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Editorial

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Food and Light Bulbs

The topics of food and light bulbs may seem unrelated, but answer this question: How many 100 W light incandescent bulbs could I power using the same energy in the food that I eat every day? When I've asked this question to groups of engineering and science students, numbers typically range from several to a few hundred light bulbs. The central challenge is that most of us have no experience in relating units of Calories (energy) and Watts (power). A 100 W light bulb running continuously uses 2×10^6 calories a day. To make this calculation relative to food more confusing, our food is labeled in Calories, where 1 Calorie (uppercase) is equal to 1000 calories (lowercase). So if you consume 2000 Calories per day in your diet, that is equivalent to continuously running a single 100 W light bulb. Consider the implications of this "unit conversion" of daily Calories and Watts.

The total energy a person in the United States uses, on average, is ~100 times our food intake. Therefore, if we completely switched from a fossil fuel- to a bio-based economy, we would have to considerably increase our agricultural production in the United States and globally. That is clearly not feasible as we have not yet solved the question of how to feed 6 billion people on the planet today, or an estimated 10 billion people in ~30 years. While I like the idea of powering our cars with fuels we can grow, using food that we can eat is just not sustainable. However, we should consider using waste biomass as part of our energy portfolio, as there are some excellent opportunities for using waste organic matter to make fuels.

The Department of Energy estimated that we could annually harvest 1.34 billion tons of biomass in the United States without affecting food production. Converting that amount of biomass into electrical power, at 50% efficiency, could produce 300 GW of electricity. Alternatively, we could use that biomass to make ethanol or other transportable fuels. For example, if we used this biomass to make hydrogen gas, we could have enough fuel to run all light duty fuel cell-based vehicles (not trucks) in the United States (after making some rather optimistic calculations). Alternatively, we could use this biomass in anaerobic digesters and make methane. While these different processes would release carbon dioxide, they are still carbon neutral in the sense that the carbon dioxide in the biomass was fixed from the atmosphere, and thus there is no net release of fossilized carbon.

The amount of organic matter that is released into domestic wastewater is equivalent to ~25 W per person, coincidentally about the same amount of power used by a compact fluorescent light bulb with the same light output as an old 100 W incandescent bulb. Capturing that amount of power on a per-person basis seems pointless. However, when you start to consider the energy demands for wastewater treatment for towns and cities, the numbers become considerably more impressive. For a town of 100000 people, the organic matter in the wastewater is equivalent to 2.3 megawatts (MW), which is ~9 times as much power as that needed to run a conventional wastewater treatment plant. From this perspective, it would seem that just capturing a part of the energy in the wastewater could make the treatment plant energy neutral. Indeed, several wastewater treatment plants can now remove organic matter and nutrients from wastewater with a zero net energy demand by using electricity produced from methane gas anaerobic digesters. There may be other opportunities to further increase energy recovery from wastewater, for example, by using microbial fuel cells or anaerobic fluidized bed reactors. At present, however, these two processes have not yet been proven at full scale.

Estimates of the amount of electricity used in the United States for our water infrastructure (both water and wastewater) vary considerably, but an approximate range is 3–5% of total electrical power production, or 15–25 GW. Extensive use of desalination to produce water would considerably increase this energy demand. To put these power requirements in perspective, a typical large nuclear power plant produces ~1 GW. There is probably sufficient organic matter in domestic, food, and animal wastewaters in the United States to substantially offset these energy demands if the energy in the wastewater can be efficiently captured. Because electrical power production is ~33% efficient, eliminating the consumption of 15 GW of electricity for our water infrastructure could save 45 GW of primary energy.

We need to develop energy-efficient technologies for producing drinking water and treating wastewater or we will never be able to provide water and sanitation to 10 or even 6 billion people on the planet. The energy demands of conventional wastewater technologies used in the United States are just not globally sustainable on a per-capita basis. Many industrialized countries are spending significant amounts of money on research to develop new water technologies, but the United States is not doing enough to maintain or improve its water infrastructure. It is time for the United States to recognize the economic and societal benefits of becoming a leader in energy sustainable water technologies. A shift in our research and development priorities to focus more on water technologies would improve the stability and sustainability of cities all around the world. There is sufficient interest among water professionals in the United States to address these issues, but there is insufficient funding. Hopefully, an increased level of attention to the global energy–water–food nexus will stimulate popular and governmental interest, produce an increase in funding, and lead to new solutions that could allow the development of energy sustainable water infrastructures in both industrialized and developing countries.

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Notes

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