Solar Energy Absorption

In the excellent article "Atmospheric effects of pollutants" by Hobbs *et al.* (8 Mar., p. 909), there is a misstatement concerning the absorption of solar energy in the atmosphere. In the section "Radiation balance" the authors state: "The infrared radiation is a minor part of the incoming solar power . . . ," and then go on to discuss atmospheric heating by absorption of solar radiation without considering absorption by H_2O, CO_2 or other species with infrared absorption bands. In fact, the infrared radiation is not a minor part of the incoming solar power. Above the atmosphere, only 50 percent of the solar energy is at wavelengths less than 0.71 micrometer, which is approximately where the infrared begins. The wavelengths below which 60, 70, 80, 90, and 98 percent of the solar energy is found are 0.84, 1.0, 1.2, 1.6, and 3.0 μm, respectively. There are important absorption bands for H_2O at 0.72, 0.81, 0.94, 1.1, 1.38, 1.87, 2.7, and 3.2 μm; for CO_2 at 1.6, 2.0, and 2.7 μm; and for O_2 at 0.78 and 1.27 μm. The water bands are the most important by far. The literature has been well summarized by Robinson (*1*).

The atmospheric absorption of H_2O, CO_2, and O_2 is almost entirely responsible for the reduction of solar energy flux from 2.00 calories per square centimeter per second at the top of the atmosphere to 1.40 at sea level. The direct heating of the atmosphere from this absorption can hardly be neglected.

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Merriam correctly points out that we excessively deprecated the influence of solar infrared radiation on the heat budget of the atmosphere. To complement his values for the integrated solar radiance as a function of wavelength, we add an approximate budget for the interaction of solar radiation with the earth (*1*): for every 100 watts of incoming power, 24 are reflected by clouds, 7 are scattered back to space by the earth's atmosphere, and 4 are reflected back to space by the planet's surface (subtotal 35); 22.5 watts reach the surface directly, 14.5 more after diffuse scattering from clouds, and 10.5 more after diffuse molecular scattering (subtotal 47.5); of the residue (subtotal 17.5), about 6 are absorbed by the atmosphere in the ultraviolet and 11.5 in the infrared. In our article, we carelessly "misspoke" our intention of stating that this last number is a minor part of the total power incident on the planet. It is, of course, a larger part of the nonreflected solar power, about 18 percent.

The main purpose of our article was to estimate the influences of potential pollutants upon the atmosphere. For a hypothetical pollutant that is very active in the infrared to absorb 10^{-3} of that 18 percent, its global concentration would have to exceed about 10 parts per million. The arguments in our article suggest that other deleterious effects would likely be observed at lesser concentrations.

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Osmotic Power Plant

I have for years used the osmotic pump fallacy to illustrate the workings of the second law of thermodynamics, and hope that none of my students see the article "The osmotic pump" by Levenspiel and de Nevers (18 Jan., p. 157) and have dust thrown into their intellectual gears. Those familiar with oceanography know that the nonequilibrium states which do obtain over short distances do not admit of practical energy-producing processes.

If one wants to engage in speculation and still be quite consistent with the laws of thermodynamics, one should calculate the amount of energy produced by having the mixing of the Hudson River with the Atlantic Ocean in New York Harbor take place under those conditions which approach reversibility and which are attainable by the use of modern ion-exchange membrane technology. A simple calculation will show that such a membrane plant would make electricity sufficient to supply all of the needs of New York City and much of the hinterland. It would require, incidentally, membrane stacks that would cover all of Central Park to a height of some 3 miles, for such is the slow rate of diffusive processes.

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We share Gregor's respect for the laws of thermodynamics; we believe our article shows that respect. As we point out in the article, the concentration-depth relationship in the oceans is far from the equilibrium one; the second law of thermodynamics makes it amply clear that one can, in principle, extract power from any such nonequilibrium situation.

We hope that in addition to teaching his students thermodynamics, Gregor teaches them to read articles all the way through, and not take parts out of context. If his students do, they will read the last two paragraphs of our article, which we hereby quote.

> In principle, at locations where the oceans are deepest the osmotic pump should be able to bring fresh water to the surface of the real ocean and the osmotic power plant should be able to generate significant electric power. However, these devices are not likely to be economically feasible at the present time. . . .
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> One may think of this as a way of harvesting some of the sun's free energy which is stored in the nonequilibrium state of the ocean. So far, mankind has harvested such solar energy where it is more concentrated—through photosynthesis, fossil fuels, hydroelectric power, winds, and tides. There are other untapped sources of solar energy and possibilities which may be more economically attractive than this one, such as the steep temperature gradients in the tropical oceans and photovoltaic conversion. For the near future this osmotic approach seems less likely to be commercialized than others, although as we have shown here it is thermodynamically feasible.

We do not believe that anyone who reads those paragraphs will be misled about the practical prospects of the osmotic pump or power plant.

We have accepted Gregor's suggestion to calculate the power obtainable from the reversible salination of the Hudson River at New York. The reversible power would be the volumetric flow rate times the osmotic pressure. The former averages about 610 m^3 sec^{-1} (*1*), while the latter is about 25.6 atm. Multiplying these together, we have (610 m^3 sec^{-1}) $\times$ (25.6 atm) $\times$ (1.013 $\times$ 10^5 watt m^{-3} atm^{-1} sec^{-1}) = 1.58 $\times$ 10^9 watts. The installed electric capacity of the United States is about 1500 watts per person, so this is approximately enough power for a population of 1 million people. The statement about "New York City and much of the hinterland" seems exaggerated.

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Wind, Waves, and Women

In his review of *Exercise and Sport Sciences Reviews* (*1*) (31 May, p. 977) Steven M. Horvath mentions that the best time for a marathon run of 50 miles was made by a woman. The best time for a 50-mile swim is also held by a woman. The indomitable Greta Andersen beat the only other swimmer (a male) and won the race by 5 hours. The question of noblesse oblige was not involved since it was a professional race in which a $10,000 purse was involved. In my book *Wind, Waves, and Sunburn* (*2*), which is a history of marathon swimming, I called Greta the greatest female marathon swimmer in the history of the sport. Twice she won the English Channel race (21 miles), beating all the men in doing so. She is also the only person to make a round-trip swim (44 miles) of the Catalina Channel. Greta at some time in her career has beaten every man she has ever swum against. And it should be mentioned that Greta is no androgyne. She has all the right padding in the right places that characterizes the feminine woman. There are many other examples of women surpassing men in this sport.

In more than 20 years of training marathon swimmers, I have observed the following. Whenever a race is more than 4 miles long (about 1½ to 2 hours), the women begin to recoup the lead the men have taken. From that time on it becomes a toss-up as to whether the winner will be a man or a woman.

Over the years, many a University of Chicago student and professor has been humbled by one of my female students in training in Lake Michigan.