Submission

No 12

# INQUIRY INTO THE ECONOMICS OF ENERGY GENERATION

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**Position**: Director

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SUBMISSION

to

INQUIRY INTO THE ECONOMICS OF ENERGY GENERATION

by

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**Executive Summary:**

This submission primarily addresses the matter of the mix of energy sources used in New South Wales. It contends that the Earth's best renewable energy resource is high altitude wind energy. This resource exists over all of NSW and elsewhere, where the annual average power density is around 20kW/m2 with a very high persistence. A levelised cost of energy (LCOE) table is presented showing that high altitude wind generated electricity could be about $50/MWh less than that obtained from conventional coal or ground-based wind systems. This cost is shown post July 2012 allowing for a carbon tax and the LREC credits. The cost advantage is primarily due to the 70% capacity factor that can be obtained with altitude generated electricity. This factor far exceeds that achieved by ground-based wind or solar systems.
The economics and the engineering of electricity generation from altitude wind needs to be vigorously encouraged in order to maintain NSW electricity prices at reasonable levels.

**Introduction:**

Altitude Energy Pty. Ltd. is an Australian owned company whose participants have had extensive experience in the design, construction and use of airborne, wind driven electric generators and similar devices.
The company was founded early in 2011 by two members who have had wide experience with electric powered rotorcraft over a number of decades. Previous to its formation, six electric powered research and development craft were built and tested. In several cases this work was undertaken in NSW universities using Federal Government, NSW Government and overseas funding.
With this background the company wishes to make a submission to the NSW Parliament's Inquiry into the "Economics of Energy Generation". In particular we wish to address items (i), (iii) and (v) in the published "Terms of Reference" (TOR) to this Inquiry.

The Company plans to manufacture and install products in Australia through the commercialization of rotorcraft technology already researched and developed.
These rotorcraft are devices to harness the extremely powerful and persistent energy from the winds aloft, particularly over all of southern Australia, namely in NSW, SA and southern WA. At altitude it is well known that major jet streams exist in both Earth hemispheres. They occur in 1000km wide bands running over the Mediterranean, northern India, China, southern Japan, north/south America, Africa and Australia.
The jet streams have annual average power densities about eighty (80) times greater and are three (3) times more persistent than the winds available to ground-based wind turbines. As a result, wind turbines at altitude would be much smaller in size with a more persistent power output than that presently obtained from conventional ground-based turbines. Such systems would avoid the current community concerns about the visual, noise and health impacts, and they would potentially produce electric energy using single rotorcraft units each in the 10 to 20MW size-range.
All of this could be achieved in spite of the complication of operating airborne craft at altitude. These craft use conventional wind turbine technology for power and attitude control, but are relatively light weight, and low on material usage, in comparison to ground-based turbines. The levelised costs of energy for the airborne and other systems are given below in a table.

Quad-rotorcraft are planned to be placed in restricted airspace close to already existing power transmission lines to save transmission infrastructure costs. Craft with four or more rotors would be mounted in a simple airframe and be inclined at an adjustable and controllable angle to the on-coming wind. The flight system is a variant of the gyroplane principle, where conventional rotors operating at significant disk incidences can generate power in the on-coming wind, while **simultaneously** producing sufficient lift to keep the system aloft. In general, the rotors would have disk incidences of up to no more than 40 degrees. The disk incidence would be reduced in increasing wind conditions so as to hold the power output at its rated value without exceeding the allowable securing force in the ground attaching tether. This electromechanical tether is used to secure the craft to the ground, while electric energy is conducted at high voltage down the tether to a ground station.
The craft's four rotors would be identical, while the craft's attitudes in pitch, roll and yaw are controlled by differential collective pitch action on the rotor blades, without the use of fatigue producing cyclic pitch action. This method of collective pitch action is identical to that used on conventional ground-based wind turbines to control their power output.
In addition, tethered craft at altitude have an inherent advantage over ground-based windmills because of their excellent ability to alleviate gust induced loads and torques within the system. This is due to tether flexibility giving in effect a 'soft mounting' of the system, along with alleviations due to changes in the draped-shape of the cable under varying wind conditions.

It is also important to appreciate that our quad-rotorcraft can operate as elementary helicopters. In this mode the electrical generators described above can function as efficient electric motors by suitable switching. Power would be supplied from the ground through the tether to drive the rotors during this mode of operation. Thus it is possible to land the craft during extensive wind lulls, or during extreme storms, onto a small ground base, helicopter-style. Later when conditions aloft are favourable, the craft can ascend to a normal operating altitude of around 3-4 km.

It has already been established with the Australian Government that our upper atmospheric technology is well-founded via a variety of approaches. A review by Australia's Chief Scientist has also been undertaken. The system has already been demonstrated in concept in university experiments in NSW and elsewhere, and the necessary research and development work has been finalized to the commercialization stage. Numerous peer-reviewed papers have been produced. 'Time' magazine in Nov. 10, 2008 rated the system as one of "The 50 Best Inventions of the Year", while 'Scientific American' magazine rated it as one among twenty "World Changing Ideas" in Dec. 2009. The cover page of the 'Power Electronics' magazine of August 2011 is attached immediately below. It shows an early version of the rotorcraft system currently being advanced in the USA under licence from Australian interests.

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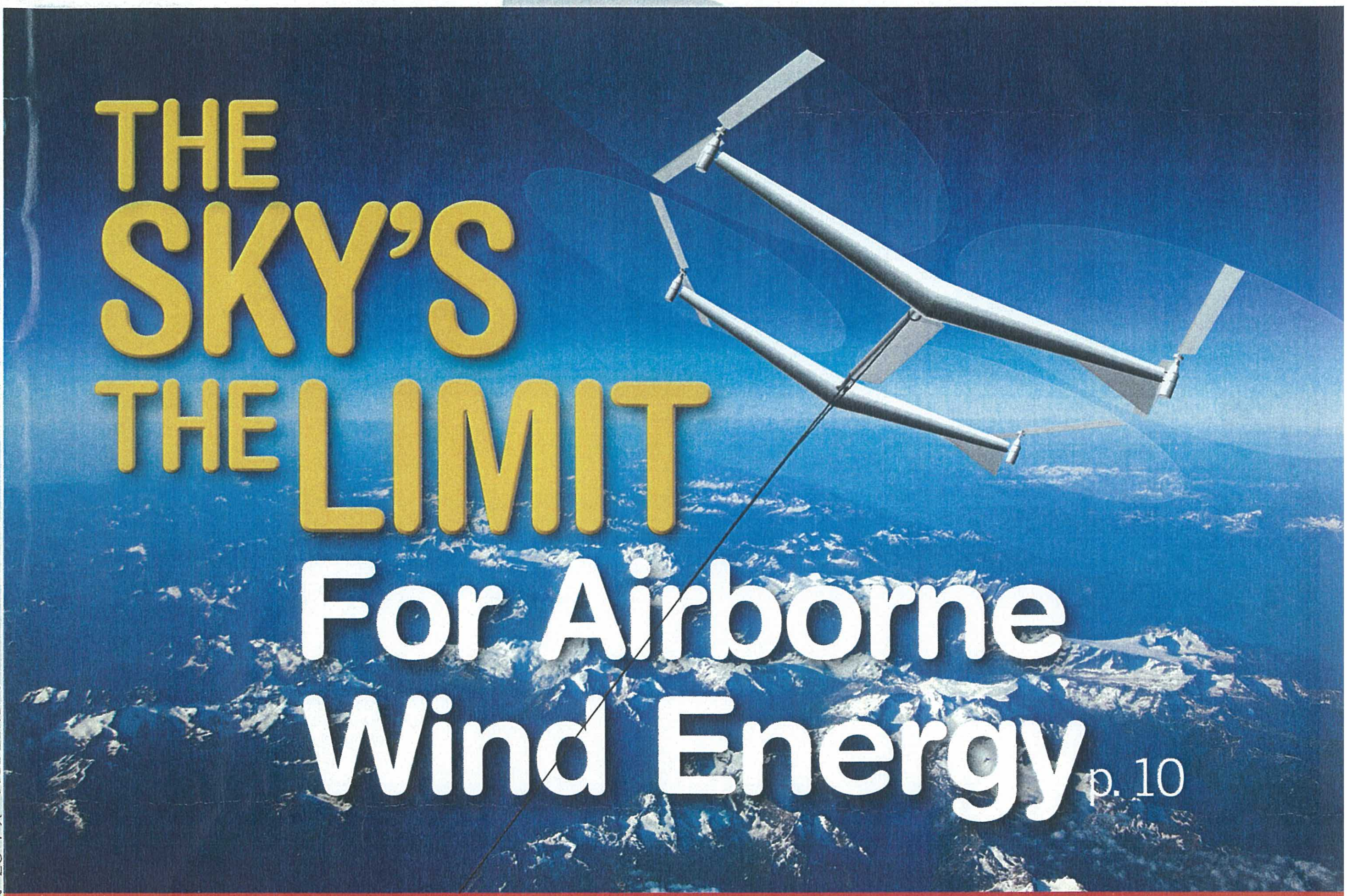


**ALSO IN THIS ISSUE:**



A PENTON PUBLICATION

**Mix of Energy Sources Used in NSW – (TOR (i))**

The object of this submission is to simply propose that the energy mix in NSW should **include an extra renewable energy production method** which is based on the capture of high altitude wind power. Australia has one of the best upper atmospheric wind resources in the world, if not the very best. Therefore, federal and state planning should include and advance this method in their mixes. The potential financial superiority of electricity generation at high altitude is demonstrated below by the well-known method of levelised cost of energy (LCOE) calculations for three different systems.

As an example, consider a basic 100 MW power station for each of three generating methods, namely from coal, ground-based wind and altitude wind. The installation costs for each have been taken from NSW Government published figures, from operator's websites or from Altitude Energy's own figures. Money is borrowed at a rate of 6%/annum for a Gov't guaranteed loan for the coal facility, 8%/annum for ground wind and 10%/annum for altitude wind. In each case the borrowed capital is returned over a period of twenty years. The price of coal is quoted below at a Gov't subsidized price of $31/tonne. Finally, return of borrowed capital in the coal example is in reality the Gov't dividend, assumed to be 5%/annum of the capital cost of the facility. All facilities are depreciated linearly at 5%/annum over twenty years.
The operating costs are reasonable estimates. These include the cost of wages, insurance, maintenance, repair/overhaul and land rental. The operating cost to the capital cost ratio in the three cases reflects the complexity of high temperature/high pressure coal-fired stations, the relative simplicity of ground-based wind systems and the additional complexity of airborne wind systems compared to ground-based wind systems. The airborne wind system's operating costs would be about two and a half times greater than those for ground-based turbines.

# Table of Levelised Cost of Energy (LCOE) Post July, 2012

| Cost Item | Coal | Ground Wind | Altitude Wind |
|---|---|---|---|
| | | | |
| Installed power, MW | 100 | 100 | 100 |
| Unit's installation cost, $/MW | 1,800,000 | 1,560,000 | 1,590,000 |
| Facility install cost, $ million | 180.0 | 156.5 | 159.0 |
| Capacity factor, % | 90 | 28 | 70 |
| Energy output, MWh/annum | 789,000 | 245,450 | 613,500 |
| Interest rate on borrowing, % | 6.0 | 8.0 | 10.0 |
| Coal consumed, tonne/annum | 320,000 | 0 | 0 |
| | | | |
| Cost of coal, $/MWh | 12.6 | 0 | 0 |
| Cost of borrowing, $/annum | 10,800,000 | 12,520,000 | 15,900,000 |
| Return of capital, $/annum | 9,000,000 | 7,825,000 | 7,950,000 |
| Operating to capital cost ratio, % | 6.50 | 2.00 | 4.63 |
| Total operating costs, $/annum | 11,700,000 | 3,130,000 | 7,365,000 |
| Operating costs, $/MWh | 14.6 | 12.8 | 12.0 |
| Depreciation allowance, $/MWh | 11.4 | 31.9 | 13.0 |
| | | | |
| Basic cost of energy, $/MWh | 63.7 | 127.6 | 63.8 |
| plus carbon tax, $/MWh | 23.0 | 0 | 0 |
| less LREC credit (LGC), $/MWh | 0 | 40.0 | 40.0 |
| | | | |
| **Net LCOE, $/MWh** | **86.7** | **87.6** | **23.8** |

The above table clearly shows the increasing cost of coal-fired electricity due mainly to the recent introduction of a carbon tax at \$23/MWh. In addition, the application of the LREC, or LGC, credit for renewable energy certificates enhances the renewable energy position. The table does not include LCOE calculations for solar or other more expensive renewable systems. The object of the table is to place the high altitude wind possibility in its correct cost perspective relative to coal and conventional wind options.

The high altitude wind resource has an annual average power density of around 20kW/m2. This is the highest power density for a large renewable resource anywhere on Earth. It exceeds the power densities of sunlight, near surface winds, geothermal and any other large-scale renewable resource. For example, Earth surface solar energy is typically about 0.24kW/m2, and the photovoltaic cell conversion of energy into electricity has an efficiency several times less than that of wind power. On this basis, and in this submission, we have considered only coal, ground-based wind and altitude wind, while excluding solar and other systems.

The installation costs have been taken from published figures for commercial-scale production in all three cases. For altitude wind a production rate of 250 units per year have been assumed in accordance with US National Renewable Energy Laboratory (NREL) guidelines. The most important item in the table is the Capacity Factor, or Availability Factor, which is around 90% for coal. It is well-known that ground-based wind's capacity factors are around 28%. We have taken a factor of 70% for altitude wind. The latter value has been derived from detailed studies using NSW high-altitude wind probability charts and typical craft disk loadings. Both of these are necessary to properly predict the abovementioned 70% capacity factor.

The operating costs for coal were taken at \$11.7 million/annum for the 100MW facility, while ground-based wind costs were relatively low at \$3.13 million/annum. In comparison, altitude wind's operating costs have been taken at \$7.4million/annum, which is much in excess of ground wind's value, thereby reflecting the added complexity of altitude wind relative to ground wind.

With all factors included, it can be seen that post-July 2012 both coal and ground-based wind systems have a levelised electricity cost of around \$87/MWh, while altitude wind gives a levelised cost of only \$24/MWh.

In summary, the greatly superior LCOE of altitude wind relative to ground wind is due to the high capacity factor. This results from operations at altitude. The LREC credit aids both wind systems while the carbon tax penalizes the coal system.

**Long Term Energy Security in NSW – (TOR (iii))**

High altitude winds are far more persistent than those near the surface, and thus they offer greater security and reliability of power production compared to other renewable energy systems.
High altitude systems operating aloft in remote areas would also avoid the recent angst and court cases over the installation of large ground-based windmills. This is because an airborne system would be operated at an altitude which would be out-of-sight and out-of-earshot from the ground community. The above unease has given rise to recent wide-ranging community protests in NSW and Victoria because of the visual, noise and health impacts associated with large ground-mounted turbines. Nevertheless, there is considerable local and global support for a clean and renewable future. Altitude Energy proposes to placate these noise, health and visual protests through the operation of electric generating rotorcraft at altitude at remote rural sites, anywhere in a band 1000km wide extending in length from Perth to Brisbane. Generating stations at altitude would be sited with CASA approval and be installed close to already existing power transmission lines. Written documentation from CASA is currently at hand.

Finally, high altitude wind systems can be easily relocated, if necessary, to a secure location in the event of a national emergency or a sabotage threat. This transportation issue could also be useful when communities need to be relocated for whatever reason, or when new population centres are rapidly established, as for example during the current Australian mining boom.

**The Potential for, and Barriers to, the Development of Alternatives – (TOR (v))**

This submission has been directed chiefly towards the potential for electricity generation using the powerful and persistent winds at altitude. A concept demonstration has been completed, while the research and development with covering patents has also been finalized. It only remains to commercialize the technology. This could be achieved now in NSW subject to the funding barrier.

Altitude Energy has a business plan ready to advance the technology in the Newcastle area of NSW. We would be willing to make this business plan available to the Inquiry on a strictly confidential basis, if requested. This business plan includes a multi-phase commercialization procedure, working drawings, performance and design software, a full cost-benefit analysis for a projected 200MW station and videos of various generating rotorcraft in operation.

Altitude Energy Pty. Limited
2nd February 2012