Corn Ethanol or Solar Panels?

In comparing how far one could drive a car utilizing either the annual production of one acre of corn ethanol or the annual production of electricity from one acre of solar panels (with an otherwise similar electric car), choose the best response:

1. you could drive about the same distance with either
2. you could drive about 10 times as far on corn ethanol
3. you could drive more than 100 times farther on corn ethanol
4. you could drive approximately 10 times farther on electricity from solar panels
5. you could drive more than 100 times farther on electricity from solar panels

The answer is e), yes e).

How could this be true? For you 470 students, recently we read the 10 percent renewables article from Jacobson et al. In that article they compared the solar radiation-to-carbohydrate conversion ratio of photosynthesis (approx. 1%). For photovoltaics, the conversion ratio (solar to electrical energy) is around 20%. So this suggests that the answer to the multiple choice question is somewhere between d) 10x and e) 100x+, likely 20 fold. (see Smil for a graph of solar energy density compared with other source types).

But this 20x solar-to-energy conversion ratio needs several adjustments in order to apply directly to the question above. The first is that the energy quality of ethanol (chemical energy) is much lower than the energy quality of electricity. This is evident in how efficiently the internal combustion engine converts liquid fuel into mechanical energy applied to the drivetrain (~20%), vs. how efficiently the electric car system converts electricity to mechanical energy (~80%). So comparing 20% to 80% gives an additional multiplier of around 4 to the advantage of the solar panel – electric car system. So rather than a twenty fold advantage to the electric system, we have an 80 fold advantage.

But we also must remember that the corn plant only grows for part of the year, and even during much of its lifecycle, it allows a large part of the solar radiation to hit the ground, especially when the corn plants are young and small. So if we estimate a 50 percent loss due to this factor, we can multiply by yet another factor of two the relative efficiency of the electric system, giving a 160 fold advantage.

We also must remember that much of the energy fixed from the sun in the corn plant does not go to the grain but rather to the plant. While some of this forage could be applied to the energy feedstocks supplying the ethanol, for the most part it is not. Another factor is the embodied energy costs of the two systems. The ethanol system has very high energy inputs, while the solar PV system is less (I have seen estimates that the embodied energy of solar pv systems is less than 10% of their eventual output, while that of the ethanol system is higher than 50%).

Also, the areas where most of the industrial solar PV are being and will be located are in the sunniest areas of the desert Southwest, where the annual solar radiation advantage over the corn belt production areas is around 50%. Thus we can multiply the 160 fold advantage from two paragraphs above by 1.5, giving us a solar panel/electric car system that is perhaps 240 times more efficient per acre at converting solar radiation to miles driven. And we did not even attempt to estimate here the forage and embodied energy disadvantages of the corn system! Had we done that the solar system might be more efficient by a factor of perhaps 300 or so.

**Summary of points made above that explain how a car on one acre of solar panel generated electricity can be driven more than 100 times farther than a car running on ethanol produced from an acre of corn:**

1. **The solar panels-electricity-EV systems is much more efficient than the corn photosynthesis-to-ethanol system at converting solar energy into kinetic energy**
2. **electric cars convert the majority of electrical energy into kinetic energy, but internal combustion motors convert less than one fourth of the chemical energy in gasoline into kinetic energy**
3. **corn plants do not harness solar radiation year round, while solar panels do**
4. **corn plants require more energy inputs per unit output that do solar panels (embodied energy)**
5. **solar pv panels can be utilized in the driest, sunniest places in the world, while corn needs to be grown in more humid, and thus somewhat more cloudy, environments**

But would such a system of solar panels supplying power to electric cars be cost effective?

For the electric car running on solar electricity, assume a kilowatt-hour of solar electricity at retail costs 9 cents. (industrial scale solar plants in the US SW are now being contracted at three to four cents, but we must add in distribution costs of four to five cents). Note that the new Tesla model 3 priced at $36,000 (which happens to be right at the median price for an auto in the United States) is rated at 4 miles per kWh. If we use the model 3 mileage we get about **2.25 cents per mile.**

A mid-sized gasoline powered gets about 30 miles per gallon on gasoline. At a retail price of $2.70, the **energy cost per mile** works out to 9 cents, or **four times as much as the electric car.**

Yes, the energy cost per mile to drive a solar electric car is about one fourth of the gasoline powered car! Retail gasoline prices would have to drop to about 70 cents to compete evenly with solar electricity. Note that the solar prices here are at industrial scale, rooftop are a bit more expensive.

Cost of ownership, electric vs conventional

The other factors besides purchase price and energy costs in determining cost of ownership include maintenance, depreciation, and longevity. While I shall not attempt a full ownership cost analysis here, some commentators in Cleantechnica (2019) believe we are near or at equality: <https://cleantechnica.com/2019/03/03/tesla-model-3-total-cost-of-ownership-update-tesla-launches-meteor-to-kill-the-dinosaurs-of-the-auto-industry/>