Airborne Wind Turbines

Clean, Consistent, and Cost-Effective Energy

Our Company

Joby Energy is developing airborne wind turbines to harness the immense and consistent power in high-altitude winds to offer a reliable, low-cost technology for producing renewable energy.

Our airborne wind turbines:

- Produce energy more consistently
  Because we operate at higher altitudes, our system produces twice the energy for the same rated power. Consistent winds at higher altitudes allow our system to achieve a net capacity factor of approximately 70% versus 35% for surface-based systems.

- Require lower capital costs
  Building our system requires significantly less materials than a surface-based turbine (approximately 1/40), resulting in low capital costs for the given rated power.

- Deliver the most cost-effective renewable energy
  Consistent energy production and low capital costs result in energy production cost per kWh competitive with the cheapest fossil fuels and much lower than any new renewable source, including surface-based wind turbines.

Our airborne wind turbines offer clean, consistent, and cost-effective energy.

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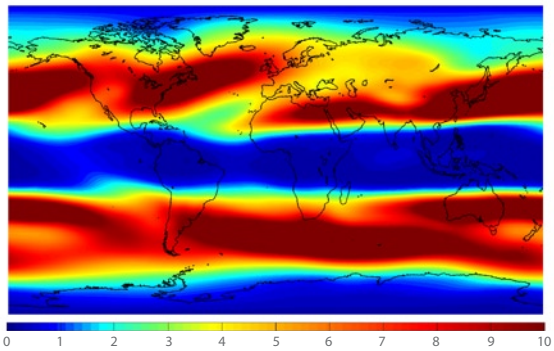
High-Altitude Wind

Wind speeds increase with altitude and when compared to surface wind and solar, high-altitude wind is more consistently available.

Our analyses have shown two potential operating regimes: the upper boundary layer (UBL) and the upper tropospheric layer (UTL). The UBL, on average, contains 25% faster winds which corresponds to double the power of surface winds. With the added benefit of higher consistency, our airborne wind turbines can produce nearly twice as much energy as a surface-based wind turbine.

UTL winds are typically five times faster than surface winds, corresponding to a tremendous power gain of 30 per unit area. Our models indicate that airborne wind turbines powered by this resource will have near baseload capacity factors and a lower leveled cost of energy (LCOE) than that of new coal power plants.

The recent confluence of technological progress, political will, and rising fuel costs create an opportune time to pursue the vast energy potential of high-altitude wind. Harnessing this resource presents a true alternative to fossil-fuel based power generation.



Average Power Density at 10,000m in kW/m^2

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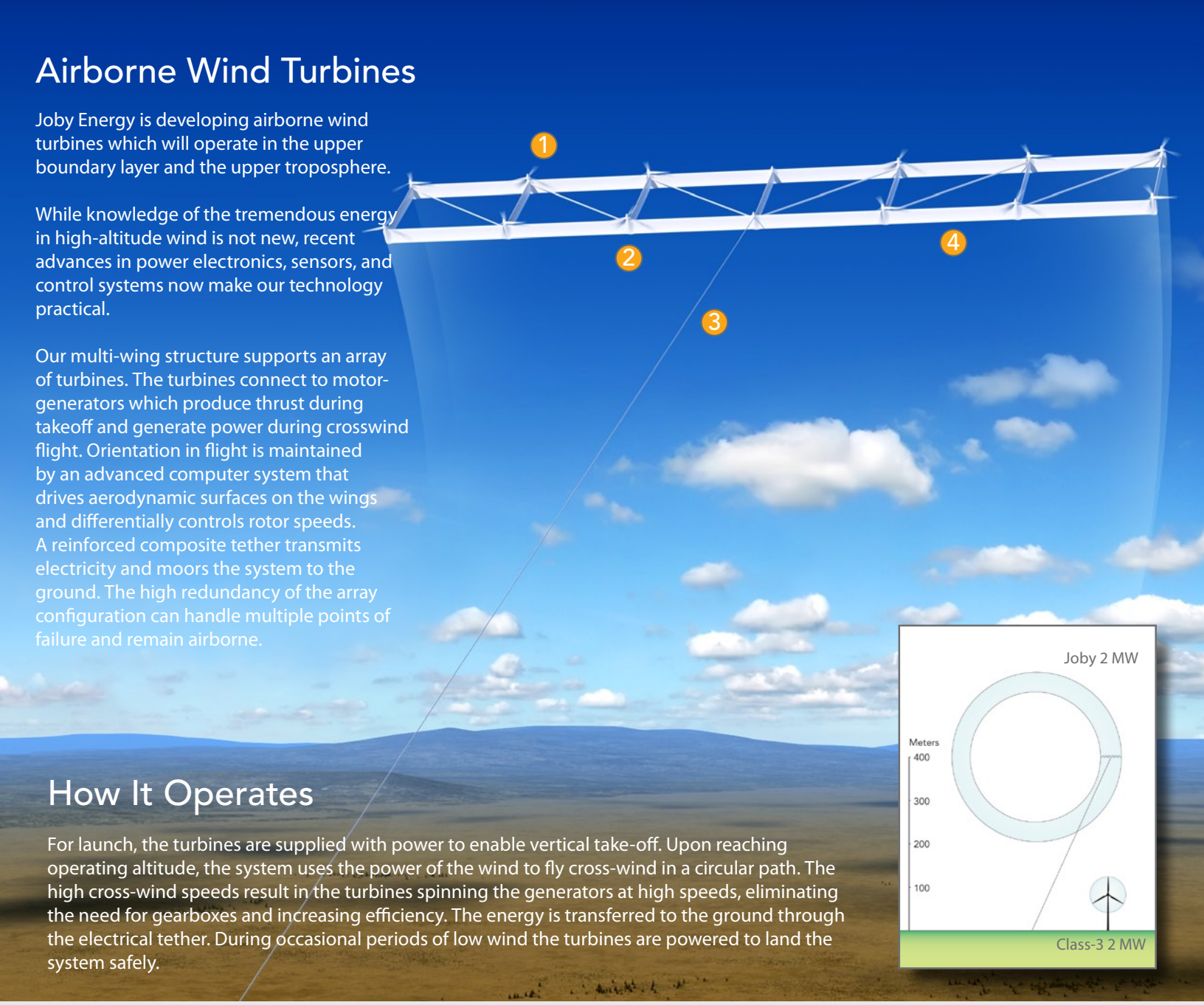
Joby Energy is developing airborne wind turbines which will operate in the upper boundary layer and the upper troposphere.

While knowledge of the tremendous energy in high-altitude wind is not new, recent advances in power electronics, sensors, and control systems now make our technology practical.

Our multi-wing structure supports an array of turbines. The turbines connect to motor-generators which produce thrust during takeoff and generate power during crosswind flight. Orientation in flight is maintained by an advanced computer system that drives aerodynamic surfaces on the wings and differentially controls rotor speeds. A reinforced composite tether transmits electricity and moors the system to the ground. The high redundancy of the array configuration can handle multiple points of failure and remain airborne.



How It Operates

For launch, the turbines are supplied with power to enable vertical take-off. Upon reaching operating altitude, the system uses the power of the wind to fly cross-wind in a circular path. The high cross-wind speeds result in the turbines spinning the generators at high speeds, eliminating the need for gearboxes and increasing efficiency. The energy is transferred to the ground through the electrical tether. During occasional periods of low wind the turbines are powered to land the system safely.

Innovations

1. **Turbine blades**
   Optimized for power generation and also provides thrust for ascent
2. **Motor-generators**
   Improve performance and reduce weight by eliminating gearboxes
3. **Tether**
   Transmits high-voltage power and provides a mechanical connection to the ground
4. **Airframe**
   Modularized for easy transportation and scalability

Capacity Factor

We analyzed the energy output potential of a 2 MW Class-3 turbine operating at 100 meters and a 2 MW Joby Energy airborne wind turbine (AWT) operating at 600 meters. The graph shows the energy output of each system based on wind data at Beaumont, Kansas USA that was collected over a period of six years. The Class-3 turbine has a capacity factor of 42% while the Joby Energy AWT yields a capacity factor of 76%.