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November 23, 2026

Energy Choices in a Water-Constrained World: Why Agriculture-Based Energy Is the Worst Possible Option

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The Issue

While technological innovations continue to expand energy abundance and access around the world, a similar revolution with water has yet to occur. As crop production, electricity generation, and computing capacity grow, so does each sector’s demand for water. The long reign of energy efficiency as the predominant factor for engineering design, industrial and consumer choice, and government policies is inexorably giving way to water-use efficiency. By that measure, agriculture-based energy is the worst possible choice, and corn ethanol is among the worst within it.

Liquid freshwater is a tiny fraction of all water on Earth, but it is the essential ingredient for sustaining all life. It is also essential to all human endeavor—from feeding the population to fabricating microchips. Freshwater is an infinite resource in the sense that nature recycles its supply through evaporation and precipitation; however, it is limited in the rate at which it can be sustainably consumed without draining lakes, lowering water tables, and turning pastures into dust bowls.

Water use can be divided into three categories: agriculture, community, and energy (ACE). *Agriculture water* is used to grow crops and raise livestock. *Community water* supports human needs, such as drinking, bathing, and washing. *Energy water* is used to produce and consume energy—with the largest amount used to run thermal power plants that generate grid electricity, and lesser portions used to mine and refine primary energy fuels and create alternative energy.

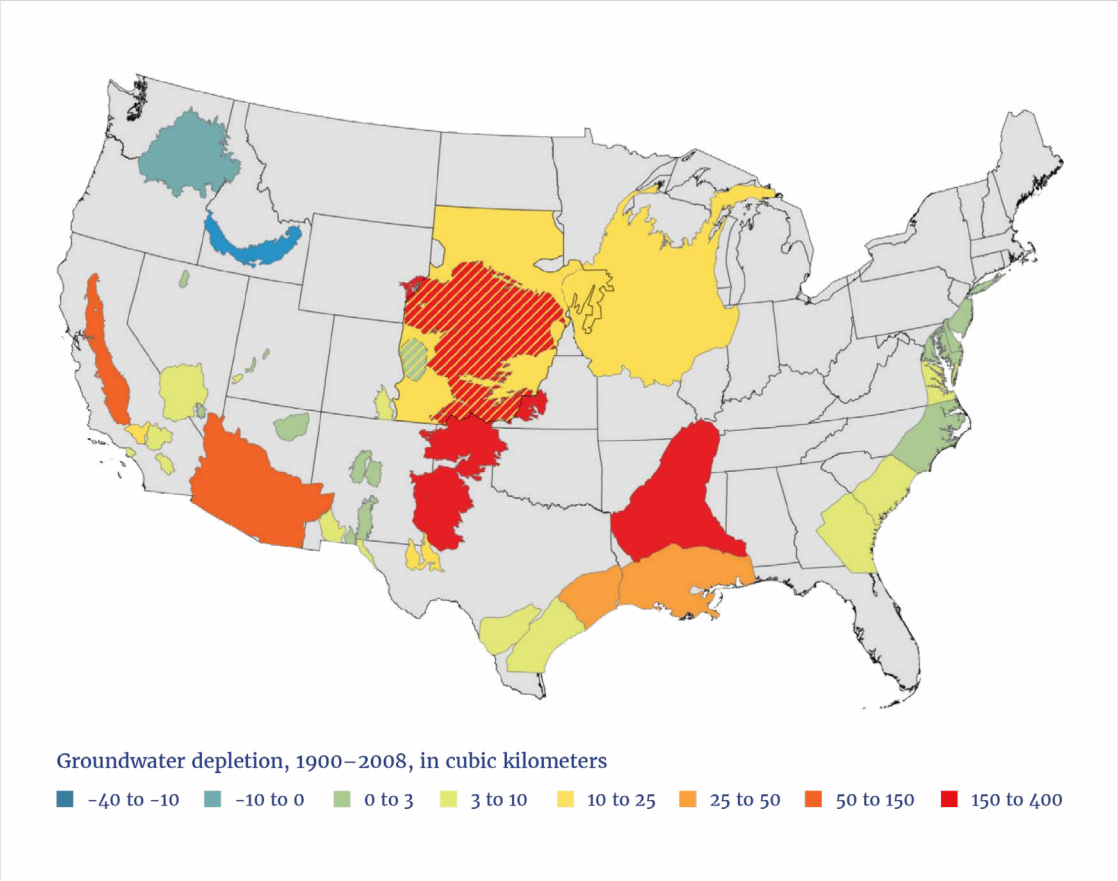
A nation’s agriculture and community water needs generally scale with its population. But its energy water demand increases with its wealth and technological advancements, which are potentially unbounded. Energy growth currently outstrips population growth as electricity expands from cities to rural areas worldwide and as countries progress from the lightbulb to data centers in years rather than generations. Per capita electricity consumption is tantamount to standard of living. Governments are increasingly rebalancing their water priorities from the historically dominant agricultural sector toward the energy sector.

The Reality

The United States provides an excellent example of a very large economy in which agriculture, communities, and energy production are competing for a limited water supply. As seen in **figure 1**, water scarcity is already a regional reality, with western reservoirs such as Lake Mead—on the Arizona-Nevada border—at all-time lows, and worrisome aquifer depletions occurring in the Mississippi Delta, the Central Valley of California, and the Ogallala Aquifer in the southern Great Plains.[1]

Figure 1.

U.S. Groundwater Depletion, 1900–2008



Source: Adapted from Brett Walton, "U.S. Groundwater Losses Between 1900–2008: Enough to Fill Lake Erie Twice," *Circle of Blue*, May 16, 2013, originally published in Leonard F. Konikow, *Groundwater Depletion in the United States (1900–2008)*, Scientific Investigations Report 2013-5079 (U.S. Geological Survey, 2013), 6, figure 2.

U.S. Water Consumption, by Category

A nationwide overview of water sources and consumers is essential to understanding the issue. A water-footprint analysis best captures the full spectrum of water sources, the life cycle of each consumer, and all consumptive categories—uses that remove water from availability or utility to its environment.

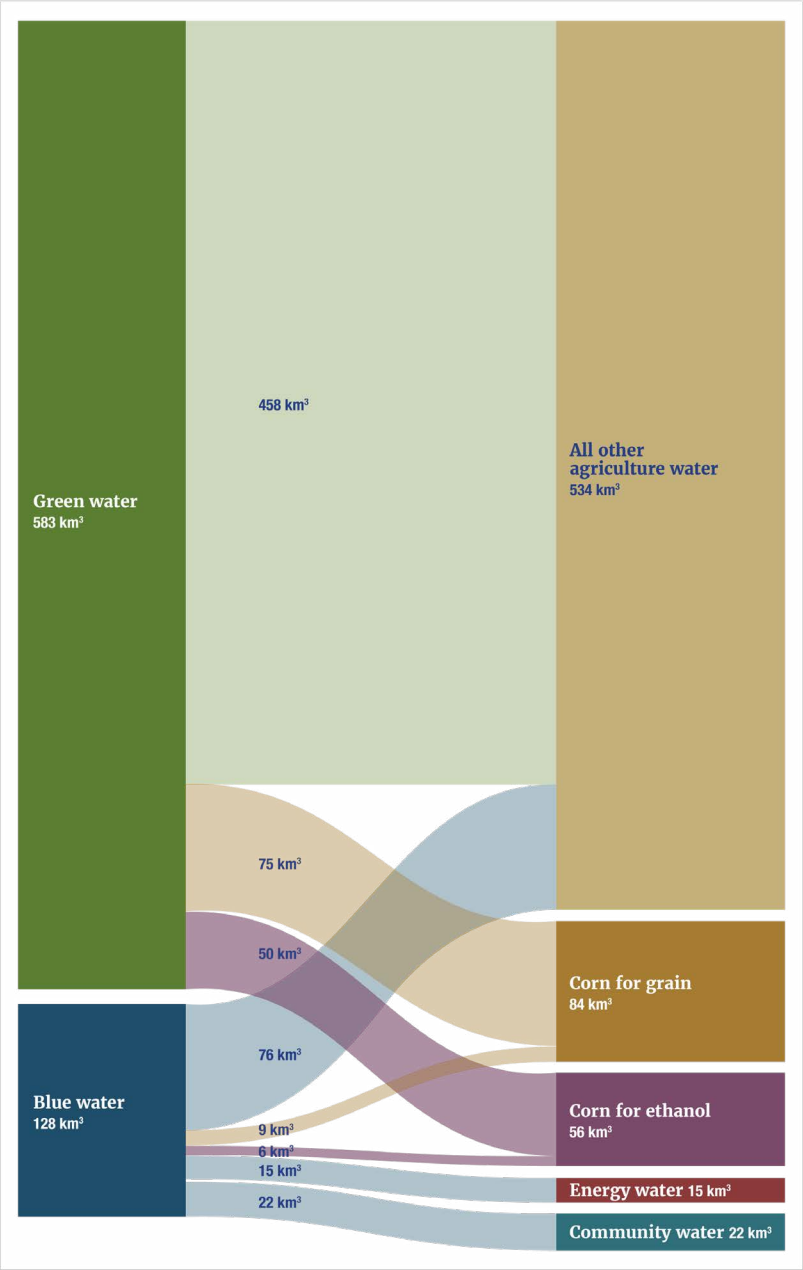
Consumptive water use is categorized as green water, fed by rain and other precipitation; blue water, fed by surface and underground water reservoirs; and gray water, the additional quantity of water needed to restore contaminated water to environmental standards through treatment and dilution. **Figure 2** shows green and blue water footprints for the 48 contiguous states in 2017.[2] Volume is measured in cubic kilometers, which gives a sense of the enormous scale.

Green water in **figure 2** represents only the precipitation water that plants actually consume, not all the water that falls to the earth. For agriculture water, a small fraction of consumed water becomes a physical part of the crops; the much larger balance is the *evapotranspiration* water, essential to photosynthesis, that plants continuously pump from their roots in the soil to their leaves and release to the atmosphere as vapor.

Blue water comprises surface and underground water that is naturally stored in lakes, rivers, and aquifers, as well as water stored in artificially created ponds, cisterns, reservoirs, and large reclamation projects.

Figure 2.

U.S. Water Footprint for Agriculture, Community, and Energy Consumption



Note: Agriculture includes crops and livestock.
Sources: Data from Yufei Zoe Ao et al., "Food, Energy, and Water Production Within Watersheds of the United States," *Water Resources Research* 59, no. 5 (May 2023): e2022WR034031; and Todd "Ike" Kiefer, *Ethanol as Fuel: A Bridge to Nowhere* (National Center for Energy Analytics, 2026). Author's calculations.

Gray water is not shown in this figure because it is not a simple measure of consumed water but rather a debt: the additional gallons needed to restore contaminated water to environmental standards. Power plants (energy water) and municipal water systems (community water) almost always pay this debt within the plant boundaries as additional metered blue water because these institutional water users have well-established and highly regulated treatment processes and discharge rules.

However, agricultural gray water debt goes largely unmeasured and unpaid because runoff contamination is rarely monitored and no robust regulatory process exists for calculating or attributing this contamination, let alone enforcing corrective action. The Environmental Protection Agency (EPA) has not regulated agricultural runoff pollution because of a farming exemption in the Clean Water Act.[3]

The Dominant Water Consumer

Agriculture dominates the other ACE sectors because of its extraordinarily high water intensity. Compared with 15 cubic kilometers (km^3) of energy water and 22 km^3 of community water, U.S. agriculture consumes 674 km^3 of water per year.[4] As **figure 2** shows with its proportional ribbons and bands, the nation consumes 18 times more water for agriculture than it does for energy and community water systems combined.

Agriculture-Based Energy

Corn is the largest intensively cultivated crop in the U.S. In **figure 2**, corn for ethanol is positioned between all other agriculture water and energy water because it is a hybrid of both—it is the use of agriculture to produce energy. The 56 km^3 of blue and green water used each year solely to produce corn ethanol represent 8% of the country's entire ACE water consumption footprint. This quantity is more than twice the amount of water used by municipalities annually and nearly four times the amount of water used by the nation's energy sector every year, yet corn ethanol contributes only 7% of the nation's gasoline energy[5]—equivalent to just 1.2% of U.S. total primary energy.[6] The blue and green water footprint of corn ethanol production throughout its life cycle is 992 gallons of water per gallon of final ethanol product.[7] If gray water is considered, corn ethanol's water-use efficiency drops even further.

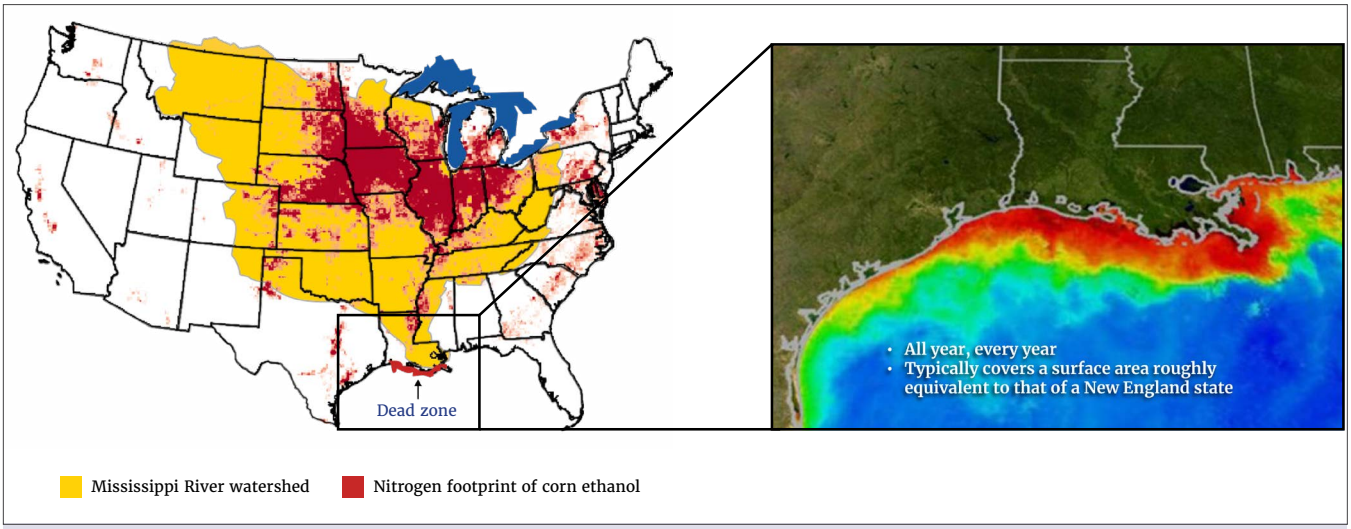
Gray Water Impact of Corn Agriculture

Nitrogen runoff is the primary contributor to agricultural gray water. Natural background levels of nitrogen in undisturbed forest or prairie are generally less than 0.3 parts per million (ppm)—well below the EPA maximum contaminant level of 10.0 ppm.[8] In contrast, corn farmers now typically apply fertilizer at an application rate of 152 pounds of nitrogen per acre (lb N/acre) using liquid anhydrous ammonia.[9] Forty years of monitoring Midwest farm water drainage and downstream contaminants consistently finds that 20% of the fertilizer applied ends up in streams and rivers.[10] Diluting that 30.4 lb N/acre stream load to the EPA's maximum contaminant limit requires 364,000 gallons of additional pure water per fertilized acre. Across the more than 29 million acres of corn dedicated to ethanol production each year, that adds up to another 40 km^3 of water—or about 700 gallons of water per gallon of ethanol. Diluting this nitrogen further to achieve the natural background levels would require 33 times more water.

This unpaid gray water debt represents real stress on water and ecosystems today that is currently unvalued ecologically and economically. The evidence of the massive gray water footprint from the Corn Belt is the perpetual Gulf Coast dead zone (shown in **figure 3**), where roughly 1.6 million metric tons per year of Midwest farm nitrogen feeds algae blooms that remove the oxygen from the water, killing all aquatic life in an area the size of a New England state.[11] The economic and ecological impact of this dead zone is calculated to be up to $2.4 billion per year.[12]

Figure 3.

Nitrification Emissions in the Mississippi River Watershed



Source: Adapted from Todd "Ike" Kiefer, *Ethanol as Fuel: A Bridge to Nowhere* (National Center for Energy Analytics, 2026), 9–10, figures 8 and 9. Figure 8 of that study is the author's map enhancement of Christopher Tessum et al., "A Spatially and Temporally Explicit Life Cycle Inventory of Air Pollutants from Gasoline and Ethanol in the United States," *Environmental Science & Technology* 46, no. 20 (2012): 11412, figure 4. This is an unofficial adaptation of an article that appeared in an ACS [American Chemical Society] publication. ACS has not endorsed the content of this adaptation or the context of its use.

Energy-Use Efficiency Versus Water-Use Efficiency

Efficient water use matters for both energy production and energy consumption. Both functions require water, and the two together form the full life cycle of the energy economy.

Corn-based production of ethanol motor fuel. Applying the water footprint of U.S. corn ethanol to the current average yield of 519 gallons of ethanol per acre-year results in 515,000 gallons of water consumed per acre-year.[13] Most of this consumption occurs in the cornfield itself, with smaller amounts used in the biorefinery and for transportation. A gallon of ethanol contains 22.4 kilowatt-hours (kWh) of energy.[14] Dividing that energy by the water consumed in its production yields just 0.023 kWh of energy per gallon (kWh/gal) of water delivered as motor fuel.

Power grid electricity generation. U.S. electric power production in 2017 consumed 15 km^3 of water (see **figure 2**), generating 4,034 million megawatt-hours (MWh).[15] This equates to an average of 1.0 kWh of electricity per gallon of water consumed—45 times the water efficiency of corn ethanol production. This average is lowered by many older power plants built when water efficiency was not a priority. New combined-cycle natural gas combustion plants with dry cooling achieve more than 50 kWh/gal by trading some energy production efficiency for higher water-use efficiency.[16]

Data center power and cooling. Data center water use includes two components: the first is direct water consumed on site for cooling servers and campus structures; the second is the indirect water used in generating the electric power needed to operate the facility. **Table 1** shows a range of water consumption scenarios for a few of the many different cooling and power configurations.[17] Modern hyperscale data centers can draw at peak more than 2 MW per built-out acre.[18]

In a scenario that maximizes water-use efficiency, a dry-cooled facility with natural gas–fired grid power running at 50% capacity factor (1 MW per acre) will have direct onsite water use limited to janitorial needs, with virtually

all of the roughly 3.25 million gallons per acre-year consumed indirectly in offsite power generation. In a worst-case scenario for water-use efficiency, an evaporatively cooled data center with onsite diesel generation might consume as much as 15 million gallons per acre-year. These scenarios equate to between 2.7 and 0.6 kWh of compute per gallon of water, depending on the water-use efficiency of the data center and its power source.[19] As with power plants, a data center can be designed to maximize either energy efficiency or water efficiency.

Table 1.

Data Center Water Use, by Cooling and Power Source

Case	Direct Onsite Water Consumption	Indirect Water Consumption (Power Generation)	Total Water Consumption	Computing (kWh per Gallon)
Theoretical best case: dry cooling + wind-like electricity	Near zero	~41,000 gal/acre-yr	~41,000 gal/acre-yr	~214
Realistic best case: dry cooling + natural gas–heavy grid	Near zero	~3.25 million gal/acre-yr	~3.25 million gal/acre-yr	~2.7
Median case: efficient wet cooling + natural gas–heavy grid	~625,000 gal/acre-yr	~3.25 million gal/acre-yr	~3.9 million gal/acre-yr	~2.3
Worst case: wet/evaporative cooling + onsite diesel generation	~6.7 million gal/acre-yr (benchmark)	~8.1 million gal/acre-yr (oil-generation proxy)	~14.8 million gal/acre-yr	~0.6

Note: Values assume an average data center load of 1 MW per acre. Wind-like electricity comes from sources that use almost no water in generation, such as wind and solar photovoltaics.
Sources: Data from Nuoa Lei et al., "The Water Use of Data Center Workloads: A Review and Assessment of Key Determinants," *Resources, Conservation and Recycling* 219 (June 2025): 108310; David Mytton, "Data Centre Water Consumption," *npj Clean Water* 4, no. 1 (2021): 11; and "Measuring Datacenter Energy and Water Use to Improve Microsoft Cloud Sustainability," Microsoft Datacenters, Microsoft, accessed October 25, 2026, https://datacenters.microsoft.com/sustainability/efficiency.

Analysis of alternatives. To put energy's competition for water into stark contrast, each option can be normalized to what a single gallon of water delivers, shown in **figure 4**. As of 2026, a gallon of water in the United States can be used to generate 1 to 50 kWh of power, perform 0.6 to 2.7 kWh of data center computing, or create 3.8 cubic centimeters of ethanol.

Figure 4.

Alternative Uses of 1 Gallon of Freshwater



Sources: Data from Yufei Zoe Ao et al., "Food, Energy, and Water Production Within Watersheds of the United States," *Water Resources Research* 59, no. 5 (May 2023): 6, e2022WR034031; "Table 3.1.A. Net Generation by Energy Source: Total (All Sectors), 2014–2024," Electric Power Annual, U.S. Energy Information Administration, accessed October 18, 2026; J. Meldrum et al., "Life Cycle Water Use for Electricity Generation: A Review and Harmonization of Literature Estimates," *Environmental Research Letters* 8, no. 1 (2013): 8, table 5, 015031; Nuoa Lei et al., "The Water Use of Data Center Workloads: A Review and Assessment of Key Determinants," Resources, *Conservation and Recycling* 219 (June 2025): supplementary table S4.1, 108310; "Measuring Datacenter Energy and Water Use to Improve Microsoft Cloud Sustainability," Microsoft Datacenters, Microsoft, accessed October 25, 2026, https://datacenters.microsoft.com/sustainability/efficiency; David Mytton, "Data Centre Water Consumption," *npj Clean Water* 4, no. 1 (2021): 11; and Mesfin M. Mekonnen et al., "Water, Energy, and Carbon Footprints of Bioethanol from the U.S. and Brazil," *Environmental Science & Technology* 52, no. 24 (2018): 14512. Author's calculations.

Water Cost of Corn Ethanol Versus Gasoline Production

Producing liquid fuel from mined petroleum requires a considerable amount of water per unit of energy delivered. According to a thorough analysis of the current water footprint of U.S. pump gasoline, the weighted national average is 5.6 gallons of water consumed per gallon of fuel.[20] When a vehicle's fuel tank is filled, each gallon of gasoline also represents many gallons of water used to produce it and refine it and deliver it to the pump. But how does gasoline's water dependence compare with that of corn ethanol?

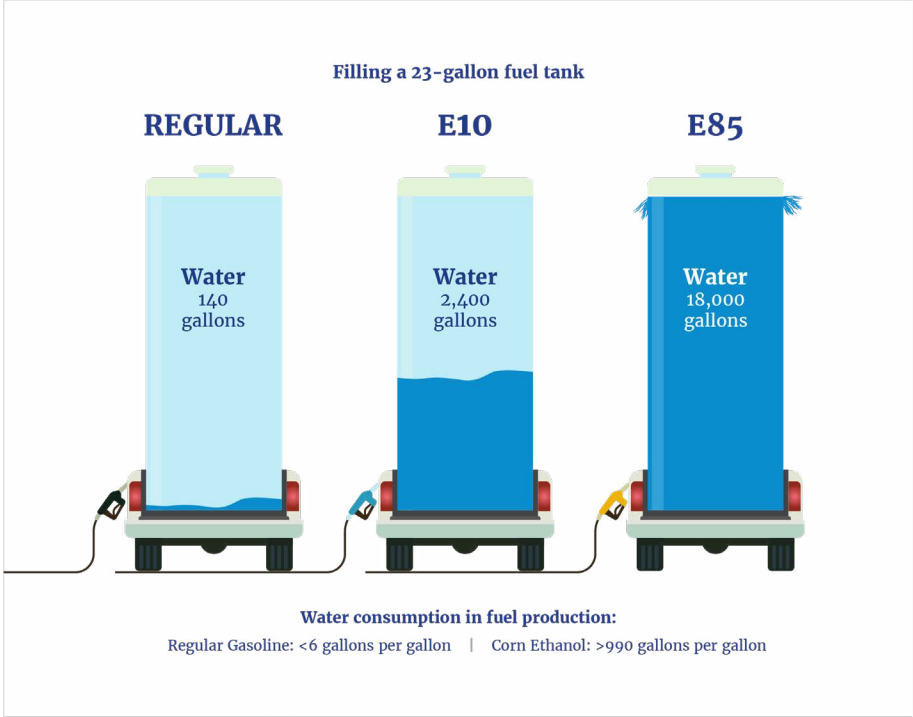
To illustrate the water consumption difference, consider three vehicle fueling scenarios: E0, E10, and E85. E0 is that rare variant of ethanol-free 87-octane "regular" fuel that is available only at select gas stations today. E10 is the now-ubiquitous 9%–10% ethanol blend sold as the lower-octane option. Per EPA rules, fuel labeled E85 can include more than 50% and up to 83% ethanol, with the remainder being regular gasoline.[21] To analyze water consumption, each fuel type must be paired with a compatible vehicle.

Of the few E85-compatible vehicle models on U.S. roadways today, the most common example may be the 3.3-liter six-cylinder Ford F-150 flexible-fuel vehicle. EPA-certified fuel efficiency for this vehicle is 21 miles per gallon (MPG) on regular gasoline for combined city and highway driving and 16 MPG on E85. These figures assume that an E10 fuel blend contains 10% ethanol and an E85 blend contains 80% ethanol. They apply the EPA mileage for gasoline and E85, along with the estimated mileage of 20.4 MPG for E10 and 20.1 MPG for E15. On that basis, driving the flexible-fuel truck has an embedded water cost of 5 gallons per mile with E10 and 50 gallons per mile with E85. By comparison, non-ethanol E0 gasoline, which uses refinery-produced aromatic hydrocarbons rather than ethanol to boost octane, has an embedded water cost of just 0.3 gallons per mile.[22]

To underscore the impact on water use, adding 10% ethanol to regular gasoline to make E10 consumes 19 times more water per mile traveled down the highway, while E15 consumes 29 times more water, and E85 consumes 186 times more water (see **figure 5**).[23] When drivers choose which type of fuel to put into their gas tanks—or when the government chooses for them—it is more a choice about water than about fuel.

Figure 5.

Embedded Water Versus Fuel



Source: Reprinted from Todd "Ike" Kiefer, *Ethanol as Fuel: A Bridge to Nowhere* (National Center for Energy Analytics, 2026), 8, figure 7.

Prospects for Improvement

Worldwide comparisons of the water footprint of corn (maize) farming have consistently found the U.S. to be among the most efficient and improving producers over the years.[24] Increased use of genetically tailored, drought-resistant crop varieties requiring less irrigation water is likely a major contributor.[25] Rising atmospheric CO_2 levels also increase water efficiency for all agriculture.[26] Further improvements are still possible through wider adoption of precision agricultural practices; however, the fundamental physics of terrestrial plant photosynthesis requires a huge volume of water. Plants must evaporate water from their leaves to create the suction force that, in combination with capillary action, performs the continual work of lifting nutrients from the soil into

the plant's tissues. Water is also required to cool the leaves and prevent sunburn. This volume of water cannot be significantly reduced without moving crop production to an enclosed greenhouse environment of hydroponics and artificial light, which is completely incompatible with the 400-million-acre scale needed to displace gasoline.[27]

The EPA has recognized that producing biofuels, even at the modest levels of the Renewable Fuel Standard (RFS) annual quotas, creates water competition with food and contributes to environmental degradation.[28] In 2010, the agency accurately predicted "adverse impacts on both water quality and quantity as the production of biofuels and their feedstocks increase."[29] Meanwhile, public interest in flexible-fuel vehicles has declined, and U.S. ethanol consumption has plateaued. Despite more than 20 years of government manipulation of the fuel market through the RFS, these trends show that ethanol has failed to become a competitive alternative choice for motorists or refiners.[30]

Wetlands and Downstream Water Impact

Corn grown for ethanol accounts for 29–36 million acres of intensively cultivated land and represents 40% of the U.S.'s annual corn crop.[31] Millions of acres of grassland and wetland have been converted to corn cultivation since the RFS expansion took effect in 2008.[32] These farmed acres contribute significantly to greenhouse gas emissions and negative ecological impacts. Forests and prairies have live roots and green canopies most months of the year and are home to diverse species of animals and plants. Wetlands serve as natural bioreactors and waste stabilization ponds where microbes break down diluted nitrogen without creating the excessive algae growth that suffocates aquatic life.

In contrast, an industrial cornfield is a chemically enforced, genetically engineered monoculture that alternates between artificially stimulated growth and barren idleness. The typical cornfield is planted by May, has a dense canopy only from June to September, and is then harvested in October, leaving bare soil or stubble until the next planting. Cover crops—those planted between regular crop cycles to protect the soil—are grown on less than 10% of fields.[33] The first rains after spring fertilization and after harvest sweep synthetic nitrogen, other agrichemical runoff, and eroded soil into surface waters, contaminating blue water rather than filtering it for users downstream.

Perspective

Freshwater is a renewable resource but only within sustainable consumption limits. More regions of the country are now reaching those limits, requiring trade-offs among competing demands. Agriculture dominates consumptive water use nationally and is the main cause of water stress in the nation. While water consumption is tightly regulated for the 3% used by communities and the 2% used by power stations, the other 95% used by agriculture is relatively unscrutinized.

This exception leads to unbalanced water interests, perpetuation of water stress and scarcity, and increased gray water pollution, creating serious economic and ecological harms. The continued growth in electricity demand—from personal electronic devices, electric vehicles, artificial intelligence, and data centers—is a national priority that competes with agricultural production for a limited water supply. It is therefore reasonable to look to the agricultural sector for a trade in water resource allocation.

Currently, 8% of the nation's water consumption is channeled into 40% of the nation's corn crop to produce only 1.2% of its annual energy supply.[34] This volume of water is nearly four times that used by the rest of the nation's energy sector, yet each gallon of water that is used to produce ethanol yields only about 1/45th as much energy as a gallon of water used by the nation's power plants.

While food agriculture is essential, energy agriculture is not. Crops must be farmed, but energy can be mined from the earth and harvested from the sun and wind with relatively tiny water consumption. The U.S. has an abundance of energy sources and power generation options that are far more water-efficient than agriculture-based options. With all of the other energy options available, there is no justification for the industrial-scale consumption and contamination of water for thirsty biofuels such as corn ethanol.

Conversely, if the RFS were repealed, much of the more than 23 million acres of farmland put into intensive cultivation since 2008 would return to the Farm Service Agency's Conservation Reserve Program or revert to their natural state. This would free up a tremendous amount of water for power plants and data centers, reduce gray water pollution, and benefit wildlife and downstream communities.

To support society's sustainable use of freshwater across the competing needs of agriculture, communities, and energy, policymakers should:

- **Eliminate subsidies for water-wasting and environmentally damaging activities.** The U.S. is awash in domestic transportation energy, and there is no national security benefit to displacing a small fraction of abundant fossil fuels with biofuel alternatives that have a disproportionate impact on water consumption, water pollution, and habitat destruction. The RFS has yet to launch a single biofuel into competitive self-sufficiency with sales not dependent on its mandates. A reasonable benefit-cost analysis of the decades-old RFS program shows it to be overdue for elimination.[35]
- **Improve water market dynamics to reduce scarcity.** Urban water scarcity and rural water profligacy are closely connected. Water rights reform is needed to allow prices to genuinely reflect water demand and supply. The best outcome for sustainable water use is achieved when all stakeholders must negotiate and when the negotiation happens on level ground in the light of day with rules set by mutual agreement.
- **Quantify and price gray water.** This is a pillar of both improving water market dynamics and the water quality of the nation. Remove the Clean Water Act exemption that allows farms to discharge agricultural runoff without federal pollution permits. Task the EPA with pricing the health and environmental costs of nitrogen in the water, as it has done for particulates in the air, and communicating these costs to the public with the same vigor.
- **Eliminate the dead zone along the U.S. Gulf Coast.** This should be a national priority. Government agencies do not tolerate environmentally damaging oil spills at any scale from the petroleum industry. Neither should they tolerate chronic, continent-scale fertilizer spills by the agricultural industry. The dead zone is a perpetual regional crisis and an international embarrassment for the nation that pioneered environmental protection.

The nation cannot build its energy and technological future on water policies that reward wasteful use and give pollution a free pass. It is time to wind down the RFS program, created in 2005, which has achieved only the perverse outcomes of increased ecological damage and water stress. It has contributed nothing to energy security and has failed to launch corn ethanol or any crop-based fuel into self-sustaining commercial viability.

Notes

1 "Lake Mead Hoover Dam and Powerplant Daily Lake/Reservoir Elevation-ft Time Series Data," Reclamation Information Sharing Environment, U.S. Bureau of Reclamation, accessed October 16, 2026, https://data.usbr.gov/catalog/4370/item/6123; and Brett Walton, "U.S. Groundwater Losses Between 1900–2008: Enough to Fill Lake Erie Twice," *Circle of Blue*, May 16, 2013.

2 Yufei Zoe Ao et al., "Food, Energy, and Water Production Within Watersheds of the United States," *Water Resources Research* 59, no. 5 (May 2023): e2022WR034031. The further breakout of corn used for grain and for ethanol is based on Todd "Ike" Kiefer, *Ethanol as Fuel: A Bridge to Nowhere* (National Center for Energy Analytics, 2026).

3 Clean Water Act, 33 U.S.C. § 1362(14) (2024); and Exclusions, 40 C.F.R. § 122.3(e)–(f) (2026).

4 A cubic kilometer equals approximately 0.24 cubic miles.

5 Renewable Fuels Association, "RFA: U.S. Ethanol Production Set a Record in 2025, New Data Show," *Ethanol Producer Magazine*, March 2, 2026. In 2025, ethanol made up 10.5% of gasoline-blend motor fuel by volume. Because ethanol contains two-thirds as much energy per gallon as gasoline, it supplied only 7% of the blend's energy.

6 U.S. Energy Information Administration (EIA), *September 2026 Monthly Energy Review*, 3, table 1.1; 195, table 10.3. In 2025, fuel ethanol consumption (minus denaturant) was 1.19 quadrillion British thermal units (Btu), compared with the total U.S. primary energy consumption of 95.5 quadrillion Btu.

7 Mesfin M. Mekonnen et al., "Water, Energy, and Carbon Footprints of Bioethanol from the U.S. and Brazil," *Environmental Science & Technology* 52, no. 24 (2018): 14512 . This analysis used the full water footprint and applied no coproduct credits for three reasons: All coproducts are obligatory to corn ethanol production; all have long-established, more economical, and more effective alternatives (e.g., soy as feed protein supplement instead of distillers grains); and the neglected gray water footprint associated with nitrogen alone far exceeds the coproduct credits. Simplifying this analysis by neglecting the questionable coproduct credits while also ignoring the more substantial gray water footprint is a conservative approach that favors corn ethanol in the accounting.

8 Gregory M. Clark et al., "Nutrient Concentrations and Yields in Undeveloped Stream Basins of the United States," *Journal of the American Water Resources Association* 36, no. 4 (2000): 849–60; and Maximum Contaminant Levels for Inorganic Contaminants, 40 C.F.R. § 141.62(b) (2026).

9 Kiefer, *Ethanol as Fuel*.

10 Laura E. Christianson and Robert D. Harmel, "4R Water Quality Impacts: An Assessment and Synthesis of Forty Years of Drainage Nitrogen Losses," *Journal of Environmental Quality* 44, no. 6 (2015): 1852–60; and Dale M. Robertson and David A. Saad, *Spatially Referenced Models of Streamflow and Nitrogen, Phosphorus, and Suspended-Sediment Loads in Streams of the Midwestern United States*, Scientific Investigations Report 2019-5114 (U.S. Geological Survey, 2019), 29. Christianson and Harmel's synthesis of nearly 1,000 site-years of data found a mean of 20% nitrogen fertilizer drainage loss within a range of 10%–40%. Robertson and Saad's newer model calibrated to 1,344 monitoring stations also shows about 20% of fertilizer reaching rivers, with 3.2% as direct runoff and 16.3% first volatizing to the atmosphere before being redeposited. This likely reflects the shift from solid nitrogen to volatile liquid nitrogen application.

11 Robertson and Saad, *Spatially Referenced Models*, 35. About 93% of the nitrogen reaching Midwest streams comes from farm sources and from atmospheric deposition, which includes ammonia volatilized from farm fields.

12 Rebecca Boehm, *Reviving the Dead Zone: Solutions to Benefit Both Gulf Coast Fishers and Midwest Farmers* (Union of Concerned Scientists, 2020), 3.

13 Kiefer, *Ethanol as Fuel*.

14 "Fuel Properties Comparison," Alternative Fuels Data Center, U.S. Department of Energy, accessed November 6, 2026, https://afdc.energy.gov/fuels/properties. Ethanol (E100) has a lower heating value of 76,330 Btu/gal ÷ 3,414 Btu/kWh = 22.4 kWh/gal.

15 Ao et al., "Food, Energy, and Water Production," 6; and "Table 3.1.A. Net Generation by Energy Source: Total (All Sectors), 2015–2025," Electric Power Annual, EIA, accessed October 30, 2026, https://www.eia.gov/electricity/annual/html/epa_03_01_a.html. Ao et al. reported that electricity generation consumed 15 km^3 of blue water in 2017; the EIA reported that the total electricity generation at utility-scale facilities is more than 4.03 billion MWh in the same year. See "State Electricity Profiles," Data for 2017, EIA, released January 8, 2019, https://www.eia.gov/electricity/state/archive/2017.

16 James Meldrum et al., "Life Cycle Water Use for Electricity Generation: A Review and Harmonization of Literature Estimates," *Environmental Research Letters* 8, no. 1 (2013): 8, table 5, 015031. National Renewable Energy Laboratory and University of Colorado Boulder researchers calculated life-cycle water consumption for natural gas power generation across different combinations of fuel, combustion cycle, and cooling system. At the high end of water consumption, a conventional Rankine-cycle steam plant with a cooling tower uses 747 gal/MWh, equivalent to 1.3 kWh of electricity per gallon of water. At the low end, a natural gas combined-cycle combustion turbine with dry cooling uses only 9 gal/MWh, equivalent to 110 kWh/gal. For the body text and chart, 20 gal/MWh (or 50 kWh/gal) is used as a representative figure for modern natural gas plants.

17 Nuoa Lei et al., "The Water Use of Data Center Workloads: A Review and Assessment of Key Determinants," *Resources, Conservation and Recycling* 219 (June 2025): 108310; and "Measuring Datacenter Energy and Water Use to Improve Microsoft Cloud Sustainability," Microsoft Datacenters, Microsoft, accessed October 25, 2026, https://datacenters.microsoft.com/sustainability/efficiency. The configurations in **table 1**, selected by the author from numerous options, are representative of best-, median-, and worst-case scenarios for water use by large data centers. Wind-like electricity is a best-case scenario for energy water efficiency, but it is not practical for any significant fraction of data center energy because data centers' operating profiles are much more aligned with 24-7 reliable baseload power than with variable renewable energy. For this reason, the dry-cooled gas turbine option is used as a realistic best-case scenario.

18 The 2 MW per acre peak power consumption density figure is based on the author's AI-assisted literature survey and analysis of operating and proposed hyperscale data center nameplate capacity, backup generator capacity, and developed acreage derived from public land acquisition documents, power company filings, and aerial imagery.

19 The dry-cooled gas turbine option is used as a realistic best-case scenario for data centers due to the impracticality of supplying data center loads with wind power.

20 May Wu and Hui Xu, *Consumptive Water Use in the Production of Ethanol and Petroleum Gasoline—2018 Update* (Argonne National Laboratory: Energy Systems Division, 2018), 9, 13. Note: liter per liter is equivalent to gallon per gallon. This water footprint for gasoline excludes green water, as precipitation makes no appreciable contribution.

21 Definitions, 40 C.F.R. § 1090.80 (2026).

22 "2023 Ford F150," FuelEconomy.gov, U.S. Department of Energy, accessed January 27, 2026, https://fueleconomy.gov/feg/PowerSearch.do?action=noform&path=1&year1=2023&year2=2023&make=Ford&baseModel=F150&srchtyp=ymm. The E10 and E15 mileage figures were calculated by the author.

23 Kiefer, *Ethanol as Fuel*.

24 P. W. Gerbens-Leenes and A. Y. Hoekstra, *The Water Footprint of Sweeteners and Bio-Ethanol from Sugar Cane, Sugar Beet and Maize*, Value of Water Research Report Series No. 38 (UNESCO Institute for Water Education, 2009), 23. This study found a U.S. corn ethanol blue-green water footprint of 1,220 gal/gal, compared with the 992 gal/gal in Mekonnen et al., 2018. This is a 19% improvement over nine years—a figure that is likely directionally accurate, if not absolutely precise.

25 See Monica Saavoss et al., *Trends in Production Practices and Costs of the U.S. Corn Sector*, Economic Research Report Number 294 (Economic Research Service, U.S. Department of Agriculture, 2021), 10, 12–13.

26 Leon Hartwell Allen Jr. et al., "Elevated CO_2 Increases Water Use Efficiency by Sustaining Photosynthesis of Water-Limited Maize and Sorghum," *Journal of Plant Physiology* 168, no. 16 (November 2011): 1909–18. A state-of-the-art crop growth model explicitly uses atmospheric carbon dioxide (CO_2) as an essential input to calculate crop response to water stress; see Oleksandr Mialyk et al., "Historical Simulation of Maize Water Footprints with a New Global Gridded Crop Model ACEA," *Hydrology and Earth System Sciences* 26, no. 4 (2022): 927.

27 The energy in 135 billion gallons of gasoline per year equals that in 203 billion gallons of ethanol, which—at the current U.S. national average of 519 gallons per acre of corn per year—would require about 400 million acres. See "Use of Gasoline," EIA, accessed October 28, 2026, https://www.eia.gov/energyexplained/gasoline/use-of-gasoline.php.

28 The RFS is a federal mandate under Clean Air Act § 211(o), created by the Energy Policy Act of 2005 and expanded by the Energy Independence and Security Act of 2007, requiring specified annual volumes of renewable fuels—including ethanol—to be used in transportation fuel. See U.S. Environmental Protection Agency (EPA), "Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program," *Federal Register* 75, no. 58 (March 26, 2010): 14670–904.

29 EPA, "Regulation of Fuels and Fuel Additives," 14683.

30 Kiefer, *Ethanol as Fuel*.

31 Kiefer, *Ethanol as Fuel*, 7.

32 Tyler J. Lark et al., "Cropland Expansion in the United States Produces Marginal Yields at High Costs to Wildlife," *Nature Communications* 11, no. 1 (2020): 2–3, 4295.

33 Stephen Wallander et al., *More Farmers Are Adding Fall Cover Crops to Their Corn-for-Grain, Cotton, and Soybean Fields* (Economic Research Service, U.S. Department of Agriculture, 2022).

34 Ao et al., "Food, Energy, and Water Production"; Kiefer, *Ethanol as Fuel*, 7; and EIA, *September 2026 Monthly Energy Review*, 3, table 1.1; 195, table 10.3.

35 "Overview of the Renewable Fuel Standard Program," U.S. Environmental Protection Agency, last updated April 16, 2026, https://www.epa.gov/renewable-fuel-standard/overview-renewable-fuel-standard-program.

About the Author



Todd “Ike” Kiefer

Todd “Ike” Kiefer is president of the North Lauderdale Water Association in Bailey, Mississippi, where he spearheads deployment of cutting-edge technology in rural utilities. His 14-year civilian career includes serving on the management team of the East Mississippi Electric Power Association, consulting on economic development and utility development for county government, and coauthoring several utility-related bills passed into law by the Mississippi legislature. Kiefer’s preceding 25 years of military service and seven combat deployments included two years on the ground in Iraq, where he commanded the sprawling Al Asad Air Base. He flew the carrier-based EA-6B Prowler as a naval aviator; was an operational test pilot; earned degrees in physics, strategy, and military history; served on the Joint Staff in the Pentagon; and capped his career as the Chairman of the Joint Chiefs of Staff Chair for Joint Warfighting at the U.S. Air Force’s Air War College, where he researched and published on primary and alternative energy. Kiefer is a graduate of the U.S. Naval Academy, the U.S. Army Command and General Staff College, and the Joint Forces Staff College.

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