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ALSO IN THIS ISSUE

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A Seaglider model will be tested on Tampa Bay this year.

Some Trends in Decarbonizing Earth, Sea and Sky Machinery

The Grid

Would an extra laundry load bring down the grid? That's all the electricity EVs need every day, on average. According to the U.S. Bureau of Transportation Statistics, the average driver in the United States drives only 29 miles per day—the equivalent electrical charging load of running a clothes dryer for one hour. The EV charger can even seamlessly share the clothes dryer circuit; there is no pressing need to install a separate circuit breaker or upgrade the house circuit breaker panel.

Unlike power generation at dams, nuclear power plants or fossil fuel fired plants, solar power can be widely distributed across rooftops and vacant land to supply power close to demand location. Local battery storage is now feasible and available. The technology is already established to feed power back into the grid from both EVs and stationary batteries, which makes the grid more robust. Some communities, such as Babcock Ranch in Florida, have built their own solar farm and accompanying battery farm. A recent Stanford University study led by Professor Mark Jacobson found that a 100% renewable grid with no blackouts is feasible.

Electric Earthmovers

Diesel engines in construction machinery are roaring loud, robustly vibrating, highly polluting, and seemingly extremely

Unlike power generation at dams, nuclear power plants or fossil fuel fired plants, solar power can be widely distributed across rooftops and vacant land to supply power close to demand location.

by Ken Sides, PE, PTOE, CNU-a
Sam Schwartz Consulting

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Volvo Electric Compact Excavator Model ERC25

Volvo E-frontloader Volvo Electric Compact Wheel Loader Model L25

powerful. Electric motors are an old, mature technology, but new materials, software design tools, electronic controllers and controller software are now rapidly advancing the state of the art. Electric motors are silent, vibrationless, emissions-free and just as powerful as the diesel engines in earthmovers. The diesel engines in Volvo's line of crawler excavators range up to 608 HP for the largest models. The Performance trim of Tesla's Model S family sedan has two electric motors totaling 778 HP, so e-motors can easily handle the demands of earthmoving equipment. (The Plaid trim has 1020 HP.) Realizing this, Volvo has introduced electromobility technology to the construction industry with a line of five small electric construction machines and a prototype mid-sized electric excavator. Lars Arnold, Product Manager Electromobility, Volvo Construction Equipment, says,

Operator fatigue is substantially reduced. The absence of diesel engine racket means a worker standing near the earthmover can talk to the operator—a boon for communication and safer operations.

"We have quite ambitious goals to be a fossil-free company by 2040, and we have committed to the science-based targets initiatives to help us reach that goal. Starting with smaller machines made sense due to customer demand and existing technology, but electrifying larger machines is definitely on our road map and the technology is in the works. I think full-sized models will likely be a mix of diesel, hybrid and electric by the end of this decade. I'm excited about the innovation that's to come in the years ahead."

The hydraulic systems in Volvo's e-earthmovers are unchanged from diesel earthmovers but instead of the hydraulic pump being driven by a diesel engine, it's driven by a smooth, clean, silent electric motor which achieves the same performance as its diesel engine equivalent. The operator's controls are the same as with diesel power but are pleasingly more responsive to operator input because electric motors don't have to first rev up to produce peak torque. Operator fatigue is substantially reduced. The absence of diesel engine racket means a worker standing near the earthmover can talk to the operator—a boon for communication and safer operations. Working at night in populated areas can be acceptable because quiet electric construction equipment doesn't disturb urban or suburban settings. Operating inside building shells requires no ventilation systems. The e-motor, controller electronics and batteries require no maintenance. Jacques Marais of early adopter company Baltic Sands in Yucca Valley, California, says, "This is where ideology meets reality."

Diesel engines must idle continuously even when the earthmover isn't performing work, but electric motors consume power only when the e-earthmover is actually working. That's why the current 4-hour battery duration is generally long enough for an 8-hour workday. Some contractors like to add charge during the lunch break. As with EVs, fast charging is an option. Electricity costs less than diesel, and contractors don't have to haul diesel fuel to the site.

Charging the Volvo e-machines at remote locations is handily accomplished with a Beam EV ARC 2020 solar array, a sustainable, scalable power source with battery that requires no permits or construction work to set up at a construction site. The Leon County Sheriff's office recently purchased one through Florida statewide contract number FSA20-EQU18.0 Heavy Equipment, under which any Florida local government or public agency can purchase the solar-powered EV chargers at pre-negotiated prices. Able to resist extreme weather events, the transportable, off-grid solar-powered chargers are flood-proof to 9.5 feet and wind-rated to 120 mph. As Beam Global CEO Desmond Wheatley points out, "It makes perfect sense for the Sunshine State to drive on sunshine."

In the Air and on the Water

Airborne electric propulsion is perhaps electromobility's greatest challenge because the weight of today's batteries limits the duration and range of the aircraft. For aviation, electric motors offer cool, quiet operation, very low complexity, extremely high reliability, and dramatically lower operating and maintenance costs compared to ICE aircraft engines. Modern electric aircraft motors can have three separate and independent windings controlled by three independent electronic controllers and powered by three independent battery sets. This triplicate redundancy can be easily doubled again by stacking two e-motors on the same propeller shaft.

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Rendering of Lilium Jet at Vertifport atop the Ft. Brooke parking garage in downtown Tampa

Pilot training is an attractive initial use case because a typical flying lesson is only 50 minutes long with 20 minutes between students—enough time to recharge. Because fuel and maintenance are a large part of what it costs to learn to fly, e-planes will dramatically reduce the cost-of-entry barrier to the aviation profession. Dramatically lowering the cost of training is key to solving the pilot pipeline problem now threatening to constrain commercial airline operations.

When President Jimmy Carter deregulated the airlines in 1978, the airline industry immediately abandoned unprofitable small airports and moved to the hub-and-spoke system of today. There are 5,000 small public airports in the United States plus many additional small private airports. Dramatically reduced ticket prices made possible by electric airplanes could at last make it profitable to provide air service to small communities.

Bye Aerospace in Centennial, Colorado, is clean-sheet designing the eFlyer 800, an 8-seat e-plane intended to serve regional routes with legs as long as 500 nm while cruising 280 knots at 35,000 feet and incurring one-fifth the operating costs of legacy twin turboprop airplanes. “The capabilities, efficiencies and low operating cost benefits of Bye Aerospace’s eFlyer 800 will be ideal for regional flight needs of Florida’s thriving tech and business hub,” said George E. Bye, CEO of Bye Aerospace. “For example, business commuters could fly with speed and high-end comfort on the 45-minute, 200-mile flight between Tampa and Miami as opposed to a 5-hour driving time with the assurance they are not contributing to the nation’s carbon footprint.”

Harbour Air plies the triangular air routes between Seattle, Vancouver, B.C., and Victoria, B.C., with as many as 300 flights daily. Its fleet of 39 classic de Havilland Beaver seaplanes have huge, very loud radial gas engines. Harbour Air is taking a more

direct route to electrification by replacing the gas radial engines with powerful, silent, vibrationless electric motors manufactured in Seattle by Chinese-owned MagniX.

Pipistrel in Ajdovščina, Slovenia, is already manufacturing the first certified electric trainer aircraft, the Alpha Electro, which flew 227 miles over Central California in a demonstration flight supported by several Beam off-grid charging stations. "This historic world record marks the start of a new chapter for zero emissions aviation while breaking down the barriers to rapid adoption of commercially available clean aircraft," said Beam Global CEO Desmond Wheatley. "Our products make airport charging infrastructure available now, ushering in a new level of aviation access for rural and suburban denizens."

Hobby drones have been autonomous for years. Pipistrel is now designing the Nuuva V300 hybrid-electric eVTOL (electric Vertical Take-Off and Landing) unmanned cargo aircraft, because the company believes freight is the best entry segment for autonomous aircraft. Pipistrel Chief Technology Officer Tine Tomažič says, "With the effects of climate changes more and more evident in Florida, it has become apparent that incremental development is no longer a viable solution. In aerospace in particular, one needs to take into account the complete lifecycle of the product and account for climate impact from conception through to recycling. Pipistrel is working across all fronts in order to facilitate carbon neutral flying and will no longer develop any aircraft that are not at least hybrid-electric, if not zero emission by nature."

Most of the Urban Air Mobility (UAM) aircraft in development, such as the Joby Aviation eVTOL, look like scaled-up consumer drones with their multiple outboard rotors. German aerospace company Lilium GmbH takes a different design approach to delivering regional air mobility with high-speed connectivity. Lilium's 7-seat Jet also employs distributed electric propulsion, yet looks like a conventional airplane, except that its 36 electric fan motors are spread out

Harbour Air Electric de Haviland Beaver

along its main wing and canard wing. The motors provide vectored thrust in ducted cowlings that tilt down for vertical take-offs and landings but rotate up to horizontal alignment for level flight.

Lilium has selected Florida to be its first market and has identified 14 inter-city routes in our state. Lilium's targeted first route is shuttle flights between downtown Orlando and downtown Tampa—with one of its small-footprint vertiports perhaps located on the top deck of the Ft. Brooke Parking Garage. Ferrovial, a global infrastructure operator, has partnered with Lilium to build scalable zero-carbon vertiports throughout Florida. Lilium projects a cruise speed of 175 mph for a range of 155 miles. Lilium calculates the Jet will emit only 12 grams CO_2 per passenger-kilometer, compared to 31 g/pkm for EVs, 142 for ICE cars and 186 for conventional passenger jets. The projected ticket price is less than $1 per passenger mile. The intent is to eventually scale the plane larger without significant increase in the near-silent sound profile. The City of Orlando has formed a partnership with Lilium to build a vertiport in the Lake Nona area and Mayor Rick Kriseman has expressed hope Lilium will do likewise in St. Petersburg. "This is the perfect

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Volvo Electric Compact Wheel Loader Model L25 charging at Beam Station

means of transportation, something that can take off and land everywhere," company founder Daniel Wiegand told the *New York Times*. "It's very fast, very efficient and low noise."

A typical hydrofoil boat employs a shipboard ICE-driven pump to suck water into the front of the submerged foil wing and up into the boat, through the pump, and back down to exit forcefully from the back of the foil to provide thrust. But in another example of distributed electric propulsion, Swedish company Candela mounts slim torpedo-shaped electric motors at the feet of its 30-passenger C-40 Ferry's hydrofoils, where they drive counter-rotating propellers for maximum thrust at the low rpms necessary to avoid inefficient cavitation, propel the craft up to 30 knots/hour, and achieve a range of 60 nautical miles. Candela states their e-hydrofoils reduce operating costs 95%.

As every pilot knows, planes flying just above the runway ride a cushion of air known as the wing-in-ground effect that provides substantial aerodynamic efficiency. The same principle is being exploited by Boston startup REGENT in partnership with Brittany Ferries in France. Its Seaglider ferry has both hydrofoils and an airplane wing with eight propellers driven by electric motors. The Seaglider ferry docks like a boat and begins each journey with its boat hull

conventionally floating on the water, rises on the hydrofoils as it gains speed to 20-40 mph, and upon reaching open water goes airborne to ride the wing-in-ground effect above the water as it retracts the foil and very efficiently flies the rest of the way as fast as 180 mph, all while staying within a wingspan of the water's surface. Seaglider models are planned to range in capacity from 50 to 150 passengers. REGENT has selected Tampa Bay to test a 12-passenger Seaglider model in 2022. Tampa Mayor Jane Castor has welcomed the new, efficient and speedy transit technology and told the *Tampa Bay Times*, "We are excited not just to host the testing of the technology demonstrator, but also for our city to be one of the first coastal routes serviced by Seagliders in 2025 and beyond." Southern Airways Express in Palm Beach has ordered 20 Seagliders to integrate into its existing air networks. " When other countries in the world are too slow, Denmark must take the lead," Danish Prime Minister Mette Frederiksen declared on New Years Day as she committed to all domestic flights to be fossil-free by 2030 and she added "The widest shoulders should carry the most." France and Sweden have similar goals.

A No-Tech, Roundabout Way to Decarbonize Intersections

Modern roundabouts have no traffic signals and consequently have no red light queues of idling vehicles burning fossil fuel and emitting quantities of toxic fumes and GHGs. The fuel savings can be substantial. Carmel, Indiana, a suburban town of about 100,000, has 140 modern roundabouts. The City of Carmel calculates that the fuel savings amount to 24,000 gallons of gas/roundabout per year. With roughly double the population, the equivalent for Tallahassee would be approximately 280 modern roundabouts and 6,720,000 gallons of gasoline not consumed annually. At final buildout and, say, $2.49/gallon the Tallahassee driving public would henceforth save $16,732,800 annually, or the equivalent every year to pay back the construction cost of three or four modern roundabouts—a virtuous circle, indeed.

Modern roundabouts are the most resilient form of intersection because they need no electrical power to operate safely and efficiently before, during and after a major storm. Modern roundabouts reduce intersection fatalities 90-100% because by design they have no head-on, T-bone or high-speed crashes. Carmel's fatality rate per 100,000 population is 2; Tallahassee's rate is more than four times worse at 8.7 (but lower than the national rate of 12 or Florida's rate of 14).

Keeping up with Developments

These sources are helpful for engineers wanting to follow developments closely: a free subscription to *Charged* magazine, which is published in St. Petersburg, Florida, by Christian Ruoff, BS Mechanical Engineering, Drexel University; and a free subscription to *Electric & Hybrid Marine Technology International* magazine. For learning in-depth consider: the *2022 International Battery Seminar & Exhibit,* to be held in Orlando March 28-31; the 2022 *Electric & Marine Expo North America* to be held in Houston March 22-23; or the *2023 Vertical Flight Society 9th Annual Electric VTOL Symposium*. *Aviation Week and Space Technology* magazine covers developments in electric air mobility. Joining the *Vertical Flight Society* (VFS) is an inexpensive way to stay current with aerial mobility developments. A VFS chapter is being formed in Tampa Bay—if interested, contact the author at KSides@SamSchwartz.com for more information.

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