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Post-peak mechanized agriculture: the RAMSES project

Posted by Ugo Bardi on April 28, 2009 - 9:50am in The Oil Drum: Europe
Topic: Environment/Sustainability
Tags: agriculture, electric vehicles, peak oil [list all tags]

The joy of mechanized agriculture. Image (1971) courtesy of Stefan Landsberger

Both in the capitalist and in the socialist world, tractors have been seen as machines of freedom, symbols of progress and modernization. Indeed, mechanized agriculture has been a worldwide revolution that has freed a large part of humankind from the Biblical curse of hard work. However, with the reserves of fossil fuels being slowly depleted, can we keep tractors running? The RAMSES project proposes an answer: a new model of agricultural mechanization based on battery powered vehicles and renewable energy sources.

Today, agriculture in the industrialized world is a task for a minuscule fraction of the workforce; people whose job is to operate heavy machinery powered by fossil fuels. But, with peak oil arriving, or perhaps already arrived, we are going to see big changes. In itself, mechanization does not affect agricultural yields, but higher costs of fossil fuels are already affecting food prices. And, without power from mechanical engines, farming would have to go back to the old ways; relying again on human and animal muscles. Richard Heinberg has spoken of the need of "50 million farmers" for agriculture in the USA. But that would imply transforming overweight and under-excercised office workers into the kind of lean and fit peasants who are the typical workforce of countries where the industrial revolution has not arrived yet. It won't be easy, especially if we were forced to do it in a short time.

When the issue of powering agricultural machines is raised, the usual answer is in terms of biofuels. But that is not a very good idea unless we can develop some new and much more efficient way of making biofuels. In their present form, biofuels need too much land, need artificial fertilizer and, more than all, are in competition with food production. Other, exotic forms of fuel, hydrogen for instance, are too expensive and complex for agriculture, at least for the time being.

As it is often the case, the solution of a difficult problem can be found thinking "out of the box".

Here, we are often locked to the concept that what we need is some kind of fuel, possibly in liquid form, to operate traditional engines. But the internal combustion engine is very inefficient; the only reason why it has had so much success is because fossil fuels have been extremely cheap so far. With that condition becoming rapidly obsolete, we need to move to more efficient systems. Modern renewable technologies (mainly photovoltaics and wind) are much more efficient than biofuels in terms of land needed per unit energy produced. In addition, most renewable sources produce electric power, compatible with cheap and efficient electric motors. These advantages are offset, in part, by the need of storing electric power in heavy and expensive batteries. Nevertheless, battery powered electric vehicles are making a comeback on roads and there exist light electric tractors available on the market. Can we think of electric motors and vehicles taking a major role in agriculture?

The RAMSES project

About three years ago, Ugo Bardi (your author) and Toufic El Asmar (agronomist at the University of Florence, Italy) sat together and conceived the idea of a complete, renewable energy system that would provide both electric and mechanical power for agriculture. We gave it the name of "RAMSES", an acronym that stands for something like "renewable multipurpose agricultural systems for farmers". But, actually, "Ramses" is an ancient Egyptian word that means *"born of the sun-god Ra"* and that seemed to us an auspicious name for the idea (later on, we learned of another vehicle named "Ramses"; a modern Egyptian battle tank).

The idea of the RAMSES system is to couple a renewable energy source (in this case a photovoltaic plant) with a multipurpose, battery powered agricultural vehicle. The system also includes a stationary battery pack for energy storage. The energy produced can be used in the farm, stored in the vehicle's batteries, in the stationary batteries, or sold to the grid. The batteries of the vehicle can also be used for powering the farm if needed. It is a complete energy system that makes the farm - potentially - independent from fossil fuels.

Once we had thought of all this, we assembled a team able to build the system and we submitted the project to the European Commission which financed it under the 6th framework program. RAMSES is a multinational effort which includes four European countries (Italy, Poland, Spain and UK) and three Mediterranean ones (Jordan, Lebanon and Morocco). After almost three years of work, a complete prototype system has been assembled.

Below, you can see the RAMSES 12 kWp photovoltaic plant, based on monocrystalline silicon cells. It has been built at the final destination where the system will be tested: the monastery of Mar Sarkis and Bakhos, in Lebanon, about 35 km from Beirut. The plant was built by the Lebanese company ADMElectric.

Here is an image of the power storage system: a pack of lead batteries capable of storing about 2000 Ah, complete with inverters for providing standard electric power to the farm. All the batteries for the RAMSES project were provided by Tudor (Spain).

And, finally, here is the RAMSES vehicle. It was built in Italy, by OELLE. Here, however, you see it in the snow, in Poland. It was moved there for adding a number of accessories (by the Krukowiak company) and for testing by IBMER, the institute of agricultural mechanization and electrification.

The RAMSES vehicle is a multi-purpose light truck powered by a 12 kW electric motor. For ease of use and ruggedness, we used standard lead-gel batteries as on-board storage. Although the vehicle doesn't look like a traditional tractor, it has many of the capabilities that normally are found on tractors. Its 4-wheel transmission lets it run on or off-road. It can be used for transportation with its ability of carrying about 1 ton load and a maximum speed on roads of about 45 km/h. It is not designed for very rough terrains or for heavy agricultural work, such as plowing all day long. But its hydraulic three points hitch permits to link it to a variety of agricultural machinery for such tasks as watering, spraying, fruit collecting, seeding and many others. In the following figure, you can see the vehicle equipped with a 200 liters agricultural sprayer.

Assessment

A prototype is a nice toy to play with but, eventually, we need to answer a few crucial questions about the RAMSES system:

1. Is it really environmentally friendly?

2. How much does it cost?

3 Can it replace conventional systems?

With the prototype still under test, we can't answer these questions with absolute certainty. But we carried out simulations and we can already give some answers.

In terms of environmental impact, there is no doubt that the RAMSES system is a winner. Our LCA calculations show that it is better than its conventional competitors on almost all pollution counts, from greenhouse gases to local pollutants. This is not surprising, since the system relies on renewable energy and it doesn't use fossil fuels except as source of energy for the manufacturing of the system itself. It turns out that the main source of pollution of the RAMSES system are the lead batteries during the manufacturing and recycling process; but lead release in the environment is truly minimal.

Cost is a critical question: how does it compare with conventional systems? If we calculate the external costs (pollution and global warming) the RAMSES system has a significant advantage. However, these external costs are not paid directly by farmers and, despite the fact that the RAMSES system does not need fuel, there are monetary costs in terms of investment and in terms of the periodic replacement of batteries and other parts. Our calculations indicate that the RAMSES system in its present configuration is slightly more expensive than a conventional, diesel powered system over a life cycle of 30 years. In order to have the same life cycle costs for the two cases - RAMSES and conventional - diesel fuel would have to cost more than 1.5 EUR/liter. That

is higher than the present cost at the pump, even without considering subsidies given to farmers. Nevertheless, this result is encouraging. In the future, the cost effectiveness of the system may be improved eliminating the stationary batteries and relying only on the grid as storage, but at present this is not possible in Lebanon because of the local regulations. The advantage of the RAMSES system, anyway, goes beyond a simple cost comparison: it lies in being independent from fossil fuels and therefore not sensible to supply interruptions and oil price spikes.

Then, there is the question whether the use of the RAMSES vehicle will be practical for agriculture. Agricultural vehicles come in many kinds and many shapes; some as large combine harvesters and some as small, hand operated cultivators. The RAMSES vehicle doesn't pretend to be compared to giant agricultural machines. It has been conceived and designed to be used in a specific environment: in a farm in Lebanon where the main product is olive oil. Here, the vehicle will be used for a variety of light agricultural tasks. Because of the specific climatic conditions there, we assume that the vehicle will work for 2-4 hours in the morning, then it will be recharged over midday, when the temperature is so high that it is impossible to work in the fields. In the afternoon, the vehicle will be used again for 2-4 hours and will be recharged again overnight. In the present configuration, the vehicle is expected to be able to perform these tasks, but modifications may be needed for different conditions. If more endurance is needed, for instance, there is space in the present prototype for adding more on-board batteries.

The final question is whether an all-electric, renewable agriculture is really possible. Can we think of an electric combine harvester? Can we plow the fields with electrical tractors? The answer is, "yes, but..." In principle, it is perfectly possible to design and build heavy electric agricultural vehicles such as tractors and combines. But, if we use lead batteries and we want the machine to keep working all the day long, we need a very large battery pack and that would be very expensive. There are many technological possibilities to improve on lead batteries and perhaps in the future the problem of storage will be solved with new possibilities. But, if we have to stay with current technology, we must think of battery powered mechanized agriculture as something more limited than the kind of mechanization we are used to.

It is unavoidable, anyway, that future agriculture will be something very different from what it is today. The problem with modern agriculture is not just that of powering tractors and vehicles. It lies with the need of artificial fertilizers and pesticides, with the erosion of the fertile soil and, not the least, with the emissions of greenhouse gases and the resulting climate change that may damage agricultural yields. For the future, we must think of an agriculture which will not destroy the fertile soil, which will need less (or no) artificial fertilizers and pesticides, and which will be, in general, less polluting and more sustainable. It will not be anymore the kind of large scale, heavily mechanized enterprise we are used to but, likely, a smaller scale operation, more based on local resources. Maybe it will be something like the "50 million farmers" that Heinberg has proposed. But it may not necessarily need human beings as engines, as it was the use before the industrial revolution. The results of the RAMSES project show that using renewable electric power is a concrete possibility to break away from the present dependency on fossil fuels in agriculture.

Technical data

The all-electric, battery powered RAMSES agricultural vehicle shown at its first appearance on roads, in Modena, Italy, in 2008. From left, Toufic El Asmar, Paolo Pasquini, and Ugo Bardi; respectively: project coordinator, vehicle designer, and coordinator of the vehicle team. At this link you can also see short movies of the vehicle in action

RAMSES doesn't claim to be the first electrical vehicle in agriculture, but it is an original idea under several respects: it has been designed from scratch as an electric vehicle, not as the retrofitting of an existing vehicle. Also, it was conceived with production in series in mind, not as destined to remain a single prototype. Finally, it is not just an electric vehicle, but a complete energy system designed for use in a world where fossil fuels are destined to become less and less abundant.

The RAMSES vehicle uses standard components which can be serviced or replaced with a minimum effort. It is powered by a 96 V, 12 kW dc brushed motor located in the center, in a position protected from damage. An auxiliary, on board 12 kW motor is used for powering external agricultural equipment and the hydraulic system. The motors are powered by 16 6V 180 Ah lead-gel batteries. The two battery packs can be connected in series at 96 volts, for street use, or in parallel, at 48 V, for the highest torque for off road use. This set of batteries is expected to be able to power the vehicle for a range of about 70-80 km on roads and for 2-4 h of work in the fields. The maximum speed on roads is around 45 km/h. The vehicle weighs 1700 kg, including the driver and has a capacity of about one ton load.

The photovoltaic plant that powers the vehicle has a maximum power of 12 kW and is based on monocrystalline, silicon panels. The stationary energy system is based a lead-acid battery pack of total storage capacity of 2000 Ah.

Acknowledgment

I would like to thank first of all the European Commission, which has financed the RAMSES project as No. 32447 of the 6th framework program. Then, I'd like to thank all the partners of the

RAMSES project; you may find a full list of them at the Project site . Thanks are also due to the University of Tehran, department of agricultural machinery engineering, and in particular to professor Alireza Keyhani and to Mr. Hossein Mousazadeh, who has performed the LCA evaluation of the system (see references). Special thanks are due to Mr. Paolo Pasquini who has given to the project a decisive contribution with his great experience in electric vehicles (see also his Boxel vehicle).

References

More data on the RAMSES system can be found in this article:

Environmental assessment of RAMseS multipurpose electric vehicle compared to a conventional combustion engine vehicle . by Hossein Mousazadeh, Alireza Keyhani, Hossein Mobli, Ugo Bardi, Ginevra Lombardi and Toufic el Asmar, Journal of Cleaner Production, Volume 17, Issue 9, June 2009, Pages 781-790

The "fifty million farmers" 2006 essay by Richard Heinberg can be found at this link