How Will Our Children Feed Themselves?
LEF's Farm Grown Fuel Project

Why is This Project Needed?

Industrial agriculture is in trouble.There are a host of issues facing farmers, not the least of which is climate change. At Living Energy Farm, we earn our living growing seeds, and we produce most of our food. We see increased volatility in the weather each year. Already, weather instability is making farming more difficult. The future may be far more challenging.

The "green revolution" was the period in the latter 20^{th} century when industrial agricultural methods (hybrid seeds, chemical fertilizer, herbicides and pesticides) supported a substantial global increase in agricultural production. Future population growth estimates have all been based on continuing expansion of agricultural productivity But we are reaching the "point of diminishing returns." You can't simply add more fertilizer indefinitely and expect unending increases in productivity. **About 1/3rd of global grainland is experiencing stable or declining production.** Global meat consumption has been increasing twice as fast as population. Consumers in wealthy countries eat the richest foods. Although the U.S. is the largest global exporter of food, we are also the largest global *importer* of food.

Three-quarters of humanity lives on less than five dollars a day. The majority of humanity lives on a simple grain diet because they cannot afford otherwise. While a *diversified* grain diet, combined with fruits and vegetables, is quite healthy, many of the world's poor live on simple, refined starches produced by modern industrial farming. Wealthy countries export these simple starches, and import meat, fruit, and choice foods from all over the world.

The mission of LEF is to re-define sustainability to include technologies and methods of farming that are accessible to most of the word's people. The problems are not simple, and neither are the solutions. Diversified tools and methods will be needed. Gardening by hand can produce a lot of healthy food (and is quite enjoyable for many of us!), but some mechanical assistance is really helpful. Small engines that can propel modest agricultural equipment make a huge difference in what farmers can produce.

This gasifier was intended to be a stationary unit, but we modified it for use on a tractor.

Farmers in many places employ draft animals, oxen being the most easily accessible. But draft animals eat year round. When agriculture was based on draft animals in the U.S., the animals themselves consumed 1/3rd of agricultural output. Draft animals will continue to be used in some parts of the world, but we need a replacement for industrial agriculture that reaches beyond draft animals.

The vision at LEF is to find a means of producing fuel on the farm that can power small tractors, and perhaps harvesters or other needed equipment to help with the heavy work of farming. We have been using woodgas some, and we are setting up equipment to use turpentine.

The History, Benefits, and Limitations of Woodgas

Woodgas involves the thermal decomposition of cellulose (burning in an oxygen restricted environment) to produce flammable gasses. These gasses can then be connected to the intake of a gasoline engine, and the engine will run on wood! Wood gasification was widely deployed in World War II in Europe. Factories were set up to manufacture both gasifiers and wood pellets to feed the gasifiers. That was a highly organized and widely deployed effort to provide non-fossil fuel for gasoline engines.

We have been using woodgas at LEF to some extent, but it is not at all clear if it is a good technology to support global village sustainability. The benefits of woodgas are:

* It is farm-grown fuel that can run or supplement the fuel of almost any fossil fuel engine.
* Gasifiers can be scaled up or down to run various size engines.
* In theory any cellulosic material can be used. Some modern gasifiers are manufactured to run on low-grade material like wheat or rice straw.

The disadvantages of woodgas are as follows:

* Woodgas might spur deforestation, as it did in World War II.
* Making good quality woodgas is not easy, and poor quality woodgas is very damaging to engines.
* The small, modern engines most easily available in modern times are not well suited to woodgas. Engines turn faster than they did in the World War II era, and have more precise fuel mix requirements.

This is our wood gasification unit on the front of a 1961 Ford tractor. We ran this tractor on woodgas for a while, but the gasifier was too small (even though the tractor only has 35 horsepower).

Such modern engines are often a little more efficient and clean-burning (some at least), but they are not tolerant of woodgas and other low-octane fuels.
* Doing woodgas well is not that easy, as we have discovered. The idea of setting up woodgas in villages all over the world would be technically challenging.
* It’s not easy starting a cold engine on woodgas, A more volatile starter fuel such as ethanol might be necessary.

Turpentine

Ever heard of Honda motorcycles? The name brand descends from a Japanese man named Honda who wanted to produce and sell motorcycles in the post World War II era in Japan. He did not have access to gasoline for his motorcycles, so he made them to run on turpentine.

Different species of pine trees can grow anywhere in the world that trees grow. If you take the sap from pine or other resinous trees and heat it, it makes vapor. Condense the vapor and you have turpentine.

Turpentine has the same combustion characteristics as kerosene. Prior to World War II, oil refiners used simpler methods than they do today. They were able to get only a small amount of gasoline out of a barrel of crude oil. Back then they produced a substantial quantity of various grades of kerosene that were referred to as “distillate” or “tractor fuel.” A lot of machines prior to the late 1940s were made to run on these various, lower-octane distillate fuels.

Could we use pine sap to make a limited amount of fuel to run small tractors that would help a village with planting and harvesting crops? It is extremely unlikely that turpentine could ever be produced on a scale that would support modern automobile fleets. At LEF, our intent is to produce fuel that would be used on the farm, not on the road.

The potential advantages of turpentine fuel to support small farm machinery could be:
* Turpentine is most often taken from live trees. As long as the trees are tapped at a reasonable rate, the process is sustainable.
* Turpentine is simply poured in the tank of an engine. Nothing like a bulky woodgas unit has to be attached to the machine.

Every wood gasifier has an hourglass shaped reactor at its core. The shape and size of this reactor core has to be correct for the type of fuel and the size of the engine. And when you have a reactor that is too small for your engine? Sadly, it melts from excess heat.

* Turpentine can be used in any size engine, whereas making clean woodgas for very small engines is challenging.
* The widespread use of turpentine as a farm-grown fuel would encourage the planting of trees, and keeping those trees alive. It's hard to know if the idealized vision of each village planting its own grove of sap-producing trees is realistic, but it could work.

The potential disadvantages of turpentine are:
* Another fuel is needed to start and warm up the engine, perhaps ethanol. Very little would be needed.
* Like woodgas, turpentine is not likely to work in modern, cheap, easily available "lawnmower" engines. Older engines will work better because they were designed to work with kerosene, but these engines are less available.
* Turpentine cannot be stored for long.
* Turpentine is likely to be available in only small amounts. This is both a good thing and a bad thing. It would limit both the work and the destruction that could be wrought with machines.
* Turpentine can be produced from live trees. It can also be produced by heating pine chips from dead trees. This latter process is very different, but people might, in times of distress, decide to cut their trees instead of tapping them. Hopefully, the scaling and re-orientation to village-level production would encourage a longer term view.

Why Not Ethanol and Biodiesel?

Ethanol and biodiesel put machines in competition with humans for food. These fuels essentially put rich people and poor people in competition for control of the highest quality industrially managed farmland. The re-orientation of farming and sustainable living to empowered villages is more important than the machines themselves. That said, different technologies support different kinds of social arrangements. Daylight drive electricity (see our discussion of Longterm Integrated Village Energy), woodgas, and turpentine support village-level economies. While grain for ethanol and biodiesel is most efficiently harvested using massive, expensive combines and

We repaired the gasifier and transferred it to this tractor, which has 1/2 the horsepower of the Ford where we used the gasifier previously. The engine on this tractor is in poor condition, and it is a more modern, higher speed, higher compression engine. The gasifier and the tractor worked, but not well.

industrial methods, turpentine is more like collecting sap for maple syrup. It is inherently decentralized and manual. Woodgas chips could be produced on either a large or small scale.

While ethanol and biodiesel need the best farmland, turpentine and woodgas can be produced from any kind of land, including more marginal areas. Trees tolerate drought much, much better than the grains that produce ethanol and biodiesel.

The bottom line is that energy production and use is always constrained by the laws of physics. Low-grade heat will always be easier to produce and store than electricity. Ethanol and biodiesel, because they use feedstock further up the food chain (starch and oil are higher up the food chain than sap and cellulose), they will always be harder to produce. We have aspired to produce our own vegetable oil at LEF for food, and haven’t gotten there yet. The idea that small farms could produce enough food-grade oil and starch to feed both themselves and their machines is detached from reality. We hope that we can produce a very small amount of ethanol as a starter fuel for turpentine engines, but that would require only a very small amount of grain.

What Kind, What Scale of Machines?

There is a plethora of research now that shows that small farms are more productive per acre than large farms. But large farms are better able take advantage of bank loans and government subsidies (which are acreage based). On small farms, the human body can do little work compared to even a very small tractor. Even a very small tractor can do dramatically more work than a draft animal, or several.

Modern American agriculture is highly industrialized and based on the use of large, expensive equipment. With small tractors, effectively transferring the energy from the engine to the ground is challenging. Large tractors are heavy, and that weight gives them traction and pulling power. For reasons that may have to do more with cultural traditions than sound mechanics, most tractors have an engine that sticks out the front. That works with large tractors, because the overall weight

This is an Oggun tractor. Notice the engine is mounted in the rear. This is a modern, well designed agricultural tractor based on similar historical designs. Incidentally, the company was founded with the mission of providing inexpensive, easily constructed and repaired tractors for small farmers around the world.

of the machine is sufficient to maintain good traction. With a small tractor, it makes more sense to put the engine over the rear wheels, and thus to maximize traction and the ability to transfer energy from the engine to doing useful work. Though the dominant trend is to have the engine in front, there are a number of tractor manufacturers, past and present, who make rear-engine tractors that are intended to be effective agricultural machines (and not just lawnmowers). At LEF, we are working with these small, rear-engine machines.

What Kind of Engines Work Best With Farm-Grown Fuel?

What kind of engines work best with farmgrown fuel? As we have said in other contexts, technology in our age moves toward profit, not necessarily toward peak performance, and certainly not toward durability. A hundred years ago, engines might have 100 pounds of metal for each horsepower of output, and they turned at a much slower rate. These old engines might run from a few hundred to 1000 rounds per minute (RPM). By the World War II era, many engines were running up to 2000 RPM. Modern engines have standardized at 3600 RPM.

Another change in engine design is that modern engines have a much higher compression ratio. They are also manufactured with the expectation of a more precise fuel mix. The primary reason for all of these changes is profit, and there are some benefits and costs to these changes. Certainly, for very portable engines like chainsaws or weed wackers, tiny powerful engines reduce the weight of the tool considerably. But high speed engines suffer much higher internal friction, and thus wear out much more quickly. The precise engineering of fuel mix helps efficiency and pollution, but makes it much harder to power an engine with woodgas or turpentine.

With a small tractor with the engine over the back wheels, a somewhat heavier engine is desirable. Certainly, a durable engine is very desirable. Both woodgas and turpentine burn more slowly than gasoline. That’s based on the laws of physics, and cannot be changed. A slower piston in an older engine more effectively transfers the expansive force of slower-burning woodgas or turpentine to mechanical power. Modern engines cannot be easily altered to run slower and will be less efficient with woodgas or turpentine. With turpentine in particular, it cannot be run in modern engines with a very high compression ratio because the fuel will pre-ignite, causing the engine to “knock.” For all of

Rear-engine Tuff Bilt tractor at LEF. Engine is being swapped to a low compression engine that we can run on woodgas or turpentine.

these reasons, we are currently putting older engines from the 1940s and 1950s on small, rear-engine tractors.

Our hope is that we can run our farm with these small machines using fuel that we grow ourselves. Then we will be able to answer the questions of scaling. How many trees occupying how much land can sustainably produce how much fuel to support how many people in a village? How difficult and expensive is it to set up a farm-grown fuel system? Can it be done in villages all over the world? These are the questions we are trying to answer. Our future food supply may depend on finding answers the these questions. We are seeking support for these efforts.