to happen within five years, will likely involve piloted flights. But the company's ultimate vision is for its electric air taxis to operate autonomously. In 2017, the company completed an uncrewed test flight in Dubai.

"Volocopter is focused on serving the inner-city mission," says CEO Florian Reuter. With one-way fares in the "hundreds rather than thousands of dollars," Reuter says the service's target customers fall into three categories: business professionals looking to get quickly from point A to B, commuters who want to beat rush-hour traffic, and tourists.

Electric air taxis could also serve as corporate campus shuttles and help shift cargo between depots and distribution hubs, says Roei Ganzarski, CEO of magniX, a Seattle-based firm developing motors for electric planes. "I don't think we will see thousands of these flying around each city as some companies would like the public to believe…but I believe eVTOLs will play a significant part in the future of mobility."

However, it could take 10 to 15 years for this vision to become reality, says Ganzarski. Among the hurdles he cites are battery power, regulatory issues, and the ability of fully autonomous aircraft to handle emergencies.

Pilots act as a fail-safe in many respects, says pilot and aviation professor emeritus Jason Middleton from the University of New South Wales, in Sydney. "Weather is unpredictable; it can quickly develop from nothing into a raging thunderstorm," he says. "Who's going to predict where [air taxis] can or can't fly? And what happens when they're in the air and can't go to their destination?"

One answer is unmanned aircraft system traffic management platforms, or UTMs for short, which are already in place for drones. Volocopter is looking to use UTMs to govern its air taxis. "You can take most of the airspace-management techniques we use in drones and apply it to air taxis," says Pamir Sevincel, who leads urban air mobility strategy at AirMap, which counts Volocopter as a client.

AirMap has developed UTM capabilities for drones, such as digital flight plans, aircraft surveillance and monitoring, and dynamic rerouting during emergencies. The California-based company plans to enable pilots or fleet managers for drones and electric air taxis to update flight trajectories based on an automated assessment of risk and potential safety issues along planned routes.

Infrastructure—vertiports with passenger lounges, as well as battery-charging and aircraft maintenance stations—must also be built before electric air taxis can become a commercial reality. Volocopter has partnered with Skyports, a British infrastructure firm that recently unveiled the first prototype of its VoloPort—the air taxi equivalent of a helipad—in Singapore.

Volocopter's Reuter says his firm is working closely with global aviation authorities, and he's well aware that public acceptance of autonomous transport will be key. "Many people picture the skies becoming dark and aircraft whizzing around the city without any control or rules. That's a very negative and chaotic image," he says. "But let's take it step-by-step and evaluate how it goes." —SANDY ONG

An extended version of this article appears in our Cars That Think blog.

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NEWS

AT LAST, WAVE ENERGY TECH PLUGS INTO THE GRID

A buoy will feed power to Oahu this month

Ocean waves are powerful and perpetually replenished. But unlike the wind and sun, waves remain a largely untapped source of renewable energy, despite their enormous potential. A slew of projects is starting to change that, with large prototypes launching near coastlines worldwide.

In Hawaii, the OceanEnergy Buoy is slated to connect to the island of Oahu's electric grid this month. The 749-metric-ton device was recently towed from Portland, Ore., to the U.S. Navy's Wave Energy Test Site, where the bright yellow buoy will undergo a year of performance tests. The project builds on a decade of research and several smaller iterations, including a quarter-scale model that was tested for three years in Ireland's Galway Bay.

"The difficulty has been in developing a technology that actually survives in the marine environment, which can be very harsh," said John McCarthy, CEO of the Irish buoy maker OceanEnergy.

To limit seawater effects, McCarthy's team designed a device that puts mechanical parts above the surface. The "oscillating water column" system features a semi-submerged chamber, inside of which an air pocket is trapped above a column of water. When waves crest and water enters the chamber, it forces the air upward, spinning a Siemens subsidiary's turbine system to generate electricity. As water recedes, it creates a vacuum that sucks in outside air and continues driving the turbine.

The 1.25-megawatt buoy will be moored to a 60-meter-deep berth and should withstand gale-force winds and extreme waves. A subsea cable will link it to Hawaiian Electric's grid, which still runs primarily on imported oil.

About 100 people built the buoy over 14 months at the Swan Island shipyard in Portland, said Tom Hickman of U.S. shipbuilder Vigor Industrial. Workers cut, formed, and welded steel plates into three massive sections to form the L-shaped hull, then installed mechanical and electrical components. On a crisp October morning, company leaders and dignitaries held a completion ceremony, days before a tugboat dragged the buoy up the Columbia River and across the Pacific Ocean.

Tyler Gaunt, a project manager for Vigor, said he was proud to have successfully finished the project but happy to see the device leave. Constructing a first-of-its-kind prototype at a large scale meant constantly solving problems under a relatively tight deadline. For instance, the supportive steel "stiffeners" that are typically applied inside ship hulls went on the buoy's exterior, to avoid creating drag within the air chamber.

"It was essentially the opposite of how we would normally construct a ship," he said from the shipyard.

Globally, about 19 megawatts of "wave energy converters" were deployed from 2010 to 2018, though some devices were decommissioned after pilot tests, according to Ocean Energy Europe (an industry organization not connected with OceanEnergy). The bulk of projects have been in the United Kingdom and Western Europe, with other devices deployed in China, Australia, New Zealand, and the United States.

Wave energy is one of several technologies that harness the ocean's natural features—tides, winds, water temperatures, salinity—and could provide significant amounts of clean electricity. Waves off U.S. shores represent some 2.64 trillion kilowatt-hours in theoretical annual energy potential—equivalent to about two-thirds of the nation's electricity generation in 2018, according to an estimate by the U.S. Department of Energy. This resource is abundant at higher latitudes, where colder temperatures and weak sunlight make it harder to operate other renewables during certain months.

"Wind and solar are really cheap and ubiquitous on land, but there are challenges with those technologies," said Bryson Robertson, codirector of the Pacific Marine Energy Center and an Oregon State University associate professor. "In places with very aggressive decarbonization agendas, we're going to need all renewable resources to really start to mitigate our impact on the climate."

Marine technologies still face significant hurdles to achieving commercial scale. It's not yet clear how spinning turbines and rotating blades will affect wildlife. Supporting infrastructure, such as offshore grid connections, isn't widely available. Licensing and permitting processes must first ensure that devices don't obstruct commercial fishing, whale watching, or other activities.

Such issues have stifled investment, so public agencies and research institutions are leading the way, with over a dozen testing hubs worldwide. In Scotland's Orkney Islands, the European Marine Energy Center has 13 grid-connected berths for wave and tidal devices. New sites are under way in Western Australia and Jeju Island, South Korea. At the U.S. Navy hub in Hawaii, three other developers—Columbia Power Technologies, Northwest Energy Innovations, and Oscilla Power—are also expected to test wave energy converters starting in 2021.

Robertson said OceanEnergy's yellow buoy represents a valuable "data point" in the broader effort to improve performance and drastically reduce electricity costs from marine technologies. "We need to start putting these devices in the water so we can start to learn lessons," he said. —MARIA GALLUCCI

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OCEANENERGY

SURF'S UP: OceanEnergy's buoy would be one of many such devices on a utility-scale wave farm.