ENERGY SELF SUFFICIENCY NEWSLETTER

August 2005

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Hydro
Solar
Wind

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A Rebel Wolf Energy Systems Publication
With thanks to Bizerka Koncul for permission to photograph her beautiful house

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From The Editor's Laptop

by Larry D. Barr, Editor

Don't Be Afraid To Start Small

When I was living in the Sierras in Northern California years ago, I heated entirely with wood. It took between seven and eight cords each winter to keep icicles from accumulating on the overhead, and the family from shivering through life in the mountains.

Late spring marked the beginning of the time to start collecting next winter's wood and I well remember the feeling of walking out each year, freshly serviced chain saw in hand and wondering where to start. The pine beetles had chosen our area as prime vacation country and there was never a shortage of standing dead pines. A large oak or two had always succumbed to the ravages of winter and so the 300 acres always provided the necessary hardwood as well.

In a classic reversal of the old cliché, it was difficult to see the trees for the forest, and the only way to get started was just to find the closest candidate for next winter's BTUs and lay it down. The same principle applies to energy self-sufficiency.

As you know, I currently live on-grid in a small (700 ft^2) house in town. My ultimate goal is to find a plot of land out of town and go back to off-grid living. But I can't do that right now. The finances just aren't there. So, I'll have to scale back, rethink the situation and start working toward energy self-sufficiency in the house I'm in.

It's not as easy in the city. You can't fly a wind generator because of all the trees lovingly planted by the city founders years ago, and there's no way to get a permit to put up a tower that will clear them (even if you could afford it), Those same trees that shade the west side of the house in the afternoon also limit the hours of effective sun for the PV panels, so you have a bit of a problem powering the whole house on renewable energy sources.

Here where I live in North Central Texas, air conditioning is a necessity in a conventional house. It requires a home specifically designed for the climate to survive here without it. Another obstacle to energy self-sufficiency in town. So, what's the answer for those of us who, in spite of the obstacles, are working toward energy self-sufficiency?

Start small! There's no shame in starting small. The only shame is in not starting at all.

My personal starting point is going to be my two-level desk/command center. You saw a picture of it a couple months ago in my article about 12VDC laptops. It's simply an old desk that was given to me several years ago. It got a bit small, so I added a shelf to it to hold my computer printer, the 9" AC/DC TV/DVD, speakers, external HDD and the phone and answering machine. The laptop and its various accoutrements sit on the lower level, leaving a fair amount of room for graph paper (I can't think without graph paper), a calculator and the occasional cold adult beverage. I'm going to begin my quest for energy self-sufficiency with the desk. If I don't get the rest of the house in order before I find the perfect piece of land, at least the command center will be ready to go when I am.

I spend a lot of time at the desk and it's the most logical place to start my endeavors. So, here's the plan. Don't worry, rest assured that I'll keep you advised of my progress on the project in the pages of ESSN. OK, now turn the page to see my plan ...

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I'm going to set up the desk so that it will run equally well off either 120VAC or 12 VDC. That'll take a little extra bit of doing since the LAN router, the printer and the DSL modem don't run off native 12VDC. So, I'll be using a small inverter to run those devices. The plan calls for a 120VAC power supply sending 13.8VDC to a West Mountain SuperPWRGate.

The West Mountain device acts as both a transfer switch and a battery charger. The battery will be a PowerSonic 12 volt 100Ah sealed lead-acid (SLA) unit and will ordinarily be charged by a pair of Uni-Solar US-64 (64 watt) amorphous PV panels. When the sun doesn't get the job done, the power supply takes over driving the charger in the SuperPWRGate.

I currently have a 300 watt modified sine wave (MSW) inverter from MPJA . I'll use that initially. If any of the digital gear gets fussy about the MSW and demands true sine wave, I'll try a Samlex true sine inverter from Backwoods Solar. I'm thinking the MSW unit will do the job, since Steve Spence is running similar equipment on an MSW inverter. Another option for those units may be a couple of voltage regulators to drop the voltage from the battery to what those devices need. The 12VDC devices on the desk will be supplied through a West Mountain RigRunner 12VDC distribution center, also from PowerWerx.

When the project is completed, the command center will be totally functional on either renewable 12VDC power or 120VAC from the grid. Once I finally get off-grid again, the 120VAC capability of the desk will only be utilized in the event of a no-wind, overcast for days, situation when I have to fire up the biodiesel genset. And that will just be to charge the battery.

And, in the meantime, I've made a start.

I encourage you to do the same. Look around your home, find a place to start, and begin your conversion to energy self-sufficiency. It needn't be a major undertaking, even a small project will confirm your dedication and give you a feeling of accomplishment.The most important thing that we can do is to actually begin to implement our transitions to energy self-sufficiency. Don't be dismayed by the immensity of the total project. Start small. Take one step at a time, always planning ahead so that what you're doing now will contribute to the final goal. You'll be making incremental progress toward off-grid living. And that's why we're here.

Join me in making progress toward our goal of energy self-sufficiency, conserve resources, and attempt to live lightly on Mother Earth. Reduce, reuse, recycle. It's not just a phrase in a public service announcement – it's our future. ldb

Circulation Info

ESSN exceeds 21,000 downloads!

After only seven months of publication our circulation, measured by downloads of the PDF and HTML files, exceeded 21,000 last month for the first time. As the word of our existence spreads, and our content increases, we will continue to share our experiences (and yours) in off-grid living and energy self-sufficiency with folks around the world. Thanks for your interest and your support. ldb

!!! STOP PRESS !!!!

ESSN EDITOR SELECTED AS MENTOR FOR BizWomenAfrica.org

ESSN Founder and Editor Larry D. Barr was selected as an Electric Power Mentor for BizWomenAfrica. BizWomenAfrica is an organization dedicated to empowering, in all ways possible, the citizens of Africa who live in remote villages without, in many cases, running water or electricity. Barr was interviewed for the website and stressed the importance of simplicity and creativity in bringing 12 VDC power to these remote areas. The interview is on the BizWomenAfrica website at http://bizwomenafrica.org/id342.htm

BizWomenAfrica is seeking mentors in all areas of expertise. Those willing to contribute their time, knowledge and skills may learn more about the project at http://bizwomenafrica.org/id84.htm

More On Methane

Al Rutan, the Methane Man

First printed in
Home Power #27 • February / March 1992 Alternative Fuels

Al with a small Digester

In the last issue of ESSN, Al's first article 'Prologue to Methane Gas' praised the ease with which methane is used – merely turning a valve to have instant vapor fuel. It takes so little effort. If gas is so easy, how does fifty pounds of stuff get pushed around without any effort? Aw...you caught the inconsistency!

That article says that we need about 50 pounds of waste daily, a mixture of manure and carbon material to feed the digester that will turn this material into about 200 cubic feet of gas.

The focus of this article is just this problem. As anyone who has done any kind of homesteading knows, there is a hard way and an easy way to do every job. Part of the endearing quality of American ingenuity is to see how people can approach a task that is downright tedious, and by some clever manipulation, make it easier.

Easy is Better

This really became a lesson taken to heart while living at Red Lodge, Montana. I was in the middle of a project raising rabbits for market – lots of them, about 200 breeding does producing litters.

Feeding and watering this number was a time-consuming chore. I made hoppers for the hay and feed pellets early on, but providing abundant water was a drag. I upgraded from water dishes to water bottles with a valve. This was an improvement in cutting down the labor. The big jump was to a system of watering valves fed by little plastic lines from a central tank with a float valve to control both the water level and pressure on the water lines.

In one situation, the water was put into 200 little water bowls which were constantly being spilled or fouled with waste. In the other, water was supplied by a small pipeline with drinking valves in each cage. The result was the same – water to drink, but the effort needed was totally different. The two situations accomplished the same effect – abundant fresh water.

Consider the Critters

There is another consideration that must be brought to mind at this point. In the methane process, we are working with living creatures. Therefore a moral dimension must be considered if we are going to achieve a measure of serenity for ourselves in this whole process.

To have a genuine sense of well-being about the entire operation, the animals and the space for which the person is responsible must have an ongoing atmosphere of serenity. If this sounds a little bit like St. Francis of Assisi, well, so be it and no apologies. The purpose of life is not merely accomplishment, but accomplishment in a caring and respectful way.

As people, we harness the work of creatures. Some may maintain this is not right. I don't agree. I do feel strongly that the animals with which we work and upon which we depend do have the right to a reasonable quality of life. So at this point we are talking about animal rights. The concept of animal rights means different things to different people. To me, it means that an animal has a right to a reasonable quality of life. An animal has a quality life when it feels good about itself. This is most clearly evidenced by grooming. Animals, if they feel good about themselves, groom themselves and their friends.

Quality of Life

Death for an animal, or a person for that matter, is not the worst thing that can happen. Quality of life while something is alive, be it plant, animal or person, is of major importance in the scheme of things. One who homesteads can not be mentally well off if such a person is not sensitive to the quality of life of the living things around the homestead. Are the animals feeling good, as evidenced by their grooming?

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A Dilemma

Now, why make a point of this if we are talking about methane and manure? We are faced with a dilemma. On the one hand we want to collect waste with the least effort possible and do it as automatically as possible. On the other hand, we need to have a measure of sensitivity to the needs and quality of life for the animals on which we depend.

If the animal wanders about freely, it will be very difficult to collect its waste. On the other hand, if the animal is tightly caged or tied, its quality of life is virtually nil. So what's the answer?

Somewhere there is a middle ground. Chickens, for instance, do most of their pooping while they are perched at night. Milk cows leave a quantity of used grass in the gutter while being milked or held in the barn during the night.

Hogs that are totally confined don't have much of a life. Hogs that are confined only through the night will leave a good share of their waste behind when penned only part of the time.

Chickens do not do well housed on hardware cloth because their natural inclination is to peck and scratch. I've seen a roost system where the area under the roost was wired with large chicken wire mesh. The chickens could not get to the manure to disturb it after a night of roosting. They were free to roam at will during the daytime.

Slatted floors are useful for both hogs and cattle from the standpoint of cleanliness if the animals are not required to stand on them at all times. In all these design considerations for an enclosed area, the needs of the animal must be considered if we are to have happy animals.

Moving the Material While It's Warm

It is the matter of manure itself. How can a person move it with the least effort possible? Manure delivery systems have been devised for various types of critters, except the horse. To my knowledge, there is no device more automatic than a scoop shovel for cleaning out a horse stall.

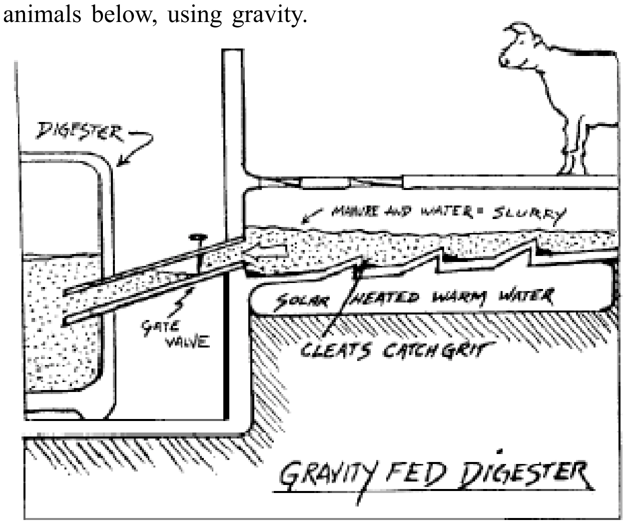
If one DOES have animals, the feces HAVE to go somewhere. So at that point it makes a great deal of sense to turn the waste into vapor fuel (methane) and compost.

When the waste comes out of an animal, it is at exactly the right temperature – body temperature. As it lies on the ground, it cools off. This cooling during the cold time of the year is severe. The sooner the waste is transported from the animal to the tank the better. If the waste loses heat, then the heat must be restored to have the methane digestive process occur in the best manner possible.

This brings us to the biggest challenges in the entire methane procedure. How do we gather the manure to begin with? How do we gather it as soon as possible after it leaves the animal and before it cools down?

Gravity Works for Free

There are two natural forces that work well for us. One is gravity and the other is water. In rolling countrysides, barns are commonly built on hillsides. The hayloft is easily accessible by simply driving in rather than having to go through the labor of hoisting every bit of hay with some kind of sling mechanism. The hay is forked down to the animals below, using gravity.



The more that gravity can be utilized for tasks the better. The animal walks around. It can walk up as well as down. If the housing for the animals can be above the digester, then this saves work.

Water has long been used for transport. Since the development of the flush toilet, in the 1850's in England by Mr. Crapper (no kidding...that really was his name!), we have been using water to move feces.

Using water has a problem. What I am going to say now is exceedingly important. Many an engineer and university professor working with the methane concept cannot seem to grasp a simple fact. It is the nature of liquid – especially water – to release heat. When water is heated, it will not retain its heat. We say, "It cools down."

Water Must Be Warm

If we are going to use water in the process of transporting manure, and have it work well, we must understand that water cannot be allowed to stand around waiting for the waste. Warm water can and certainly should be used to wash down a gathering point below a slatted floor. The gathering point had better not be a holding pit in the ground because the whole thing will cool off to ground temperature. Another consideration is that in a pit the methane activity begins right away, so animals above a pit are breathing contaminated air. This is why holding pits MUST have ventilation fans if they are under confinement areas.

Continued on next page

Think in Terms of Free Energy

How does one have warm water with which to transport? Each location will have its own plusses and minuses in working out this design problem. A person has to consider all the ways of capturing "free" thermal energy – solar, wind, whatever, and applying it to the situation at hand.

We're most likely looking at periodic washing down of a gathering area with warm pressurized water. This will both increase the force of the wash and cut down on the amount of warm water needed. The more automatic the concept can be and the less labor intensive, the more of a ideal situation a person can enjoy.

Do We Really Need Animals?

So just how practical is the thought of having animals around a homestead? The trend is increasing for relying less and less on animal parts for human food. Folks tend to become more and more vegetarian. We still need the family mule to plow the garden, a few milk goats for the delicious and healthful treat of fresh goat's milk, or a few sheep to produce wool for hand spinning and the cottage loom. There is wisdom in involving some kind of animal support in our homesteading.

Farmers who raise nothing but corn are still hooked into the food "grid" when they drive to the store for their butter, milk, and eggs. Our great grandparents would shake their heads!

Al Rutan

Al Rutan – RIP

SIMPLY EV's

by Jerry Dycus

I hope to show you in this article how to make your own Electric Vehicles (EV's). Electric vehicles are fun, useful, easy to build and low cost. Some will be street legal, others designed for utility, and some will be just plain fun!

A simple, moderate-speed three-wheeler (or 'trike') motorcycle design was chosen for those who need good transport, errand running, or commuting at a really low cost. It can be designed with a top speed of 25 to 60 mph depending on how you set up the drivetrain and electrical system.

As for fuel, it costs less than half a cent/mile for electricity to run it! That's equal to 400 mpg or more at present fuel prices, and about 150 mpg with battery replacement cost over the long haul included!! Furthermore, it could easily be re-charged by a wind generator or solar panels, depending on how much you drive and your renewable energy (RE) system output.

The easiest, cheapest and most useful is a 40-45 mph EV with about a 40 mile range, and this is what will be described. It'll be useful for local shopping, or anything else that takes your fancy! Feel free to modify it in any way you want, but if you are new to 3-wheel 'trikes' or EV's, it would be smart to join one of the great groups on the web that can help you modify it safely and correctly.

Good handling demands that the weight on each wheel should be equal with the driver on board, and the batteries should be mounted as low as possible, with about half of them in front and half behind the main rear axle (the transaxle). The motor, driver and the front end of the vehicle provide the balancing weight at the front and, if necessary, the weight distribution can be trimmed by moving some of the front batteries a bit further forward.

A very cost effective option is to use a golf cart transaxle. These are very reliable and can be found cheap to free almost anywhere in the USA. Similar rear axles may be found on many other types of small vehicles elsewhere.

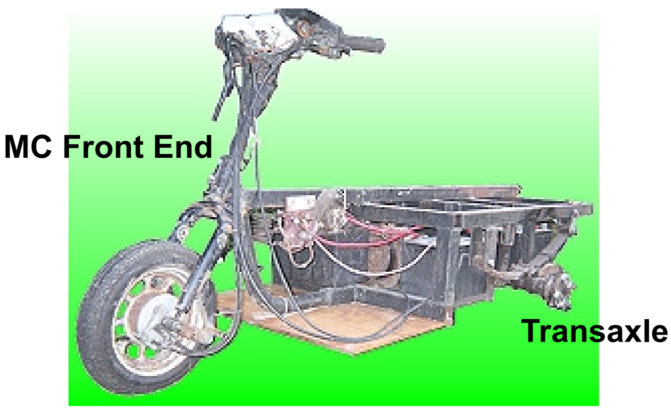
Look for old golf carts that are being junked because they are rusting to death, or just sitting unused merely because they need a new battery pack. Either way, the owners don't want to put money into such equipment and you should be able to get it for next to nothing. Try to get one with the highest power you can in horsepower and rated amps. The more, the better.

The one shown in the pictures is 2.2 hp, as many are, and is good for 45 mph at higher voltages than rated. Electric motors are quite easy to work on and safe to hotrod or rebuild! Be sure to get any controllers, solenoids, resistors, battery chargers, wires, reverse switches, etc. as part of the deal, for they will probably be very much cheaper than buying them new.

Continued on next page

Don't worry because it's old equipment, for EV components even as ancient as the 40 year old one shown – if not older – still have decades of life left in them. I pulled a 40 year old one that sat under a parrot cage for 10 years and replaced the tires, put in two 12 volt batteries, then totally freaked out the former owner by driving it home! Most already come with cable brakes, which are easy to hook up to the motorcycle (MC) brake lever by simply buying the correct length of cable that has the correct cable ending bit – most MC shops can make that for you.

Of course, the original vehicle may have been designed to travel quite slowly, but one simple way to get higher speeds is to use larger wheels, such as standard 4-lug trailer wheels in 13 to 14 inch sizes. These usually fit very well without modification, as do some car wheels. As a final touch you can get shiny 'mags' to really dress it up!



All you need then is to find a MC front end that will work at the higher speeds you will be going. Most front ends from anything bigger than a 150cc motorcycle will work. Before you lay down your money, make sure the assembly has a good tire, brakes and speedo, and that the suspension in good shape.

If you are not going to make a fairing like I did, make sure the front end has all the vital accessories like headlight, turn signals, etc. to reduce the work needed. Be sure to note the year, make and model in case you need spare parts later.

Such front ends, like the transaxles mentioned before, can be found in repair shops, junk yards, or just lying around. However, be sure to get a receipt for it – and title too if possible – and receipts for EVERYTHING else, so when you go to get it titled you will have them ready for the registration authorities. Without them, you will probably not be able to register it legally.

Registration or titling isn't hard as long as you have all the proper ownership documentation ('title'). You might be able to slide by with just the ownership papers for the MC front end, especially if you use more of the MC frame to connect the rear to the front, and simply call the rear a 'modification'! However, the more documentation you have, the better your chances will be for a painless experience when you apply for permission to take it on the road.

Now that you have the main pieces, you need to figure out how to attach them to each other and build battery boxes, as batteries are extremely heavy, weighing 60 or so pounds each. Have a close look at the pictures, and see how it was done for my front motor type golf cart (GC) transaxle. There are other GC transaxles that have the motor on the top, and inline with the axle. Personally, I find the second type is easier to work with although either type is good. You'll need to make the battery boxes and frame a bit differently, depending on the type of axle you have. One method that works well for either axle type (albeit with a few variations) is the square box frame that allows for the attachment of spring hangers and battery boxes.

The frame in the pictures was built from two-inch mild steel tubing with one-inch angle stock for the battery boxes, which were just hung from the top frame. This is cheap, especially if you buy cut-offs ('drop') that most steel suppliers have left over from cutting material to size for other customers. Since you only need short lengths, drop is just fine. It's fairly easy to cut with a hack saw, if you take your time or have some friends take turns.

If you you don't have facilities or the ability to weld, then you can save a lot of money by just cutting the steel to length and getting it ready for a welder to do the job for you without wasting time. Just check that everything fits together well with the transaxle, front end, battery shapes, etc. before taking it all to be welded. It cost me just $27 for the steel, and I bartered with a friend for the welding, so the new chassis was almost free!

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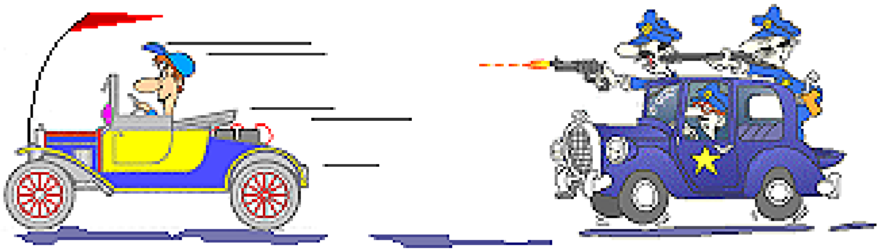
The rear leaf springs, hangers, etc. of my EV are all trailer parts available almost everywhere at trailer suppliers or other outlets. Notice one hanger is solid and the other swings to give room for the springs to move when bouncing. Hangers of different heights are available, so you can fit most any frame you design. The body chosen is a pick-up style for carrying groceries, hardware, and so on, and is designed to be very versatile. It will have tandem seating for two, although three could be easily carried when it's finished. The bed of the vehicle also acts as fenders for the rear wheels. The picture opposite shows the basics of the body, with the front fairing, seat and windshield still to be put on. The front fairing is important as it cuts air drag for higher speed and longer range, so it's not just for show.

Next month I will describe the electrical side: the controller, batteries and charger, and how the body will be finished – so stay tuned! We can be fun, self sufficent and low cost in our transport!

Jerry Dycus

AND NOW FOR SOMETHING COMPLETELY DIFFERENT ... AND IT ACTUALLY HAPPENED !!!



Jerry's article brought back old memories for me ... of the days long, long ago when I was a student in Christchurch, New Zealand.

In those days, quite a few old Model Ts were still on the road, and if you were a student then it was a huge status symbol to be seen puttering around in one. One particular engineering student was one of those elite, and had spent many hours lovingly repainting it from its original black to colors that he considered to be rather more modern and trendy ... a violent clash of blue, yellow and red! But his main claim to fame was that he had applied what he had diligently learned and had converted his Pride and Joy into an electric vehicle. It was silent, clean, and he was often to be seen cruising around the streets of Christchurch ... an ideal place for his vehicle as the city is as flat as a pancake.

The day naturally came when an enterprising young reporter from the local newspaper interviewed this dashing young man, for although we still had electric trams then, an electric car was a novel sight ... particularly a garishly painted Model T !

"It cost me nothing!" the student bragged. "I got all the batteries free from the local scrap yard, together with an old electric motor that had been thrown away, and I simply put it all together. I don't pay a penny now for fuel ... I just charge the batteries overnight and away I go ... free motoring!"

This was news indeed ... and that same Bright Student appeared in the local Magistrate's Court a week later. His landlady had read the article with great interest, for she had wondered why her electricity bills had suddenly soared!

Moral? A really smart student would have remembered the old saying ...
"There ain't no such thing as a free lunch!"

Mike Nixon (and I swear that it wasn't me!)

INSULATING YOUR OLD HOUSE

Seventh in a series of Articles on Passive Solar Building Design

by Laren Corie

This world is full of many fine old houses. They can be grand to live in, but they can also be very expensive to heat and cool. Their walls are generally leaky, and contain no insulation beyond their basic building materials and an empty air space. Even houses built in the fifties and sixties may only have 1½" of sagging fiberglass in the void. Even that will often allow air to pass right through. Tearing open the walls to add bat type insulation would be a nightmare of wasteful destruction. Foam-in-place insulations are quite expensive. Though I'm sure there are a few who might disagree with me. To my way of thinking there is only one outstanding insulation to use in the walls of such a house. That is dense pack, blown-in cellulose.

Cellulose insulation has been around since early in the last century, but only started gaining popularity after the oil embargo of the 1970s. It began as a decentralized method of recycling newspapers, part of the grass roots environmental movement. Since then, its use has been growing steadily. I've heard that the annual US production is well over a billion pounds. Cellulose insulation is 70-80% ground up, recycled newspaper. To that is added boric acid as a fire retardant, and vermin proofing. It is a natural non-toxic product that presents no harm to humans. However, it is the active ingredient in natural ant and roach control products. Boric acid is also commonly used as an eyewash. Sometimes cellulose insulation also includes the salts of borax, which are used in laundry products, and have a toxicity level even lower than boric acid. There may also be a little ammonium sulfate, which is used as a food preservative and soil fertilizer.

Only a very small fraction of the energy to produce fiberglass insulation is needed to produce cellulose (2.5-5%). The only sensitivity that seems to exist to cellulose insulation is an allergy to newsprint. If you have this allergy to newsprint, there is special cellulose insulation available which is made from other recycled papers. Unlike fiberglass insulation, which must carry an OSHA warning about being carcinogenic, cellulose is only considered to be a "nuisance dust" on the work site, like sawdust. It also does not cause the skin irritation that fiberglass insulation is know for, and carries no guidelines for special handling and clothing, like fiberglass. Cellulose insulation is very "green," as they say. It also happens to be very economical.

I recently insulated the wall of a 1,200 square foot home, with 9 foot high ceilings, with just $173.60 of cellulose – and that included a recent price increase. It also included the use of the special machine to blow it into the walls. This added between R14 and R15*, and also sealed up all the little air leaks. This is really a great way to insulate old walls. I have looked around the net, but there seems to be a lack of detailed information on how to do this kind of job, so I took along my camera for a few shots, and will go through the finer points here so that you can be fairly well prepared to insulate your own old house, in a smooth efficient process.

Insulating the Attic

First, I want to briefly discuss insulating an attic with cellulose. It's a very simple process. The person doing the actual insulating just climbs up into the attic, points the hose and flips the switch, and the insulation roars out the end of the hose to fill to whatever depth is required. The depth that you will need, for the R-value you want, is on a chart usually displayed on the side of the cubes of insulation. Cellulose used to come in big loose bags. Nowadays it is usually compressed into cubes that stack better and take up less space.

* Insulation is identified and labeled by R-value. "R" stands for resistance to heat flow. The higher the R-value, the more heat flow it can resist.

Continued on next page

As you insulate the attic, you will be blowing it out loosely, so it will originally lie deeper than the thickness it finally settles to. Measure your area, look at the charts, and buy the right number of bags. Don't even bother measuring the depth. The R-value selected will take care of that for you.

This is not a job for one person. Just loading the machine into your vehicle usually takes two, and you definitely need a second person to handle the machine outside the house and keeping the hopper filled while you blow in the insulation. Insulating an attic goes very fast. Adding about R20 to a 1,000ft^2 attic should take less than an hour with the blower on, and you could even be able to cover as much as 1,800ft^2 in that time. Most of your time is likely to be spent in travel, setup, and final cleanup. When insulating an attic, you just cut open the cubes and then drop them into the hopper. Many machines will even break and grind it up for you before blowing it out. The person at the machine will be busy just filling it as it works very quickly.

There are floors in some very old house attics. Cellulose works very well for insulating under these. There is usually some open area around the perimeter where you can run the hose under the flooring, then pull the hose back as the space fills with insulation. When you are filling these hidden spaces, it is a smart practice to count how long they take to fill up. Then, if one takes longer, shut the machine off!

There is a good chance that you've found a hidden plumbing chase, or some other opening. If it is just a soffit over kitchen cabinets, or a ceiling drop over the bath tub, you may want to just fill it. Cellulose is cheap, and the space will usually fill faster than blocking it off with a barrier. However, if it's a plumbing chase then it may run all the way down to the basement! I found out about this many years ago, when I was insulating an attic for some in-laws. Fortunately, I was counting, and realized that it was taking too long, and stopped. Even so, we still ended up with a two foot high pile of insulation in front of the washing machine, three stories below!

It turned out that there was a plumbing chase, and it was so big that it actually had a permanent ladder in it. It had probably been costing them thousands of dollars in heat loss. It was literally a chimney up the middle of the house, with all of the uninsulated hot water pipes running up it. Fortunately, we were able to simply cover the hole and insulate over it.

Even in attics with no flooring, you can expect to find big holes that will eat up insulation. A typical place is over stairwells that have a sloping ceiling. In some old houses, you may often find that fiberglass insulation has been simply stapled over the opening, with gaps where the warm air rises and cold air drops through to take its place. You will want to remedy these situations. A staple gun and some polyethylene sheet should do.

Be careful to not block your soffit ventilation. If you are insulating deep, you may have to instal some sort of baffle to keep the insulation from blocking the air flow. There are expensive polystyrene baffles at the home stores, but you can sometimes simply staple up polyethylene sheet, or use HDPE drainage tubing to maintain an air passage through the insulation between the attic and the overhangs. I am not going to get into the subject of vapor barriers, attic vents or any other attic related details here. There is plenty of information on those subjects available on www.buildingscience.com . What I mainly want to tell you about is insulating your walls.

Cellulose insulates more per inch than fiberglass. Fiberglass bats are about R3.17 per inch, and blown-in fiberglass about R2.5 per inch. In contrast, cellulose is about R3.75 per inch. The thick walls of older homes will give you space to add about R14 or R15 to the insulation value of your existing wall materials. In the case of the house I just did, that totals about R20 through the insulation, and somewhere around R15 to 17 after averaging in the framing That is as good as a lot of houses with six inches of fiberglass! The cellulose will also fill every little crack and cranny. As you blow it in, the air seeks out the leaks, carrying the insulation with it to fill and stop them up. With cellulose, you will not have all those gaps and spaces that you get as you attempt to precisely cut and fit fiberglass. Cellulose will not allow air to blow through, and has been shown in tests to reduce heat loss about 25% better per rated R-value, than fiberglass.

"Dense Pack Cellulose"

Cellulose has basically the same insulation value per inch, regardless if it is loose fill at 1.6 lb/ft^3, or packed into the walls under pressure so that it is 3.25 to 3.75 lb/ft^3. This allows the insulation to be packed so densely that it will never slump. It will also do several other things. It makes great sound insula-

Continued on next page

tion. It absorbs, then gradually releases moisture up to 15% content without losing significant insulation value. It plugs up most air leaks, and it flows around all the pipes, wiring, etc. to fill every gap.

Now, how it is installed? There are a few basic ways you can access the interior of your walls. First determine whether you want to go through from the outside or the inside. You can remove a high course of siding and then feed a tube down into the wall, or you can remove two or three courses and blow the insulation directly in with a reduced size hose end.

However, you can also blow it in from the interior. This is a definite advantage for a brick house. It also works well if you are planning to paint, and it can be considered as part of finishing the interior of a room. The hole patching is not difficult, and goes fast, even with so many holes. The 1,200ft² home I just did, with holes at both the top and bottom of all the stud spaces, took about 135 holes. I patched all the holes in five to six hours. That Beatles lyric, about Albert Hall, kept going through my head. Now I know what all those holes were filled with!

Old houses can have some pretty tough plaster to bore through. Where there is brown coat, which contains sand, a tungsten carbide hole saw will be needed. You might even go through a couple of them. Drilling can be the biggest job on an old house. However, working on your own house gives you the opportunity to spread the job out to ideally fit your schedule and needs.

You can even insulate one room at a time as you paint. One room will probably use up less than ten bags of cellulose, but you can put the remainder aside for later, or just blow it into the attic. A full house could mean days of drilling, about half that time up on a ladder, with your hands over your head. Very tiring! Good brown coat is very tough stuff, and the multiple layers of the wall can mean a lot of stopping to clean out the hole saw. Even so, rather than attempting to feed a small hose down through one hole, it is often simpler to drill two holes, one near the top and athe other two or three feet above the floor. This will allow you to pressurize the whole wall cavity.

After you have decided from where you will drill the holes, you have to figure out exactly where on the wall to drill them. It would be nice if all of the studs were neatly on 16" centers, but unfortunately older houses are not usually that consistent. I suggest getting a good electronic stud finder, for about $20. Be sure that you get one that has extra sensitivity for plaster walls. The basic units are only designed to read through 1/2" drywall. A wet plaster wall may be as much as 1½" thick, including wood lath, so you will need that extra sensitivity.

Do not forget the traditional technique of tapping on the plaster to listening for the solid, less drum-like places where the studs and other framing are located. Once you are pretty sure you have located a couple of studs, and marked their locations, you can drill a hole. If you are careful, you may even be able to establish a pattern of 16" centers.

After you have a hole, you can use a probe, such as a section of metal coat hanger wire, to verify the spacing inside of the wall. Upper holes are best drilled at about a foot from the ceiling. Lower holes can be two or three feet above the floor. There will also be practical considerations that will dictate variations. Bathroom tile is one. Another may be paneling below chair rails. With kitchen cabinets, you may choose to drill from inside of them.

Expect to find some real surprises. I have found headers extending out more than a foot beyond the sides of windows! Watch out for blocking, firestops, and other interference.

Be cautious, and do NOT drill into wiring, plumbing, or gas lines! Also watch out for balloon framing that will let insulation blow out into ceilings, attics, and maybe your basement or crawlspace. You need to understand the building structure, so take your time to explore.

After you have drilled your holes, you are ready for the insulation and blower. Since insulation takes up a lot of space, you may want to purchase and transport it a few days before you get the machine to blow it into the walls. Most places that sell the insulation also rent the blowers, and many offer free usage with a minimal purchase. Though I owned my own blower system twenty-five years ago, I now simply use the free ones from the insulation sellers. Usually, only a purchase of ten packages of insulation (less than $60) is required to receive twenty-four hour free usage.

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A common machine is the "Predator II" which is made with a light-weight aluminum housing, and plastic hopper. These machines have wheels and are sized to just fit into the back seat of most cars. You can buy your ten bags of insulation, then bring your receipt in a few days later to get the blower. You can also buy the insulation at one store, then get the blower from another of the same company. At least that is the case with the biggest home store chain. I strongly suggest that you buy your insulation in ten bag lots. This will insure you the maximum available free blower usage, just in case you need it. You can always return what you don't use.

There is a learning curve to using a cellulose blower. I will try to eliminate your biggest headaches, or at least give you enough information, so that you can work your way through them. You can get a little guidance when you get the machine, but it is likely that you will still get a clog, especially when blowing insulation into walls. Once you can get through a wall installation, you are not likely to ever have many problems in an attic.

Some stores stock special attachments for blowing into walls. These include a tapered nozzle to reduce the diameter of the hose down to one inch. If the store does not have this attachment, and they cannot direct you to their other store that does, then you may have to do what we did in the old days and duct tape a section of tubing to the end of the hose. You may even want to do that with the tapered nozzle, so you can drill just one hole per stud space and feed the tube down into the wall. Duct tape is usually a must-have for this job. Between the connections at both ends of the hose, and other possibilities, you may go through a whole roll.

Some machines have nice fittings on the end of the hose. Some may have hose clamps. Most seem to just have bare hose, and you are left to hold the connection together yourself. With an attic job, you might even get away with just pushing the hose over the outlet on the machine. However, be warned! With the pressures that occur when blowing the walls full, this will not hold more than a few seconds. Tape it, and tape it good, or buy a big hose clamp – but still tape it to prevent leaks. The tapered nozzle requires taping too.

As I mentioned before, and cannot over-emphasize, clogging of the nozzle, tube or hose are the biggest troubles you can create for yourself. To alleviate this problem somewhat, the manufacturer of the Predator II make a piece that drops into the hopper which stops large hunks of insulation from getting out. This piece is called a "material block plate". Not all of the stores will have this piece, or the tapered nozzle, so call round first to make sure. It is also wise to call and reserve the machine before you drive out to get it. At some times of of the year, usually Autumn through Winter, the machines are very popular and there can be a lot of breakage. Some stores may therefore have only a couple of broken machines, and no good ones available.

Once you have your stockpile of cellulose, and have procured the use of the blower, you can set them up outside the house where any dust will just blow away harmlessly. The hose should be long enough to reach most areas of the house, but you may want to measure first and ensure you can get a hose long enough to reach where you want to go.

Plug the blower into a circuit with no other loads. Most new rental machines only require 15 amps, but some older models may take more, with the start-up tending to trip breakers or burn out fuses!

The blower will probably come with its hose and cord in a trash can. The can is handy to use as a receptacle for breaking up the insulation by hand before dumping into the blower. This is a recommended step to avoid clogs when insulating walls. There is usually also a blower switch on a long cord, this being for the person who handles the hose.

This will be a dusty job, so cover what you can. If you are insulating a whole house, it will be wise to plan a trial run on a day that you are drilling holes. This is one of the reasons to allow yourself multiple days of free blower use, one day for a

Continued on next page

trial, one day for the actual job, then a safety day just in case it takes longer.. The trial run will give you a chance to work through your procedures and technique.

There are lots of variations in walls, and how they react to the air and insulation. You are likely to encounter insulation blowing out of adjacent holes. This will definitely happen when you drill multiple holes, top and bottom, instead of just feeding in a long tube. You can remedy this by simply stuffing a rag or piece of paper in the hole.

You could also get a lot of air and insulation blowing back around the nozzle. A wrap of duct tape will prevent most of this, and also grip the hole to allow you to hang the hose in the upper holes as you switch positions, or just relax. Holding the hose above your head, or off to your side while up a ladder, can get very tiring after a few hours.

This next part is very important. You must observe closely to know when to turn off the blower, or you will produce a nasty clog that is no fun to remove. Listen to the sound of the insulation as it moves through the hose. It will be traveling as much as at a hundred feet per second! You can also often see the shadows through the wall of the hose. These are some main clues as to how well things are going. If the insulation is flowing fast, then you are doing everything right, and a stud space will fill in as little as two minutes.

When the insulation is running through fast, but the hose has few shadows in it, then the insulation is not getting past the "blocking plate" in the hopper. This usually means that the hopper is nearly empty and the machine is just sucking air. However, it can also mean that the insulation is 'bridging', to form a void in the lower hopper, so it helps to occasionally press down lightly on the insulation in the hopper to ensure that it is pressing evenly on the blocking plate. This can save you hours, for it keeps the flow volume high.

You will be filling the wall cavities until they will take no more insulation. The sounds, the shadows in the hose, and even more so, the vibrations of the hose, will tell you if the insulation and air are no longer flowing. The hose will stop vibrating. When this happens, shut off the switch immediately. Remember that, **immediately!** Then wait a few seconds for the blower to coast to a stop, and for the pressure in the hose to relax. If you don't wait before you remove the hose from the wall, then you will receive a face (and a room) full of cellulose!

If the space you were filling is full, there will be insulation packed inside the hole, and also some in the end of the nozzle. If these things are not visible, you probably have a clog somewhere in the hose.

There is one more possibility. The clog could be in the wall, backing up into the hose. Place the tip of the nozzle back into the wall, in a fresh hole, and turn the blower back on. It will either blow insulation, or it won't. If it does, then continue. If it does not, shut it off right away. You will need to unclog the hose.

The first place that the hose is likely to be clogged is right in the taper of the nozzle. Your first effort can be to simply stick something down the nozzle opening to push the clog back. Use whatever you have. I recently used the tip of an old pool cue. This sometimes works. However, it often reclogs immediately. If this happens, you will need to remove the nozzle, empty its contents, then try again.

When you remove the nozzle, if there is no insulation in the hose, the clog is not in the nozzle and you may have a problem. Walk the hose end out to the hopper, where you can stick it down into the insulation and turn the blower on again. This should do it, unless you have left the blower on too long with a clog and have packed the hose. If that is the case, then you are in for a little work.

Do not just turn on the blower. That will just pack even more insulation, even tighter, inside the hose. If you empty the hopper then you can try reversing ends of the hose to blow in the opposite direction. Disconnect the hose and try to shake out some the insulation before you ever try to use the blower to clear it. Some insulation will shake out of the hose, a little at a time, but it is a tedious process. It has happened to me, when I got too used to the way one blower sounded, then switched to a different type of machine. It is no fun, but should take no more than about fifteen minutes to resolve.

Once you have all the walls filled, you just need to patch the holes. I've heard of a lot of ways to do this, and there are even supposed to be special plugs for the job. I've heard of dowels being cut to fit and glue in place, and recently read of using spray urethane like 'Great Stuff,' then trimming it flush and just spackling over the surface. However, that sounds like it would dent too easily, so what I prefer is a plaster wall patch, then a quick coat of spackle or drywall compound to smooth it. If there is a deep hole back into the insulation where the hose nozzle was, then wad up a little newspaper to stuff into the hole as a backing.

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That's it. a typical house may take from two days to a week, depending on a lot of factors, but you can double or triple your insulation values. With reduction in infiltration, you are also likely to reduce your heat loss/gain through your walls by as much as 75%. No amount of insulation will eliminate your need to caulk around your windows, and baseboards, but unlike bat insulations, cellulose insulation will seal around your electrical outlets and plumbing.

On the subject of electrical matters, the codes generally recommend against insulating right up against exposed wiring, like 'knob and tube'. Also, do not insulate around built-in light fixtures, which are designed to have air circulation.

Follow all other safety procedures, and good practices. Wear a simple particulate respirator face mask, and check with a professional, if you have any questions.

Here is a list of what I used in this recent house.

• 10 packs of insulation	$56.80
• Another 10 packs of insulation (price increase)	$58.40
• Yet another 10 packs of insulation (four bags were blown in to the attic)	$58.40
• Three 24 hours usage	free
• One roll of duct tape	$2.84
• Two 1¼" tungsten carbide hole saws from the same large home store (not needed for drywall or rocklath)	$20.98
• One 4lb Plaster Wall Patch	$3.95
• Spackle (surplus)	-
• Sand paper (surplus)	-
Total	**$201.37**

In addition you will need a few tools:

A drill that will take a good day's work
A couple of putty knives
A shop vacuum.
Step ladder
A box cutter, or utility knife (for opening insulation)
Electronic stud finder.
Particulate respirator face masks

If you have any questions, I will be available on the LittleHouses Yahoogroup:
http://groups.yahoo.com/group/LittleHouses

-Laren Corie-
Integral Solar and Energy Efficient
Building Design and Consultation
for Owner-Builders, Since 1975

SMALL WIND TURBINE BASICS

Part 2

by Dan Fink

In the first part of this series of articles, I covered how to calculate the power available in the wind and its relationship to turbine swept area and wind speed, plus other mechanical and electrical efficiency losses in a wind turbine. These losses give a realistic maximum Coefficient of power (Cp, or efficiency) of 35% of the power available in the wind for a small turbine. This crucial formula is:

Expected power output (in Watts) =
Cp * ½ * air density * swept area * wind velocity^3
where:
Cp = % efficiency loss of entire system
Air density = 1.23 kg per cubic meter at sea level (1.0 here in Colorado)
Swept area is in square meters
Wind velocity is in meters per second

So, a 10-foot (3.048 m) diameter wind turbine rotor gives a 7.30 m^2 swept area, and in a 10 mph (4.4704 m/s) wind, we can expect no more than:
Power output (Watts) =
$0.35 * ½ * 1.23 * 7.30 * 4.4704^3$ = 140 Watts
and in a 20 mph wind:
Power output (Watts) =
$0.35 * ½ * 1.23 * 7.30 * 8.9408^3$ = 1123 Watts

Key concept:
double the windspeed, and the available power increases by a factor of **EIGHT !**

SURVIVING HIGH WINDS

All wind turbines must have a way to deal with this massive increase in available power as the wind speed goes up. In Part 1 of this series (see ESSN July 2005), we discussed the distribution of wind speeds, and how most wind comes to us at lower speeds. So, manufacturers try for the best performance between 7 and 30 mph, and design the turbine to simply "survive" winds higher than that while still producing near peak power. If the turbine was allowed to keep making power over 30 mph, it would – but only to the maximum power production rating of it's generator or alternator, which can't harvest much more power beyond that rating— so the huge amount of extra power in the wind will cause overheating, overspeeding, and possibly burn out the generator or cause the turbine to shed a blade.

Variable pitch blades

The most elegant, efficient and effective way to regulate incoming power, and also the most expensive and complicated to build.

600 kW utility-scale Advanced Research Turbine at NREL's National Wind Technology Center near Golden, CO, USA. Note how the variable-pitch blades are positioned so they can't make power—the turbine is shut down and can't spin. Photo by the author.

The blades can rotate in the hub and change the angle at which they hit the wind. All large utility-scale turbines use this method, regulated by sensors and active controls. Only a few small turbines use variable pitch blades, notably the **Jacobs.** Jacobs has been building the system since the 1920s, and you can still buy one new! The system is not high-tech, but is extremely effective—the blade pitch changes mechanically

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using a flyball governor and centrifugal force. In low winds, the blade pitch is very steep, and at peak output the blade pitch is very flat—this matches the blade's angle of attack to the apparent wind (more on apparent wind later). If winds increase more, the blades pitch **past** flat, causing aerodynamic stall to prevent overspeeding.

Furling tail

This photo shows a home-built 17-foot diameter 3.5 kW turbine with the tail in fully furled position. The machine is still making near maximum power, but it facing at an angle into the wind to reduce wind input. Photo by Dan Bartmann.

This is the most common high wind regulation technique in small wind turbines. The turbine frame is designed with a built-in offset, and the tail or the generator head is hinged both upwards and inwards. When windspeed starts to approach the generator's maximum power output capacity, the tail or head folds up, yawing the machine at an angle to the wind.This reduces the effective swept area and thus the available power to the maximum power output level of the generator, so it continues to make peak power while furled. When wind speed drops, the tail or head drops back into a normal configuration via gravity and tracks the wind straight on once again.

Twisting blades

Some very small wind turbines use flexible plastic blades that bend, twist and flutter when power input gets too high for the generator to handle. This technique is effective, but also noisy. Some of the extra power in the wind is being turned directly into noise, and the sound of blades fluttering at high speed is very distinctive. It's only used on very small turbines, and is effective only using modern plastic blades that are highly resistant to fatigue.

Mechanical and air brakes

These regulation techniques are no longer used in commercial turbines because they are very noisy and prone to mechanical failure from fatigue, rust, and ice. Nevertheless, I have to admit it's exciting watching and hearing a 1930s vintage Wincharger deploy its air brakes during a gale!

Emergency shutdown

All wind turbines should have some mechanical or electrical way to shut them down (stop the blades from spinning) during severe weather events. These can including shorting the alternator phases, a crank that turns the tail into fully-furled position, or a mechanical brake. There's no sense in abusing your expensive turbine and tower by letting the machine run during a hurricane, severe thunderstorm, or tornado, since the machine will make no more power in 100 mph winds than it will in 30 mph winds if it is furling properly.

Unless you are working with a tiny 'science fair project' windmill that's capturing wind from an electric fan, some sort of regulation is needed or bits **will** fall off! Beware of any wind turbine whose builder claims that it doesn't need to furl because it is built so sturdily (tested to 100+mph!). But how many times and for how long can it withstand such abuse? Also beware if the builder advises you to lower the turbine to the ground if high winds are forecast—it probably lacks a shutdown system.

WIND TURBINE TYPES

If you are considering buying or building a wind turbine for making electricity, you'll almost certainly be comparison shopping for a modern, electricity producing, lift-based horizontal axis machine. But by taking a look at some historical wind turbine designs, it gets easier to explain the physics concepts involved.

Drag vs. Lift

Wind turbines are divided into two types, drag machines and lift machines, based on the aerodynamic principles they utilize, and two more types - Horizontal Axis and Vertical Axis machines - depending on their physical configuration.

Designs that use drag to make them spin are the oldest way to harvest wind power, and the easiest to understand. The blades or cups push against the wind, and the wind pushes against the blades. The resulting rotation is very slow. And the blades or cups that are swinging back around after making power are hurting power output because they are moving

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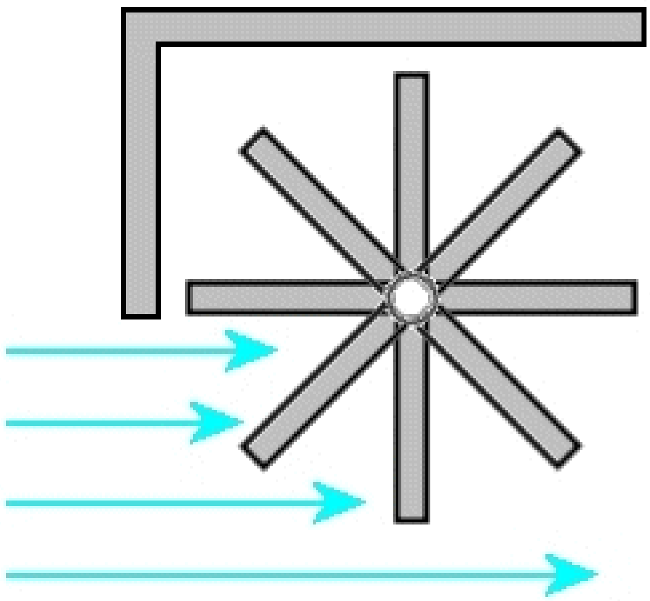
in the wrong direction, against the wind. The earliest examples of drag-based wind power design are grain grinding and water pumping machines from Persia and China, with records dating back to 500-1500 AD.



Looking down on a 'Panemone'
an early design of a drag-based machine
(just like a steamboat paddle)

Note the wall that's erected around the half of the machine that is hurting performance by moving against the wind. **In any drag-based design, the blades can never move faster than the wind**. This turns out to be a critical concept for both efficiency and the ease of generating electrical power.

Lift-based wind turbines are the standard now, but lift concepts have been in use for thousands of years. Mariners as early as 3200 BC used lift whenever they took a boat with sails out onto the water and turned the sails to give the boat maximum speed. An airfoil shape (just like the cross section of an airplane wing) gives lift, and has a curved surface on top. Air moves over the curved top of the airfoil faster than it does under the flat side on the bottom, which makes a lower pressure area on top, and therefore an upward force—that's lift. The key concept of lift and wind power is that **lift forces allow the blade tips of a wind turbine to move faster than the wind is moving**.

HORIZONTAL AXIS WIND TURBINES (HAWTs) and VERTICAL AXIS WIND TURBINES(VAWTs)

HAWTs are what most people first think of when someone says "windmill" — blades moving perpendicular to the ground.

In a VAWT, the blades move parallel to the ground. Both HAWTs and VAWTs can be either drag or lift based, though only lift designs are commonly used as they are reasonably efficient for electricity generation. Below are some commonly seen wind power designs, and explanations of the principles on which they work.

"Dutch" HAWTs

While not exclusively Dutch in origin, these machines were built all over Europe for grinding grain, and the earliest ones were drag-based.

The Maud Foster grain-grinding mill, Boston, England. Built in 1819, and still used for grinding grain commercially (and as a great tourist attraction) today. Photo by Ron Fey

The Dutch made major improvements circa 1390 AD by incorporating lift into the blade design. The machine was pointed into the wind manually by the operator.

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American Waterpumping HAWTs

Over 6 million of these were installed on farms and ranches across America, starting in the mid 1800s.

A typical Aermotor water pumping windmill, still common and in operation all over the American West. Photo courtesy of DeanBennett.com, Denver, CO. This company sells all the replacement parts to keep these beautiful old machines running, and also sells new waterpumping windmills.

They were used purely for mechanical power to drive a pump shaft in a well, and point into the wind via a tail vane. Many of these antiques are still in use, and some are still manufactured new! Companies like Dean Bennett in Denver, CO, USA still sell all the replacement parts to restore and maintain waterpumper mills, and also sell brand new machines. These designs are mostly drag-based, providing high torque for the pump shaft, but low blade speed. This makes them difficult to use for electricity production, but excellent for moving that heavy pump shaft.

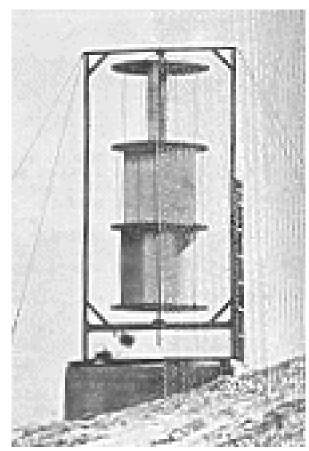
Modern Electricity-Generating HAWTs: They come in sizes ranging from tiny (4 foot diameter, to mount on a sailboat or remote cabin) to huge (300 foot diameter, multi-megaWatt, utility-scale machines). These machines can be designed for either 'upwind' or 'downwind' operation. In upwind turbines, the blades are in front of the tower toward the oncoming wind, and point into the wind using a tail vane or (in giant turbines) electronic controls. Downwind turbines don't have a vane, and the blades are behind the tower relative to the wind. While upwind designs are the most common, there are excellent downwind machines commercially available.

All modern electricity-producing HAWTs are lift-based, so the blade tips can travel faster than the wind.

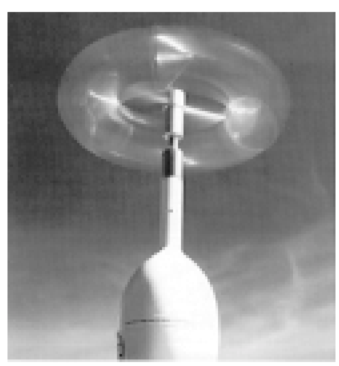
The resulting high RPMs are ideal for producing electricity, and these machines can be highly efficient. Small machines are approaching 35% efficiency (Cp=35%), while utility-scale machines are rapidly approaching the Betz Limit (Cp<59.26%, see Part 1 of this series, ESSN July 2005).

Drag-based VAWTs

The ancient Persian design shown before, the Panemone, is one example. Other designs include the Savonious Rotor which can be easily built using coffee cans, plastic buckets, or metal barrels.



Savonius



Anemometer

Photos courtesy the American Wind Energy Association AWEA

A simple anemometer is another drag-based VAWT design. While fun for experimenters and students to build and test, these designs are extremely inefficient, and give only low torque since the blades or cups can never travel faster than the wind. Yes, I know ... anemometers often spin quite fast, but as they usually have a very small arm length, they have very little torque.

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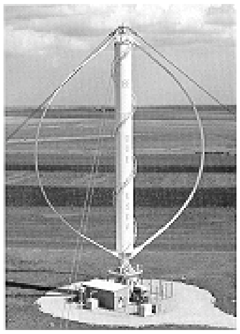
Lift-based VAWTs

Darrieus, Giromill, and H-rotor designs are big improvements over drag-based machines, since the blades have airfoils and utilize lift to move faster than the wind. However, there are inherent difficulties with any VAWT design, and these problems are why VAWTs have never been very successful in the commercial market, on either small or large scales.

Photos courtesy the American Wind Energy Association AWEA



Darrieus

Giromill

H-rotor

Should I choose a HAWT or a VAWT for my installation?

If you are looking for a fun wind power experiment or science fair project, a VAWT might suffice. You can find some good ideas here.

If you **really** need to make some serious electricity to power an on- or off-grid home, a lift-based HAWT is the best choice. Plus, you'll have a very hard time even finding a commercial VAWT from a reputable manufacturer for sale in any size.

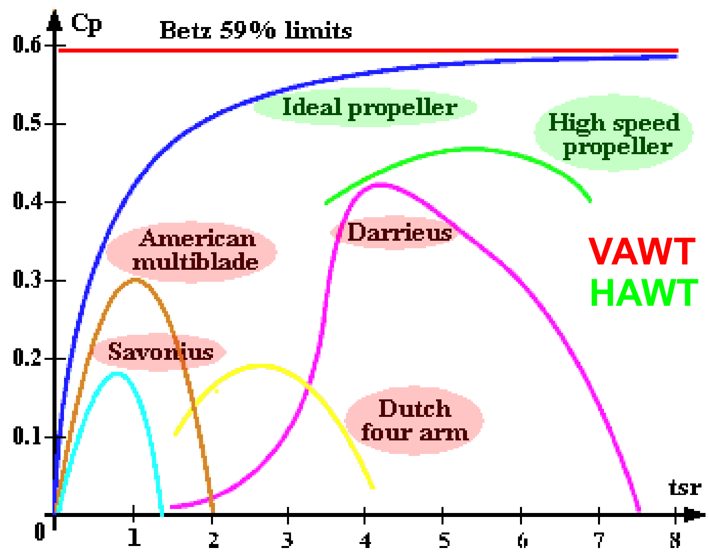
The disadvantages of VAWTs are numerous:

VAWTs must be built at least **twice as big** as HAWTs to make the same amount of power, since half of the machine is moving in the wrong direction (towards the oncoming wind) at any given time (remember the Panemone?)

Because of this, VAWTs go through a fatigue cycle on every rotation. This means the design must be very strong and sturdy—which also translates to higher cost and more weight.

More weight also mean that the tower must be more sturdy, another added expense. **All** wind turbines must be flown high in the air to get above obstructions. Near the ground, on a rooftop, or in any direction from obstructions such as buildings, slopes, or trees, turbulence steals large amounts of power and causes unnecessary fatigue in both HAWTs and VAWTs.

In general, VAWTs are also lower in efficiency than HAWTs. Drag-based designs of any kind are the worst because maximum possible efficiency (Cp) is directly related to how much faster than the wind the blade tips are moving. This ratio of blade speed to wind speed is called the Tip Speed Ratio (TSR), and the best possible Cp is obtained around TSR = 5-6. Only lift-based VAWT designs can even approach this TSR, and are still limited by the other factors listed above.



This diagram shows the maximum Cp theoretically possible, versus Tip Speed Ratio, for different wind turbine designs. Courtesy of http://www.windturbine-analysis.com/ (Note: used without permission - email address on website no longer valid)

WIND TURBINE BLADE AND ROTOR DESIGN

Many people are surprised the first time they look at wind turbine blades and rotors close up. The flat sides of the blades face the wind, and they have a distinctive twist to them, from a steep pitch at the root to a very shallow pitch at the tip. Why is this, and why do some turbines have more blades than others?

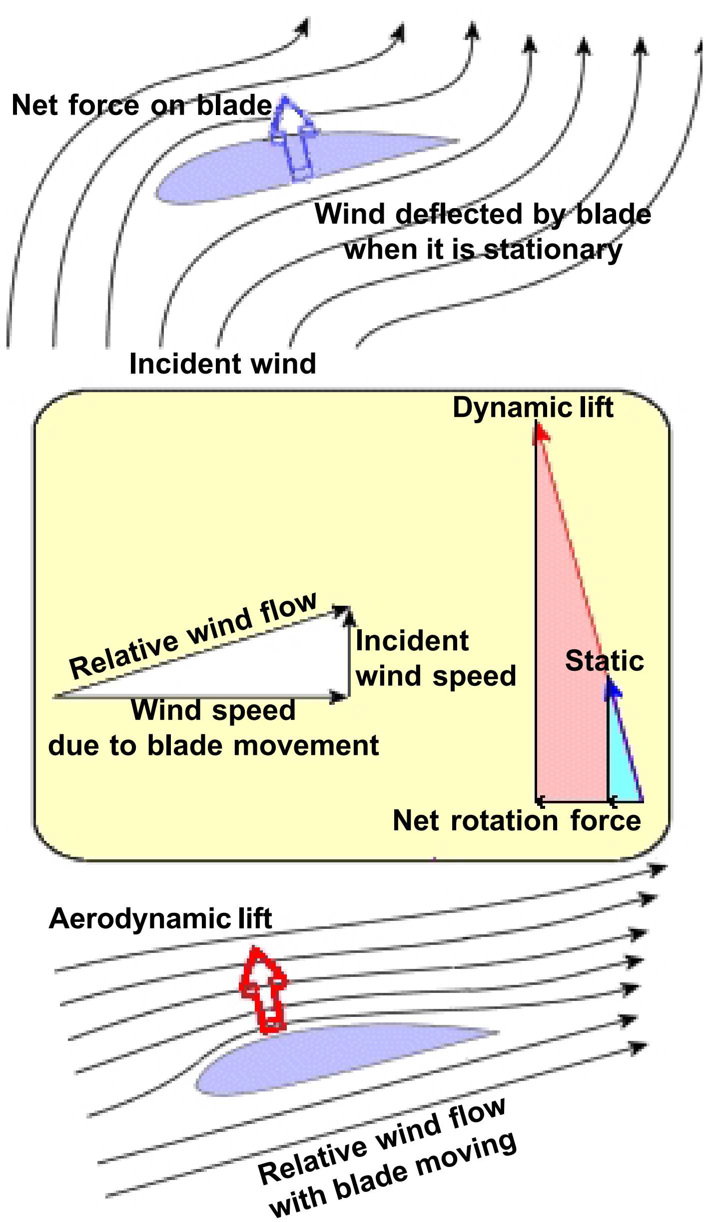
With HAWTs, the blades are inclined to the oncoming wind and constrained to move around a horizontal axis of rotation. They start to move by deflecting the wind, just like a rudder inclined to the flow of water forces a boat to change direction. However, like an aircraft wing, their airfoil cross section adds lift to the blades as they speed up, and greatly increases the rotational force. The blades are wide at their base and taper as they go out because the tips move faster

Continued on next page

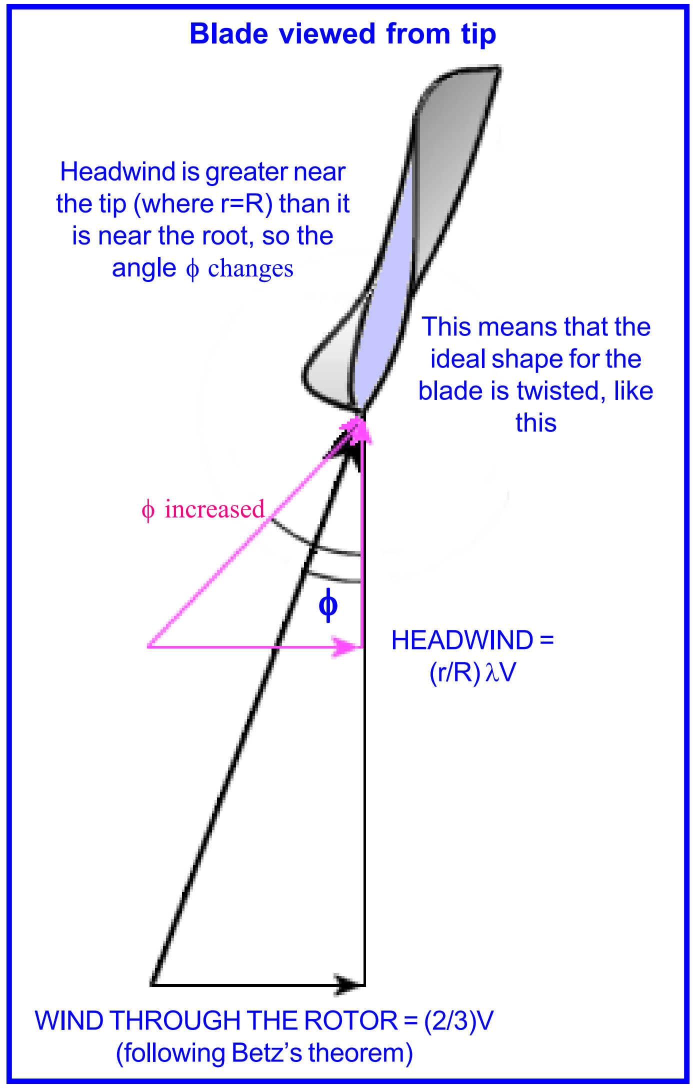
than the base. They are also twisted so that the angle off attack decreases from where the air is moving relatively slowly near their axis. to where it is moving very much faster at the tips. As with aircraft, the faster you go, the less angle of attack you need to get the same lift. The mathematics of all this is complicated for there are so many variables to take into account, such as drag, stalling speed, noise, etc.

The sum of the real wind's vector (direction and speed) and the wind vector seen by the blade is called "apparent wind" , and they are angled to match this apparent wind—the "angle of attack" of the airfoil.

COMPARISON OF FORCES ON BLADE



BLADE TWIST



Freshly carved blades, showing the inherent twist that keeps the angle of attack correct from the tip to the root.

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When the angle of attack is wrong for the apparent wind, the airfoil stalls and ceases to produce lift—the same thing that happens when an airplane tries to climb too steeply for its speed and begins to fall. When a wind turbine rotor begins to start spinning from a full stop, it is always stalling. As the wind increases and the blades pick up speed, the angle of attack gets better and better, and the turbine accelerates dramatically from the added lift force. It's fun to watch this happen! And a turbine can stall at higher windspeeds too—it will no longer pick up RPMs as the wind increases. This is not frequently observed, as the turbine has usually furled by that point to reduce wind input.

As the number of blades and the amount of the swept area that's taken up with their surface area increase (this ratio of blade surface area to swept area is called "solidity"), more torque and less RPM are produced, the tip speed ratio is lower, and the blades must be proportionally narrower. The typical 3-bladed rotor is the best compromise for physical strength and rotation speed.

MORE MYTHS

Now for some more myths, as promised in part one of this series. There are many myths going around about wind turbines, especially VAWTs. Unfortunately for VAWT enthusiasts (some of whom are probably already drafting irate emails to me), almost every wind turbine investment scam (ranging from small scale to utility scale) in the last 50 years involved VAWTs. The reason for this abundance of scams is simply that VAWTs **look** new and different, and are intriguing to the public. Some examples (fictional, but similar to actual advertising claims):

Invest now in this unobtrusive, world-changing, previously suppressed, new technology that will put a (insert company name) wind turbine on every rooftop in America, solving our energy crisis and oil shortage problems!

First of all, VAWTs are not new technology—see the ancient Persian Panemone VAWT pictured before. The technology has **not** been suppressed—The US Government NREL, DOE and Sandia laboratories have extensive tested and computer modelled VAWT performance. Furthermore, rooftop installations are not practical—turbulence affects both HAWTs and VAWTs, and they **must** fly in smooth air, well above any obstructions. Now take the average energy usage for an average home – about 9000 kW/h per year in the US, and 5000 kW/h per year in Europe. Take the yearly power production estimates from a reputable wind turbine manufacturer at a reasonable average wind speed (say 5 m/s, 11 mph). For a Bergey XL.1 (8.2 foot diameter rotor), Bergey estimates 1800 kW/h per year. So you'd need 5 of these flying on tall towers and above all obstructions to possibly power your 9000 kW/h per year house. Now remember that VAWTs must be twice as large as HAWTs to make the same power. The 5 Bergeys would sweep 284 square feet. The VAWT would have to sweep 567 square feet to get the same power output—that means a machine at least 24 feet high by 24 feet wide, mounted at least 20 feet above the nearest tree or building. That doesn't sound either practical or unobtrusive. Hold on tightly to your wallet, and consult an investment counsellor before spending money.

Wind turbines with only 2 or 3 blades let too much wind slip through and be wasted—my Savonious VAWT (or multi-blade waterpumper-type) design will capture ALL the wind.

This is a myth! The Betz limit of $Cp<59.26\%$ applies to both HAWTs and VAWTs. Behind and in front of every operating wind turbine the air is moving slower, and the wind tends to go around the machine instead of through it. Plus, both the Savonious and American Multiblade designs are mostly drag machines, and therefore very limited in efficiency because of their low Tip Speed Ratio (see chart on previous page). Modern utility-scale wind turbines are coming close to the Betz limit, but drag designs have little chance of ever coming near even half of it.

More blades means you get more power! Replace your existing 3-blade rotor with our 6/8/12/16 bladed rotor and outperform all 3-blade designs.

Not a good idea, you'll actually get **less** power from your existing machine! Wind turbine alternators and generators are designed to work in a specific RPM range, and lowering their RPM and TSR by adding more blades means you get less power, not more. The torque will increase, but that doesn't help your electrical generation at all. For the same reason, it's not practical to convert an American Multiblade Waterpumper windmill to make electricity—the RPMs are much too low, and adding any kind of gearing to increase shaft speed seriously hurts power output, especially in (the most common and most important) low wind speeds. 3 blades are the best compromise of RPM vs. torque. Any design with high solidity won't be suitable for producing electricity efficiently.

In conclusion: we've made it through most of the wind power math now (heave a sigh of relief!). Forthcoming articles on this subject will be USDA-certified math-free, and cover wind turbine siting, towers, electrical regulation and dump loads, off-grid vs. grid-tied systems, and resources for choosing a commercial or home-built wind turbine design.

Dan Fink

On The Bright Side

Second Article On How To Make A 12 VDC 20-LED Desk Lamp

by Larry D. Barr

Back in our June issue I wrote about an LED desk lamp that I built. At that time I mentioned that since I didn't have a potentiometer in the junk box that would handle the ~300 mA load of the 20 LED (10mm, 15,000 mcd) lamp and also fit in the housing, I assembled the lamp without a dimmer, just a switch.

Tonight I got bored and dug out a Pulse Width Modulation (PWM) DC motor speed control that I built from a kit a year or so ago, and never got around to even hooking up to power.

I spent a few minutes making up some patch cables with Anderson PowerPoles so I could connect to a PowerSonic 12 volt, 5 Ah sealed lead acid (SLA) battery. First, I measured the current draw of the lamp without the control inline with a Medusa Research Digital Power Analyzer. Current consumption was, as I remembered, 300 milliamps.

Then I connected the control inline after the DPA and flipped the switch. With the control turned all the way down, the lamp gave (subjectively) about 20% illumination and had a current draw of 50 mA. The increase in light output was linear up to the maximum, where the draw was 250 mA. Fifty mils less than without the controller in the circuit.

However, the light output at the max setting on the PWM controller wasn't as bright as without it inline. I turned the trim pot on the kit slowly up to max while observing the light output. At the maximum setting, the lamp's output was subjectively a little brighter than without the controller, and the current draw remained at 250 mA. Over the long haul, on a renewable energy source, that's a real saving. As you can see the kit, in it's "as built" form, won't fit in the base of the lamp. But, no problem is unsurmountable. Bases can be built, or the PWM unit can just be left outboard.

Controller Theory of Operation

A Pulse Width Modulation controller works by maintaining a constant DC output voltage (12.6 in this case), but delivering that voltage to the load in pulses of variable width (duration) depending on the setting. The higher the setting, the longer each individual pulse lasts.

The greatest advantage of this mode of operation is in the control of DC motors. The speed of a DC motor can be controlled simply by varying the voltage, but as the voltage is lowered to reduce the speed, the motor draws more current and therefore runs hotter. This can increase to the point where the motor is destroyed.

However, when full voltage is applied to the motor with each pulse, the heating effect does not occur and the speed is reliably controlled by the duration of the pulses. Although we're not concerned with heat in a properly designed LED light, the PWM controller does offer efficient intensity control at a lower current consumption than a series pot.

The PWM kit that I used is the 6067KT from Marlin P Jones & Associates. The cost is US$12.26 plus shipping. The kit is manufactured by KitsRUs, and their website lists international distributors. ldb

CO_2, GLOBAL WARMING & POLLEN ALLERGIES

by Thomas Ogden

This article first appeared in New Scientist Magazine, in London

Sneeze-Weed

The benefits of added organic matter to the soil have long been known and are usually attributed to increased nitrogen, greater water-holding capacity and an increase in activity of soil earthworms and microbes. But experiments have shown that the increase in carbon dioxide ($C0_2$) release that accompanies added organic matter is certainly one of the main reasons why adding organic matter to the soil increases plant growth.

Greenhouse owners have long understood that plants consume $C0_2$ and release oxygen. In a greenhouse packed full of plants, through the process of photosynthesis, the plants can quickly use up most of the available $C0_2$ and then their growth slows down or stops. To compensate for this, old time growers used to place boxes or flats of fresh manure underneath their greenhouse benches. As the manure decomposed it released $C0_2$ into the greenhouse air and the plants grew faster as a result.

In today's modem greenhouses, especially those with concrete floors, lack of $C0_2$ is always a concern. Most of the newer greenhouse ranges are now equipped with automatic $C0_2$ regulators that $C0_2$ monitor the amount of $C0_2$ in the air inside the greenhouse and then release more as needed.

In these greenhouses with their gas growth $C0_2$ generators the plants don't just grow bigger— they also mature earlier. So, what has all this to do with global warming and allergies? As we become more and more reliant on burning petroleum products and as our global temperatures continue to rise, carbon dioxide levels in our air are rising. Before the last election we in the US had assumed, incorrectly, that no matter which candidate won the election, new controls were going to be placed on $C0_2$ emissions. We know better now.

The US with its huge consumption of fossil fuels, (the U.S. produces nearly 25 percent of man-made carbon dioxide emissions worldwide), also is experiencing the greatest increase in $C0_2$. Actually, $C0_2$ accounts for 80-85 percent of the heat trapping (greenhouse) gases contributing to global warming.

The idea that is now called the "Greening Theory" holds that all this extra $C0_2$ is good. It will result in increased plant growth and thus in resulting increases in food supplies. There is some merit to this theory but there are numerous downsides too.

Pollen-Allergies

There are many negative effects from global warming but let's just consider one here, pollen production and it's affect on allergies . Since 1959 allergies have dramatically increased in the US from 2 to 5 percent of the population affected, to a whopping 38 percent now.

Continued on next page

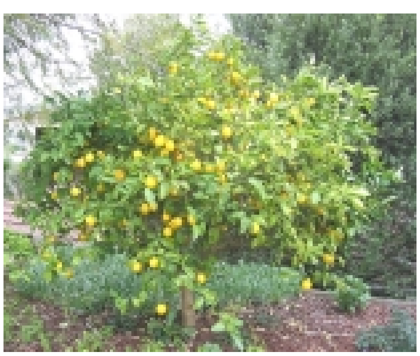
Largely because of the huge horticultural "success" of the much over-simplified theory of "litter-free" landscaping we already have vast urban landscapes that are heavily loaded with wind-pollinated dioecious male cultivars (clones) of trees and shrubs. These modem landscape trees result in surrounding air with unnaturally large amounts of allergenic pollen. Because the "messy" urban female trees are now so rare, almost none of this pollen is now trapped, removed from the air and turned into seed. (Female trees produce no pollen, ever, but they do make seeds, pods, and fruit.)

We have tidy sidewalks but pollen-filled air

Under normal carbon dioxide levels these male cloned trees will always produce abundant amounts of pollen. Under increased levels of carbon dioxide, they produce considerably more. The increase in temperature itself also results in increased pollen production, and in pollen production that starts earlier in the spring and lasts further into the fall. There is research that shows that under stress conditions male plants are able to take up more water than are females. Under stress conditions, such as drought, male trees are also able to hold onto the water they already have better than are female plants.

Where there are abundant water and soil nutrient sources the increases in carbon dioxide levels in our air will result in larger urban trees, which if they're allergy trees, will be capable of producing ever more pollen.

Increases in carbon dioxide increase plant growth but only if there is enough available extra water and nitrogen in the soil to support this additional growth. When the supplies of water and nutrients are not adequate to support this added $C0_2$-induced growth interesting physiological things happen in plants. Foremost, it is an added stress on the plants and stress often results in an increase in unusual reproduction factors.



A stressed lemon tree, for example, will often produce a huge crop of tiny, very seedy lemons. This is simply the lemon tree's way of preparing for it's own imminent demise and also it's own legacy of possible seedlings.

Another stress example: In daily pollen collections taken by biology professor Dr. Lee Parker and his students from the top of the Fisher Science Building at Cal Poly, San Luis Obispo, California, taken during the middle of a severe seven year drought, all-time record oak pollen count levels were recorded.

In the past twenty years in particular there has been a huge increase in this planting of male cloned street trees. These trees can not produce pollen until they mature but with the increases in $C0_2$ levels, we can predict that they will mature earlier than expected.

Shannon L. LaDeau, a researcher at Duke University found that pine trees grown with elevated levels of $C0_2$ produced three times the normal amount of seeds and also matured prematurely.

Lewis H Ziska, PhD, a USDA researcher, recently found that increased $C0_2$ resulted in huge increases in the pollen production of ragweed and other weeds.

David Karowe, a researcher at the University of Michigan, found another interesting factor about increased $C0_2$ levels and plants: their leaves contain fewer nutrients than normal.

Nancy Tuchman, biology professor at Loyola University in Chicago, is also researching the feed value of $C0_2$ enhanced leaves on microorganisms and insects. She found that they all grow slower when fed these "enhanced" leaves. "If all the plants are altered on a global level, then it's certainly going to affect all the organisms on Earthy she said. "No one is going to escape."

Compounding all of this is that excessive burning of fossil fuels and the resulting pollution may well be compromising our very endocrine and immune systems. Theo Colburn explored this well in the very interesting book, "Our Stolen Future".

Great increases in the already excessively high rates of urban pollen, combined with further compromised immune systems, may well be the recipe for allergies of true epidemic proportions in the not too distant future.

Dr. Robert C. Stebbins, renowned biologist from UC Berkeley, told me recently in a phone conversation, that the planting of all these cloned male dioecious and compromised monoecious trees, "is a classic example of how they just didn't think about the ecology involved."

If we don't start paying closer attention to how we landscape our cities, and we don't start getting serious about alternative clean energy sources, rampant allergies and other pollen-related illnesses may well be the end result.

Thomas Ogden

SUMMER ON ŠIPAN

Suzanne Ubick

ON VACATION
AND HAVING A WONDERFUL TIME!

On Šipan, pronounced SHE-pun, the summer daytime temperatures peak in the low to mid 80s, Fahrenheit, moderated by the sea. It's hot enough that cicadas start zinging early in the morning, and tourists early turn an interesting shade somewhere between puce and deep khaki. The sky is the true pale blue of hot climates; often it seems as if is the sky itself that is singing rather than the cicadas.

Although this is a transition zone between grid and off-grid living (there is electricity, but people use bottled propane for indoor cooking, and most use rainfed cisterns for water, backed up by bought water pumped in from storage tanks supplied by undersea pipelines from the Dubrovnik River), there is no such thing as airconditioning. The thick stone walls of the old Dalmatian houses coupled with the heavy tiled roofs and shuttered windows make for a delicious indoor ambience. The windows open inward, allowing the shutters to be kept closed all day, barring the sun from the tiled or concrete floors yet permitting air to flow freely.

All photographs taken by Suzanne Ubick personally

Lifestyle is the major strategy here for dealing with the heat. People get up early and do whatever needs doing; milk the goat, work in the garden, prune the grapes, visit the store, do the housework and start dinner cooking. Shops and open air markets are open early, around 7 a.m. By 11 a.m. there's nothing happening to the untutored eye, and visitors are apt to snort at the laziness of the residents who are sprawling on the numerous benches in the plentiful shade. The shops and the post office are closed, usually till around 3 p.m. in the cities but until 8 p.m. here on Sipan, remaining open until 11 or 11.30 p.m. depending on the state of business or the chattiness of the owner. There are no lawns – too much work, too much water, not enough use. Beds of bright flowers dot the edges of the plaza, and demarcate the waterfront area. These are watered late at night, when soil and water are alike cool after the day, and thirsty roots can drink deeply.

Fishing people, for women are as often active in the business as men, are usually patiently, endlessly running thread after thread of the nets through their hands, making a new knot here, cutting out and replacing a hopelessly damaged section there. Their hands are brown, thick and calloused, yet amazingly deft. Watching them work always makes me think of people saying the rosary, or running their prayer beads through their fingers, and I wonder if it is coincidence that Christ's disciples were fishermen. But most people are doing nothing, immobile and often as weathered as gargoyles. Nothing, that is, except strengthening the bonds of community with a word here, a well-worn joke there, batting ancient memories about there, drinking a tiny cup of Turkish coffee or glass of juice that lasts an hour or more.

Around noon everybody disappears indoors. The children come home from school, and alike disappear. Dinner is consumed, and then people take a siesta. Kipling noted a century ago that "only mad dogs and Englishmen go out in the noonday sun" and the Italian siesta has been noted (and envied) for at least three times as long.

Meals are simple, to save on preparation time, fuel and heating up of the house. Some people still have a traditional summer kitchen in all its glory: a deeply shaded veranda on one side of the house, with a small woodburning hearth, and a shallow limestone sink.

Meals are prepared and eaten here, clothes are washed and ironed in this pleasant cool space. Dinner might well be some kind of green vegetable, boiled, roughly chopped, and served with boiled potatoes, flavoured with olive oil. A dish of sliced tomatoes will accompany this; the tomatoes are so tasty that they need no dressing. There will be fresh bread – Dalmatians plan their meals around the bread. Meat, or cheese, or eggs, or maybe all three, in small portions, will also be served, as well as other salads. A favoured delicacy is the male flowers of pumpkin vines, sliced in half longways, dipped in crepe batter and quickly fried. Butter is not seen on the table; olive oil is freely used instead, and it's amazing how quickly it becomes normal and delicious to dip one's bread in it. "Bevanda" is commonly drunk; water flavoured with white or red wine. People who take their wine neat are said to drink it "Macedonian style" which is, of course, less civilized than the "Greek style" favoured by bevanda drinkers. Fruit juice is very popular, and there is always "Trkse kava" (Turkish coffee) to round off the meal. The evening meal is very similar, with fish supplying the main protein source.

The long siesta period, rather than shortening the day, has the desirable effect of making each day into two, one fairly short, and then a long day of which a goodly proportion is actually evening. More physical labour is undertaken, if necessary, in the cool of the evening, followed by a shower and change of clothes before the serious socializing starts. The fisher folk set out around 11 p.m., if there is no moon, coming home around 4.30 a.m. to get their catch sorted and cleaned, loaded onto the 5.30 ferry to Dubrovnik for sale in the early market. Meanwhile, the landlubbers are sitting around, watching the young folks parading, recalling their own youths, repeating stories their grandparents told them. Sometimes a man or a girl will start strumming a guitar, or somebody else will play a CD of Dalmatian folk music, and everybody who knows the words will sing along. There's a well-used bocce ball court, with deepchested calls of approval and howls of freely expressed scorn punctuating all the other conversations.

In closing, lifestyle adaptation to a hot climate is neatly summed up in the words of a Šipansku, Kuzma Stjepovic: "You know, it takes a lot of time to live here." Time, it seems, is the one thing we lack in our western culture; we've replaced it with technology. Is there a way to blend them so as to have the best of both worlds?

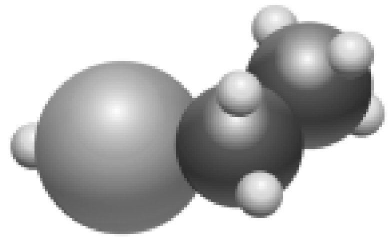
Suzanne

Šipan is the largest of the Elaphite Islands with a surface area of about 16.5 square km. It is located about 12 nautical miles to the NW of Dubrovnik and is separated from the mainland by the Kolocep channel which is about 1500m wide.

The island is 9.2 km long with an average width of 2.3km. The highest point is Velji Vrh (243m) with St Ilija (223m) the second highest.
The only link with the mainland is by boat with the 'Postira' making three trips a day and car ferry which stops twice a week (once in each direction) at the village of Sudurad.
Šipan has a population of about 500 people, many of who work away from home in the tourist and maritime industries.

MAKING ETHANOL FOR FUEL

by Mike Nixon



ETHANOL
C_2H_5OH

Spirit Hydrometer

First of all, let's just recap what was discussed in the first article on ethanol as a fuel (way back in ESSN April 2005 – so I've been kept busy doing ESSN's layout by our slave-driver Editor !). It was shown that ethanol can be mixed with either gasoline or diesel in various proportions, and that this can raise the octane rating so that cheaper grades can be used without the use of pollution producing anti-knock additives. However, as Steve Spence illustrated so well in his Biodiesel article last month, the presence of even small amounts of water in the blend will result in separation, making the blend useless.

The highest concentration of ethanol that can be achieved by ordinary methods is 190 proof, or 95% alcohol by volume, and as Steve found out the hard way, less than 1% water can do the damage at room temperature. As the temperature is lowered, amounts as small as 0.01% can cause separation!

200 proof or almost 100% 'dry' ethanol can be obtained, but at the cost of more complicated methods involving either distillation with benzene or distillation at reduced pressure. Alternatively, various substances such as benzene, acetone, and butyl alcohol can be added to the blend to increase water tolerance. However, our aim is to reduce pollutants, not increase them, so it is fortunate that simpler ways do exist whereby ethanol can first be dried so that only a trace of water remains.

DRYING

The oldest and simplest method of drying alcohol is dehydration with lime. Ordinary lime (calcium oxide, formula CaO) reacts with water to form calcium hydroxide (formula $Ca[OH]_2$), so the water is chemically removed.

The process is simple. The water-containing alcohol is mixed with lime at a ratio of about 35 pounds (or more) of lime for each gallon of water to be removed, and allowed to "slake" for 12-24 hours with occasional stirring . The lime reacts with the water to form calcium hydroxide and, as this is insoluble in alcohol, it settles to the bottom, leaving relatively pure (99.5%) alcohol at the top of the container.

You can easily assess how much water is to be removed by measuring the percentage alcohol by volume with a spirit hydrometer. Simple arithmetic will do the rest.

After drying, the usual method of separating the lime and calcium hydroxide from the alcohol is by distillation. However, it is also possible to use a very fine filter for the job, and things called "molecular sieves" are now readily available and do the job very well indeed.

Now all that bother is required if your aim is to use ethanol with another fuel to make a blend. The good news is that all those problems with water disappear if you intend using the ethanol alone as your fuel. It's the longer chain molecules in gasoline, and particularly diesel, that cause all the problems of separation, but shorter chain alcohols associated with production of ethanol remain miscible with ethanol, as does any water you might have mixed in there. Relatively pure 80-95% alcohol, when not mixed with gasoline or diesel, sits for as long as you like in the tank without separation, and burns very nicely thank you! The only snag is, your standard engine has to be modified to use the stuff. However, as all the major vehicle manufacturers around the world are now rushing to produce engines that will work quite happily with 'pure' ethanol (as they have done for years in Brazil), the ground has

Continued on next page

been prepared for a raft of modification kits that make conversion simple, and getting cheaper every day.

So, if you decide to follow that route, the drying step is unnecessary and you should be able to produce your fuel for less than the cost of gasoline. You will find that there will be little, if any performance penalty, and by leaving 5-15% or more water in the alcohol you also gain the benefits of water injection! The only disadvantage is the trouble and expense of modifying your engine to burn ethanol and the lack of dual-fuel capability (but I recall reading somewhere that the backroom boffins are working on that).

The choice is all yours! Now, although I was an an engineer in a previous life, and love to get my hands black and greasy, I do not propose turning this series of articles into a clone of "Popular Mechanics". My aim is simply to describe how you can make your own ethanol for fuel, whether you use it to make biodiesel, as Steve is doing, or intend using it just as it comes. Maybe I might be tempted later, but I'm sure that there are many more competent engine people out there just panting to contribute articles to ESSN on engine modifications! (Hint! Hint!!)

Now, before getting down to the nitty gritty of how you can make your own ethanol as a fuel, let me take time out to offer a serious bit of advice. Most will be aware that ethanol is one of those magical cash cows that governments rely on to gain revenue. It doesn't matter a jot or a tittle whether your intentions are upright and honorable, or that your dewy-eyed gaze is innocently raised alone to the admirable goals of ecological purity and self sufficiency. If you do not take time out to first fill out all the application forms and pay your dues, then you will be hammered … and hammered good! Depriving revenue from a government without first being armed with its Official Sanction is a far more dangerous activity than bare-handed removal of a juicy bone from a possessive dog … and goverments have very sharp, very long teeth! So before you even think of trying to make your own ethanol, get all the necessary permits. It will make no difference at all if you plead in court that you were just "experimenting with a few drops, purely for my own use", or any other feeble excuse. In most countries, if you do not first have an approved permit, that is **ILLEGAL**! Fortunately, it is NOT illegal to describe or read about the process!

RAW MATERIALS

Ethanol may be made by the fermentation process from three basic types of raw materials.

SUGARS in which the carbohydrate (the actual substance from which the ethanol is made) is present in the form of simple, directly fermentable sugar molecules such as glucose, fructose, and maltose. Such materials include sugar cane, sugar beets, fruit, cane sorghum, whey and skim milk.

STARCHES that contain more complex carbohydrates that can be broken down into simpler sugars by hydrolysis with acid or by the action of enzymes in a process called malting. Such materials include corn, grain sorghum, barley, wheat, potatoes, sweet potatoes, cacti, and so on.

CELLULOSE such as wood, wood waste, paper, straw, corn stalks, corn cobs and cotton, etc.which contain material that can be hydrolyzed, like starches,to form sugars.

You will see that all of these raw materials must be treated in order to end up with sugars, for it is that which yeast feeds on to make ethanol as a byproduct.

PREPARATION

Obviously, if you start out with ordinary sugar then you can miss out a lot of intermediary steps, but that will often not be the most economical way to go.

For a start, I'm going to rule out cellulose immediately. Cellulose requires the use of strong acid, and cooking under pressure in order to raise the boiling temperature to around 350F (177C).

This is a procedure fraught with dangers, and it should not be tried by any amateur under any circumstances!!!

ENZYMES

The same process of using acid and cooking under pressure can be used with starches, but fortunately there are simpler ways of converting starches to sugars that are perfectly safe. If that were not so, then generations of Russians would have grown up 'dry' for the lack of potato vodka! The process is called 'malting', and involves the use of enzymes to do the conversion.

Enzymes are interesting critters. They are very large molecules with specially shaped cavities in them. These cavities

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are just the right size and shape for a particular molecule (or group of molecules) to fit into, and when the molecules sit in the cavity just right, a chemical reaction happens. This process is driven by all the energy present in all material – the constant collisions of molecules against one another, millions of times a second. The enzymes themselves are not affected by these chemical reactions, so continue to survive and process the affected molecules continuously.

And another interesting word – 'malting'. What is it? Simply put, you get the right enzymes when you sprout, or 'malt' grain. The grain is moistened, then left to start growing. After about 5 days, tiny sprouts appear and the seed is in full production of those enzymes, for it is they which convert the starch in the kernel into sugars which the seed uses for food. The grain is then stopped dead in its tracks by careful kiln drying and partial cooking in a forced flow of hot air. A proportion of the enzymes produced during malting is partially inactivated by this kilning process, so care must be taken not to overdo it. The grain is then cracked or milled to break the husk and expose the enzymes. The enzymes produced by this process can now be stored and later added to any starchy slurry to convert that starch to sugars, and it really doesn't matter where that starch came from … corn, potatoes, or anything else you might have to hand – even breakfast cornflakes!.

In passing, home brewing afficianados may be smirking as they think that I forgot to mention that enzymes are not the only safe method, but that the Japanese have produced saki from rice for centuries using Koji, which is not an enzyme. Well, just for them, let me add that several bacteria have the same ability as those enzymes to convert starches to sugars. Koji is steamed rice that has had koji-kin, or koji mold spores, cultivated onto it. This forms a mold (Aspergillus Oryzae), which creates several enzymes as it propagates, and these are what break the starches in rice into sugars. So (I smirk back), it comes down to enzymes in the end, no matter how they first saw the light of day!

The next stage is to take all that starch-bearing material and crush it, mill it, beat it, or generally batter it around to expose the starch. You then add water to form a slurry, and cook that to gelatinize the starch. Once that is done, let the whole mess cool. Add more water if the mix is too thick and sticky, then add a relatively small amount of the malted corn. The enzymes will then start their job of converting all that gelatinized starch into sugars. If you enjoyed making mud pies when you were a kid, then this part of the process will bring back happy memories.

The enzymes produced in this natural way can also be obtained in their 'pure' form from just about any good brewing supplier, and added to any starchy slurry to convert it into sugars. Little is required to convert a large mass for, as explained before, the enzymes act merely as intermediaries and are not destroyed in the process. Enzyme extracts are usually a cheaper option than doing your own malting, and are also specifically designed for the job. You are therefore more likely to get predictable results and higher yields.

The three basic types of commercially available enzymes are alpha, beta, and gluco amylases. Alpha amylases randomly split the starch molecules to produce a type of sugar called dextrose. Beta amylases act similarly to produce maltose. Gluco amylases can reduce the remaining starches, and the use of all three can achieve almost total conversion of the starch.

There is a simple way of checking progress when converting starches to sugars, and that is the iodine test. Simply take a small sample of the mix and strain it to remove solids, then add a drop of iodine tincture to the liquid. Iodine tincture is what Grandma always painted cuts and grazes with (and which is still used in hospital operating rooms), and should be readily available at any chemist/drugstore. If it turns blue then starches are still present and you need more time for the enzymes to do their work.

To summarize, the processes for all sugar- or starch-bearing material are these:

Break up raw sugar-bearing material and extract the sugars by seeping in water and/or crushing,

OR:

Break up starchy materials and cook with water to form a gelatinous slurry. Dilute with more water if the mix ends up being too stodgy and viscous, then add enzymes to convert the starch to sugars.

FERMENTATION

You should now have a good quantity of sugar ready for fermentation. However, before you start that, you have to ensure that the mix, usually called 'wash' or 'mash', is sufficiently diluted so it doesn't foam too much when the yeast starts to produce carbon dioxide. The amount of this gas that is produced in the early stages of fermentation can be quite considerable, and if the wash is too 'sticky' then it will foam and make a horrible mess. The acidity of the wash also has to be carefully adjusted as this can have a big effect on the fermentation.

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ACIDITY

Acidity is usually measured as pH. This is a measure of the acidity or alkalinity of an aqueous solution expressed on a scale of 1-14. pH1 is highly acid, pH14 is highly alkaline, and pH7 is neutral. It's most conveniently measured with test papers that change color according to the pH of the solution being tested. These papers are readily available from swimming pool supply houses, garden shops, and laboratory supply companies.

Control of acidity during the mashing and fermentation process is important for two reasons: The growth of harmful bacteria is retarded by acid solutions, but the yeast will only grow if the wash is slightly acid. Most grain mashes have a naturally acid pH of between 5.4 and 5.6 after malting has been accomplished. Other materials, particularly sugar bearing raw materials like molasses or fruit pressings, have a naturally alkaline pH and must be acidified prior to fermentation.

The most common bacterial contamination results in the formation of lactic acid. We're not concerned about the taste of the product, for it's going in the gas tank, but any lactic acid that may be formed subtracts from the yield of alcohol, and should therefore be avoided as much as possible. The development of these bacteria is severely repressed at acid values pH5 or less, but their growth is rapid in alkaline conditions. You should try for an optimum pH range of 4.8 – 5.0 and, if it is higher than that, then it should be reduced by the addition of acid. Conversely, if it is too low, then add a bit of alkali. The acid most commonly used when making ethanol for fuel is diluted sulfuric acid (battery acid), although any mineral acid is perfectly suitable. Hydrochloric (muriatic) acid, for example, is available from swimming pool suppliers. The acid should be added cautiously, and the mash stirred while you are doing that.

ABOVE ALL, REMEMBER THESE SAFETY RULES:

If diluting sulphuric acid then ALWAYS add the acid to the water – NEVER the other way round!!!

If you add water to concentrated sulphuric acid then the water will boil and spit drops of hot acid all over you!!!!

Wear eye goggles, rubber gloves and and a full apron whenever handling strong chemicals!

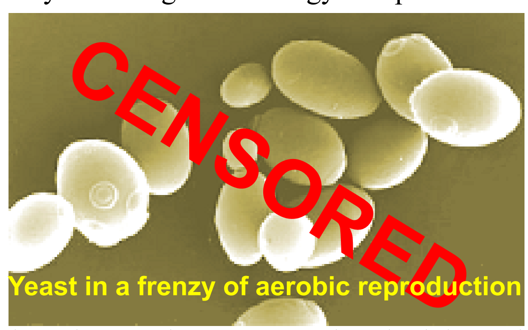
Always be near running water in case any chemical splashes on you! Wash the chemicals off immediately and, if necessary, seek immediate medical attention!

While adjustment during mashing is desirable, the proper pH during fermentation is absolutely essential. As soon as the pH falls below about 4.1 the fermentation stops. If this occurs prior to complete conversion of the sugars, the yield will be low. On the other hand, yeast needs a slightly acid environment in order to grow, and actually secretes acids in order to promote this. Consequently, the pH should be regularly monitored and kept between 4.8 and 5.0 for optimum results.

Once the pH goes beyond the optimum range, attempts to salvage the process by adding acid or caustic soda do more harm than good. So keep a close watch and adjust before the pH goes out of range.

So, not only do you now have all your sugar ready, but you have also carefully checked that the "acid climate" in the mix is perfect for the yeast you are about to add. Before you do though, and if you are using dried yeast, make sure that you first hydrate it in a very weak sugar solution. It's no different for yeasts as it is with us ... they just hate being turfed headlong into a party immediately after being rudely woken up from a deep sleep. Give them time to recover and grow nice and plump, nudging their interest with that small amount of sugar. Just half an hour for 'breakfast' will do, then you can safely add them to the main brew and get to work.

At first, while there is still plenty of oxygen dissolved in the slurry, the yeast will go into an orgy of reproduction!



Yeast in a frenzy of aerobic reproduction

Now I don't know what your moral outlook is on this rather unseemly behaviour, but you have to make a choice. While reproducing in this frantic manner, the yeast has no time for anything else. However, once all the oxygen they need for this has been used up, then they stop all that licencious behaviour and settle down to make ethanol. Bit of a social dilemma really – is it better to let the yeasts give way to unbridled passion shortly after being woken up, or better to have them concentrate instead on making that demon likker?

As it turns out, the choice is taken out of our hands, for without that first aerobic (with oxygen) frenzy there would not be enough yeast to make any significant amounts of ethanol under anaerobic conditions (no oxygen).

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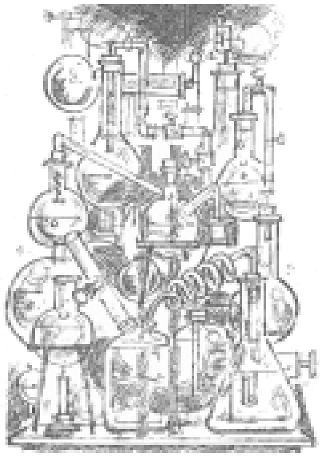
SUGAR CONTENT vs ALCOHOL



OK. We've now covered all the basic steps you need to take in order to start making ethanol, and in the next article I will describe how you extract it from the fully fermented wash. It's a good time to take a break anyway, for you will need a bit of time to get all the proper permits you need in order to carry out the next stage, that of distillation.

Just a final note, some may be wondering what sort of yield they can expect. Well, on average, the amount of alcohol that can be produced from a given feedstock will be about half of the convertible starch or sugar content – on a weight/weight basis. Ethanol weighs about 6.6 pounds per gallon. A ton of grapes, for example, with a 15% sugar content is capable of producing about 150 pounds or 22.7 gallons of alcohol (assuming 100% extraction). Corn, with 66% convertible starch should produce 660 pounds or 100 gallons. Remember, this is only an approximation and actual yield depends on many interrelated factors.

Mike Nixon

Ghost Writing

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On the other hand, if you'd rather not do your own writing, this forumis the place where you can get together with folks who'd like to do some writing with you: http://www.green-trust.org/forum/viewtopic.php?p=1050 . So, if you're one of those folks who wants to work on a collaborative article, just post here that your available and check out the posts from the folks who are looking for you.

I'm hoping to see a lot of fresh content for ESSN come from this forum. We'll be waiting for your posts. All of you!

Peace,
ldb

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