The Savonius Rotor: A Durable Low-tech Approach to Wind Power

An on-farm research project funded by Northeast SARE (Sustainable Agriculture Research and Education)

by Erik Andrus

One of the realities of small-scale energy generation is the seemingly inescapable economic disincentive to invest in long-term solutions. This project is an instance of one farmer's effort to see past the present condition of cheap energy (electricity and liquid fossil fuels) to a future where farms will likely be increasingly compelled, as they have in the past, to take responsibility for their own energy needs. But in order to clearly think one's way around this topic, it is important to frame the problem correctly.

We are accustomed to think in dollars-and-cents economics, which rarely have a clear relationship to the amount of energy involved. Although the Savonius is usually considered as an electrical energy generation proposition, let's set electricity aside for a moment and consider one of my major farm operations. My farm captures approximately 70 million kilocalories in our annual square bale hay harvest. In order to accomplish this, we exert probably about 2 million kcal of effort in the following categories:

Horse muscle power	150,000 kcal
Tractor diesel fuel	1,500,000 kcal
Electricity for bale conveyors	24,000 kcal
Wear and tear on all equipment	300,000 kcal
Human muscle power	36,000 kcal
Total energy invested	2,010,000 kcal

All of which seems quite reasonable when you consider that we are stacking up 70 million calories in hay. But of course we humans can't eat the hay ourselves, can't use it to keep the lights on very easily, so we feed it to our stock, a time-honored practice. This hay contributes to an annual production of beef animals (as well as horsepower for farm work) to the tune of about 7 animals per year at 550 lbs hanging weight each, of which about 350 lbs is eaten. There are about 800 kcal in a pound of beef.

7 beef animals x 350 lbs beef each x 800 kCal = 1,960,000 kCal

If we were to include the use of the draft horses for non-haying farm work then that would add a few more hundred thousand calories in the benefit column. But in the main, our hay harvest is a break-even energy proposition. It is viable economically, but in terms of energy, it does not have significant net production, mostly because the small amount of tractor fuel I use has almost as much energy in it as the beef I sell. I offer this example to illustrate the difficulty of thinking of farm systems in terms of sustainable energy dynamics.

Present-day dollars-and-cents economics are a huge distraction from long term thinking about farm energy and renewable energy in general, since any discussion of finances makes a host of assumptions about what things cost and are worth. If the value of goods and services in our economy bears little relation to the amount of energy their production demands, we are very easily tripped up in efforts to think in the financial long-term and energy long-term simultaneously.

Add to this fact most of us are not easily able to separate energy "needs" from energy "wants." For instance, my household uses about 700 kWh per month. When it comes right down to it, very little of this usage is truly necessary.

And even on the production side of the farm, wants and needs are easy to confuse. I want to use a square baler because it helps me get the job of haying done. But as I have illustrated, the baling has a large energy cost, much more than a crew of 20 people with pitchforks would. If we lived in a society where energy truly mattered, that society would routinely consume renewable human labor (for instance in the form of a crew of 20 hardy workers with pitchforks) rather than machine labor. But we live in the here and now, and 20 people will not come when I call, at least not for a price less than or equal to that of running a tractor and a square baler. But the need for farmers is great at this time in history. We are here to play a pivotal role. I for one anticipate the day when northeastern fields will not lack for people. We are already on the way there, and the presence of people at work will revise all of our current assumptions regarding renewable energy.

I offer this introduction in order to help frame the problem correctly, and in order that the modest results be put in perspective and not be discouraging. The Savonius Rotor has virtues over an expensive high-tech wind turbine in the way that a crew of workers with pitchforks has virtues over a tractor and square baler. The Savonius (like the crew of workers with pitchforks) is:

1. *Technically easy to create.*
2. *Very low capital costs.*
3. *Simple enough that anyone can understand how it works.*
4. *It is not very dangerous to operate and be around.*
5. *It will function in a wide variety of applications.*
6. *It does not demand specialized parts or maintenance.*
7. *It is modular in nature, and can be made larger or smaller as needs dictate*

If our goal is to develop energy self-reliant farms and communities, these are very significant advantages, and may well outweigh the lower efficiency of this class of device, for which it undeservedly receives the scorn of most wind engineers. As in the case of the square baler, efficiency is not the entire story.

The Savonius rotor was originally designed by Finnish inventor Sigurd Savonius in 1922. It is classed as a drag-type device, and is understood to have relatively low efficiency but high reliability. Interest in the Savonius rotor and other types of Vertical-Axis Wind Turbines (VAWTs) became elevated during the oil embargo and resulting energy crisis. Also, during the 60s and 70s, the Savonius was considered as an example of appropriate technology for rural development in the third world due to its low maintenance requirements.

In that the Savonius is low speed and high torque by nature, it is more similar to the windmills of medieval Europe than most contemporary horizontal-axis wind power devices.

Given that we are currently facing escalating liquid fuel costs, and that the long-term costs of nuclear power are becoming clearer (even more so now that Entergy Nuclear has made clear its intent to operate how it pleases, whether the people of Vermont wish it to or not) I feel it is well worth considering durable generation technologies as a means to meet present-day needs.

Our farm is known to have marginal wind conditions, with an annual average speed of 11 mph. At this velocity, investment in large prop-type wind arrays is seldom advised. But given the low cost and the reputation for functionality at lower speeds, the VAWT seemed a possible alternative. Of the various types of low-tech wind devices, the Savonius stood out for its ability to be constructed out of wood, and its simple design requirements. Retired Charlotte, Vermont engineer Victor Gardy helped us towards a draft design.

Several questions motivated our consideration of the Savonius rotor. Given the high cost and long payback periods for most commercially available wind and solar technologies on the market today, could a home-built Savonius rotor, or collection of rotors, be a financially viable alternative? What is the potential of a modular windmill for non-electric power, such as direct mechanical application or in storage as compressed air? How important is a prime wind site in these considerations? How difficult is the device to build and maintain?

Our first ("Mark I") design is constructed of plywood and dimensional lumber. It uses an automotive wheel bearing at its base and can be put together with only basic woodworking tools by two people in a week or so. Our design featured a "drive disc" six feet in diameter at the base, against which the generator wheel coasted. The large diameter of the drive disc and the small one of the generator worked to gear the generator up to 1800 rpm in about 12 mph of wind. Its wattage production (as measured through the generator) ranged from about five watts in very light winds to close to 2 kilowatts. We trialed the Mark I for several months and charted its production.

At the end of our trials we decided that the tower design and the durability of the materials left room for improvement, and began thinking about a "Mark II" design, made of cut-up 275 gallon fuel oil tanks the likes of which you see everywhere. We also decided that the most promising application of this kind of windmill for us was not to generate and store electricity, but to use the rotary power directly for pumping water. This led us to discard the design feature of the drive disc in favor of a 90 degree gearbox (in the form of an old bolt-on thresher belt pulley). Our Mark II device thus features a PTO-type drive train that can power any number of implements, much as horse-treadmill manufacturers have successfully done.

The Mark II design also uses a pressure-treated wooden tower and stabilizing guywires, and uses babbit bearings that bolt onto the tower frame in lieu of automotive wheel bearings; this allows the driveshaft end to drop down below the turning unit where it is easy to affix a gearbox or pulley to use the rotary power.

We were able to raise the tower and hoist the assembled rotor (weighing about 1000 lbs) into it using simple machines, though a crane would have been handy as well as safer. Once placed in the tower the Mark II began to spin gracefully and has performed well at windspeeds ranging from 4 to 35 mph.

Illustration 1: 1/6th scale model of our "Mark I" Savonius built by Victor Gardy

Project Conclusions

Revisiting Our Research Questions

Ultimately we determined that the Savonius rotor, particularly when constructed of cheap yet durable materials as in the Mark II prototype, is a financially viable investment. Its potential for non-electric power is particularly compelling. On farm uses for the direct-drive power of our rotor might include:

- irrigation and drainage pumps (this is what we intend to use our unit for, primarily)
- stone-burr grain mills
- vacuum pumps for maple syrup operations
- ice cream makers or cream separators
- stationary woodworking equipment or small lumber mills
- square bale conveyors
- cement mixers
- feed mixing units
- wood splitters
- cordwood saws
- two-stage air compressors

We also asked at the outset whether a prime site would be important for an economically viable installation. Both units were found to reach peak velocity at around 12 mph windspeed when no load was present, and to begin turning at a windspeed of 5 mph or less. Additional torque is generated at higher windspeeds. Through measurement we estimate the efficiciency of the Mark II design to be in the neighborhood of 30%, a very respectable capture of wind energy.

We also wondered about the ease of building and maintaining a unit. While the Mark I and Mark II are both fairly easy to build, the Mark II is better from a maintenance perspective due to the higher durability of its components. The Mark I as described demands carpentry skills only while the Mark II demands both carpentry and welding skills. The Mark II is also more challenging to erect, but was still accomplished by a crew with no prior experience putting up windmills and towers with no incident. In general we feel this device is quite easy to make and master, much more so than a fussy tractor or bailer.

An additional thought in closing: there are many possible installations depending on the site and the end use of the rotational power. Multiple units, each with their own generator, could charge a common battery bank. Both the Mark I and the mark II type towers can be expanded vertically to accommodate more rotors on a common shaft, though bear in mind that any shaft should be stabilized with babbit bearings every 10 or 15 feet. The steel Mark II rotor could be installed in the Mark I style tower and vice versa.

We feel that our Savonius project was modestly successful and that our prototypes can be recreated by any reasonably handy person, and the power output recreated on any site with winds equal or greater to ours. As the monetary and externalized costs of our current energy system continue to stack up, there is a growing need for farm and community power that can be created and managed by generalists. Perhaps the strongest future possibilities for future wind use are those that have dominated wind power's past: water pumping and mechanical power. The Savonius is a proven, adaptable concept that can be put to work for such needs around the region.

Comparing the Mark I and Mark II

Our chief aim in this project is to design, build, and evaluate a prototype that can be built by farmers and serve farm energy needs. In most respects, our Mark II design excels the Mark I. However for some individuals, the Mark I design or aspects thereof may be more desirable. For purposes of easy comparison, let's look at the following table:

	Mark I wooden unit	**Mark II steel unit with pressure-treated wooden tower tower**
Cost of materials	$871.00	$935.00
Our hours of labor to build	60	104
Value of labor at $25/hr	$1,500.00	$2,600.00
Total unit cost, labor and materials	$2,371.00	$3,535.00
Wind swept area (m2)	4.46	9.29

Portability	feasible	Not portable
RPM in 11 mph winds	60	50
Output	Drive disc	Low-speed pto shaft
Estimated watts in 11 mph winds	75	200
Annual est. energy production at our site (kWh)	650 kWh	1752 kWh
Paypack period, materials alone, at $0.25 per kWh	5.4 years	2.1 years
Payback period, labor and materials, at $0.25 per kWh	14.6 years	8 years
Approximate projected working lifespan	10 years	20 years

It's significant that if labor costs are considered, the payback period of the Mark I (at current energy costs) exceeds its working lifespan. However if this is the case it is far from alone in this regard as this is also true for many conteporary wind and solar applications. The Mark II steel unit on the other hand, has a very competitive payback period even when labor costs are included. With a much greater durability and sail area, it represents a better investment in most regards. The Mark II unit lacks the high-speed drive disc of the Mark I and would need either to be fitted with one or with a gearbox of some kind to be effectively employed for electricity generation or other high-speed low torque use.

For a more complete description of our experiment, and for plans and construction manuals for both the wooden Mark I and steel Mark II design, please visit the following website:

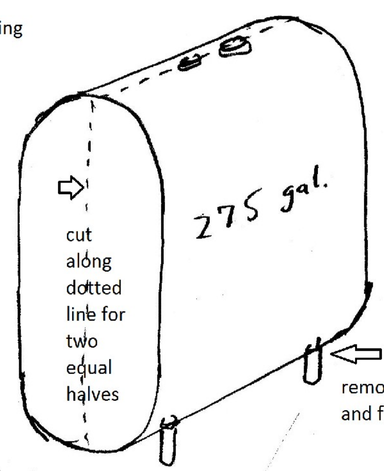
http://mysare.sare.org/mySARE/ProjectReport.aspx?do=viewProj&pn=FNE10-676

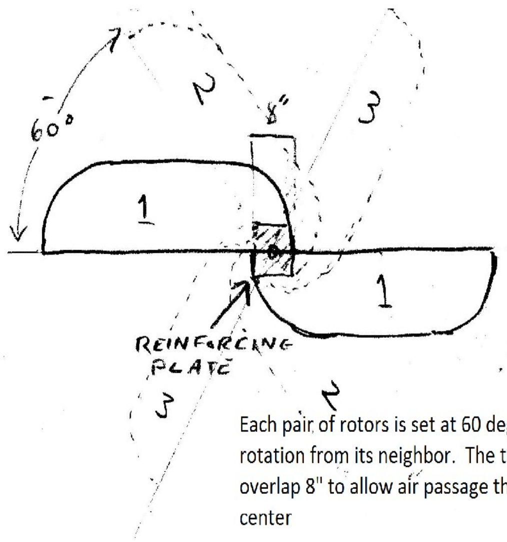
Or, contact the offices of Northeast SARE:

Northeast SARE
655 Spear Street | University of Vermont | Burlington, VT 05405-0107
Phone: (802) 656-0471

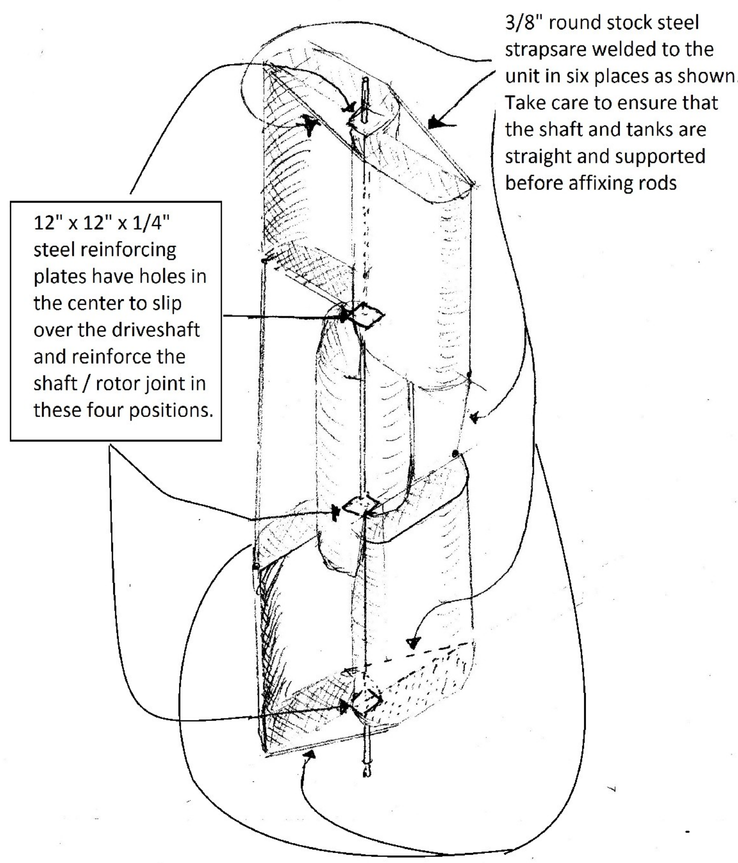
A single 12' tower of the "Mark I" variety can be moved around on a flatbed trailer or hay wagon. This allowed us to trial our Mark I prototype in multiple locations.

Robin, 3 years old, finds the Mark I rotor cup rotor a great place for hide-and-seek.

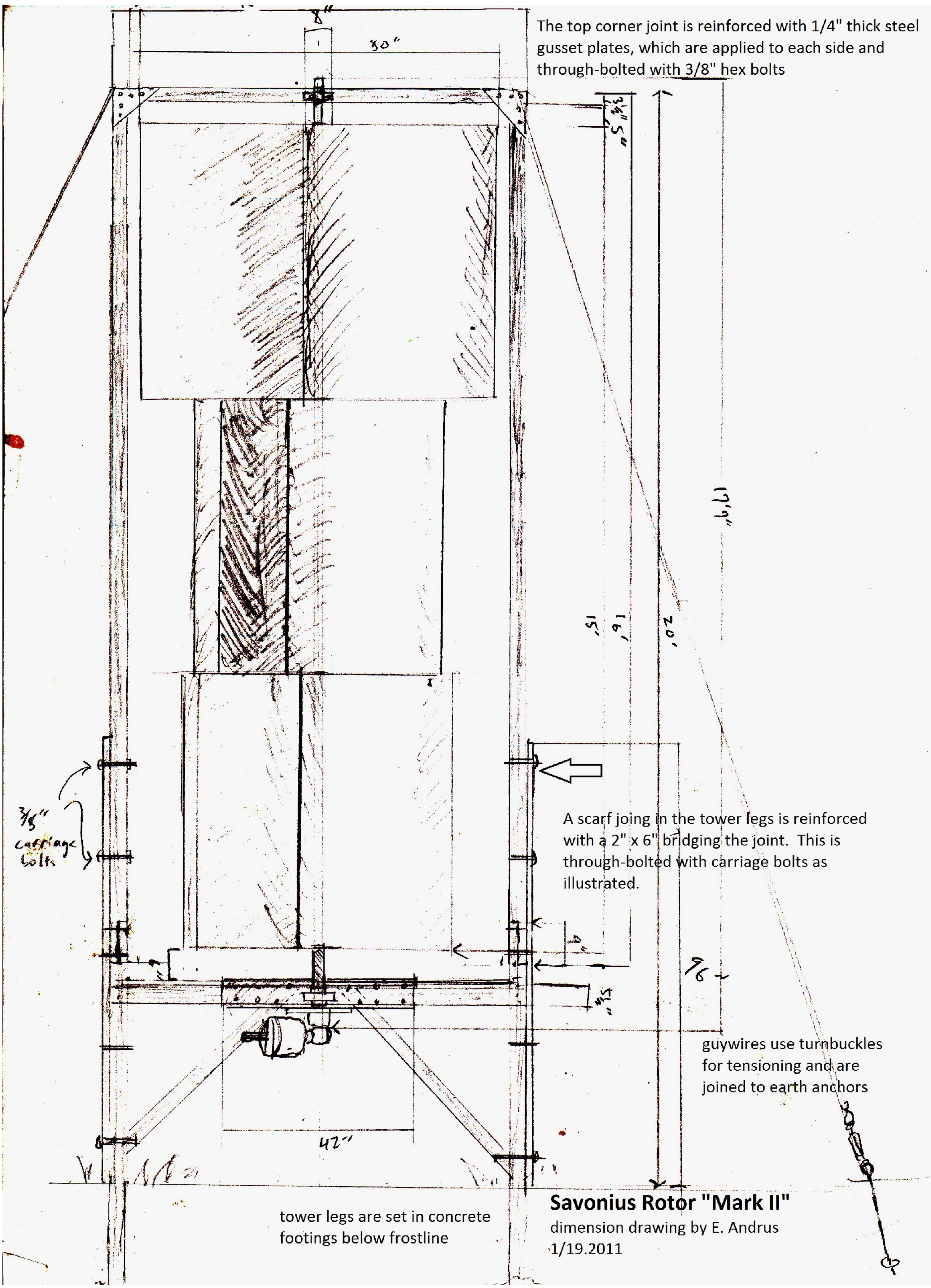




Each pair of rotors is set at 60 degrees of rotation from its neighbor. The tanks overlap 8" to allow air passage through the center



The finished product: A big green windmill. It's job beginning in the 2012 growing season will be to pump water from the reservoir (frozen water on the left) to the rice paddies (off to the right of the frame).


The top corner joint is reinforced with 1/4" thick steel gusset plates, which are applied to each side and through-bolted with 3/8" hex bolts
8"
80"
3/8" carriage bolts
A scarf joing in the tower legs is reinforced with a 2" x 6" bridging the joint. This is through-bolted with carriage bolts as illustrated.
17'9"
16'
15'
20'
96"
42"
guywires use turnbuckles for tensioning and are joined to earth anchors
tower legs are set in concrete footings below frostline
Savonius Rotor "Mark II"
dimension drawing by E. Andrus
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