ATMOSPHERIC VORTEX ENGINE DESCRIPTION

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I. INTRODUCTION

My name is Louis Michaud. I am a 79 year old Canadian engineer I am seeking support for the development of the atmospheric vortex engine (AVE). An AVE creates a controlled tornado-like vortex by admitting warm or humid air tangentially into a circular area. Electrical energy is produced in turbines located at grade.

An appendix provides links to websites and tweets with additional information including drawings, photos, videos, thermodynamic basis, and sample energy calculations.

The atmosphere is heated from the bottom by solar radiation and cooled from above by infrared radiation to space. There is a potential for producing work when heat is carried upward by convection because the work of expansion of warm air is greater than the work required to compress the same air back to its original pressure after it has been cooled.

The atmosphere is an engine in which heat is converted to work. The work normally degrades to heat but could be captured by controlling the convection process. There is a potential for producing 6000 TWe by converting 12% of the atmospheric upward convective heat flux of 50,000 TWt to work because the atmosphere receives and gives up heat at average temperatures of +15°C and -15°C respectively.

A vortex engine could have a diameter of 200 m and produce 200 MWe. The vortex could have a base diameter of 50 m and extend to a height of 14 km. There would be a pressure reduction of 2 to 10 kPa at the center of the vortex which could drive turbines. There could be twenty 10 MW turbines around the periphery of the station.

AVE's could be the solution to the energy and climate problems. The process has the potential of producing 300 times the current human primary energy usage of 20 TW. One thousand 2 GW AVE's could supply current human electrical energy usage of 2 TW.

A 6 m diameter prototype using 250 kW of propane heating produced vortices 50 m high in Canada. The technology needs scaling up. The vortex must be large because the air has to be raised several kilometres to release the latent heat of its water vapor. Prototypes are costly and require large heat sources. Several prototypes will be required; there are many design options.

Fires occasionally produce fire whirls. Fire whirls can be produced and controlled by surrounding a fire with tangentially oriented deflectors. Therefore, convection can be initiated and controlled by supplying heat and rotation at ground level. The heat source could be gas turbine stack gas instead of a fire thereby eliminating the need for burning additional fuel which would increase carbon emissions. The heat source for dust devils is air heated to a temperature of 40 to 50°C; the temperature of gas turbine stack gas ranges from 80°C to 600°C. An established vortex could persist with reduced or stopped heat input when ambient air is warm or humid.

Alternatively, the starting heat source could be a ring of steam nozzles. Condensation would make the vortex visible. The air could be sprayed with warm sea water via tangentially oriented nozzles to eliminate the need for deflectors while increasing its heat content. Once established, this vortex could persist without steam; the heat would be provided by the warm water.

A 40 m diameter prototype could produce a vortex extending upward a few kilometres. A 200 m diameter vortex producer could produce a vortex extending approximately 14 km.

A new clean energy source must be found because humans will not accept reduced energy availability. Richard Smalley, who won the 1996 Nobel Prize of Chemistry, wrote: *“Without finding an abundant source of clean energy, there is no hope of stopping climate change.”*

II. MY STORY

In 1970, I was working as a process control engineer on a distillation process and wondered whether fresh water could be produced by condensing atmospheric water vapor instead of by distillation. I tried expanding air to condense its vapor content and realised that the process would require more energy than distillation because the air had to be compressed back to its original pressure. A few days later, I happened to read that the atmosphere is heated from below and cooled from above and realised that the process I had been considering had to be responsible for the energy of tornadoes and hurricanes.

III. ENGINE HISTORY

Early steam engines showed that heat can produce work. In 1776, James Watt increased their efficiency from 0.5 to 2 % by adding of an external condenser. Engineers tried for years to calculate the maximum work that could be produced by a given quantity of heat using Newton’s Laws. In 1824, Sadi Carnot tried a different approach. He imagined an ideal engine and realised that it is possible to produce work whenever heat flows from hot to cold because the heat could be transported with his ideal engine.

It took 30 years before Kelvin rediscovered Carnot. When engineers realised that efficiencies of 40% were possible, they made it happen. Since 1770, the quantity of fossil fuel required to produce a unit of work has decreased by a factor of over 50. Fuel consumption and carbon emissions increased by a factor of over 2000 despite the increase in efficiency. Energy usage increased by a factor of over 10,000 because energy improves quality of life. As a result, carbon emission increased by a factor of over 50.

Carnot wrote: "*To the flow of heat is due all movement including wind and precipitation*". Willard Gibbs, in the 1890's, calculated ideal work using "*Free Energy*"; an approach, now called "*Exergy*", which is applicable to the atmosphere and which needs no dynamic model. There is a potential for producing free energy when warm or humid air is raised; there is an abundance of sufficiently warm or humid air.

In 1903, Max Margules used closed thermodynamic systems to explain wind energy. He received little support from atmospheric scientists; he abandoned meteorology and died of starvation in Austria during the famine that followed the First World War. Nilton Renno, Axel Kleidon, Olivier Pauluis and I pointed out that atmospheric exergy is approximately 15% of the atmospheric convective upward heat flux. In 1967, Edward Lorenz wrote: "*The determination and explanation of efficiency constitutes the fundamental problem of atmospheric science*". Nonetheless, he recommended 1% and not 15% as the most reasonable maximum atmospheric efficiency based on estimates of dissipation.

The enormous energy production potential of the atmosphere has occasionally been recognised. Frank Marks and Chris Landsea pointed out that a large hurricane produces more energy than humans produce in a year. The energy dissipated by friction in natural convection need not be dissipated; it could be captured**.** Hydro and wind together produce 0.5 TWe. Atmospheric upward heat convection has an exergy of 6000 TW and could produce over 1000 TWe if controlled.

Richard Feynman said: *"In science, the authority of thousands of opinions is not worth as much as one tiny spark of reason in an individual"*. Respect the laws of nature. Do not listen to the scientific consensus. Listen to the engineers who have to reject wrong hypothesis to produce things that work. Consider suggestions from any quarter.

I published nine peer reviewed papers related to the thermodynamic basis of atmospheric convection and the vortex engine. I used continuous ideal cycles – an engineering approach not used in meteorology**.** Like Carnot and Gibbs, I simplified the problem to make it analysable. Figuring out how much work could be produced is easy for continuous processes and difficult for processes involving a mixture of fluids with unrelated properties.

IV. ATMOSPHERIC SCIENCE

In atmospheric science, dynamic models are more popular than thermodynamic ones, I submitted a paper pointing out that hurricane intensity can be calculated using a standard chemical engineering simulator to an atmospheric science journal; an anonymous reviewer wrote: "*He uses an engineering simulator*". So much for E. O. Wilson's consilience approach which says that a hypothesis is more likely to be correct when applicable to several disciplines.

John Molinari showed that Convective Available Potential Energy (CAPE) is typically 1500 to 2000 J/kg in hurricane formation areas. CAPE is essentially the same as exergy. Spraying surface air with warm sea water can increase CAPE to 10,000 J/kg. Models are based on Newton's Laws – the approach which was unsuccessful at finding maximum engine efficiency. Atmospheric models and Carnot engines both obey Newton's Laws. Exergy can take many forms and can degrade to heat in seconds or days. As a result, models are of little value for indicating maximum possible work. Model do not reveal how much energy could be produced when the process is carried out reversibly.

V. THERMODYNAMICS

Atmospheric scientists generally believe that the energy of hurricanes and tornadoes comes from above. Net work is the expansion work minus work required to raise the air to the height of the lower pressure. Thermodynamics show, that lifting of warm or humid air from near the bottom of the atmosphere, is essentially the only process capable of producing work. Without a machine with a shaft to take the work out of the system, the work is bound to eventually degrade to heat.

A simulation of a pot of boiling water would not reveal that the addition of an inverted funnel could lift water and create a percolator wherein water is lifted. Determining ideal work requires imagining an ideal engine. Experience with engines and industrial processes is as important for understanding the atmosphere as familiarity with the atmospheric science literature.

Kelvin wrote: "*In science physics is everything; all the rest is stamp collecting*". Finding the reason for an observation is science; collecting climate statistics is stamp collecting. We cannot change the laws of nature but there is more than one way of solving a problem. Modern inventions are the result of gradual improvements to which many disciplines contribute. James Watt realised that using an external condenser would eliminate the need to cool the cylinder after each stroke; subsequent inventors realised that using multiple expansion stages would further reduce unnecessary cooling and further increase efficiency even before Carnot came along.

The peer review system limits contribution to solving the climate crisis to atmospheric scientists with little process engineering experience. There are many engineers in the power industry who could contribute to solving these problems. I was more effective as a process control engineer at Esso Chemicals Canada (Imperial Oil / ExxonMobil) than many process control postgrads because I had been exposed to variety of processes to which I had paid attention.

The 50 kWe 200 m high by 10 m diameter Manzanares Spanish solar chimney demonstrated that atmospheric upward heat convection can produce work which can be captured at ground level. Henri Nazare, Normand Louat, Sandro Nizetic and I independently proposed replacing the solid solar chimney with a vortex. Increasing convection height can increase efficiency, by a factor of 100, from 0.15 % to 15 %. A natural draft chimney is a cylinder in radial compression; at any level, the pressure is higher outside than inside the chimney. An opening in the chimney wall would allow surrounding cool air to be drawn in, would dilute the rising warm air, and would decrease draft and flow at the bottom of the chimney. *In the AVE, centrifugal force replaces the physical wall.*

The chimney effect of a vortex can extend much higher than that of a physical chimney. Efficiency and draft are proportional to chimney height. Producing work from low temperature heat is notoriously difficult but upward heat convection can produce movement from low temperature difference. The greenhouse of the Manzanares solar chimney only increased the air temperature by 20°C. A vortex can extend to much greater height than a physical chimney. As a result, AVE's can use lower temperature heat sources than other thermal engines. In the tropics, the heat source can be 26°C or higher water, or 35°C or higher air; in higher latitudes, these temperatures can be lower.

The source of hurricane energy is 26 to 30°C warm sea water. Water spray can increase sea to air heat transfer by a factor of 100, from 500 to 50,000 W/m^2, because small droplets have much higher surface to mass ratios than the sea surface. Cooling towers have much higher heat flux per unit area than cooling ponds. Hurricanes are difficult to start because producing heavy spray requires a wind velocity of over 20 m/s. Controlled vortices must be large because the air may have to be raised several kilometres to become buoyant and because, for a given flow, friction losses are inversely proportional to the fourth power of updraft diameter. Spraying warm water in surface air from a ring of spray nozzles could provide the two conditions required to produce a waterspout: warm humid air and rotation.

V1. DEVELOPMENT APPROACH

There may be several ways of producing controlled atmospheric vortices. Several designs based on best engineering judgement will have to be built and tested. Like for other machines, design will improve with experience. Early machines are invariably improved upon. The realization that there is a thermodynamic potential for producing work is far more important than the specific way of doing so.

Starting a vortex requires warmer air than sustaining the vortex after it is established because after the vortex is established the buoyancy of the air above can provide the lift for the air below. Gas turbine stack gas is a good heat source because there is no need for heat exchangers and because there is no need for additional turbines. The pressure reduction at the gas turbine outlet is sufficient to increase power output. Stack gas flow and rising air temperature could be manipulated from the existing control room.

There is a conceptual drawing of an AVE using gas turbine stack gas as its heat source in the first tweet of the appendix. This conceptual design could be improved in many ways. The ambient air could enter the periphery of the AVE directly rather than be mixed with stack gas prior to entering the AVE as shown. The ambient air could be heated with waste heat in wet or dry peripheral heat exchangers. This heated air could be directed to either in the lower or upper AVE level. The ambient air could go through turbines where additional power would be produced.

An alternative design could be a wet AVE consisting of: a circular tower, an inner ring of start up steam jets, peripheral wet cross flow direct contact heat exchangers, a condenser cooling water circulation system including: a cooled water basin, circulation pumps, upper level tangential air entries, turbo-generator in the wet heat exchanger air inlets, and dampers for directing the heated air either to the lower or upper level.

Another alternative design could be a dry AVE consisting of: a circular tower, an inner ring of start up steam jets, a ring of peripheral dry heat exchanger, a condenser cooling water circulation system including pumps, upper level tangential air entries, turbo-generator in the heat exchanger air inlets, dampers to direct the heated air either to the lower or upper level. Existing dry natural draft cooling towers could be converted to dry AVE's by the addition of deflectors and turbo-generators.

The initial objective of the development program will be to produce a large, well behaved vortex extending as high as possible. Producing power will be secondary to developing vortex handling expertise. A central turbine like a cup anemometer could be used to demonstrate power production potential. Mature geo-thermal AVE's could have central or peripheral turbines.

The development project would consist of many tests of a few hours duration rather than of continuous operation. There will be a need for many tests because there are many parameters that can be manipulated to improve the vortex including: flue gas and rising air flow and temperature, directing heated air flow to the lower level or to upper level tangential air entries.

In additions there will be changes in uncontrolled environmental variables such as wind, atmospheric turbulence and shear, air temperature and humidity, atmospheric sounding, time of day and time of year and location. Keeping the vortex close to vertical vortex may require a higher plume temperature under higher wind conditions. There will be opportunities for major design improvements. Initial prototypes should be in warm light wind areas. Initial testing would be under light wind conditions.

There will be a need for a sophisticated instrumentation, data acquisition, and control system. One of the aims of the tests would be to find the appropriate sweet spots for different environmental conditions. Another goal would be to improve design based on experience. The ability to remotely manipulate parameters during the test would speed up finding the most favorable operating conditions for the current atmospheric conditions.

The ability to produce tall and stable vortices will improve with station and heat source size because small vortices are more easily disturbed or diluted by wind. A 50 m diameter AVE will not be able to produce tall vortices as often as 200 m one. A 400 m diameter AVE in a favorable location should be capable of producing vortices extending to the tropopause with a high service factor and produce power on demand.

The power industry has the skills and resources required to develop the AVE. The technology is closely related to chemical and power engineering. The process can be analysed with chemical engineering process simulators. The atmosphere is in a metastable state; starting a vortex is akin to starting a difficult to start thermo-syphon. Computational fluid dynamic models could be used to improve design but must first be capable of duplicating experimental results. Given objectives and resources a strong process engineering teams would come up with appropriate design.

VII. OPPORTUNITIES

An AVE could have an area of under 1 km^2 and a power production of 200 MW. There is no need for large area solar collector. When the heat source is warm sea water, the cooled water sinks, and more warm water flows in. When the heat source is warm humid air, more surface ambient air moves in to replace the air that rose in the vortex.

The maximum average power of solar photovoltaic is 20 W/m^2. A 200 MW photovoltaic plant would need a 10 km^2 collector and the power output would vary with time of day and weather.

An AVE where the heat source is warm sea water could provide power continuously and on demand. An AVE requires less equipment than fossil plant of the same capacity and there is no fuel cost. Therefore, the cost of AVE energy should be less than that of alternatives. There is no need for energy storage; the heat is already stored in warm sea water, in warm humid air or in industrial waste heat.

The atmosphere is in a metastable state; it is like for a syphon, energy must be provided to start the flow. In the tropics, air sprayed with sea water does not become buoyant immediately because the sea water is only a few degrees warmer than surface air. Tropical maritime air may have to be raised 3 to 5 km to become buoyant. Work is required to raise the air to its level of neutral buoyancy; work is produced as the air is raised beyond its level of neutral buoyancy. In continuous flow, the net work is transferred to the bottom of the vortex, where the flow is restricted. Net work can be transferred downward to turbines located at the earth surface via a chimney or a vortex.

There are many options for warm climate AVE's. The heat source could be warm tropical sea water, naturally warm and humid ambient air, solar heat, geothermal heat or waste heat from thermal power stations and other industrial processes. The waste heat from a thermal power plants could increase its power output by 15% without additional fuel consumption.

AVE's could be located on land or on floating platforms. AVE's could produce far more electrical power than currently needed. Surplus power could be used to produce fuel such as hydrogen or to sequester CO_2. Sea water cooled by the AVE would be saturated with CO_2. The solubility of CO_2 and oxygen in water increases with decreasing water temperature. The CO_2 rich water could be made to sink in a pipe or in a water vortex to sequester CO_2 at depth and to restore sea water oxygen content.

Alternatively, CO_2 could be extracted from air and put in tanks later deposited to the bottom of the sea.

In warm climates, controlled vortices could reduce surface temperatures and reduce the risk of natural storms. The environmental effect would be like that of natural tornadoes but without any local destruction.

There is an urgent need to put a stop to global warming. The vortex engine could: produce abundant clean energy, eliminate carbon emissions, sequester atmospheric CO_2 deep in the sea, and help cool the atmosphere by moving heat above part of the greenhouse gas.

I am a process control engineer. I accept climate statistics and worry about future climate. The atmosphere is a process capable of providing both valuable goods and weather disasters. Control can improve the performance of any process. The first objective of process control is usually to stabilize the process - to make plant performance at least as good as it has ever been for the current constraints. AVE's could be used to make the weather less variable. The goal would be to make climate as good as it is at the best of time. There is nothing to fear AVE's can be stopped at any time by turning off the heat supply. Well controlled processes always perform better.

VII. GEOTHERMAL OPPORTUNITY

The heat source could be geothermal. Iceland would be a good location for AVE development because it has two assets: geothermal heat and low air temperature. In Iceland, raising 20°C saturated air 10 km can produce 10,000 J/kg which corresponds to a velocity of 140 m/s. 20°C saturated air can be produced by spraying ambient air with either 30°C water or 130°C steam. Geothermal and volcanic vortices occasionally occur naturally. In January 2020, a vortex formed naturally in the Faroe Islands. The surface air had been warmed by spray produced by waves hitting shoreline rocks.

Low temperature geothermal heat sources are more abundant than high temperature ones but cannot presently be used to produce electricity. Conventional geo-thermal typically has efficiency of 15% and require heat source at temperatures greater than 300 °C. Vortex geo-thermal could use geo-thermal heat at temperature as low as 30 °C and convert 15% of the heat content of the water to electrical energy.

VIII. SUMMARY

Developing and commercializing the atmospheric vortex engine will require the participation of organizations with proven engineering expertise and could make an organization the leading provider of renewable carbon free energy.

APPENDIX - REFERENCES

Additional information can be found on the vortex engine web and twitter sites. The web site is a repository of AVE information and has links to relevant reference material and FAQ's. The tweets provided concise explanations including figures and sample calculations. The last file is a video pitch.

Vortex Engine web site
http://vortexengine.ca/

Peer reviewed papers

1975 proposal
http://vortexengine.ca/BAMS/BAMS%20ALL.pdf

Thermodynamic cycle approach
http://vortexengine.ca/Cycle/Tcycle_SV.pdf

On Hurricane Intensity
http://vortexengine.ca/Isabel/MAP_HES_Text_Fig.pdf

Applied Energy article
http://vortexengine.ca/VPS_ARTICLE.pdf

Technical description – (not peer reviewed)
http://vortexengine.ca/VSC/AVE_WEB.pdf

Twitter
https://twitter.com/VortexEngine

Gas Turbine AVE
https://twitter.com/VortexEngine/status/1376576396898791432?s=20

Ideal work calculation
https://twitter.com/VortexEngine/status/1334161955813289985?s=20

Free Energy
https://twitter.com/VortexEngine/status/1312555391583051776?s=20

Ideal work vs CAPE
https://twitter.com/VortexEngine/status/1366078066917793795?s=20

Thermodynamic Cycle
https://twitter.com/VortexEngine/status/1364395791926890496?s=20

YouTube pitch video
https://www.youtube.com/watch?v=JTRWklR9yP4&t=3s