric	Fuel Cell Electric
GHG Emissions		Blend limited		SR[1] limited		H_2 Production
AQ Emissions	NRMM V				ZEV	
Noise Pollution			SI[1] Only			
Maturity		Partial OEM			Niche supplier	
Availability (2021)						
Availability (2030)			Could be phased out	Somewhat uncertain		Availability uncertain
Typical Operation		Fuel Use / Storage				
Intensive Operation		Fuel Use / Storage			Energy Storage	
Vehicle Weight			Gas tanks		Batteries	Batteries + Gas tanks
Vehicle Costs						
Fuel Costs						
Maintenance Costs					Predicted improvement	
Existing Infrastructure					Depot Power	
Infrastructure Cost			Varies by site	Varies by site	Varies by site	Varies by site
Infrastructure Viability			Varies by site	Varies by site	Varies by site	Varies by site

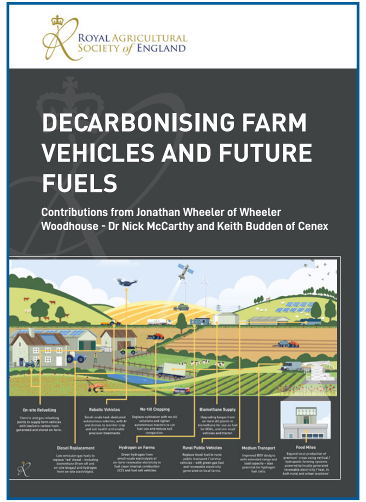
Summary of Low Emission Vehicle Fuel Technology Options, and Key, right

Key	Cost and Emissions	Maturity and Availability	All Others
	Better than diesel	OEM product	Advantage
	Same as diesel	Conditional	Neutral
	Slightly worse than diesel	Low volume	Minor disadvantage
	Worse than diesel	Demonstration phase	Disadvantage

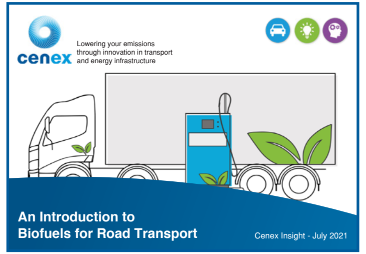
Further Reading



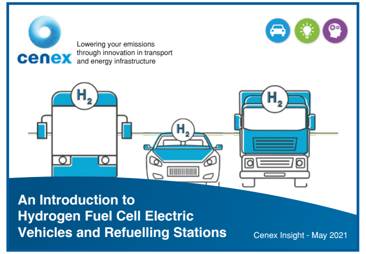
Farm of the Future: Journey to Net Zero
https://vm-01-crm02.altido.com/clients/rase-c3c5ffc2133a3eed/uploads/documents/website-report/FARM%20OF%20THE%20FUTURE-%20JOURNEY%20TO%20NET%20ZERO.pdf



Decarbonising Farm Vehicles and Future Fuels
https://vm-01-crm02.altido.com/clients/rase-c3c5ffc2133a3eed/uploads/documents/website-report/Decarbonising%20Farm%20Vehicles%20and%20Future%20Fuels.pdf



An Introduction to Biofuels for Road Transport
www.cenex.co.uk/app/uploads/2021/08/Intro-to-Biofuels.pdf



An Introduction to Hydrogen Vehicles and Refuelling Infrastructure
www.cenex.co.uk/app/uploads/2021/05/Intro-to-hydrogen-1.pdf

Project: Red Diesel Replacement Study
www.cenex.co.uk/case-studies/red-diesel-replacement-stakeholder-engagement-pre-innovation-study/

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