The sky's no limit

Pilot trials are due to begin in India in 2012 for an ambitious and innovative project that could harness the power of the winds at over 30,000ft. At that height they blow at over 200mph, so it's a goal worth pursuing to add to the world's growing renewable energy portfolio and help ease the pressure on fossil fuels. PES investigates…

SkyMill Energy is a relatively small US/Indian company attempting to harness those limitless high-altitude jet-stream winds, although they are not the first to attempt this ambitious feat. Other ventures used tethered kites but SkyMill think they may have solved the problems by using a remote small-scale rotary-lift aerial vehicle, similar to a conventional helicopter, attached to a generator on the ground. If successful, the rewards are measureless: vast renewable energy with no pollution and delivered by a comparatively straightforward technology and permanently available materials.

Speaking from the company's HQ at Friday Harbor in Washington State, its president, Grant Calverley, told PES the project's conception was unique. "We are confident it holds great potential especially for the Middle East and Asia," he said. India and China have some of the best winds in the world and also have the greatest needs for new power. The Middle East and Asian jet stream blows for about five to six winter months a year and this amount of wind energy contains enough power to some day power all of India and China for the winter months.

"There are winds which cover the entire northern half of India and blow in excess of 110 knots or around 200km/hr 24/7 throughout the winter. This is huge power." Together with his Indian colleague, Chetan Kumar, Mr Calverley, a graduate of the University of California in San Diego, has recently been travelling throughout the Indian sub-continent in order to establish a development group of aerospace engineers. "We're looking for major Indian investment partners, after visiting IIT Bombay, the National Wind Tunnel test facility at IIT Kanpur, as well as Pune and a VCcircle clean-tech investment forum in New Delhi," he said.

SkyMill's core innovation is to fly a remote-controlled, rotary–lift unmanned aerial vehicle (UAV), resembling an auto-gyro aircraft into the upper atmosphere on a high-strength tether. To produce power, the vehicle is allowed to fly outbound, its lift pulling the tether through a spool attached to a generator on the ground. In response to ground command, the vehicle's lift is dramatically reduced to permit a low-power rewind with a full cycle taking around 20 minutes.

The key components of the system had already been fully tested and a patent was pending, said Mr Calverley. "This system is flying successfully today in sub-scale prototypes and high-fidelity simulations. Its essential performance capabilities have been confirmed by a team of experts, including Advanced Rotorcraft Technology and Boeing," he told PES. The company is working with other partners to conduct a series of system demonstrations of increasing scale. A full-scale commercial pilot plant using SkyMill technology could potentially be on the grid in just over four years, producing an annual average of 1.4 MWh/hr at a low total cost of between 1.5 and 3.5 cents per KWh. The company hopes that this fully renewable energy source and attractively low- cost production overheads could trigger explosive commercial potential.

Mr Calverley is not the first to allude to the bleak future for the planet unless we endorse these kinds of technologies. "Global warming and peak oil are looming problems with no consensus on effective technical or economic solutions. Incremental gains in existing power technologies and energy efficiency will have little net benefit in the face of the world's growing reliance on fossil fuels," he said.

Meanwhile, others from the world of academia are backing his vision. Dr Ken Caldeira, for instance, a climate scientist at Stanford University's Carnegie Institution, said: "High-altitude winds represent the largest highly-concentrated form of renewable energy on Earth. If we could learn how to extract energy from winds and distribute it globally, we could potentially power all of civilisation." Dr Wubbo Ockels Dutch high-altitude wind power researcher and former SkyLab astronaut quantified the amount of untapped wind energy simply by saying: "Raise your hand to cover a patch of sky. The cone of sky behind your hand contains enough wind energy to power the Netherlands."

High-altitude wind is largely an unanticipated power source and yet it is conceivable that it could provide over 10 times the entire world's energy needs. High-altitude winds are present over most of the developed and fast-developing countries and SkyMill believes its technology offers a near-term and practical approach to tap this vast renewable energy source. Below is a power density chart for high altitude winds. The vast areas shaded in red and yellow have strong high-altitude winds making them potentially profitable sites for the project. The company's system can be sited anywhere above land or sea in these red and yellow zones, not just on windy plains or mountain passes.

Grant Calverley continues: "SkyMill's goal is to demonstrate the world's first commercially practical approach to tap this virtually unlimited energy resource. Our aim is to develop the SkyMill as an energy resource with a cost cheaper than coal-fired plants, particularly in India and China. Our short-term goals include the developing and selling the concept as a persistent high-altitude platform with civilian and military uses."

So how viable is the technology and where are we headed as regards global energy resources? Worldwide total energy use in 2008 was approximately 14 terawatts (14,000,000,000 KW), which represents a $6 trillion industry. The world will need 50TW/yr of power by 2050 just to maintain current growth rates. Even assuming contributions at current levels from greenhouse gas-producing fossil fuels 36TW of new energy will have to be found in the next 40 years. In the best case scenario, 20 TW of savings might result from energy efficiency (more efficient cars, LED lighting and so on) but this

still leaves a 16 TW shortfall – more than all the energy used in the world today.

If all surface wind, geothermal, tidal, new hydro, nuclear and bio-fuels were aggressively developed in the next 40 years, these would contribute only 4 TW of additional power – nowhere near the 30 TW of clean energy needed to make that essential reduction in global warming by 2050. Grant Calverley argues that, apart from high-altitude wind energy, solar is considered the only other viable source of power that could significantly contribute to this future energy demand (a $13 trillion annual market). Wind is the second largest potential source of renewable energy, he points out, yet 99.9 per cent of it is out of reach of conventional wind turbines. "However, high-altitude wind is all but being overlooked," he said.

"This is the gap that the SkyMill technology concept aims to fill. SkyMill Energy's long-term mission is to develop the system's capability to tap this abundant energy," he told PES. "Inexpensive access to energy is linked to development and our entire way of life. Everything we touch in our modern world has oil or coal energy embedded into it – our food, our water, our education, recreation, housing transportation, everything. Without inexpensive energy there is no development and if we run short of it, those who can't afford it will backslide.

"For developing countries, access to inexpensive energy is critical to growth. If worldwide energy supplies run short, as they did in 2008, worldwide growth slows or even reverses. SkyMill offers an inexpensive and inexhaustible supply of clean, domestically-produced, energy to sustain development. Energy additionally has a critical role in supporting vital agricultural productivity and in powering large and small businesses, essential in raising the income generation levels of a country.

"Through clean, affordable, and sustainable energy streams an increasing proportion of the population of China and India and other nations will be able to afford modern commercial energy services. Since the opening up of the Indian economy for instance, and its integration at a global level, the rate of growth has picked up from close to two per cent to peaks of eight per cent. There are clear roadblocks to going further or even sustaining these levels unless the infrastructure provides support – power being the most important."

It's a highly complicated business that others have tried before, without any great degree of success, it should be said. Companies in Germany, for instance as well as Holland, Italy and the US have developed and tested high-altitude kite power systems that have shown power-generating potential. "Hitherto, however, they have failed to discover the key rotary airfoil innovation that makes the SkyMill system practical on a commercial scale," said Grant Calverley. "These projects instead, focus on the use of controllable fabric traction kites or kite planes which need to fly complex figure-eight manoeuvres to generate apparent wind and their fly-by wire electronic control systems are necessarily complex. SkyMill's superior failure tolerance, scalability and capacity factors set it apart."

The SkyMill project was recently taken to a massive trade show in Abu Dhabi and on to the United Arab Emirates. "This was an amazing networking opportunity to build a network of interested government ministers, individuals, venture capitalists and corporate co-operative partnerships. The Abu Dhabi summit is the premier renewable energy meeting with 24,000 people from 180 countries attending," said Grant Calverley.

But, as with all other wind-based technologies, there has to be some concern over what happens when the wind drops. Grant Calverley thinks his company can

"Raise your hand to cover a patch of sky. The cone of sky behind your hand contains enough wind energy to power the Netherlands"

Dr Wubbo Ockels

provide the answer. He takes up the story: "When sensors aboard the SkyMill detect a wind drop speed, the ground system compensates immediately by increasing the tether tension. In the unusual case of the wind aloft dropping to zero, the SkyMill can still be recovered with complete control. The apparent wind created by retrieval keeps the rotor turning in autorotation and the SkyMill in stable flight all the way down to a gentle landing on its ground support equipment.

"SkyMill has far superior capability to handle gusts, high winds, and turbulent conditions than any fixed-wing or fabric-wind kite system. SkyMill's spinning blades operate in a much higher apparent wind and wing load regime. Wind gusts and turbulence that would overwhelm a lightly-loaded fixed or fabric kite wing will produce comparatively small transient effects on SkyMill's rotor blades. Also, in the event of a tether break, the SkyMill would have the ability to manoeuvre during its slow, controlled descent in autorotation. The SkyMill is designed with a capability to shift its centre of gravity to provide three axis controls. With onboard GPS and a stored map of surrounding surface features, the descending SkyMill could descend towards areas where it would be most safe to land and avoid areas were landing could pose a threat."

So if that's the wind drop and other attendant problems taken care of, what about the threat of lightning? Grant Calverley remains upbeat. "SkyMill's system design deals effectively with that particular threat," he said. "The system deploys a high-dielectric-constant, non-conducting tether, instead of an electrically-conductive tether as proposed by other high-altitude wind power systems, to reduce the likelihood of lightning strikes. With Boeing's help, SkyMill will incorporate damage limitation technologies as used on commercial airliners, to protect onboard systems from occasional strikes.

"SkyMill rotors, especially, will deploy lightning-tolerant designs and material proven effective on all heavy-lift helicopters. Existing high-altitude tether operations have successfully addressed long-term lightning issues. For instance the Tethered Aerostat Radar System operates along the southern US border and employs balloon-borne radar systems tethered at altitudes of up to 5,000m to detect illegal flights into the US. SkyMill systems would be taken out of operation in advance of serious lightning storms, using the ample warning provided by current technology. This 'storm downtime' has been factored into SkyMill's net power production calculations."

"The SkyMill platform system employs a flight vehicle lifted by a rotor disc turning in wind-driven autorotation to carry its payload to a desired altitude. A small portion of the torque from the rotor is used to provide permanent power to the onboard electronics. The system can be kept aloft in lower wind conditions through energy transfer from the ground in the form of 'tether pumping' or through towing behind ships. Endurance through the lowest wind conditions could be achieved with an onboard sustainer propulsion system. Military forces employ manned and unmanned aircraft, tethered aerostat and satellites to achieve a 'high-ground' advantage for surveillance, reconnaissance and communications."

So what is the next stage of the development plan? Grant Calverley remains optimistic about the project: "Our low-risked phase technical approach is to build and test prototypes at three levels of scale, though with comparable levels of complexity in three project phases. These will advance from SkyMill's sub-scale prototypes, today performing successfully, through a 48-month design, build and test programme conducted in three phases, with clearly measurable intermediate milestones to ensure high-schedule confidence."

The whole project, certainly at this stage, seems ambitious, daring and bold in its scope. Pull it off however and it might just herald a much-needed exciting new phase in the critical search for a sustainable future. Keep on watching those skies… ■

For more information, please visit:
www.skymillenergy.com