to the electrification of the car fleet and will raise challenges of adequate material supply: Today, the advanced Tesla Roadster has a lithium-ion battery pack weighing 900 pounds, which delivers just 190 MJ of energy. In contrast, a 10-gallon tank of gasoline weighs 62 pounds and delivers 1,200 MJ of energy. To provide the equivalent energy to a typical gasoline car, an electric-car battery pack would need to consume resources weighing 5,700 pounds, nearly the weight of the last Hummer model.

The more dense an energy form is, the less land is needed for its deployment. Because many alternative energies are far less energy dense than fossil fuels, large-scale deployment will incur considerable land costs. For example, a single 1,000-megawatt coal-fired power plant requires 1 to 4 square kilometers (km^2) of land, not counting the land required to mine and transport the coal. In contrast, 20–50 km^2, or the size of a small city, would be required to generate the equivalent amount of energy from a photovoltaic array or from a solar-thermal system. For wind, 50–150 km^2 would be needed; for biomass, 4,000–6,000 km^2 of land would be needed. The sprawling city of Los Angeles, in comparison, covers 1,200 km^2. The land-use issue is thus a problem not only of biofuels production; siting of alternative energy projects will likely be a constant challenge because of the inherent high land footprint.

7. WATER

Water ranks with energy as a potential source of conflict among peoples and nations, but a number of alternative energy sources, primarily biomass-based energy, are large water consumers critically dependent on a dependable water supply. As seen in Figure 2, the "full-cycle" water requirement (including water for growing and processing biofuels) for key ethanol and biodiesel feedstocks is in some cases hundreds or even many thousand times higher than for the refining of gasoline. In well-watered regions with regular and adequate rainfall, much of this water can be provided through rain; in a region such as California, where no rain falls during the summer growing season because of its Mediterranean climate, irrigation is an absolute necessity for growing commercial biomass feedstocks. However, all of California's water resources have already been

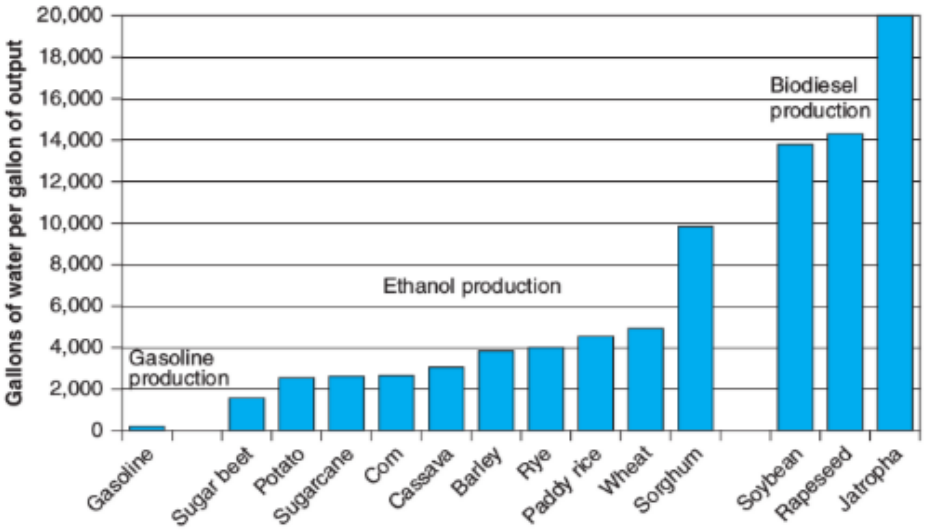

FIGURE 2 Full-cycle water requirements for biofuel production.
Source: Winnie Gerbens-Leenes et al., "The Water Footprint of Bioenergy," *Proceedings of the National Academy of Sciences* 106, no. 25 (June 23, 2009), 10219–10223.