World fossil energy consumption entirely replaced by biomass as renewable source

Data

In 2011, world primary energy consumption was:

- 4059 Mtonne oil, of equivalent chemical formula $C_7H_{14}N_{0.1}O_{0.1}S_{0.3}$
  (=> molar weight = 110 g/mol), ρ = 0.88 kg/L
- 3 223 Gm^3 natural gas (=2905.6 Mtoe), ρ = 0.7 kg/m^3,
  → take as equivalent to methane CH_4 (=> molar weight = 16 g/mol)
- 7.5 Gtonne coal (=3724 Mtoe), heating value 20 MJ/kg, carbon content 0.5 carbon/kg coal
  (molar weight of carbon = 12 g/mol)

Questions 1 :

1. Estimate the CO_2 emission (molar weight = 44 g/mol) from these 3 fossil sources and their relative shares to the total world emission in 2011.
2. How much does every person emit on average? (world population: 7 billion)
3. Convert the 12275 Mtoe total primary energy consumpion in 2011 to TW-equivalent (world), and to kW-equivalent/per person

Replacement by biomass

We want to replace, in energy-equivalent terms, all fossil fuel by renewable biomass:

- coal by wood (for electricity generation)
  with coal plant electrical efficiency = 40%, but wood plant efficiency = 20%
- oil by bioethanol (for transport fuels)
- gas by biogas (for heating in buildings and industry)

Let's use the following simplified conversions
(we will cover these conversion factors in the Biomass chapters of the course) :

- we can grow 2 kg wood per year per m^2 of forest, with lower heating value = 17 MJ/kg
- we can obtain 3000 L bioethanol (heating value = 21 MJ/L, ρ = 0.78 kg/L) per year per hectare (=10'000 m^2) of biomass fields such as wood, corn, sugar cane, manioc
- we can digest agro-wastes from 1 hectare of land to 2000 m^3 of methane contained in biogas (lower heating value of methane CH_4 = 10 kWh/m^3)

Questions 2 :

4. What would be the land-use for all this biomass to replace all fossil fuel?
5. Compare the obtained result with the available forest and agricultural area (11% and 3% of the Earth surface, respectively).
6. Compare it also with the yearly biomass production of 32 Gtoe in forests and 3.6 Gtoe in agriculture.

Atmospheric CO_2 concentration (ppm)

In the Exercise above we saw that fossil fuel combustion emits a certain quantity of Gt CO_2 per year.

Question 3:

Reckoning that ca. 1/2 of this CO_2 amount is absorbed and stored in the ocean or bound on land (biomass), by how much ***ppm*** does the atmospheric CO_2 concentration increase yearly ?

Hint 1 : atmospheric air density = 1.21 (kg/m^3) * exp (- altitude / 8500 m)

Hint 2 : remember the definition of 1 atm pressure itself !

(namely to compute how much air is contained in a column of 1 m^2 section from the earth's surface to the atmosphere limit)