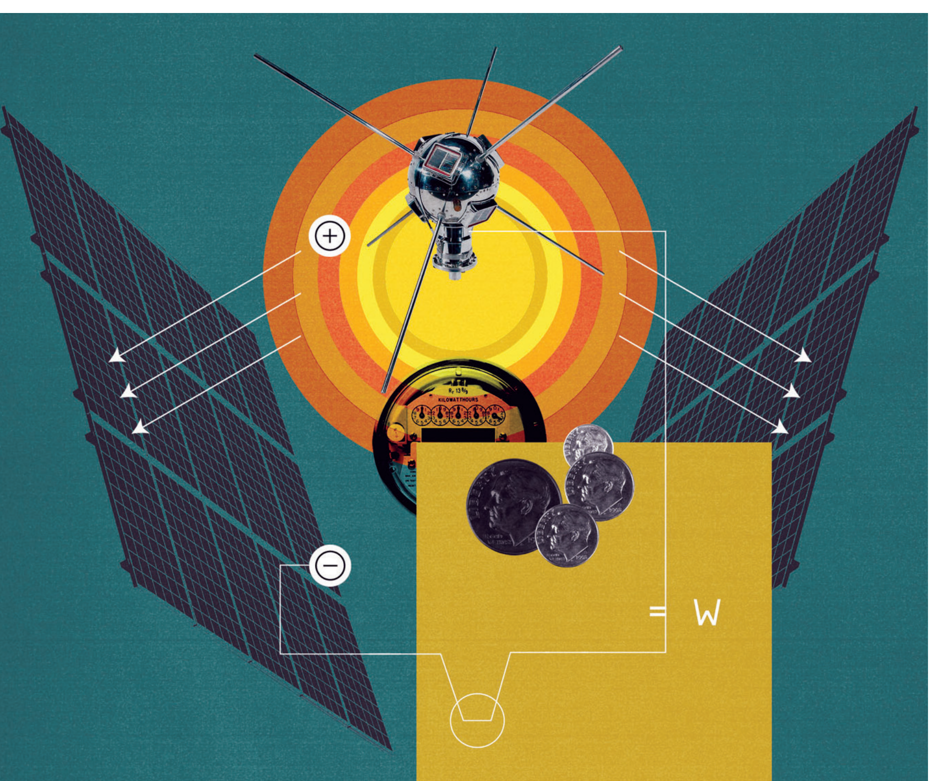
MARCH 1958: THE FIRST PVs IN ORBIT

SIXTY YEARS AGO THIS MONTH, a rocket lifted off from Cape Canaveral bearing the Vanguard 1 satellite, a small, 1.46-kilogram aluminum sphere that was the first to use photovoltaic cells in orbit. • As a safeguard, one of the satellite's two transmitters drew power from mercury batteries, but they failed after just three months. The six monocrystalline silicon cells, each roughly 5 centimeters on a side and delivering a total of just 1 watt, kept on powering a beacon transmitter for 14 months, until May 1964. • It happened in space because cost was no object. In the mid-1950s, PV cells ran about US $300 per watt. The cost fell to about $80/W in the mid-1970s, to $10/W by the late 1980s, to $1/W by 2011, and to about 40 cents per watt in 2017. That's enough to bring the total system cost–for installations with single-axis tracking–close to $1/W. Forecasts indicate that the cost will fall by as much as 60 percent further by 2025. • This is good news because PV cells have a higher power density than any other form of renewable energy conversion. Even as an annual average they already reach 10 watts per square meter in sunny places, more than an order of magnitude higher than biofuels can manage. And, with rising conversion efficiencies and better tracking, it should be possible to increase the annual capacity factors by 20 to 40 percent. • But the anniversary of the launch reminds us that it has taken quite a while to get to this point. Edmond Becquerel first described the photovoltaic effect in 1839 in a solution, and William Adams and Richard Day discovered it in 1876 in selenium. Commercial opportunities opened up only when the silicon cell was invented at Bell Telephone Laboratories, in 1954. Even then, the cost per watt remained around $300, and except for use in a few toys, PVs were just not practical.



It was Hans Ziegler, an electronic engineer with the U.S. Army, who overcame the U.S. Navy's initial decision to use only batteries on the Vanguard. During the 1960s, PV cells made it possible to power much larger satellites that revolutionized telecommunications, spying from space, weather forecasting, and the monitoring of ecosystems. As costs declined, applications multiplied, and PV cells began to power lights in lighthouses, offshore oil and gas drilling rigs, and railway crossings.

I bought my first solar scientific calculator–the Texas Instruments TI-35 Galaxy Solar–when it was introduced, in 1985. Its four cells, each one about 170 square millimeters, still serve me well more than 30 years later.

But serious electricity generation had to wait for further module price declines. By 2000, global PV generation had reached 1.2 terrawatt-hours; a decade later it came to 33.8 TWh, and by 2016 it stood at 333.1 TWh. The annual rate of installation rose from the 0.015 square meters of the Vanguard 1, in 1958, to the approximately 500 million m^2 that were added to solar farms and roofs in 2016–a rise of 10 orders of magnitude. But all that PV area still accounted for just 1.3 percent of the world's total electricity.

Another order-of-magnitude increase is thus needed before PV will rival global hydroelectricity generation, which supplied more than 16 percent of world demand in 2016. Not even the most optimistic forecast–that of the International Renewable Energy Agency–expects PV output to close that gap by 2030. But PV cells might be generating 10 percent of the world's electricity by 2030.

By that time some seven decades will have passed since Vanguard's small cells began to power its beacon transmitter, and some 150 years since the photovoltaic effect was first discovered in a solid. Energy transitions on a global scale take time. ■

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