Reaching new heights

Could wind drones be the next evolution in wind power generation?

By Udo Zillmann

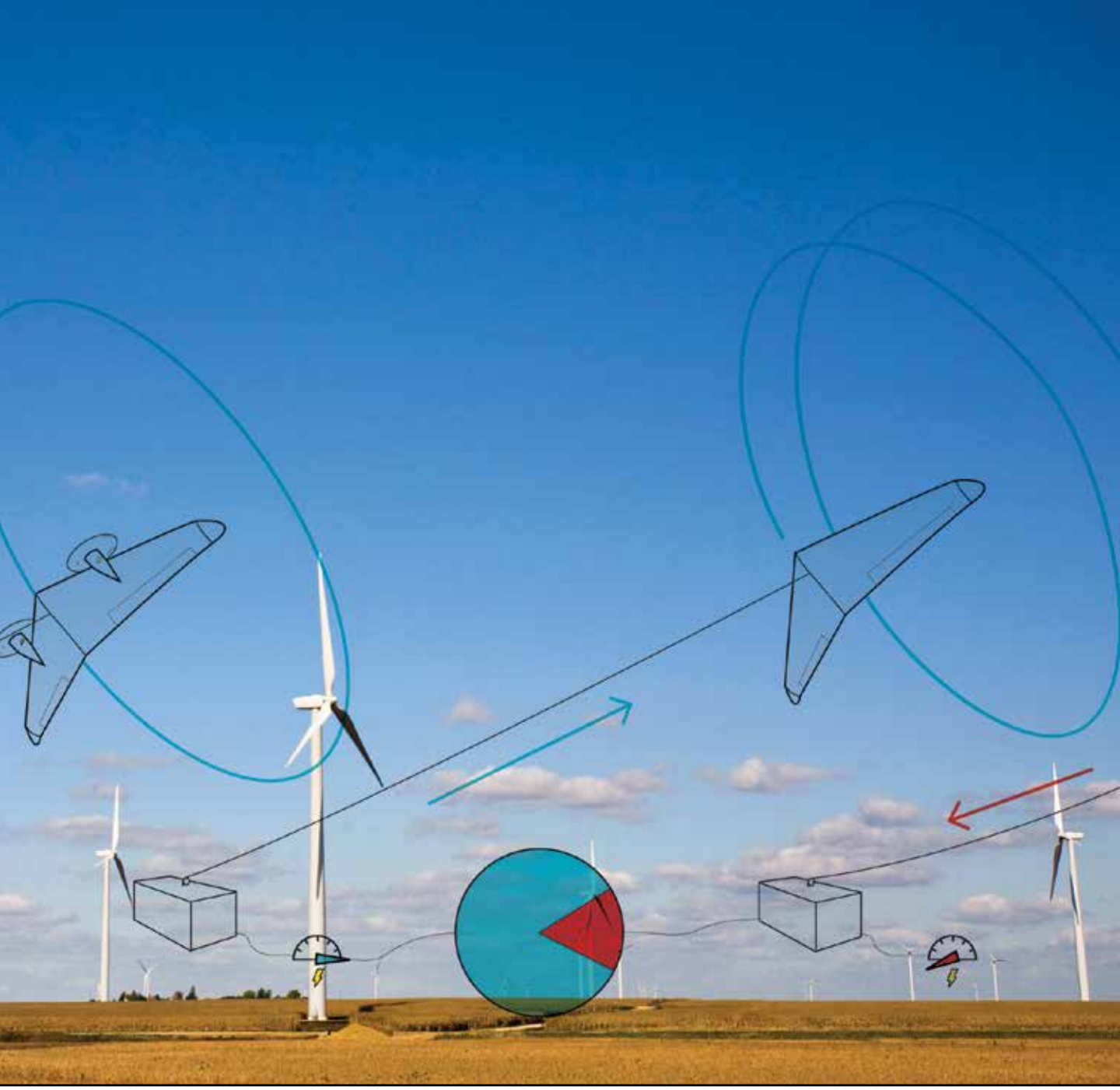
Drones will eventually be "as ubiquitous as pigeons," London-based futurist Liam Young recently predicted. They are omnipresent already. Only five years ago drones belonged to the realm of the military, unaffordable for anyone else. Today, they are for hobbyists and even kids. Drones arrived in our lives and conquered the extreme ends of the market for technical goods. They proved to provide the best value for both, defense budgets and pocket money. Now the race is on to fill the gap in the middle: startups, corporates and analysts try to find the most promising commercial applications for drones. That is quite a challenge since drones can be used for a surprising variety of tasks. Much media attention was paid to Amazons', Google's and DHL's announcement of using delivery drones. Others see the future for drones in surveillance, detecting fires, cracks in pipelines or illegal wood logging. They can also monitor farmland in detail for precision farming. Autonomous solar powered drones can also be used to hover at high altitude over an area for months to provide wireless communication similar to a satellite. Facebook and Google have invested in startup companies in this field. But there are other disruptive uses for drone technology which the current debate is largely unaware of.

One example is Elon Musk and his SpaceX company. He is working at landing and later reusing Falcon rockets after they have delivered their payload into space. It is impossible for a pilot to control a precision upright landing of a rocket that literally falls out of the sky. Only cutting-edge drone technology can do the job. If the rocket was to be recycled it would lower the flight costs from the cost of building a rocket to the cost of refueling it. That is $200,000 instead of $55 million.[1] The business potential for the "rocket drone" would be enormous.

Or take Miles Loyd. In the energy crises of the late 1970s Miles Loyd worked as an engineer at Lawrence Livermore National Laboratory. He attempted to build the best wind generator imaginable.

He had the radical idea of building it without a tower, only using a flying wing connected to the ground by a tether, much like a kite. He calculated the expected energy output of his "flying wind generator". Based on the formula he first established – today known as Loyd's Formula – he found that a wing with the size, weight and aerodynamics of a standard plane wing of the 1970s could produce 6.7 MW of power. Even larger wings with an output of 45 MW seemed feasible. To put this into perspective: even today, 35 years later, the average wind turbine is still below 3 MW and the largest existing prototype has 8 MW. Loyd obtained a patent[2] and published an article[3] on this new technology.

And here the story ends. He could not convince investors to finance his flying wind generator, because he had no solution for one problem: how to control the flying wing without a pilot? Today, we have a technology that lets us control flying objects without a pilot. It is called: drones. If we can apply this new technology to Loyd's old formula we can build a new type of drone: the wind drone.



WIND DRONE TECHNOLOGY

How exactly does a wind drone work? There is a great resemblance to kite surfers. Kite surfers use a kite and a tether to pull a surfer through the water. The same mechanism can be used to generate electricity. The tethered kite or wing is connected to a drum and a generator on the ground and the tether is wound around the drum. The wing tears at the tether and turns the drum to generate electricity. Once the tether is fully unwound, the wing nosedives and the tether is quickly reeled in. Then the cycle starts again. This up-and-down motion inspired the name "yo-yo" type wind drone (Fig. 1).

Google X, overseen by Sergey Brin, is working on a different wind drone in its Makani[4] project. Google's approach is to use little

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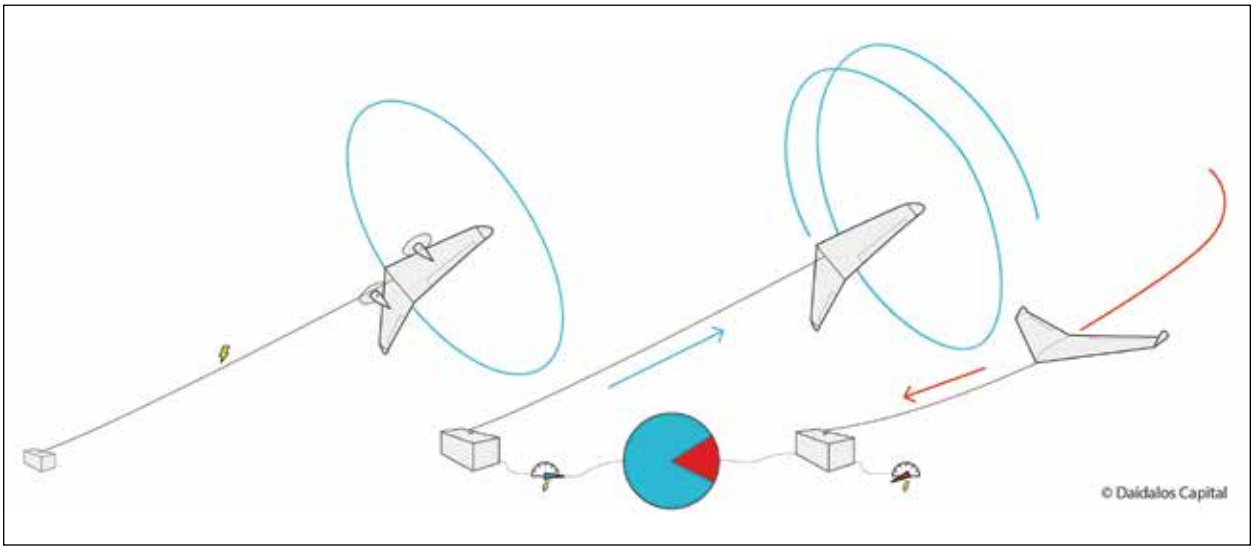

Figure 1: Illustration of wind drone technology.

propellers (mini wind turbines) and generators directly mounted on the wing where they produce electricity. An electric cable is woven into the tether and transfers the electricity to the ground. In 2013 Makani presented a working prototype. They already built their first scaled up product with 600 kW output and announced that it will fly in 2015.

Google will be the first team to show a wind drone with power outputs comparable to today's wind turbines. But they are not the only ones who have realized that drone technology is ripe to take on Loyd's formula. Companies including 3M, ABB, Alstom, E.ON, Honeywell, Statkraft and Softbank have conducted research on wind drones and/or financed one of the dozens of airborne wind energy startups worldwide. Some of the prototypes use soft wings resembling a surf kite or a paraglider, others use hard wings like the wing of an airplane. The designs also differ in many other details. A dominant design has not yet emerged. But irrespective of their final design, wind drones share three characteristics that could turn them into the killer application for drone technology: they will disrupt their market, they will be one of the first autonomous drone applications to be market ready and they will have the largest market of all drone applications.

DISRUPTING THE MARKET

Producing wind energy is not a new idea and we already have a tried and trusted device for this task: the wind turbine. Wind drones will have to offer significant advantages over wind turbines to conquer this market. Airborne wind energy companies claim that wind drones can be built at half the price of wind turbines. In addition, they claim that downtimes for wind drones will be significantly lower and wind drones therefore produce twice as much energy with the same rated power. According to their calculations energy from wind drones could therefore be available at just one quarter of the price of energy produced by wind turbines. But are such claims realistic?

COSTS

Can you manufacture wind drones more cheaply than wind turbines? The capital costs of a wind turbine which make up the bulk of the total costs of wind energy are the following (see Figure 2).[5]

The structural elements, the tower, the blades, the foundation and the rotor hub make up half of the total capital costs of wind turbines. Material requirements are extremely high: Up to 700 tons of steel for the tower,[6] another 100 tons of steel for the rotor hub,[7] up to 100 tons of glass-fiber reinforced plastic for the blades,[8] and up to 4,000 tons of concrete for the foundation.

Wind drones lack theses massive structures. The tower is replaced by a thin tether. A wind drone with the power of the largest existing wind turbine (8 MW) requires a tether that is 2.5 inches/6 cm thick and would weigh less than one ton.[9] Only minimal foundations are required and the wings can be much lighter requiring only 1 to 10 percent of the material of the blades of a wind turbine.[10] The Google Makani 600 kW wing weighs below 2 tons including the tether and generators on board.[11] A comparable 600 kW wind turbine weighs between 50 and 100 tons without foundation.

The required components for power generation are cheap in comparison: the costs for the electricity producing generator amount to less than 3 percent of total costs. Certainly, wind drones will need more and better sensors, processors and other control components, but these cost much less than the saved materials.

STOP BUILDING LEVER ARMS

How can a wind drone save half the costs of a wind turbine? It is all about physics. A basic construction principle in engineering is to avoid a 90-degree force on an unsupported lever arm wherever possible. Large bridges are therefore supported by arches, columns, or suspension tethers. If parts cannot be supported they have to be made as short as possible.

Wind turbine engineers have done the opposite. Rightfully wanting to build ever larger and more efficient wind turbines they worked to increase the height of the towers and the length of the blades. Both are lever arms in a 90 degree angle to the wind force and they are not supported. Wind engineers would love to tether the tower and the blades. But it is not possible. The wind can blow from all directions, so the rotor has to be able to rotate around the tower and the blades have to spin freely. Nonetheless, wind engineers have excelled in building ever larger wind turbines. They hold the record for building the longest unsupported lever arms in the world. Undoubtedly a great achievement, but one that does not help saving material. The tether of a drone can be 1,000 times lighter than the tower of a turbine simply because it avoids lever arms.

UNLEASH THE DRONES

A simple physical fact cuts costs in half. Can other physical facts double the output? Since wind drones are not restricted by lever arms they can fly higher. They easily reach altitudes twice as high as normal wind towers (300 m/1,000 ft. instead of 150 m/500 ft.). Physical facts: on average the wind speed increases with altitude; higher wind speed means more wind power; wind power increases with the cube of the wind speed. Double the wind speed therefore means wind power multiplied by eight (2^3).

Altogether these physical facts lead to the conclusion that there is no such thing as a "bad location" for wind drones. Wind drones only know good and excellent wind sites. They will find enough wind at almost any site.

The impact of height differences can easily be illustrated by using wind data of Dresden, Germany (See Figure 3).[12] At the altitude of wind turbines it is a very poor wind location. Not even with the support of the generous German feed-in tariffs does it allow economic energy generation. At wind drone altitude, the wind speed is 60 percent higher (grey columns). This does not sound spectacular, but due to the cubed relationship between wind speed and power the available wind power almost quadruples (blue columns).

At this altitude Dresden becomes an extremely windy place with a wind force only matched by few wind turbine locations such as coasts, mountains or offshore locations. The world's largest offshore wind park London Array, has a comparable average wind speed of 9.2 m/s at 100-meter hub height.[13] The reason is simple. Obstacles on land like forests, hills and buildings slow the wind down. Offshore winds partly owe their

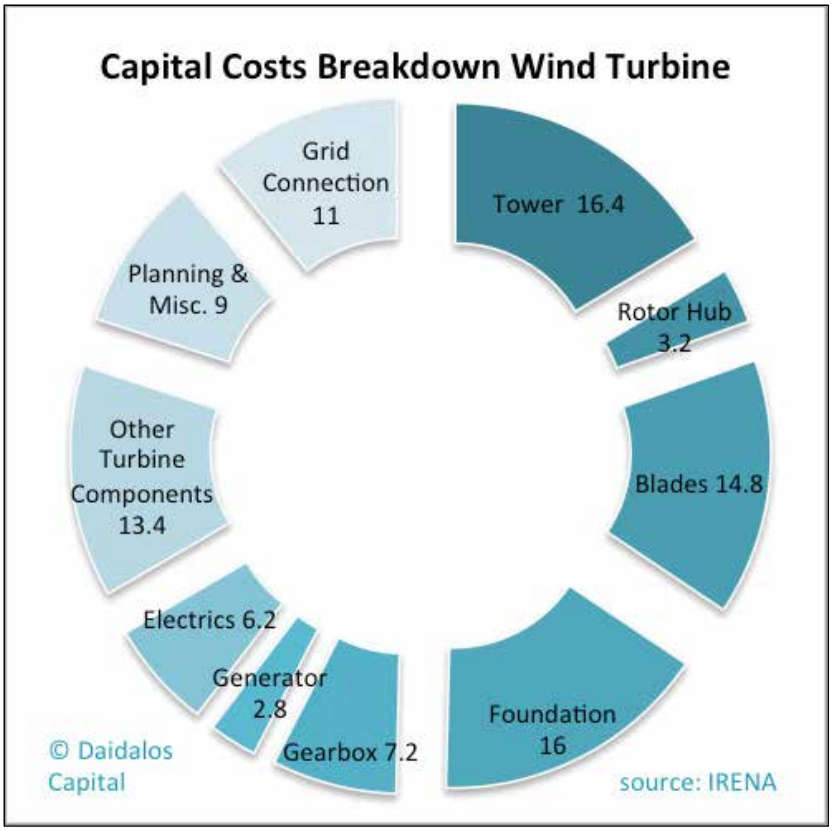

Figure 2: Capital costs breakdown of wind turbines.

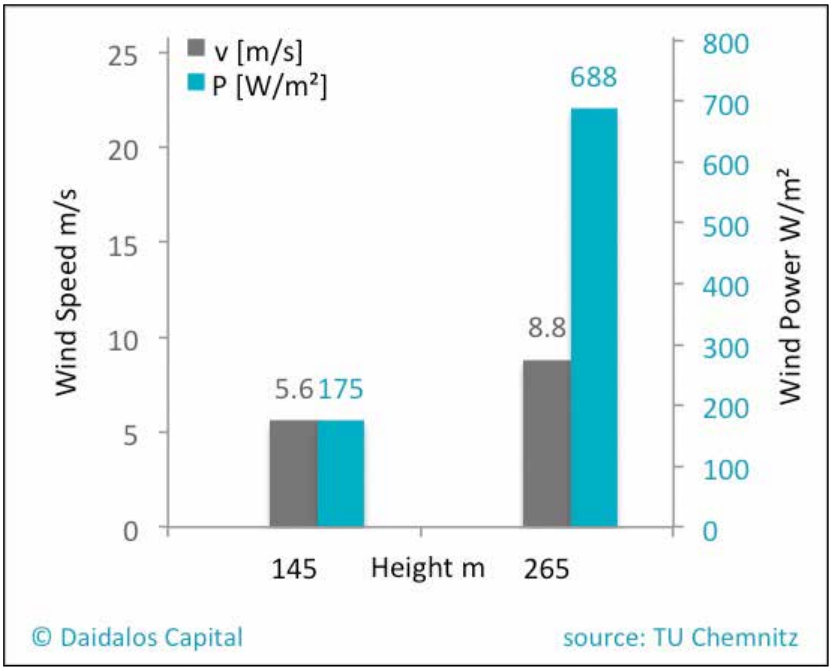

Figure 3: Wind data of Dresden, Germany, forest site.

strength to the lack of obstacles. The same applies to high altitude winds: no obstacles to slow them down.

In addition, offshore or high altitude winds are steadier and therefore a more reliable source of electricity. Offshore wind turbines run at full capacity more often. Their idle periods per year are much shorter. Their so-called capacity factor is higher. They are therefore better suited to provide base load electricity. On average the output of offshore turbines is twice as high as that of onshore turbines with the same rated capacity.[14] But since offshore turbines cost two to three times as much as onshore turbines, the advantage is quickly outweighed. Offshore wind energy is still more costly than onshore wind.[15] According to research conducted by E.ON, Germany's largest utility, offshore wind drones can boost offshore wind turbines' high yields by another 50 percent. They can run at full capacity 70 percent per annum.[16]

In summary, wind drones have lower production costs, they can access much stronger high altitude winds and therefore run at full capacity for greater amounts of time. The estimate of many airborne wind energy startups seems realistic: electricity for a quarter of the price of today's wind energy.

Google shares this belief in the cost-cutting power of wind drones. Google calculated that less than 16 percent of all the onshore U.S. sites are suitable for economic wind energy production with wind turbines. For wind drones this figure more than quadruples. 66 percent of the United States become viable.[17]

The higher capacity factor does not only lower the price, it also increases quality. The intermittency of most renewable energy sources causes a lot of concerns. Electricity grid operators face the challenge of matching the fluctuating production of renewables with demand. Current scenarios foresee the necessity to invest billions into stronger grids and energy storage. If wind drones can produce with a capacity factor of 70 percent as envisaged by E.ON, they could replace coal, nuclear and gas power plants without the necessity of massive new investments in grid and storage. Grid and distribution costs already make up for the greater part of our electricity bills. The high quality of wind drone power could become a decisive factor, even more important than its low cost.

TIME TO MARKET

The first wind drone prototypes are in operation. But when will they be market ready? Soon. Sooner than many other autonomous drones. The reasons: simplicity, safety, and the law.

ROUND AND ROUND WE GO

Various drones have various tasks which vary in difficulty. Wind drones are the ones with the easy job. They fly the same simple pattern, say a circle, over the same space over and over and over again. Conventional wisdom has it that robots and drones will first get into the dull, dirty and dangerous jobs. Sorry, wind drones, we cannot get you dirty and dangerous, but when it comes to dullness it is hard to beat your job.

Flying the same patterns over the same area means that the sensors know exactly what to expect, that the software has to know only a few flight patterns, and that the only variation can come from different weather, namely changes in wind speed and direction. And if the wind drone has to land for inspection or due to extreme weather, the landing site is also always nearby.

SAFETY (MAKES THEM) FIRST

No matter how simple a task, something can always go wrong and in case of flying objects the result can be a crash. To be a com-

mercial success, every drone will have to prove that it is safe.

In the beginning wind drones will only be installed in controlled areas in the countryside, or over the sea, where unauthorized access is not allowed. If the public cannot access the flight area, the public cannot be harmed. This is the simplest recipe for safety. Amazon on the other hand might find it difficult to deliver its parcel to your doorstep while keeping a safe distance from people.

Wind drones also have a built-in safety feature that is unique to drones: They are kept constantly on the leash, pardon, tether. So even if all controls go out of control, wind drones can only crash within the area of the tether and will not do any harm outside.

Stationary operation and the strictly defined flight area of wind drones not only increase safety on the ground but also in the air. Wind drone parks can be included in air maps and turned into no-flight zones for low flying air traffic, just as wind parks are today. Air regulators have already honored the additional safety and special features of wind drones. A draft decree of the European airspace authority EASA has an exemption for wind drones (and other drones on the tether) allowing them to fly higher than other drones without the same restrictions.[18] And under the new EASA "concept of drone operation"[19] the degree of regulation will depend on a specific risk assessment for each use of drones. In case of operation in segregated areas, where drones do not pose a risk to the public, the operator might even approve its own risk assessment. Airspace regulators worldwide are currently working on regulation for drones. They will mostly use comparable flexible concepts, since applying existing strict regulation standards for manned aviation to drones would choke off the respective national drone industry without any safety benefits. So wind drones are not only safer in practice, but this additional safety in the air and on the ground will lead to much lighter regulations. This will make them faster, easier and cheaper to build than other more hazardous and therefore stricter regulated free flying drones or aircraft.

What is true for drones is also true for autonomous cars. Many believe that autonomous cars will become commercial reality in a few years. This is not true. Fully autonomous cars have long ago hit the market. They have been available for purchase since 2008. Where? At your local Caterpillar[20] or Komatsu[21] dealer, specialized in mining equipment. More and more mines are equipped with fully autonomous haul trucks, which transport rocks and minerals within the mine. Have the engineers at Caterpillar and Komatsu outclassed their counterparts at Google, GM, Tesla, BMW, Volvo, Toyota, Audi, Mercedes by launching their product a decade earlier? Not quite. Haul trucks perform limited and well defined repetitive tasks. They operate stationary in mines, which are controlled distant places with no access for the public. There is little or no regulation on their development and use. The conclusion for drones is obvious.

HUGE MARKET

The strongest argument for wind drones is their potential market: it is huge.

To begin with, the global wind turbine market is a large market. Its volume amounted to $80 billion in 2013.[22] Its growth rate averaged 25 percent per year over the last decade[23] and the market will continue to grow strongly. But wind drones are not limited to the existing market for wind turbines. A look at the top 20 global companies with the largest revenue as compiled by the Fortune Global 500 list[24] illustrates their full market potential:

Energy is big business. But wind energy is still minuscule and accounts for less than 1 percent of total global energy use.[25] This will change. And it is mostly a question of competitiveness. Onshore wind turbines are on the brink of becoming competitive with coal and natural gas. This so called grid-parity has been reached in some regions. It means that wind energy is already the cheapest source of electricity even without subsidies. Add wind drones' potential to slash these costs to one quarter, add steadier production and add their ability to be deployed almost anywhere.

This means that wind drones cannot only compete with wind turbines in their niche but will become the cheapest source of electricity. Cheaper than coal, gas, nuclear and hydro power.

And since electric cars are on the rise, the electricity produced by wind drones will be able to play in the energy major league and compete with oil as a transportation fuel. And oil will have a hard time competing, even at the current "cheap" oil prices. Taking into account the inefficiencies of the combustion engine, oil at $60 per barrel is still a more expensive source of power for a car than the electricity produced by today's wind turbines. Based on the analysis above, oil would have to sell at a quarter of that price, below $15 per barrel to compete with wind drone energy on a pure cost of fuel basis.

The digital revolution has disrupted many markets, created vast riches and young billionaires. But we have to bear in mind that the digital revolution has only taken

place in very limited markets so far. The so-called digital giants Google and Facebook — and many others — are all competing for a share of the online advertising market. This market has a total global volume of $150 billion.[26] Compare this to the annual average $2 trillion investment into energy supply required in the next 20 years according to the International Energy Agency.[27] Compare this to the $3.4 trillion revenue that the 11 largest energy companies on the Fortune Global 500 list share. Or compare it to the total global energy market that is assumed to have a size of $6 trillion to $10 trillion. This is a difference in market size that could come close to a factor of 100. We cannot imagine what it will look like when the drones the digital revolution created take on the largest market of the world, the energy market.

WORLD CHANGING

We have illustrated how the laws of physics in combination with sensors, chips and smart algorithms can replace the tons of steel and concrete wind turbines are made of. This can make wind drone power cheaper than electricity from fossil fuels. Their ability to harvest stronger winds higher up in the air gives wind drones the potential to provide power where it is needed irrespective of the existing wind resource. Cost-effective electricity made by wind drones could even provide the basis for the clean synthetic fuels of the future. And this fuel could be available at less than today's oil price.

A lack of wind will no longer be a problem. We have seen how the wind resource dramatically increases by doubling the altitude. But this is only the first humble hop of wind drones into the air. Once these altitudes are mastered, it will be tempting to gradually go higher, until they reach the jet stream at 10 km/33,000 ft. Before, many technical and legal problems will have to be solved. But it will be attempted. The wind resources at this altitude are simply too enticing. The median energy density over New York at this height is more than 10 kW/m² [28] of which about 5 kW/m² can be used.[29] The total energy consumption per person in the U.S. amounts to 10.5 kW. This includes all electricity use, heating, car and aviation fuels, and even industrial energy consumption.[30] This means that harvesting wind in an area of 2m² (22 sq.-ft.) per person, the size of an open front door, could on average provide all our energy. If 10 wind turbines with today's dimensions were installed in that altitude over New York, they could have the same rated power as an average nuclear power plant, over 1 GW.[31] High-altitude wind energy is not only an extremely concentrated source of energy, it is also abundant. It can provide about 100 times of today's global energy consumption.[32] High altitude wind energy could allow us to live a greener lifestyle without the need to reduce our use of energy. For the energy sector this could mean nothing less than finally solving the conflict between economy and ecology.

Burning fossil fuels started the industrial revolution. It enabled the advances of mankind in the last 200 years. Without fossil fuels feeding 7 billion people on this planet would be impossible. But fossil fuels also destroy and pollute nature, poison our cities and homes and cause an ever more dangerous climate change. Furthermore, our reliance on fossil fuels leads to unjustified wealth and power imbalances, to wars over their control and to undemocratic regimes.

When mankind started to burn fossil fuels it made a huge leap forward. When it stops to burn fossil fuels, it will make another big step towards a better world. Drones will help to bring this day much closer than most of us believe today.

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Manufacturing versus remanufacturing: A technician's perspective

By Walter Christmas
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Not all wind energy students plan to climb towers for a living. Fortunately, there are plenty of career opportunities for Ecotech Institute grads that don't require them to leave the safety and security of terra firma. Two options that I discuss at length in the classroom are jobs in manufacturing of turbines and components as well as remanufacturing.

TURBINE AND COMPONENT MANUFACTURING

If you were to follow Colorado news regarding turbine manufacturing employment in the wind industry, you might think that employees are all hired and laid off routinely as they ride the waves of the on-again/off-again Production Tax Credit and the turbine sales that spike every time it is renewed. For a young, unmarried technician with little more than a car payment and some student loans, this rollercoaster is nothing to worry about. But for the rest of us, the impression of a lack of job security may dissuade us from considering employment options in turbine manufacturing. In actuality, we may be doing ourselves and our careers a major disservice by steering our careers clear of the factories, however. After all, we cannot ignore how impressive the numbers look for wind turbine manufacturing employment.

- Up to 7,000 jobs in Colorado are credited to the wind industry, the vast majority of them in the manufacturing and supply chain sector.
- Vestas Colorado manufacturing facilities employ around 3,000 people.
- Vestas plans to add 600 more Colorado employees for manufacturing.
- More than one quarter of U.S. wind energy jobs are in manufacturing.
- More than 500 supply chain/manufacturing facilities are spread out amongst 43 states.

Clearly, the occasional news headlines announcing a few hundred layoffs look more like a small market correction than a true crash. Since mid-2013, Vestas, under the leadership of Anders Runevad, has implemented efficiency measures and restructuring that has turned the company around to show healthy growth and profits. Rather than sell a Pueblo, Colorado tower factory, the Pueblo facility is operating at full throttle building tower sections to meet high demand. Sales are booming as our industry enjoys the residual effects of the most recent Production Tax Credit for safe-harbored development projects. Will a new PTC for 2015 keep the party rolling? We certainly hope so!

COMPARED TO REMANUFACTURING

Mention "remanufacturing" in a group of uptower technicians and you're likely to receive comments that might be better suited to describe rebuilt and counterfeit electronics from Asia. For reasons of propriety, most remanufacturing facilities are not openly discussed. Therefore, their virtues are quietly extolled by a handful of discrete advocates. Original equipment manufacturers (OEMs) might set them up in nondescript warehouses with small lettering on one door to ensure UPS and FedEx know where to find them. Press releases are almost unheard of, and tours for outsiders are often forbidden.

Why is such careful discretion regarding remanufacturing a common practice in our industry? OEM representatives will never utter the word "recall", but this is essentially what most remanufacturing projects are all about. While OEM sales departments fight for market share in America, arguably the world's largest potential market for turbine sales, the last thing they need is for would-be customers to learn about serial gearbox, generator, or blade issues. Warrantied or not, turbine downtime is costly. OEM asset managers carefully dance around the topic in discussions with customers to explain why a crane will be visiting several turbines over the next few weeks. Engineers

scramble to resolve the serial issues quickly and quietly. Process work instructions (PWIs) are drafted and revised as technicians and engineers collaborate to develop cost-effective solutions.

When skillfully managed, the outcome of such projects can be a wealth of knowledge regarding failure modes of components. Brand new techniques are often developed on the fly with astonishing results. In fact, this author has seen components roll out of a remanufacturing facility that are better than factory new! Performance increases beyond customer expectations can draw attention that OEMs may not appreciate. An overexposed successful recall program might gain so much positive attention that the OEM must alter their dialogue and call it something like a "Component Upgrade Program." Soon, customers will want to know why only some of their warrantied turbines are receiving this upgrade.

Secrecy is a necessary aspect of many remanufacturing projects. Loose lips sink ships; OEMs can lose millions if the public perception is not carefully controlled. So proud, accomplished technicians and engineers that deserve to brag about saving the day must quietly lurk in the shadows.

It should be noted that not all remanufacturing is provided by OEMs, and therefore they do not all have to operate under a shroud of secrecy. Shermco Industries rebuilds motors and generators in addition to many other services. Gearbox Express provides better-than-factory gearboxes built from OEM cores. As long as representatives from these companies aren't sharing damaging or otherwise proprietary OEM information, they benefit by singing their praises from the rooftops. It's clear what they have to offer, and nobody needs to apologize for it.

SIDE-BY-SIDE COMPARISON

Manufacturing and remanufacturing are options for our students who do not wish to climb turbines. But how would an entry-level job applicant choose between these options?

From a technician's perspective, manufacturing and remanufacturing share a few things in common.

- They both involve an assembly process, which is obvious.
- They both tend to be located in or near cities as opposed to wind farm jobs, which are usually at least an hour from the nearest city if not several hours.
- Beefy overhead cranes offer safety and versatility in material handling that a turbine's gantry crane cannot offer.
- Access for engineers is easier to manage than an uptower visit.
- Tools do not have to be transported and lifted uptower, nor are they limited in size and power.
- Specialist technicians trained in the PWI's are not usually required to travel for their job.
- Overtime is often expected and/or offered to technicians in both types of facilities.

How do manufacturing and remanufacturing differ from a technician's perspective?

- Bolting new components together to build a new turbine or component doesn't require deep knowledge of how a wind turbine functions, but helping to diagnose a failure mode in a component does.
- Disassembly of a failed or deteriorating component is very messy work requiring endless housekeeping, whereas a factory floor is often kept nearly spotless with little effort.
- Manufacturing a turbine exposes technicians to the opportunity to learn about all of the components rather than a single one that happens to be prone to failure.
- Manufacturing technicians might spend their entire day performing one small task on an assembly line. A remanufacturing technician will likely be responsible for solving problems that look different with every component that passes through their station.
- Manufacturing technicians might be laid off when sales slump. Remanufacturing technicians might be laid off when a recall program has been completed but is not at the mercy of the PTC.
- Manufacturing technicians often work with a large team of managers in a facility and therefore have ample opportunity to be recognized and promoted for their skill and dedication. Remanufacturing technicians tend to be part of a much smaller team with far fewer managers, but they become specialists in a particular component.

WELL-ROUNDED APPROACH

There are no rules forbidding a technician from migrating back and forth between manufacturing and remanufacturing. In fact, this practice can help a wind energy worker avoid the unemployment line during the dips in the roller-coaster ride that is the PTC. The knowledge base to be gained from such two-sided experience can be leveraged to propel a technician to quick promotions and raises as he or she would quickly prove to be too valuable to lose regardless of the current state of industry subsidies like the PTC.

VESTAS RECEIVES 429 MW OF ORDERS FROM SUNEDISON

Developer's projects in Texas and Maine to be powered by 3.3 MW platform

Courtesy of Vestas Wind Systems A/S

SunEdison, Inc. has placed two firm and unconditional orders with Vestas totaling 429 MW for wind farm projects in the United States. Vestas will supply 83 V117-3.3 MW turbines (274 MW) for a wind power plant in Texas, as well as 47 V112-3.3 MW turbines (155 MW) to power the Bingham wind power plant in Somerset County, Maine.

The total capacity of the Texas project, including equipment previously purchased from Vestas, will be 300 MW. With an installation and commissioning expected in 2015, the Texas installation will be the largest V117-3.3 MW project in the world.

The Texas order is a call-off from the Master Supply Agreement announced between Vestas and SunEdison in December 2014 for multiple U.S. projects, the potential of which totals approximately 600 MW. With today's order, Vestas has announced contracts against that agreement representing 334 MW. Likewise, the Maine order is a call-off from a similar Master Supply Agreement agreed upon in December 2013 between Vestas and First Wind, which SunEdison acquired this year. This MSA for multiple U.S. projects has a potential totaling up to 718 MW. With the Maine order, Vestas has announced orders against that agreement representing 453 MW.

To date, Vestas has secured more than 9 GW of orders for the 3 MW turbine platform globally.

Both projects include supply and commissioning of the wind turbines as well as a 10-year Active Output Management (AOM) 5000 service agreement designed to maximize energy production.

"We're pleased to move forward with this project and to further our relationship with Vestas," Paul Gaynor, SunEdison's executive vice president for Europe, Americas, and MENA said regarding the Texas order. "We look forward to installing Vestas' V117-3.3 MW turbines in Texas. The Vestas turbines we have at other projects around the country have performed well and we expect this project to enjoy similar success."

"Our 3 MW turbine platform is proving its versatility across a variety of North American

wind regimes, and we are starting to see much broader deployment across the wind belt," said Chris Brown, president of Vestas' sales and service division in the U.S. and Canada. "This project will be its first deployment in the important Texas market, where the combination of a robust design, outstanding grid support, and a large rotor make this turbine the best choice to minimize the cost of energy throughout the life of the project. We're very happy to add this latest agreement to our growing strategic relationship with SunEdison."

108 MW SUPPLY ORDER RECEIVED FOR U.S. PROJECT

Vestas has also entered an agreement to supply turbines totaling 108 MW for a project in the U.S. Vestas will provide 54 of its V110-2.0 MW model wind turbines for the project. The customer, project name, and location were not disclosed at the request of the customer. Turbine delivery is expected for the third quarter of 2016, with commissioning set for the following quarter. The contract includes supply and commissioning of the wind turbines, as well as a five-year customized Active Output Management service agreement.

— Source: Vestas

GAMESA CHOSEN AS TURBINE SUPPLIER FOR NC WIND FARM PROJECT

OEM will supply 208 MW for Iberdrola's Amazon Wind Farm U.S. East

Gamesa recently announced that Iberdrola Renewables has placed a firm order for Gamesa to supply 208 MW for the Amazon Wind Farm U.S. East in North Carolina.

Under the terms of the agreement, Gamesa will provide supply, transportation, construction supervision, technical guidance and commissioning of these 104 G114-2.0 MW turbines at the Amazon Wind Farm US East, located in Perquimans and Pasquotank counties, North Carolina. Turbine deliveries are expected to begin in Q2 of 2016, with the project to be commissioned before the end of 2016.

This project is the first utility-scale wind farm in North Carolina. The power generated by the wind farm, enough to power more than 61,000 US homes, will be supplied exclusively to an Amazon data center.

"This agreement reinforces Gamesa's presence in the United States and strengthens the long-standing relationship we have with Iberdrola Renewables globally and in North America," said Gamesa's CEO in the US, Borja Negro. He added: "This large order for our G114-2.0 MW, one of our most competitive models, was possible thanks to our technological leadership, our local know-how and our credibility with our customers."

The order is the largest order placed to date in the U.S. for the G114-2.0 MW, which is designed to yield more power, at lower cost, at low and medium wind speed sites. Gamesa has already signed orders for the supply of close to 1,500 MW in markets as diverse as Sweden, Uruguay, the US, Poland and Brazil.

With this order, Gamesa will have supplied approximately 2,300 MW of installed capacity to Iberdrola Renewables in the United States. Gamesa has a long and substantial presence in the United States, where it has installed more than 4,000 MW.

— Source: Gamesa

Siemens receives 402-MW order for German offshore project

Deal includes record 15-year service and maintenance agreement

Siemens will supply, install and commission 67 of its 6-MW direct drive offshore wind turbines with a total capacity of 402 MW at the Veja Mate Offshore wind power plant in the German North Sea. Veja Mate Offshore Project GmbH, a company owned by Highland Group Holdings Ltd, Copenhagen Infrastructure II, a fund managed by Copenhagen Infrastructure Partners and Siemens Financial Services (SFS) have now come to a final investment decision. This confirms the collaboration that had been started with a public signing at the EWEA Offshore trade show in Copenhagen in March. Also included is a 15-year service and maintenance agreement, representing the largest ever wind service order for Siemens in Germany and the second largest globally.

Siemens will provide a highly advanced offshore service logistics concept, tailored specifically for far-shore projects such as Veja Mate that uses both helicopters and a specially designed, purpose-built service operation vessel (SOV). It will be the fifth SOV to be deployed by Siemens in European waters. To ensure increased energy production this concept allows maintenance work to be carried out at almost all times irrespective of the weather conditions or wave height.

The project in German Waters is located in the North Sea northwest of Borkum island at 115 km from the shore. It will be installed at water depths ranging from 39 to 41meters. With average wind speeds of more than 10 meters per second at a hub height of 80 meters

above sea level, the site offers excellent conditions for a high energy yield. Grid access will be provided by BorWin2, a HVDC grid connection also built by Siemens. BorWin 2 was handed over to operator TenneT early this year and is already in commercial operation. Its 800 megawatts capacity encompasses the grid connection for both Veja Mate and also the Global Tech I offshore wind farms.

The financing is being provided through a combination of equity and debt, with SFS working in partnership with Highland Capital Group and Copenhagen Infrastructure Partners in the multi-source project financing structure. SFS is investing a substantial amount as equity and thus contributes a notable piece to the overall project funding.

— Source: Siemens

NORDEX TO INSTALL 10-MW TURNKEY WIND FARM IN FRANCE

Nordex SE has received a new order via its project development division in France. The customer is Saméole and the manufacturer will be installing four Gamma N100/2500 turbines for its Ondefontaine wind farm. The order includes the delivery of the turbines, their turnkey installation and long term service for the wind farm. In addition, Nordex developed the project in close collaboration with its customer Saméole.

Ondefontaine is situated near the north-west coast of France in the Basse-Normandie region, an area with a moderate amount of forest cover.

Nordex started construction work on the project in June and it is due to be connected to the grid in May 2016. Following commissioning, the manufacturer will support the wind farm for a period of 10 years on the basis of a premium service agreement. The turbines are able to supply more than 6,500 households with green electricity.

Nordex has more than 10 years of experience in developing wind projects in France. Saméole similarly has a strong local presence, and is able to contribute a lot of knowledge about the region to the project. The developer currently runs nine wind farms in France.

— Source: Nordex

PRODUCT

WindTalker cold weather turbine control anemometer

Nor-Cal Controls is releasing a new product which will increase efficiency and reduce costs to wind project owners and operators. The WindTalker-1000 is an innovative smart relay device designed to allow any existing sensor to integrate seamlessly into an existing wind turbine control platform, no matter the age, type or communication characteristics of the Programmable Logic Controller (PLC). Nor-Cal Controls partnered with Lufft, manufacturer of the VENTUS ultrasonic wind sensor, to provide a state of the art, turnkey wind sensor replacement solution resistant to the elements as well as time.

The need for a device like this arose from discussions with countless wind turbine operators and owners. Wind sensors are required for each wind turbine installed in order to correctly point the turbine into the wind. The turbines wind sensor only affects optimal performance of the turbine, but is a safety measure as well. As the sensors age, they often need replacing. Not only are mechanical wind sensors prone to repair and replacement, but they also require regular calibrations, costing time and money. Often, owners are not able to choose a sensor appropriate to their installation because of the limitations of communication with the PLC. The WindTalker-1000 removes these barriers.

Traditional wind sensors can be liable to mechanical break down and require periodic repair and/or replacement. This is due to moving mechanicals parts such in traditional cups and vanes. Mechanical parts sometimes accumulate rust, scale or other substances that can impede movement. In cold climates ice or rime is likely to build up on a sensor causing breakdown or highly inaccurate readings.

The WindTalker-1000 solution combines the intelligence of a smart relay device with the robustness of the VENTUS wind sensor. The result is a wind sensing system that is a direct

replacement to older, end-of-life sensors, providing the end user with a highly accurate, maintenance free system that will far exceed previous operable lifetimes of older technology sensors.

Nor-Cal Controls, located in Diamond Springs, CA, is a fast growing company founded in 2005 by Robert Lopez that offers complete automation solutions for the power generation industry.

— Source: Lufft USA