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The red-and-white 600-foot tower rose up from the fields near Manzanares in south-central Spain, looking like an industrial smokestack lost in a rural landscape. The tower, now long demolished, wasn’t sending smoke into the atmosphere, but instead was a chimney for air heated under plastic and glass panels at its base. The goal was to see if the draft created by rising air could be harnessed to generate clean electricity.

The experimental plant, constructed in 1982, had a maximum output of 50 kW and could generate electricity without fuel. But the costs of construction and land acquisition have been a stumbling block for groups trying to replicate this design on a commercial level.

We believe the key to making this sort of technology practical is to rely not on simple updraft confined by physical towers, but on rising air that twists to form a vortex. Such vortices can confine the updraft, enabling them to rise undiluted many miles into the sky.

By building what we call an atmospheric vortex engine, one could capture the mechanical energy produced during upward heat convection when warm or humid air is admitted tangentially at the base of a cylindrical enclosure. Essentially, it’s the same source of power that drives hurricanes, tornadoes, and waterspouts. The feasibility of the concept has been demonstrated theoretically and with small scale models, but not yet in an installation large enough to power turbines.

In a natural draft chimney, like the one at Manzanares, the draft at the bottom is proportional to the difference in temperature between the rising warm air and the surrounding cooler ambient air, as well as to the height of the chimney. In a vortex, the centripetal force in the rotating column of air replaces the physical chimney and prevents cooler ambient air from entering the rising warm air stream. This happens because, when rotating air is forced inward, its tangential velocity increases to conserve angular momentum, resulting in an increase in centrifugal force which in turn pushes the air back outward as evidenced by the smooth appearance of dust devils, waterspouts, and tornadoes.

The diameter of the vortex is self-regulating and adjusts itself until centrifugal force balances radial pressure differential. The rising air in the vortex chimney is continuously replaced by moist or warm air at its bottom. The chimney and the rising air column are essentially the same.

Thermodynamically, the rising of air in this way entails work, equal to the reduction in the enthalpy of the volume of air minus the increase in its potential energy. Because the sun warms the lower atmosphere during the day, the heat content of oceanic tropical surface air is usually sufficient to produce work of between 1,000 and 2,000 J/kg. (A kilogram of air occupies about a cubic meter.)
of just 3 °C increases the work of convection by 1,000 J/kg. Indeed, sea surface temperatures of 26 °C are sufficient to sustain a hurricane; tropical sea surface temperatures can be as high as 31 °C.

By comparison, the temperature of power plant waste heat can be as high as 50 °C.

As the heated air rises, it will cool, but moisture-saturated air cools more slowly than dry air because the heat of condensation reduces the cooling rate of the rising air. Heat of condensation comes into play once the condensation level has been reached; that's usually at elevations of between 1,500 and 10,000 feet.

The heat source in a solar chimney, which cannot extend high enough to reach the condensation level, is sensible heat. The heat source in a vortex engine, where the vortex can extend well past the condensation level, can be either latent heat or sensible heat. The heat source in an atmospheric vortex engine can have a lower temperature than the heat source in a conventional solar chimney because evaporation into unsaturated air can occur at lower temperature than sensible heat flux. Reduced pressure at the base of the vortex also further enhances the heat transfer from water to air thereby increasing the enthalpy of the air and the power production.

An atmospheric vortex engine would increase the thermodynamic efficiency of a thermal plant in other ways. Cooling towers transfer waste heat to the atmosphere, which generally has an ambient temperature of between, say, 0 °C and 30 °C in temperate regions. A vortex that rises tens of thousands feet effectively dumps the waste heat at the tropopause, which is the boundary between the lower atmosphere and the stratosphere. Dumping waste heat at the tropopause makes the effective temperature of the heat sink much colder—in the neighborhood of -60 °C. By our calculations, rejecting 1,000 MW of waste heat from a 1,500 MW thermal plant to the upper atmosphere instead of doing it at ground level can generate an additional 200 MW of electrical energy. In addition, an AVE would reduce the cooled water temperature, thereby improving the efficiency of the conventional part of the power plant.

An atmospheric vortex engine would look like a natural draft cooling tower with a controlled vortex emerging from its open top. An AVE tower could have a diameter of 300 feet and stand 10 to 20 stories tall. Inside, the structure might be reminiscent of an open-air stadium, except for the presence of a vortex, some 100 feet across, anchored at the center and extending as far as 10 miles into the air.

The vortex would be generated when warm air enters the area within a cylindrical wall via tangential entry ducts, thereby filling it with spinning warm air. An annular roof with a central circular opening forces the air to converge. As the air escapes through the roof, a vortex with a diameter somewhat smaller than the opening would form.

Once the vortex is established, the pressure difference between the surrounding ambient air and the base of the vortex draws in air through the tangential ducts with enough force to turn turbines. Thus, the vortex engine could extract energy in two ways: indirectly, by increasing the efficiency of the attached thermal power plant, and via the direct action of wind turbines situated in the ducts.

Unlike naturally occurring vortices in hurricanes and tornadoes, the airflow in the vortex engine can be controlled—or even cut off—by adjustable restrictors either upstream of the heat exchangers or within the tangential entry ducts. This means that while the vortex may possess great power, it cannot become destructive.

We have tested the atmospheric vortex engine concept in small-scale models. The larger of the models was some 12 feet in diameter. Four 20 kW propane heaters located upstream of the tangential entry ducts were used to warm the air. As expected, the warm air spiraled out of the top of the model to create a vortex between one and two feet wide and extending up to 60 feet in the air. The vortex, which looked like a small dust devil, was rendered visible with saltpeter smoke emitters.

To fully demonstrate the AVE concept, however, it's likely necessary to build and test a prototype at an existing thermal power plant. Building the prototypes at existing thermal power plants would be advantageous because of the availability of a controlled heat source of relatively high temperature. Possessing some 20 or 30 percent of the capacity of the existing cooling tower, the prototype would be able to accept a fraction of the waste heat from the plant. A small gas-fired power plant in a rural location with a dry cooling tower that is considering adding cooling capacity could be a good candidate site for an AVE prototype, since it could be developed without risk to existing plant operation.

As a minimum, the prototype would add valuable cooling capacity and would reduce cooled water temperature for the plant. But once vortex control has been demonstrated under low-heat and low-airflow conditions, turbines could be added to the air ducts. Eventually, the prototype could be replaced with a full-scale vortex engine capable of handling the complete plant-cooling load while also producing power.

Although the atmospheric vortex engine offers many advantages for thermal power plant cooling, it should be noted that man-made heat sources are not required for the AVE to generate power. Air that has been warmed over sun-drenched land or warm seawater can be the heat source. Thanks to the vortex's ability to reach miles into the atmosphere, it doesn't take a high temperature to drive the built-in turbines.

While the atmospheric vortex engine promises to draw a great deal of energy from the waste heat of fossil-fuel-burning power plants, they have the potential to generate electricity using no fuel at all.