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Electric tractors by 2020? – a review of advanced vehicle technology in the agricultural sector

A research / position paper for the NFU

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Why is this of interest to NFU members?

This thought-provoking "blue sky" paper revives a theme previously raised by a number of NFU officeholders – given the drive to decarbonise both agriculture and the transport sector, and based on current trends, what is likely to be powering agricultural and farmyard machinery in ten or twenty years' time? Covering a popular subject for discussion among farmers, the authors aim to inspire and shape agricultural opinion about recent technological developments through this far-sighted strategic briefing.

What the NFU is doing

The NFU remains up-to-date with the latest technological developments in British agriculture and horticulture, in order to campaign more effectively for farmers and to champion a forward-looking industry. We are aware of emerging trends in both vehicle technology and agricultural practice, and we want our members to be well-informed in their business planning and future investments.

Introduction

The UK agricultural machinery market includes about 10,000-15,000 new tractor sales per year[1], plus around 3000 telehandlers and thousands of combines, sprayers, ploughs, harrows, balers, etc. Here in the UK and worldwide, there is growing evidence now of possible future trends in vehicle technology for the agricultural sector – including smaller driverless tractors, electric farmyard and other vehicles like telehandlers and ATVs, and safer electrical interfaces between agricultural equipment, replacing mechanical PTOs and hydraulics. In the past year or two, we have heard about an electric Land Rover Defender being trialled, and Jaguar Land Rover and its competitors are about to introduce electric or hybrid 4x4 vehicles, opening up opportunities for rural personal transport with reduced running costs.

Imagine a farm where electric agricultural vehicles, some autonomous, some conventional, are connected to charging points in large solar PV equipped 'carport-style' machinery sheds, earning additional income from so-called 'vehicle-to-grid' network balancing services while they are on-charge. This may be no longer science fiction, but instead the technology of the near future.

[1] http://www.aea.uk.com/industry-facts

Recent progress in electric/hybrid traction for heavy vehicles

Most of the technological progress seen to date in electrification of transport has been in light electric and plug-in hybrid vehicles (private cars and delivery vans), with more limited expectations for heavy goods vehicles, buses and other commercial/ industrial vehicles carrying large payloads or travelling long distances daily.

However, recent announcements from Mercedes-Benz, Tesla Motors and others suggest that the prospects for both range and payloads of heavy electric vehicles may change markedly over the next 5-10 years. Daimler Benz has already demonstrated a Fuso light truck with a 2-tonne payload and 100 km range in Portugal[2], while Mercedes has shown a pre-production version of its heavy duty 'Urban eTruck' (26-tonne, 200 km range), aimed at clean-air city deliveries in the early 2020s.

In North Dakota, USA, the Autonomous Tractor Corporation already offers replacement diesel-electric hybrid drivetrains for refurbished tractors[3]. Their 'eDrive' transmission, involving an electric motor in each driven wheel hub, is available in 200-hp or 400-hp packages – and is claimed to be lighter than a conventional powertrain, offering improved fuel consumption and reduced soil compaction. Similar fuel-saving diesel-electric transmissions have been available from Caterpillar, Komatsu and John Deere in their ranges of earthmoving, mining and construction equipment for around the past five years.

In very recent news, John Deere is expected to show off a battery-electric tractor in February 2017 at the Paris International Agribusiness Show. The SESAM (Sustainable Energy Supply for Agricultural Machinery) project tractor builds upon Deere's earlier petrol-electric hybrid transmission by incorporating a large 130-150 kilowatt-hour battery. However, its present capability cannot yet match a diesel tractor, being limited to about 4 hours operation and requiring some three hours to recharge.

Energy efficiency, new fuels and solar power

Energy efficiency

Opportunities to reduce business costs and carbon emissions through improved energy management in field operations have been highlighted through initiatives such as the agricultural Greenhouse Gas Action Plan, in which the Agricultural Engineers Association remains a partner. Measures such as controlled-traffic farming, precision farming and tractor driver training programmes can all complement the drive towards improved engines and transmissions.

Efficient20 was an EU-funded programme, supported by the European agricultural machinery association CEMA, to share information between 30 pilot groups in nine Member States on attaining a goal of 20% savings in tractor fuel use[4], through better

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[2] http://www.fuso-trucks.com/fuso-europe/0-1179-1827328-1-1827329-1-0-0-0-0-1-18022-1578825-0-0-0-0-0-0-0.html

[3] http://farmindustrynews.com/tractors/bringing-hybrid-power-diesel-tractors

[4] https://ec.europa.eu/energy/intelligent/projects/en/projects/efficient20

engine and tyre maintenance, improved fuel storage, adaptive driving, and improved management of implements and payload weights[5]:

Biodiesel and vegetable oil fuel

In recent years, a number of tractor manufacturers have approved their equipment for operation on 100% biodiesel fuel, although the vast majority of the European biofuel market is for 5-10% blends with petroleum fuels. Both Deutz-Fahr and Fendt previously offered vegetable-oil conversions for diesels using technology from Elsbett of Germany. Former racing driver Jody Scheckter, who farms at Laverstock Park, Hampshire, has such a converted tractor. Vegetable oil conversion kits (both Elsbett and ATG technology) remain available from a number of suppliers, and it has been reported that just 9 hectares of oilseed rape, yielding about 10,000 litres/year of cold-pressed and filtered oil, would be sufficient for typical crop tillage operations on about 100 hectares.

Biogas engine options

In 2009, Austrian manufacturer Steyr (now part of CNH) revealed a prototype dual-fuel system whereby 40% of the fuel for a 200hp tractor was provided by biogas[6]. The following year, Valtra (now AGCO) showed a prototype 110hp model that could derive 70-80% of its power from biomethane fuel, produced with an on-farm AD plant plus a biogas upgrading and compression unit[7]:

Building upon its original N101 biogas tractor, Valtra's 2015 range included the N103.4, N113 and N123 dual-fuel tractors, capable of running on diesel alone or a dynamically-adjusted mixture of diesel and up to 90% biogas[8]:

Most recently, a handful of pioneering UK farms have trialled a CNH/New Holland T6 prototype tractor which runs on 100% biomethane, using technology already deployed in commercial road vehicles. An on-farm compression plant for upgraded biogas could enable tractors and other farm vehicles to be powered by this renewable fuel, and might possibly provide a refuelling facility for neighbouring farms.

Hydrogen fuel cell power

Since 2009, CNH (New Holland) have publicised an experimental fuel-cell powered tractor, the NH2, a renewable hydrogen-powered tractor concept. Their original animated video "The Virtuous Cycle" which portrayed a futuristic energy-independent farm, has evolved into ongoing research around the concept of an “Energy Independent Farm”, based upon their prototype hydrogen and biomethane tractors

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[5] http://www.cema-agri.org/newsletterarticle/project-efficient20-reducing-fuel-use-through-enhanced-operator-efficiency

[6] http://www.fwi.co.uk/Articles/2009/04/01/114960/Steyr-launches-first-biogas-powered-tractor.htm

[7] http://www.fwi.co.uk/machinery/valtra-unveils-prototype-dual-fuel-biogas-tractor.htm

[8] http://www.valtra.co.uk/335.aspx; http://www.valtra.co.uk/New-generation-of-biogas-tractors_3345.aspx

as well as a variety of other on-farm renewable energy resources,[9] presently deployed in trials at La Bellotta near Turin, Italy.

Solar powered vehicle charging and electricity storage

As early as 2010, Same Deutz-Fahr offered a solar PV tractor cab roof option[10], generating about 100 watts of power, a relatively modest amount but sufficient to run the cab ventilation fan when the TTV 7.260 tractor was parked in the sun, to avoid over-heating and supplement the air-conditioning system.

More recently, there have been numerous reports of NFU members with rooftop and ground-mounted solar arrays charging electric cars such as the Nissan Leaf with surplus on-site power. The first 'solar carports', now common in the USA and throughout Europe, have been seen around Britain and are expected to develop as a niche market for electric and plug-in hybrid vehicle charging on farms. Alongside stationary battery electricity storage, it is expected that vehicle battery packs may soon be able to earn income towards their recharging and maintenance costs by providing network balancing services to the local grid.

Robot tractors

Fully autonomous tractors take the principles of GPS-guided precision agriculture to new heights, and enable one controller to manage several vehicles and operations at once. In the future, such robot tractors may be able to make full use of periods of favourable weather for farming operations by working day and night, under monitoring and control from the farm office[11].

The Autonomous Tractor Corporation (ATC) of North Dakota, USA, was one of the first to develop a robotic control system in 2012 for their 'Spirit' lightweight tracked vehicle, using a local guidance system based upon laser/radio navigation[12]. More recently, major manufacturer CNH demonstrated driverless tractors from both its Case IH and New Holland brands in August 2016. Elsewhere, John Deere and Fendt/AGCO have also been developing guidance systems, for example, allowing a driverless tractor to follow or reflect the movements of an operator-driven tractor, carrying out a similar or following field operation.

While some robot tractors are being developed around compatibility with conventional-sized agricultural machinery, others are exploring the potential to reduce vehicle size and weight, avoiding soil compaction and enabling all-weather field operations. This is consistent with the growing uptake of lightweight semi-autonomous vehicles in the form of drones for land surveying of land, crops and livestock, and the carrying and distribution of small payloads such as crop protection products. Driverless tractors and drones, perhaps with several operating in one place as a robotic 'swarm', are thought to offer particular opportunities for smaller

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[9] http://agriculture1.newholland.com/eu/en-uk/about-us/new-holland/clean-energy-leader/growing-energy-pioneers/hydrogen-energy-independent-farm

[10] http://www.fwi.co.uk/machinery/eima-2010-same-deutz-fahr-launches-scr-tractor-with-solar-panels.htm

[11] http://agriculture1.newholland.com/eu/en-uk/about-us/whats-on/news-events/2016/new-holland-nh-drive-new-concept-autonomous-tractor

[12] http://www.autonomoustractor.com/

farms to increase their productivity[13]. Along with other present and future applications such as robot livestock feeders and fruit pickers, these new developments in 'agri-tech' could even help farmers and growers to manage post-Brexit anticipated changes in the availability of seasonal labour.

Implications of new drivetrain technology for farm safety and efficiency

The substitution of electric interfaces between agricultural equipment in place of power take-off (PTO) shafts and hydraulic systems could potentially offer benefits in terms of improved farm safety. Poorly-guarded PTO shafts and other moving parts are responsible for numerous injuries and fatalities, as well as other operator hazards such as high-pressure oil leaks from hydraulic hoses or couplings. The development of simple 'plug-and-play' electrical standards could lead to greater flexibility and inter-compatibility of equipment. Introduced first around 2007/2009, a number of diesel-electric tractors already offer a variety of electrical outputs (DC, single-phase, three-phase) from an on-board generator, which enable a wide range of tools and agricultural implements to be connected to the tractor.

NFU comment and conclusions

This brief review of a wide range of advanced agricultural machinery technologies shows that they have considerable potential to contribute to 'sustainable intensification' in our industry, enabling farmers to "produce more with less". However, technological advances alone may not be enough: there will also be a need for agronomists, farmers and workers to understand how to use data and advanced control systems to enable improved agricultural production.

So, of all the options described above, which are the most likely to be powering agricultural and farmyard machinery in the 2020s and 2030s? The NFU anticipates that both diesel-electric hybrid and battery electric tractors will be widely available from 2020 onwards, while bio-based low-carbon fuelling of agricultural vehicles may remain more of a niche opportunity. Autonomous aerial and ground vehicles are expected to make a growing contribution to farm management.

Appendix: who's who

Consolidation in the agricultural machinery industry worldwide has resulted in the following current list of major manufacturers, although there are still many others:

AGCO – incorporates Massey Ferguson, Fendt, Valtra
Argo – incorporating Landini, McCormick
CNH (Case-New Holland, including Steyr) – now owned by Fiat Industrial
Claas tractors and harvesters
John Deere (Deere and Company)
Same Deutz-Fahr (SDF Group) including Lamborghini
Kubota and other Japanese manufacturers, and various Chinese and Russian firms

[13] Prof. Simon Blackmore, Harper Adams University, quoted in Farmers Guardian, 25-Nov-2016