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Air emissions and Climate change from gasoline

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ABSTRACT

Environmental impacts of energy use can impose large costs on society. We quantify and monetize the life-cycle climate-change and health effects of greenhouse gas (GHG) and fine particulate matter (PM) emissions from gasoline. For each billion gallons of fuel produced and combusted in India, the combined climate-change and health costs are Rs. 469 million for gasoline. Moreover, a geographically explicit life-cycle analysis that tracks PM emissions and exposure relative to Indian population shows regional shifts in health costs dependent on fuel production systems. Because biofuels can offer health benefits from PM reduction that are of comparable importance to its climate-change benefits from GHG reduction, a shift from gasoline to biofuels has greater advantages than previously recognized. These advantages are critically dependent on the source of land used to produce biomass for biofuels, on the magnitude of any indirect land use that may result, and on other as yet unmeasured environmental impacts of biofuels.

Keywords: fine particulate matter, biofuel, biomass, greenhouse gas.

INTRODUCTION

There is widespread concern that observed increases in the concentration of carbon dioxide and other greenhouse gases in the earth's atmosphere will ultimately lead to changes in the earth's climate. Although it is clear that the atmospheric concentration of carbon dioxide is increasing and that the increase is being driven in large measure by the burning of fossil fuels (coal, oil, and natural gas), the climatic consequences of increasing atmospheric carbon dioxide are not so clear. Recognizing that fossil fuels play a very important role in the economies and lifestyles of people throughout the world, and acknowledging that great uncertainty exists regarding the climatic consequences of burning fossil fuels, it is reasonable to ask if the global economy can be powered in ways that might have less impact on the environment because they discharge less carbon dioxide.

In this discussion we focus on minimizing the risk of global climate change through minimizing carbon dioxide emissions, but we recognize that other criteria go into land-use decisions. For example, in some regions of the world, deforestation is a major source of carbon dioxide emissions. Currently, an estimated 15 to 20% of atmospheric carbon dioxide emitted by human activities results from deforestation or, more generally, from changes in land use. Clearly, many motivations, including the need for food production, are involved in decisions on land use and will affect the amount of land available for reforestation or for biomass energy crops. Although we are considering the possibility of planting new areas of forest, the rate of growth in atmospheric carbon dioxide could also be reduced substantially by decreasing the current rate at which forest is being converted to other land uses. Coincidentally, the amount of carbon dioxide emitted annually from deforestation around the world is of the same order of magnitude as the amount of additional carbon dioxide that would be discharged if the 14% of primary energy now supplied by biomass fuels globally were instead supplied by oil and coal.

The net impact of land management and the use of biomass-based products on the cycling of carbon will depend on the type of land used, the management practices used on that land, how the biomass products are used, and the time frame of the analysis. Especially important are how much carbon is stored on the land (including in trees and other plants and in the soil and plant litter on the ground) at the beginning and end of the analysis, how much fossil-fuel use is displaced, how much carbon is stored in durable wood products, and how much energy is required for forest and other land-management operations. Also important are how efficiently forest and other biomass products are used and the alternate products for which they substitute, including whether biomass fuels are substituted for coal, oil, or natural gas; whether they are used to produce liquid fuels, heat, electric power, or some combination of these; and the efficiency with which they are used. The net impact on carbon cycling will depend on the mix of forest and other biomass products used for short-lived products like paper, long-lived products like construction lumber, and fuels. It will depend on whether the lumber displaces aluminum, concrete, glass, or plastic. It will depend ultimately on whether the waste products are reused, buried in landfills, burned for energy, or incinerated.

Although we have focused on trees and forest products in our analyses to date, the most advantageous land use for confronting the carbon balance may not necessarily involve trees. If the primary intent is to store carbon on site, the obvious choice is a high-density forest. On the other hand, if production of biomass energy is the goal, a fast-growing herbaceous crop such as switch grass may be the best choice for some biomass energy technologies and some types of land. Under other circumstances, wood, biodiesel, or another fuel may be able to displace the most fossil fuel. And, if we broaden consideration to include other biomass products, we may find other alternatives. It is important to examine the full range of the affected system and to see how the carbon balance is affected.

Air Pollution facts:

Smog hanging over cities is the most familiar and obvious form of air pollution. But there are different kinds of pollution—some visible, some invisible—that contribute to global warming. Generally any substance that people introduce into the atmosphere that has damaging effects on living things and the environment is considered air pollution.

Carbon dioxide, a greenhouse gas, is the main pollutant that is warming Earth. Though living things emit carbon dioxide when they breathe, carbon dioxide is widely considered to be a pollutant when associated with cars, planes, power plants, and other human activities that involve the burning of fossil fuels such as gasoline and natural gas. In the past 150 years, such activities have pumped enough carbon dioxide into the atmosphere to raise its levels higher than they have been for hundreds of thousands of years.

Other greenhouse gases include methane—which comes from such sources as swamps and gas emitted by livestock—and chlorofluorocarbons (CFCs), which were used in refrigerants and aerosol propellants until they were banned because of their deteriorating effect on Earth's ozone layer.

Another pollutant associated with climate change is sulfur dioxide, a component of smog. Sulfur dioxide and closely related chemicals are known primarily as a cause of acid rain. But they also reflect light when released in the atmosphere, which keeps sunlight out and causes Earth to cool. Volcanic eruptions can spew massive amounts of sulfur dioxide into the atmosphere, sometimes causing cooling that lasts for years. In fact, volcanoes used to be the main source of atmospheric sulfur dioxide; today people are.

Industrialized countries have worked to reduce levels of sulfur dioxide, smog, and smoke in order to improve people's health. But a result, not predicted until recently, is that the lower sulfur dioxide levels may actually make global warming worse. Just as sulfur dioxide from volcanoes can cool the planet by blocking sunlight, cutting the amount of the compound in the atmosphere lets more sunlight through, warming the Earth. This effect is exaggerated when elevated levels of other greenhouse gases in the atmosphere trap the additional heat.

Most people agree that to curb global warming, a variety of measures need to be taken. On a personal level, driving and flying less, recycling, and conservation reduces a person’s "carbon footprint"—the amount of carbon dioxide a person is responsible for putting into the atmosphere.

On a larger scale, governments are taking measures to limit emissions of carbon dioxide and other greenhouse gases. One way is through the Kyoto Protocol, an agreement between countries that they will cut back on carbon dioxide emissions. Another method is to put taxes on carbon emissions or higher taxes on gasoline, so that people and companies will have greater incentives to conserve energy and pollute less.

Key Steps to the Calculation

There are six key steps to estimate the annual greenhouse gas emissions associated with a passenger vehicle:

Step1: Determining the carbon dioxide (CO_2) produced per gallon of gasoline **-** A gallon of gasoline is assumed to produce 8.8 kilograms (or 19.4 pounds) of CO_2. This number is calculated from values in the Code of Federal Regulations at 40 CFR 600.113-78, which EPA uses to calculate the fuel economy of vehicles, and relies on assumptions consistent with the Intergovernmental Panel on Climate Change (IPCC) guidelines. In particular, 40 CFR 600.113-78 gives a carbon content value of 2,421 grams (g) of carbon per gallon of gasoline, which produces 8,877 g of CO_2. (The carbon content is multiplied by the ratio of the molecular weight of CO_2 to the molecular weight of carbon: 44/12). This number is then multiplied by an oxidation factor of 0.99, which assumes that 1 percent of the carbon remains un-oxidized.[1.] This produces a value of 8,788 g or 8.8 kg (19.4 lbs) of CO_2.

Step 2: Estimating the fuel economy of passenger cars and light trucks (in miles per gallon [mpg])**-**There are two sources of data which EPA has used for the average fuel economy of passenger cars and light trucks. MOBILE 6.2(EPA's computer model for estimating emissions for highway vehicles) can calculate an average fuel economy across the fleet, based on the EPA annual Fuel Economy Trends reports. For 2003, MOBILE calculates values of 23.9 miles per gallon (mpg) for passenger cars and 17.4 mpg for light trucks. These values are weighted averages (based on vehicle age data for the fleet, including vehicles up to 25 years old) of the Fuel Economy Trends sales-weighted average fuel economy of passenger cars and light trucks for each model year. MOBILE6.2 calculates an overall average fuel economy for passenger vehicles of 20.3 mpg (weighted by vehicle miles traveled [VMT] for passenger cars and light trucks).The Federal Highway Administration's (FHWA) "Highway Statistics 2001" EXIT Disclaimer gives average values of 22.1 mpg for passenger cars and 17.6 mpg for light trucks as a fleet wide average in for the year 2001 (includes all vehicles on the road in 2001). These values are obtained by dividing vehicle miles traveled by fuel use.[2.] These values are used in the development of the "Inventory of U. S. Greenhouse Gas Emissions and Sinks."Recommendation: Values were calculated using both sets of fuel economy numbers. Depending on the circumstances, use of one set of numbers or the other may be more appropriate. Generally EPA staff should use the MOBILE6 estimates. However, EPA uses the FHWA numbers in developing the National Inventory for Greenhouse Gas Emissions because they are consistent with the methodology used to develop the inventory. (Note that a small variation in the fuel economy number will not change the rough estimate of greenhouse gases derived here.).

Step 3 : Determining the number of miles driven **-** The number of miles driven per year is assumed to be 12,000 miles for all passenger vehicles. This number is based on several sources. Calculations from EPA's MOBILE6 model show an average annual mileage of roughly 10,500 miles per year for passenger cars and over 12,400 miles per year for light trucks across all vehicles in the fleet. However, these numbers include the oldest vehicles in the fleet (vehicles 25 years of age and older), which are likely not used as primary vehicles and are driven substantially less than newer vehicles. Since this calculation is for a typical vehicle, including the oldest vehicles may not be appropriate. For all vehicles up to 10 years old, MOBILE6 shows an annual average mileage of close to 12,000 miles per year for passenger cars, and over 15,000 miles per year for light trucks. FHWA's National Highway Statistics contains values of 11,766 miles for passenger cars and 11,140 miles for light trucks across the fleet. However, as with the MOBILE6 fleet-wide estimates, these numbers include the oldest vehicles in the fleet. EPA's Commuter Model uses 1997 data from Oak Ridge Laboratories for the number of cars nationally and number of miles driven which produces a value of just over 12,000 miles per year. Due to the wide range of estimates, 12,000 miles per vehicle is used as a rough estimate for calculating the greenhouse gas emissions from a typical passenger vehicle.)

Step 4: Determining the emissions of greenhouse gases other than CO_2 (methane [CH_4], nitrous oxide [N_2O], and hydro fluorocarbons [HFCs]) **-** In addition to carbon dioxide, automobiles produce methane (CH_4) and nitrous oxide (N_2O) from the tailpipe, as well as HFC emissions from leaking air conditioners. The emissions of CH_4 and N_2O are related to vehicle miles traveled rather than fuel consumption, and the emissions of CH_4, N_2O, and HFCs are not as easily estimated from a vehicle as for CO_2.[3.] On average, CH_4, N_2O, and HFC emissions represent roughly 5 - 6 percent of the GHG emissions from passenger vehicles, while CO_2emissions account for 94-95 percent, accounting for the global warming potential of each greenhouse gas. (These percentages are estimated from the EPA "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 - 2001".) To simplify this estimate, it is assumed that CH_4, N_2O, and HFCs account for 5 percent of emissions, and the CO_2 estimate was multiplied by 100/95 to incorporate the contribution of the other greenhouse gases.

Step 5: Estimating the relative percentages of passenger cars and light trucks- Because FHWA calculates fuel economy for passenger cars and light trucks separately, it is necessary to determine the relative percentage of cars and light trucks in order to derive the greenhouse gas emissions for an average passenger vehicle. (This step is not necessary when using the MOBILE6 fuel economy data because MOBILE6 already calculates a weighted average fuel economy for all passenger vehicles.) Passenger cars are assumed to make up 63.4 percent and light trucks make up 36.6 percent of the passenger vehicle fleet. These values are derived from table 6.4 (2000 data) of the "Transportation Energy Data Book: Edition 22," (published by the Center for Transportation Analysis, Oak Ridge National Laboratory) which states there are 127,721,000 passenger cars on the road and 73,775,000 light trucks (less than 8500 lbs [4.]). Note that this percentage is changing over time, as light trucks now represent roughly 50 percent of annual new vehicle sales.

Step 6: Calculating the resulting annual greenhouse gases from a typical passenger vehicle-

A: Using EPA MOBILE6.2 fuel economy numbers
Metric tons of CO_2e for the average passenger vehicle =(VMT/passenger vehicle avg. MPG) x CO_2 per gallon x (100/95) /1000 =(12,000/20.3) x 8.8 x (100/95)/1000 =5.48 metric tons CO_2e for the average passenger vehicle (1.49 metric tons CE)

B: Using DOT fuel economy numbers
[%LDV x (LDVVMT/LDVMPG) x CO_2 per gallon x (100/95) /1000] + [%LDT x (LDTVMT/LDTMPG) x CO_2 per gallon x (100/95) /1000] =[0.634 x (12,000/22.1) x 8.8 x (100/95)/1000] + [0.366 x (12,000/17.6)] x 8.8 x (100/95)/1000] =5.03 metric tons CO_2e for passenger cars and 6.32 metric tons CO_2e for light trucks (= 1.37 metric tons CE for cars and 1.72 metric tons CE for trucks) = 5.50 metric tons CO_2e for the average passenger vehicle (1.50 metric tons CE)

Recommendation: To calculate rough translations of GHG reductions into an equivalent number of cars off the road, use 5.5 metric tons of CO_2, or 1.5 metric tons of carbon equivalent. This number is rounded to the nearest tenth of a ton (using either DOT or EPA fuel economy estimates). This rough estimate will also allow for some variability in the underlying variables.
CO_2 only numbers

A: Using EPA MOBILE6.2 fuel economy numbers
Average passenger vehicle = 5.20 metric tons CO_2e (1.42 metric tons CE)

B: Using DOT fuel economy numbers
Passenger Cars = 4.78 metric tons CO_2e (1.30 metric tons CE)
Light Trucks = 6.00 metric tons CO_2e (1.64 metric tons CE)
All passenger vehicles = 5.23 metric tons CO_2e (1.43 metric tons CE)

Recommendation: For CO_2 only estimate, use 5.2 metric tons CO_2e, or 1.4 metric tons CE

Fuel Life-Cycle Emissions

Quantities of GHG and PM related emissions released from various sources are determined for each stage of fuel production and use. For gasoline, the following sources are included:

- Process emissions from exploration and extraction of crude oil
- Electricity generation for use in exploration and extraction of crude oil
- Transportation of crude oil to refineries
- Refinery process emissions
- Electricity generation for use at refineries
- Upstream natural gas and coal emissions (e.g., extraction and mining)
- Distribution of finished product (gasoline)

- Sales and combustion of finished product (gasoline)

For ethanol, the following sources of emissions are included:

- Land-use change
- Process emissions from lime and fertilizer production
- Electricity generation for lime and fertilizer production
- Process emissions from pesticide (herbicide and insecticide) production
- Fossil fuel use on farms
- Electricity generation for farm use
- Soil emissions of N_2O, NO_x, and NH_3 from N fertilizer application
- Transportation of corn or biomass to biorefineries
- Biorefinery process emissions
- Combustion of natural gas, coal, or biomass at biorefineries
- Electricity generation for use at corn-ethanol biorefineries
- Upstream natural gas and coal emissions (e.g., extraction and mining)
- Distribution of finished product (ethanol)
- Sales and combustion of the finished product (ethanol).

Spatial Allocation of Emissions

For gasoline, emissions are allocated to counties based on the following spatial data:

- Areas where crude oil is extracted
- Locations of electrical plants providing power for crude oil extraction
- Areas over which crude oil is transported
- Locations of refineries
- Locations of electrical plants providing power to refineries
- Areas from which natural gas is extracted and coal is mined
- Areas over which the finished product (gasoline) is transported
- Areas in which the finished product (gasoline) is sold and combusted
- For ethanol, emissions are allocated to counties based on the following spatial data:
- Areas where agricultural lime and N, P, and K fertilizer is produced
- Locations of electrical plants powering lime and N, P, and K production
- Pesticide production facility locations
- Areas farmed for corn and biomass, and their relative productivity
- Locations of electrical plants providing power to farms
- Areas over which corn and biomass are transported
- Locations of biorefineries
- Locations of electrical plants providing power to biorefineries
- Areas from which natural gas is extracted and coal is mined
- Areas over which the finished product (ethanol) is transported
- Areas in which the finished product (ethanol) is sold and combusted

REFERENCES

[1] The International Panel on Climate Change Guidelines (IPCC) recommends a fraction of carbon oxidized factor of 0.99 for all oil and oil-based products. Based on the fundamentals of internal combustion engine design and combustion, EPA is currently examining whether this fraction is higher (closer to 100 percent) for gasoline vehicles in the US.

[2] U.S. Department of Transportation, Federal Highway Administration, "Highway Statistics 2000," Washington, DC, 2001. Vehicle travel and fuel use data are kept separately for passenger cars and light trucks.

[3] EPA is currently examining ways to better disaggregate the HFC emissions from vehicles.

[4] Vehicles over 8500 lbs are often not included in the light truck category. These vehicles are not required to meet CAFE standards. Examples of these vehicles include the Hummer and the Ford Excursion.