Earth Sea and Sky
National Science Olympiad, May 15, 1999

Results Notebook

Team (school)＿＿＿＿＿＿＿＿＿＿

Team Number＿＿＿＿＿＿＿＿＿＿

Team member 1＿＿＿＿＿＿＿＿＿

Team member 2＿＿＿＿＿＿＿＿＿

Important! Be sure to pick up a copy of the "handbook," where you will find much useful data and formulae.   Be sure to consult it. Please turn in the handbook at the end of the session, along with your answers. Please do not write in the handbook.

Design-a-Planet

You are a planetary engineer. You are given the job of designing new planets for various aliens. The aliens have definite preferences for the temperature they would like to live at.

The basic planet you offer has a pure Nitrogen atmosphere with a surface pressure equivalent to 1 Earth atmosphere. It has a radius of 1000 kilometers. The surface is covered with "black goo," which absorbs 100% of the sunlight falling on it. At a distance of one Astronomical Unit (a.u.) from the planet's star, the flux of solar energy is 3000 W/m^2.

You have the following materials and supplies available to you.

Basic tools:
Planet mover. The basic planet is delivered at an orbit lying 1 a.u. from the star. You can use your planet mover to move the planet to a circular orbit at any other distance.
White paint. This can be mixed with black goo to make the surface of the planet more reflective. Each gigaton of white paint you mix in adds another 10% to the reflectivity, up to 100%. That is, if you mix in 1 gigaton, the reflectivity (or *albedo*) is 10%, if you mix in 2 gigatons it's 20%, and so on up to 10 gigatons at which point the planet reflects all the solar energy. You can mix in fractions of a gigaton to get any albedo you want.

Advanced tools:
Carbon Dioxide (CO_2) You can mix carbon dioxide into the atmosphere to achieve any desired atmospheric concentration. The atmospheric concentration is measured in parts per million volume (ppmv). See the Handbook for details, if necessary. The radiative effects of CO_2 are described in a graph in the Handbook.
Ocean Option. The basic planet comes without any water whatsoever. However, you can add an ocean. The effect of the ocean is to keep the atmosphere 50% saturated with water vapor. The way water vapor affects the radiation budget may be inferred from a graph in the Handbook.

In the Handbook , you will find various formulae, data and graphs useful in designing your planet.

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Job 1

It's your first job after graduating planetary engineering school. You are to design
a planet for some aliens who like a temperature of 10 Celsius (283.15 Kelvin).
Since you are a rookie, you are only allowed to use the basic tools. You can pick
the distance of the planet from its Sun (in a.u.), and you can use enough white
paint to make the surface of the planet as reflective as necessary.

First, as a warm-up, say what the temperature is for the basic planet at delivery (1
a.u. from the star, completely black surface). Give your answer *in degrees Kelvin*
here: _____ degrees Kelvin.

Now record your specifications for a planet meeting the aliens' temperature
requirements, in the table below.   Be sure to record the distance from the sun at
which your planet is located. *Do not* put down the distance you moved the planet
from its original orbit.

Important! Do not leave any boxes blank. You cannot receive any credit
for this or the next task if you leave any amounts blank here.

Design Parameter	Specification/Amount
Distance from Sun (in a.u.)	
Amount of white paint (in Gigatons)	

Getting the temperature right is the main thing. However, provided you get the
temperature right to within 1 degree C, you will get a bonus for keeping the cost low.
The cost is 1 billion credits for each a.u. you need to move the planet from its delivery
orbit (prorated for fractions of an a.u), plus 200 million credits for each gigaton of white
paint used.

Comments and scratch calculation space:

_____
Job 2

The original aliens decide to move on to a bigger planet. The new guys who move in find the planet too chilly, and would like a warmer planet. Their preferred temperature is 50 degrees C (323.15K). Use your advanced tools to modify the planet so as to meet their requirements. You may not change the orbit or the albedo of the planet at this point. These must remain fixed at the values you used for Job 1.

Do not leave any items blank. In order to receive any credit, you must at least guess a value for all items.

Action	Specification/Amount
Add atmospheric Carbon Dioxide (in ppmv)	
Add Water ocean? (yes or no)	

Comments and scratch calculation space:

Carbon Cops

The planet Carbonia is completely covered by identical townships, each one with an area of 1 square kilometer (1 million square meters). The inhabitants have been measuring the CO_2 concentration of their atmosphere, and, to their alarm, have found that it is rising rapidly. To figure out what to do about it, they want to find who or what is responsible for the rise. You have been called in to find out.

Each township has three geographical features: A volcano (Mt. Vesuviana), a rocky mountain (Mt. Baldy), and an ocean (the Specific Ocean). These have been there for millions of years.

Each township on Carbonia has four inhabitants, with habits as described on the display. They only moved in and began their activities in 1950.

On the display area for this station, you will also find various information useful in your search for the carbon culprits.

1. Rank the suspects

Rank each of the suspects according to how responsible each is for the *increase* in the CO_2 content of Carbonia's atmosphere. The most "guilty" should be ranked "1," the next most guilty should be ranked "2,"   and the least guilty (or most helpful) should be assigned rank "6."   In case of a tie between two or more suspects, you can assign their relative ranks at random without any effect on your score.

Mount Vesuviana _____

Mount Baldy   _____

Tex, the driver _____

Biff, the wood-burner _____

Sally, the gas cogeneration-plant operator_____

Frieda, the coal-fired electricity plant operator_____

2. Find the missing carbon

How much *carbon* (in kilograms) is going into the Specific Ocean each year, in each township?

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When CO_2 dissolves in ocean water, most of it reacts with the carbonate ion (CO_3^{--}) and is converted into bicarbonate ion (HCO_3^-). The reaction is

$$H_2O + CO_2 + CO_3^{--} = 2\ HCO_3^-$$

Assuming that the ocean has a volume of 5×10^8 liters, by how many Moles per liter does the concentration of bicarbonate increase? (Note: these are "big moles" or "kilogram-moles" we are talking about, i.e. 2 Kg of H_2 contains 1 Mole of Hydrogen molecules).

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Scratch space and comments:

Eye in the Sky

Answer the following questions, based on the satellite images posted on the display. Choose from among the features labeled with letters on the images. Each label is unique, so you need not state which image the feature is located on. In some cases more than one feature meets the criterion. You will get one point for each correct answer, and lose one point for each incorrect answer.

1. Identify the hurricane(s)

2. Identify the midlatitude synoptic storm(s)

3. Identify a group of tropical cyclones that probably aren't hurricanes

4. Identify a frontal cloud

5. Identify a (relatively) cold air layer banked up against a mountain range

6. Identify smoke plume(s) from a fire

7. Identify the following features as consisting of either low clouds or high clouds. Mark low-cloud formations with an "L" and high cloud formations with an "H"

B _____   F_____   C_____   A_____   D_____   H_____

Handbook of Useful Formulae and Data

Stefan-Boltzman law: $F = \sigma T^4$, where F is the rate at which energy is radiated (Watts per square meter), T is the temperature in degrees Kelvin, and σ is the Stefan-Boltzman Constant, which is 5.67×10^{-8} Watts/(m^2 deg-K^4).

Inverse square law: At a distance R from a star, measured in astronomical units (a.u.), the flux of radiant energy is $F_s = L_o/R^2$, where L_o is the flux at 1 a.u.

Surface area of a sphere: $A = 4\pi r^2$, where r is the radius. This is the area of the sphere that radiates infrared energy to space.

Cross section area of a sphere: $A = \pi r^2$. This is the area of the beam of sunlight intercepted by the sphere.

Degrees Kelvin = Degrees C + 273.15

The following graph gives the rate at which energy is radiated to space for a planet with a dry atmosphere having no CO_2, and for a planet with a moist atmosphere but no CO_2.
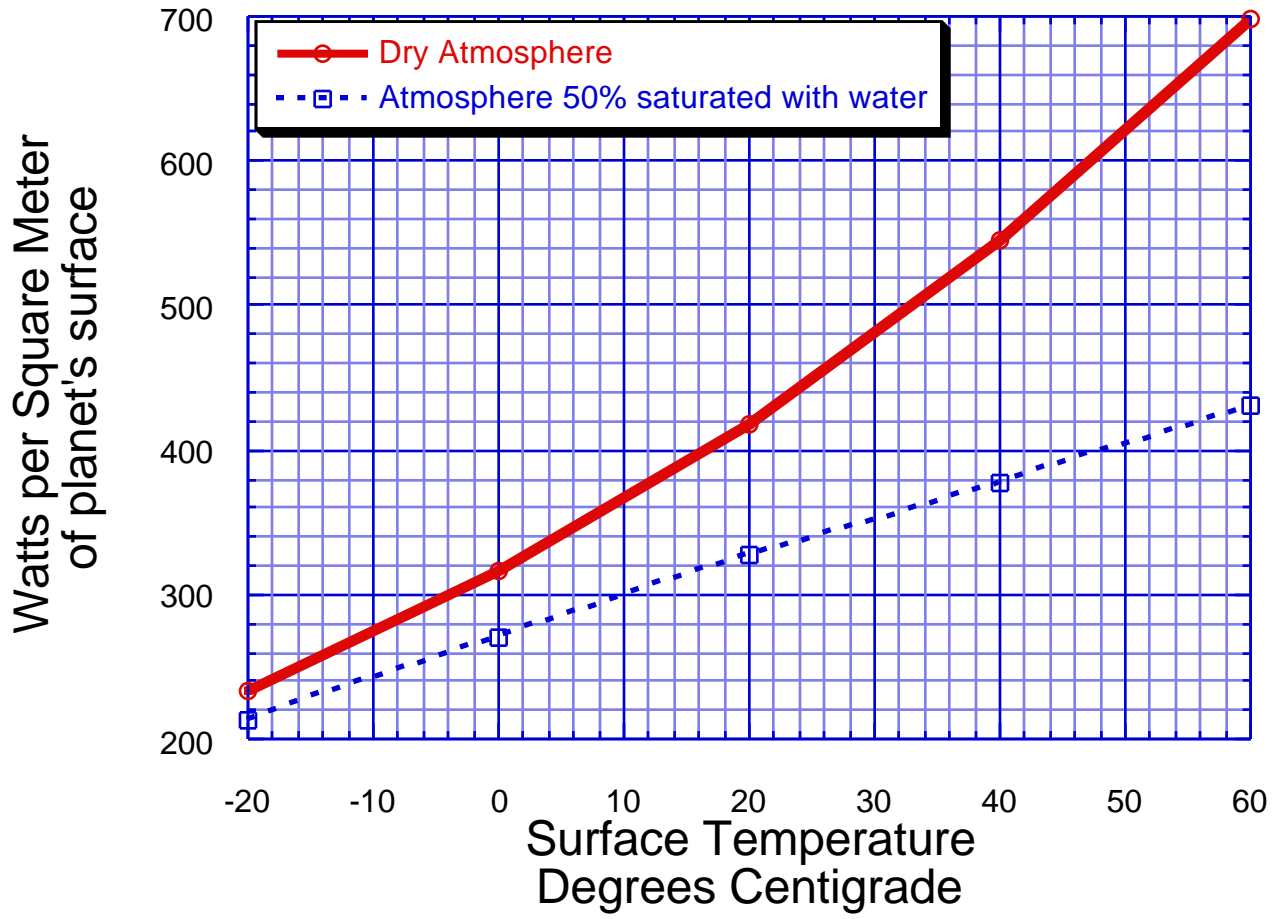
The following graph shows the additional amount of infrared radiation trapped by carbon dioxide, as a function of the concentration of carbon dioxide in the atmosphere.

Example: A dry atmosphere with no CO_2 radiates 420 W/m^2 if the temperature is 20C. If we add 100ppmv of CO_2 to the atmosphere, then the radiation drops to 390 W/m^2
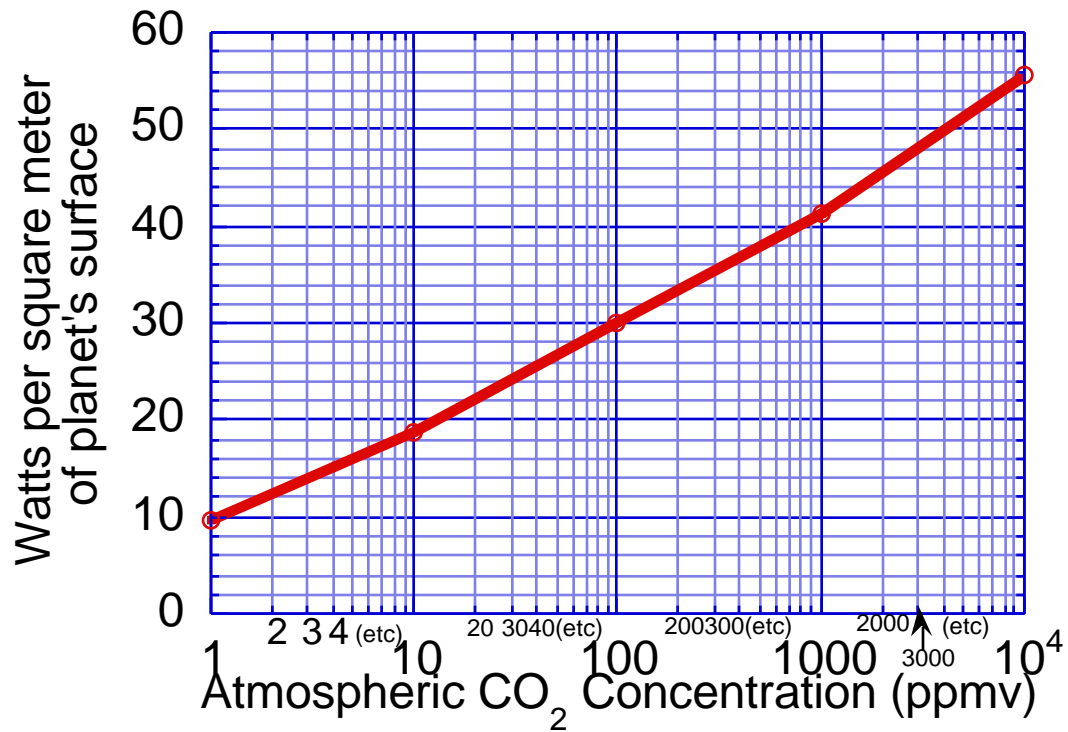
1 ppmv CO2
    = 1 part per million by volume
    = 1 molecule CO2 per million molecules air

There are 10^{10} kilograms of air over each square kilometer of surface.

BTU (British Thermal Unit) is a unit of energy commonly used in fuel and energy industry figures.

Molecular Weights:

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H	1
C	12
O	16
Ca	40
"air"	29 (weighted mean of N_2 and O_2)

Wood contains 45% Carbon by weight

Gasoline releases 19.5 Kilograms of carbon for each million BTU's of energy produced (= 2.4 Kg. carbon for each gallon of fuel burned)

Coal releases 25 Kilograms of carbon for each million BTU's of energy produced.

Natural Gas (CH4, Methane) releases 14.5 Kilograms of carbon for each million BTU's of energy produced

Carbon Cops Display Materials (1999)
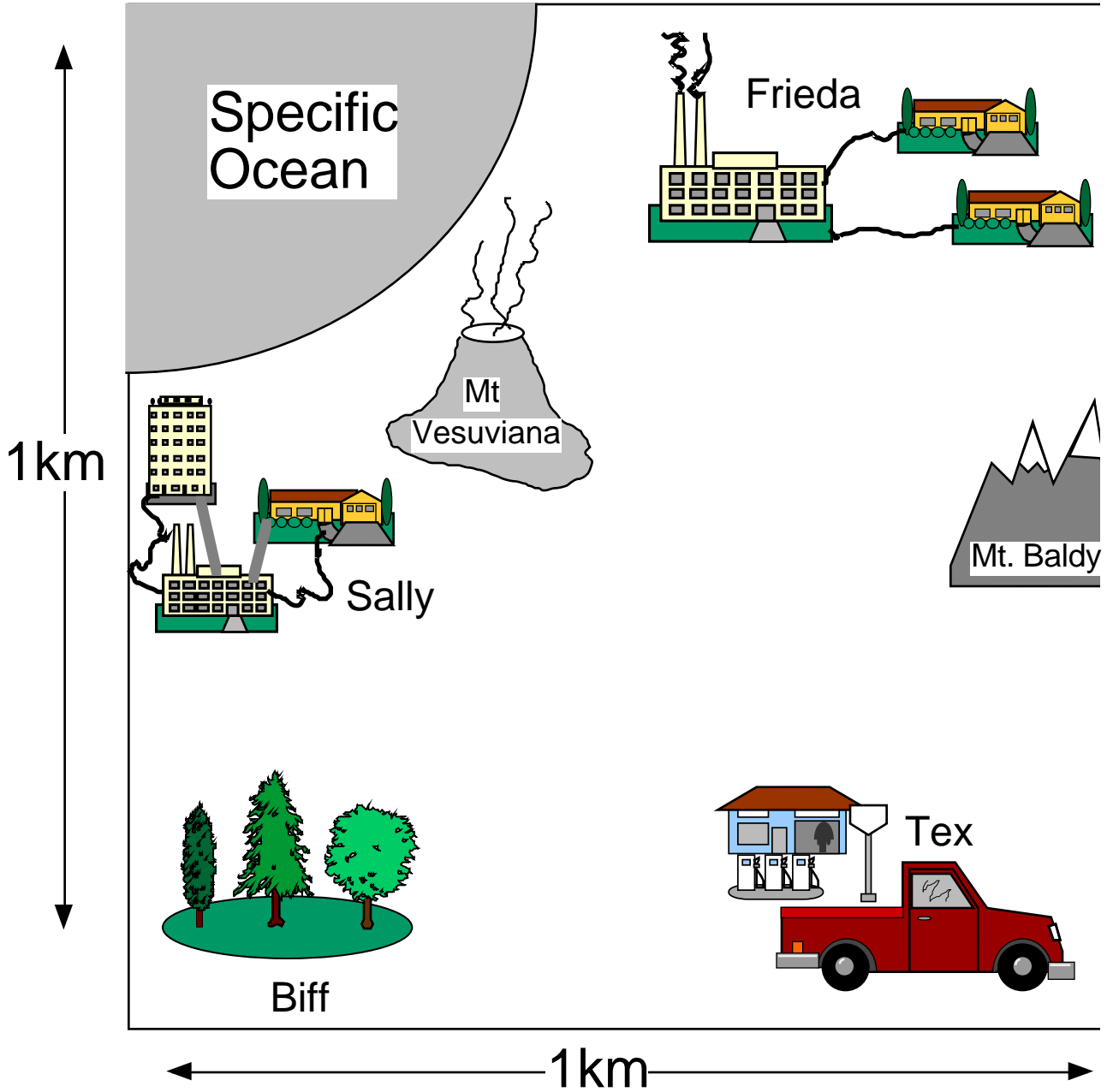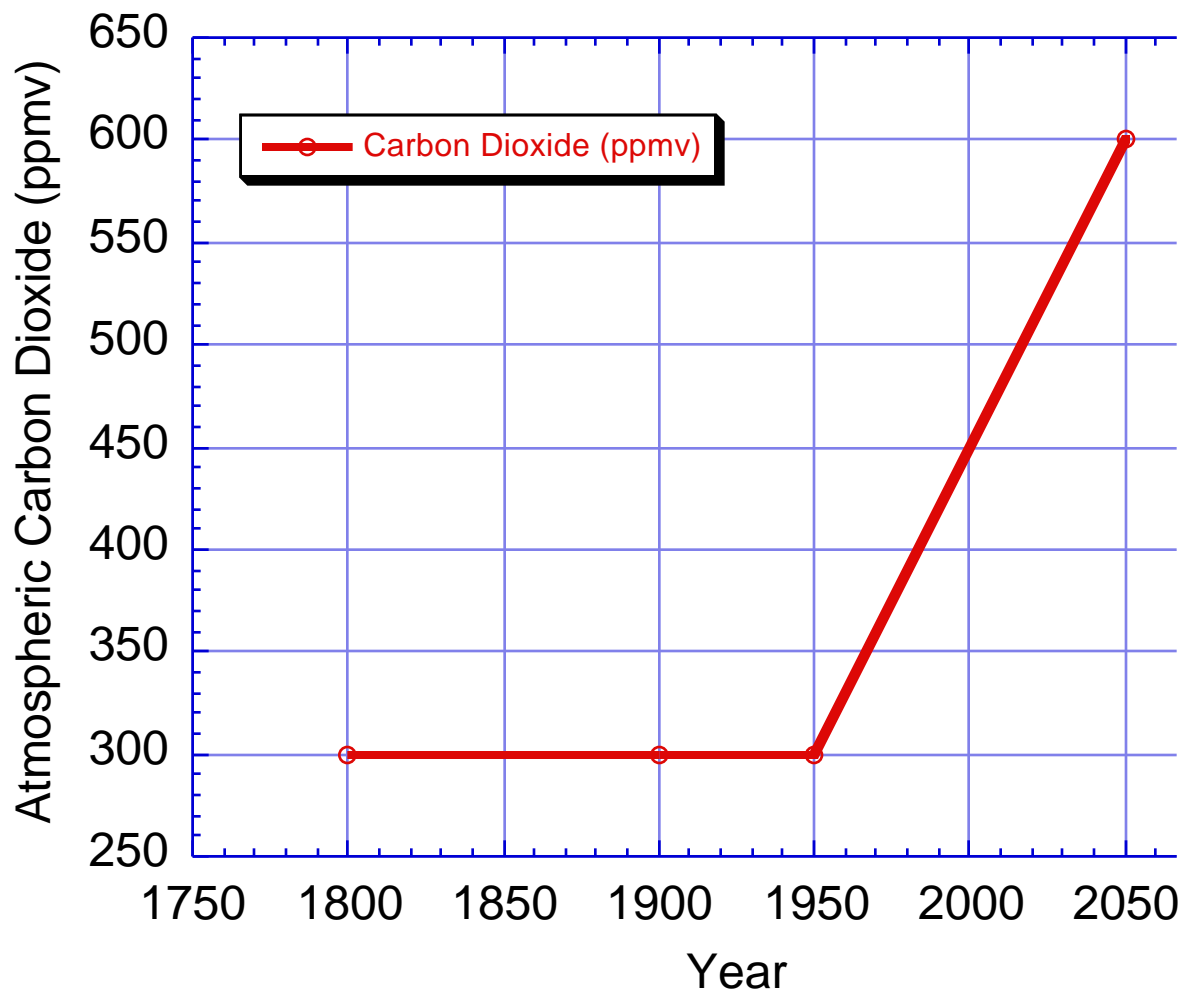
Geography of Carbonia

Mt. Vesuviana: Belches out 7000 kg of CO_2 per year, and has been doing so since time immemorial.

Mt. Baldy: Made of Calcium Silicate ($CaSiO_2$). Under the action of weather and erosion, is turning to Calcium Carbonate ($CaCO_3$) at a rate of 20000 kg of Calcium Carbonate per year. The $CaCO_3$ is washed away in rivers, and winds up dissolving in the Specific Ocean.

The Specific Ocean: It has a volume of 5×10^8 liters. Other than that, the inhabitants of Carbonia have never studied its behavior in detail.

Spotlight on the Citizens: Tex

Tex loves to drive. He loves to drive his LandCrusher^{TM} so much he drives it 50,000 miles per year. His LandCrusher^{TM} gets 12 miles per gallon gas mileage.

Spotlight on the Citizens: Biff

Biff runs a forest for Metla Forest Products Industries. In his forest he grows 8000 Kg of wood per year. Half of this wood is burned for heat used in his maple-syrup business. The other half is made into paper for junk mail, which eventually winds up in a landfill and rots.

Spotlight on the citizens: Sally

Sally runs a "cogeneration" plant for an apartment and light-industry complex. She burns enough natural gas to produce 1000 million BTU's of energy per year. With this energy, she provides 400 million BTU's of electricity, and another 400 million BTU's of hot water for home heating. The remaining 200 million BTU's are lost as waste heat.

Spotlight on the citizens: Frieda

Frieda runs a coal-fired power plant. She has contracted to provide 500 million BTU's of electricity (which is mostly used for home heating and industrial processes). Her power plant is only 50% efficient in turning the energy released by burning coal into electricity (the rest being lost as waste heat).