The Vortex Engine: Energy from Nature

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Business Plan

Prepared with assistance from Upland Consulting, Western Australia: www.upland.com.au.

Executive Summary

> *"We are like tenant farmers chopping down the fence around our house for fuel when we should be using nature's inexhaustible sources…"*
> *Thomas Alva Edison*

The Proposal covered by this business plan is to fund an accelerated R&D program culminating in commercialisation of a new energy-producing technology: the ***Vortex Engine***.

The Vortex Engine harnesses natural energy in the earth's atmosphere to produce electricity on the scale of current fossil-fuel power stations. The principles are well understood and the technology has been demonstrated many times at small scale.

Successful execution of the R&D program will put the supporter(s) in a first-to-market position with a renewable energy technology that represents the next wave after solar PV and wind farms. It is environmentally benign, cheap to build, and has major side-benefits.

The Opportunity

The Vortex Engine is a new way of meeting our human need for sustainable, renewable energy from natural forces.

Just as sunlight, wind, wave and tidal energy have been harnessed to create prosperity and economic growth, the Vortex Engine harnesses another great force of nature: the “latent” heat stored in our atmosphere itself, to generate electricity on a large industrial scale.

Solar and wind energy have already shown that 21st Century economies can substantially reduce their reliance on burning fossil fuels – a 19th Century energy source. The Vortex Engine is the next wave: a cheaper, more scalable, and 24/7 reliable energy source for our cities and industries.

Although the principles of the Vortex Engine have been known and understood since the 1940s, and validated by engineers and physicists, a real-world prototype has yet to be built. However small-scale proof of concept prototypes have been built. The opportunity awaiting the country or company that builds the prototype is to be first-to-market with a new, benign technology that has enormous market potential.

Extra Benefits

Sustainable, zero-emission power generation is just one benefit of the Vortex Engine.

Natural vortices in the atmosphere, such as tropical storms, actually assist the Earth to shed some of the excess heat that has been building up. Each Vortex Engine built will help to moderate global warming by “dumping” excess heat from the surface to space. Indeed, the Vortex Engine is the first energy source to contribute to global ***cooling***, not warming.

In addition, it is calculated that a Vortex Engine will increase rainfall in its immediate area; not dramatically, but by enough to help cleanse particle pollution out of the air, or assist dry-region agriculture and forestry.

Finally, a Vortex Engine can be used not only to generate electricity, but to take waste gases, such as scrubbed flue gases, out of the lower atmosphere. Some industries, including alumina refining, produce large amounts of water vapour, and this can be efficiently disposed, with all the associated benefits, using a Vortex Engine. Clean electricity can then be a by-product of waste disposal.

The "Asian Brown Cloud"

Because a Vortex Engine increases local precipitation, deploying the technology would be a way to address the "Asian brown cloud" of particulate pollution that covers much of East Asia during the dry winter monsoon period each year. It is clearly visible in the satellite photograph below, with Shandong Province to the upper centre and the Korean Peninsula to the right.

The brown cloud is made up of airborne particles and pollutants from combustion in wood fires, cars, and factories, biomass burning, and industrial processes with incomplete burning. As such, it is "washed" out of the atmosphere by the monsoon rains, and therefore can be reduced by the precipitation generated from Vortex Engines.

Market Size

The market for renewable energy construction in 2015 was on the order of USD$200 billion. It is currently growing at a rate of 12% per annum. On this basis, the renewable energy construction market in 2020 will be USD$350B. Based on an achievable 20% share of this for the Vortex Engine, the potential market would be US$70 billion.

However, these expenditures are nowhere near enough to mitigate global warming to the extent required to meet the objectives of the United Nations Paris Climate Conference. The Vortex Engine technology is therefore in an excellent position to attract investment away from conventional thermal power plant construction, which could easily double the available market.

In this connection, it has recently been reported that China is to halt the construction of more than 250 coal-fired power plants, with a combined output of 170GW, due to air pollution concerns. If the indicative capital cost of 1GW of generating capacity in China is USD$750M (a reasonable figure), there is more than $125B of power station construction to be replaced with one or more non-coal technologies. The Vortex Engine would be an excellent fit; based again on capturing a conservative 20% of that gap, there is another $25B market in China alone.

A third opportunity arises from the ease of retrofitting Vortex Engines to existing conventional power stations in place of cooling towers and cooling ponds. This substantially increases the generating capacity of such plants, while making them more sustainable, efficient and less polluting. This market is vast.

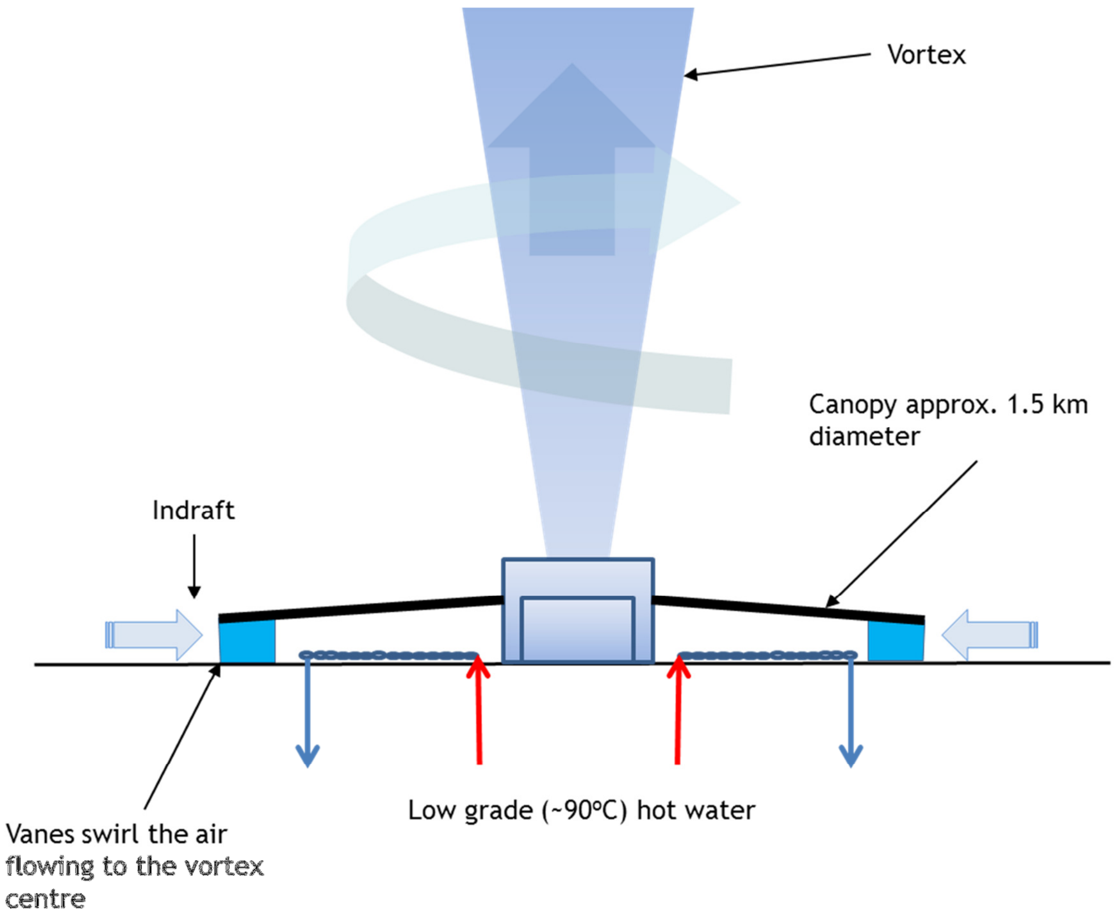
How Does it Work?

The Vortex Engine uses the same reservoir of energy that powers thunderstorms and tornadoes – but controllably. It uses a low-grade heat source to initiate a tall, controlled atmospheric vortex that in turn produces large amounts of energy in the form of airflow. The airflow is readily harnessed to drive turbines that then drive generators.

The ultimate source of energy is the “latent” heat in the atmospheric water vapour at the bottom of the column. Given a small impetus of heat, the surface air will start to rise. Given a rotational impetus, it will form a stable and self-bounding vortex, carrying the water vapour to altitude.

As the water vapour condenses and eventually freezes, its latent heat energy is released. This warms the surrounding air, resulting in an increase in buoyancy and sustaining the updraft of air within the plume. The compensating indraft at the base of the vortex is harnessed by the turbines.

The following diagram (*not to scale*) illustrates the structure that generates the vortex.



At commercial scale, calculations show that the vortex will overcome inversion layers and other convection inhibitors, and deliver the waste heat to the top of the troposphere (the tropopause).

At the top of the plume, the heat is radiated into space.

The vortex can be shut off simply by stopping the heat supply to the ground-level structure.

Our atmosphere has a reservoir of water vapour very roughly equivalent, in energy terms, to the world's remaining oil. Importantly, natural weather processes replenish this reservoir on a cycle of less than 10 days. As water vapour is by far the most potent "greenhouse" gas, sending some of it aloft to the freezing levels will actually assist the radiation of excess surface heat from the Earth. In this respect, the Vortex Engine simply does more of what natural processes do.

There is plenty of energy in natural atmospheric vortices – a large typhoon or cyclone, for example, has more energy than humans consume in a year. A tornado, closer to the scale of the Vortex Engine, is roughly equivalent to a large commercial power station.

Heat Source

The Vortex Engine requires a constant input of low grade heat (<100°C) to sustain the vortex. This is an ideal use of sources such as low-grade geothermal energy, which is often available well away from built-up areas. Alternatively, the heat source can be waste process heat from a factory or even a conventional power station, which can be retrofitted with a Vortex Engine in place of cooling towers.

At present, many abundant sources of low-grade heat are simply wasted.

Scale

A reasonable commercial scale for a Vortex Engine, once the technologies have been proven and fine-tuned in a prototype, would be on the order of 200MWe of power output to the grid. This is comparable to a large commercial power station burning fossil fuels. Such a Vortex Engine would have a vortex energy of around 1GW, and a plume height around 10km (*i.e.* near the tropopause).

To demonstrate waste flue gas disposal, a considerably smaller scale would suffice. An actual metallurgical plant examined for this purpose has a waste gas stream, downstream of a wet scrubber, at a temperature of 82°C, a water vapour content around 50%, CO_2 content 10%, volumetric flow rate ~40m^3/sec, and total energy flux around 50MW.

This gas stream, if fed into a small Vortex Engine around 20m across, would produce a plume height of around 1km and could generate around 1MWe of electrical power. It would be much less efficient than a full-scale machine with a

10km plume height, but still a very worthwhile use of waste gases, as well as a proving ground for the technology at small scale. On current projections, it would cost in the region of USD$4M to build in China.

Location

The Vortex Engine can bring electric power to under-serviced regions while bypassing the expense and pollution of fossil fuel power stations. Countries with abundant low-grade geothermal heat and growing energy demands, for example, include Bangladesh, Indonesia and the Philippines. Very suitable geothermal resources are also found in Afghanistan, China (Tibet), Ethiopia, northern India, Jordan, Kenya, Nepal, Pakistan and Somalia. Mexico and the south-western USA are also prospective. Large parts of outback Australia are underlain by hot sedimentary aquifers.

Offshore Vortex Engines are also possible. Suitable locations include offshore China and north-west Europe. Warm surface sea water in the tropical “doldrums” is a further possible source of heat and water vapour.

Risks

The price of opportunity is risk; no progress is made without calculated risk-taking. The risks of building a prototype Vortex Engine are small, but must be understood and managed.

Here is an analysis of the key risks identified to date.

Geothermal Complications

Long-term heat extraction from hot sedimentary aquifers has not yet been widely practised. It may turn out to be more complex, or require more boreholes or more pumping, than the industry currently expects. The porosity of the aquifer is the main determinant of these engineering requirements. The R&D program must cover researching these factors to allow rapid identification of the most suitable aquifers.

Aviation and Birds

Air velocities are high only near and within the Vortex Engine structure itself. The energy of the vortex is rapidly diffused as it rises and extends horizontally. A commercial jet at cruise altitude, typically a little below the tropopause, would encounter almost calm air. The region of very high energy is confined to around 200m upwards from the Vortex Engine structure, and approximately three vortex radii from the centre. That is, an aircraft or bird only 30m from the centre of a vortex 20m across would encounter noticeable, but not dangerous, wind.

It is expected that birds would give the dangerous part of the vortex a wide berth, as they do other hazards.

A person could safely stand by the vanes at the edge of the canopy, and experience a mild, steady breeze.

Noise

Like any heavy industry, Vortex Engines should be located away from residential areas.

Runaway vortex

Some have suggested that the generated vortex could "run away" – that is, become self-sustaining and unstoppable. In practice there are very good controls against this happening. The humidity of the Vortex Engine's environment would be below the critical level at which the vortex would be self-sustaining. Only after passing hot water through the Vortex Engine heat exchangers would the energy level become super-critical. The air temperature achieved would be in the region of 40 – 50°C above ambient. Thus shutting off the heat would stop the vortex.

The boundary layer fence surrounding the structure would also act to quarantine the vortex from the surrounding air, allowing flow only through the control dampers and turbines.

The Economics

Any CAPEX estimates at this stage are naturally surrounded with considerable uncertainties. However, based on extrapolation from other large circular structures such as cooling towers, plus the fairly well-known costs of turbines and generators, it is reasonable to estimate that a 200MWe Vortex Engine power station would cost in the region of USD$175M to build in China. This excludes electricity transmission infrastructure, the cost of which will vary widely by location.

On the same basis, a solar tower, discussed below, is projected to cost around $260M to build at 200MWe output. A straight geothermal power station of similar output would cost around $280M. Of other low-emission technologies, nuclear and hydro are much more expensive to build (and have other issues).

Wind farm capacity is of roughly equivalent capital cost, but suffers from low load rates (*i.e.* power availability time), which can be as low as 8% at rated output. The Vortex Engine should easily match the load rates of mature fossil fuel-fired technologies at around 80%.

Therefore the Vortex Engine, once proven, is potentially the ***cheapest*** way to deliver a 200MW baseload power station – and then costs next to nothing to run.

The Georgia Institute of Technology project, discussed below, will if successful produce electricity at around USD$0.07/kW-hr, which is 65% cheaper than current solar PV and better than 20% cheaper than current wind turbines.

The Competition

The US Department of Energy has funded the Georgia Institute of Technology (GaTech) to research and develop a system based on a large array of small vortex machines. This approach entails greater land use, higher construction costs, and less efficient vortices than the Vortex Engine proposed here.

Nevertheless, GaTech modelling indicates substantially lower infrastructure costs and as a result significantly cheaper electricity compared with both solar PV and wind farm technologies. Land use is also more efficient, calculated at 16MW/km^2 compared with 3 to 6MW/km^2 for current wind farms.

These calculated benefits will be even greater for the Vortex Engine.

In particular, the power of the GaTech updraft plume is insufficient to penetrate inversion layers and other conditions of convective inhibition, meaning that the thermal efficiency of the design is severely limited. With a plume height of approximately 1km, a maximum thermal efficiency in the region of only 3% could be expected, as against around 30% for the full tropospheric-scale Vortex Engine with a 10km plume.

Two other concept-stage technologies are based on large vertical air movements: the gravity tower and the solar updraft tower.

Neither technology has been demonstrated at commercial scale, and both require very large vertical infrastructure.

A 50kW prototype solar updraft tower was built and operated for eight years in Spain in the 1980s. Even this small output required a tower 195m tall and 46,000m^2 of glazed roof. The tower eventually blew over. It should be noted in fairness that one of the prototype objectives was to test cheap, lightweight materials to minimise construction cost and embodied energy. Nevertheless, this can hardly be called a convincing demonstration, and apart from small experimental structures no other solar updraft tower has been built since.

It is suggested that a solar updraft tower producing electricity on the scale of a conventional power station would need a 1,000m tower. A full-scale Vortex Engine, say 200MWe, would need a structure no more than 100m high.

Even if successfully constructed at commercial scale, the solar updraft tower would not be capable of lofting its air and water vapour to the tropopause, as it does not take advantage of vortex effects. The Vortex Engine is thus a more effective, and also a more efficient, design, using the full depth of the troposphere.

The gravity tower proposal is a downdraft machine, requiring pumped water, purely hypothetical to date, and seems to offer no particular advantages.

Nuclear fusion promises a clean, sustainable source of abundant energy. However, the fact that this promise has been held out since the 1950s, with to date not one kW-hr of electricity delivered, shows that there remain very difficult problems with harnessing fusion. In any case fusion reactors would not reduce the atmosphere's water vapour or heat.

It is fair to conclude that the Vortex Engine is the most promising new renewable energy technology.

R&D Program

The plan offered here is for a phased, accelerated, research and development program designed to produce a commercial-scale power generating Vortex Engine in approximately 2 ½ years.

The reason for an accelerated program, in addition to the great need for this technology, is the lack of IP protection – the basic physics and engineering have been in the public domain for decades. Therefore a first-to-market position, and a commanding lead in development, are best obtained by an accelerated program. Opportunities will certainly arise to patent or otherwise protect improvements and ancillary inventions during the program.

Phase 1 would develop and test a generic technology demonstrator, fully instrumented. This would be a small Vortex Engine to use as a test bed and proof of concept. For an example, see above under ***Scale***. Phase 1 would begin with a discovery and due diligence process, plus detailed budgeting..

Preliminary budgeting for Phase 1 suggests a cost of USD$3.8M, if the work is carried out in China.

Completion of Phase 1 would allow detailed cost modelling for Phases 2 and 3.

Phase 2 would develop a waste gas Vortex Engine which would carry industrial waste gases toward the tropopause. This would contribute to overcoming Asia's smog problem, and would generate a return on the R&D investment.

Phase 3 would be to develop a larger scale Vortex Engine for power generation. This more expensive undertaking would be funded from the commercialisation of Phase 2.

It is not yet possible to meaningfully cost Phases 2 and 3, particularly given the commercialisation opportunities that can be expected once Phase 2 is demonstrated.

From there, as noted above, it should be possible to deliver 200MWe Vortex Engine power stations for around USD$500M in the USA, or $175M in China.

Business Models

There are many opportunities for supporters of the R&D program to harvest commercial returns once the technology is proven.

Examples include:

- Contract turnkey construction for local utilities and authorities;
- Build-own-operate projects under contract to the same customers; and
- Standalone projects where the investment is from private funds and the revenue is simply from the sale of electricity.

In all cases the very low cost of power produced, and the additional benefits of the Vortex Engine, will make the product highly competitive with any alternative currently known.

Glossary

PV: Photovoltaic, the method by which "solar cells" produce electricity.

Tropopause: The upper boundary of the troposphere, usually at an altitude around 10km in temperate latitudes.

Troposphere: (Greek *tropos* = turning or mixing). The lowest layer of our atmosphere, within which all our familiar weather phenomena occur, including clouds, storms and precipitation.

Stratosphere: (Latin *stratum* = a layer). The layer of our atmosphere above the tropopause, characterised by little vertical mixing.