Exploding U.S. Grain Demand For Automotive Fuel Threatens World Food Security And Political Stability

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WASHINGTON, DC — "Now that the year's grain harvest is safely in the bin, it is time to take stock and look ahead," writes Lester Brown, President of the Earth Policy Institute. This year's harvest of 1,967 million tons is falling short of the estimated consumption by 73 million tons. This shortfall of nearly 4 percent is one of the largest on record. In six of the last seven years world grain production has fallen short of use, drawing world grain carryover stocks down to 57 days of consumption, the lowest level in 34 years. The last time they were this low wheat and rice prices doubled.

The growth in world grain consumption since 2000 averaged roughly 31 million tons per year. Of this, close to 24 million tons were consumed as food or feed. The annual growth in grain used to produce ethanol for cars in the United States alone averaged nearly 7 million tons per year, climbing to a high of 14 million tons in 2006.

Wheat and corn prices have climbed by a third or more over the past several months. Corn and wheat futures are both trading at 10-year highs. With corn stocks at the lowest level on record and demand soaring, corn prices appear headed for historic highs. Wheat and rice prices will likely follow corn prices upward.

Corn importers like Japan, Egypt, and Mexico are worried that a likely reduction in U.S. corn exports, which are 70 percent of the world total, will disrupt their livestock and poultry industries. In some importing countries, corn is the staple food. In the United States, most corn is consumed indirectly. The milk, eggs, cheese, chicken, ham, beef, ice cream, and yogurt in the typical refrigerator are all produced with corn. In effect, the refrigerator is filled with corn. And the price of every item is affected by the price of corn.

This clash between motorists and people over the food supply is occurring when 854 million of the world's people are chronically hungry and malnourished. The U.N. goal of reducing by half the proportion of people suffering from hunger by 2015 is now failing as the number who are hungry edges upward, and it could collapse completely in the face of the food-for-cars onslaught.

The attempt to solve one problem - growing U.S. dependence on imported oil - is creating another far more serious problem. Fortunately this can be avoided. The 3 percent of U.S. automotive fuel supplies now coming from ethanol could be achieved, several times over and at a fraction of the cost, by raising automobile fuel-efficiency standards by 20 percent. On the food-versus-fuel issue, the world desperately needs leadership. As the world's leading grain producer and exporter, and the largest producer of ethanol, the United States is in the driver's seat.

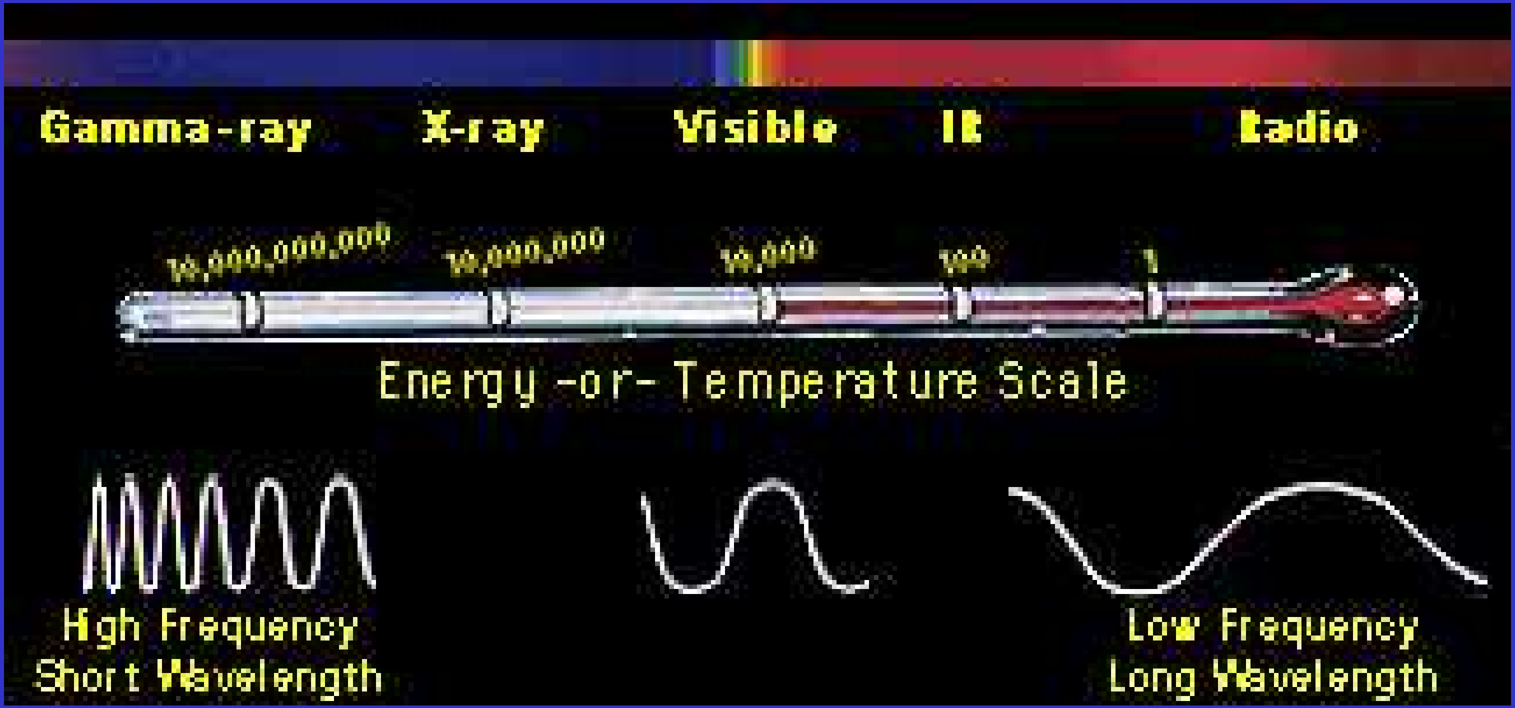
The amount of grain used to produce fuel is exploding. Investment in crop-based fuel production, once dependent on government subsidies, is now driven by the price of oil. With the current price of ethanol double its cost of production, the conversion of agricultural commodities into automobile fuel has become hugely profitable, leading to a jump in groundbreakings for new ethanol distilleries. Between October 25, 2005, and October 24, 2006, construction started on an astounding 54 new ethanol distilleries in the United States. With a typical construction period of 14 months, virtually all of them will be producing by the end of 2007. Together these plants, with 4 billion gallons of annual production capacity, will consume 39 million tons of grain per year, nearly all of it corn.

Photochemistry, Part 1: Radiation

Objectives for Lecture 8

- Review the electromagnetic spectrum
- Review the relationship between energy and wavelength
- Learn about the nature of photolysis
- Review the Beer-Lambert law

The Electromagnetic Spectrum



For more information on the electromagnetic spectrum, see this website.

Essentials of Electromagnetic Energy

The "unit" of electromagnetic energy is the photon. It can be thought of as a very tiny particle, but also possesses many properties that are more like those of a wave. This is the so-called "wave-particle duality" of light [quantum mechanics!].

The wavelength and frequency of light are related via the speed of light, which in a vacuum, is the same value for all wavelengths:

$$\lambda\,\nu = c = 3.00 \text{ x } 10^{8} \text{ m s}^{-1}$$

wavelength x frequency = speed of light

$$\text{m x s}^{-1} = \text{m s}^{-1}$$

Wavelength is the distance from peak to peak in a wave, and is always given in units of meters, nanometers (1 nm = 10^{-9} m), micrometers or “microns” (1 µm = 10^{-6} m), and even centimeters (1 cm = 10^{-2} m) or millimeters (1 mm = 10^{-3} m). This is to span the very wide range of wavelengths that are encountered in our daily lives (see Sample Problem in next slide)

Frequency is the number of waves that pass in a second and is typically given as s^{-1} or Hertz (Hz).

Energy = Planck's constant x frequency

Thus, energy of a photon is related to its wavelength via:

$$E = h\nu = hc/\lambda$$

where h = 6.626 x 10^{-34} Joule seconds (or “J s”)

Energy is sometimes given in Watts (W), which are joules per second, or J s^{-1}.

In reality, a Watt is a unit of power, the rate at which energy is done (i.e. energy per unit time)

Sample Problem**:** A microwave oven puts out radiation at 50 GHz. What is the corresponding energy of the microwave photons? What is the wavelength of the photons? How does a microwave oven heat food anyway?

First note that 50 GHz is a frequency (Hz = s^{-1})

$$E = h\nu = (6.626 \times 10^{-34}\ \mathrm{J\ s}) \times (50 \times 10^{9}\ \mathrm{s}^{-1})$$

$$= 3.313 \times 10^{-23}\ \mathrm{J}$$

$$\lambda\nu = c$$

$$\text{so } \lambda = c/\nu$$

$$\lambda = (3 \times 10^{8}\ \mathrm{m\ s}^{-1})/(50 \times 10^{9}\ \mathrm{s}^{-1})$$

$$\lambda = 6 \times 10^{-3}\ \mathrm{m}\ (= 6 \text{ millimeters or “mm”})$$

Microwaves heat food by exciting a rotational transition within water molecules. The excited water molecules exchange their energy with other molecules in the food, warming it up.

Sample Problem: A typical laser pointer puts out about 5 mW of red light at a wavelength of 653 nm. How many photons is this in one second?

We are given a power for the laser pointer, 5 mW (5 milliW, or 5×10^{-3} W)

$$5 \times 10^{-3}\ \mathrm{W} = 5 \times 10^{-3}\ \mathrm{J\ s^{-1}}$$

Since we're asked for the number of photons in one second, we are dealing with a total energy of 5×10^{-3} J.

Next we calculate the amount of energy in a single 653 nm photon:

$$E = hc/\lambda$$

=€€ $(6.626 \times 10^{-34}\ \mathrm{J\ s}) \times (3 \times 10^{8}\ \mathrm{m\ s^{-1}})/(653 \times 10^{-9}\ \mathrm{m})$

$= 3.04 \times 10^{-19}$ J (per photon)

Then,

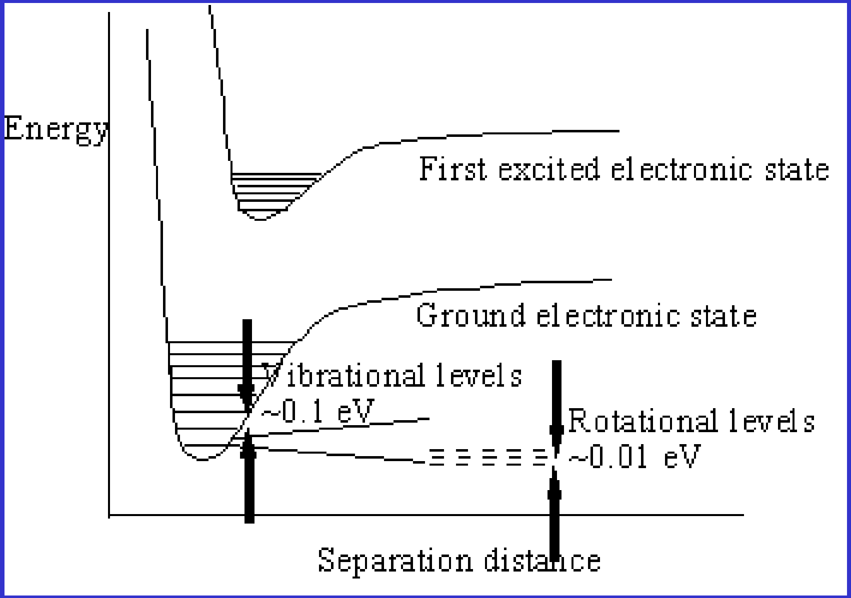
$$\text{Total photons} = (5 \times 10^{-3}\ \mathrm{J})/(3.04 \times 10^{-19}\ \mathrm{J\ photon^{-1}})$$

$$= 1.64 \times 10^{16}\ \text{photons}$$

The Nature of Photolysis

When a molecule or atom absorbs (or emits) light energy, it must undergo an internal change of some type to account for the change in its total energy.
That change may be in vibrational, rotational, or electronic energy (i.e., the configuration of the electrons in the molecule).

Chemists illustrate the electronic state of a molecule using what is called an "energy level diagram". Energy level diagrams come in many forms, and can be relatively simple to understand, or quite complex. Here is an example of an energy level diagram for a diatomic molecule:



What determines photolysis rates in the atmosphere?

The photolysis rate for any molecule is determined by a combination of factors:

- Absorption cross section, as a function of l
- Amount of solar radiation, as a function of l, which depends on season, latitude, time of day, O_3, O_2 column, and amount of aerosol

To calculate a photolysis rate, one performs a complex integration:

$$J = \int_{\lambda} \sigma(\lambda)\varepsilon(\lambda)q(z,\chi,\lambda)d\lambda$$

where σ is the molecular absorption cross-section (as we have seen before)

ε is the "quantum yield"

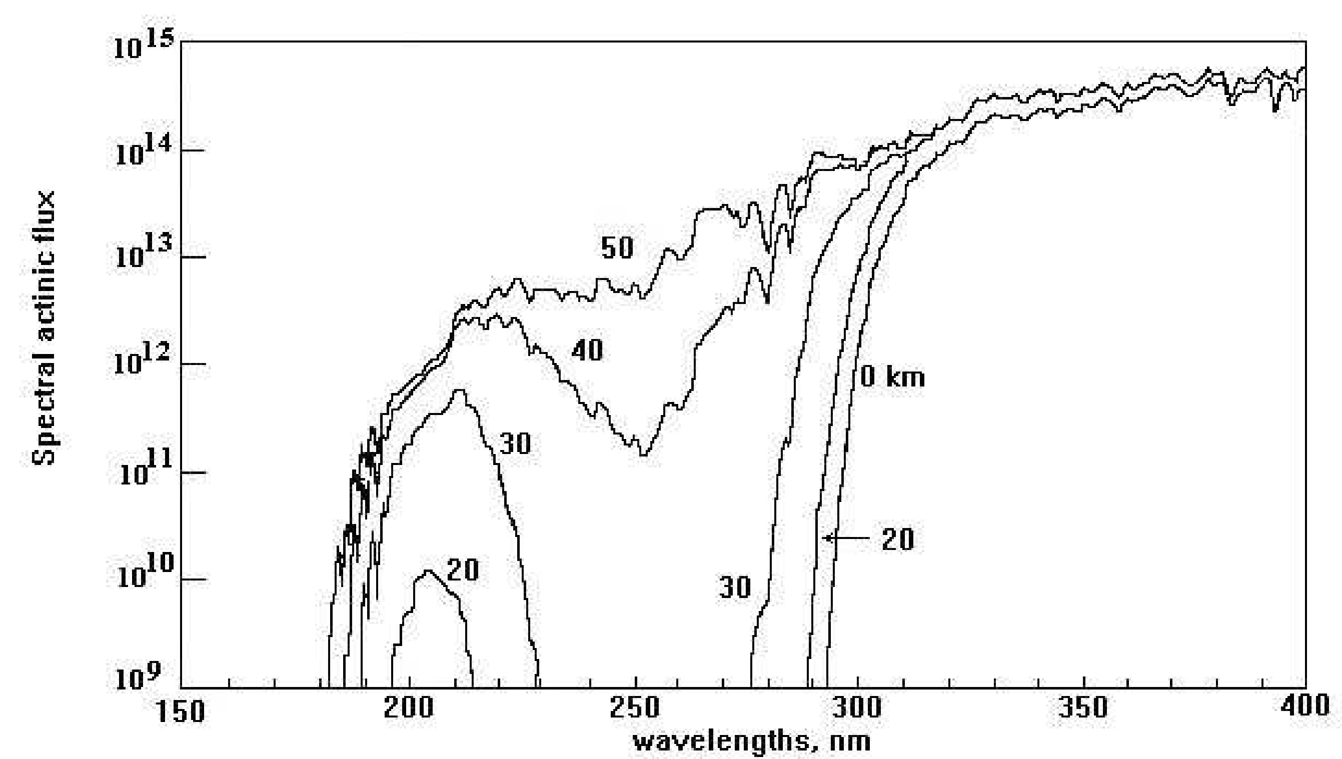
q is the solar flux, as a function of altitude (z), solar zenith angle (χ) and wavelength (λ)

Most molecules of atmospheric significance photolyze in the UV, but some can be dissociated by visible light.

UV: O_3, O_2, CFCs, N_2O, HNO_3

Visible: Cl_2, NO_3, NO_2

Solar Flux at Various Altitudes



This is similar to the figure in the stratospheric ozone lecture

We can determine the amount of light reaching the surface of the earth using Beer’s Law (also called the Beer-Lambert law)

$$I = I_o \exp(-\sigma\, l\, n)$$

I = amount of light with absorber present
I_o = amount of light with no absorber
σ = absorption cross section (cm^2 $molec^{-1}$)
l = pathlength (cm)
n = number of absorbers (molec cm^{-3})

Problem: Column O_3 over midlatitudes has decreased about 4% over the past decade. How much more radiation at 300 nm now reaches the surface? There are about 8×10^{18} O_3 molecules cm^{-2} in the column and the absorption cross section of O_3 at 300 nm is 3.4×10^{-19} cm^2.

If there are 8×10^{18} O_3 molecules cm^{-2}, then a 4% reduction will leave 7.68×10^{18} cm^{-2}.

Note that for a column of air, the quantity given is $n \times l$ (units of cm^{-2})
Using the Beer-Lambert law,

Original ozone: $I/Io = \exp[-(8 \times 10^{18} \text{ molec cm}^{-2})(3.4 \times 10^{-19} \text{ cm}^2)] = 6.59 \times 10^{-2}$
4% less ozone: $I/Io = \exp[-(7.68 \times 10^{18} \text{ molec cm}^{-2})(3.4 \times 10^{-19} \text{ cm}^2)] = 7.34 \times 10^{-2}$

Change in radiation at 300 nm: (0.0734 - 0.0659)/0.0659 = 11% increase!!!