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PV-supported electrification of agriculture

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1. One billion liters of fossil diesel could be saved through electrification

The degree of electrification is already relatively high in the stationary area of agricultural operations - i.e. in the supply of buildings and systems from photovoltaics and biogas. The situation is different for vehicles, however, simply because it is difficult to transfer the electricity to mobile machines. The savings potential there is very high:
The complete electrification of agricultural machinery with low power requirements could save up to 1 billion liters of fossil diesel per year; that is almost half of the average amount of fuel consumed in agriculture and forestry between 2016 and 2020. Dr. Edgar Remmele from the Technology and Promotion Centre at the Competence Centre for Renewable Resources (TFZ) pointed out this immense amount at a specialist conference.

The calculated theoretical potential is particularly high because 24% of fuel is consumed for animal husbandry tasks alone, where all mobile implements could be electrified in the long term, plus light field work, where a further quarter (23%) of the current fuel requirement could be substituted by consistent electrification. The remainder of the potential savings would result from the at least partial electrification of medium-duty field work with a diesel requirement of between 5 and 15 l/ha.

2. advantages of electric drives

There are three main advantages of the electric drive over the classic combustion engine:

1. **Electrical systems**, in particular tractors plus attachments, are better dynamically controllable and can therefore work more precisely than mechanical or hydraulic drives. With the help of servomotors, seed drills, for example, can achieve more precise seed placement at high speed, even in conjunction with soil cultivation, e.g. during chopping.
2. **Electric drives** work much more precisely because they contain sensors, for example to record the torque and motor speed.
3. **Full-electric machines** are more reliable and practically wear-free. All in all, this results in a higher potential degree of automation with reduced variable operating costs.

It is interesting to note that electrification is now a global trend, especially in countries where smaller mobile agricultural machinery with lower power requirements is used, such as India. There, the government is massively supporting the electrification of rural regions through PV systems. The electricity produced there can then be used directly in agriculture.

3. Development in the area of soil cultivation

3.1 Huge untapped potential


Abbildung: Fendt E-Vario 100 (Foto Werksbroschüre)

Around 300,000 tractors are in use in German agriculture, according to figures from the Federal Motor Transport Authority, and around 30,000 are newly registered every year, over 90 % as replacements. These and other agricultural machines burn 2 billion liters of diesel. The 5 million tons of CO_2 this produces account for around 7% of all climate emissions in the agricultural sector. Lightweight electric tractors with up to 100 kW of power are available for use in stables and for farm work, as well as in vegetable cultivation or viticulture, for example. All major agricultural machinery manufacturers already have models on offer. Our picture shows the Fendt E-Vario 100.

In Sweden, which is aiming for fossil-free agriculture by 2030, many farms have already switched to electric drives. The 88 kW Traktorarvid developed by Arvid Örde is frequently used there. This is also suitable for field work. The developments there are leading the way: The models currently under development drive autonomously and replace the battery without human intervention, which is then recharged in the charging station on the farm or in the field. But small tractors could also play a major role in the future. India is a good example of this development. There are over 1.2 million farms there. Even today, the best-selling tractor in Germany is the Indian Solis 26, with over 1,000 units sold. The small tractor has 26 hp. There is now also an electric version.
In 2022, the start-up Cellestial e-mobility presented India's first electric tractors: The Hyderabad-based company offers three small series with outputs ranging from 27 to 55 hp at prices between €7,000 and €10,000 that also cost less to run than comparable tractors with combustion engines. The machines can be fully charged in six hours using a conventional 16-amp socket and in two hours using an industrial infrastructure. The range of a single charge is 75 km, and interchangeable batteries mean that work can be carried out almost without interruption. The tractors have a PTO shaft, hydraulics and all-wheel drive and offer a peak torque of 53 Nm.

3.2 Electrical systems: precise, economical and climate-neutral
Tractors with electric drives are not only interesting because electricity is a cheaper and ideally CO2-free fuel compared to conventional diesel. Electric drives require much less maintenance and are considered to be particularly reliable. Electric motors can also be controlled very precisely and provide more accurate sensor data, for example on torque and engine speed. In conjunction with precise GPS position data, electric drives are paving the way for precision farming and increasing automation in agriculture. Examples include sowing machines (e.g. ExactEmerge from John Deere), whose precision grain placement at high speed can only be achieved with the help of servomotors.

Conclusion: All-electric machines work more precisely and reliably than units with combustion engines and are also virtually wear-free.

3.3 The necessary changes in soil cultivation speak in favor of electric tractors
Compared to heavy, conventional tractors, electrically powered, lightweight models not only offer a more ecological solution, but also improve maneuverability in the field. These tractors not only minimize resource consumption, but also reduce soil compaction, which is particularly beneficial on smaller and hilly farmland. Soil pressure is becoming increasingly important with ever larger machines. The use of several small work units, the so-called field swarm, is therefore being discussed as a new approach. Instead of a huge agricultural machine, small robots are used that communicate with each other and work together as efficiently as possible. All in all, the robots then do the same work as the large machine, but put much less strain on the soil.
Another major trend is the identification and treatment of individual plants. Up to now, the watering can principle has been used and the entire field has been sprayed and fertilized. However, the major goal is to proceed in an environmentally friendly and resource-saving manner and to provide each individual plant with the care it needs. Even today, parts of the field can be recognized and treated differently for specific areas. This is known as “precision farming”. The machines and equipment for precision farming use navigation systems and GPS receivers to determine their position, which access “digital maps” created using geographical information systems.
In the next stage, the targeted individual plant recognition, a robot must be able to differentiate between crops or weeds, for example, in order to react accordingly. The robot can then also learn exactly what the crop needs and whether it is diseased, for example. This is still a dream of the future for large arable areas, but it is already being used successfully in vegetable growing.
But it is not just agricultural technology that will make farming more sustainable.
A reassessment of the soil is also necessary. Every farmer has an interest in ensuring that the soil, his most important means of production, is both healthy and productive. In the past, intensive plowing was used. As plowing is the most energy-intensive part of farming, this intensive soil cultivation is associated with a high use of resources and high CO2 emissions. Today, so-called conservation tillage is used in most cases, which releases much less CO2. The soil is worked with disc harrows or so-called cultivators, for example, which loosen the soil but do not plow it up.
This preserves the soil structure and the capillary system better. This is particularly important in areas with little rainfall, as moisture is retained in the soil and does not evaporate so quickly. As much lighter machinery is needed for this, there is much less need for heavy tractors.

4. Electrification of farms through self-generated electricity

The developments outlined above are driving the agricultural sector towards sustainability and efficiency.
In this context, the increased use of photovoltaics as a driver for the electrification of farms through self-generated electricity is combined with innovative technologies, particularly in battery and charging technology.
Agriculture was a strong driver for the dynamic development of PV expansion figures, particularly in southern Germany. The development was particularly dynamic in the years 2005 to 2012 due to the relatively high feed-in tariff compared to the installation costs. Using the generated electricity yourself was not economically viable in those years. A rethink only took place due to the sharp rise in electricity prices in recent years, particularly as a result of the war in Ukraine. This meant that established business models, e.g. in fruit and potato cultivation, often no longer paid off due to the months

of cooling required before marketing (up to 6 months for apples).
This development is one of the reasons for the great interest in the generation of PV electricity close to the farm, e.g. through AgriPV systems.


Illustration: TrackerPV system close to the farm (©GridParity AG)

Illustration: BerryPV system close to the farm (©GridParity AG)

The following case study of a 1.5 MW PV tracker system including a 2 MWh battery for own use of the generated electricity in the operation of e.g. cooling systems and charging the electric machines shows that the electrification of farms is also extremely interesting from an economic point of view.

On-farm power generation AgriPV Tracker	1,5 MWp
Costs AgriPV tracker system with electrical installation	1,1 Mio. €
Costs battery container 2MWh incl. AC installation charging technology	0,8 Mio. €
Electricity production p.a.	2.300 MWh
Electricity costs at 3% interest, amortization 15 years	8,2 ct/kWh
Operating costs per tractor hour (50kW) compared to diesel	10 %

5. New forms of cooperation

The above investment could also be carried out by a local energy community that makes the electricity generated directly available to its members and feeds surpluses into the shared storage system. These battery centers can be installed centrally in the village or distributed decentrally at nodes in various fields. The electric agricultural machinery can control these independently for charging or exchanging batteries.

In addition, the storage systems can provide load management services and thus help to relieve the electricity grid and generate interesting additional income. This is an absolute model for the future for remote regions. It makes it possible to increase the proportion of renewable energies and be self-sufficient to a certain extent while maintaining the electricity grid.

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