EIP-AGRI Focus Group

Enhancing production and use of renewable energy on the farm

MINIPAPER: “Electromobility on farms”

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Research demands in the area of electro mobility on farms

Electro mobility is a tool for making farm machinery more energy efficient and less dependable on fossil fuels, and it is also an important enabler for automatization of farm work and precision farming which enable sustainable intensification. To do so, farming has to go from experience based decision by a single farmer to fact based decisions which will be done by collecting and analyzing a lot of data. Electro mobility also enables local production of fuels for farm machinery and has large benefits in minimizing maintenance and maximizing uptime for the machinery.

The research needed to achieve a sustainable productive farming system by electro mobility:

- Business models
- Infrastructure
- Logistics
- Demonstrators

Demonstrators are needed to develop, test, and to create market pull for the new technology with high importance for enabling sustainable intensification.

Business models

Electro mobility introduces new components in the system that opens up for new business models. One example is from a recent study (Engström et al, 2017) where it was shown that two 36 kW autonomous battery electric machines on a 200 ha dairy farm would be used in field work on average 11 % of the whole year, see figure 3. As batteries are expensive the total cost of the system benefits if they are used more than when active in the machinery work. This means that business models can be developed where the batteries installed could be used as energy storage and energy regulators in the electric grid in remote areas when not needed for field work. In the study mentioned above the battery capacity needed was about 1 kWh per hectare, which would mean 1 MWh capacity on a large farm.

An interesting research topic is also to study ownership of the machinery on the farms. One reason to look into this is to further utilize the machines and to reduce costs including maintenance and uptime.

Todays farm machinery consists mainly of tractors and implements conforming to standards which makes the farmer not dependable on one brand for compatibility between different tractors and implements. With new machinery based on electro mobility, and also connectivity and autonomous control, it is important that the undependability is maintained and this needs more research.

Infrastructure

Todays battery technology limits the development of battery powered electric farm machinery mainly by high costs and weight of the batteries. It is important to be part of the battery development to be able to influence the development. Another limitation is the high power needed for fast charging of machines on farms. Also this area needs more research and development.

Besides using batteries as energy storage of electric energy there are other interesting cases that should be further investigated: grid connected tractors or using hydrogen as energy storage and fuels cells on the machine.

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Logistics

Many farm activities can be conducted by small autonomous battery powered machines, however when it comes to internal or external transports of goods on the farm there is a need for more research on efficient transport systems. The logistics system has to be developed to save both energy and money. Modelling of different cases is part if the research.

Demonstrators

In order to boost development in this new area of electro mobility on farms demonstration initiatives are needed. The research should lead demonstrators and demonstration farms where the whole system is tested for a longer period of time. The demonstrations gather parties developing new systems as well as showing the farming community what is possible and thus boost the market pull on new more efficient and fossil free technology.

Background

Increasing awareness on climate change, the scale of the challenges involved and the pressing need to prepare for a post-fossil fuel future have prompted most of the world's developed countries to step up the research, trialling and deployment of systems that use more energy-efficient and less fossil fuel-dependent vehicles. In response to the objective on fossil fuel dependency, electric power offers a potentially ground breaking solution, provided that the production supply chain of components does not extensively emit climate gases. Electro mobility makes it possible to reduce the use of fossil fuels and vehicle operating costs and at the same time eliminating local emissions including sound (Moreda et al, 2016). For a conventional agricultural tractor the main environmental effects today originates from the usage phase, more specifically from the diesel exhausts. Emissions from machinery in Sweden have increased by about one third compared since 1990, according to the Swedish Environmental Protection Agency (2016).

When dimensioning a machine with battery-electric drive line it is essential to know which tasks that the machine must be able to handle and which requirements they place on the machine. Agriculture includes many different tasks currently mainly carried out by the agricultural tractor with various implements.

Development in agriculture is driven forward by rationalization. One way to make farm machinery more productive is to make the machines bigger to reduce the proportion of driver costs in the machine calculation. A serious disadvantage of big sized machinery in agriculture is that they increase harmful soil compaction which, in turn, reduces the growth of the plants and hence the harvest. Today agriculture work machinery use exclusively fossil diesel as energy source which is not sustainable in the long term, thus alternative fuels are important to obtain.
One solution is to make the machine electric and autonomous, which means that you can eliminate diesel and at the same time go down in size without losing productivity. The battery can then be dimensioned by a shorter work cycle, which makes it easier to find an optimum machine size and weight and economically optimum battery capacity. This means that the machine charge the batteries when needed, rather than having to match a driver's needs and an eight hour workday. In order to obtain an autonomous, electric machine, the machinery work load in agriculture needs to be investigated to optimize a compromise between the size, capacity and power of the machine.

Since many farms have their own electricity production via biogas, solar or wind power, electricity is an attractive way to drive agricultural machinery and thus make the farm less dependent on fuel prices and also less vulnerable to international crises affecting the supply of fossil fuels.

Autonomous control is an enabler for battery powered machines for field work, but electro mobility is also an enabler for precision farming, since electric motors are much easier to control

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and therefore they are preferable to combustion engines when precision is needed, and precision control is essential in precision farming (Aumer, 2008). In an electric driveline the components can be connected by electric wires and almost no transmission is needed, since the electric motor have full torque from start. In a diesel machine the machine consists of the diesel engine and a transmission to translate the combustion engines high rpm to proper wheel speed with high torque. Less moving parts also means less maintenance needs. One big negative aspect of electro mobility consists of the need for rare earth metals in motors and batteries in todays technology.

While procurement requirements can speed up technology development by creating niche markets, increased taxation of fuel can reduce the relative cost of fuel efficient and electrified work machines. The more expensive fuel the stronger is the incentive to switch to electrified and hybridized work machines that are more energy efficient and have significantly lower fuel consumption.

Increased fuel costs also have the advantage that it also provides incentives for more efficient use. A general increase in carbon dioxide tax is a very wide instrument that affects far more than just the work machines. Instead, if you want to increase the fuel price for particular work machines, a reduction for agriculture, forestry and mining may be an option. However, one needs to analyse what effects this has on the international competitiveness, so that a tax increase does not lead to production, and thus emissions, moving abroad.

Table 1. Coarse categorization of work tasks in farming and their suitability for electrification.

Type of work	Examples of work tasks	Power and energy profile	Complexity (suitability to use autonomous control)	Suitability electric power
In-farm machinery tasks	Feeding, mocking, internal farm transports. Mainly animal farms	Low power need, Low energy consumption, short works cycles.	Low to high as the driver often performs many tasks while using the machine, such as checking animal health etc	Battery powered machines with driver suitable. Due to low usage and good charging possibilities a low capacity battery is possible
Road transportation	Transports to/from fields, some including spreading/collecting goods	Intermittent high power need. High energy need during transport intensive season	High complexity, but autonomous control solvable with same technology as for autonomous road vehicles	Battery powered machines with driver suitable if charging can be accomplished while loading/unloading at the farm. Battery powered combined with autonomous control makes the system less sensitive to charging capacity and increases the productivity among

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				other benefits.
Light field work	Tumbling, tethering, crop protection, fertilizing	Low power need, Medium energy need (long work hours)	Can be well defined and suitable for autonomous control	Battery powered machines with driver suitable for the lightest work cycles. Battery powered combined with autonomous control makes the system less sensitive to charging capacity and increases the productivity among other benefits.
Heavy field work	Ploughing, harrowing, Sowing, harvesting	High continuous power need, this high energy need.	Can be well defined and suitable for autonomous control	Possible with tractor connected to grid with cable. Autonomous control probably makes implementation of the cable tractor easier. Battery powered combined with autonomous control is possible and increases the productivity among other benefits. Also hydrogen as energy storage possible.

Table 2. Large reduction potential in both energy consumtion and climate gas emissions in different applications in agriculture.

		Exchange of diesel driveline to battery electric driveline	
Type of work	**Method**	**Reduction in energy usage**	**Reduction in climate gas emissions** (Swedish electricity mix)
All field work one year on a dairy farm	Simulation of field activities with autonomous battery electric machines (Engström et al, 2017)	58%	92%*
On farm work, like feeding and internal transports	Practical tests of battery electric compact loader with driver in relevant work cycles (Pettersson et al, 2016)	75%	95%

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* including production of battery using Swedish electricity mix

Practical test of battery electric machine for agricultural operations

Studies conducted at RISE Agrifood and Bioscience (former JTI – Swedish institute of agricultural engineering) shows that there are significant advantages in using electric drive in agricultural machinery, especially when it comes to sustainability and reducing environmental pollution. In practical tests an electric compact wheel-loader, Weidemann EHoftrac, cut climate gas emissions by 95% and energy usage by 75% compared to a diesel powered machine doing the same work cycles. (Pettersson et al, 2016)

It was also shown that the battery lasted much longer than expected from theoretical calculations. In theory the battery was to be charged every day, but in reality on the farms the battery had to be charged every fourth day. This is of great importance since this means that the battery would not have to be exchanged as soon as it was predicted. The battery is a large cost in a battery powered machine, and if it lasts longer the total cost for the machine will be much less.

Another advantage found in the study was that operating the electric tractor was much easier in many cases. The electric loader had more torque than the diesel tractor as it had separated motors for hydraulics and for driving, and electric motors are much easier to control than a diesel engine. The electric loader also has much better work environment for the driver as it is emission free, which is particularly good when working indoors, and very quiet that makes it possible for the farmer to hear the animals and to estimate their health much better.

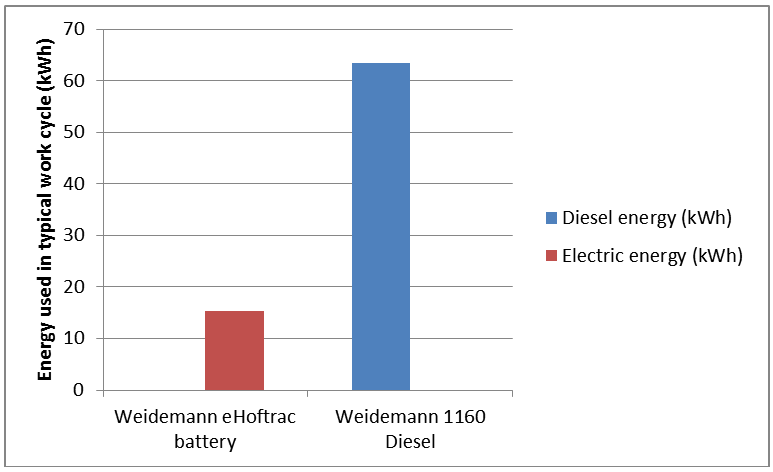

Figure 1. The figure shows total energy used to do a typical work cycle comparing a diesel machine to a electric machine. The machines have the same size. The result show that 75% less energy is used by the electric machine. (Pettersson et al, 2016)

Autonomous electric machines can replace diesel tractors

In a study conducted by RISE Agrifood (Engström et al, 2017) electric farm machines have been compared to conventional diesel tractors by simulation of all machine activities in the field on a hypothetical milk farm of 200 hectares during an entire year. The simulations demonstrated that one conventional 160 kW tractor could be replaced by two autonomous battery powered machines, each with a power of 36 kW and a battery capacity of 113 kWh, without losing productivity and at 15% lower cost, reducing energy use by 58% and greenhouse gas emissions by 92% compared to the diesel tractor. The energy usage and the emissions from the battery production are included. The high reduction in both energy usage and greenhouse gas emissions can be explained by the higher efficiency of electric power drivelines and by the very low greenhouse gas emissions and environmental impact in the Swedish electricity mix.

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What is unique about this project is the combination of battery for power and the autonomous control. With a driverless machine, batteries do not have to last an entire work day and the machine can charge itself when needed. Battery cost is balanced by lower costs for an operator needed a few hours a day, instead of a full time driver. Lower capacity due to smaller size is balanced by two vehicles being able to work 24/7.

In the study it was also shown that two 36 kW autonomous battery electric machines on a 200 ha dairy farm would be used in field work on average 11 % of the whole year, see figure 3. This opens up for new business models where the whole machine could be used for other tasks, such as road or park maintenance. Also separate components of the system could be used in new ways, for example the battery could be monetized as an energy storage service to energy providers or local energy production. It was also shown that the charger is used on average 2% of the time, which opens up for new business models where a farms charging station could be used by the community etc.

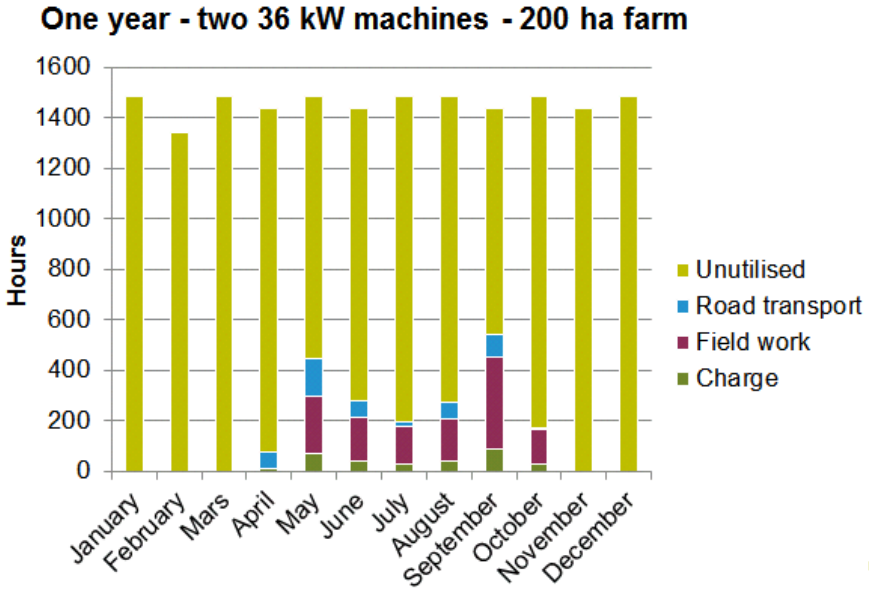

Figure 2. Diagram describing time distribution of different activities for the two 36 kW autonomous battery electric machines on the simulated 200 ha dairy farm. Low utilisation of machines and components (primarily the batteries) opens up for new business models. Engström, J., & Lagnelöv, O. (2017)

Batteries as energy storage in farm machinery for heavy work is now a possibility for the future, because of the rapid developments in autonomous control, electric drivelines and battery technology, making it both a technical and economical possibility.

The present project has demonstrated that it is not only possible, but that it can also reduce costs and substantially reduce climate emissions compared to the diesel tractor. Combining autonomous electric machinery and your own production of electricity on the farm, by for example solar panels or windmills, may also make it possible for a farm to be self-sufficient in energy.

Design study autonomous battery electric machine for farm and city

In a design study (Lagnelöv et al, 2016) a concept for a smaller working machine, aimed at lighter municipality and agricultural work, was designed. It´s a battery electric mainly autonomous vehicle design with capacity for manual drive. The goal was to design a machine

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viable for light work both in the city and on farms. This project was conducted by RISE in cooperation with Lighthaus industrial design, Valtra, Ålö, SSAB and Atlas Copco. It was discovered during the project that heavier work and larger machines were far from impossible and if combined with autonomous drive they could be scaled up to a fairly large tractor and still be battery electric, which would yield large benefits.

Figure 3. Design study on a batteryelectric autonomous machine for urban and farm work. Illustrations by Lighthaus Industrial Design. (Lagnelöv et al, 2016)

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