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SUSTAINABLE ENERGY

Spring 2005

QUESTION 1

(35 points) Ford has recently released its first hybrid car and they need your help to evaluate the effectiveness of their regenerative braking system. Let's consider a "normal" commuting day where the vehicle which weighs 2800 lb is traveling on the Mass Turnpike at 65 mph and then comes to a complete stop in bumper to bumper traffic.

(a) 50% Estimate how much energy is available for recovery and storage by the regenerative braking system.

(b) 25% In early designs a mechanical flywheel was proposed to capture and store the recovered energy. A flat right circular cylinder of radius 1/3 m and thickness 3.5 cm constructed of high strength steel (max tensile strength 550 MPa, density = 7.8 g/cm^3) What rotational speed would be needed to capture the energy released from 65 mph to a full stop? Is it possible to achieve this for this device?

(c) (25%) Can you propose any alternatives to capture and store the braking energy that might work better?

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QUESTION 2

(35 points) The Kaya equation described in Chapter 6 of the text equates growth in GHG emissions to a combination of factors:

[CO_2] = Population x [GDP/population] x [Btu/GDP] x [CO_2/Btu]

where [CO_2] is the net amount of carbon dioxide emitted *to the atmosphere* per unit time, usually per year,
[GDP/population] represents the standard of living,
[Btu/GDP] represents energy intensity

Table 6.1 in the text shows the Kaya equation factors with the annual value of change per year over the period from 1980-1999. A partial copy of Table 6.1 follows the questions.

If you are unsure about anything, just make an assumption and state it clearly!

a. The British White Paper on energy says that by 2020, annual UK carbon emissions would be about 135 MtC if no measures were taken. They are aiming for cuts of about 20 MtC per year as a result of new initiatives. What reduction in annual growth rate in C emissions over the period from 2005 to 2020 would be expected?

b. The UK experienced a reduction in carbon emissions of about 0.75% per year over the 1980-1999 period covered in the Table above. Why was their carbon emission growth rate so much lower than that shown above for OECD Europe?

c. The annual US GHG emissions for 2020, without intervention, are estimated to be 7.8 B TCO_2. How many times larger (by mass) are they than those projected without intervention for the UK? (Be careful about differences in units and conventions!)

d. The present rate of growth of GDP in the US is about 4%. Assume the US GDP is $12 trillion in 2005. What would the GDP be in 2020 at an average 3% GDP growth rate? At a 2% GDP growth rate? What are the implications for carbon emissions?

e. Discuss your views about the future of the US economy if carbon mitigation becomes a goal? (Write a couple of paragraphs and also discuss what mitigation measures might be more palatable to the American public.)
Note: The present US deficit, about $450 B, due largely to trade imbalances and some to military spending, is getting political attention now.

Table 6.1 Kaya equation factors from *Sustainable Energy: Choosing Among Options.*

	Average Annual Percent Change 1980-1999				
Region	**Population**	**Standard of Living**	**Energy Intensity**	**Carbon Intensity**	**Carbon Emissions**
China	1.37%	8.54%	-5.22%	-0.26%	4.00%
Japan	0.41%	2.62%	-0.57%	-0.96%	1.47%
OECD-Europe	0.53%	1.74%	-1.00%	-1.06%	0.18%
United States	0.96%	2.15%	-1.64%	-0.21%	1.23%
World	1.60%	1.28%	-1.12%	-0.45%	1.30%

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QUESTION 3

(35 points) For the United States the annual production, P(t), of petroleum from domestic sources can be fitted to a normal function,

$$P(t) = Q_{ultimate} \frac{1}{\sqrt{2\pi}\,\sigma} e^{-\frac{1}{2}\left(\frac{t-t_o}{\sigma}\right)^2},$$

where $Q_{ultimate}$ = 400 billion barrels*
t_o = 1970
σ = 15 yr
t = year of production

* 1 barrel (bbl) = 42 gal.

It is proposed to exploit suspected oil deposits in the Alaska National Wildlife Reserve (ANWR), located near the Prudhoe Bay oil fields of the Alaska north slope (estimated productive resource = 10 billion bbl).

- If this were to be done, how would the ultimate U.S. oil production be changed?
- How would the time scale for depletion of U.S. oil resources change (assuming that the ANWR oil were used to replace all U.S. oil imports as long as they would last)?
- Opponents of oil production in the ANWR argue that its value as a wildlife and aesthetic resource is much greater than the value of the oil that could be produced (see attached typical web page). Do your answers above support them?

Extra Credit (5 points):

What additional factors could explain the strong backing from Alaskan voters for ANWR exploitation?