Wind powered (Air to Water System)

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Introduction

The wind based Air to water system directly leverages wind energy to deliver chilling energy using a small turbine which can be ground or pole mounted and installed easily by 2 people.

In this design a low speed wind turbine is used to drive a compressive pump which is used to modify the dew point of the air and make condensation possible. The chilling available when the gas is allowed to expand is used to cool the condensed gas stream which increases the amount of water which can be harvested from a given body of air.

It is intended for where there are consistently more than 6 hours per day of 12MPH or faster wind. If there are faster winds available not as many hours of wind are required.

Advantage of this turbine

This turbine design is nearly immune to the effects of turbulent air which can destroy the efficiency of most other designs. This feature makes it feasible for use directly mounted on short fence posts rather than requiring tall poles.

This design has been exposed to wind speeds in excess of 107 MPH in both summer and driving snow conditions with no damage.

The savings in mounting costs can allow systems with more than twice the number of unit at the same cost.

The turbine blade turns relatively slow and never exceeds the speed of the wind so it is much less dangerous to birds and humans.

It makes less noise than the same speed of wind blowing through trees and is nearly silent in 12 MPH winds. It makes generally makes much less noise than propeller based.

Where to use it

Air to water harvest systems are normally considered when there is no cost effective ground water or surface water available. It can also be very effective where the quality of available water can not be trusted or where the waste stream from purifiers or desalinates would require excess permitting or would be too expensive.

This system is ideal for locations with humidity above 45% and where winds above 12 MPH are available for at least 8 hours per day. It can also be used the driest deserts but the cost per gallon goes up in drier locations.

In locations where there are 12 hours per day of 24 MPH wind it can actually beat the 20 year ROI from large scale coastal desalination systems.

Mountain locations in Hawaii and Australia along with coastal locations in most of the pacific coast have been identified as particularly good areas for use of the system. Pacific and Caribbean islands having problems with contamination of their fresh water lenses are also good candidates.

Any location with relatively consistent wind which can not be development due to lack of water represents lucrative areas for deployment of the technology. Analysis indicates that in the Hawaiian mountains 1/3 of an acre of these turbines would produce 600 gallons per day average.

Hurricane zones

Many areas at risk from hurricane can also deliver adequate wind to drive this system. These areas are as serious risk from loss of potable water after hurricanes or even major storms strike an area. In these areas this system provides an ideal source of water that can allow people to stay in their home when they would otherwise be forced to leave to seek water. These systems are specifically designed to be sufficiently robust to withstand 110 MPH winds without damage and can be mounted low enough that they do not suffer the damage from pole failure common with other units. In other words unless they are destroyed by flying debris they are likely to survive the severe weather. In the USA it is wise to plan on a minimum of 8 gallons per person per day of potable water. If used for toilet flushing and other domestic needs then plan on 30 gallons per day.

Costs

Small 6 gallon per day system

Using a 75% humidity environment with an 10 hours per day of 14 MPH wind it would require an estimated 4 turbines. Assuming an estimated price of $530 per turbine this would result in a cost of $530 * 4 = $2,120 for a 6 gallon per day system.

> In the same conditions electric powered A2WH system would consume about 7,200 watts which would require electric generation capacity of 720 watts plus the electric condenser. Using a 8 hour solar day this would require 7 solar panels at 100 watts each. At a cost of $600 per 100 watts installed this would cost $4,200 plus the cost approximately $2,000 for the electric air to water harvest system capable of running from 700 watts of DC power. The total electric system cost would be about $6200. This makes the electric system 290% the cost of our wind powered A2WH units.

It is reasonable to expect the cost to drop from $530 to $160 per turbine in qty 50,000 which would bring cost for the 6 gallons system down to $640.

300 gallon per day system for home use

Using these estimates and minimum county requirement of 300 gallons per day needed for a single family residence it will require a set of 450 turbines. Due to the volume these could be delivered for about $300 each which would bring the total cost in at $135,000 units. Even in areas with ½ as much wind the cost would be under $250,000.

A smaller number of larger turbines can be used to reduce the number of turbines in the system but the overall impact on costs is minimal.

Land development opportunity enabled by this system

To put this in context a 5 acre parcel in the mountains of Hawaii increases in value by over 400,000 when it can be developed. There are areas in these mountains where wells are prohibited due to concerns about overdraw causing contamination of the saltwater lenses. The lack of water is preventing development of these lots.

For an investment of approximately $135,000 some of these mountain locations can be developed which are currently not salable. An average increase of $400,000 would show a margarine of over $265,000 per parcels. Even if an additional $100,000 is used to install required roads, gutters and other infrastructure it could still deliver over $165,000 margin per lot.

There are currently tens of thousands of acres in this condition just in Hawaii, There are similar opportunities in Southern California and Australia. Using a conservative development of 5,000 acres approximately 1,000 parcels could improved in this fashion. Using a marginal gross profit of $250,000 per parcel this would yield a profit of $250,000,000 (250 million USD). Assuming a baseline cost of 80,000 per parcel prior to improvement this would require an original investment of 80 million USD for the land. Once a few parcels are improved for demonstration and validation the rest of the parcels can be improved once the sale occurs so it requires relatively little capital (less than 10 million) for the system.

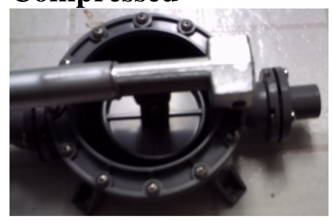
The same condition is likely to become prevalent throughout the all ocean basins where global warming is causing increased severity of droughts on the islands. The increase in land value is not always as high but there is almost always a correlation and on many islands they may need much less water so it may require less than $10,000 to deliver enough water for some parcels.

How it works

This is a direct acting compression system which uses direct compression strategy to compress ambient air. This compression heats the air raises the dew point. The compressed air stream is allowed to cool to ambient which allows condensation to occur which gives us the water harvested from the system. As the air is allowed to expand back to ambient it chills (ideal gas law) by the amount of heat dissipated while compressed. This chilling gas stream is used to chill input air to the compressor and chills the compressed gas stream below ambient which allows even more moisture to be harvested. The excess chilling energy is used to pre-chill ambient air and in some conditions allows condensation to occur even before the air is compressed.

Commercially pump capable of up to 10 PSI.

Compressed



Expanded after intake

Can to direct drive from wind turbines.

A specially designed low RPM high torque wind turbine is used to minimize noise and to provide the high torque needed to drive the compressive pumps. An intrinsic portion of the system design creates a backpressure as turbine speeds go up so that the system becomes self regulating. The turbine is designed to withstand 115 MPH winds even when non regulated and the pump is rated to run at RPM higher than the turbine can reach in 100 MPH winds even with no back pressure.

The compressive pumps are designed for 50 to 500 RPM and can be sized to be paired with rotors of various sizes. We use a conservative COP 0.24 with a 80% efficiency in the pump system. Target PSI of compression runs from 2 PSI up to 20 PSI depending on the local climatic conditions.

Why this approach rather than generate electricity?

This turbine is available for electrical generation however the alternator portion of the system is actually the most expensive part to produce both in parts and labor. The high strength magnets and copper required for high quality PMG alternators are expensive. In contrast the pumps, heat exchange tubing and valves required to convert the wind energy directly to atmospheric water generation energy are less expensive both for the core materials and labor.

The same amount of wind energy tends to be required per gallon harvested either way but the electrical system has higher losses and would be about 300% more expensive. In addition an electrically based system would also require adding the Electric version of a Atmospheric water generator large enough to consume the average maximum available power which could increase the cost to over 400% the cost of the mechanical system.

The Physics.

The wind turbine is used to operate a low pressure high volume compression pump. Ideal gas law indicates that when under compression gas will heat. In addition compressing a gas lowers the dew point and allows condensation at higher temperatures.

Our process starts with a gas stream that is at ambient which is compressed by up to 20 PSI.. This gas while compressed is allowed to cool to an ambient temperature such as then when the gas is then allowed to expand when it chills by the amount of heat shed during while compressed. Using this strategy it is possible to chill air up to 100F below ambient.

The chilled gas stream is ran through a series of heat exchangers over which ambient outdoor air is also ran and as the air reaches it's dew point any water it contains condenses out.

Heat must be removed from the air to condense a water. This is equal to the heat required to chill the air to the a point below the dew point and then the latent energy from condensation.

At 70F and 50% RH the dew point is 50.5F and it requires 3,603 cubic foot of air to contain 1 gallon of water but closer to 4,800 cubic foot must actually be processed.

It requires 1 BTU to heat or cool 1 pound of water by 1 degree F and 1 cubic foot of water weighs 62.3875 pounds and the weight of air at sea level is .0765 pounds per cubic foot or 815.5 times less dense than water so it requires 62.3875 / 815.5 = .0765 BTU per cubic foot to chill air by 1 degree F. To harvest 1 gallon we much chill 4,500 cubic foot of air from 70F to 45F which will consume (4,000 * (70-45) * 0.0765) = 7,650 BTU. The latent heat recovered from 1 gallon of water condensing is 8,097 BTU so the total heat removal per gallon condensed is 15,747 BTU

If the system was converted to a high efficiency ranking style chiller using refrigerant then it may be possible to obtain a Coefficient of performance of 3.5 however it would also increase cost and environmental risks due to leaking refrigerant.

A temperature sensor is used to control the air flow through the secondary air exchanger such that the exit temperature of the air is dew point -5F. In this way variable wind speeds can be accommodated and the excess energy can be used to drive direct condensation from some ambient air without going through the compressor. The total temperature drop below dew point versus air flow rate can be adjusted for optimal performance.

Heat Harvest

There is a substantial amount of waste heat generated in this process which runs from 20F to 100F above ambient. This heat is normally shed directly to the ambient air however if there is a viable use such as using the heat to pre-heat water being circulated into a Geo-exchange heat pump then this excess energy can be harvested. The amount of heat available tends to 15,700 BTU per gallon condensed of which 8,000 BTU are consistently available at temperatures elevated over ambient.

Cool Harvest

There are substantial volumes of air that is drier than ambient and which can be 20F to 80F below ambient generated during the process. There are generally 800 to 4500 cubic foot of chilled air produced per gallon condensed. This cool air can be harvested and used to chill near by buildings. It requires additional engineering and special planning to harvest this energy but in some conditions it can completely eliminate the need for traditional space cooling via electricity.

Pre-chilling the gas stream

One way to pre-chill the gas stream at a very low cost is to cycle the air through pipes buried in the ground. Even if the ground is not cool enough to reach the dew point any BTU that can be removed from the air in the ground are those which do not have to be removed by the turbine. In some conditions this can triple the effective output of the system.

During clear nighttime conditions night radiant chilling panels can reach temperatures 8F to 20F below ambient. This can be used to chill air to near the dew point removing BTU at a lower cost than removing the same BTU in the compression pump. This can allow the system to more than double output per unit of wind energy input.

Post chilling the gas stream

In areas where the ground temperature is consistently below ambient then it is possible to extend the compressed gas tube such that a length of it is buried at about 5 foot deep. The heat of compression can be rapidly reduced to ground temperature prior to allowing the gas to cool further before the secondary chilling step. This can increase the production of water per unit of wind energy with nominal additional cost.

Mounting considerations

In general the higher the turbine can be mounted above the structure the faster the average wind speeds however higher mounting also increase costs, stress on the mounting surface increased risks of running afoul of local codes. The heating system is specifically designed for installation on the roofs of urban homes so it must be optimized for effective operation at lower speeds common at the rooftop.

The mounting height of the turbine can have an effect on power delivered. Some experts quote a 2MPH increase in wind speed for every 60 foot off the ground. On the other hand large complex mounting systems increase cost so the most cost effective in stallion tends to favor a closer to ground mounting system. This can change in areas where trees and buildings are blocking too much wind. The ideal installation location is generally on the top of a ridge line.

Environmental limits

This system depends on water staying in a liquid state to drain from the condenser. That means if the dew point is at or below freezing the system is likely to experience freeze blockages and will not produce. In general a freezing blockage will prevent gas flow through the system which will allow the condenser to rise to ambient. As long as ambient is above freezing the blockage will melt and allow operation but production will be lost during the time the freeze blockage exists.

Minor design enhancements are needed to prevent freeze damage in areas where the ambient temperature regularly drops below freezing.

Breakout on Materials

Main turbine plate
Wind scoop / sail
2 End support plates
4 mid body support pieces
Labor for forming
Glue or thermal weld

Support Frame
2 X 76” X 1” steel tube
1 X 26” X 1” steel tube
¼ pound welding wire
3 bearings ball ¾”
1 pieces threaded rod or tube
2 bearing support brackets

Heat pump system
Compressive pump with shaft input
6 1 way valves
1 expansion valve
1 gas to air heat exchanger allow gas to cool

1 gas to air heat exchanger main condensing coil
1 gas to air heat exchanger for secondary condensing
Drain valve for condensate harvest
Fluid collection tubing and associated fittings from 4 turbines
Spring enabled linkage from turbine to pump.

Mounting
2 field fence posts 6 foot heavy duty
4 U bolt clamps

Basic expansion valve

The more simplified mechanism uses a very small pinhole valve between the condenser and the chiller section.   The pinhole is sized for the system flow so if the system expects to be able to pump 3 CFM at 8 PSI when running at 10MPH winds then the pinhole is sized to allow sufficient flow that once it builds up 8PSI it maintains that provided the wind continues to run the compressor at the same speed.   As the wind blows slower the pressure drops which reduce back pressure against the turbine.   As long as the system can maintain 1/8 the design pressure it should be able continue providing some chilling. As the wind blows faster it will begin pushing more air into the condenser and increasing the pressure a part of this will be relieved by faster flow through the pin hole.

There is some risk of the condenser exceeding design pressure during extremely strong winds so a secondary spring loaded ball valve is used to release at 85% of maximum design pressure which is normally 3 to 12 times minimum operating pressure. This gas is simply released and provides no chilling.

For wind speeds below 10 MPH a spring loaded valve which blocks the pin hole flow is used to maintain the minimum design pressure for the system.

A computer control system can be used to adjust the back pressure based on current measurements of ambient temperatures and dew points which can optimize production rates in a wider range of conditions. The computer controlled valve system is not deemed necessary in most conditions.

Basic Savonius Notes

See other document for more detailed notes

Completed Savonius turbine sized for 150 watts at 26 MPH winds. Hooks to PMG alternator custom designed by Joseph Ellsworth to reach 12 Volt charging voltages at 80 RPM.

Completed 165 watt @ 28 MPH winds designed and build by Joseph Ellsworth Winter 2008. Includes PMG alternator capable of reaching 48 V charging aat 80 RPM or 12 MPH winds.

Three Bladed blade designs:

- By Joseph Ellsworth Oct 2008
- Adapted from mathematical description of 2 bladed designs.
- Runs about 30% faster in same wind conditions than 2 bladed versions.
- Looks nicer since same shape of turbine runs top to bottom.
- It is self starting in all winds
- More difficult to ship due to more size in both width and depth when placed in shipping container and can not be turned to collapse like the 2 bladed design.